YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

EXPLORATORY STUDIES FACILITY (ESF)

TITLE I

DESIGN SUMMARY REPORT

REVISION 1, DRAFT H

AMENDMENT NO. 1, ERRATA 10/16/91

The attached pages correct errors in Volume 1 (Executive Summary and Chapters 2, 3, and 14) and Volume 5 (Appendix 5.14). Corrected text in the Executive Summary and Chapters 2 and 3 is in bold type.

Volume 1, Narrative

The seven Executive Summary pages attached (0-1, 0-10, 0-11, 0-12, 0-20, 0-21, and 0-22) dated 10/10/91 supersede the seven August 1991 Executive Summary pages with these numbers.

In Chapter 2, page 2-7 dated 10/15/91 (attached) supersedes page 2-7 dated 8/23/91.

In Chapter 3, page 3-103 dated 10/15/91 (attached) supersedes page 3-103 dated 8/23/91.

In Chapter 14, the attached Summary Cost Estimate page dated 9/10/91 supersedes the Summary Cost Estimate page dated 8/23/91.

Volume 5, Appendices

In Appendix 5.14, the six pages attached (Account Summary, Contingency Analysis, and Reconciliation Summary--two pages each) dated 10/8/91 supersede the corresponding six pages dated 8/23/91.

Part 1

EXECUTIVE SUMMARY

In compliance with U.S. Department of Energy (DOE) Order 4700.1, Project Management System, dated March 6, 1987, this revised Title I Design Summary Report for the Exploratory Studies Facility (ESF) replaces the original Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report dated December 21, 1988.

The revised document reflects: a name change from Exploratory Shaft Facility to Exploratory Studies Facility; and also the changes to the ESF configuration based on the findings presented in SAND90-3232, Findings of the ESF Alternatives Study (see Chapter 7 and Appendix 5.1). The configuration of the ESF presented in this report **is as defined in Project Document YMP/CC-0012, Yucca Mountain Mined Geologic Disposal System Description.** This **configuration** revised the surface-to-underground access from two vertical shafts to a pair of declined ramps. It also greatly enlarged the underground site characterization areas at the Topopah Spring and Calico Hills levels.

The report provides the Yucca Mountain Site Characterization Project Office (YMPO) with summary design information for approval prior to authorizing the start of definitive design (Title II). It also provides the DOE/Headquarters Program Office with the necessary project information to assist in program planning, policy improvement, and criteria guidance for future projects.

protection, (10) rock handling, (11) sanitary, (12) monitoring and warning, and (13) the IDS.

Tests proposed for the ESF are to acquire data on geologic, hydrologic, geomechanical, geochemical, and waste-package environment characteristics. Forty-two different test activities, some planned to be performed at multiple locations, have tentatively been identified.

ENVIRONMENTAL ASPECTS

The environmental aspects associated with ESF activities **(see ESFDR Appendix J, Exploratory Shaft Facility Environmental Requirements)** include air quality, water quality, surface land disturbances, hazardous and solid wastes, and construction permitting. The regulatory framework for the ESF is based on the environmental requirements set forth in the Nuclear Waste Policy Act of 1982, the Nuclear Waste Policy Amendment Act of 1987, DOE Orders, the National Environmental Policy Act, the Atomic Energy Act (AEA), and applicable federal and state statutes and regulations. The DOE will comply with the applicable environmental statutes and regulations.

SAFETY AND HEALTH ASPECTS

The design, construction, and operation of the ESF will conform to the applicable requirements of federal regulations, DOE Orders, and miscellaneous safety and health codes and **standards. (See ESFDR Appendix E, Applicable Regulations, Codes, Standards, and DOE Orders, for the minimum requirements applicable.)** The design is subject to review, which will ensure that conformance to the codes and regulations can be achieved during construction and operation of the facility. Representatives of the Mine Safety Health Administration (MSHA) conduct onsite inspections. The DOE has the ultimate responsibility to ensure that all health and safety requirements are adhered to during the life of the project.

TITLE I DESIGN

The following information identifies specific design features in the Title I design of the ESF.

The design speed for the main ESF access road is 35 mph, based on the Nevada Department of Transportation (NDOT) standards which take into account the traffic volume and type of terrain. Included in the road calculations and volumes are heavily loaded vehicles such as water trucks, concrete trucks, and tractor-trailer rigs.

All sites are constructed in a similar manner. Topsoil is removed and stored and the area brought to grade. Type II aggregate is placed in two lifts. The first lift is a leveling course and the second is full depth, up to grade and compacted. Sites used for heavy traffic such as vehicle turnarounds or access to the ramp sites will be surfaced as determined during Title II design.

Several methods are used to protect embankments from erosion. Interceptor ditches, adjacent to berms built on fill, are concrete-lined. Runoff is diverted and piped down the embankments. Approved concrete-grouted riprap is also used for erosion control. Embankments are protected with an approved soil stabilizer, trimmed, and compacted during construction.

The goal of the site drainage system design is to protect the site against potential floodwaters and to control runoff. Drainage channels and ditches are used to control flows in the existing water courses. A berm or ditch may be added on the upper side of each site's hillside to deflect any possible uncontained floodwaters.

The TS north portal and TS south portal sites are protected from inundation by the probable maximum flood as defined in the U.S. Bureau of Reclamation Probable Maximum Flood Study GR-87-8. Auxiliary sites are protected from the waters of a 100-year flood. All roads, parking areas, and related improvements are protected from the effects of a 25-year flood. A site-specific USBR flood study is currently being conducted.

Test constraints are requirements imposed on the ESF design that must be satisfied to ensure that tests can be located properly. Constraints that impact the underground layout can be classed into three types: (1) sequencing constraints; (2) physical location constraints; and (3) construction and operational constraints.

The zone of influence for each test is an important consideration because of the requirement to separate tests sufficiently to preclude test-to-test interference and the requirement to limit, as much as possible, construction influence on the dedicated test area.

The ESF Test Plan is documented in the Project Site Characterization Program Baseline (SCPB) (see Appendix 5.5), ESFDR Appendices B and C, and the associated test planning packages. Specific design features accommodating the planned testing in the ESF will be incorporated into the RSN Title II BFD. Section 8.4 of the SCPB discusses ESF testing with respect to the facility design.

POTENTIAL REPOSITORY REQUIREMENTS FOR THE ESF

In accordance with Project Document YMP/CC-0011, Yucca Mountain Mined Geologic Disposal System Repository Design Requirements, the Exploratory Studies Facility supports a potential repository in three ways: (1) the ramps and TS drifts supply ventilation air to support waste emplacement operations,

(2) the exploratory drifts on the TS access waste emplacement areas, and (3) the ramps and drifts may later be used in construction of a potential repository.

Permanent items are items or facilities constructed or installed as part of the ESF that may be converted for operational use by a potential repository. These items include underground openings, operational seals, and ground support.

Because no radioactive waste is handled or transported in the ramps or drifts during the site characterization phase, a ramp or drift collapse will not cause a radiological release. During the operations phase, waste may be transported through the access drifts in containers enclosed in transfer casks. However, the casks would be designed to meet radiation shielding requirements and maintain their structural integrity in the event of a drift collapse with no release of radioactivity.

During retrieval, specific drifts may be used for transportation of waste. Structural failure in any of the access drifts is accommodated either by cleanup or by seeking alternate transportation routes using adjacent existing or newly excavated drifts.

The potential repository facilities, including the ramps, will be designed to escape the effects of surface flooding. The ramp portals are located above the height of the probable maximum flood, and the surface around the facilities is graded with flood protection as a requirement. Additionally, any water entering the ramps/shaft is collected in a sump at potential repository level or higher and pumped to the surface.

The approach taken to evaluate potential impacts of site characterization activities on postclosure performance is to ascertain how each category of activity in both the surface-based testing and underground testing programs affects the thermal, mechanical, geochemical, and hydrological conditions of the site, then determine the potential impacts on the performance objectives under these modified conditions.

CLOSURE AND DECOMMISSIONING

The ESF site, both surface and underground, will undergo closure and decommissioning at some future, undetermined date. Closure and decommissioning will place the site into a permanently non-operable and safe condition. The ESF shall be decommissioned in a manner that protects the health and safety of the workers and the public.

ESF closure and decommissioning activities will include: subsurface closure involving equipment removal, backfilling, and access sealing; surface restoration, which includes surface facilities removal/salvage, sealing of surface drillholes, and site reclamation using stored topsoil; and identifying possible alternative uses of the ESF.

2.1.3 FAULTING

Yucca Mountain is divided into a number of structural blocks by a set of north-trending, west-dipping, high-angle normal faults (see Figure 2-2). Several of these faults will be crossed by accesses to the ESF. The north ramp will cross the Bow Ridge fault; the south ramp will cross the Boundary Ridge fault. In addition, **three** of the drifts to be constructed in the ESF are designed to examine the subsurface nature of the Ghost Dance fault.

Within each structural block are numerous west-dipping, high-angle normal faults that trend north to northwest and are closely spaced. These imbricate normal faults are more common in the eastern portion of each structural block, and in the southern part of Yucca Mountain versus the northern.

In the northern part of Yucca Mountain (from the north edge of the site northward), vertical, right-lateral strike-slip faults transect the structural blocks. The strike-slip faults may have associated breccia zones ≥20 m wide.

3.9.31 HYDROLOGIC PROPERTIES OF MAJOR FAULTS

This activity is designed to provide hydrologic information in parallel with a portion of geologic mapping of the ESF. All faults encountered in the ESF will be characterized geologically under the geologic mapping activity. Hydrologic properties of major faults encountered in the ESF will be determined in this activity. The major faults or fault zones expected to be tested are the Ghost Dance fault, a suspected fault in Drill Hole Wash, the imbricate fault zone, the Solitario Canyon fault, and the Bow Ridge fault. Other faults will be tested if flow is observed.

On the basis of the identification of major faults by the geologic mapping activity, a hydrologic testing program will be implemented. This program will consist primarily of tests conducted in boreholes drilled through fault zones and tests on cores collected from the coreholes. Air permeability tests will be conducted between boreholes to determine the permeability to air of the fault zones. Some boreholes will be instrumented to determine in situ conditions of the rock mass and monitored for any changes in these conditions over time. Other sets of boreholes will be used for cross-hole water-injection tests. One borehole at each location will be used for geothermal measurements. All water used for injection will be tagged with an approved tracer. Cores recovered from the holes will be tested to provide a water-content profile across the fault zone. This profile may provide information relative to any recent moisture occurrence in the fault zone.

ESF TITLE I DESIGN SUMMARY REPORT
SUMMARY COST ESTIMATE WBS 1.2.6
[FY'92 - FY'00]

9/10/91

MANAGEMENT & INTEGRATION		**$135,050,500**
CONSTRUCTION		**$426,523,216**
SITE PREPARATION	$61,991,122	
SURFACE FACILITIES	$15,979,916	
NORTH ACCESS	$80,685,344	
SOUTH ACCESS	$86,364,793	
SUBSURFACE EXCAVATIONS	$135,834,917	
OPTIONAL ACCESS	$45,667,124	
OPERATIONS		**$176,877,285**
OPERATIONS [MTCE.& SAFETY]	$125,098,500	
INTEGRATED DATA SYSTEM	$51,778,785	
TOTAL ESF COST ---- [TO END OF CONSTRUCTION]		**$738,451,001**

ESF TITLE I
ACCOUNT SUMMARY
W.B.S. 1.2.6

10/8/91 13:41

ITEM	W.B.S.	F.T.E.	CAPITAL EQUIP.	CONSTRUCTION	CONTINGENCY	PERCENT	TOTAL COST
YUCCA MT. EXPLORATORY FACILITY	1.2.6	1177	$163,066,884	$503,231,842	$72,152,274	11%	$738,451,001
MANAGEMENT & INTEGRATION	1.2.6.1	NA	NA	$135,050,500	NA	NA	$135,050,500
MANAGEMENT, PLANNING, & TECHNICAL	1.2.6.1.1	NA	NA	$84,880,500	NA	NA	$84,880,500
QUALITY ASSURANCE	1.2.6.1.2	NA	NA	$9,263,500	NA	NA	$9,263,500
SAFETY ANALYSIS	1.2.6.1.3	NA	NA	$3,862,500	NA	NA	$3,862,500
TITLE III ENGINEERING	1.2.6.1.4	NA	NA	$21,370,500	NA	NA	$21,370,500
TECHNICAL ENGINEERING MANAGEMENT	1.2.6.1.5	NA	NA	$5,439,000	NA	NA	$5,439,000
TEST MANAGEMENT	1.2.6.1.6	NA	NA	$10,234,500	NA	NA	$10,234,500
SITE PREPARATION	1.2.6.2	179	$13,978,542	$39,000,843	$9,011,736	17%	$61,991,122
DESIGN	1.2.6.2.0	NA	NA	$1,822,000	NA	NA	$1,822,000
ROADS AND PADS	1.2.6.2.1	103		$22,747,663	$3,639,626	16%	$26,387,290
SURFACE UTILITIES & COMMUNICATIONS	1.2.6.2.2	76	$13,978,542	$14,431,180	$5,372,110	19%	$33,781,832
SURFACE FACILITIES	1.2.6.3	42	$4,266,668	$9,206,458	$2,506,791	19%	$15,979,916
DESIGN	1.2.6.3.0	NA	NA	$1,392,000	NA	NA	$1,392,000
BUILDINGS	1.2.6.3.1	42	$4,266,668	$7,814,458	$2,506,791	21%	$14,587,916
NORTH ACCESS	1.2.6.4	149	$39,128,464	$28,698,718	$12,858,162	19%	$80,685,344
DESIGN	1.2.6.4.0	NA	NA	$4,020,000	NA	NA	$4,020,000
PORTAL & PLANT SETUP	1.2.6.4.1	5	$2,110,282	$1,860,950	$921,642	23%	$4,892,873
TSL EXCAVATION, UTILITIES & EQUIPMENT	1.2.6.4.2	66	$20,739,916	$12,118,801	$6,525,779	20%	$39,384,495
CHL EXCAVATION, UTILITIES & EQUIPMENT	1.2.6.4.3	57	$16,278,267	$8,780,251	$4,931,062	20%	$29,989,581
CONSTRUCTION TEST SUPPORT	1.2.6.4.4	21		$1,918,716	$479,679	25%	$2,398,395

ESF TITLE I
ACCOUNT SUMMARY
W.B.S. 1.2.6

10/8/91 13:41

ITEM	W.B.S.	F.T.E.	CAPITAL EQUIP.	CONSTRUCTION	CONTINGENCY &	PERCENT	TOTAL COST
SOUTH ACCESS	1.2.6.5	172	$40,246,242	$32,256,982	$13,861,568	19%	$86,364,793
DESIGN	1.2.6.5.0	NA	NA	$3,884,000	NA	NA	$3,884,000
PORTAL & PLANT SETUP	1.2.6.5.1	10	$1,883,392	$2,672,261	$1,059,117	23%	$5,614,770
TSL EXCAVATION, UTILITIES & EQUIPMENT	1.2.6.5.2	76	$21,975,579	$13,802,444	$7,194,988	20%	$42,973,011
CHL EXCAVATION, UTILITIES & EQUIPMENT	1.2.6.5.3	73	$16,387,271	$10,721,409	$5,313,247	20%	$32,421,926
CONSTRUCTION TEST SUPPORT	1.2.6.5.4	12		$1,176,868	$294,217	25%	$1,471,085
SUBSURFACE EXCAVATIONS	1.2.6.6	503	$31,536,285	$79,852,205	$24,446,427	22%	$135,834,917
DESIGN	1.2.6.6.0	NA	NA	$4,356,000	NA	NA	$4,356,000
TOPOPAH SPRING LEVEL	1.2.6.6.1	347	$22,813,788	$46,786,866	$15,821,666	23%	$85,422,319
TSL CONSTRUCTION TEST SUPPORT	1.2.6.6.1.3	39		$3,418,485	$854,621	25%	$4,273,106
CALICO HILLS LEVEL	1.2.6.6.2	156	$8,722,497	$25,075,286	$7,705,470	23%	$41,503,253
CHL CONSTRUCTION TEST SUPPORT	1.2.6.6.2.2	2		$215,568	$64,670	30%	$280,238
OPTIONAL ACCESS	1.2.6.7	115	$15,365,186	$24,499,614	$5,802,324	15%	$45,667,124
DESIGN	1.2.6.7.0	NA	NA	$8,596,000	NA	NA	$8,596,000
ACCESS COLLAR & PLANT SETUP	1.2.6.7.1	10	$5,581,340	$2,907,811	$1,697,830	20%	$10,186,982
ACCESS EXCAVATION, UTILITIES & EQUIPMENT	1.2.6.7.2	64	$9,783,846	$9,539,495	$3,413,232	18%	$22,736,573
ACCESS CONSTRUCTION & TEST SUPPORT	1.2.6.7.3	41		$3,456,308	$691,262	20%	$4,147,569
OPERATIONS	1.2.6.8	16	$18,545,497	$154,666,522	$3,665,266	2%	$176,877,285
SITE & EQUIPMENT MAINTENANCE	1.2.6.8.1	NA	NA	$34,846,000	NA	NA	$34,846,000
PROJECT OPERATIONS	1.2.6.8.2	NA	NA	$48,186,500	NA	NA	$48,186,500
ENVIRONMENTAL, HEALTH & SAFETY TRAINING	1.2.6.8.3	NA	NA	$4,989,000	NA	NA	$4,989,000
INTEGRATED DATA SYSTEM	1.2.6.8.4	16	$18,545,497	$29,568,022	$3,665,266	8% IDS[15%]	$51,778,785
INTEGRATED DATA SYSTEMS OPERATIONS	1.2.6.8.5	NA	NA	$37,077,000	NA	NA	$37,077,000

ESF TITLE I
CONTINGENCY ANALYSIS 10/8/91

THE FOLLOWING CONTINGENCIES ARE INTENDED TO COVER MATERIAL, EQUIPMENT PHYSICAL CONDITION OVERSIGHTS AS WELL AS RISK SITUATIONS AND DESIGN SHORTCOMINGS. THESE ITEMS ARE NOT ALLOWED FOR ELSE WHERE IN THE ESTIMATE DUE TO UNCERTAINTY OF THEIR EXSISTENCE, NATURE, LIKELIHOOD OF OCCURRENCE OR MAGNITUDE OF EFFECT.

THESE CONTINGENCIES DO NOT COVER ANY ADDITIONS TO THE SCOPE OF WORK, COST ESCALATION, CHANGES IN PAY RATES OR REVISIONS TO COST ADDERS.

THE CONTINGENCY PERCENTAGES ARE BASED ON THE ESTIMATORS FIRST HAND KNOWLEDGE OF THE CURRENT DESIGN LIMITATIONS, THE LACK OF FIELD DATA/SURVEYS, KNOWLEDGE OF DRILL CORE SAMPLES AND PROPOSED SIZE, METHOD OF AND LOCATIONS OF CERTAIN EXCAVATIONS.

ITEM	W.B.S.	PERCENT	CONTINGENCY	TOTAL COST
YUCCA MT. EXPLORATORY FACILITY	**1.2.6**	**11%**	**$72,152,274**	**$738,451,001**
MANAGEMENT & INTEGRATION	**1.2.6.1**	**0%**	**$0**	**$135,050,500**
NO CONTINGENCY HAS BEEN PROVIDED FOR IN M&I AND/OR ANY CORPORATE BUDGETS.				
SITE PREPARATION	**1.2.6.2**	**17%**	**$9,011,736**	**$61,991,122**
10% IS DUE TO THE CURRENT STATE OF DESIGN, 7% ACCOUNTS FOR POSSIBLE UNFORESEEN BACKFILL REQUIREMENTS OR ROCK EXCAVATION.				
SURFACE FACILITIES	**1.2.6.3**	**19%**	**$2,506,791**	**$15,979,916**
10% IS DUE TO THE CURRENT STATE OF DESIGN, 3% ACCOUNTS FOR POSSIBLE UNFORESEEN ROCK EXCAVATION AND 1% FOR INTERIOR FURNISHINGS NOT DETAILED. FIVE PERCENT [5%] ALLOWS FOR THE EXPANSION OF THE CHANGEHOUSE AND SHOP FACILITIES AT THE RAMP SITES ONLY.				

NORTH ACCESS	**1.2.6.4**	**19%**	**$12,858,162**	**$80,685,344**
10% IS DUE TO THE CURRENT STATE OF DESIGN, 2% FOR POSSIBLE INCREASES IN PROCUREMENT COST CAUSED BY Q.A. REQUIREMENTS, 4% FOR UNFORESEEN GROUND SUPPORT REQUIREMENTS, 1% FOR UTILITY OMISSIONS, 2% FOR TESTING SUPPORT AND ASSOCIATED DELAYS.				
SOUTH ACCESS	**1.2.6.5**	**19%**	**$13,861,568**	**$86,364,793**
10% IS DUE TO THE CURRENT STATE OF DESIGN, 2% FOR POSSIBLE INCREASES IN PROCUREMENT COST CAUSED BY Q.A. REQUIREMENTS, 4% FOR UNFORESEEN GROUND SUPPORT REQUIREMENTS, 1% FOR UTILITY OMISSIONS, 2% FOR TESTING SUPPORT AND ASSOCIATED DELAYS.				
SUBSURFACE EXCAVATIONS	**1.2.6.6**	**22%**	**$24,446,427**	**$135,834,917**
10% IS DUE TO THE CURRENT STATE OF DESIGN, 2% FOR POSSIBLE INCREASES IN PROCUREMENT COST CAUSED BY Q.A. REQUIREMENTS, 4% FOR UNFORESEEN GROUND SUPPORT REQUIREMENTS, 3% FOR POOR EQUIPMENT PERFORMANCE, 1% FOR UTILITY OMISSIONS, 2% FOR TESTING SUPPORT.				
OPTIONAL ACCESS	**1.2.6.7**	**15%**	**$5,802,324**	**$45,667,124**
15% IS DUE TO THE CURRENT STATE OF THE SHAFT DESIGN ... THIS IS A PLANNING LEVEL ESTIMATE FOR A 25' SHAFT WHICH WILL POSSIBLY BE ONLY 16' IN THE FINAL DESIGN.				
OPERATIONS	**1.2.6.8**	**2%**	**$3,665,266**	**$176,877,285**
2% [15%] IS DUE TO THE CURRENT STATE OF DESIGN OF THE INTEGRATED DATA SYSTEM [I.D.S.] AND THIS CONTINGENCY APPLIES ONLY TO THE I.D.S., W.B.S. 1.2.6.8.4.. 1.5% IS TO COVER INCREASED LABOR INSTALLATION COST AND 0.5% FOR POSSIBLE INCREASES IN PROCUREMENT COST CAUSED BY Q.A. REQUIREMENTS.				
NOTE: COST & PERCENTAGES ARE "LINKED" TO SPECIFIC SPREAD SHEETS.				

ESF TITLE I
RECONCILIATION SUMMARY

10/8/91

The estimate summary following is a comparison between the Independent Cost Estimate [ICE] and the Title I cost estimate contained in this report. Prior years expenditures are not included in this estimate and the ICE figures have also been reduced by the FY'91 WAS values and the time span is to the end of construction .

1.2.6 ESF TOTAL CONSTRUCTION COST

ICE = $667,074,432 [FY'92-FY'99] TITLE I = $738,451,001 [FY'92-FY'00]

1.2.6.1 MANAGEMENT & ENGINEERING

ICE = $123,198,000 TITLE I = $135,050,500

LENGTHENED DURATION OF THE [TESTING AND CONSTRUCTION] SCHEDULE IS THE CAUSE OF COST INCREASE.

1.2.6.2 SITE PREPARATION

ICE = $67,725,983 TITLE I = $61,991,122

COST REDUCTION IS DUE TO DESIGN REVISIONS TO SOUTH SITE LOCATION.

1.2.6.3 SURFACE FACILITIES

ICE = $15,462,037 TITLE I = $15,979,916

CRUSHING PLANT ADDED TO CONCRETE BATCH PLANT SETUP.

1.2.6.4 NORTH ACCESS

ICE = $68,584,168 TITLE I = $80,685,344

LENGTHENED EXCAVATION DURATIONS, CAPITAL EQUIPMENT REQUIREMENTS & TEST SUPPORT COST ACCOUNT FOR THE INCREASE.

1.2.6.5 SOUTH ACCESS

ICE = $69,033,088 TITLE I = $86,364,793

LENGTHENED EXCAVATION DURATIONS, CAPITAL EQUIPMENT REQUIREMENTS & TEST SUPPORT COST ACCOUNT FOR THE INCREASE.

1.2.6.6 SUBSURFACE EXCAVATIONS

ICE = $112,671,271 TITLE I = $135,834,917

INCREASE IS DUE TO TEST ALCOVE EXCAVATION QUANTITIES, CAPITAL EQUIPMENT REQUIREMENTS & TEST SUPPORT COST.

1.2.6.7 OPTIONAL ACCESS

ICE = $42,309,038 TITLE I = $45,667,124

INCREASE IS CAUSED BY COMBINED EFFECTS OF COST ADDER REVISIONS--SMALL TOOLS-6%, SALES TAX-1%, HANDLING-1%.

1.2.6.8 OPERATIONS - INTEGRATED DATA SYSTEM

ICE = $168,090,847 TITLE I = $176,877,285

LENGTHENED DURATION OF THE [TESTING AND CONSTRUCTION] SCHEDULE IS THE CAUSE OF COST INCREASE. REFINEMENT OF THE IDS ESTIMATE PLAYS A SECONDARY ROLE.

RAYTHEON SERVICES NEVADA

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

TITLE I
DESIGN SUMMARY REPORT
FOR THE EXPLORATORY STUDIES FACILITY

REVISION 1

DRAFT H

VOLUME 1

NARRATIVE

SEPTEMBER 3, 1991

Prepared by:

RAYTHEON SERVICES NEVADA

101 Convention Center Drive

Las Vegas, Nevada

Recvd with letter dtd. 11/25/91

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

EXPLORATORY STUDIES FACILITY (ESF)

TITLE I

DESIGN SUMMARY REPORT

REVISION 1

Prepared by Yucca Mountain Site Characterization Project (YMP) participants as part of the Civilian Radioactive Waste Management Program. The YMP is managed by the Yucca Mountain Site Characterization Project Office (YMPO) of the U. S. Department of Energy, Office of Civilian Radioactive Waste Management.

Prepared for

U.S. Department of Energy
Yucca Mountain Site Characterization Project Office
P. O. Box 98608
Las Vegas, Nevada 89193-8608

Compiled by:

Raytheon Services Nevada

From input developed by:
Technical and Management Support Services Contractor
Los Alamos National Laboratory
Sandia National Laboratories
Reynolds Electrical & Engineering Company, Inc.
United States Geological Survey
Lawrence Livermore National Laboratory
Raytheon Services Nevada

102.8

SUBMITTALS AND APPROVALS

This Yucca Mountain Project Exploratory Studies Facility Title I Design Summary Report, Rev. 1 is submitted by:

Richard L. Bullock, TPO
Raytheon Services Nevada

9-3-91
Date

Edgar H. Petrie, Acting Director
Yucca Mountain Engineering and Development Division
Yucca Mountain Site Characterization Project Office

9/3/91
Date

Donald G. Horton, Director
Yucca Mountain Quality Assurance Division

9/3/91
Date

Carl P. Gertz, Yucca Mountain Site Characterization Project Manager
Yucca Mountain Site Characterization Project Office;
Associate Director
Office of Geologic Disposal

9/4/91
Date

TITLE I ESF DESIGN SUMMARY REPORT

REVISION 1, DRAFT H

TABLE OF CONTENTS

VOLUME 1, NARRATIVE REPORT

VOLUME 5, APPENDICES

5.1 "Findings of the ESF Alternatives Study," SAND90-3232

5.2 Letter, Gertz to Bullock dated 02/22/91, "Authorization for Conducting a Design Study to Develop a Reference Exploratory Shaft Facility (ESF) Design to be Used as Input to Title I Design Summary Report"

5.3 "Exploratory Shaft Facility Design Requirements," Volumes 1 & 2, YMP/CC-0013

5.4 "Reference Information Base," Version 4, Revision 4, YMP/CC-0002

5.5 "Site Characterization Program Baseline," YMP/CM-0011

5.6 Yucca Mountain Administrative Procedure AP-5.19Q, Interface Control

5.7 "Synopsis of Past Stability Analyses for the ESF Title I Design," SAND88-2294

5.8 "Preliminary Evaluation: Three-Dimensional Far-Field Analysis for the Exploratory Shaft Facility," Draft SLTR-PDM75-13

5.9 "Technical Letter Memorandum RSI(ALO)-0037"

5.10 "Drift Design Methodology and Preliminary Application for the Yucca Mountain Site Characterization Project," SAND89-0837

5.11 Holmes & Narver, Inc., Nevada Nuclear Waste Storage Investigation, Exploratory Shaft Facility, "Life Safety Systems, Special Study 6A," Rev. 2

5.12 Holmes & Narver, Inc., Nevada Nuclear Waste Storage Investigation, Exploratory Shaft Facility, "Communications Systems, Special Study 6B," Rev. 1

5.13 Draft "Preliminary Safety Analysis Report for the Yucca Mountain Project ESF and Site Characterization Program," Rev. 1

5.14 "Exploratory Studies Facility Title I Cost Estimate"

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

In compliance with U.S. Department of Energy (DOE) Order 4700.1, Project Management System, dated March 6, 1987, this revised Title I Design Summary Report for the Exploratory Studies Facility (ESF) replaces the original Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report dated December 21, 1988.

The revised document reflects: a name change from Exploratory Shaft Facility to Exploratory Studies Facility; and also the changes to the ESF configuration based on the findings presented in SAND90-3232, Findings of the ESF Alternatives Study (see Chapter 7 and Appendix 5.1). The configuration of the ESF presented in this report is similar to one of the options evaluated in the ESF Alternatives Study (ESFAS), Option 30, with two exceptions. First, the main test area has been relocated from a position adjacent to the TS south ramp to a position adjacent to the TS north ramp, and second, an optional shaft has been added. This selection revised the surface-to-underground access from two vertical shafts to a pair of declined ramps. It also greatly enlarged the underground site characterization areas at the Topopah Spring and Calico Hills levels.

The report provides the Yucca Mountain Site Characterization Project Office (YMPO) with summary design information for approval prior to authorizing the start of definitive design (Title II). It also provides the DOE/Headquarters Program Office with the necessary project information to assist in program planning, policy improvement, and criteria guidance for future projects.

This report presents a general description of the overall ESF design effort, the site geology, and the general arrangements of the ESF, including the ESF's principal facilities. A review of the environmental, safety, and health aspects is included. The report presents a justification for Title I preliminary design concepts, reviews the proposed testing requirements, identifies potential repository requirements within the ESF, and discusses the plans for ESF closure and decommissioning. The report also addresses the approach to Title II definitive design, Title III construction and inspection, and operations and testing in the ESF. The report concludes with ESF Title I design drawings, outline specifications, and cost and schedule information.

PURPOSE AND SCOPE

The ESF will be constructed to meet a 10 CFR Part 60 requirement to perform a program of in situ exploration and testing above, at, and below the depths to which waste might be emplaced to determine the suitability of the Yucca Mountain site. This occurs prior to submittal for construction authorization of a potential repository. The DOE (YMPO) is responsible for the design, construction, and operation of the ESF. The general objectives of the ESF at Yucca Mountain are to acquire access to underground tuff horizons to obtain the necessary technical data regarding the unsaturated zone to assist in determining the suitability of the Yucca Mountain site for the construction of a potential underground high-level nuclear waste repository.

The ESF consists of: (1) two surface-to-underground ramps; (2) one optional shaft, if required; (3) underground test areas to characterize the potential repository site; and (4) surface and underground facilities with all necessary utilities.

The Yucca Mountain site is in southern Nevada, approximately 90 miles northwest of Las Vegas. The site is located on three contiguous parcels of U.S. Government land; the Nellis Air Force Range, the Nevada Test Site, and land administered by the Bureau of Land Management.

Support to the YMPO for the management, direction, and coordination of the ESF Title I design effort is provided by several participating organizations. The Technical & Management Support Services (T&MSS) contractor is responsible for supporting the YMPO in management and integration. Raytheon Services Nevada (RSN), the Architect/Engineer (A/E), is responsible for engineering and design of the surface facilities and utilities; subsurface utilities related to testing; communications; data facilities; and life safety systems. RSN is also responsible for the engineering and design of the two ESF ramps and the optional shaft, any surface hoist system required, the ESF underground facilities and utilities, surveying, access roads, excavated rock and top soil stockpiles, and the surface conveyor system.

Los Alamos National Laboratory (LANL) coordinates and integrates the site characterization test criteria and design requirements, provides design-related information to RSN for the Integrated Data System (IDS) and operates the IDS, and conducts an extensive site characterization testing program. Sandia National Laboratories (SNL) conducts certain rock-mechanics tests and supports the development of design requirements for the ESF by using performance assessment techniques to examine compliance with regulations; SNL may also support the development of design controls by similar calculations if they are needed in addition to the design requirements. The United States Geological Survey (USGS) performs geologic mapping and a variety of tests relating to rock properties, site hydrology, fault analysis, and seismic potentials. Lawrence Livermore National Laboratory (LLNL) is in charge of the waste package environment test and provides some informational support to LANL's underground test program. Reynolds Electrical & Engineering Company, Inc. (REECo) is the constructor for the ESF and provides technical advice on its constructibility.

The Quality Assurance program for the Title I design phase and subsequent phases of the Exploratory Studies Facility is described in the Project Quality Assurance Requirements Document (QARD)(DOE/RW-0214, Rev. 4). The QARD provides direction to the YMP participants on the content of their Quality Assurance Program Descriptions (QAPDs) and the internal procedures used to implement the QA requirements.

GEOLOGY

Yucca Mountain is underlain by more than 1,800 m of Miocene ash-flow tuffs, volcanic breccias, and volcaniclastic sediments. Yucca Mountain is divided into a number of structural blocks by a set of faults. Lateral exploratory drifts will be excavated in the ESF to examine the subsurface nature of these faults and fractures in the tuffaceous units at Yucca Mountain. The fractures are ubiquitous.

ESF DESCRIPTION

The principal elements of the ESF configuration are: (1) two nominally parallel underground access ramps, Topopah Spring (TS) north ramp and TS south ramp, each descending from a surface portal to the TS level; (2) extensions of these ramps from turnouts above the TS level to the Calico Hills (CH) level, identified as CH north ramp and CH south ramp; (3) full length drifts, the TS main drift and CH main drift, connecting the north and south ramps at both levels; (4) seven lateral drifts (three on the TS level, four on the CH level) planned to explore various fault zones; (5) underground test facilities; (6) an optional shaft (if built) to the TS level; (7) surface and underground utilities; (8) communications systems; and (9) an Integrated Data System (IDS).

Each of the ramps is associated with a site on which surface facilities are located. The 10.3-acre TS north portal site accommodates a portal control center (PCC) building, the surface data building, the test support building, a change house, a shop/warehouse, the main warehouse, an electrical substation control building, an electrical switchgear building, a microwave tower building, and the conveyor drive tower. The TS south portal site, 5 acres in area, accommodates a PCC building, a change house, a shop/warehouse, an electrical substation control building, an electrical switchgear building, the conveyor drive and transfer building, the airlock building, a microwave tower building, the ventilation fan hydraulic control building, and the ventilation fans.

Additional auxiliary sites and ESF surface features include a 55-acre excavated rock stockpile site, a 20-acre topsoil storage site, an approximately 17-acre aggregate borrow area, and other auxiliary sites occupying a total area of about 16 acres. The auxiliary sites accommodate a variety of facilities and functions, including test support facilities, batch plant, explosives storage, equipment and scientific trailers, vehicle maintenance facility, fuel supplies, parking, and security facility.

If included in the ESF, the optional shaft would probably be excavated by mechanical methods for a lined diameter of 16 feet. Its location would be in the north end above the TS level; its primary ESF function would be to facilitate the acquisition of scientific data about the rock above the TS level, should the data be needed. Major components of the shaft would include headframe, hoist, shaft liner, shaft internals, test stations, and a conveyance. The optional shaft collar site would contain support facilities, including a change house trailer, an office trailer, the hoist house, the headframe structure, electrical control and switchgear buildings, and a microwave tower building.

Roadways are provided to access the ESF from offsite locations and to connect the TS north portal and TS south portal sites with the auxiliary sites, storage areas, and disposal areas.

The ESF surface buildings consist of pre-engineered steel structures on concrete slabs, engineered buildings, or portable double-wide trailer units. The surface buildings are equipped with heating, ventilating and air conditioning (HVAC), plumbing and sanitary facilities, fire protection systems, lighting, and communications.

The ventilation distribution system provides surface-based control of underground air supply and exhaust. The electrical power distribution system supplies power for construction and operational requirements for the surface and subsurface activities, and includes standby and Uninterruptible Power Supply (UPS) systems as required. The water distribution system supplies and distributes the potable, fire protection, and process water required for construction and operation activities. The sanitary water sewage system provides for the collection, treatment, and disposal of sanitary waste generated at the site. The communications system consists of the telephone system, underground intercoms, public address, and closed circuit television. The surface waste water disposal system handles non-sanitary waste water from underground; requirements for storm water discharge will be addressed during Title II design. The compressed air distribution system provides compressed air to the ESF underground and surface facilities as required.

Each TS ramp, TS north and TS south, is 25 feet in diameter and 491 sq. ft. in cross-sectional area. The TS north ramp's surface elevation is about 3,687 feet above sea level; the TS south ramp's, about 3,930 feet. Respective ramp slope lengths are 5,744 feet and 7,936 feet from the portal working point (wp) to the beginning of the underground curve at the TS level; respective grades of descent are 9.57 percent and 1.6 percent. Elevations of the ramps at the TS level are about 3,100 feet (TS north ramp) and 3,800 feet (TS south ramp). Excavation of both ramps is by Tunnel Boring Machine (TBM). **NOTE:** Ramp lengths, elevations, and slopes are tentative pending determination of the TSw1/TSw2 interface.

In the ESF operational phase, both ramps are used to support scientific activities and provide emergency egress. The TS north ramp, the ventilation system's air intake path, is also used for men and materials transport. The TS south ramp, the ventilation system's air exhaust path, also has provisions for excavated rock handling. Before reaching the TS level, both ramps connect with turnouts (TS/CH intersections) configured to allow extension of the ramps to the CH level. These "internal" ramps (CH north ramp and CH south ramp) are excavated, also by TBM, to a diameter of 18 feet for a cross-sectional area of 254 square feet.

The CH north ramp runs from an elevation of 3,160 feet at the TS level to an elevation of 2,702 feet at the CH level. This ramp, excavated at an approximate 10-percent grade, is 5,232 feet in length. The CH south ramp runs from an elevation of 3,802 feet at the TS level to an elevation of 3,134 feet at the CH level. This ramp, excavated at an approximate grade of 10 percent, is 7,416 feet in length. CH ramp lengths are calculated from the TS/CH intersections to the beginning points of the CH main drift. **NOTE:** These details are subject to change pending Title II design decisions.

The ESF underground facilities consist of: (1) test alcoves and stations located in the TS north ramp, the TS south ramp, and at both the north and south TS/CH intersections; (2) the TS operations area for access, transport space for men and materials, operational space, and storage space; (3) the TS main test area for subsurface site characterization testing; and (4) exploratory drifts to access geological features potentially important to characterization.

The underground support systems consist of the following: (1) power distribution, (2) communications, (3) life safety and environmental monitoring and alarm, (4) lighting, (5) ventilation distribution, (6) water distribution, (7) waste water collection, (8) compressed air distribution, (9) fire protection, (10) rock handling, (11) sanitary, (12) monitoring and warning, and (13) the IDS.

Tests proposed for the ESF are to acquire data on geologic, hydrologic, geomechanical, geochemical, and waste-package environment characteristics. Forty-two different test activities, some planned to be performed at multiple locations, have tentatively been identified.

ENVIRONMENTAL ASPECTS

The environmental aspects associated with ESF activities include air quality, water quality, surface land disturbances, hazardous and solid wastes, and construction permitting. The regulatory framework for the ESF is based on the environmental requirements set forth in the Nuclear Waste Policy Act of 1982, the Nuclear Waste Policy Amendment Act of 1987, DOE Orders, the National Environmental Policy Act, the Atomic Energy Act (AEA), and applicable federal and state statutes and regulations. The DOE will comply with the applicable environmental statutes and regulations.

SAFETY AND HEALTH ASPECTS

The design, construction, and operation of the ESF will conform to the applicable requirements of federal regulations, DOE Orders, and miscellaneous safety and health codes and regulations. The design is subject to review, which will ensure that conformance to the codes and regulations can be achieved during construction and operation of the facility. Representatives of the Mine Safety Health Administration (MSHA) conduct onsite inspections. The DOE has the ultimate responsibility to ensure that all health and safety requirements are adhered to during the life of the project.

TITLE I DESIGN

The following information identifies specific design features in the Title I design of the ESF.

The design speed for the main ESF access road is 35 mph, based on the Nevada Department of Transportation (NDOT) standards which take into account the traffic volume and type of terrain. Included in the road calculations and volumes are heavily loaded vehicles such as water trucks, concrete trucks, and tractor-trailer rigs.

All sites are constructed in a similar manner. Topsoil is removed and stored and the area brought to grade. Type II aggregate is placed in two lifts. The first lift is a leveling course and the second is full depth, up to grade and compacted. Sites used for heavy traffic such as vehicle turnarounds or access to the ramp sites will be surfaced as determined during Title II design.

Several methods are used to protect embankments from erosion. Interceptor ditches, adjacent to berms built on fill, are concrete-lined. Runoff is diverted and piped down the embankments. Approved concrete-grouted riprap is also used for erosion control. Embankments are protected with an approved soil stabilizer, trimmed, and compacted during construction.

The goal of the site drainage system design is to protect the site against potential floodwaters and to control runoff. Drainage channels and ditches are used to control flows in the existing water courses. A berm or ditch may be added on the upper side of each site's hillside to deflect any possible uncontained floodwaters.

The TS north portal and TS south portal sites are protected from inundation by the probable maximum flood as defined in the U.S. Bureau of Reclamation Probable Maximum Flood Study GR-87-8. Auxiliary sites are protected from the waters of a 100-year flood. All roads, parking areas, and related improvements are protected from the effects of a 25-year flood. A site-specific USBR flood study is currently being conducted.

Space requirements for surface buildings are developed from the projected staffing requirements of the participants. Areas around the buildings allow sufficient space for access to mechanical equipment, materials delivery and storage, limited vehicle parking, pedestrian circulation, and fire/emergency escape. Pre-engineered steel buildings are used to provide office and laboratory space, except that two trailers may be used at the optional shaft collar site. Installations requiring special or unique features such as computer facilities, high ceilings, or heavy equipment repair are housed in pre-engineered steel buildings designed for these applications.

The surface water supply system design features all relate to the demand requirements, which vary with fire protection needs and sanitary use. The non-potable water will supply the fire protection system and underground needs, and will contain an approved tracer. The potable system will be supplied to all buildings for sanitary requirements, drinking water, and change house needs, and will contain no tracer.

The ESF optional shaft's excavated cross-section would be 18 feet in diameter, based on an analysis that considered the known subsurface test and wall mapping requirements and industry construction practices. This diameter permits efficient construction and drilling of test-related horizontal holes. A mechanical excavation method would be used for shaft construction to reduce overbreak, original crack dilation, and new crack development.

Station cross-sections on the TS level are large enough to accommodate shaft and station furnishings and meet the requirements of the test configuration.

The hoist system for the optional shaft would provide safe, controlled access into the shaft and egress therefrom. The primary function of the hoist system in the ESF operational phase would be to service in-shaft testing for site characterization.

The ESF has several principal areas of subsurface development: ramps, ramp intersections, main test area, test alcoves and stations, TS exploratory drifts, and the CH exploratory drifts. Each element is designed both to the individual requirements of the item and as a part of the overall site characterization plan. Subsurface development and testing will follow the Yucca Mountain Site Characterization Project "Plan for the Phased Approach to ESF Design Development and Implementation," February 1991, YMP/91-13.

The sizes of certain TS level test stations will be governed by the Principal Investigator (PI) requirement to test in full-sized repository-type openings. The sizes of these stations will be determined during Title II design. **NOTE:** Construction of some TS ramp stations will be deferred until completion of ramp excavations.

Drifts on the TS level are excavated according to priority needs. Three exploratory drifts (TS imbricate, TS east, and TS west) are excavated to predetermined areas of interest. These drifts are driven along the grade and heading in accordance with the Site Characterization Program Baseline (SCPB).

Four exploratory drifts are to be excavated on the CH level, the CH imbricate drift, CH east Ghost Dance drift, CH west Ghost Dance drift, and CH Solitario drift.

Underground opening sizes are based on two major criteria: safety of operation, which dictates the minimum opening dimensions necessary to accommodate excavation equipment used in TS and CH development and ensure worker safety; and needs associated with testing and site characterization. Opening sizes will also be based on the maximum allowable stable span under the given rock characteristics and in situ stresses. See Provision for 10 CFR 60.74(a) in Chapter 7 for additional information.

For personnel safety, stability implies that no localized rockfall of a size sufficient to cause serious personnel injury occurs, and that no catastrophic failure of the openings--which could block personnel access or egress--occurs. Rock support design will be applied to ensure personnel safety.

The larger TS openings are equal in size to the full-scale openings for the potential repository. In addition, the sizes of pillars separating various test areas are based on test requirements and the need to protect specific underground facilities vital to operation of the ESF.

Three types of loads are considered during stability analysis of the underground levels: geostatic loads, seismic loads, and thermal loads. Design analysis of the underground openings concludes that they would be stable and usable for the life of the project (see Appendix 5.7).

The TS power center is the main subsurface electrical power supply for all TS underground electrical loads. This configuration is based on the RSN BFD (Basis for Design) criterion that redundant 15kV-rated armored power cables be supplied down each ramp, feeding a substation or power center with adequate capacity to supply all construction, operations, and testing loads for site characterization and providing adequate redundancy for acceptable system reliability. The subsurface lighting system consists of incandescent, fluorescent, and emergency lighting.

The system designed for subsurface communications and subsurface-to-surface communications is a dual-function dial/page type telephone system that combines the capability of a conventional public telephone exchange with a page-all paging system. Permanent telephone stations will be installed where operations, maintenance, or testing personnel are located. Where personnel may be located for performing periodic work tasks, a plug-in telephone jack is installed. The underground dial/page phone system provides the convenience of a telephone station plus additional paging facilities in dusty locations where standard telephone equipment is considered unsuitable for the environment. In addition to the dial/page telephone system, the audio alarm communicators of the fire detection and alarm system are utilized as emergency communications speakers for the public address system.

Air distribution into the underground development and test areas is controlled by a combination of fans, ducts, regulators, and doors. Dust suppression techniques include the use of water and dust collectors. Water use will be minimal.

The underground non-potable water supply system design features all relate to the demand requirements, which vary with the fire protection needs and the types of equipment required during various phases of construction, testing, and operation. Reliability and safety features of this water supply system include distribution looping, pressure regulators, line break valves, relief valves, and water hammer dampening. Underground potable water will be supplied in bottles.

The underground waste water collection system design incorporates both collection and transfer features. The sources of underground waste water include water from construction, testing, maintenance and repair operations, fire protection, and possibly naturally occurring ground water inflow. The pumping system consists of various types of pumps feeding into two sumps (one at each level) with pumps capable of transferring in stages all waste water inflows to the surface.

The compressed air distribution system design features are developed to meet the demand requirements for ESF construction, testing, and maintenance/repair operations. The equipment utilizing compressed air includes pneumatic rock drills, blast face sprays, blowpipes (for drilled hole cleaning), diaphragm pumps, pneumatic drill test equipment, pneumatic winches, air door cylinders, and air-powered wrenches. Compressed air (100 psig) is provided from each ramp portal and is boosted by local booster compressors where higher working pressures are required. The compressed air system will contain an approved tracer gas.

The fire protection system design features include automatic sprinkler systems, system monitoring and control, fire doors, fire dampers, and portable extinguisher units. The fire protection system utilizes the same water as the underground non-potable water supply system. The fire doors are provided to isolate the TS level or the CH level in an emergency.

Automatic water sprinklers are required for primary fire protection by DOE Order 5480.7, Fire Protection. The requirements pertain to all surface structures meeting the improved risk criteria. The surface data building computer areas will have on-off, quick-response sprinklers. All underground areas requiring sprinklers shall also use on-off, quick-response sprinklers.

An excavated rock handling system is provided for each of the four major ramps, two north (TS and CH) and two south (TS and CH). The system is comprised of conveyors, transfer assemblies, and rubber-tired excavated rock haulers.

During Title II design, many items of operational monitoring and control will be added to the life safety system, including power monitoring; ventilation monitoring and control; hoist operations monitoring for the optional shaft; air compressor monitoring; and water system monitoring. Monitor and control setpoints are controlled by software and can be changed as criteria become better defined or field operations progress.

The life safety monitoring and alarm system provides for the subsurface monitoring of gases, including noxious and toxic gases. Gases monitored, according to the Exploratory Studies Facility Design Requirements (ESFDR) document (see Appendix 5.3), are carbon monoxide, carbon dioxide, nitric oxide, nitrous oxide, hydrogen sulfide, sulfur dioxide, and oxygen.

Test constraints are requirements imposed on the ESF design that must be satisfied to ensure that tests can be located properly. Constraints that impact the underground layout can be classed into three types: (1) sequencing constraints; (2) physical location constraints; and (3) construction and operational constraints.

The zone of influence for each test is an important consideration because of the requirement to separate tests sufficiently to preclude test-to-test interference and the requirement to limit, as much as possible, construction influence on the dedicated test area.

The ESF Test Plan is documented in the Project Site Characterization Program Baseline (SCPB) (see Appendix 5.5), ESFDR Appendices B and C, and the associated test planning packages. Specific design features accommodating the planned testing in the ESF will be incorporated into the RSN Title II BFD. Section 8.4 of the SCPB discusses ESF testing with respect to the facility design.

POTENTIAL REPOSITORY REQUIREMENTS FOR THE ESF

The Exploratory Studies Facility supports a potential repository in three ways: (1) the ramps and TS drifts supply ventilation air to support waste emplacement operations, (2) the exploratory drifts on the TS accesses waste emplacement areas, and (3) the ramps and drifts may later be used in construction of a potential repository.

Permanent items are items or facilities constructed or installed as part of the ESF that may be converted for operational use by a potential repository. These items include underground openings, operational seals, and ground support.

Because no radioactive waste is handled or transported in the ramps or drifts during the site characterization phase, a ramp or drift collapse will not cause a radiological release. During the operations phase, waste may be transported through the access drifts in containers enclosed in transfer casks. However, the casks would be designed to meet radiation shielding requirements and maintain their structural integrity in the event of a drift collapse with no release of radioactivity.

During retrieval, specific drifts may be used for transportation of waste. Structural failure in any of the access drifts is accommodated either by cleanup or by seeking alternate transportation routes using adjacent existing or newly excavated drifts.

The potential repository facilities, including the ramps, will be designed to escape the effects of surface flooding. The ramp portals are located above the height of the probable maximum flood, and the surface around the facilities is graded with flood protection as a requirement. Additionally, any water entering the ramps/shaft is collected in a sump at potential repository level or higher and pumped to the surface.

The approach taken to evaluate potential impacts of site characterization activities on postclosure performance is to ascertain how each category of activity in both the surface-based testing and underground testing programs affects the thermal, mechanical, geochemical, and hydrological conditions of the site, then determine the potential impacts on the performance objectives under these modified conditions.

CLOSURE AND DECOMMISSIONING

The ESF site, both surface and underground, will undergo closure and decommissioning at some future, undetermined date. Closure and decommissioning will place the site into a permanently non-operable and safe condition. The ESF shall be decommissioned in a manner that protects the health and safety of the workers and the public.

ESF closure and decommissioning activities will include: subsurface closure involving equipment removal, backfilling, and access sealing; surface restoration, which includes surface facilities removal/salvage, sealing of surface drillholes, and site reclamation using stored topsoil; and identifying possible alternative uses of the ESF.

LONG-LEAD PROCUREMENT ITEMS

Long-lead procurement items are critical engineered items that require special design outputs to mitigate schedule problems. In addition, it is necessary to consider the Procurement Acquisition Time (PAT), which is the estimated time needed to award a contract. The PAT process may involve special requirements that extend the time needed to issue a purchase order.

TITLE II DESIGN

The Yucca Mountain Site Characterization Project Office is responsible for overall management of the ESF Title II Design. The Project Office is assisted in this management function by the T&MSS Management and Integration group, which coordinates the activities associated with engineering analysis, technical assessment, project studies, project participant integration, and project task management. The Quality Assurance group, an autonomous organization reporting directly to DOE Headquarters, is responsible for ensuring that overall project quality as it relates to facility licensability is in compliance with quality assurance requirements.

Development of the ESF design and test program is divided into separate areas, each the responsibility of a separate organization. Each organization has a design responsibility, and reports directly to the Project Office. The design areas are surface and underground facilities and underground testing.

Title II design in these areas will be based on the approved ESF Title I design and the design-related requirements and guidance documents of the Project as interpreted by the design basis documents of the responsible individual design participant. Surface and underground facilities design is the responsibility of RSN, an A/E firm experienced in nuclear industry-related and underground design and development. LANL is responsible for integrating the testing requirements with the design, and for coordinating and integrating all the participant PI requirements to ensure that Title II design will meet overall site characterization testing needs.

While underground testing program development and design are coordinated by LANL, the test design and facility development are produced through the cooperative efforts of the participants delegated the responsibility for conducting the individual tests. In addition, the constructor (REECo) reports directly to the Project Office, and participates in a design oversight capacity during the Title II design process to ensure constructibility, maintainability, operability, and worker health and safety.

The QA program for ESF Title I and Title II design phases is governed by the DOE QARD. The methodology of QA Grading of items and activities requires that specific quality control measures be applied in the preclosure and postclosure phases of the ESF.

Items and activities associated with ESF Title I and Title II design and appearing on the Q-List, Quality Activities List (QAL), or Project Requirements List (PRL) require "grading" according to their relationship with and importance to public radiological safety and waste isolation. In this context, grading is defined as the determination of QA measures, based on the 20 criteria of the Office of Civilian Radioactive Waste Management (OCRWM) QARD (Quality Assurance Requirements Document), application of which is necessary to develop and maintain confidence in the quality of an item or activity.

During ESF Title I design, the documentation and traceability of interface requirements and other design information are based on QA requirements. ESF design decisions for Title II will be as rigorous as those required for a licensable activity. A readiness assessment review board and team provide the Project Office with an independent evaluation of the management and quality assurance activities necessary, and provide insight into the risks associated with alternative courses of action.

The bases for design of the Title II ESF are Project-level documents and A/E documents. Other information may be provided as design input by the Project Office in the form of letters. Design criteria exist as a result of ESF planning activities, correspondence, meetings, and special studies; the criteria further define the ESF or performance requirements, and are included in the basis for design.

TITLE III CONSTRUCTION

The Project Office is responsible for the management, direction, and coordination of the overall ESF construction, inspection, and acceptance testing effort. The T&MSS supports the Project Office in the management and integration of ESF construction and operations. Duties include project management and integration; technical review/analysis of project construction and operations progress and results; evaluation of project reports; and ongoing regulatory, institutional, quality assurance, socioeconomic, transportation, and environmental studies. MACTEC provides quality assurance and project management support to the Project Office. RSN is responsible for surveying; inspection of the construction of surface and subsurface facilities and utilities, subsurface utilities related to testing, communications, data facilities, and life safety systems; engineering and design-related technical support of the ESF underground facilities and utilities; and any surface hoist systems. LANL coordinates and integrates the efforts of the PIs of the participating organizations with the designers, constructors, and operators, and the resulting overall site characterization testing program at the ESF site.

SNL is responsible for developing and evaluating the preclosure and postclosure requirements in the ESFDR by assessing compliance with the performance requirements of 10 CFR 60. Additionally, SNL has lead responsibility for the demonstration breakout room and the sequential drift excavation, heated block, canister-scale heater, plate loading, small-scale heater, slot strength, thermal stress, and heated room experiments. The USGS is in charge of the following test activities: geologic mapping; overcore stress; vertical seismic profiling; matrix hydrologic properties; intact fracture; percolation; bulk-permeability; radial boreholes; excavation effects; Calico Hills; perched water; hydrochemistry; multipurpose boreholes; and hydrologic properties of major faults. LLNL is in charge of the waste package environment test and provides informational support to some LANL testing. REECo is the constructor for the ESF.

The ESF Title III phase follows the requirements of the DOE QARD with emphasis on the QA Grading criteria associated with construction inspection. Administrative procedures are developed to enforce criteria involving procurement, control of processes (welding, etc.), and inspection. These requirements are imposed upon the A/E and construction contractors who develop and issue quality control operating procedures for inspection and construction operations including welding, stress relieving, warehousing, and testing.

During Title III, QA emphasizes achievement of quality in the construction process in addition to the meeting of programmatic requirements such as record keeping. The QA program concentrates on the actions and processes that directly affect quality of construction by specifying training of all personnel whose workmanship capabilities contribute to the construction of the ESF and its eventual operation.

The majority of the construction is completed by REECo as the constructor using direct hire labor. Work now planned to be subcontracted by REECo is the excavation of all underground openings and the construction of three 200,000-gallon fire/excavation/construction water storage tanks, three 50,000-gallon domestic water storage tanks, and two 20,000-gallon booster pump forebay (surge) water tanks.

A readiness review process is conducted and documented in accordance with Administrative Procedure AP-5.13Q. DOE/Headquarters and the Project Office have agreed to conduct readiness reviews before the start of site preparation and the start of ramp excavation.

OPERATIONS AND TESTING

The Title I design of the ESF is sufficiently flexible to provide space for the conduct of performance confirmation tests. The performance confirmation tests are defined in 10 CFR Part 60 as a "program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met." Details of such scientific tests are not available at this time. However, it is anticipated that certain site characterization tests for which the ESF is being designed, may become performance confirmation tests. Further discussion of the performance confirmation testing program, including NRC concerns, is provided in Chapter 7 under Provision 10 CFR 60.137.

CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

This report complies with U.S. Department of Energy (DOE) Order 4700.1, Project Management System, dated March 6, 1987. The Title I report is an overview and record document of preliminary engineering and project management planning, reflecting completed Title I design for the Exploratory Studies Facility (ESF) of the Yucca Mountain Site Characterization Project (YMP). ESF design shall comply with applicable 10 CFR 60 requirements and DOE-accepted Nuclear Regulatory Commission (NRC) recommendations (see Chapter 7).

The report serves two purposes: (1) to provide the Yucca Mountain Site Characterization Project Office (YMPO) with summary design information for approval prior to authorizing the start of definitive design (Title II), and (2) to provide the DOE/Headquarters Program Office with the necessary project information to assist in program planning, policy improvement, and criteria guidance for future projects.

The report gives a general description of the work, the overall concept and layout, and the types of facilities. A brief analysis of environmental and safety aspects is provided. The justification for the design concepts chosen is included, along with the Title I design drawings and outline specifications. Cost and schedule information is also provided as stipulated in the Order.

Title I preliminary design continues the design effort utilizing the conceptual design and the project design criteria as the bases for project development. Title I design develops topographical and subsurface data and determines requirements and criteria that will direct Title II definitive design. Tasks include preparation of preliminary planning and engineering studies, preliminary drawings, outline specifications, project cost analyses, preliminary cost estimates, and scheduling for project completion. Preliminary design also identifies long-lead procurement items and analyzes risks associated with continued project development.

Title II definitive design continues development of the project based on approved preliminary design (Title I). Definitive design includes: any required revisions of the Title I effort; preparation of final working drawings, specifications, bidding documents, and cost estimates; the results of coordination with all parties who might affect the project; development of firm construction and procurement schedules; and assisting in analysis of proposals or bids.

1.2 ORGANIZATION OF THE REPORT

This report is organized into functional areas significant to Title I design of the ESF. Chapter 1 begins with introductory remarks defining the purpose and scope of the report; the organization of the report; a description of the role of the ESF in the Yucca Mountain site characterization program; the participant organizations and their responsibilities; and the quality assurance program for the Title I design. Chapter 2 describes the ESF's geology, including analyses of geologic units, rock properties, and faults. Chapter 3 describes the general arrangement and layout of the ESF and its major facilities and utilities, and identifies the planned underground tests. Chapter 4 covers the ESF regulatory, environmental, and construction permitting concerns. Chapter 5 deals with the safety and health aspects and strategy for the ESF. Chapter 6 explains the design approaches and practices used in the preparation of the Title I ESF design and the proposed test program. Chapter 7 provides historical perspective on NRC concerns related to ESF design, and specifically addresses concerns raised in Objection 1 in the Site Characterization Analysis (NRC, 1989). It also attempts to reconcile the requirements of the Exploratory Studies Facility Design Requirements (ESFDR) (DOE, 1991c), RSN's Basis for Design (BFD) document, and other pertinent documents with the provisions of 10 CFR 60. Chapter 8 discusses ESF closure and decommissioning, site restoration, and possible alternative uses of the ESF. Chapter 9 enumerates the material and equipment items identified as long-lead procurement items and their acquisition strategy. Chapter 10 discusses the approach to Title II ESF design. Chapter 11 covers the Title III ESF management, construction, and inspection plans. Chapter 12 conceptualizes the operational phase of the ESF, including the long-range testing plans. Chapter 13 proposes schedules for long-lead item procurement, Title II design, and construction, testing, and operations. Chapter 14 provides cost estimates. Chapter 15 contains **RSN-prepared technical design analyses.** Chapter **16** contains the ESF reference design study drawings; Chapter **17**, the ESF Title I outline specifications. The appendices hold the supporting documentation.

1.3 ROLE OF THE ESF

The DOE YMPO is responsible for the design, construction, and operation of the ESF to provide access for detailed study of the host rock and the overlying and underlying geologic strata. The general objectives of the ESF at Yucca Mountain are to acquire access to underground tuff horizons and to obtain the necessary technical data on the unsaturated zone for use in determining the suitability of the Yucca Mountain **site** for the construction of a potential underground high-level nuclear waste repository.

The ESF will be constructed to meet a 10 CFR Part 60 requirement to perform a program of in situ exploration and testing above, at, and below the depths to which waste would be emplaced prior to submittal for construction authorization of a potential repository.

The Yucca Mountain site is in southern Nevada, about 90 miles northwest of Las Vegas. The site is on three contiguous parcels of land owned by the U.S. Government. Most of the site is on the Nellis Air Force Range, managed by the U.S. Air Force; a smaller portion, part of the Nevada Test Site, is managed by DOE; and the remainder is administered by the Bureau of Land Management (Figure 1-1).

The ESF configuration (see Figure 1-2) includes the following elements: two declined ramps, Topopah Spring (TS) north ramp and TS south ramp, excavated from the TS north portal and TS south portal to the TS level; two ramp intersections, TS/Calico Hills (CH) north and TS/CH south; two ramps, CH north ramp and CH south ramp, excavated from the intersections to the CH level; full-length drifts, TS main drift and CH main drift, connecting the north and south ramps at both levels; underground test areas, including the main test area on the TS level and test stations and alcoves in the TS north ramp and the TS south ramp; exploratory drifts on the TS level (TS imbricate drift, TS east drift, and TS west drift) and the CH level (CH imbricate drift, CH east Ghost Dance drift, CH west Ghost Dance drift, and CH Solitario drift); an optional shaft providing access to the TS level; and surface and underground utilities and facilities supporting the construction and operations of the ESF.

The data obtained from scientific investigations conducted underground in the ESF by the Principal Investigators (PIs) of the participating organizations will be used to determine the suitability of the Yucca Mountain site.

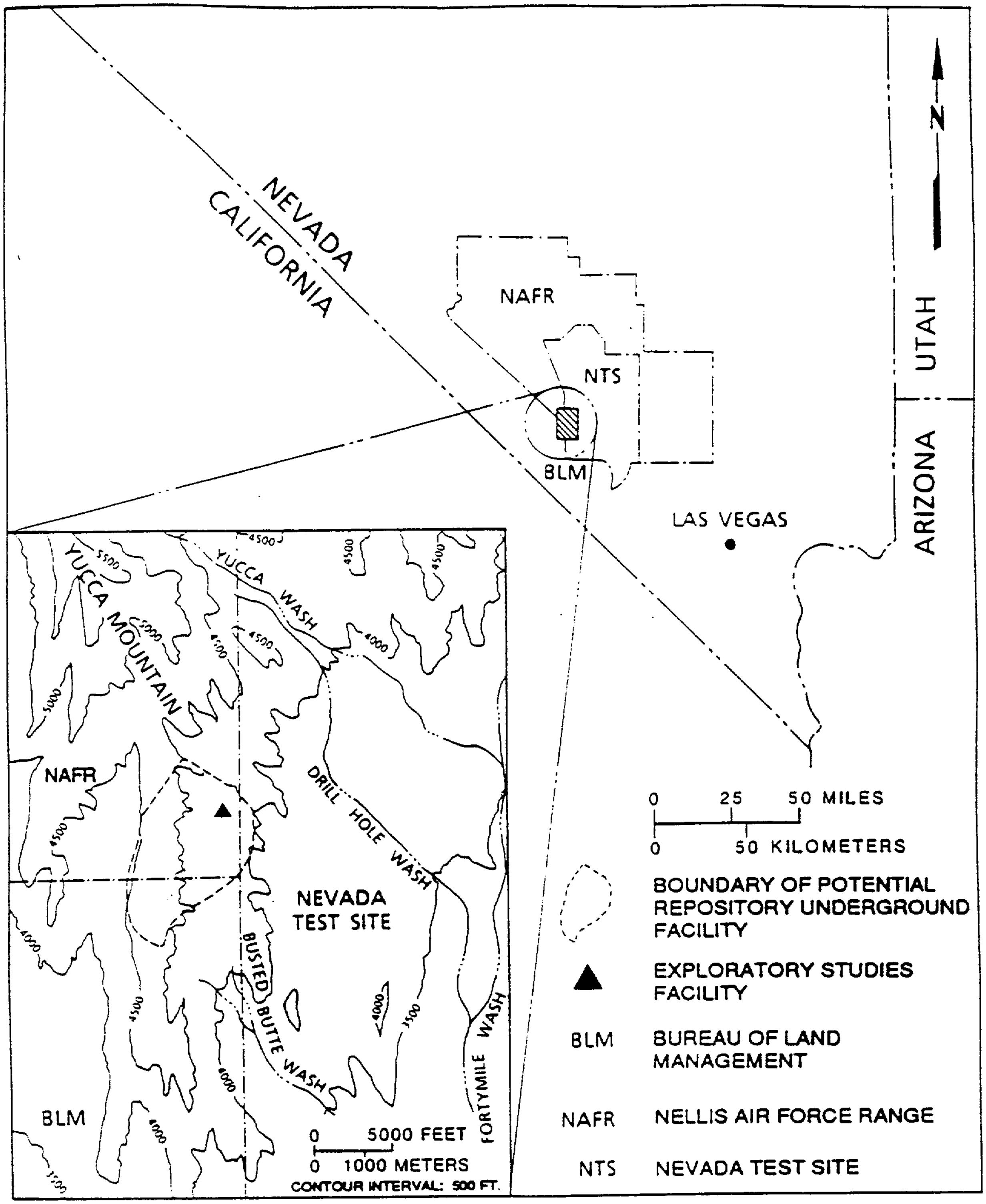
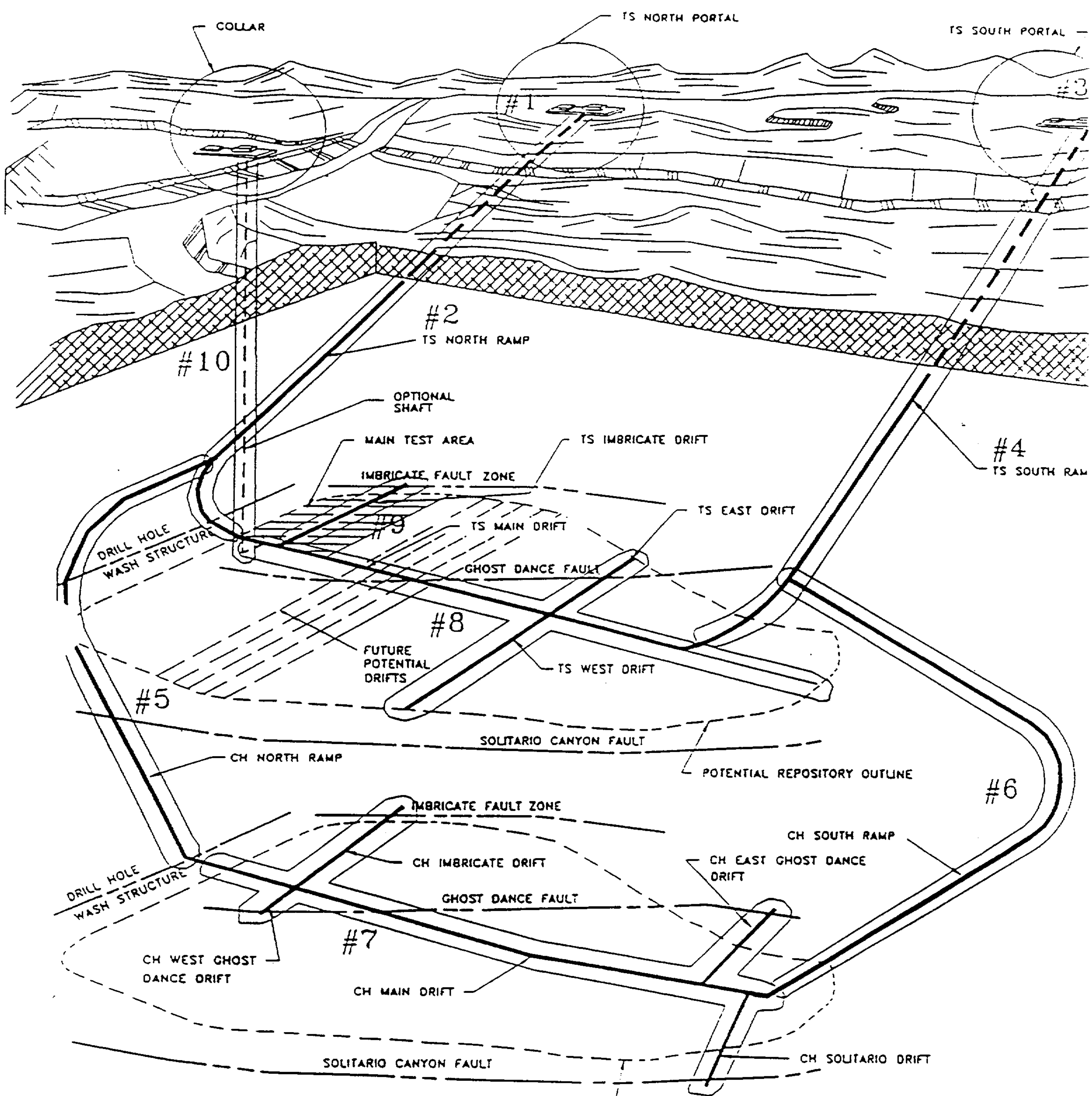


Figure 1-1. Location of Exploratory Studies Facility.



NOTE: THIS IS PICTORIAL ONLY AND NOT DRAWN TO SCALE. **#1-#10 DENOTE SEQUENCE OF TITLE III ACTIVITIES.**

Figure 1-2. ESF Configuration.

The ESF will provide sufficient flexibility to accommodate performance confirmation activities as necessary, which may extend beyond the ESF testing phase.

The closure and decommissioning of the ESF will be accomplished as described in Chapter 8.

1.4 PARTICIPANT ORGANIZATIONS

Participant organizations are identified and their responsibilities defined in the Executive Summary. Chapter 10 addresses management aspects.

1.5 QUALITY ASSURANCE

The Quality Assurance program for the Title I design phase and subsequent phases of the ESF is described in the Project Quality Assurance Requirements Document (QARD). The QARD provides direction to the YMP participants and the A/E for the content of their Quality Assurance Program Descriptions (QAPDs) and internal implementing procedures, which describe how the technical disciplines implement the QA requirements. Because each organization has different responsibilities, these QAPDs may differ in prescribing how some of the basic 10 CFR Part 50, Appendix B criteria are to be applied. However, all YMP participants utilize a graded approach to quality assurance as directed by the QARD.

The QA program for ESF Title I and Title II design phases is governed by the DOE QARD and implemented by the RSN-YMP-QAPD. The methodology of QA Grading of items and activities requires that specific quality control measures be applied in the preclosure and postclosure phases of the ESF.

Items and activities associated with ESF Title I and Title II design and appearing on the Q-List, Quality Activities List (QAL), or Project Requirements List (PRL) require "grading" according to their relationship with and importance to public radiological safety or waste isolation. In this context, grading is defined as the determination of QA measures, based on the 20 criteria of the Office of Civilian Radioactive Waste Management (OCRWM) QARD (Quality Assurance Requirements Document), application of which is necessary to develop and maintain confidence in the quality of an item or activity. Accordingly, QA Grading reports are developed prior to starting ESF design activities. This grading process is based on requirements presented in Administrative Procedure AP-5.28Q. QA Grading Reports RSN-GR-013 and RSN-GR-016 were developed with regard to RSN work performed for the current Reference Design Study. As the design matures the QA Grading reports may be revised. **NOTE:** The phase or objective related to the item or activity being graded is carefully considered. The extent of QA measures applied may be directly proportional to this relationship. Phases can range from preliminary through construction (Title I through Title III). Objectives can include design scoping and licensing support activities. 10 CFR 60 requirements and related NRC concerns are also addressed in Chapter 7 under the Provisions for 10 CFR 60.151 and 60.152.

CHAPTER 2

GEOLOGY

2.1 ESF SETTING

The following summary of the geologic and structural setting of the ESF accesses is based primarily on two sources: Chapter 1 of the Site Characterization Plan (SCP) (DOE, 1988) for formal geology and structure and Nimick et al. (1988) for the thermal/mechanical units. Refer also to Spengler et al. (1979, 1981), Maldonado and Koether (1983), Scott et al. (1983), Scott and Castellanos (1984), Spengler and Chornack (1984), and Ortiz et al. (1985) for additional details.

The U.S. Bureau of Reclamation (USBR) has issued a preliminary engineering geology reconnaissance report dated May 10, 1991. This report concludes that "The five shaft (sic) locations (alignments) would penetrate similar stratigraphic sections;" in effect, that preferred locations are those with favorable surface conditions.

2.1.1 GEOLOGIC UNITS

Yucca Mountain is underlain by more than 1,800 m of Miocene ash-flow tuffs, volcanic breccias, and volcaniclastic sediments. Approximately the upper half of this material is represented in the column headed "Geologic Stratigraphy" in Figure 2-1. Because engineering properties are associated with specific thermal/mechanical units, the formal geologic stratigraphy is not discussed in detail here.

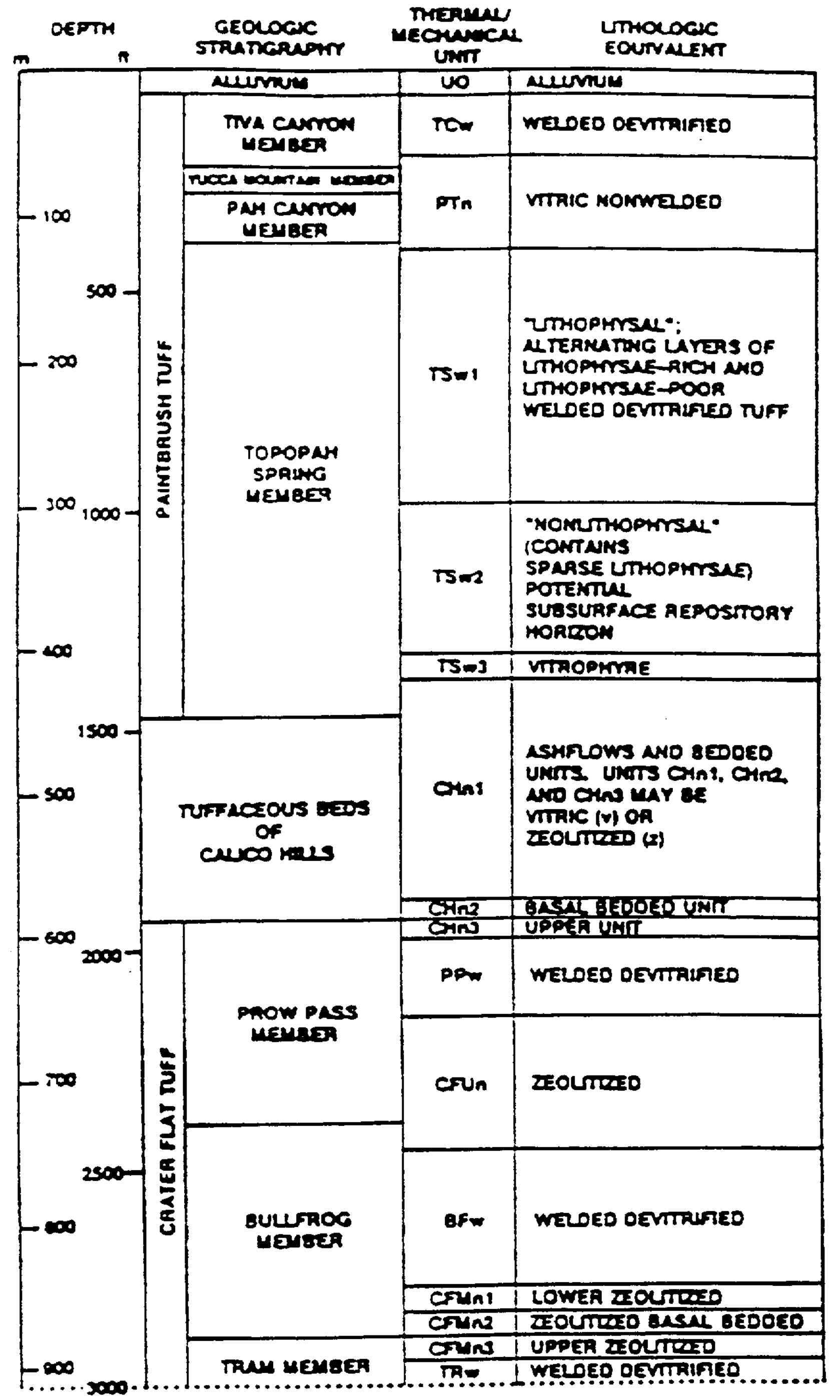


Figure 2-1. Thermal/mechanical and geologic stratigraphies.

2.1.2 THERMAL/MECHANICAL UNITS

Each of the thermal/mechanical units shown in Figure 2-1 has been defined according to thermal properties, mechanical properties, or both (e.g., compressive strength, grain density, porosity, thermal expansion), that are statistically distinguishable from the same properties in adjacent units. The thicknesses shown in Figure 2-1 are averages for the five deep coreholes at Yucca Mountain.

The following subsections provide very brief descriptions of the thermal/mechanical units that are expected to be penetrated during construction of ESF accesses.

2.1.2.1 Unit TCw

Unit TCw consists of the welded ash flows that comprise most of the Tiva Canyon Member. These ash flows contain variable amounts of lithophysae (Scott et al., 1983). The unit has a thickness range inside the boundary of the underground facilities of 0 to 159 m; the ramps are expected to be within this unit for the distances shown below.

TS RAMP	LENGTH WITHIN UNIT TCw(m)
North	N/A*
South	0

*Most of the ramp length is outside the reliable range of the existing model of the thermal/mechanical units.

2.1.2.2 Unit PTn

This unit is a collection of nonwelded ash-flow tuffs and bedded tuffs. In general, the unit thins to the south across Yucca Mountain. The thickness range inside the boundary of the underground facilities is 18 to 62 m; the distances in the unit traversed by the ramps are expected to be as shown below.

TS RAMP	LENGTH WITHIN UNIT PTn(m)
North	N/A*
South	0

*Most of the ramp length is outside the reliable range of the existing model of the thermal/mechanical units.

2.1.2.3 Unit TSw1

Unit TSw1 is comprised of welded, devitrified ash-flow tuffs of the upper part of the Topopah Spring Member of the Paintbrush Tuff. Characteristically, these ash flows contain more lithophysae than do the ash flows of Unit TSw2 (Nimick and Schwartz, 1987; Nimick et al., 1988); the base of Unit TSw1 is defined to be the base of the most lithophysae-rich zone in the Topopah Spring Member (the upper lithophysal zone of Byers and Moore (1987)). The thickness of this unit ranges from 25 to 147 m inside the boundary of the underground facilities; the ramps are expected to traverse the distances shown below.

TS RAMP	LENGTH WITHIN UNIT TSw1(m)
North	>210*
South	0*

*Most of the ramp length is outside the reliable range of the existing model of the thermal/mechanical units.

2.1.2.4 Unit TSw2

Unit TSw2 consists of the welded, devitrified ash-flow tuffs of the Topopah Spring Member that occur between Unit TSw1 and the basal vitrophyre (Unit TSw3). In general, the ash flows of this unit contain only sparse lithophysae. Unit TSw2, the horizon of the area of interest, has a thickness range of 147 to 244 m within the boundary of the underground facilities. Distances traversed within the unit by the ramps are expected to be as shown below.

TS RAMP	LENGTH WITHIN UNIT TSw2(m)
North	311
South	>421*

*Most of the ramp length is outside the reliable range of the existing model of the thermal/mechanical units.

2.1.2.5 Unit TSw3

This unit is equivalent to the basal (moderately to densely welded) vitric tuffs of the Topopah Spring Member. The expected thickness is slightly larger than 16 m. The thickness range inside the boundary of the underground facilities is not well quantified; the range in existing coreholes is 16 to 25 m.

2.1.2.6 Unit CHnl

Unit CHnl is comprised of partially welded to nonwelded ash-flow tuffs, bedded tuffs, and air-fall tuffs of the lowermost Topopah Spring Member of the Paintbrush Tuff and of the Rhyolite of Calico Hills. The unit is subdivided into CHnlv, the mineralogy of which is dominated by glass, and CHnlz, the dominant minerals of which are zeolites. In general, Unit CHnlv is thin or absent in the northern and eastern portions of the area inside the boundary of the underground facilities, and thickens to the south and west at the expense of Unit CHnlz.

Unit CHnl ranges from approximately 55 to 110 m in thickness within the boundary of the underground facilities. The accesses to testing areas within this unit are expected to traverse the following distances of Unit CHnl:

TS/CH RAMP	LENGTH WITHIN UNIT CHnl(m)
North	[TBD]
South	[TBD]

2.1.3 FAULTING

Yucca Mountain is divided into a number of structural blocks by a set of north-trending, west-dipping, high-angle normal faults (see Figure 2-2). Several of these faults will be crossed by accesses to the ESF. The north ramp will cross the Bow Ridge fault; the south ramp will cross the Boundary Ridge fault. In addition, two of the drifts to be constructed in the ESF are designed to examine the subsurface nature of the Ghost Dance fault.

Within each structural block are numerous west-dipping, high-angle normal faults that trend north to northwest and are closely spaced. These imbricate normal faults are more common in the eastern portion of each structural block, and in the southern part of Yucca Mountain versus the northern.

In the northern part of Yucca Mountain (from the north edge of the site northward), vertical, right-lateral strike-slip faults transect the structural blocks. The strike-slip faults may have associated breccia zones $\geq$20 m wide.

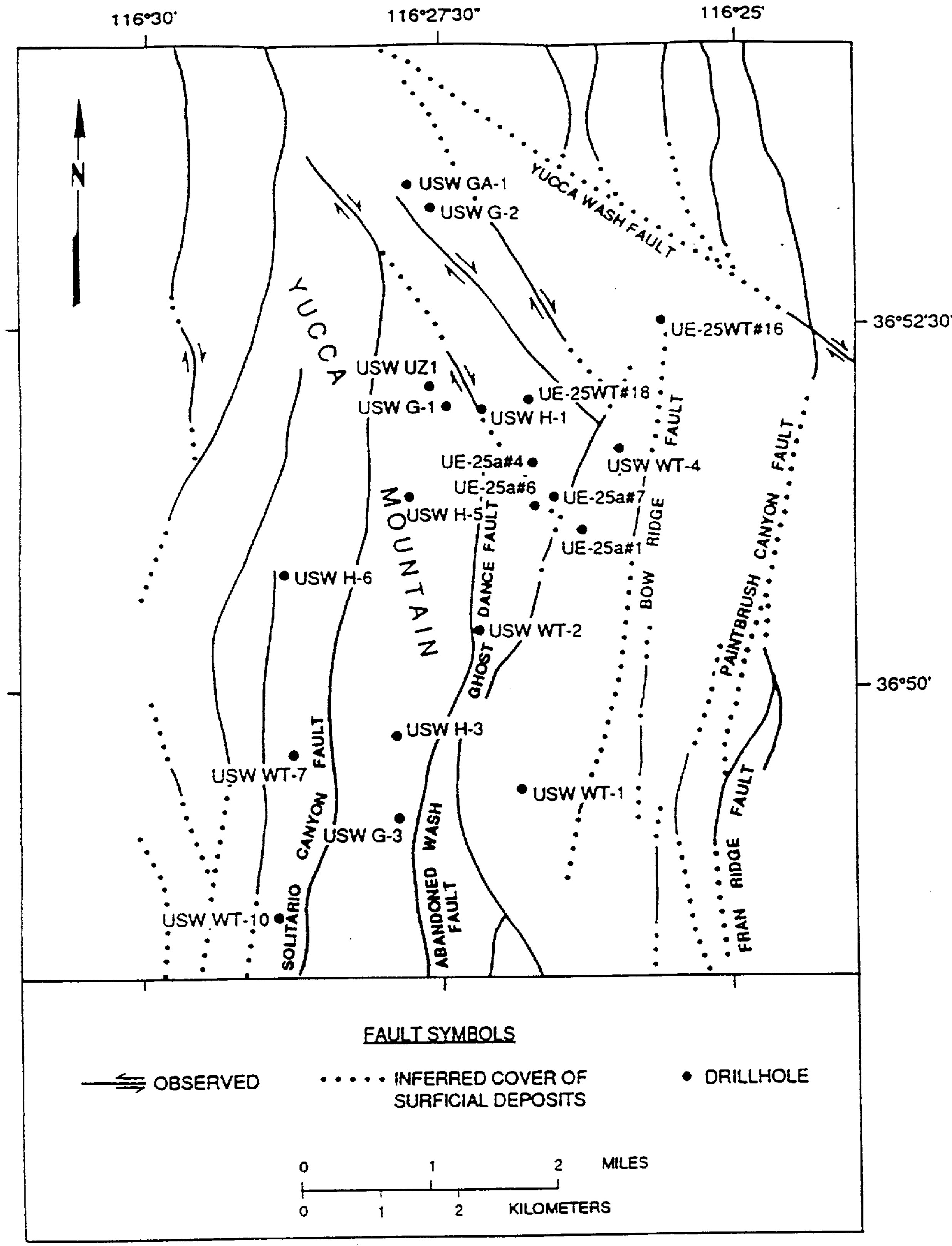


Figure 2-2. Structural features at Yucca Mountain.

2.1.4 FRACTURING

Fractures are ubiquitous in the tuffaceous units at Yucca Mountain; in general, fracture frequency is correlated with the degree of welding. The following reported fracture frequencies (for USW G-4 as listed in the Reference Information Base (RIB), Version 4, Rev. 1, Item 1.2.11) can be used for the different thermal/mechanical units: (1) TCw, 33 to 41 fractures/cubic meter; (2) PTn, approximately 1 fracture/cubic meter; (3) TSw1, 3 to 29 fractures/cubic meter; (4) TSw2, 10 to 34 fractures/cubic meter; (5) TSw3, 26 fractures/cubic meter; and (6) CHn1, 1 to 2 fractures/cubic meter. (These fracture densities are provided in the RIB for geologic units and have been assigned to thermal/mechanical units based on lithology.)

Data for inclinations of fractures observed in USW G-4 are also given in the RIB (Version 4, Rev. 1, Item 1.2.11). Vertical to near-vertical inclinations are common; some fractures in Units TCw and PTn have shallow (< 20°) inclinations.

2.2 ENGINEERING GEOLOGY

This section describes the rock properties, ground water, and expected seismic conditions considered in the Title I design of the ESF.

2.2.1 ROCK PROPERTIES

The general character of the relevant thermal/mechanical units is given in Section 2.1.1. The properties of these units and estimated in situ stress conditions are discussed in the RIB (Items 1.2.5 and 1.2.6 for mechanical properties and Items 1.2.9 and 1.2.10 for in situ stress).

2.2.2 GROUND WATER

Special analyses of groundwater flow and the characterization of rock permeability are beyond the scope of Title I work. However, qualitative consideration of these factors was included and will be further evaluated during Title II design.

Hydrologic Considerations

The RIB specifies the values for density, porosity, saturated hydraulic conductivity, and matrix permeability as depicted below.

PROPERTY	RIB ITEM
Density	1.2.1
Porosity	1.2.1
Saturated Hydraulic Conductivity	1.4.3

2.2.3 SEISMIC CONSIDERATIONS

Seismic considerations for the ESF design include the effects of underground nuclear explosions (UNEs), earthquakes, and construction blasting. The RIB specifies that the seismic events shown below be used in the ESF design.

Event	Acceleration (g)		Return Period (Yr)
	a_h	a_v	
Design Earthquake (DE)	0.40	0.27	2000
Design UNE (DUNE)	0.15	0.18	2000

The potential for damage to underground excavations caused by ground motions can be better assessed in terms of ground peak particle velocity (PPV) rather than ground acceleration. The Exploratory Shaft Seismic Design Basis report (Blume, 1986), from which the maximum accelerations of seismic events given above were taken, additionally specifies the ground PPVs shown in Table 2-1. The RIB also defines a third design earthquake, referred to as the postclosure earthquake. The postclosure earthquake is proposed for evaluation of the long-term performance of the potential repository.

Table 2-1. Peak particle velocities used for design (Blume, 1986).

	PPV			
	V_h		V_v	
Event	(ips)	(m/s)	(ips)	(m/s)
DE-1	9.8	0.25	6.6	0.17
DE-2	5.3	0.13	3.5	0.09
DUNE-1	6.3	0.16	7.6	0.19
DUNE-2	4.7	0.12	5.7	0.14

REFERENCES

Blume (URS/J. A. Blume and Associates, Engineers), February 1986. "Ground Motion Evaluations at Yucca Mountain, Nevada With Applications to Repository Conceptual Design and Siting," SAND85-7104, Sandia National Laboratories, Albuquerque, NM.

Byers, F. M., Jr., and L. M. Moore, 1987. "Petrographic Variation of the Topopah Spring Matrix Within and Between Cored Drill Holes, Yucca Mountain, Nevada," LA-10901-MS, Los Alamos National Laboratory, Los Alamos, NM.

DOE (U.S. Department of Energy), 1988. "Site Characterization Plan, Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0199, U.S. Department of Energy, Office of Civilian Waste Management.

MacDougall, H. R., L. W. Scully, and J. R. Tillerson, 1987. "Site Characterization Plan Conceptual Design Report," SAND84-2641, Sandia National Laboratories, Albuquerque, NM.

Maldonado, F., and S. L. Koether, 1983. "Stratigraphy, Structure, and Some Petrographic Features of Tertiary Volcanic Rocks at the USW G-2 Drill Hole, Yucca Mountain, Nye County, Nevada," USGS-OFR-83-732, U.S. Geological Survey, Denver, CO.

Nimick, F. B., L. E. Shephard, and T. E. Blejwas, 1988. "Preliminary Evaluation of the Exploratory Shaft Representativeness for the Yucca Mountain Project," SAND87-1685, Sandia National Laboratories, Albuquerque, NM.

Nimick, F. B., and B. M. Schwartz, 1987. "Bulk, Thermal, and Mechanical Properties of the Topopah Spring Member of the Paintbrush Tuff, Yucca Mountain, Nevada," SAND85-0762, Sandia National Laboratories, Albuquerque, NM.

Ortiz, T. S., R. L. Williams, F. B. Nimick, B. C. Whittet, and D. L. South, 1985. "A Three-Dimensional Model of Reference Thermal/Mechanical and Hydrological Stratigraphy at Yucca Mountain, Southern Nevada," SAND84-1076, Sandia National Laboratories, Albuquerque, NM.

Scott, R. B. and M. Castellanos, 1984. "Stratigraphic and Structural Relations of Volcanic Rocks in Drillholes USW GU-3 and USW G-3, Yucca Mountain, Nye County, Nevada," USGS-OFR-84-491, U.S. Geological Survey, Denver, CO.

REFERENCES (Cont'd)

Scott, R. B., R. W. Spengler, S. Diehl, A. R. Lappin, and M. P. Chornack, 1983. "Geologic Character of Tuffs in the Unsaturated Zone at Yucca Mountain, Southern Nevada," Role of the Unsaturated Zone in Radioactive and Hazardous Waste Disposal, J. W. Mercer, P. S. C. Rao, and I. W. Marine (eds.), Ann Arbor Science Publishers, Ann Arbor, Mich., pp. 289-335.

Spengler, R. W., D. C. Muller, and R. B. Livermore, 1979. "Preliminary Report on the Geology and Geophysics of Drillhole UE25a-1, Yucca Mountain, Nevada," USGS-OFR-79-1244, U.S. Geological Survey, Denver, CO.

Spengler, R. W., F. M. Byers, Jr., and J. B. Warner, 1981. "Stratigraphy and Structure of Volcanic Rocks in Drillhole USW-G1, Yucca Mountain, Nye County, Nevada," USGS-OFR-81-1349, U.S. Geological Survey, Denver, CO.

Spengler, R. W., and M. P. Chornack, 1984. "Stratigraphic and Structural Characteristics of Volcanic Rocks in Core Hole USW G-4, Yucca Mountain, Nye County, Nevada, with a Section on Geophysical Logs by D. C. Muller and J. E. Kibler," USGS-OFR-84-781, U.S. Geological Survey, Denver, CO.

CHAPTER 3

PROJECT DESCRIPTION

3.1 GENERAL ARRANGEMENT

The Exploratory Studies Facility (ESF) is located at Yucca Mountain, about 90 miles northwest of Las Vegas. Yucca Mountain lies north of Forty Mile Wash, which drains to the Amargosa Valley. The Topopah Spring (TS) north portal is located on the east side of Exile Hill, and the TS south portal is located on the east side of Boundary Ridge. The TS north portal site is northeast of the area of interest and the TS south portal site is southeast. Both locations are above the anticipated probable maximum flood zone according to the U.S. Bureau of Reclamation Probable Maximum Flood Study GR-87-8. (See also Drawing No. YMP-025-1-CIVL-CI02). A site-specific USBR flood study is currently being conducted.

The various components of the ESF have been evaluated based on presently available design criteria. Title II design must further evaluate the various ESF components with regard to their reliability, maintainability, and availability.

Drill Hole Wash Road ("H" Road on Drawing No. YMP-025-1-CIVL-PL01) leads to the road that accesses the TS north portal site (see Drawing No. YMP-025-1-ARCH-PL01). Along the northwest side of this site is the surface data building that contains the surface components of the Integrated Data System (IDS), the test support building, a portal control center, a change house, a microwave tower building, and the conveyor drive tower. A shop/warehouse, the main warehouse, an electrical substation control building, and an electrical switchgear building, along with an open storage yard and electrical transformers and generators, are located on the southeast side of the TS north portal site. The west side of the site has a 50-foot cut excavated in rock. On the south and east sides, the site has a 50-foot fill. The TS north portal site nominally encompasses 10.3 acres. Structures required for excavation and scientific investigation are also located here. All utilities are routed to the required areas. At the northeast corner of the site is a parking area for 100 vehicles.

Off the "H" road beyond the TS north portal access road is the access road to the TS south portal site, on which is located a portal control center, a change house, a shop/warehouse, the conveyor drive and transfer building, the ventilation fan hydraulic control building, an electrical substation control building, an electrical switchgear building, a microwave tower building, and the airlock building (see Drawing No. YMP-025-2-ARCH-PL01). The TS south portal site is approximately 5 acres in area.

A 1.84-acre collar site will be located per Option 2 of Design Analysis No. ST-MN-003 to serve the optional shaft. This site will contain a change house trailer, the hoist house, the headframe structure, a trailer office facility, an electrical substation control building, an electrical switchgear building, and a microwave tower building.

3.2 SITE PREPARATION

Tortoise abundance in or near all areas of planned disturbance will be considered during Title II design. Adverse impact-mitigating measures may be required at certain disturbance areas per Appendix J of the ESFDR.

Various areas at the Yucca Mountain site require clearing and grubbing. The north area is a steep hardrock hill, with a few large boulders and moderate to sparse grass. The south area, also on a steep, hardrock hill, is sparsely vegetated. Other areas requiring clearing and grubbing include lagoons, conveyor routes, and excavated rock storage areas.

The stony, sandy wash areas are sparsely vegetated with moderate grass and single bushes. The root systems of live and dead bushes generally penetrate the soil up to a foot in depth while grass roots penetrate up to an inch. The site surface is prepared by removing the topsoil and placing this material in piles in the topsoil storage area. Topsoil thickness for removal is specified for each site in the Reclamation Implementation Plan. On the sidehill are large boulders and rock outcroppings with some plants and grasses. Clearing and grubbing in these areas require bulldozing off the large boulders to prepare the area for excavation following topsoil removal and transport.

3.2.1 ACCESS ROADS

3.2.1.1 TS North Portal Access Road (Drill Hole Wash Road)

The TS north portal is served from the east by Drill Hole Wash Road (the road name changes from Road H in Area 25 to Drill Hole Wash Road at Forty Mile Wash). Drill Hole Wash Road is an approximately 24-foot wide roadway with 6-foot shoulders. The road is built with increasing grades in the moderately rolling hills approaching the TS north portal site, but the grade exceeds 5 percent only at the entrance to Forty Mile Wash with a grade of 10 percent. (See Drawing No. YMP-025-1-CIVL-PR12 and Drawing No. YMP-025-1-CIVL-PR13.)

Approximately 18,200 linear feet of the Drill Hole Wash Road will be improved from the J-13 wellsite to the intersection of the access road to the TS north portal and excavated materials storage. Improvements consist of two 12-foot travel lanes with a 6-foot shoulder on each side. The road is designed to accommodate a traffic capacity of [TBD] vehicles per day at a maximum speed of 35 miles per hour. The roadway is constructed on a subgrade compacted to 95 percent laboratory maximum density. The base course is a minimum 6-inch layer of type II aggregate base also compacted to 95 percent laboratory maximum density. The wearing surface is a 3-inch application of asphalt. The construction of Drill Hole Wash Road will require some excavation, and the importation of [TBD] cubic yards of fill material. This material will be acquired from the borrow area shown on the ESF Overall Site Plan, Drawing No. YMP-025-1-CIVL-PL01.

3.2.1.2 South Portal Access Road

The roadway is constructed on a subgrade compacted to 95% laboratory maximum density. The base course is a minimum 6-inch layer of type II aggregate base also compacted to 95% laboratory maximum density. The wearing surface is a 3-inch application of asphalt. (See Drawings No. YMP-025-2-CIVL-PR01, YMP-025-2-CIVL-PR02, and YMP-025-2-CIVL-PR03.)

3.2.1.3 Optional Shaft Collar Site Access Road

Drill Hole Wash Road provides access to the optional shaft collar site. This road runs north of the intersection of the access roads to the TS north portal and excavated materials storage, and is the continuation of the TS north portal access road.

3.2.1.4 Auxiliary Site Access Roads

3.2.1.4.1 Explosives Storage Road

This all-weather road has two 12-foot lanes. For vehicular safety, the side slopes are shallow, cut and fill, and the grade does not exceed 10 percent. The road will be oiled and chipped for dust control. (See Drawing No. YMP-025-2-CIVL-PR12.)

3.2.1.4.2 Excavated Materials (Rock) Conveyor Service Road

Running northwesterly of Drill Hole Wash Road, this road serves for transport of excavated material removed by conveyor from the TS portals. The road is 24 feet wide, which is sufficient to accommodate a 12-foot 8-inch wide, 20-ton dump truck. The road grade does not exceed 4 percent, and the curve is designed for 25 mph.

3.2.1.4.3 Water Tank Access Roads

The water tank access roads are two-lane, each lane 12 feet wide, of compacted type II fill material with no shoulders. (See Drawings No. YMP-025-1-CIVL-PR21, YMP-025-2-CIVL-PR06, and YMP-025-2-CIVL-PR07.)

3.2.2 MAIN AND AUXILIARY SITES

3.2.2.1 TS North Portal Main Site

The 10.3-acre (500 feet by 900 feet) TS north portal site has been designed to accommodate major ESF support facilities. This site is the location for the surface data building, a change house (including first aid, training and walker's office), a shop/warehouse, the test support building, the conveyor drive tower, the main warehouse, a portal control center, switchgear/substation control buildings, and a microwave tower building. (See Drawing No. YMP-025-1-CIVL-PL02.)

The site is at a nominal elevation of 3,687 feet mean sea level. It sheet-drains to the east, away from the portal at a 2-percent grade. The cut side (west) of the site is excavated out of rock, with a maximum cut of 50 feet at a 1 (horizontal) to 4 (vertical) slope.

A drainage channel planned for the top of the highwall cut will divert runoff from the slope, off the north side. The south and east sides of the site are of fill material with an approximate depth of 20 feet at a 3 to 1 slope.

One road accesses the TS north portal site. This road, which is used for all vehicular traffic, enters the site at the northeast corner. Parking will be restricted to the northeast corner of the site and the change house area.

3.2.2.2 TS South Portal Main Site

The 5-acre (390 feet by 600 feet) TS south portal site has been designed to accommodate major ESF support facilities, including a change house, a shop/warehouse, the ventilation fan hydraulic control building, a microwave tower building, a portal control center, the conveyor and transfer drive building, the airlock building, and electrical substation control and switchgear facilities. There is also a parking lot. (See Drawing No. YMP-025-2-CIVL-PL01.)

3.2.2.3 Optional Shaft Collar Site

The 1.84-acre (200 feet by 400 feet) optional shaft collar site would also be designed to support major facilities, including a change house trailer, an office trailer, hoist house, microwave tower building, headframe structure, and electrical switchgear/substation control facilities.

3.2.2.4 Auxiliary Sites

Auxiliary sites at the ESF include the booster pump station, batch plant and aggregate stockpile, topsoil storage, excavated **rock** materials **(muck)** stockpile, explosives storage, and water tank sites.

3.2.2.4.1 Booster Pump Station Site

The small booster pump station site, which accommodates the booster pump building, is located at the intersection of the Drill Hole Wash Road and the access roads to the TS north portal and excavated rock storage adjacent to the two 20,000-gallon forebay (surge) water tanks. It provides access for station maintenance and parking. (See Drawing No. YMP-025-1-CIVL-PL04.)

3.2.2.4.2 Batch Plant and Aggregate Stockpile Site

Located off the southwest side of the borrow area, this site provides an area for the subcontractor's batch plant and aggregate stockpiles. This approximately 5-acre site is provided with utility stubouts for water, power, sewer, and wash water disposal. (See Drawing No. YMP-025-2-CIVL-PL07.)

3.2.2.4.3 Topsoil Storage Site

This approximately 20-acre site is used for storage of soil material, weathered by nature and containing minerals and seeds for plant growth. The thickness of topsoil varies, depending on its location on the site. Topsoil will be removed from all affected areas; e.g., the TS north and TS south portal sites, and stored here for later use in reclamation. (See Drawing No. YMP-025-1-CIVL-PL07.) Site-specific topsoil removal is required and specified in the Reclamation Implementation Plan (RIP) for each site location during preactivity surveys. The RIP also provides details for management of the topsoil storage pile.

3.2.2.4.4 Excavated Materials (Rock) Stockpile Site

Approximately 2,840,000 cubic yards of rock are expected to be excavated at the ESF, 140,000 cubic yards from the surface and 2,700,000 cubic yards from underground. The excavated material will be stored on this approximately 55-acre site, which is located between the TS south portal and the TS north portal. (See Drawing No. YMP-025-1-CIVL-PL07.)

In keeping with the requirement for a 100-percent uncertainty allowance, this site can be expanded to store twice the expected excavated rock. A perforated pipe collection system collects water from the rock and discharges it into a small, lined collection basin at the northeast end of the site. The water can be tested here and released to the waste water disposal system if appropriate.

3.2.2.4.5 Explosives Storage Site

The explosives storage site is located southwest of the batch plant. The site is designed to accept mobile trailer magazines transported to the site by tractor-trailer.

3.2.2.4.6 Water Tank Sites

The water tank sites are small areas for the siting, construction, and maintenance of the 200,000-gallon fire/excavation/construction non-potable water storage tanks and the 50,000-gallon domestic (potable) water storage tanks. (See Drawings No. YMP-025-1-CIVL-PL13 and YMP-025-2-CIVL-PL05.)

3.2.3 SITE DRAINAGE

The TS north portal, TS south portal, and optional shaft collar sites lie on steep hills or ridges separated by washes. The washes are at a moderate slope and are normally dry except during occasional storms. The drainage areas involved are usually small, although drainage flow velocities are relatively high. In any case the three main sites (TS north portal, TS south portal, and optional shaft collar) have been located above the levels reached by 100-year and probable maximum flood waters (see Section 3.1).

The auxiliary sites do not require the same degree of protection because of their functions. They are protected from a 100-year storm runoff. Roadways are protected from 25-year runoff events.

3.3 SURFACE FACILITIES

Surface buildings supporting the ESF phase of the Yucca Mountain Site Characterization Project (YMP) are designed for a nominal 15-year life and are complete with heating, ventilation, and air conditioning (HVAC), plumbing and sanitary facilities, fire protection systems, lighting, communications, and compressed air where applicable. The buildings are all new, pre-engineered steel structures or engineered steel or concrete block buildings on concrete foundations, except for a change house trailer and an office trailer planned for the optional shaft site. Building interiors are designed to provide optimum use of space with low maintenance finishes. All facilities are designed per DOE Standards, the Uniform Building Code, and National Fire Codes to meet the requirements for their intended use.

The individual buildings are described in detail in this chapter, with the Title I drawings showing the proposed designs in Volume 3, Chapter 16, and associated outline specifications in Volume 4, Chapter 17.

3.3.1 VENTILATION SYSTEM

The surface-based ventilation system will supply and exhaust adequate quantities of acceptable quality air to and from underground working areas, to provide personnel safety, health, and productivity in accordance with applicable federal and state regulations. To support the various phases of the ESF construction, operation, and test characterization, the system will be configured as follows.

During construction of any ramp (TS north or south, Calico Hills (CH) north or south), a vent duct of appropriate size and in-line fans will be installed in each ramp to pull the fresh air into the ramp and into the working face, maintaining an air velocity at the face of about 100 to 150 feet per minute, and exhausting contaminated air through the duct. (See Drawing No. YMP-025-2-MING-MI54.)

As soon as the TS north and TS south ramps and/or the CH north and CH south ramps are connected, the primary exhaust fans at the TS south portal will be installed to establish a flow-through ventilation system. Fresh air will intake in the TS north ramp and exhaust through the TS south ramp to the surface.

Subsurface air flow distribution, sizes and locations of vent ducts, and locations of fans and inspection doors are shown on Drawing No. YMP-025-2-MING-MI53.

The surface ventilation equipment arrangement includes two similarly sized primary exhaust fans located at the TS south portal, one in continuous operation and one as standby in case the operating fan fails (see Drawing No. YMP-025-2-STRU-GA03). In addition, exhaust air will be discharged vertically to avoid adverse air blast conditions affecting personnel and vehicle traffic. The fan area will be protected by barriers and/or gates to minimize the possibility of collision accidents and the attendant disruption of service, yet provide clear access for maintenance or replacement of fans. Ventilation system fan size and other design details will be determined during Title II design; the Reliability, Maintainability, and Availability (RM&A) report will be considered.

All fans for both surface and underground are provided with attenuators to reduce the noise to 85 dBA or below within [TBD] feet of the work area.

The ventilation system will generate a minimum air cooling power of 260 watts per square meter of personnel skin surface area to maintain an acceptable subsurface ambient temperature. This will be attained without using mechanical air cooling and refrigeration because estimated temperature of the virgin rock at the Topopah Spring and Calico Hills levels is below 80°F. The rock temperature warms the subsurface air in winter and cools it in summer.

3.3.2 TS NORTH PORTAL

3.3.2.1 Test Support Building

The test support building provides office and laboratory space to support the ESF construction, operation, and maintenance personnel for the site characterization program. (See Drawing No. YMP-025-1-7005-AR01.)

The 20,000-square foot pre-engineered steel building combines the various user groups into a single, integrated building. The user agencies and their area allocations within the building are: USGS (600 square feet), LLNL (550 square feet), LANL (1016 square feet), SNL (1808 square feet), RSN (860 square feet), SAIC (1,362 square feet), REECo (2,300 square feet), and DOE/NRC and State of Nevada (1,120 square feet). Also included within the facility are a lunch/breakroom designed to accommodate 50 persons, two conference rooms, a report message center, segregated male and female toilet facilities with shower compartments, a mechanical equipment room, electrical equipment room, and a fire riser room.

The structure, which has a 14-foot eave height, will be fully insulated with rolled batt insulation and fully protected by an ordinary hazard, group 2 wet pipe sprinkler system to comply with the DOE improved risk concept.

The test support building is provided with two roof-mounted packaged heat pumps with variable air volume zone control and main duct bypass dampers. The system provides heating and cooling with multiple zone controls for comfort.

The facility does not require any special electrical equipment. General power is based on the use of 120V, 20A duplex receptacles and ground fault circuit interrupter (GFCI) in the restrooms, at the kitchen units located in the lunchroom, and in each user group area. For lighting, fluorescent luminaries with energy-saving lamps and ballasts will be used. Emergency lighting and self-powered exit signs are also incorporated into the design.

3.3.2.2 Change House

The change house is a 6,660 square foot, 16-foot eave height, pre-engineered steel building designed to support excavation operations. (See Drawing No. YMP-025-1-7002-AR01.) The building provides segregated facilities for men and women with a combined total of 155 lockers and hanging baskets for workers, 17 lockers for visitors, and shower and toilet facilities. A non-skid surface finish is used in the locker room to prevent personnel from slipping on wet floors. The building also houses a first aid station, training room, lamp room, and life safety and fire control command post, including a carport for two small, open personnel underground transportation vehicles and an ambulance. These services will also be utilized by optional shaft site personnel. **NOTE:** Facility services are subject to review during Title II design.

An emergency eyewash/shower is provided in the lamp room in the event of a battery acid spill. An exhaust duct is provided to vacate any hydrogen gas that may be emitted by the lamp batteries during recharging.

The HVAC system for the change house is divided into two zones, with the men's locker room/toilets in the first zone and all remaining areas in the second zone. A ventilation fan unit for cooling and electric infrared heating are provided in the first zone. Per the American Society of Heating, Refrigeration and Air Conditioning Engineers Standard for "Ventilation for Acceptable Indoor Air Quality" (ASHRAE 62-1982), ventilation air is provided at a flowrate of 0.5 cfm per square foot of locker room floor space. The second HVAC zone, the location of first aid, life safety, training, and lamp repair, is conditioned by a packaged heat pump system.

The building is protected by an ordinary hazard, group 2 wet pipe sprinkler system in keeping with the DOE improved risk concept.

The electrical systems for the change house are divided into the same two zones as the HVAC systems. In zone one, receptacles are located where appropriate, using GFCI near the lavatory area. In zone two, standard 120V, 20A duplex receptacles are used because no special electrical equipment is required there.

Interior lighting is provided by fluorescent luminaries with enclosed general use type fixtures. Exterior lighting is provided by high-pressure sodium luminaries. Emergency lighting and self-powered exit signs are also incorporated into the design.

3.3.2.3 Shop/Warehouse

This building is a complete facility with all systems and services required to accomplish routine maintenance and repair of equipment and scientific test equipment assembly and staging. The facility, based on present criteria, is a 4,200-square foot, 20-foot eave height, pre-engineered steel building with 12-foot by 12-foot roll-up doors, double 6-foot by 7-foot doors, 3-foot by 7-foot exterior personnel doors, offices, toilets, and secure storage area, and is structurally designed to accommodate two 5-ton monorail hoists, one 2-ton monorail hoist, and one 1-ton jib crane. (See Drawing No. YMP-025-1-7000-AR01.) The building's size is based on presently available information; its final size will be determined during Title II design.

Evaporative cooling is used in the high bay areas because of the low relative humidity of the region and the large building volume. This is the simplest and most cost-effective way to provide cooling for non-critical comfort applications. Electric infrared heating is used to heat the high bay areas. The office areas are fitted with split system heat pumps providing both heating and cooling. An ordinary hazard, group 2 wet pipe sprinkler system is provided for fire protection.

The building is provided with general type duplex receptacles throughout, three each: 60A, 208V, 3-phase receptacles; 30A, 480V, 3-phase receptacles; quadraplex 120V, 20A, 1-phase; and 20A, 120V single receptacles. The high bay areas incorporate high-output fluorescent luminaries, while the other areas use normal fluorescent luminaries with energy-saving lamps and ballasts. High-pressure sodium luminaries are used on the exterior.

3.3.2.4 Main Warehouse

The main warehouse building provides a common facility for the safe storage and handling of supplies and materials required to support ESF construction and operation. The warehouse is a 5,000-square foot, 20-foot eave height, pre-engineered steel building with offices, toilets, receiving area, high bay storage, secure storage, and miscellaneous storage. A 10-foot by 12-foot roll-up door provides access from the loading dock. The offices and toilets have vinyl flooring while all other areas are concrete with hardener and sealer. (See Drawing No. YMP-025-1-7001-AR01.) The building's size is based on presently available information; its final size will be determined during Title II design.

Evaporative cooling is used in the warehouse because of the low relative humidity of the region and the large building volume. Electric infrared heating is used to provide heating in the building. The office has a through-the-wall heat pump to provide both heating and cooling. Additional exhaust fans are provided in the miscellaneous storage rooms for cooling; unit heaters provide freeze protection during cold weather.

An ordinary hazard, group 2 wet pipe sprinkler system is provided in the building except that in the high bay storage area the sprinkler system complies with NFPA 231 for storage racks.

General type duplex receptacles are provided for the facility. The electrical power required for heating, ventilation, air conditioning, and plumbing is sized and located based on the mechanical design.

The lighting is based on the use of high-output fluorescent luminaries because of the high bay area. In other areas, fluorescent luminaries with energy-saving lamps and ballasts are used. High-pressure sodium luminaries are used on the exterior of the building.

3.3.2.5 Surface Data Building

The surface data building provides a controlled environment computer room for the IDS data processing, data communication, and data archiving equipment. It also provides a venue for Principal Investigator (PI) access to the IDS at the surface and for specialized data collection and/or display. The facility is a 4,800-square foot, 14-foot eave height, pre-engineered steel building with a raised floor for the IDS mainframe computer equipment and peripherals. Equipment for supporting any required communication of data to offsite PI locations will be housed in the surface data building and/or the TS north portal site microwave tower building (Section 3.3.2.9). Likewise, termination of fiberoptic network(s) for transfer of data from the subsurface will be in the surface data building and/or the microwave tower building. Per DOE/EP-0108, the computer room is separated from the rest of the building by a 1-hour rated firewall with vapor barrier and fire-rated glass observation windows. Fire-rated corridors are not required due to building occupancy load, but all walls and partitions are of noncombustible construction. In addition to the computer room the facility provides a reception area, offices for a manager, assistant manager, quality assurance, and two programmers, a workstation room for visiting scientists, a records vault, restrooms, a fire riser room, a telephone communications equipment room, a multipurpose/supervisor area, and a fire-rated enclosure with sound batts for the UPS equipment. (See Drawing No. YMP-025-1-7003-AR01.)

In the IDS computer room, air-cooled process cooling units provide approximately [TBD] tons of cooling via underfloor air distribution, which allows full room flexibility for equipment. A separate package air conditioning unit with economizer, which allows free cooling using the outside air, is used for the UPS room because of the year-round high equipment heat load. The remainder of the building is heated and cooled with a packaged heat pump.

An ordinary hazard, group 2 wet pipe sprinkler system is used throughout the building, with quick-response on-off sprinklers in the computer room. An automatic detection system is provided in the computer room for early warning via smoke detectors at the ceiling and in the underfloor air plenum.
The systems shall meet the "Standard for Fire Protection of DOE Electronic Computer/Data Processing Systems," DOE/EP-0108.

Except for the building's main entrance, all doors will be fitted with restricted access hardware and intrusion alarms.

The electrical requirements for the computer area, UPS power, and lighting are based on 50kVA, 120/208V, 3-phase UPS power and lighting at 100 foot-candles (fc) with provision for emergency lighting. A power shutdown switch at each principal exit of the computer room cuts all power to computer equipment and related HVAC systems. The remainder of the building has general power using 120V, 20A duplex receptacles. The entire building is served by standby power. The UPS time duration requirement will be determined during Title II design.

The building also requires an expandable power distribution system, acoustical treatment to reduce noise, and interior air cleaning/filtering.

3.3.2.6 Portal Control Center

The portal control center building provides a checkpoint for personnel entering and leaving underground operations. The structure is a pre-engineered steel building, 900 square feet, with a 12-foot eave height. Incorporated in the building is the access control area with three turnstiles to record the passing of personnel entering and exiting the underground, an access monitoring room, a briefing room, restroom, and storage area. Four-foot high windows in the exterior skin of the building allow visual access from the monitor room to the portal entrance. (See Drawing No. YMP-025-1-7004-AR01.)

The building is fully insulated and has a suspended lay-in ceiling at 8 feet above finish floor.

This facility is provided with a split-system heat pump for heating and cooling. The facility is protected by an ordinary hazard, group 2 wet pipe sprinkler system.

3.3.2.7 Electrical Substation Control Building

The electrical substation control building is a single-bay, pre-engineered steel building with a 12-foot eave height. The building, 600 square feet in area with a concrete floor slab on grade, will house the electrical controls for the portal and ramp operations. Access for both personnel and equipment will be through a single opening with two 3-foot wide by 7-foot high hollow metal doors. The building will be fully insulated with rolled batt insulation. (See Drawing No. YMP-025-1-7006-AR01.)

This facility is provided with a high-temperature setpoint ventilation system. An automatic fire sprinkler system will also be provided.

3.3.2.8 Electrical Switchgear Building

The electrical switchgear building is a pre-engineered steel building with 4,000 square feet open area, a 14-foot eave height, and a concrete slab-on-grade floor. The building will house the switchgear equipment for the portal and ramp distribution system. Two personnel access doors are located at opposite ends of the building; equipment access is provided by two 3-foot wide by 7-foot high double doors. The building will be fully insulated with rolled batt insulation. (See Drawing No. YMP-025-1-7007-AR01.)

This facility is provided with a high-temperature setpoint ventilation system. An automatic fire sprinkler system will also be provided.

Located close to the electrical switchgear building are the emergency power generators. These generators are the weatherproof, outdoor type requiring no enclosure.

3.3.2.9 Microwave Tower Building

This facility, which contains the equipment required to operate the microwave system, is a 12-foot by 36-foot engineered concrete block building with an eave height of 12.5 feet. The primary purpose of the facility is to house the electronic communications equipment used to transmit and receive telephone, data, and various alarm information. The electronic equipment includes the underground intercom system switch, electronic private automatic branch (EPAB) exchange, and the uninterruptible power supply (UPS). The building is located adjacent to the microwave tower on an on-grade concrete slab.

An automatic fire sprinkler system will be provided for this facility. A temperature control system will be provided when more information on this facility becomes available.

3.3.2.10 Conveyor Transfer Tower

The conveyor transfer tower, an 18-foot by 22-foot engineered facility, will occupy 396 square feet. Tower height will be 38 feet. (See Drawing No. YMP-025-1-STRU-GA03.)

3.3.3 TS SOUTH PORTAL

TS south portal surface facilities are largely identical to those of the TS north portal. Differences are identified.

3.3.3.1 Change House (Drawing No. YMP-025-2-7011-AR01)

The TS south portal change house is identical to the TS north portal change house (see Section 3.3.2.2).

3.3.3.2 Shop/Warehouse

This building includes all systems and services required to accomplish routine maintenance and repair of equipment. The facility is a 2,400-square foot, 20-foot eave height, pre-engineered steel building with roll-up doors, double exterior doors, personnel doors, office, toilet, and parts storage area, and accommodates a 5-ton monorail hoist. (See Drawing No. YMP-025-2-7010-AR01.)

Provisions for cooling, heating, power, and lighting are similar to those for the larger TS north portal shop/warehouse (see Section 3.3.2.3).

3.3.3.3 Portal Control Center (Drawing No. YMP-025-2-7012-AR01)

The TS south portal control center (PCC) is identical to the TS north portal PCC (see Section 3.3.2.6).

3.3.3.4 Electrical Substation Control Building (Drawing No. YMP-025-2-7016-AR01)

This facility is identical to the electrical substation control building planned for the TS north portal site (see Section 3.3.2.7).

3.3.3.5 Electrical Switchgear Building (Drawing No. YMP-025-2-7017-AR01)

This facility is identical to the electrical switchgear building planned for the TS north portal site (see Section 3.3.2.8).

3.3.3.6 Airlock Building

The airlock building will be a 2,970-square foot engineered facility with an eave height of 28 feet. (See Drawing No. YMP-025-2-7015-AR01.) Additional details are [TBD].

3.3.3.7 Conveyor Drive and Transfer Building

This 50-foot by 50-foot engineered steel building, an airlocked facility with an eave height of 40 feet, will be provided with a controlled air leakage ventilation system to cool the conveyor drive motor assembly. A high-temperature setpoint thermostat will modulate a motorized damper. A dry-pipe sprinkler system will also be provided in this building. (See Drawing No. YMP-025-2-7013-AR01.)

3.3.3.8 Microwave Tower Building

This facility is identical to the microwave tower building planned for the TS north portal site (see Section 3.3.2.9).

3.3.3.9 Ventilation Fan Hydraulic Control Building

This 20-foot by 24-foot pre-engineered steel building, which has an eave height of 10 feet, is used to house the hydraulic controls and operation status indicators of the TS south portal ventilation fans. The building will also be protected with an automatic fire sprinkler system. As more information becomes available on this facility, a temperature control system will be provided. (See Drawing No. YMP-025-2-7014-AR01.)

3.3.4 OPTIONAL SHAFT COLLAR

3.3.4.1 Change House

The change house facility for the optional shaft collar site will be a double-wide, 24-foot by 40-foot long trailer. The trailer will provide locker storage, toilet, and shower facilities for support of the shaft workers. Other support functions such as training, first aid station, life safety, and fire control command post will be located at the TS north portal change house.

3.3.4.2 Hoist House

This 3,600-square foot, 24-foot eave height, pre-engineered steel building will be designed to house the optional shaft hoist and its associated relays and controls. Work areas will be provided for routine maintenance.

Because of the heat produced by the hoist motors and relays, no additional heating will be required for the building except in the toilet, fire riser room, and hoist operator cab. Intake and exhaust fans will be provided to create air movement over the motors and relays and exhaust the heat to ensure that the indoor temperature does not exceed 120°F.

An ordinary hazard, group 2 preaction sprinkler system will be provided for fire protection. The preaction system, which is used because the building is not heated, is activated by fixed temperature heat detectors that enable an automatic fire alarm to sound prior to flow of water.

The hoist will require 4,160V, 3-phase power, which will be provided through separate power feeders in cable trenches in the floor. The feeders will have main disconnects outside the building. Lighting for the high bay will be provided by metal halide luminaries, with additional emergency lighting and self-powered exit signs.

3.3.4.3 Headframe

The headframe will be an engineered, 66-ton steel structure (14 feet wide, 14 feet long, and 82 feet high) with backlegs and vertical columns located symmetrical to the shaft centerline. The headframe will be designed to accommodate all operational phase requirements.

3.3.4.4 Trailer Office Facility

A double-wide trailer 24 feet wide and 56 feet long with an eave height of 10.5 feet will be used as the optional shaft collar site office facility.

3.3.4.5 Electrical Substation Control Building

This facility is identical to the electrical substation control buildings planned for the TS north portal site and the TS south portal site (see Sections 3.3.2.7 and 3.3.3.4).

3.3.4.6 Electrical Switchgear Building

This facility is identical to the electrical switchgear buildings planned for the TS north portal site and the TS south portal site (see Sections 3.3.2.8 and 3.3.3.5).

3.3.4.7 Microwave Tower Building

This facility is identical to the microwave tower buildings planned for the TS north portal site and the TS south portal site (see Sections 3.3.2.9 and 3.3.3.8).

3.3.5 MISCELLANEOUS FACILITIES

3.3.5.1 Temporary Facilities

Temporary trailer facilities will be utilized as needed by support personnel during construction.

3.3.5.2 Materials Storage Areas

During construction, the contractor requires laydown areas to store equipment, supplies, and building components waiting to be erected. The main laydown area is on 2 acres located southeast of the TS north portal site.

The explosives storage area is located away from populated areas as recommended by guidelines set by the Bureau of Alcohol, Tobacco, and Firearms. There is sufficient space to accommodate the explosives and related equipment, and to allow a tractor-trailer to turn around.

3.3.5.3 Staging Areas

A Tunnel Boring Machine (TBM) subcontractor is to be utilized for excavating the TS north and TS south ramps to the Topopah Spring level and the Calico Hills level. Staging areas for the subcontractor are incorporated into the design.

On both the TS north and TS south portal sites, areas are provided for parking of mobile equipment and storage of immediate and near-term use TBM equipment. Utility stubouts are provided for power, water, sewer, and compressed air.

Additional storage areas provided on auxiliary sites located [TBD] are used for long-term storage of TBM equipment, materials, or supplies. These might include structural steel, rockbolts, and spare equipment. These areas are also provided with power, water, and sewer stubouts.

An auxiliary site of approximately 5 acres is provided for the erection of a concrete batch plant and stockpile storage of aggregate. This site has utility stubouts for power, water, and sewer, and a connection for disposal of aggregate wash water into the waste water disposal system. Ample space is provided for parking of mobile equipment.

3.3.5.4 Parking Areas

Parking and bus turnarounds are provided for the construction and scientific personnel. There are sufficient spaces to park 100 vehicles on the TS north portal site and 48 parking spaces on the TS south portal site.

3.3.5.5 Site Security

The primary security for the ESF is provided by an NTS security contractor. At present, the single access road to the ESF for all personnel is through the main NTS Mercury guard gate. It is anticipated that Amargosa Junction (Lathrop Wells) guard station 510 will become the ESF access point. The ESF will be under the existing Area 25 security system.

3.4 SURFACE UTILITIES

The TS north portal and south portal utilities plans are shown respectively on Drawing No. YMP-025-1-CIVL-PL12 and Drawing No. YMP-025-2-CIVL-PL04.

3.4.1 POWER DISTRIBUTION

The surface electrical power transmission and distribution system provides sufficient electrical power to meet construction and operational requirements for the surface and subsurface. Standby and uninterruptible power supply (UPS) systems are available for equipment required during any utility power outage. The main power source for the ESF site is a 69kV transmission line fed from the existing Canyon Substation. (See Drawings No. YMP-025-1-ELEC-EL01 and YMP-025-1-ELEC-EL02.)

The design requires rerouting the existing 69kV transmission line to the TS north portal and TS south portal substations where the 69kV transmission voltage is stepped down to 12,470V, the primary distribution voltage. The 15kV-rated power cables are routed in concrete-encased duct banks to various surface facilities, including site lighting, and supply subsurface power to the TS north portal, TS south portal, and optional shaft collar sites. Grounding provisions will be determined during Title II design.

Standby power is provided by diesel engine generators. During utility power outages, power is supplied to the ventilation fans; the optional shaft hoist (if required); subsurface facilities; communications and security equipment; UPS; security lighting; life safety; and other required equipment.

The UPS power is used for communications, security, life safety, IDS equipment, and PI-supplied site characterization test equipment that must operate during any utility or standby power outage. Each UPS time duration requirement will be determined during Title II Design.

3.4.2 WATER DISTRIBUTION SYSTEM

The water distribution system supplies and distributes potable and fire protection/underground water required for construction and operation of the ESF. The requirements for operations are [TBD] gpm for typical usage. The typical operational flow accommodates [TBD] personnel in a 24-hour period, with an average per person usage of [TBD] gallons/day. Peak potable demand during a shift change is estimated to be [TBD] gpm.

Water is supplied from existing well J-13 in Area 25 at the NTS and transmitted through 4.25 miles of new 8-inch mortar lined and coated ductile iron pipe to a booster pump station located near the intersection of H-Road and the TS north portal access road. The design of the pump station incorporates pumps, both primary and backup, of sufficient size to supply water to the two portals, the batch plant, and possibly to an optional shaft collar. A forebay (surge) tank will be provided at the booster pump for positive suction head.

The water distribution system to the TS north or TS south portal or the optional shaft collar consists of an [TBD]-inch distribution line from the booster pump. This line is buried with a minimum of 3-foot cover to provide protection from the elements and from construction. Air release valves will be installed in the high points of the line to provide surge and vacuum protection to the line. The water is pumped from the booster to two water storage tanks "uphill" of each portal. One tank (200,000 gallon) is sized to provide fire protection, construction, and underground water to the site and one tank (50,000 gallon) to provide the site with potable water. These tanks will be constructed of plate steel. The potable tanks are provided with a packaged chlorinator system to purify the water for potable uses.

Approved tracer elements, [TBD] during Title II design, will be introduced to the underground and fire protection water for environmental and scientific monitoring purposes. Additional appurtenances, such as fire hydrants, gate valves, and backflow preventers, will be provided as needed throughout the system. The location of the underground waterline will be marked to minimize the possibility of damage from future construction or operational activity.

3.4.3 SANITARY SYSTEM

The sanitary waste sewage system provides for the collection and treatment of sanitary waste generated within the portal buildings. The waste system collects sanitary waste water from the buildings on each portal site in an 8-inch main line. This line will be sloped to provide sufficient velocity, a minimum of 2 feet per second, to maintain the solids in suspension. Manholes will be provided for access and maintenance at changes in grade or direction of the pipeline. These manholes will be a minimum of 48 inches in diameter with traffic-rated lids and frames. Each lid will have the word "Sanitary" cast into it to identify it as a sanitary manhole.

A septic tank will be provided to collect and treat the solids from the system. This tank will be sized, constructed, and installed in accordance with Nevada Administrative Code, Chapter 444 "Regulation Governing Individual Sewage Disposal Systems." The criteria for designing and constructing a septic tank system are normally controlled by county government; however, this part of Nye County is under the control of the Nevada State Division of Health, Consumer Health Protection Services. The major areas of concern the state has for septic systems is that the system be designed and constructed so that it will not:

1. Contaminate any drinking water supply
2. Give rise to a public health hazard by being accessible to insects, rodents, or other possible carriers which may come in contact with food or drinking water

3. Create a nuisance due to odor or unsightly appearance
4. Contaminate any body of water
5. Violate laws or regulations governing sewage disposal.

A leachfield connected to the septic tank will utilize the soil for absorption and treatment of the septic tank effluent. This waste line will be sized, both in diameter and length, based on the soil's ability to percolate the effluent into the soil. Percolation tests will be accomplished by a qualified soils engineer to determine these rates prior to final design and permitting by the state.

3.4.4 COMMUNICATIONS SYSTEM

The communications system design consists of the telephone system, underground intercom systems, public address, and closed-circuit television (CCTV).

The telephone system consists of standard telephone instruments that provide access to the Federal Telecommunications System (FTS), the DOE/NV system, and long distance networks. The system provides voice communications from the surface facilities to subsurface locations, Area 25, Mercury, and Las Vegas, as well as long distance access. The system functions by using a microwave system or fiberoptic link connected to the existing NTS microwave system. The telephone system also supports alarm services for fire, medical, and security.

The underground intercom systems are located in the ESF surface buildings and at each work location underground.

The CCTV system allows YMP personnel to view their respective access openings and other critical underground locations. It also allows visual surveillance of personnel to ensure safe operations in these areas.

3.4.5 WASTE WATER DISPOSAL SYSTEM

The surface waste water disposal system handles non-sanitary waste water from underground. This water is delivered to the ramp portals under pressure through an anticipated 6-inch pressure rated pipe. A construction/test peak flow rate of 250 gpm and a steady flow rate of 20 gpm are anticipated. These flow rates include a 35-percent uncertainty allowance. Potential fire flows are estimated at 550 gpm based on an hydraulic design area of 3,000 square feet at 0.165 gpm density, and 150 gpm for hose streams. It is assumed that the construction/test peak flow will cease upon a fire alarm. Sump designs will be based on a total flow of 700 gpm (550 + 150) for a duration of 60 minutes (42,000-gallon capacities).

It is anticipated that a fully redundant system with a flow capacity of 700 gpm will be developed during Title II. An analysis of system water storage levels to allow for evaporation and address overflow prevention will also be conducted.

It will be necessary to separate the hydrocarbons and the suspended solids from the underground waste water. This will be accomplished by means of a settling basin with an oil skimmer. The settling basin is sized to handle the peak underground discharge. The discharge is routed into a separate evaporation pond at each portal area where the water will be evaporated into the atmosphere. No waste water will be allowed into the natural washes in the area. The evaporation pond is off-block, which provides assurance that impacts to waste isolation and testing will be limited.

3.4.6 COMPRESSED AIR SYSTEM

The compressed air system supplies compressed air for ESF construction, testing, and operation. The surface compressed air system consists of pad-mounted compressor units producing the compressed air, as well as auxiliary equipment conditioning the compressed air. (See Design Analysis ST-ME-011, Compressed Air Distribution System.) The compressed air system will contain an approved tracer gas metered for control.

The conditioning equipment includes oil separators and aftercoolers to provide a product safe for personnel use. The surface compressed air system supplies compressed air to meet the 100-psig demands of subsurface construction and testing. Booster compressors will be provided for the 200-psig pressure requirements of the large diameter drills.

3.5 ESF RAMP ACCESSES

3.5.1 TS NORTH PORTAL (See Drawing No. YMP-025-1-MING-MI01.)

Initial construction begins with the removal and storage of topsoil followed by excavation of the site area's unconsolidated material to bedrock. Some near-surface bedrock may also be removed using rippers until that equipment's capabilities are exceeded. Most site area rock removal is performed using dozers, front end loaders, and trucks. (See Drawing No. YMP-025-1-CIVL-GP01.)

A highwall is excavated into the hillside portion of the site, allowing initial portal entry construction. Using a benching method of drilling and blasting, a vertical rockwall face is exposed to an extent sufficient to allow portal construction; i.e., a rockwall higher than 60 feet. (This height will be subject to verification when more field data is available.) Initial ground support is provided on the highwall by installing rockbolts and wire mesh around the targeted portal entry.

TS north ramp excavation is then begun using controlled drilling and blasting methods to drive an initial approximately 150-foot drift 28 feet high by 28 feet wide. At this point excavation stops while a concrete portal structure is constructed. The portal structure consists of approximately 50 feet of liner and support, and concrete tube and wing wall structures that extend out and away from the rock highwall. During the time that concrete in this structure is curing, the 25-foot diameter Tunnel Boring Machine (TBM) is assembled on the site area directly in front of the TS north portal.

The portal structure (see Drawing No. YMP-025-1-STRU-GA02) is constructed of reinforced concrete, and extends into the ramp for about 50 feet or that distance deemed necessary for near-portal rock support. The outside structure is essentially a building complete with controlled entry, doors, utilities, and special construction to accommodate ventilation and rock removal equipment. The underground portion of the portal consists of an approximately 1-foot thick reinforced concrete liner with concrete invert. This is installed only to the depth where it is field-determined that a stable subsurface rock mass has been reached, and it is no longer necessary to control a fractured rock mass associated with the portal entrance. Beyond this area regularly scheduled ground support is installed in the form of rockbolts and/or other methods as required.

3.5.1.1 Rock Support/Ramp Reinforcement

During the intended life of the ESF, the ramp will not have a reinforced concrete liner. For its intended purpose (access to the subsurface) it is not deemed structurally necessary to fully line the ramp, and testing can more easily be accommodated with minimal but adequate rock support.

Rock support in the ramp, as well as in all underground openings, will be installed to the extent considered necessary by both design and field inspection. Design analysis will first determine the stability of an opening within a given stratigraphic horizon and interface, and classify the result relative to other rock types. Next, a suggested method of reinforcement will be determined for each classification or rock section. These methods may range from rockbolts only in very competent rock to full concrete lining and/or steel support in extremely poor ground. Various combinations of support will be prescribed for those sections of intermediate strength, and for special sections such as intersections of openings. It is expected that all underground areas will be rockbolted on a regularly gridded pattern as a minimum. As the requirements for support increase, this will change to closer bolt spacing, bolts and wire mesh, or bolts, mesh, and shotcrete before the need for full concrete lining is realized. Reinforcement will be installed in the ramp as soon as possible behind the advancing face as allowed by the TBM structure and mapping activities.

3.5.1.2 TS North Ramp Stations

For the purpose of this report, ramp stations are defined as the intersection of the ramp with a lateral drift extending from either side of the ramp. These stations may include cutouts for testing or test support facilities such as the IDS, as well as major intersections of levels or ramps.

Numerous stations are planned along the TS north ramp. Examples include: a TS/CH north ramp intersection; approximately 14 test locations; several stations accessing the main test area; and two conveyor belt tangential drifts. Excavation of the stations will be performed by mechanical or controlled drill and blast methods as dictated by rock type. The excavation of many of these stations may be deferred until TBM excavations are complete. However, stations such as the TS/CH intersection and several testing locations will be excavated prior to ramp completion due to testing or scheduling requirements. In these cases, station excavation will proceed as soon as practical after the TBM passes the station location. The TBM will be stopped, and all related utilities will be removed or covered to protect them from the effects of the excavation activity. As a minimum, approximately 25 feet will be excavated to either side of the ramp before TBM activity resumes.

The TS/CH north ramp intersection will provide an assembly/launching chamber with adequate clearances for cranes and personnel to assemble the smaller (18-foot diameter) CH TBM and its trailing gear. The assembly/launch area will extend approximately 200 feet from the TS north ramp. A transfer assembly will be installed to transfer broken rock from the CH north ramp onto the main conveyor system.

3.5.1.3 TS North Ramp Roadway

Due to functional requirements and decline angle, transportation for personnel and material access is by diesel or electric powered rubber-tired vehicles. This dictates the necessity for establishing a roadbed on the ramp invert suitable for vehicular and pedestrian traffic.

The TS north ramp is sufficiently wide to allow most vehicles to pass, given that ramp furnishings, including the main conveyor, will be supported from the ribs and back. At selected intervals the roadway will be restricted due to the presence of a mobile refuge chamber parked against the rib. Occasional passing areas are provided for large vehicles and equipment being transported underground.

Roadway base material is obtained from TBM-excavated material diverted onto the invert behind the TBM. Once the base is installed for a predetermined length of ramp, it is graded/dozed to a depth of about two and a half feet on the ramp centerline. A layer of crushed stone is added to achieve a total depth of about three feet at the centerline. This top layer of aggregate is produced by diverting excavated rock from the main conveyor into a portable crusher to reduce the material in size. (Resulting dust will be controlled by methods to be determined during Title II design.) The road surface is then graded and treated with an approved material(s) to suppress dust and stabilize the road surface to support the movement of traffic. Roadway maintenance is done by wetting the surface with a minimal amount of water (to avoid impacting waste isolation or site characterization) and regrading as necessary. The ramp roadway may be paved with concrete at a later date.

A potential exists for the use of TBM excavated material containing mordenite as a roadway base material. Regulatory action may be required depending on the conclusions reached by studies planned to be conducted.

3.5.1.4 TS North Ramp Furnishings

Furnishings in the TS north ramp fall into five basic groups:

- main rock removal conveyor
- ventilation
- compressed air supply
- water supply and removal
- power and instrumentation

All ramp furnishings are designed to be removable.

All utilities are designed to be suspended by brackets from the rib and back to provide maximum roadway clearance.

Ventilation ducting is provided in appropriate lengths; at the joints, the duct sections are clamped and attached to brackets bolted to rockbolts in the back. Booster fans are provided at regular intervals, installed in-line in the duct sections. The ventilation ducting, provided for the development phase of construction prior to the establishing of flow-through ventilation, may be left in place for subsequent excavation activities.

The main rock removal conveyor belt is approximately three feet wide; the conveyor frame is rockbolted to the rib. Exact height and position of the conveyor will vary in areas of transfer points from side drifts and at the point of TBM feed, but generally will be located in the lower left or right quadrant of the excavation. Conveyors are equipped with all necessary emergency shutoff cabling and protective devices to prevent spillage.

Electrical power and instrumentation cabling is carried in cable trays suspended from the back by rockbolts and extension rods. Power access is achieved by routing the desired cabling to a junction box on the rib at any desired interval, or to transformer stations as prescribed by the design. Instrumentation cabling (only some of which is fiberoptic) is run in separate cable trays placed a sufficient distance from the power cable tray to avoid electrical interference. Power cable locations will be re-evaluated during Title II design.

Compressed air and water lines (supply water and waste water removal) are suspended from hanger brackets attached to the rib or, alternately, on hangers attached to the conveyor support frame. Piping is provided in random lengths except where stations or cutouts are encountered. In these areas, piping is routed up and over the intersection opening to avoid traffic interference.

3.5.1.5 Tunnel Boring Machine Excavation, TS or CH North Ramp (See Drawing No. YMP-025-1-MING-MI04.)

Tunnel Boring Machines (TBMs) are currently considered one of the most effective available means of rapid excavation for underground tunneling. Most excavation planned at the ESF will be done by TBM due to the types of rock present.

TBMs excavate or "bore" circular openings that can vary in diameter from approximately 6 feet to greater than 40 feet, depending upon the machine used. The basic means of excavation is a full face, rotating cutterhead that consists of a series of disc cutters which track at a predetermined radius about the center of the cutterhead. The spacing of the tracks, and consequently the disc cutters, is a function of rock strength, quality, and composition. The disc cutters typically range from 15 to 19 inches in diameter.

The rotating cutterhead is thrust at the rock face to be excavated by means of hydraulic thrust cylinders and gripper assemblies. Generally, side grippers, located behind the cutterhead near the middle of the machine, are pushed out from the machine to press against or "grip" the tunnel walls. The hydraulic thrust cylinders then extend between the TBM body and the cutterhead, applying the thrust to the rotating cutterhead. After the thrust cylinders reach the end of their approximately 5-foot stroke, the gripper cylinders are retracted toward the center of the machine; the thrust cylinders are also retracted, pulling the TBM assembly forward. A new grip is then established and the process repeated.

It is possible to steer the TBM around corners by using the main grippers and a set of steering cylinders located at the periphery of the cutterhead. In the past, long radius curves in the range of 600 to 1,000 feet radius were achieved. New technology and machine design now allow 300-foot radius curves using an 18-foot diameter unshielded TBM.

During cutting, the rock chips or cuttings fall to the tunnel invert and are picked up by buckets or "scoops" located at the periphery of the face of the cutterhead. As the cuttings are scooped into the buckets the cutterhead rotates, carrying the full buckets toward the top of the machine. The cuttings are then funneled from the buckets, through the cutterhead, into a small hopper which feeds a conveyor belt. The conveyor belt runs the full length of the machine to a rear discharge point behind the TBM unit. From there, the rock is loaded onto another conveyor for final transport out of the tunnel.

The TBM cutterhead is powered by electric drive motors located on the main shaft behind the cutterhead. Electric panels, switchgear, hydraulic pumps, and reservoirs are commonly located on a trailing deck or sled pulled along behind the actual TBM. Separate sleds can also be attached for materials and supplies, lunchrooms, refuge chambers, etc. The machine conveyor runs from the cutterhead, over the top of all trailing deck units, to a discharge point at the rear of the system. (Note that long trailing decks generally dictate longer radius curves.) A 500- or 1,000-foot power cable is wrapped accordion style at the back of the system, which lets out cable as the machine advances. Permanent power cable is then installed off-shift and the TBM's power cable rewrapped.

Ventilation at the TBM is accomplished by a negative-pressure fan mounted on the TBM behind the cutterhead. An accordion-style, ribbed ventilation bag in a canister is attached between the fan and the permanent ventilation duct behind the TBM system. Any dust that escapes suppression (see Section 6.6.4) is sucked from the tunnel into the ventilation exhaust duct. A fan does not have to be located on the machine, but can be located in the hardline vent duct behind the machine if it is more compatible with ventilation plans. The fan can then pull the air and dust through the ribbed vent bag and into the permanent vent duct. Where water use is not a major concern, small quantities of water are typically sprayed at the cutterhead to aid in dust control. In addition, dust collectors will be provided at strategic locations. (Additional dust control measures will be considered during Title II design.) As the TBM advances, the ribbed ventilation bag is pulled out of its canister until its limit is reached. At that time, the TBM is stopped and the vent bag retracted into the canister while the permanent ventilation duct is installed up to the TBM system.

The TBM to be used at Yucca Mountain is an open-style machine designed for use in fairly competent ground conditions that typically don't initially require extensive rockbolting. The ramp is accessible directly behind the cutterhead, allowing initial rockbolting and ground support to be accomplished. Additional rockbolting and other ground support are accomplished after the machine and trailing decks pass and any required site characterization tests have been completed.

3.5.2 TS SOUTH PORTAL (See Drawing No. YMP-025-1-MING-MI01.)

Construction of the TS south portal, including site preparation, highwall excavation and ground support, and ramp excavation, will be accomplished as described for the TS north portal (see Section 3.5.1). The TS south portal grading plan is shown on Drawing No. YMP-025-2-CIVL-GP01; Drawing No. YMP-025-2-STRU-GA02 depicts the portal structure.

3.5.2.1 Rock Support/Ramp Reinforcement

TS south ramp rock support and reinforcement will be installed with reference to the criteria cited in Section 3.5.1.1 for the TS north ramp.

3.5.2.2 TS South Ramp Stations

As stated in Section 3.5.1.2 for the TS north ramp, TS south ramp stations are defined as the intersection of the ramp with a lateral drift extending from either side of the ramp. These stations may include cutouts for testing or test support facilities such as the IDS, as well as major intersections of levels or ramps.

Approximately 13 stations are planned for the TS south ramp, including the TS/CH south ramp intersection. Similar to the TS north ramp, excavation will be deferred or accomplished depending on test and schedule requirements.

TBM operations for the TS south ramp are similar to those described in Section 3.5.1.2 for the TS north ramp.

3.5.2.3 TS South Ramp Roadway

An underground roadway for vehicular and pedestrian traffic will be constructed in the TS south ramp as described in Section 3.5.1.3 for the TS north ramp.

3.5.2.4 TS South Ramp Furnishings

TS south ramp furnishings related to rock removal, ventilation, compressed air supply, water supply and removal, and power are identical to the furnishings described in Section 3.5.1.4 for the TS north ramp, and are similarly designed to be removable.

3.5.2.5 Tunnel Boring Machine Excavation, TS or CH South Ramp

Tunnel Boring Machine (TBM) information applicable to the TS or CH south ramp is identical to that given in Section 3.5.1.5 for the TS or CH north ramp.

3.6 OPTIONAL SHAFT

See Section 6.4.3 of this report.

3.7 UNDERGROUND EXCAVATIONS

Underground excavations planned at the ESF include the TS north ramp, the TS south ramp, the TS main drift, the north and south TS/CH ramp intersections, the main test area off the TS north ramp, three exploratory drifts on the TS level, the CH north and CH south ramps, the CH main drift, and four exploratory drifts on the CH level. Additionally, alcoves and stations will be excavated in the ramps and main drifts to accommodate a wide variety of site characterization tests and experiments.

The mobile excavation equipment is refueled from a diesel storage tank in the area shown on Drawing No. YMP-025-2-MING-MI25. The diesel fuel is transported to this area by small tanker. Adequate containment of spills is provided by concrete-lined sumps; potential fire and fire-generated gases are contained by automatically closing fire doors. Spills of fuels and other fluids will be cleaned up.

Explosives are delivered as needed. The explosives are temporarily stored in approved containers located in unused and unoccupied single-ended drifts away from active excavation.

Rock is transported from active excavation areas to the conveyor belt haulage system shown on Drawing No. YMP-025-1-STRU-GA06 and Drawings No. YMP-025-2-STRU-GA05 through YMP-025-2-STRU-GA07. Rock transport in all other areas is restricted to the absolute minimum required for construction and maintenance. Rock handling is done by a fleet of diesel-powered, rubber-tired, load-haul-dump (LHD) vehicles supported by diesel-powered service vehicles and/or transfer conveyors. **NOTE:** Diesel emissions will be controlled to ensure compliance with applicable codes and standards.

Many details of the underground excavations are [TBD]. The following sections pertain to use of excavated areas in the investigation of faults and other underground phenomena important to ESF site characterization.

3.7.1 RAMPS

The TS north and TS south ramps provide for personnel walking escape from the subsurface in less than one hour. Refuge chambers are also provided. During testing operations after all excavation and electrical and mechanical construction are complete, this subsurface population may decline; however, support systems are designed to support the maximum population, with a 35-percent uncertainty factor. (See Drawing No. YMP-025-2-MING-MI07.)

The ramps, in addition to providing access to the TS and CH levels, will be used in wall mapping and fault exploration. The following paragraph gives an example.

The Drill Hole Wash fault structure is explored by the TS north ramp. Characteristics important to the construction and performance of the potential repository will be observed. Structural features, such as faulting, that are postulated based on surface mapping and drillholes are examined. If the examination shows little or no faulting, the area north of Drill Hole Wash might be suitable for potential repository use should contingency emplacement space be needed in the future. The hydrologic character of the structural features is also studied. If the wash tends to concentrate surface waters and channel them along a specific path, higher than average infiltration rates could occur. Possible movement of water and any seasonal change in flow rates at this fault zone are to be investigated in this area.

The TS north and TS south ramps and the CH north and CH south ramps (see Drawing No. YMP-025-2-MING-MI21) also contain test areas. The ramp walls will be mapped, and experiments installed at various ramp locations.

3.7.2 TS/CH INTERSECTIONS (See Drawings No. YMP-025-1-MING-MI02 and YMP-025-2-MING-MI45.)

[TBD]

3.7.3 TOPOPAH SPRING (TS) LEVEL

The principal excavations on the TS level are the TS main drift, the main test area, and three exploratory drifts.

3.7.3.1 TS Main Drift (See Drawings No. YMP-025-2-MING-MI02 and YMP-025-2-MING-MI03.)

[TBD]

3.7.3.2 Main Test Area (See Drawing No. YMP-025-2-MING-MI25.)

Access from the surface to the main test area is via the TS north ramp. The main test area consists of an operations area and a testing area.

3.7.3.2.1 Operations Area

The operations area provides space for all the support activities and installations necessary to do the excavation and construction and to perform the test program. This includes the maintenance and equipment shop, scientific equipment shop, IDS room, electrical power center, uninterruptible power supply source (UPS) area, and haulage ways connecting the support and testing areas.

The operations area also provides access to various site characterization test areas; space for conducting construction, drilling, and equipment maintenance and assembly operations; and space for the warehousing of equipment and materials.

The ground support system utilizes rockbolts to reinforce the arched excavation shown in the various cross-sections. Rockbolt length, diameter, and spacing are designed to provide a safety factor of 1.5 to 2 or more with respect to the calculated stresses. Shotcrete and steel sets may be installed in the station area to supplement, when necessary, the primary rockbolt reinforcement system.

Ventilation ducting and fans are located in the operations area; the locations within the drift cross-section are designed to make best use of the available space and to protect the ventilation equipment.

Safety features of the operations area include the following: fire doors at strategic places to contain fire and fire-generated gases; two directional or bypass approaches to the TS north ramp for escape; strategically located refuge chambers; and a ventilation system designed to remove airborne toxic materials. The drift widths are designed to comply with applicable safety regulations governing clearances for pedestrians and mobile machinery.

3.7.3.2.2 Test Areas

The core test panel area contains approximately 800,000 square feet of space dedicated to subsurface testing. An additional 3,280,000 square feet area is available for test expansion. The core test panel area will require about 5,000 feet of drifting.

The arrangement, dimensions, and orientations of the main test area may change as additional design analyses are completed and as testing activities and construction requirements are considered further. For some tests, confirmation of a particular location in the main test area is made based on the results of physical examination of the local rock features exposed in the access drifts and TS north ramp. The final locations are determined based on specific test criteria. The design considerations may include such variables as the excavation method used (wet vs. dry); blast damage; proximity to operations (rock hauling); test-to-test interference; test duration; geologic features; fracture frequency; and drift and fracture orientation. This approach requires substantial flexibility to locate the tests within the core test panel area.

The sequence of test area development is designed to permit efficient excavation and to develop such items as certain test stations, the power center, and elements of the IDS, which are required as soon as possible after the start of core area construction. Test areas are excavated in an order governed by the ability of the subsurface infrastructure to support the various tests.

The equipment to be used will be transported down the TS north ramp and assembled and mobilized on the TS level.

During the initial main test area excavation, electrical power will be supplied down the TS north ramp to a portable power center of sufficient capacity to service operations and testing until the permanent underground power center is constructed. Compressed air and water will be supplied by permanent pipelines and valves, usually carried to within 100 feet of the active heading. Any waste water generated will be handled by a portable steel tank and submersible pump arrangement feeding waste water to the waste water pump line. Once a permanent sump is established, the portable tank and pump unit may be used to pump waste water from the exploratory drifts to the permanent sump.

Testing is delayed until excavation and other construction activity are far enough advanced that interference does not occur. Wire mesh is placed over unmapped drift sections if there is a safety hazard. Test hole drilling starts in the various alcoves and test locations as soon as space and utilities are available and it is safe to do so.

3.7.3.3 TS Exploratory Drifts

Three exploratory drifts (see Drawing No. YMP-025-2-MING-MI01) are excavated to predetermined targets from off the TS main drift, which transects the long access of the area of interest (see also Chapter 1, Figure 1-2). These exploratory drifts, which lie on alignments coincident with future potential drifts, are excavated to explore the Ghost Dance fault and the suspected imbricate fault zone, and to explore east to west near the center of the area of interest. The drifts will be excavated using mechanical methods. The drifts are compatible with the conceptual design for a potential repository and access geologic features potentially important to characterization.

The drift to the Ghost Dance fault (TS east drift) (see Drawing No. YMP-025-2-MING-MI04) examines features potentially important to the design and performance of the potential repository. The fault is a potential transmission zone for water from the surface to the water table. The drift allows direct observation, collection of samples, and other measurements to model the hydrologic environment. Other information obtained in this drift includes the nature of the fault zone, the time of last movement, and the magnitude and direction of fault offset.

The TS west drift, similar to the TS east drift, examines features important to a potential repository (see Drawing No. YMP-025-2-MING-MI05). This includes investigation of the hydrologic environment.

The TS imbricate drift to the suspected imbricate normal fault zone (if these faults exist at depth) studies the fault zone characteristics at the depth of the area of interest (see Drawing No. YMP-025-2-MING-MI06). The studies aid in the determination of the eastern boundary of this area. Hydrologic studies are also performed to determine if this fault zone is transmitting water.

3.7.4 CALICO HILLS (CH) LEVEL

The CH level is located approximately [TBD] feet below the surface. Access from the surface is via the TS north ramp and the CH north ramp to the CH main drift. In addition to the CH main drift the CH level consists of four exploratory drifts excavated to predetermined targets off the CH main drift, which transects the long access of the area of interest (potential repository). The drifts will be excavated using mechanical methods.

3.7.4.1 CH Main Drift (See Drawings No. YMP-025-2-MING-MI14 and YMP-025-2-MING-MI15.)

[TBD]

3.7.4.2 CH Exploratory Drifts

The four exploratory drifts (see Drawing No. YMP-025-2-MING-MI13) extend from the CH main drift east to the imbricate normal fault zone, east and west to the Ghost Dance fault, and west to the Solitario Canyon fault (see also Chapter 1, Figure 1-2). The drifts are compatible with the conceptual design for a potential repository and access geologic features potentially important to characterization.

The CH imbricate drift to the suspected imbricate normal fault zone (if existing at this depth) studies the fault zone characteristics at the depth of the area of interest (see Drawing No. YMP-025-2-MING-MI17). The studies also aid in the determination of the eastern boundary of this area. Hydrologic studies are performed to determine if this fault zone is transmitting water.

The drifts to the Ghost Dance fault (CH east Ghost Dance and CH west Ghost Dance) (see Drawings No. YMP-025-2-MING-MI19 and YMP-025-2-MING-MI18) examine features potentially important to the design and performance of the potential repository. The fault is a potential transmission zone for water from the surface to the water table. The drifts allow direct observation, collection of samples, and other measurements to model the hydrologic environment. Other information obtained in these drifts includes the nature of the fault zone, the time of last movement, and the magnitude and direction of fault offset.

The CH Solitario drift to the Solitario Canyon fault zone studies the fault zone characteristics at the depth of the area of interest (see Drawing No. YMP-025-2-MING-MI20). The studies also aid in the determination of the western boundary of this area. Hydrologic studies are performed to determine if this fault zone is transmitting water.

3.7.4.3 CH Level Underground Operations

The equipment to be used on the CH level will be transported down the TS north ramp and assembled and mobilized on the TS level. Mechanical excavators will be used to excavate drift openings wherever possible. Excavated material removal will be done by rubber-tired units and/or transfer conveyors, and a service vehicle and self-propelled scissor lift truck will be employed for mapping and utility installation. The exploratory drifts will be excavated using mechanical equipment; excavated material (rock) will be removed by rubber-tired units and/or transfer conveyors.

Information applicable to operations on the TS level (see Section 3.7.3.2.1) also applies to operations on the CH level.

3.8 UNDERGROUND SUPPORT SYSTEMS

3.8.1 POWER DISTRIBUTION SYSTEMS

The subsurface (Topopah Spring and Calico Hills) electrical general arrangements consist of the underground power centers (see Drawing No. YMP-025-2-ELEC-EL34); the various motor control centers for pumps and fans; and the associated power and lighting panels for overall lighting and shop loads.

The 12,470V/4,160-2,400V underground power centers or unit substations are totally enclosed integral units arranged as double-ended or secondary selective substations. These arrangements consist of redundant 15kV primary switchgear and cabling feeding two 12,470V/4,160-2,400V dry-type transformers that supply the 4,160V secondary circuit breakers. Portable power centers located throughout the subsurface areas will step 4,160V down to 480V for use by various equipment items on those levels.

Both the 15kV primary switchgear and 4,160V circuit breaker installations utilize a tie switch and a tie breaker to increase the overall reliability of 4,160V system power. Redundant 15kV mine power cable runs from the north portal and south portal surface electrical systems down each ramp feed each transformer in the TS and CH power centers. This type of power arrangement allows for electrical system reliability in case of failure to one section of a unit substation.

Drawings No. YMP-025-1-ELEC-EL07 through YMP-025-1-ELEC-EL09 show the TS north ramp power center one-line diagrams; Drawings No. YMP-025-1-ELEC-EL13 through YMP-025-1-ELEC-EL15 show the CH north ramp power center one-line diagrams. One-line diagrams for the south ramps are shown on Drawings No. YMP-025-ELEC-EL23 through YMP-025-2-ELEC-EL25 (TS) and Drawings No. YMP-025-2-ELEC-EL29 through YMP-025-2-ELEC-EL31 (CH).

The 480V electrical equipment includes the motor control centers and starters for controlling ventilation fans, waste water pumps, and exploratory drilling equipment, and a dedicated feeder supplying the UPS for critical loads. Also included are the power panels for supplying shop and miscellaneous loads, and the lighting panels for supplying TS and CH area lighting.

The underground power centers are fully backed up by the surface standby generators; therefore, if utility power is lost, all 12.47kV subsurface loads can be supplied through the power center from the generators. The UPS system, which feeds all subsurface critical loads, also receives backup power from the standby generators. The required UPS operating time durations will be determined during Title II design.

The protective relaying system for the distribution system includes overcurrent, ground-fault, undervoltage protection, and ground-check capability features. The UPS power system is used to supply the IDS equipment, the data acquisition stations (DAS), communications systems, life safety systems, and computers that cannot tolerate a power outage.

3.8.2 COMMUNICATIONS SYSTEM

The subsurface communications system consists of the telephone system, underground intercom, public address, and closed-circuit television (CCTV).

The telephone system provides access to the FTS, the DOE/NV system, and long distance networks. The system provides voice communications from the subsurface facilities to surface locations, including Area 25, Mercury, and Las Vegas, as well as long distance locations.

The underground intercom systems provide paging capability from a conventional telephone. Both personnel and station areas can be paged. Details follow.

This subsurface system allows: (1) selective paging capability to any single, specific underground station; (2) a dial-access, all-station paging capability to call personnel not at their normal location or to alert all underground personnel; and (3) automatic switching to a pushbutton-operated page partyline mode in the event of a telephone equipment power failure or severance of the cable interconnecting the standard telephone equipment through the interface unit. The underground intercom stations are equipped with speaker phone jacks to allow hands-free operation or with headsets to use in high noise areas. The underground intercom system provides multichannel capability. When connected to the conventional telephone system through a 12V to 48V circuit provided for each line, this system provides any underground intercom station with the ability to call another underground intercom station directly, call any standard telephone at surface locations, or receive calls from any surface standard telephone.

The underground intercom systems are located at each working location underground. There will be at least one intercom at each subsurface test location. When the experiments/tests are performed during ramp, optional shaft, or drift construction, a multichannel intercom system provides separate and simultaneous communications for both the excavation operation and the scientific personnel.

The CCTV system allows the underground access operators to view their respective access areas and other critical underground locations. This system allows visual surveillance of personnel to ensure safe operations by the access equipment operators.

3.8.2.1 Life Safety Monitoring and Alarm System

The life safety monitoring and alarm system allows for the subsurface monitoring of gases, including noxious and toxic gases. Gases monitored are carbon monoxide, carbon dioxide, nitric oxide, nitrous oxide, hydrogen sulfide, sulfur dioxide, and oxygen. Sensor-transmitters, which are located throughout the drifts and in both ramp accesses, are connected to the signal gathering and processing stations. Multiplexed signals from the stations are sent to the computer in the surface central control room (CCR) for monitoring and alarm.

The setpoint limits for alarm are set at the sensor-transmitters so as not to exceed the Threshold Limit Value (TLV) defined by the American Conference of Governmental Industrial Hygienists (ACGIH). The design includes the system of sensor-transmitters, cabling system, and interface at the field data stations.

3.8.2.2 Environmental Monitoring and Alarm System

Environmental monitoring consists of monitoring of temperature, relative humidity, and barometric pressure. Temperature and humidity are monitored on the surface, in the exhaust ducts at the TS portals, in ramp stations, at the TS and CH levels, at the primary booster fans, in the DBR, and at various other locations throughout the TS and CH drifts. Barometric pressure is monitored on the surface in the intake air flow ducts at the portals and in ramp stations at the TS and CH levels. Air velocity (and mass air flow as a derivative) is monitored in the intake air at ramp stations, at the TS and CH levels, and in the exhaust ducts at the portal entrances. Various types of dust, including mordenite fibers, will be monitored at conveyor transfer points, during TBM operations, and at ventilation stations.

The environmental parameters are monitored continuously by sensor-transmitters connected to the data-gathering multiplexer stations and to the computer in the CCR. Other environmental conditions such as dust pollution, noise level, presence of radon daughters in air, and gamma radiation background are monitored periodically by portable hand-held sensors and meters at selected locations throughout the underground workings.

3.8.2.3 Conduit and Cable Tray Arrangement

In all subsurface areas the power, control, and communications cables are placed in metal cable trays with solid bottoms and solid covers to comply with NFPA-70, NEC Art. 300-22(c).

All branch connections to local devices are made of rigid or flexible metal conduit. Power, control, and lighting cable trays shall be separated to the maximum extent possible from the IDS instrumentation and communications cable trays. The crossovers between cable trays are made as close to right angles as possible. The cable tray supports are trapeze type hangers attached to the back, or rib brackets.

3.8.3 LIGHTING SYSTEM

The general subsurface lighting system consists of incandescent, fluorescent, and emergency lighting. Incandescent fixtures are utilized in the access drift areas, stations, and test and equipment alcoves. The incandescent illumination level for the drift areas is a minimum of 3.0 fc on a plane 30 inches above floor level. The incandescent lamp fixtures are a simple pigtail socket arrangement alternately-mounted on either side of the drift or alcove. The incandescent lamp is rated 120V, 150W frosted to allow for good color rendition, good light control for zoned lighting, instant start capability, and low noise emission for shop and test alcoves.

Fluorescent lighting is utilized in the test areas, shop areas, power centers, and refuge chambers in various TS and CH locations. The fluorescent illumination level for the areas mentioned above is 50 fc on a plane 30 inches above floor level, using 90-watt preheat fixtures. The fixtures are direct diffusion, pendant type with four lamps per fixture, hung from the back or ceiling. They have high efficiency, high power factor ballasts, and low electrical noise emission.

The emergency lighting system for the subsurface layout is located in each shop area, test area, power center, station, and access drift as necessary. The fixture consists of two polycarbonate lamp heads of 30 watts each in a noncorrosive molded thermoplastic enclosure. Input voltage rating is 120VAC with a backup 12VDC, 90-minute rated battery.

3.8.4 VENTILATION DISTRIBUTION SYSTEM

3.8.4.1 Airflow and Distribution

The ventilation distribution system supplies and exhausts adequate quantities of acceptable quality air to and from the underground working areas to ensure personnel safety and health. The system is designed, constructed, and maintained in accordance with applicable federal and state regulations.

The general airflow direction uses the TS north ramp as intake and the TS south ramp as exhaust. The primary exhaust fans are installed on the surface at the TS south ramp portal. The fresh air supply is pulled down the TS north ramp and into the various areas of the TS and CH, and exhausted into the TS south ramp.

Air flow rates are controlled so that air quantities are distributed to satisfy the following design criteria: (1) ramp and drift air velocities shall not exceed 1500 fpm; (2) a minimum of 60-fpm air velocity shall be maintained in any active airway, to avoid air stagnation or toxic gas accumulation; (3) areas with operating diesel equipment are ventilated at least 100 cubic feet per minute per brake horsepower; and (4) personnel working underground shall be provided with at least 200 cubic feet of air per minute per person.

The airflow available for the ESF ventilation is about 400,000 cfm including allowance for leakage. The air quantities are distributed at 285,000 cfm for the TS level and 115,000 cfm for the CH level. (See Drawing No. YMP-025-2-MING-MI51.)

The breakdown of the 285,000 cfm for the TS level is as follows: (1) core area, 130,000 cfm; (2) TS imbricate drift, 40,000 cfm; (3) TS east drift, 40,000 cfm; (4) TS west drift, 40,000 cfm; and (5) equipment maintenance shop, 35,000 cfm.

The breakdown of the 115,000 cfm for the CH level is as follows: (1) CH imbricate drift, 25,000 cfm; (2) CH west Ghost Dance drift, 25,000 cfm; (3) CH east Ghost Dance drift, 25,000 cfm; (4) CH Solitario drift, 25,000 cfm; and (5) equipment maintenance shop, 15,000 cfm.

The flexibility to ventilate additional drifts for future needs will be supported by reusing the air allotment of existing drifts.

Drawing No. YMP-025-2-MING-MI53 shows the details of the ESF subsurface airflow distribution in various test areas and shops, along with the locations of fans, doors, and regulators.

3.8.4.2 Primary and Auxiliary Fans

The primary exhaust fans on the surface (south portal) operate at pressures ranging from [TBD] to [TBD] inches of water gauge, and are powered by an 800-BHP motor. Auxiliary fans supporting long lateral drifts, installed in series as needed, are sized not to exceed an operating pressure of 8 to 10 inches of water gauge. This will minimize leakage due to high pressure differentials between the pressure inside the vent duct and the drift. All fans are provided with attenuators, if required, to limit the sound pressure level to 85 dBA or less, the 8-hour exposure Threshold Limit Value (TLV) required by the American Conference of Governmental Industrial Hygienists (ACGIH) within [TBD] feet of the work area.

Auxiliary fans and ducting are installed to satisfy the required air velocity in the drifts. Drawing No. YMP-025-2-MING-MI51 shows the ventilation of the TS and CH levels along with the locations of fans and ducting. The main test area ventilation plan is shown on Drawing No. YMP-025-2-MING-MI52.

Table 3-[TBD] lists the sizes and performance specifications of all primary and auxiliary fans for the final ESF operating mode.

3.8.4.3 Dust Control

Airborne dust from mechanical excavation, roadways, rock transfer points, drilling, bolting, and after-blasting must be controlled to concentrations below the ACGIH threshold limit values. Dust control techniques will be fully developed during Title II design.

Dust suppressants consisting of water and an approved biodegradable/ nontoxic chemical additive are applied regularly to subsurface roadways, using a 500-gallon mobile tank with a spray applicator. Water is used to suppress dust during mechanical excavation, blasthole drilling, after-blasting, rockbolting, and rock handling. Where the use of water or other wetting agents is not feasible or is limited, a mobile dust collector is provided.

Permanent rock transfer points such as loading/unloading pockets and dump stations are provided with enclosures and water sprays for dust control. Where the use of water or other wetting agents is not feasible or is limited, a stationary dust collector is installed.

A typical dust collector unit consists of a series of cyclones and fabric filters. This combination effectively removes respirable airborne dust at an efficiency of 99 percent for particles greater than three microns and 96 percent for particles down to one micron. A mobile dust collector follows the excavation activity. The unit has an extendible inlet hood with high-volume suction capacity of 10,000 to 16,000 cfm. Dust control is applied as near the dust source as possible. Dust control design details will be provided during Title II design.

3.8.4.4 Heating and Cooling

The subsurface ambient temperature is maintained so as to generate a minimum air cooling power (ACP) of 260 watts per square meter of personnel skin surface area. This ACP is attained without using mechanical air cooling or refrigeration, because the virgin rock temperature at the TS and CH levels is below 80°F.

Utility lines and instrumentation on the TS north ramp portal intake will be properly insulated to protect them from freezing during extended periods of cold weather. Ice may occasionally accumulate along the fringes of the upper TS north ramp during extremely cold weather and will be removed if it becomes a safety hazard.

3.8.4.5 Control and Monitoring

The ventilation system's operational control and monitoring network continually indicates the primary fan operating status. The system also includes switches for forward and reverse airflow and sensors for fan-bearing temperature and vibration monitoring. Airflow quality and quantity, which are monitored separately, are discussed in Section 3.8.11, Monitoring and Warning System.

3.8.4.6 Temporary Ventilation During Early Development

Drawing No. YMP-025-2-MING-MI53 shows Phase 1 and Phase 2 ventilation during early ESF development. During Phase 1, the temporary ventilation configuration before the TS or CH north and TS or CH south ramps are connected, about 124,500 cfm of fresh air is supplied to support simultaneous TBM operations for both the TS and CH ramps. Still prior to connection of the ramps, the Phase 2 system supplies a total air quantity of about 188,500 cfm to support Phase 1 operations and two more headings, one CH lateral drift and another at the TS level.

After Phase 2, connection of the ramps is necessary to establish a permanent flow-through ventilation operation, which will allow fresh air to intake in the TS north ramp and exhaust to the TS south ramp.

3.8.4.7 Preliminary Acceptance Test

Primary and auxiliary fans designed and procured for the ESF project must pass a preliminary acceptance test at the manufacturer's test location.

Fans are not shipped to the ESF site until performance requirements for design air volumes, pressures, and horsepower have been satisfactorily met. An onsite performance test for design verification and validation is conducted after each primary fan is placed in operation.

3.8.5 WATER DISTRIBUTION SYSTEM

The underground supply water is brought from the supply source by a separate pipeline to each of the TS ramp portal areas. The system distributes water throughout the ESF for construction, testing, and operation (see Drawing No. YMP-025-2-MECH-PI01 and Design Analysis ST-ME-001, Underground Water Distribution System). Because operational requirements include fire protection demands, a single piping system provides both supply water and fire protection water. The underground water distribution system is not suitable for drinking purposes (nonpotable). To provide reliable water distribution and system safety, both portal supply lines are utilized, and supply pressure is regulated at the station levels to 80 psig.

The underground water system lines are sized to provide adequate flows and pressure for fire protection as well as construction and testing. A water metering and monitoring system will also be provided. The approved tracer in the water system shall also be metered.

For system reliability, automatic excess flow (line break) valves are installed at strategic locations in the piping to limit water loss, which could have an adverse affect on site characterization testing. The drift piping and hose connections are installed during the construction phase as the various drifts are excavated.

3.8.6 UNDERGROUND WASTE WATER COLLECTION SYSTEM

The underground waste water system collects waste water from various sources in the ESF, then transfers the combined inflow to a surface disposal system (see Drawing No. YMP-025-2-MECH-PI03 and Design Analysis ST-ME-006, Underground Waste Water Collection System). The possible sources of underground waste water include water used in construction, testing, and operations (such as drilling, washing, dust suppression, supply water inflow due to pipeline breakage, fire protection system runoff, and naturally occurring ground water). Water from sources containing petroleum products passes through a skimmer prior to entering the underground waste water collection system. The petroleum products are collected and transferred offsite for disposal. Drill water from exploratory drift construction is collected with diaphragm pumps and skid-mounted tanks. The tanks contain submersible pumps that transfer the water to a sump located at the base of the TS north ramp. Another sump will be located at the base of the CH north ramp. **NOTE:** Waste water must be controlled to avoid impacting site characterization or waste isolation. See discussion in Chapter 7 on Provision 10 CFR 60.15(c)(1) and the additional design requirements of 10 CFR 60.133(d).

The underground waste water system is required to be fully redundant. Duplicate sump pumps will be provided at the TS and CH sump locations. The discharge pipe will be capable of an anticipated 700-gpm peak design flow. During the ramp construction phase, waste water disposal system piping will be provided for each ramp activity. Depending on the sequence of construction activities and the results of borehole tests for perched water, permanent sump discharge pipes may be required only at the TS north portal. Details of the underground waste water collection system will be developed during Title II design as additional criteria are established.

3.8.7 COMPRESSED AIR DISTRIBUTION SYSTEM

The compressed air system supplies and distributes compressed air throughout the ESF for construction, testing, and operation (see Drawing No. YMP-025-2-MECH-PI05 and Design Analysis ST-ME-011, Compressed Air Distribution System). The peak compressed air demand varies with underground activity needs and excavation equipment fleet activity required during various phases of construction and testing. The major use is by test drilling/coring equipment. The compressed air supply system is maintained at 100 psig at the takeoff.

The total peak demand value from the construction and testing schedule and corresponding equipment complement is corrected for altitude and leakage. Details are to be completed during Title II design.

Booster compressors increasing the ESF supply system pressure to 200 psig will be provided for the large diameter drills. A typical booster compressor unit is portable, and is relocated as required for certain test drilling equipment or for high-pressure test drilling operations.

Aftercoolers are required on compressors to reduce the air temperature to a level safe for personnel. The compressed air piping requirements are to be developed in Title II when additional criteria will have been established.

3.8.8 FIRE PROTECTION SYSTEM

Subsurface fire protection consists of portable fire extinguishers in the data acquisition areas, the TS main test area, and exploratory drifts. Sprinkler systems are to be installed in specific drift locations and refuge areas where significant quantities of combustible materials may be present.

The fueling/lube/high-pressure wash area, when defined, may be equipped with a curtain/fire door automatically activated by a fire water flow switch. The system in this area may consist of on-off quick-response sprinklers with an Aqueous Film Forming Foam (AFFF) capability.

Areas considered high hazard areas such as the maintenance shop and science shop may be equipped with 1-hour rated firewalls and class B fire doors.

3.8.9 ROCK HANDLING SYSTEM

Broken rock must be removed from the development headings of both mechanical excavation methods and drill and blast methods. In each case, this material is picked up, moved away from the face, and transported to the nearest conveyor belt loading facility for removal to the surface.

When dealing with controlled drill and blast rounds, rock may be found in small pieces to large rocks greater than one foot square. For these headings, a Load Haul Dump (LHD) unit will be used to load the material and tram it to the nearest rock handling facility. Due to maneuverability of the LHD and drilling system, this method can be used for tight corners and limited space cutouts.

Mechanical excavation methods used in long lateral drifts and in the TS core test area utilize a mobile miner excavator. This machine picks up rock at the workface and loads it onto an integral loading conveyor for discharge at the back of the machine. Under the discharge is an LHD which fills to capacity, then trams the broken rock to the conveyor. Here it is discharged from the LHD into a loading hopper or feeder-breaker which feeds a conveyor belt leading to a transfer point on the main rock haulage conveyor.

The main rock haulage conveyor is installed directly behind the 25-foot diameter TBM as it progresses down-ramp and across the TS level in the TS main drift. As development progresses, rock from lateral drifting is removed to either the TS north or TS south portal as scheduling permits.

3.8.10 SANITARY FACILITIES

The underground sanitary facilities consist of portable toilet units and a mobile collection/storage unit to facilitate sanitary waste removal. The portable toilet locations will be developed as ESF construction proceeds. Final locations on the TS level will be determined when the main test area layout is complete. Use of portable toilets is enforced, and maintenance and service must be provided to keep the units clean. Upon removal or relocation, the vacated area shall be disinfected. A sanitary waste collection system will be developed during Title II design.

3.8.11 MONITORING AND WARNING SYSTEM

Gases continuously monitored subsurface include carbon dioxide, carbon monoxide, oxygen, air (volume flow), hydrogen, sulfur dioxide, and oxides of nitrogen. Subsurface temperature, humidity, and barometric pressure are also monitored. Equipment monitoring is designed for water supply pumps, ventilation, underground waste water, power, hoist alarms, and air compressors. The surface central control room for the monitoring of the systems provides a central location for instrument readouts, alarms, equipment status indicators, and automatic and/or manual override equipment controls. REECo periodically monitors for dust, radon, methane, and noise.

The detection system provides fire and smoke detection. The alarm system indicates when monitored conditions exceed pre-determined limits so that personnel are notified of hazardous conditions. The ESF emergency and evacuation alarm system has both audio and visual notification tied in with the public address system and the central reporting station. Redundant systems are installed for all systems that monitor potentially life-threatening conditions per National Fire Protection Association (NFPA) codes.

The detectors and alarms are located in the TS north ramp at data acquisition stations as required by code. The DBR, TS level, and CH level have detectors and alarms near the ramp breakout areas and at 100-foot and 400-foot spacing in the testing and extension drift areas. Visual indicators and speakers are located every 100 feet.

3.8.12 INTEGRATED DATA SYSTEM (IDS)

The Integrated Data System provides support for site characterization tests within the ESF through electronic acquisition, storage, and archiving of test data. The IDS is designed as a separate task by RSN under the technical direction of LANL. As such, it is not a part of this Title I report except insofar as IDS equipment and facilities must be accommodated, constructed, or supplied as part of the overall ESF task. These crossover areas are identified in the preceding sections of Chapter 3. Anticipated provisions for IDS communications at the ESF are identified in the following paragraphs.

An IDS-dedicated data highway will be installed throughout the ESF to allow data processing equipment located in the TS north portal site surface data building to accept data from test-specific data acquisition equipment located throughout the ESF.

IDS data transfer via dedicated lines to Principal Investigator (PI) sites remains an IDS option. PIs will define their specific needs during Title II design.

Alcove enclosures and instrument buildings will be required by the IDS and the PIs. The types, numbers, and sizes of these facilities will be further defined during Title II design.

3.9 UNDERGROUND TESTS

The ESF Test Plan is documented in the Project Site Characterization Program Baseline (SCPB) (see Appendix 5.5), the Exploratory Studies Facility Design Requirements document (ESFDR) Appendices B and C (see Appendix 5.3), and the associated test planning packages. Specific design features accommodating the planned testing in the ESF are also incorporated into the RSN BFD. Section 8.4 of the SCPB discusses ESF testing with respect to the facility design. See also in Chapter 7 the Provisions for 10 CFR 60.15(b) and 10 CFR 60.74(a).

Tests proposed for the ESF are to acquire data on geologic, hydrologic, geomechanical, geochemical, and waste-package environment characteristics. Forty-two different test activities, some planned to be performed at multiple locations, have tentatively been identified. Preliminary locations for proposed test activities are indicated on the following drawings:

No.	ESF Location
YMP-025-1-MING-MI06	TS (North Portal)
YMP-025-1-MING-MI07	TS (North Portal)
YMP-025-1-MING MI08	TS (North Portal)
YMP-025-1-MING-MI09	TS (North Portal)
YMP-025-1-MING-MI10	TS (North Portal)
YMP-025-1-MING-MI11	CH (North Portal)
YMP-025-1-MING-MI12	CH (North Portal)
YMP-025-2-MING-MI26	TS South Ramp
YMP-025-2-MING-MI27	TS South Ramp
YMP-025-2-MING-MI30	TS Main Drift
YMP-025-2-MING-MI31	TS Main Drift
YMP-025-2-MING-MI33	TS Main Test Area
YMP-025-2-MING-MI37	TS East & West Drifts
YMP-025-2-MING-MI38	CH Level Drifts
YMP-025-2-MING-MI39	CH Main Drift
YMP-025-2-MING-MI40	CH Main Drift

No.	ESF Location
YMP-025-2-MING-MI42	CH South Ramp
YMP-025-2-MING-MI43	CH Level Drifts

Certain constraints apply to determining test locations. Test constraints are requirements imposed on the ESF design that must be satisfied to ensure that tests can be located properly. Constraints that impact the underground layout can be classed into three types: (1) sequencing constraints; (2) physical location constraints; and (3) construction and operational constraints.

NOTE 1: The ESF test program must be designed to ensure that interferences among tests and from construction/operations do not adversely impact the test program, and that the test program does not adversely impact waste isolation. See Chapter 7 for relevant 10 CFR 60 Provisions, NRC concerns, Responses to the concerns, and applicable ESFDR requirements.

NOTE 2: The ESF test program is preliminary in status. The preliminary nature of the testing program, particularly with respect to test locations, results from a lack of detailed geologic information at this stage of the design process. Precise test locations will be based on results from geologic mapping performed during excavation. Similarly, although test scheduling is under study, the distinction between tests to be performed during construction and those to be deferred is not final.

3.9.1 REPOSITORY HORIZON NEAR-FIELD HYDROLOGIC PROPERTIES TESTS

A series of heater tests is planned in the main test area and in the TS north ramp as prototype ESF tests. All are designed to investigate moisture movement and saturation conditions in the host rock during heating and cooling periods of waste storage and to investigate the scale effect of the heater hole on the measured parameters. Some tests will measure the parameters during the thermal cycle using ambient moisture as the initial condition. The other tests will include a simulated percolation event to examine the effect of water percolating or diffusing through the rock mass.

For each of the tests, instruments will be installed in the rock mass around the heaters to measure temperature, moisture content, gas and liquid pore pressure, stress change, and displacement as a function of time and location. Various geophysical probes will be used to measure the moisture content in the rock before, during, and after thermal cycling. Rock cores will be obtained before and after the thermal cycles for mineralogical and geochemical analyses. Laboratory measurements of hydrologic properties and thermal-mechanical properties will be made on similar samples.

The heaters in the test will be cycled through heating and cooling stages. The duration of the period during which the heater is at maximum power and the initial thermal loading for the heater are based on the criterion that the boiling conditions encompass a sufficiently large volume of rock to include several fractures within the dry, hot region. Scoping calculations will be used to determine the initial power of heating and the duration of heating at the maximum power.

Prototype tests, possibly of long duration, will be conducted before or concurrently with the ESF tests.

3.9.2 REPOSITORY HORIZON ROCK-WATER INTERACTION TESTS

This activity is designed to obtain large-diameter (6- to 8-inch) dry-drilled or dry-mined samples (cores or blocks) from the lithophysal zone of Topopah Spring tuff at the contact of Tiva Canyon and Topopah Spring, the Topopah Spring welded unit, the basal vitrophyre of Topopah Spring, and the top of the vitric Calico Hills unit. They will be used for laboratory tests to evaluate rock-water interactions at high temperatures in the various rock types found at these locations. In situ water and gas samples will also be collected for laboratory analysis.

3.9.3 GEOMECHANICAL ATTRIBUTES OF THE WASTE PACKAGE ENVIRONMENT FIELD TESTS

A series of heater tests is planned in the north ramp of the ESF as the prototype of the ESF tests. These tests are designed to characterize the geomechanical response of the rock in the near-field environment to the changing environmental conditions expected to occur over an extended period of time. Some tests will study the effect of a heating/cooling cycle on the stability of rock blocks formed by excavation of the emplacement hole.

Other tests will assess the potential for spalling or other types of borehole breakout that may occur due to the heating/cooling cycle and associated changes in the rock/fracture properties.

For each test, instruments will be installed to measure temperature, stress, and displacement as functions of time and location. Rock cores and blocks will also be obtained before and after the thermal cycles for laboratory determination of thermal-mechanical properties.

The heaters in the test will be cycled through heating and cooling stages; in some cases, temperatures and/or stresses imposed on the rock may be higher than expected. The intent of testing at these temperatures and stresses will be to accelerate the rate at which rock deformation occurs. This may serve to delimit the estimates of geomechanical deformation over time.

ESF design flexibility has allowed for the availability of additional space for use in long-term thermal testing, if required.

3.9.4 LABORATORY TESTS (THERMAL AND MECHANICAL) USING SAMPLES OBTAINED FROM THE ESF

The laboratory geoengineering properties test will provide bulk, thermal, and mechanical properties data for evaluation of opening stability and related design and performance studies and/or modeling. Data from the laboratory test will also support analyses of the geomechanical and thermomechanical field tests planned in the ESF. The ESF activities are basically the collection, packaging, and labeling of the selected bulk samples taken from the ramps, optional shaft, or drifts. See SCPB Section 8.3.1.15.1 for descriptions of individual laboratory test activities.

3.9.5 ACCESS CONVERGENCE TESTS

Access convergence tests are required to monitor rock mass deformation around the accesses and measure in situ stress at the station where convergence is being measured.

Rock mass deformation around the accesses will be monitored at measurement stations using multiple-point borehole extensometers (MPBXs) placed at 120° intervals around the opening. The MPBXs consist primarily of anchors installed at predetermined depths. Movement in the rock mass is recorded as the anchors move. Deformations will be measured across the TS north ramp/optional shaft diameters and as a function of distance from the access at multiple locations in the accesses. In addition to MPBX measurements, deformations will be measured with rod extensometers at each of the three measurement stations. Extensometer measurements will be made along diameters in the same plane as the MPBXs at 60° from the MPBX heads.

Each station will also include hydraulic pressure cells in the liner to monitor radial stress changes over time as excavation continues below the test location. This part of the test applies only to the portals and the optional shaft.

3.9.6 DEMONSTRATION BREAKOUT ROOM (DBR)

This test, which will be used to demonstrate constructibility and stability of the underground openings in the upper lithophysal zone of the Topopah Spring Member (TSw1), will be performed in a demonstration breakout room (DBR) to be located in the TS north ramp.

The size of the DBR opening will be consistent with the maximum width planned for special openings. The excavation techniques for the DBR should be similar to the excavation techniques to be used for the special openings. This test will evaluate excavation techniques and rock support requirements. Rock mass response will also be measured in the DBR excavation using extensometers and convergence anchors.

3.9.7 SEQUENTIAL DRIFT EXCAVATION

The purpose of this activity is to measure deformational response of a special opening as the opening is being excavated. This is accomplished by installing instruments from adjacent drifts into a rock mass and subsequently excavating the instrumented rock mass.

Instruments installed in boreholes will monitor stress change caused by excavation. Tests of bulk permeability changes will be conducted and deformation will be measured. To measure rock mass response to excavation, data will be obtained before excavation of the center parallel drift. Air and water permeability in boreholes adjacent to the new drift opening will be measured after excavation.

3.9.8 HEATER EXPERIMENT IN UNIT TSw1

The heater experiment measures thermomechanical and thermally-induced hydrologic responses in high-lithophysal rock for design and performance modeling, for assessment of retrievability, and for monitoring radon emanation as a function of heating. During the tests, heat fluxes will be increased so that temperatures near the canister heater exceed design limits. This phase of the test is to aid in determining limits on waste-emplacement borehole stability.

In the DBR, a heater-emplacement and parallel small-diameter holes will be drilled. Baseline moisture data in neutron probe holes will be recorded. A heater and instrumentation (thermocouples, MPBXs, borehole deformation gages, and radon monitors) will be installed. Finally, heating steps will be initiated and thermal, thermomechanical and hydrothermal phenomena, and radon release rates will be monitored at increasing heat loads.

3.9.9 CANISTER-SCALE HEATER EXPERIMENT

The canister-scale heater experiment will monitor thermomechanical and hydrothermal responses in the ESF host rock for design and performance modeling, for assessment of retrievability, and for monitoring radon emanation as a function of heating. During the tests, heat fluxes will be increased so that temperatures near the canister heater exceed design limits. This phase of the test is to aid in determining limits on waste-emplacement borehole stability.

At a location within the dedicated area, a vertical heater hole and parallel small-diameter instrumentation holes will be drilled. Baseline moisture data in neutron probe holes will be recorded. A heater and instrumentation (thermocouples, MPBXs, borehole deformation gages, and radon monitors) will be installed. Finally, heating steps will be initiated and thermal, thermomechanical and hydrothermal phenomena, and radon release rates will be monitored at increasing heat loads.

3.9.10 YUCCA MOUNTAIN HEATED BLOCK

The Yucca Mountain heated block experiment will (1) measure three-dimensional deformation and temperature changes; (2) measure relationships among fracture permeability, stress, and temperature; (3) monitor moisture movement relative to temperature; and (4) evaluate cross-hole measurement methods in large blocks of welded tuff. Results from 1, 2, and 3 will be used in modeling.

At a selected location in the dedicated test area, an alcove will be excavated and a 6 ft by 6 ft (2 m by 2 m) area of rock will be defined within the alcove. Baseline fracture permeabilities will be measured, reference survey pins established, and cross-hole ultrasonic measurements made. Next, slots will be cut on each side of the block approximately 6 ft (2 m) deep and flatjacks inserted. An array of heaters will be installed in holes on opposite sides of the block. Other instrumentation holes will be drilled and instrumented with thermocouples, MPBXs, and deformation gages. Finally, cyclic tests will be conducted at various mechanical loads (imposed using flatjacks) and thermal loads (imposed using heaters). The rock responses and permeability changes under induced conditions will be monitored.

3.9.11 THERMAL STRESS TEST

This test, which will measure thermal stresses in a relatively large volume of jointed rock and relate the stress changes to thermomechanical displacement for numerical modeling, will be performed in the main test area. At the experiment location, single slots with nominal dimensions of 6 ft (2m) long and 6 ft (2m) deep will be cut in both the back (roof) and rib (wall) after reference pins are established on either side. Heaters will be installed in the holes drilled on either side of the slots. An insulating blanket will be installed over the test area of the drift to reduce heat loss. Heaters will be started and displacements in the near-field volume will be monitored as thermal loading increases.

3.9.12 HEATED ROOM EXPERIMENT

The heated room experiment is intended to measure thermomechanical responses in fractured welded tuff at a drift-size scale to acquire data for evaluating both pre- and post-closure design. Measurements will also be used to support the validation phase of both empirical and numerical design methods. It is planned to conduct this experiment in the main test area.

Upon completion of the sequential drift excavation experiment in the core test area, the rock around the central drift will be heated to representative temperatures.

3.9.13 PLATE LOADING TESTS

The plate loading test loads parallel, diametrically opposed surfaces of rock for the purpose of deformation measurements. Experiment results can be used to calculate rock-mass modulus and interpret the depth of the disturbed zone. This test, which will follow ISRM and ASTM standard testing procedures, will be performed at several ESF locations.

3.9.14 ROCK MASS STRENGTH EXPERIMENT

This activity evaluates the mechanical behavior of the rock mass. Experiments will obtain information on the mechanical response of single-jointed and multiple-jointed volumes of rock. This experiment will be conducted in several areas representative of the range of conditions encountered in the main accesses, the main test area level of TSw2, and in the Calico Hills. The information will evaluate scale effects between laboratory and in situ conditions, provide data to evaluate empirical design criteria, and provide data to evaluate and validate jointed-rock models.

3.9.15 EVALUATION OF EXCAVATION METHODS

These tests will monitor and evaluate excavation methods for ramp, optional shaft, and drift openings, with emphasis on rock responses in a variety of lithologic and structural settings that may be encountered in the long exploratory drifts. This activity will be conducted to develop recommendations for excavation in large underground cavities, and will include TBM performance measurements and examination of induced damage, as appropriate.

3.9.16 MONITORING OF GROUND-SUPPORT SYSTEMS

This activity will develop recommendations for ground support in drifts in large underground cavities, based on evaluations of the ground-support techniques used in the underground excavations, and on experimentation with other ground-support configurations. This activity will be carried out in many ESF locations, and may occur in all parts of the ESF. The selection, installation, and performance of the support systems used will be monitored. Experimentation with ground supports will include pull tests on rockbolts, observation of unsupported rock, strength measurements on shotcrete cores, and trials of alternate ground-support configurations from those prescribed for the ESF. The effects of heat on ground support will be considered in the heated room experiment.

3.9.17 MONITORING DRIFT STABILITY

These tests will monitor drift convergence throughout the ESF, along accesses and in the Calico Hills. Convergence measurement stations will be selected by the Principal Investigator. In the long drifts, convergence measurements will be taken in a continuous manner; if practical, rock mass relaxation will be investigated in the long drifts using multiple-point borehole extensometers. Rockfalls and maintenance activities will be documented.

3.9.18 AIR QUALITY AND VENTILATION EXPERIMENT

The purpose of these tests is to assess the impact of site characteristics on ventilation requirements to ensure a safe working environment. This activity consists of (1) measurements of radon emanation; (2) surveys of airflow and pressure, temperature, and humidity; (3) determinations of air resistance factors; and (4) dust characterization. The radon emanation measurements will be made in a dead-end drift that has been sealed with a bulkhead at equilibrium conditions and at various rates of airflow. Radon concentrations might also be measured in a borehole. The air quality and ventilation measurements are not expected to interfere significantly with other underground activities.

3.9.19 DEVELOPMENT AND DEMONSTRATION OF REQUIRED EQUIPMENT

This SCPB activity was originally proposed for the purpose of development and demonstration of special equipment. Further specific equipment needs have not been identified to date.

3.9.20 IN SITU TESTING OF SEAL COMPONENTS

The seal tests have not been developed in sufficient detail to evaluate their impact on excavation of the underground facilities. However, ESF flexibility has allowed for the availability of sufficient space to accommodate various seal tests in both short-term and long-term configurations.

The objectives of the seal tests are to characterize discrete geologic features and to characterize the performance of seal components. Testing will be performed to enhance understanding of the materials used in sealing and the ability of components to achieve specific performance objectives. Tests will be performed on small seals such as those used in boreholes and larger seals such as shaft/ramp seals. Tests will also be performed on backfills, shaft/ramp fills, single embankment dams, and specific engineered features to enhance drainage.

Additional evaluations will be required before defining appropriate field tests for seal components. The most important needs will be the characterization of a potential repository environment and results of laboratory studies on seal material properties. See Chapter 7, Provision 10 CFR 60.134 for related discussion.

3.9.21 MATRIX HYDROLOGIC PROPERTIES TESTS

The purpose of the matrix hydrologic properties tests is to develop a comprehensive data base on matrix flux properties in the unsaturated zone tuffs at Yucca Mountain. This activity includes collecting bulk and/or core samples taken from the ESF. The collected samples will be packaged, labeled, and sent to an offsite laboratory for various analyses.

3.9.22 INTACT-FRACTURE TESTS

The intact-fracture tests will be used to evaluate fluid-flow and chemical transport properties and mechanisms in relatively undisturbed and variably stressed fractures to enhance understanding of the physics of low flow and for flow modeling.

Fracture-sampling locations will be selected on the basis of detailed fracture maps. At about 12 or more locations (to be determined), a small pilot hole will be drilled across a fracture, a rockbolt anchor installed, the pilot hole overcored, and the sample withdrawn. The sample will be packaged, labeled, and transported to an offsite laboratory for intact-fracture analyses.

3.9.23 PERCOLATION TEST

This test will be used to observe and measure fluid flow through a network of fractures under controlled in situ conditions to characterize and quantify important flow processes in fractured welded tuff. The test is to be conducted in large, isolated blocks of rock, about 2 m on a side, in as many as six locations. Each block will be instrumented to detect fluid flow under physical conditions that can be mechanically controlled and systematically varied. Approved tracer-tagged water will be introduced from a trickle system/sand bed on the surface of the block.

3.9.24 BULK-PERMEABILITY TEST

The purpose of the bulk-permeability test is to assess the fluid transport properties in relatively large volumes of minimally disturbed tuff. Tests are planned at various separate locations in the ESF, selected on the basis of detailed fracture maps. At each location, a small-diameter hole 100 to 200 ft (30 to 60 m) deep will be air-cored and logged. Air permeability will then be measured in packed-off intervals. If the rock is deemed suitable for the test based on the preliminary results, three additional holes, sub-parallel (frustrum configuration) to the first, will be air-cored, logged, and instrumented.

Cross-hole air permeability (injection) tests will be conducted. Pressure, temperature, and humidity sensors will be installed in experiment boreholes. Selected holes will then be pressurized, and the air movement outward to sensors in the other holes will be monitored. The measurements will be repeated as required by using positive or negative pressures in the boreholes.

3.9.25 RADIAL BOREHOLE TESTS

The radial borehole tests will investigate vertical and lateral movement of gas, water, and vapor on and across hydrogeologic contacts and within the various units, and evaluate near-field excavation effects on hydrologic properties.

Tentatively, 24 locations in the ESF have been chosen as sites for performance of the radial borehole test. At each location coreholes will be drilled using air as the drilling agent. Orientation of the radial boreholes at each location will be determined by analyzing fracture data collected during ramp/optional shaft wall mapping. Cores will be collected, packaged, labeled, and transported to an off-site laboratory for hydrologic analyses (fracture and matrix properties). The holes will be logged and surveyed for fracture and moisture data. Air-permeability tests in packed-off intervals will be conducted to obtain gas permeability data. Across stratigraphic contacts, cross-hole permeability tests will be run with both gas and water. Long-term monitoring of matrix water potential, pressure, and temperature will also be conducted; formation gases will be sampled periodically.

3.9.26 EXCAVATION EFFECTS TESTS

The excavation effects tests will measure stress changes in the near-field wall-rock as the ESF is excavated, and measure air-permeability changes that result from the stress redistribution.

At each test location, multiple small-diameter holes will be drilled parallel or sub-parallel to the unexcavated opening wall but set back selected distances from it. All holes are planned to be air-drilled/cored, logged, and surveyed; some of the holes will be instrumented to monitor stress changes and some to monitor permeability changes as the excavation is advanced. Stress and permeability data will be taken in drill holes extended beyond the excavation. Long-term permeability measurements will be made and temperature and moisture data collected. Additional holes may be drilled to handle the instrumentation packages if they are determined necessary during prototype testing.

3.9.27 CALICO HILLS TESTS

In concept, the Calico Hills tests should provide in situ access to fractures, to various layers within the unit, and to various faults where they cross the unit. The majority of tests to be performed in the Calico Hills Unit will also be performed in the accesses and the Core Test Panels of the main test area. The following is a list of tests tentatively planned to be performed in the Calico Hills Unit:

- Repository Horizon Near-Field Hydrologic Properties
- Repository Horizon Rock-Water Interaction
- Laboratory Tests (Thermal and Mechanical) Using Samples Obtained from the Exploratory Studies Facility
- Plate Loading Tests
- Monitoring Drift Stability
- In Situ Testing of Seal Components
- Rock Mass Strength Experiment
- Matrix Hydrologic-Properties Testing
- Intact-Fracture Test

- Infiltration Tests (Percolation)
- Bulk-Permeability Test
- Radial-Borehole Tests
- Perched-Water Testing
- Hydrochemistry Tests
- Hydrologic Properties of Major Faults Encountered
- Underground Geologic Mapping
- Seismic Tomography/Vertical Seismic Profiling
- Overcore Stress Experiment
- Chloride and Chlorine-36 Measurement of Percolation
- Diffusion Tests
- Mineral Distributions Between the Host Rock and the Accessible Environment
- History of Mineralogic & Geochemical Alterations of Yucca Mountain
- Fracture Mineralogy Studies
- Radionuclide Transport Test
- Biological Sorption & Transport

3.9.28 PERCHED-WATER TEST

The purpose of the perched-water test is to detect the occurrence, and delineate the lateral and vertical extent, of perched-water zones (if encountered) during excavation, to identify perching mechanism(s), and to sample the water for chemical analyses. Because there is significant uncertainty regarding the likelihood of encountering perched water, the perched-water test is categorized as a "contingency test."

If perched water is encountered during excavation, one (or more) small-diameter hole(s) will be drilled to enhance drainage, facilitate collection of water samples, and allow flow and/or pressure measurements to be made. The hole(s) will also be instrumented and sealed during testing to obtain data on hydraulic pressure and water potential over time.

3.9.29 HYDROCHEMISTRY TESTS

The hydrochemistry tests will determine the chemical composition, reactive mechanisms, and age of water and gas in pores, fractures, and perched-water zones within the unsaturated tuffs accessible from the ESF and/or affiliated coreholes. The ESF will provide access for the collection of gas, rock, and possibly perched-water samples at several locations.

3.9.30 MULTIPURPOSE-BOREHOLE TESTING

One or more multipurpose boreholes will be constructed using dry-drilling and spot-coring techniques, to the extent practicable. The borehole(s) would be located such that they do not penetrate within a distance of two diameters, as appropriate, of any underground openings. The borehole(s) would be drilled to depths approximately equal to the corresponding opening, with walls as smooth as possible to maximize the quality of geophysical logging and provide adequate packer seats. The drilling activities are planned to be completed and monitoring begun before the start of ESF construction.

3.9.31 HYDROLOGIC PROPERTIES OF MAJOR FAULTS

This activity is designed to provide hydrologic information in parallel with a portion of geologic mapping of the ESF. All faults encountered in the ESF will be characterized geologically under the geologic mapping activity. Hydraulic properties of major faults encountered in the ESF will be determined in this activity. The major faults or fault zones expected to be tested are the Ghost Dance fault, a suspected fault in Drill Hole Wash, the imbricate fault zone, the Solitario Canyon fault, and the Bow Ridge fault. Other faults will be tested if flow is observed.

On the basis of the identification of major faults by the geologic mapping activity, a hydrologic testing program will be implemented. This program will consist primarily of tests conducted in boreholes drilled through fault zones and tests on cores collected from the coreholes. Air permeability tests will be conducted between boreholes to determine the permeability to air of the fault zones. Some boreholes will be instrumented to determine in situ conditions of the rock mass and monitored for any changes in these conditions over time. Other sets of boreholes will be used for cross-hole water-injection tests. One borehole at each location will be used for geothermal measurements. All water used for injection will be tagged with an approved tracer. Cores recovered from the holes will be tested to provide a water-content profile across the fault zone. This profile may provide information relative to any recent moisture occurrence in the fault zone.

3.9.32 GEOLOGIC MAPPING

Geologic mapping and photogrammetry will be used to document lithologic and fracture variability throughout the vertical and horizontal extent of the underground excavations, to investigate structural features, and to provide siting data to confirm (or modify) planned test locations within the underground excavations. It is planned that all excavations in the ESF be mapped. A complete photographic record will be obtained of all the excavations including accesses to the Topopah Spring (Tsw) and the Calico Hills (CHn) formations. Where stratigraphic contacts occur or where geologic anomalies are encountered, the mapping details will be comparable in all accesses. Details on mapping area cross-sections will be provided during Title II design.

3.9.33 SEISMIC TOMOGRAPHY/VERTICAL SEISMIC PROFILING

The purpose of seismic tomography and vertical seismic profiling is to remotely characterize subsurface fracture networks.

This activity requires access to all walls of the excavated ESF. A vertical environment (optional shaft) will require the drilling of short boreholes for the emplacement of geophones to obtain information on fracture characteristics using this technique. A horizontal or sub-vertical (ramp) environment will require access only to competent rock. After the instruments have been installed, seismic stimuli will be initiated by using either small explosives charges or vibroseis.

3.9.34 OVERCORE STRESS EXPERIMENTS

The overcore stress experiments will be performed at approximately six locations to determine the in situ state of stress above, within, and below a specified horizon, in that portion of the unsaturated zone penetrated by the ESF, to determine the extent of excavation-induced stress changes and to relate stress parameters to rock mass heterogeneities.

Soon after access is available, small-diameter holes will be drilled to prescribed orientations and lengths (longer than three ramp, optional shaft, or drift diameters). A stress sensor will then be installed, and the instrumented center hole overcored in stages. Stress data will be taken as the instrumentation of each stage is overcored.

3.9.35 DIFFUSION TESTS

The diffusion tests will take place in specially constructed alcoves in the main test area and in the zeolitic and the vitric zones of the Calico Hills Unit. Each test will require boreholes dry-drilled, vertically downward, or sub-horizontally in each alcove. Each hole will be approximately 10 cm in diameter for the upper 10 meters and about 4 cm in diameter for the lower 45 cm. The bottom of each hole will serve as a source region for the tracer diffusion tests. The core removed from the bottom of each hole will be examined for fractures to minimize the possibility of fractures intersecting the source region. In addition, the boreholes will be examined for fractures using a downhole borescope.

About 10 ml of solution containing a suite of approved tracers will be placed at the bottom of the 4-cm diameter hole. One of the tracers will be bromide. The 10-cm diameter hole will be sealed with an inflatable packer to isolate the bottom of the hole from air pressure and humidity changes in the alcove while diffusion occurs. The hole will then be overcored, and the bottom portion of the core sectioned and analyzed for tracer concentration as a function of position.

The results of the diffusion experiments will be used to estimate the effective diffusion coefficients of conservative radionuclides in the unsaturated zone. Two sets of experiments will be performed for each zone (vitric and zeolitic) in the Calico Hills Unit. The initial experiment (3 months) will be performed to establish the length of time required and the size and type of overcoring needed to affect the transport rate via diffusion through the unsaturated tuff unit. Then a period of one year will be required to conduct a conclusive experiment to be described in a milestone report.

3.9.36 MINERAL DISTRIBUTION BETWEEN THE HOST ROCK AND THE ACCESSIBLE ENVIRONMENT

This activity will provide a three-dimensional description of the distribution and abundance of major minerals for potential flow paths for both water and gas between the repository horizon and the accessible environment. Statistical evaluation of the three-dimensional distribution will be performed to estimate natural variability, sample density requirements, and extrapolate between boreholes. Data to be collected are quantitative X-ray diffraction (XRD) determinations of mineral abundances, X-ray fluorescence determinations of major and trace element abundances in bulk rock, and electron microprobe analyses of mineral composition. Sampling density is dependent on statistical considerations, but also on needs of other studies such as sorption and results of studies such as the History of Mineralogic and Geochemical Alteration of Yucca Mountain (see Section 3.9.41).

3.9.37 FRACTURE MINERALOGY STUDIES

The fracture mineralogy studies will be conducted to determine mineralogic variability throughout the ESF to establish the time and conditions of fracture mineralogy deposition alteration, and to identify fracture-coating mineral types, sorptive characteristics, and health hazard potential of fibrous zeolites.

In addition to mineralogic sampling by drilling cores and collecting samples from walls and at the working face in the ESF and drifts, samples may be collected on the surface from the removed rock. The samples will be packaged and labeled for shipment to a Los Alamos laboratory for detailed analyses, including age determinations.

3.9.38 RADIONUCLIDE TRANSPORT TESTS IN THE CALICO HILLS FORMATION

The tests will be conducted in approximately eight locations in the Calico Hills Unit. Dual breakout rooms will also be required. Sampling instruments will be located in the main room (lower). The upper room will contain equipment to apply water and approved tracers to the intervening block. Access to this room will be maintained to service equipment.

During room excavation, samples will be collected from the alcove area for laboratory characterization of hydrologic and chemical properties. A geologic map of the test block will be compiled.

Tests will involve increasing water content of the test block by either ponding or sprinkling water on top. Both reactive and nonreactive approved tracers will be used. The slow response of the system will require that tracers be injected during the wetting phase of the experiment rather than by bringing the block to a steady-state water content. Water content will be measured in the block, and water flux determined by effluent collection. Tracer concentrations and total mass will be measured in the effluent. For reactive tracers that have not broken through, a sampling program will be undertaken once the flux part of the experiment is considered complete.

3.9.39 CHLORIDE AND CHLORINE-36 MEASUREMENTS OF PERCOLATION

These measurements will be made at various depths to determine the rate of water movement downward through the unsaturated zone tuffs using the chlorine-36/chloride concentration ratio. Large bulk samples will be periodically collected, packaged, and labeled for laboratory analysis. Because of the requirement to extract pore water to conduct the chlorine-36 test, several hundred pounds of samples may be needed at each sampling location. If perched water is encountered, perched-water samples will also be provided.

3.9.40 PETROLOGIC STRATIGRAPHY OF THE TOPOPAH SPRING MEMBER

The goal for this activity is to determine the petrologic variability within the devitrified Topopah Spring Member and to define the stratigraphic distribution of this variability. Studies of the distribution of phenocyst and rock matrix textures in this member have been shown useful in defining stratigraphic position. Analysis will be conducted with X-ray diffraction. Chemical analyses will also be used to determine variability.

3.9.41 HISTORY OF MINERALOGIC AND GEOCHEMICAL ALTERATIONS OF YUCCA MOUNTAIN

This study will include petrologic analysis of alteration sequences and structures. Mineral growth sequences will be studied using an electron microprobe. Ages of alteration events will be estimated using potassium-argon dating of clays and zeolites and electron spin resonance dating of quartz and calcite.

Samples will be collected at any location where alteration is observed. The underground samples will provide large oriented samples of alteration products. Any natural gels found in the ESF will also be sampled.

3.9.42 BIOLOGICAL SORPTION AND TRANSPORT

Underground operations will introduce microorganisms into the environment. This study will address the effects of these organisms on retardation (positive or negative) of radionuclides. This study will determine the growth of microorganisms in fluids used in excavation and drilling, evaluate the influence of microorganisms on actinide mobility, and determine binding constants of microorganisms to actinides. Indigenous populations as well as introduced organisms will be characterized.

Microorganisms will be cultured from samples collected by drilling and from the ESF. These organisms will then be cultured, in the presence of fluids expected to be introduced, to examine growth. These microorganisms will also be used to examine actinide sorption characteristics.

CHAPTER 4

ENVIRONMENTAL ASPECTS

4.1 REGULATORY FRAMEWORK

The regulatory framework for the Exploratory Studies Facility (ESF) responds to the environmental requirements set forth in the following documents: The Nuclear Waste Policy Act (NWPA), the Nuclear Waste Policy Amendments Act (NWPAA), U.S. Department of Energy (DOE) Orders, the National Environmental Policy Act (NEPA), the Atomic Energy Act (AEA), and other applicable federal and state statutes and regulations as identified in Table 4-1.

The DOE is committed to conducting its operations in an environmentally safe and sound manner, thus complying with the letter and spirit of applicable environmental statutes and regulations. These objectives are identified in DOE Order 5400.1, General Environmental Protection Program Requirements, and described in the Environmental Protection Implementation Plan (EPIP) (DOE, 1990).

Environmental regulations and statutes applicable to activities at Yucca Mountain can be divided into three categories: (1) federal and federally-delegated environmental regulatory requirements, (2) state-administered environmental regulatory requirements, and (3) DOE Orders. The federal, federally-delegated, and state environmental regulatory requirements applicable to the site characterization program at Yucca Mountain are shown in Table 4-1.

TABLE 4-1 ENVIRONMENTAL REGULATORY COMPLIANCE
FOR SITE CHARACTERIZATION OF YUCCA MOUNTAIN

STATUTE	COMPLIANCE ACTION	AGENCY*	APPLICATION FILED (EXPECTED)	AGENCY APPROVAL GRANTED (EXPECTED)
AMERICAN ANTIQUITIES ACT	PROGRAMMATIC AGREEMENT	ACHP	12/86	10/88
AMERICAN INDIAN RELIGIOUS FREEDOM ACT	PROGRAMMATIC AGREEMENT	ACHP	12/86	10/88
ARCHAEOLOGICAL RESOURCES PROTECTION ACT	PROGRAMMATIC AGREEMENT	ACHP	12/86	10/88
COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT	CERCLA COMPLIANCE	DOE	N/A	N/A
ENDANGERED SPECIES ACT	ENDANGERED SPECIES COMPLIANCE	USFWS	10/89	2/90
FARMLAND PROTECTION POLICY ACT	FARMLAND PROTECTION	SCS	1/88	3/88
FEDERAL LAND POLICY AND MANAGEMENT ACT	RIGHT-OF-WAY-AGREEMENT			
BLM LAND		BLM	11/87	1/88
AIR FORCE LAND		BLM/AIR FORCE	3/87	10/89
HAZARDOUS MATERIAL TRANSPORTATION ACT	CARRIER COMPLIANCE	DOT	N/A	N/A

TABLE 4-1 ENVIRONMENTAL REGULATORY COMPLIANCE
FOR SITE CHARACTERIZATION OF YUCCA MOUNTAIN
(Continued)

STATUTE	COMPLIANCE ACTION	AGENCY*	APPLICATION FILED (EXPECTED)	AGENCY APPROVAL GRANTED (EXPECTED)
MATERIALS ACT PERMIT	FREE USE	BLM	8/89	10/90
NATIONAL ENVIRONMENTAL POLICY ACT	NEPA COMPLIANCE	CEQ	N/A	N/A
NATIONAL HISTORIC PRESERVATION ACT	PROGRAMMATIC AGREEMENT	ACHP	12/86	10/88
NOISE CONTROL ACT	NOISE CONTROL COMPLIANCE	DOE	N/A	N/A
EXECUTIVE ORDER 11988; FLOODPLAIN MANAGEMENT	FLOODPLAIN MANAGEMENT COMPLIANCE	DOE	N/A	(6/91)
EXECUTIVE ORDER 11990; PROTECTION OF WETLANDS	WETLANDS COMPLIANCE	USFWS	1/88	3/88
CLEAN AIR ACT	SURFACE DISTURBANCE	NDEP	1/88	(6/91)
	SOURCE REGISTRATION PERMITS	NDEP	(12/91)	(6/92)
	OPERATING PERMITS	NDEP	(7/92)	(12/92)
FEDERAL WATER POLLUTION CONTROL ACT (CLEAN WATER ACT)	NPDES PERMIT (ZERO DISCHARGE DEMONSTRATION)	NDEP	(12/91)	(6/92)

TABLE 4-1 ENVIRONMENTAL REGULATORY COMPLIANCE
FOR SITE CHARACTERIZATION OF YUCCA MOUNTAIN
(Continued)

STATUTE	COMPLIANCE ACTION	AGENCY*	APPLICATION FILED (EXPECTED)	AGENCY APPROVAL GRANTED (EXPECTED)
CWA SECTION 404	SECTION 404 PERMIT	COE	3/88	7/90
RESOURCE CONSERVATION AND RECOVERY ACT	RCRA PERMIT (I.D. NUMBER)	NDEP/EPA	5/89	6/89
SAFE DRINKING WATER ACT	WATER TREATMENT SYSTEM PERMIT	NDEP	(12/91)	(6/92)
NEVADA UNDERGROUND INJECTION CONTROL PROGRAM	PERMIT TO INJECT TRACERS IN THE ESF	NDEP	(12/91)	(6/92)
NEVADA APPROVAL OF PLAN TO CONSTRUCT SANITARY AND SEWAGE COLLECTION SYSTEM AND PERMIT TO OPERATE SYSTEM	PERMIT TO CONSTRUCT AND OPERATE A SEWAGE COLLECTION SYSTEM	NDEP	(12/91)	(6/92)

TABLE 4-1 ENVIRONMENTAL REGULATORY COMPLIANCE
FOR SITE CHARACTERIZATION OF YUCCA MOUNTAIN
(Continued)

STATUTE	COMPLIANCE ACTION	AGENCY*	APPLICATION FILED (EXPECTED)	AGENCY APPROVAL GRANTED (EXPECTED)
PERMIT TO APPROPRIATE PUBLIC WATERS OF NEVADA	WATER APPROPRIATION PERMIT	NSE	7/88	(7/91)
NEVADA WATER POLLUTION CONTROL LAW	WATER POLLUTION CONTROL PERMIT	NDEP	(12/91)	(6/92)

* LIST OF ACRONYMS

ACHP ADVISORY COUNCIL ON HISTORIC PRESERVATION
BLM BUREAU OF LAND MANAGEMENT
CEQ COUNCIL ON ENVIRONMENTAL QUALITY
COE CORPS OF ENGINEERS
DOE DEPARTMENT OF ENERGY
DOT DEPARTMENT OF TRANSPORTATION
EPA ENVIRONMENTAL PROTECTION AGENCY
NDEP NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
NSE NEVADA STATE ENGINEER
SCS SOIL CONSERVATION SERVICE
USFWS U.S. FISH AND WILDLIFE SERVICE

The table contains information from the Environmental Regulatory Compliance Plan (ERCP) for Site Characterization of the Yucca Mountain Site (DOE, 1988).

The DOE Orders that relate to environmental protection, safety, and health are listed in the ERCP, and must also be considered when determining the environmental requirements that apply to the site characterization program. In most instances, by complying with the federal and state regulations the DOE is in compliance with these Orders. DOE periodically reviews the Orders to determine whether additional standards, requirements, or procedures apply to the Yucca Mountain site.

Occupational radiological protection, occupational health and safety, fire protection, building safety codes, and other registration requirements are addressed in Chapter 5 of this report.

4.2 AIR POLLUTION CONTROL

Because the Yucca Mountain Site Characterization Project (YMP) is in an area where existing air quality is better than state and federal air quality standards, emissions associated with site characterization activities are subject to examination under the Clean Air Act regulations on Prevention of Significant Deterioration (PSD). Pollutant emissions, however, should be considerably less than 250 tons per year per individual pollutant (Environmental Assessment of Yucca Mountain, DOE, 1986, DOE/RW-0073).

Construction of the ESF may cause impacts to air quality. Activities and facilities that may contribute to air quality impacts include surface disturbances, underground access ramp and optional shaft excavation, standby generators, gravel screening plant, and concrete batch plant facility. Impacts are expected to be minimal and short term.

The most significant pollutant emitted during site characterization will be fugitive dust. Other pollutants (primarily oxides of nitrogen) from operating equipment also affect air quality. Nevada Air Quality Operating Permit requirements may dictate emission limits.

Airborne dust from mechanical excavation, roadways, parking areas, excavated materials transfer points, laydown areas, borrow areas, drilling, bolting, and blasting will be controlled and limited to concentrations below the Threshold Limit Values (TLVs).

Where applicable, plain water spray or other approved wetting agents will be used to suppress dust in amounts consistent with the goal of minimizing dust to levels compatible with health and safety. Appropriate stationary or mobile dust collection systems will further enhance dust control. For example, water spray and a cyclone/centrifuge and bag system are proposed for use in controlling dust in the ESF ramps and optional shaft. (The manufacturer's guaranteed control efficiency for an in-shaft dust collection system is 99.8 percent.) Particulate emissions from the standby generators will be controlled by pollution control equipment incorporated into generator design. Periodic equipment emission checks will help preclude accidental releases.

The Nevada Division of Environmental Protection is the agency responsible for implementing and enforcing the Clean Air Act at the state level. Air quality requirements include registration certificates and operating permits for surface disturbances, ESF ramps and the optional shaft, standby generators, gravel screening plant, and the concrete batch plant. The ERCP provides more information on air quality permitting requirements.

4.3 WATER USE

Construction and operation of the ESF will require water. The State of Nevada requires a permit for the appropriation of state waters to prevent possible interference with prior water rights.

Water use will be metered at the wellhead to ensure that water use does not exceed quantities allowed by the permit. New facilities, including pumps and water pipelines, will be constructed as specified by the permit. Water withdrawal will not start until a permit is obtained. Approved non-radioactive tracers will be injected into all water (except potable water) used in the ESF to assure its traceability.

Potable water used will meet national drinking water standards. A permit will be obtained for the drinking water system. Drinking water will be periodically tested to ensure that it meets the standards and permit conditions.

4.4 WATER QUALITY

The great depth to groundwater and the lack of surface water in the ESF area reduce the potential for water quality degradation (Environmental Assessment of Yucca Mountain, DOE, 1986, DOE/RW-0073). However, sources that could adversely affect water quality are the underground waste water collection system, sewage treatment system, excavated materials storage, and land disturbing activities.

Discharge of effluents from ESF construction activities into dry streambeds or into a leachfield could impact water quality if not properly controlled and monitored. This includes water used for dust control, excavation and construction activities, firefighting, and human consumption. The majority of water from the underground waste water system settling pond will be released into the dry streambed. Discharge rates for this system in the event of fire or perched water are estimated at 545 gallons per minute, with peak flows up to 700 gallons per minute. Sewage disposal utilizes a leachfield, which is expected to have an average flow of [TBD] gallons per day. Water from runoff is not contained, but directed away from facilities into dry drainage channels.

As described below, control measures are planned to minimize the potential impact of ESF discharges on water quality. Effluent water quality is expected to be good and in compliance with the Clean Water Act (CWA) and all applicable state standards.

Comprehensive plans and the use of pollution control equipment (e.g., oil-water separators, settling basins) will be implemented to reduce pollutants in the discharge waters. Liners will be used in the excavated materials storage area and storage pond to capture the leachate and runoff water. The potential for accidental releases will be reduced by oversizing holding ponds, frequent inspection of facilities, and utilizing good operating and maintenance practices and procedures. A Section 404 permit from the Corps of Engineers will be obtained before constructing facilities in the drainage channels around Yucca Mountain.

Runoff from disturbed and potentially contaminated areas will be controlled to minimize erosion and prevent contamination of adjacent areas. Facilities built in the 100-year floodplain will be designed to minimize impacts to the floodplain and downstream resources.

Waste water handling activities for the ESF (including effluent and sanitary discharges) require compliance with several regulations and statutes, and the obtaining of several permits. Applicable regulations include: Safe

Drinking Water Act, Federal Water Pollution Control Act (including National Pollution Discharge Elimination System), Resource Conservation and Recovery Act (RCRA), Nevada regulations for Constructing and Operating a Sewage System, Nevada Underground Injection Control regulations, and DOE regulations for floodplain management. The ERCP provides more detailed information about permitting requirements.

4.5 LAND DISTURBANCES

Proposed construction activities for the ESF will create surface land disturbances, among which are man-made changes affecting vegetation, wildlife habitat, soil stability, archaeological sites, and site access and control. ESF site characterization activities should not create major land disturbance impacts, however. Remedial action for these land disturbances is based on the requirements of the responsible agency (DOE, Bureau of Land Management (BLM), U.S. Air Force, or U.S. Fish and Wildlife Service). Plans require reclamation of disturbed sites as soon as all studies or work has been completed, as described in the Reclamation Implementation Plan (RIP) (DOE, 1991).

Site access and control are affected by two Right-of-Way Reservations and a Land Withdrawal. These documents, which apply to the BLM portion of the Yucca Mountain site, specify how activities will be conducted at the site. Site characterization activities will take precedence over any other proposed activity (e.g., new mining claims).

Most surface land disturbance will result from ESF construction activities, which are expected to disturb approximately [TBD] acres. These activities include construction and improvement of access roads, utility services, surface support services, underground ramps, the optional shaft, and land transportation, storage, and disposal of excavated materials.

Actions to reduce land disturbance impacts are planned. These include approved dust control measures, soil surveys to aid in reclamation plans for disturbed sites, and pre-activity surveys to ensure avoidance or mitigation of disturbance of archaeological sites or sensitive biological resources, such as the desert tortoise. Noise levels will be controlled and monitored in accordance with applicable regulations. Land disturbing activities will also be minimized through training and oversight programs that provide employee environmental awareness, emphasizing compliance with applicable federal and state requirements. Personnel will be trained to avoid disturbing wildlife, especially the desert tortoise.

A potential exists for land disturbing activities to resuspend radionuclides in the air. Potentially contaminated equipment will be assayed prior to use. Specifications in the Radiological Monitoring Plan will be followed to ensure public radiological health and safety.

Land disturbing activities will be performed in compliance with applicable federal and state requirements, including the Endangered Species Act, Farmland Protection Act, Wetlands Protection Act, NEPA, Federal Land Policy and

Management Act, Material Use Permits, and Nevada's wildlife and vegetation statutes. The ERCP provides a complete description of the required permits and compliance actions applicable to site characterization activities.

4.6 HAZARDOUS AND SOLID WASTES

The handling, storage, treatment, and disposal of hazardous solid waste and disposal of non-hazardous waste are regulated by a complex and interrelated array of state and federal laws. The RCRA, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and its reauthorization, the Superfund Amendments and Reauthorization Act (SARA) which include Title III (Emergency Planning and Right-to-Know), are federal laws requiring implementation of compliance measures during site characterization. The State of Nevada received authority to administer Subtitle C of RCRA (management and disposal of hazardous waste) on November 1, 1985. CERCLA is administered by the Environmental Protection Agency (EPA), and in part by the State of Nevada.

Administrative Procedure AP-6.13 requires each Project Participant to review proposed waste streams to determine if they contain hazardous wastes, and to determine the amount of hazardous waste generated each month. Regulated hazardous wastes are identified in 40 CFR 261. Even if not listed in 40 CFR 261, a waste (e.g., mordenite) may still be considered hazardous if it has any of the following characteristics: ignitibility, corrosivity, reactivity, or toxicity. Hazardous wastes that may be generated by site characterization activities have as yet been only partially identified. The list of hazardous wastes will be prepared during Title II design.

Initial reviews of planned site characterization activities indicate that hazardous substances may be used in amounts that, if spilled, meet "reportable quantities" under CERCLA. Other aspects of site characterization that fall under environmental regulatory oversight include RCRA-regulated hazardous wastes, underground storage tanks (USTs) with associated piping, and used oils. Non-hazardous solid wastes (e.g., used lumber, paper products) are generated by virtually all site activities. Disposal of those materials must also comply with State of Nevada requirements.

To ensure compliance with the applicable hazardous and non-hazardous solid waste regulations, the Project Office has implemented a coordinated program encompassing all YMP activities. The program is described in the draft Hazardous Materials Management and Handling Program (HMMHP) (DOE, 1991). AP-6.13 requires that all field activities and the materials proposed for use on site be reviewed against a comprehensive list of regulated substances and approved prior to use. If a proposed material is regulated and a non-hazardous substitute is not available, the Participant is required to prepare a Material Reporting and Handling Plan (MRHP) to describe waste management plans, emergency reporting and response, personnel safety and handling, monitoring, transportation, and other applicable requirements outlined in the HMMHP. The EPA, the State of Nevada, and local emergency preparedness committees are to be notified if reportable quantities of CERCLA-listed materials are spilled. Worker safety training programs and emergency spill response and contingency plans are also included in the MRHP. All hazardous wastes generated during site characterization are closely managed from "cradle to grave." Methods of hazardous waste disposal will be finalized during Title II design.

ESF activities will comply with Subtitle I, which regulates USTs and requires notification of existing or new tanks. It also establishes minimum tank standards and leak detection and monitoring requirements. The Nevada Department of Environmental Protection administers the UST program and is notified before USTs are installed. Final Subtitle I tank requirements for installation, leak detection, and monitoring were issued in September 1988. All UST designs are reviewed to ensure compliance with Subtitle I criteria. State requirements are reviewed to determine if additional measures are needed to meet state standards.

Used oil is regulated under Subtitle C and is not considered a hazardous waste if it is to be "recycled." All used oil will be recycled as outlined under RCRA and the state hazardous waste program. Land disposal of oil, such as road oiling, is banned under both RCRA and the Clean Water Act (CWA).

Non-hazardous waste is regulated under Subtitle D and the Nevada Solid Waste Disposal Program. Subtitle D encourages recycling of non-hazardous solid waste and non-landfill disposal options. The existing Nevada Test Site landfill in Area 25 will be utilized initially for the disposal of non-hazardous waste. A new on-site landfill will be developed and operated in accordance with state requirements. Waste reduction, recycling, and environmentally sound disposal methods will be utilized to reduce the volume of solid waste.

An impermeable liner will be incorporated in the excavated materials storage pile and leachate collection and evaporation ponds. The evaporation pond will be designed to meet CWA standards. Leachate and pond residue will be sampled to determine if hazardous materials are being generated and accumulated. Accumulated wastes will be managed in accordance with state and federal requirements as outlined in the HMMHP.

Implementation of the materials review procedure and compliance steps outlined in the HMMHP provide compliance monitoring and mitigation options for hazardous and solid waste handling. Field activities that do not comply with the state and federal hazardous and solid waste programs are not permitted.

4.7 CONSTRUCTION PERMITTING

ESF construction activities must comply with the requirements established by applicable federal and state permits. These compliance actions are addressed in previous sections of this chapter. Permits or compliance actions requiring long lead times are prepared first. Permits are filed as the required specifications and design criteria become available.

The schedule for obtaining the required permits is shown in Table 4-1. The time frame for obtaining a permit includes review time by the Yucca Mountain Site Characterization Project Office. Actual time required by the permitting agency to grant the permit varies.

CHAPTER 5

SAFETY AND HEALTH ASPECTS

5.1 APPLICABLE CODES AND REGULATIONS

The design of the ESF shall conform to the applicable requirements of the latest effective dates or revisions of the following summary list of safety and health codes and regulations.

Code of Federal Regulations (CFR)

Code of Federal Regulations, Title 10, Part 60, Disposal of High Level Radioactive Wastes in Geologic Repositories, Nuclear Regulatory Commission (NRC)

Code of Federal Regulations, Title 29, Part 1926, OSHA Safety and Health Standards, Occupational Safety and Health Administration (OSHA)

Code of Federal Regulations, Title 30, Part 57, Safety and Health Standards Underground Metal and Non-Metal Mines, Mine Safety and Health Administration (MSHA)

U.S. Department of Energy (DOE)

DOE Order 6430.1A, General Design Criteria Manual

DOE Order 5480.1B, Environmental Protection, Safety, and Health Protection Program for DOE Operations

DOE Order 5480.4, Environmental Protection, Safety, and Health Protection Standards

DOE Order 5500.3, Reactor and Nonreactor Nuclear Facility Emergency Planning, Preparedness and Response Program for DOE Operations

EV-0043, Standard on Fire Protection for Portable Structures

EP-0108, Standard for Fire Protection of DOE Electronic Computer/Data Processing System

Safety and Health Plan (YMP/90-37)

State of Nevada Regulations

Nevada Revised Statutes, Title 46, Chapter 512, Mine Safety and Health Standards for Open Pit and Underground Metal and Nonmetal Mines and Sand, Gravel and Crushed Stone Operations (46 NRS 512)

California Administrative Code (CAC)

Title 8. Industrial Relations. Chapter 4, Division of Industrial Safety

Subchapter 17, Mine Safety (8 CAC 4.17)

Subchapter 20, Tunnel Safety Orders (8 CAC 4.20)

Electrical Safety Orders and Part 3, Title 24 and Title 8

American Concrete Institute (ACI)

ACI 318 Building Code Requirements for Reinforced Concrete

American Conference of Government Industrial Hygienists (ACGIH)

American Institute of Steel Construction (AISC)

Manual of Steel Construction

American Iron and Steel Institute (AISI)

Cold-Formed Steel Design Manual

American National Standards Institute (ANSI)

ANSI C2	National Electrical Safety Code
ANSI A117.1	Specifications for Making Buildings and Facilities Accessible to and Usable by Physically Handicapped People

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)

American Society of Mechanical Engineers (ASME)

ASME Boiler and Pressure Vessel Code, Division 1

American Welding Society (AWS)

AWS D1.1 Structural Welding Code-Steel

Factory Mutual Research and Engineering Association (FM)

Factory Mutual Approval Guide

Institute of Electrical and Electronic Engineers (IEEE)

International Conference of Building Officials (ICBO)

Uniform Building Code

Uniform Mechanical Code

Uniform Plumbing Code

National Association of Plumbing, Heating, Cooling Contractors (PHCC)

National Standard Plumbing Code

National Fire Protection Association (NFPA)

National Electrical Code (NEC)

National Fire Codes

Underwriters' Laboratories, Inc. (UL)

UL Building Materials Directory

UL Fire Resistance Directory

EXCEPTIONS TO SAFETY REGULATIONS

DOE Order 5480.4 establishes DOE policy concerning applicability of regulations and standards promulgated by other organizations. This policy includes the principle that when conflicts occur between different standards, the criteria providing the greater degree of protection shall apply. Authority to interpret and enforce standards applicable to the YMP rests with the DOE (Memorandum of Understanding between the DOE and the Department of Labor, 12/23/86). Consequently, situations where differing requirements can be cited as applicable to an aspect of the Exploratory Studies Facility (ESF) design need to be reviewed by the DOE organization with enforcement authority. This review will establish an interpretation of the applicability of each standard or code and a determination of which standard provides the greater degree of protection. Exceptions will be requested when compliance with the requirement affording the greater degree of protection cannot be accomplished.

5.2 SAFETY AND HEALTH STRATEGY

Design activities of the YMP and its contractors are conducted in accordance with DOE policy to protect the health and safety of its employees, contractors, and the public by complying with the spirit as well as the letter of applicable health and safety statutes, regulations, orders, and standards.

This has been accomplished during Title I design by selecting a design team with extensive experience in the design of mines and other underground facilities, initiating a safety analysis process, and reviewing the design to identify potential safety concerns. Safety analysis and review activities will continue throughout Title II with a Safety Analysis Report (SAR) issued for Title II. The results of these efforts to incorporate safety into the design will be carried forward into the construction and operation phases of the ESF.

5.2.1 RESPONSIBILITIES

The DOE has the ultimate responsibility to ensure that all health and safety requirements are adhered to during the life of the project.

The Architect/Engineer (A/E) has a responsibility to ensure that the design is free of recognized hazards that can be mitigated through design changes, and that the design conforms to the codes and regulations outlined in Section 5.1.

During ESF construction, representatives of the Mine Safety and Health Administration (MSHA) will conduct onsite inspections to ensure compliance with the provisions of 30 CFR Part 57 with regard to working conditions and operations per the memorandum of understanding between the DOE and the MSHA. Such inspections include monitoring of ventilation, construction methods, personnel qualifications and performance, methods of ground control, general housekeeping, and working environment. Nonconformance with safety or health requirements will be brought to the attention of the Construction Contractor and the DOE for remedial action.

The NRC will conduct onsite inspections to verify that ESF construction complies with 10 CFR 60.

The Construction Contractor is responsible for onsite monitoring of compliance with applicable safety requirements during construction and operation of the ESF, including compliance with DOE Orders and procedures as well as requirements of the Construction Contractor's Safety and Health Department.

Any construction subcontractor shall be familiar with, and comply with, all applicable safety and health procedures prior to commencing work. The subcontractor is responsible for prompt remedial measures upon notification by the Construction Contractor of any nonconformance with requirements. Subcontractors shall institute a safety program to be followed by their work crews, and periodically conduct safety meetings to ensure compliance with their program.

5.2.2 HAZARDS ANALYSIS

During Title I, a draft Preliminary Safety Analysis Report (PSAR) was prepared to ensure, in compliance with DOE Order 4700.1, that: (1) potential hazards are systematically identified; (2) potential consequences are analyzed; and (3) reasonable measures are taken to eliminate, control, or mitigate the hazards. This draft PSAR was based on the two-shaft configuration. The PSAR has been revised (see Appendix 5.13) to reflect the Reference Design Concept as described in the System Description (YMP/CC-0012). Raytheon Services Nevada (RSN) is responsible for the surface and underground engineering design and Los Alamos National Laboratory (LANL) is responsible for the Integrated Data System (IDS) and the description of the planned tests. The safety analysis process performed by RSN focuses on mitigation of hazards by design.

The intent is to mitigate significant risks by the design, construction, or operational processes. When the mitigation must be achieved by construction or operations, the necessary action must be referred to the constructor/operator by a documented and controlled process. This process is supported in part by existing safety operating procedures already in effect at the Nevada Test Site as part of the Construction Contractor's Safety and Health Program.

Potential accident and failure scenarios and their initiators have been identified for the ESF design. Some preliminary analyses of these scenarios have been performed and are scheduled for completion during Title II. These scenarios concern equipment, systems, and structures that are identified as safety-related items.

A safety analysis is a complex process that considers scenario identification, probability assessment, consequence assessment, and risk evaluation. The process requires multiple iterations of the process components by properly qualified personnel to ensure the accuracy of the identified scenario. A summary of some credible accidents considered, and resulting observations, are given in Section 5.2.4.11.

5.2.3 SAFETY PLANS

The Safety and Health Program Plan drafted by the Construction Contractor for the YMP ESF, subordinate to the YMP Safety and Health Plan (YMP/90-37), represents a coordinated approach that tailors all aspects and disciplines of a comprehensive safety program. The plan provides safety and health plans, procedures, and practices for the overall surface and underground construction effort, and operational safety and health responsibilities for the duration of the ESF. The plan includes safety and health considerations (consistent with DOE procurement regulations) for use as provisions and/or special conditions for subcontract solicitations.

The plan results in the maintenance of a suitable environment for employees and visitors at the ESF. In addition, the plan provides further assurance that all facilities are properly constructed and maintained, and that there is minimal adverse environmental impact.

Any "authorized person" approved or assigned to be underground shall be trained in accordance with applicable MSHA standards, California Division of Industrial Safety Mine Orders, and REECo Occupational Safety Codes. This training must be given to all personnel going underground at the ESF including miners, scientists, and visitors.

Mine rescue team members must hold a current certification for use of National Institute for Occupational Safety and Health (NIOSH)/MSHA approved two-to four-hour self-contained breathing apparatus. All training is in accordance with the current MSHA Mine and Rescue Apparatus and Auxiliary Equipment Handbook, and conducted by an MSHA Certified Mine Rescue Instructor. Certification is by a Construction Contractor mine rescue examiner.

Surface and underground emergency and evacuation plans reflect the requirements of DOE 5500.3.

Other safety plan elements address the balance of the spectrum of relative functional considerations such as:

(1) Employment of detailed procedures that include safety steps, usually as checklists, although they may be augmented by Job Safety Analyses (JSAs).

(2) Accident and incident investigation and reporting at all levels of severity in compliance with DOE and Construction Contractor reporting requirements.

(3) Assurance that all procedures are reviewed for safety considerations in accordance with the hazard present. Such reviews ensure the acceptance of risk at the proper level of management.

(4) Recognition of formal design and facility readiness reviews as a vital element of the safety program.

(5) Inclusion of adequate safety requirements in all work orders, subcontracts, and similar documents. Briefings are recognized as essential to safety on all hazardous work with documentation required for enforcement.

(6) Conducting of in-depth surveillance of all work activities and associated personnel with special attention to unusual situations and work patterns with applicable safety codes, standards, and regulations strictly enforced.

(7) Provision for continued attention to and control of such concerns as ventilation, dust control of airborne contaminants, explosives and blasting, first aid, personal protective equipment, self-rescue devices, specialized equipment, underground work procedures, ground control, and lock and tag procedures. Corrective action in any of these areas shall be prompt and complete.

(8) Requirement that employees: (a) observe all safety and health rules; (b) use all prescribed personal protective equipment; (c) follow established health and safety practices and procedures; and (d) immediately notify supervisors of suspected exposures to harmful agents or conditions.

The essence of the plan is that safety is the responsibility of each worker while implementation of safety procedures and controls is the responsibility of line management. To this end, execution of this program is coordinated with all participants.

5.2.4 DESIGN BASIS EVENTS

The basis for a safe design of the structures and facilities for the support of the site characterization program to be conducted at Yucca Mountain considers a host of natural and man-made events. A summary of natural events and characteristics being considered in the design follows. See Section 7.5 Provision 10 CFR 60.133(a)(2) for a related discussion.

5.2.4.1 Soils

An investigation of the soils at the Nevada Test Site (NTS) has been performed using standard soil-test procedures. The studies (H&N, 1983) indicate that there should be no problems with soil shrinkage, swelling, freezing, or thawing and that all components are excellent for use as foundation materials. The study recommends that all foundations be compacted to a minimum 95 percent relative compaction.

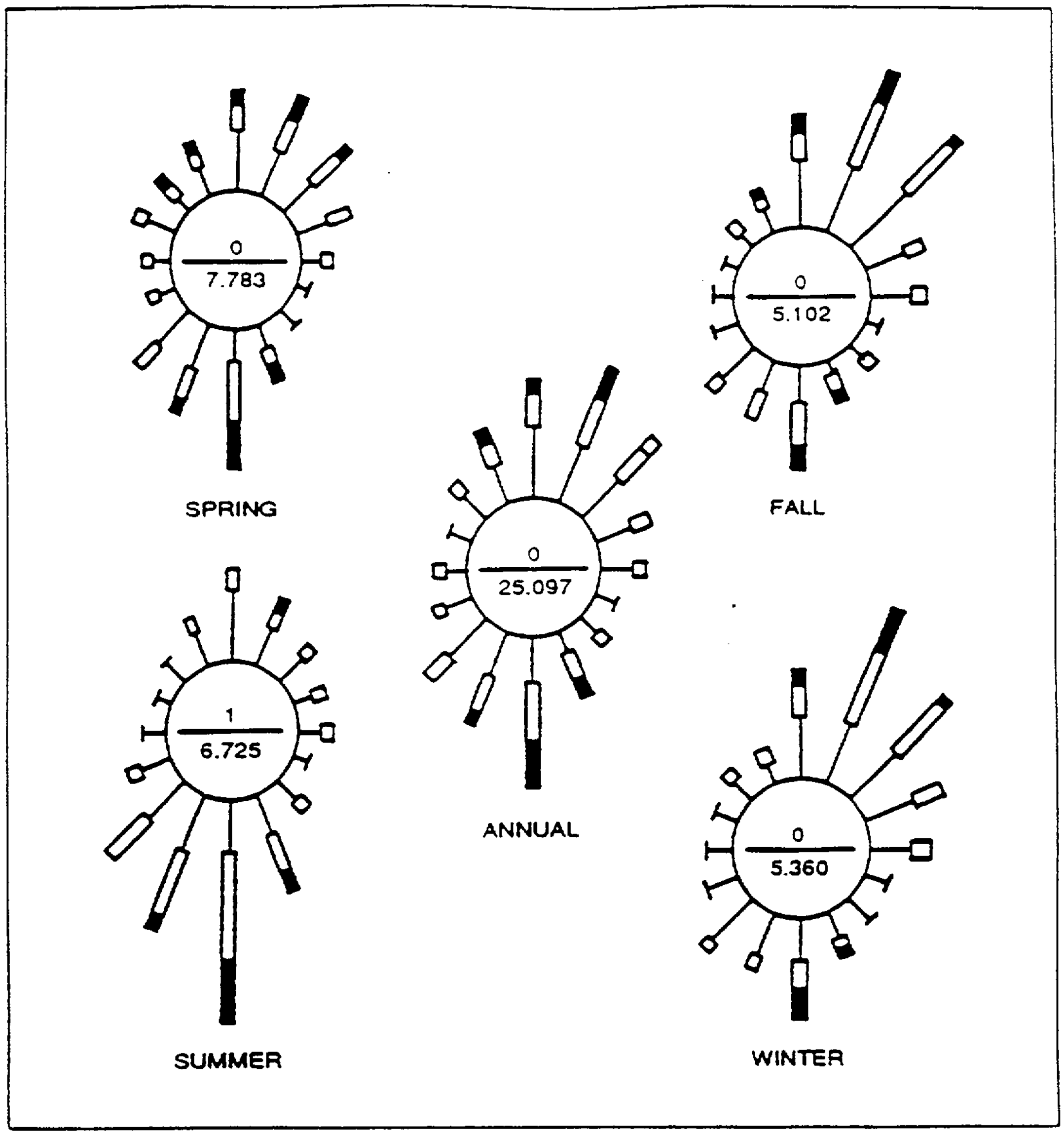
Percolation tests have confirmed that the soil is sufficiently absorptive to permit the use of drainage tile and/or seepage pits in conjunction with individual sanitary sewage disposal functions at remote facilities.

5.2.4.2 Wind

Seasonal wind roses showing fractions of time relative to three wind speed classes are shown in Figure 5-1. The charts indicate a predominately southerly wind direction in summer and a northerly direction in winter. Distribution of wind speeds above Jackass Flats (about 7 miles southeast of the surface facilities) is available, and used as design data. Diurnal wind reversal and seasonal directional shifts were noted based on data taken in the Jackass Flats area.

5.2.4.3 Tornadoes and High Winds

Tornadoes and high winds for the NTS have been characterized by Fujita (1981). The probabilities for these events are summarized in Figure 5-2 (Fujita, 1981). The design basis tornadoes (DBT) were characterized in the Fujita report: (1) DBT-77, an axisymmetric tornado; and (2) DBT-78, the DBT-77 tornado with suction. The parameters associated with these two design basis tornadoes are shown in Table 5-1. **NOTE:** ESF structures will not be designed for tornadoes, but for a wind factor of 30 psf.



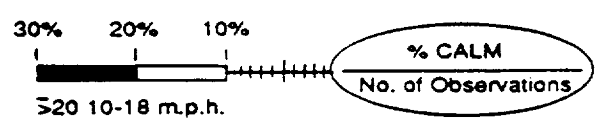


Figure 5-1. Wind speed classes.

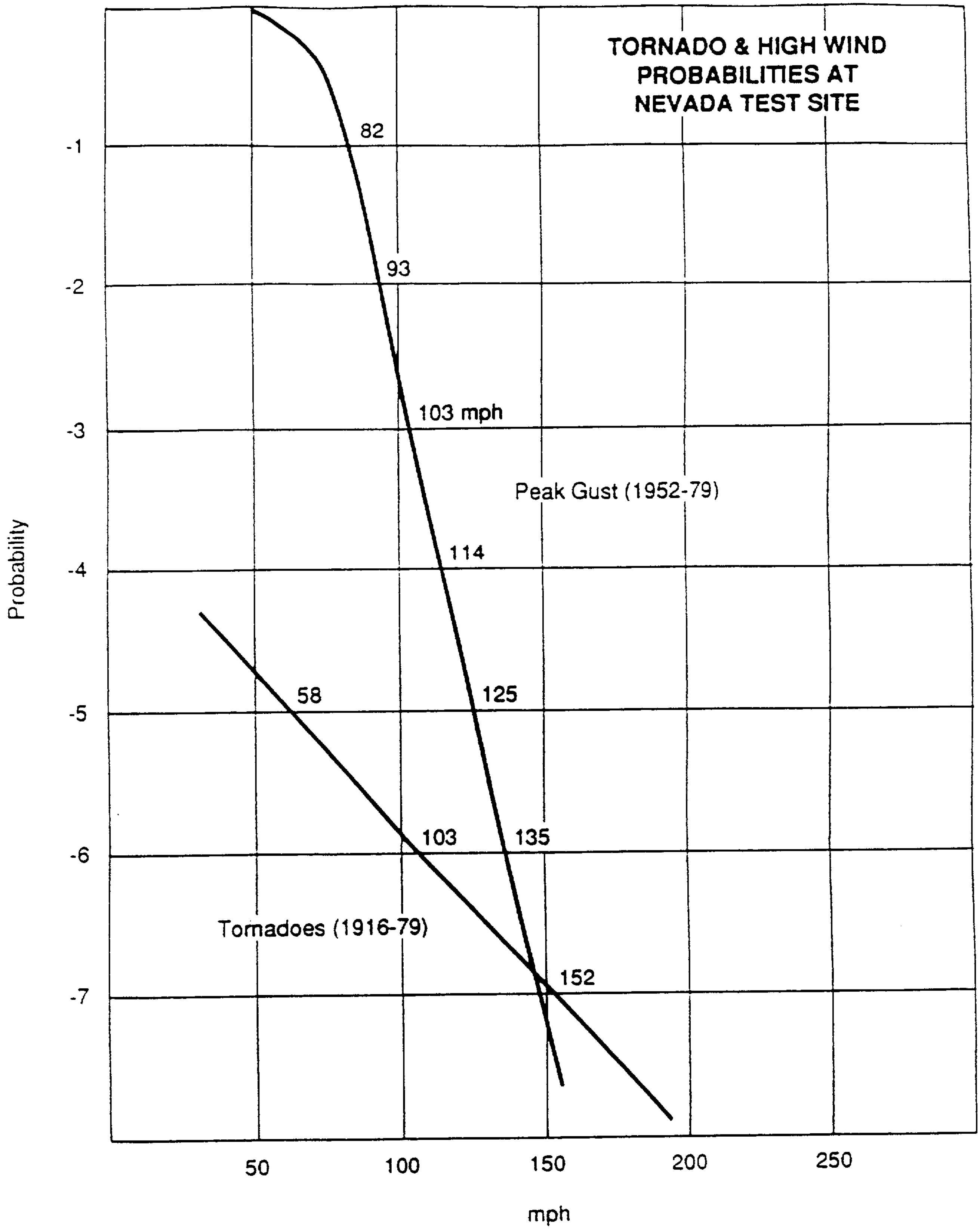


Figure 5-2. Tornadoes and high wind probabilities.

Table 5-1. Parameters of design-basis tornadoes applicable to the Nevada Test Site[a]

	Design-Basis Tornado	Tornado Probabilities Per Year			Unit
		10^{-5}	10^{-6}	10^{-7}	
Maximum Windspeed (F-scale wind)		58.0	103.0	152.0	miles per hour
Maximum Tangential Velocity (tornado)	DBT-77	44.3	83.9	129.7	miles per hour
	DBT-78	41.2	71.7	103.9	miles per hour
Core Radius (tornado)	DBT-77	35.4	67.1	103.8	meters
	DBT-78	33.0	57.4	83.1	meters
Translational Velocity (tornado)	DBT-77	14.8	28.0	43.2	miles per hour
	DBT-78	13.7	23.9	34.6	miles per hour
Maximum Pressure Drop (tornado)	DBT-77	4.2	15.1	36.3	millibars
	DBT-78	3.7	11.9	23.2	millibars
Maximum Tangential Velocity (suction vortex)	DBT-77	----	----	----	
	DBT-78	20.6	35.8	51.9	miles per hour
Core Radius (suction vortex)	DBT-77	----	----	----	
	DBT-78	11.4	17.9	23.4	meters
Translational Velocity (suction vortex)	DBT-77	----	----	----	
	DBT-78	23.1	42.3	64.1	miles per hour
Maximum Pressure Drop (center vortex)	DBT-77	----	----	----	
	DBT-78	0.9	2.7	5.8	millibars

[a]Air density = 1.079 kg/m^3

[b]Fujita, 1981.

5.2.4.4 Hailstorms

One hailstorm per year can be expected for design purposes. Hailstones with diameters of 0.5 to 1 inch have been reported (Houghton et al., 1975).

5.2.4.5 Thunderstorms

The frequency of thunderstorms compiled by the Yucca Flat Weather Station between 1962 and 1968 is shown in Table 5-2. The Yucca Flat Weather Station is located approximately 28 miles east of the surface facilities site.

5.2.4.6 Temperature and Humidity

Temperature extremes of -30°F and 115°F have been observed on the NTS. The temperature conditions, including the daily ranges, are shown in Table 5-3. Dry bulb temperature values decrease 3°F per 1,000 feet increase in elevation.

Table 5-2. Thunderstorm occurrence at Yucca Flat[a]

Thunderstorm Days[b]	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Number	c	0	1	c	1	2	3	4	2	c	c	c	14
Greatest Number	1	0	2	3	4	4	8	9	6	1	1	1	22

[a] Holmes and Narver, Inc., and Fenix and Scisson, Inc., 1970.

[b] A thunderstorm day is one in which thunder was heard at the station.

[c] Indicates less than 1 occurrence in 2 yrs.

Table 5-3. Temperature and humidity tabulations at the Nevada Test Site Jackass Flats (Station 4JA)[a]

	Daily Temperature F[b]			Daily	Hourly Relative Humidity (%)			
Month	Max.	Min.	Avg.	Range	0400	1000	1600	2200 PST
Jan.	72	8	40	22	67	49	35	60
Feb.	76	14	50	22	67	45	32	56
Mar.	80	23	52	25	58	31	23	44
Apr.	91	28	60	26	52	27	21	38
May	97	32	65	27	46	22	17	31
Jun.	109	43	76	29	39	19	14	25
Jul.	109	53	81	28	40	20	15	28
Aug.	106	50	78	27	44	23	16	30
Sept.	100	45	73	27	43	21	17	32
Oct.	94	34	64	25	46	24	19	36
Nov.	83	22	53	23	61	39	31	52
Dec.	73	20	53	23	68	50	49	69

[a] Based on data taken between May 1956 and December 1966.

[b] Quiring, 1968.

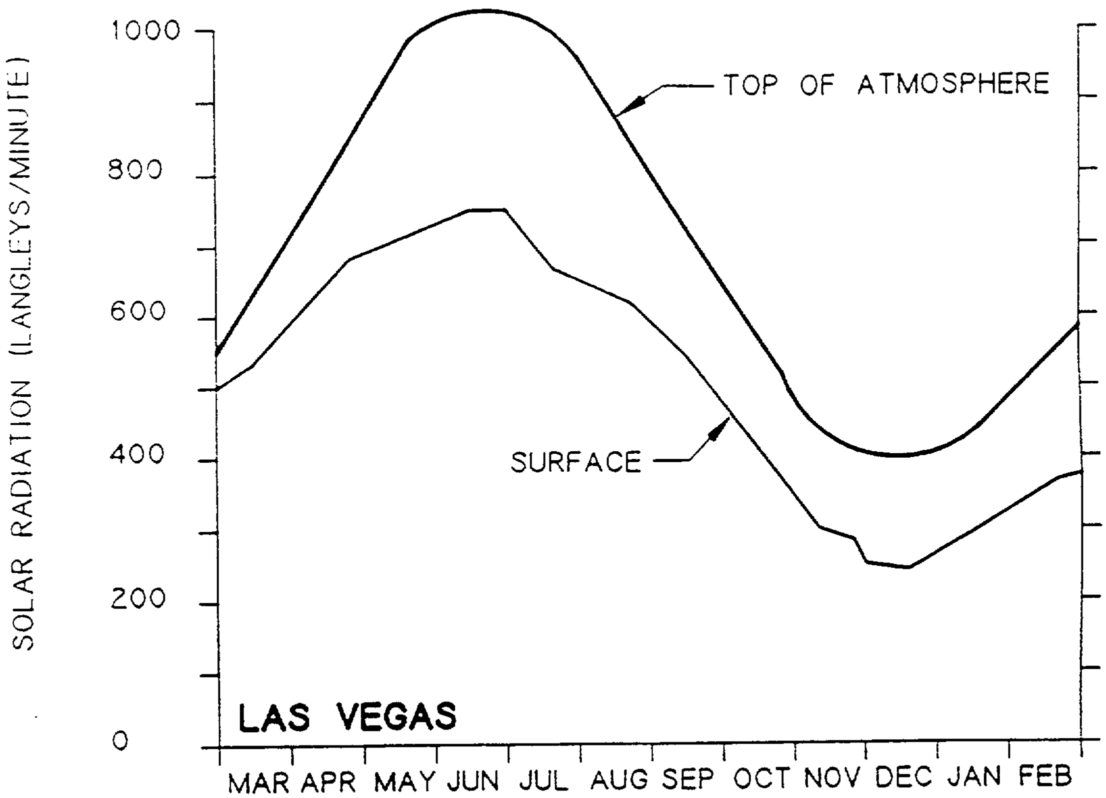
5.2.4.7 Precipitation

Precipitation summaries for weather stations near Yucca Mountain are available and are incorporated in the design. All amounts are expressed in inches and include the water equivalent of snowfall during that period. Rainfall probability for durations from 5 minutes to 24 hours at the NTS were reviewed (Quiring, 1978). Snowfall is usually light and melts quickly.

Fog is a somewhat rare cold-weather phenomenon in Nevada. When it occurs, it is usually confined to the night and morning hours between November and March, when relative humidities are highest. As defined by the National Weather Service, fog is a condition that reduces the visibility to 1/4 mile or less. Heavy fog occurs approximately 2 days per year. Light ground fog (visibility greater than 1/4 mile) occurs occasionally. Poor visibility may also be caused by heavy blowing snow (Houghton et al., 1975).

5.2.4.8 Solar Radiation

The monthly solar radiation for the Las Vegas area is shown in Figure 5-3 (Houghton et al., 1975). Peak radiation occurs in May, June, and July. The cloudiness for the Yucca Flat area from 1962 to 1968, expressed in percentage of the sky covered, was also reviewed. The amount of solar energy received in a day can be expected to fall within the lines of 1 standard deviation 68 percent of the time (Houghton et al., 1975).



NOTE: A LANGLEY EQUALS ONE CALORIE OF HEAT RECEIVED ON A SURFACE AREA OF ONE SQUARE CENTIMETER, OR 3.69 BRITISH THERMAL UNITS (BTU) PER SQUARE FOOT. THE LATITUDE AT LAS VEGAS (McCARRAN INTERNATIONAL AIRPORT) IS 36°-05'N.

Figure 5-3. Monthly solar radiation levels.

5.2.4.9 Tectonics/Seismicity

Tectonic activity in the region has decreased markedly during the past 10 million years. The pattern of tectonism appears to be responding to a cooler, more stable crust in which deformation now tends to be concentrated in relatively narrow zones. Localization and slowing of tectonic activity have allowed areas such as Yucca Mountain to remain relatively stable during the past few million years. See the Site Characterization Program Baseline (SCPB)(DOE, 1991) (Appendix 5.5).

Stress measurements and modeling indicate a stress field with minimum principle stress in a northwest direction in the vicinity of Yucca Mountain. Hydrofracture experiments in one drillhole at Yucca Mountain show a low least-principal-stress value that is one-third of the effective confining pressure and effective vertical load. This state of stress warrants careful evaluation with respect to the possibility of incipient normal faulting at Yucca Mountain.

Yucca Mountain has been seismically quiet for even very small earthquakes over the 13-year monitoring period. A maximum probable magnitude of 7+ was calculated for potential earthquakes occurring on active faults in the Yucca Mountain region. The most probable peak acceleration at Yucca Mountain for a 6.8 event on a nearby fault is 0.4 g, assuming that faults at Yucca Mountain itself are inactive. See Subramanian et al., (1989) for information on the design basis earthquake.

Seismic studies at the NTS have evaluated the adequacy of available data pertaining to ground motion resulting from underground nuclear explosions or earthquakes and used to evaluate the stability of the site, design the waste disposal facility, and meet the licensing requirements of the NRC. Other major components of the seismic design criteria have been reviewed, including identification of structures, systems, and components important to safety; establishment of performance criteria; and prediction of seismic effects.

Recent studies on the potential for volcanic activity in the area (Crowe et al., 1983) have shown that the hazards of large volume silicic volcanism are negligible because of the absence of this type of volcanism in the region during the past 6 to 8 million years. Crowe's calculations have also shown that the probability of a basaltic eruption is extremely low.

5.2.4.10 Flood Potential at the Yucca Mountain Site

The mean annual rainfall for the region is less than 4 inches; however, the potential for severe rainstorms exists as indicated in a U.S. Weather Bureau tabulation (Table 5-4) of expected maximum rainfall in Nye County for 100-year occurrence intervals.

U.S. Geological Survey Report 83-4001 analyzes the floodplain hazards in Forty-Mile Wash and its principal tributaries (Squires and Young, 1982). Data from 12 peak-flow gauging stations adjacent to the NTS are used as the basis for an estimation of the magnitude of the 100-year and 500-year flood peaks and maximum probable flood in cubic feet per second. The conclusions of a site-specific USBR flood study currently being conducted will be compared with those of the USGS report.

The maximum flood inundation limits for the 100-year and maximum probable flood do not reach the optional shaft collar or the ramp portals. The 100-year flood is that magnitude flood that has a 1-percent chance of being equaled or exceeded in any given year. The maximum regional flood is estimated from records (or estimates) of thunderstorms of unusually large magnitude in a five-state region (Arizona, California, Nevada, New Mexico, and Utah) that encompasses the site without reference to recurrence interval.

Table 5-4. Expected maximum rainfall occurrence for 100 years in Nye County*

Duration (hr)	Total Rainfall (in.)	Intensity (in./hr)
0.5	0.75	1.5
1.0	1.0	1.0
2.0	1.25	0.6
3.0	1.5	0.5
6.0	1.8	0.3
12.0	2.0	0.2
24.0	2.5	0.1

*DOE, 1980.

5.2.4.11 Credible Accidents

All safety issues associated with the ESF deal with protection of the environment and the health and safety of the public, worker safety both above and below ground, loss of experimental scientific data, protection of Government property against loss or damage, and cost and scheduling impacts. An accident's consequence can be as simple as a nuisance; cause a low, medium, or high loss of time or money; or catastrophic, resulting in loss of life. At this stage of the Project there is no assurance that the list of accident scenarios considered in the draft PSAR is complete. RSN believes the list includes a majority of the scenarios that will ultimately be considered to give a full representation of the risks associated with the Project.

Examples of above-ground accident scenarios considered are:

- Fire and smoke hazards in each of the facilities
- Personnel injuries due to falls
- Flooding--Various causes, various facilities
- Gas cylinder explosions
- Electrical power failures, various items and locations
- Extrinsic accidents such as tornadoes, earthquakes, volcanoes, aircraft crash, and lightning strikes.

Examples of below-ground accident scenarios considered are:

- Failure of ground support system
- Underground fires/explosions--small to large in various locations
- Machinery accidents--due to the motion of machinery for such items as electric or air powered tools, large and small mining equipment, and shop equipment
- Mobile equipment accidents including conveyors
- Ventilation system failure.

Refer to the Preliminary Safety Analysis Report for more detailed information.

5.3 LIFE SAFETY SYSTEMS

Offsite support services are provided by following NTS management plans. This provides for notification of the fire department, medical, mine rescue, industrial safety, Nye County sheriff, DOE operations, or the security system. Additional life safety provisions are available at the TS north portal site, including a first aid station and an ambulance.

REFERENCES

Crowe, B., et. al., 1983. "Aspects of Potential Magmatic Disruption of a High Level Radioactive Waste Repository in Southern Nevada," Journal of Geology V. 91.

Houghton, J. G., et. al., 1975. Nevada's Weather and Climate, Special Publication Number 2, Nevada Bureau of Mines and Geology, Mackay School of Mines, University of Nevada, Reno, NV.

Quiring, R. F., 1968. Climatological Data, Nevada Test Site, Nuclear Rocket Development Station (NRDS), ERLTM-ARL-7, ESSA Research Laboratories.

Subramanian, C. V., et. al., 1989. Preliminary Seismic Design Cost-Benefit Assessment of the Tuff Repository Waste-Handling Facilities, SAND88-1600. Sandia National Laboratories, Albuquerque, NM.

CHAPTER 6

DESIGN ASPECTS

6.1 INTRODUCTION

Chapter 6 presents information on the selection of specific design features in the Title I design of the ESF. Key factors used in establishing the design are presented for each major subsystem. Alternatives evaluated are described, where appropriate. Studies, calculations, and analyses addressing the applications of various ESF components were performed, and/or reports prepared based on presently available design criteria. Title II design must further evaluate the various ESF components with regard to their reliability, maintainability, and availability.

Table 6-1 summarizes the design requirements of the Exploratory Studies Facility Design Requirements (ESFDR) document, Revision 5/31/91. For an expanded listing of ESFDR/10 CFR 60 cross-references see Appendix F.1 of the ESFDR. Section 7.5 of this report also provides ESFDR/10 CFR 60 cross-references.

Table 6-1. 10 CFR 60 Requirements and Related ESFDR Requirements Applicable to ESF Design.

10 CFR 60 REQUIREMENT		RELATED ESFDR REQUIREMENTS
60.15(b) In situ exploration & testing required	1264, PC 1a (i-iv) 1265, PC 1a (i-iv) 1266, PC 1l (i-iv)	
60.15(c)(1) Site characterization to limit impacts to waste isolation	1260, Con C(1) 1264, PC 2a (i-v) 1265, PC 2a (i-v) 1266, PC 2a (i-iv) 1267, Con B (i)	1261, Con A 1262, Con A
60.15(c)(2) Limit number of penetrations	1260, Con C(2) 1264, PC 1b 1265, PC 1b 1266, PC 1b	
60.15(c)(3) Locate shafts where underground facility shafts or pillars are planned	1260, Con C(3) 12611, Con A 1264, PC 2b (i-iv) 1265, PC 2b (i-iv) 1266, PC 2b (i-iii, a-c) 1268, Con D (i-iii)	1260, PC 2c (vi)
60.15(c)(4) Coordinate site characterization with Geological Repository Operations Area (GROA) design	1260, Con C(4) (i-viii) 1266, PC 2c (i-x)	
60.72(a,b) Maintain records	1260, PC 1f	

Table 6-1. 10 CFR 60 Requirements and Related ESFDR Requirements Applicable to ESF Design (cont).

10 CFR 60 REQUIREMENT	RELATED ESFDR REQUIREMENTS		
60.74(a,b) Accommodate additional NRC-requested tests	1260, Con D 1264, Con A (i) 1265, Con A (i) 1266, Con A (i,ii) 1267, Con C (i)		
60.122(b)(5) Thickness of overburden	1266, PC 2e (i-v)		
60.122(c)(i) Potential for flooding of underground facility	12614, Con A		
60.130 DOE not relieved from omissions in 60.131-60.134. Design bases must be consistent with site characterization activities	1260, Con E (i-iii) 1264, PC 2c 1265, PC 2c 1266, PC 2d	1261, Con E 1264, PC 2a (ii, a-c) 1264, PC 2a (iii-v) 12642, Con D 1264, PC 1d (vi)	1265, PC 1d (vi) 12652, Con C 1266, PC 1d (ix) 1266, PC 2a (ii-iv)
60.131(b)(a) GROA to include worker safety provisions per Mine Safety and Health Administration (MSHA)	1260, Con G		

Table 6-1. 10 CFR 60 Requirements and Related ESFDR Requirements Applicable to ESF Design (cont).

10 CFR 60 REQUIREMENT		RELATED ESFDR REQUIREMENTS	
60.133(a)(1) Underground facility layout to contribute to containment, isolation	1264, PC 2d (i-v) 1265, PC 2d (i-v)	1266, PC 2e (i,ii,v)	
60.133(a)(2) Design underground facility to prevent spread of disruptive events	1264, PC 2e (i,ii) 1265, PC 2e (i,ii) 1266, PC 2f (i-iv) 1267, Con D (i,ii)	1261, PC 1b 1262, Con C 1262, Con D 1266, PC 1d (iii,iv,xi)	1267, Con J 12676, PC 1b (i,v) 12678, Con A 12678, PC 1a
60.133(b) Underground facility to be designed with flexibility	1264, PC 2f 1265, PC 2f 1266, PC 2g (i-iii) 1267, Con E (i-iii)	1265, PC 1c (i,ii) 1264, PC 1c (i,ii) 1264. PC 1a (iv)	1266, PC 1d (xiv) 1266, PC 1c (ii-iv)
60.133(d) Control water, gas intrusion	1260, PC 2e 1264, PC 2g (i-iv) 1265, PC 2g (i-iv) 1266, PC 2h (i-viii) 1267, Con F (i-iii) 1268, Con E (i-ix)	1261, Con F (i-v) 1261, Con O 1262, Con E 1264, PC 1l (iii) 1264, PC 1d (i-iii)	1265, PC 1d (i-iii) 1266, PC 1d (iv-viii, x) 12676, PC 1b (i,ii)

Table 6-1. 10 CFR 60 Requirements and Related ESFDR Requirements Applicable to ESF Design (cont).

10 CFR 60 REQUIREMENT		RELATED ESFDR REQUIREMENTS	
60.133(e)(2) Openings to reduce deleterious rock movement, fracturing	1264, PC 2h (i-iii) 1265, PC 2h (i-iii) 1266, PC 2i (i-v)	1264, PC 2 (i,ii) 1265, PC 2 (i,ii) 1266, PC 2j (ii)	1266, PC 2c (ix) 12662, Con A
60.133(f) Excavation methods to limit groundwater pathways	1264, PC 2i (i-viii) 1265, PC 2i (i-viii) 1266, PC 2j (i-x)	1261, Con C (ii)	
60.133(i) Underground facility to account for thermal, thermomechanical response of system	1264, PC 2j (i-iii) 1265, PC 2j (i-iii) 1266, PC 2k (i-v)		
60.134(a,b) Seals design to not impact long-term performance	1260, Con H 1264, PC 2k (i-v) 1265, PC 2k (i-v) 1266, PC 2l (i-vi)		
60.137 Design to permit performance confirmation program	1264, Con B (i-iii) 1265, Con B (i-iii) 1266, Con B (i-iii) 1267, Con G (i)	1261, Con D 1266, PC 1c (iv) 1267, Con E (ii)	

6.2 SITE PREPARATION

6.2.1 ACCESS ROADS

The ESFDR requires a design basis of [TBD] construction and support personnel using the ESF. Transportation to the ESF is by bus or government vehicle; most personnel will utilize bus transportation.

Maximum speed on access roads is 35 mph except for the approaches to the portal site areas and water storage tanks, etc., which will be reduced speed zones based on Nevada Department of Transportation (NDOT) standards. The standards take into account traffic volume and type of terrain. Peak traffic volume is expected during shift change. Included in the ESF road considerations are traffic volumes and the presence of heavily loaded vehicles such as water trucks, concrete trucks, and tractor-trailers. The maximum road grade to the TS north portal site is <9.5 percent, the maximum road grade to the TS south portal site is [TBD] percent, and the maximum road grade to the optional shaft collar site is [TBD] percent.

The explosives storage road is designed for tractor-trailer use. The explosives are delivered as needed in a tractor-trailer; however, a pickup truck or other light vehicle transports explosives to the portal or shaft site. The roadway is 24 feet wide, with 4 to 1 side slopes. (See Drawing No. YMP-025-2-CIVL-PR12.)

The existing H Road/Drill Hole Wash Road, which has had a surface treatment, will be improved from Well J-13 to its intersection with the access roads to the TS north portal, TS south portal, and the optional shaft collar site. The improved road will be 24 feet wide with 6-foot shoulders. (See Drawings No. YMP-025-1-CIVL-PR01 through YMP-025-1-CIVL-PR08.)

6.2.2 SITES

All sites are constructed to minimize the effects of construction. Topsoil from the three main sites (TS north portal, TS south portal, and optional shaft collar) will be removed and transported to the topsoil storage site (see Drawing No. YMP-025-1-CIVL-PL07) for later use in reclamation. The sites shall be prepared to conform to the site grading plans and specifications.

Various methods are used to protect side slopes of fill from erosion, depending on the fill slope characteristics. Side slopes are protected with an approved soil stabilizer and compacted and trimmed by side rolling during their construction. Slope protection may include methods such as use of vegetation, mulch, geotextile filter fabric, or sprayable soil stabilizer. Ditches adjacent to berms built from fill are concrete-lined if water velocities are greater than 4 feet/second. Runoff collects in catch basins and is piped down slopes where approved concrete-grouted riprap is used for erosion control. Site drainage and flood protection are discussed in Section 6.2.3.

Sites used for heavy traffic such as vehicle turnarounds or access to main sites will be surfaced as determined during Title II design. Lightly traveled areas such as parking or personal vehicle traffic areas are lightly oiled and sand blotted if required.

6.2.3 SITE DRAINAGE

The goal of the site drainage system design is to protect the site against potential floodwaters and control the runoff. Drainage channels and ditches are used in flow control. Channeling is designed to contain a 100-year flood, and the 25-year flood is controlled by ditches. Minimum side slopes of 2 to 1 are used on all ditches and channels. Culvert design incorporates corrugated metal pipes (CMP) with end sections or concrete headwalls and tailwalls. Riprap protection is added as necessary. Although the grades of both channels and ditches conform to the general slopes of the existing water courses, scouring and erosion may still take place. Protection from and control of erosion are accomplished by using reduced channel gradient, structures at abrupt changes in gradient and entrances of water course branches, drop spillways, energy dissipaters, or riprap protection at key points.

The Topopah Spring (TS) portal sites (north and south) and the optional shaft collar are protected from the probable maximum flood (see Drawing No. YMP-025-1-CIVL-CI02) by their high elevations. Protection on the upper side of the site is improved by adding an earth berm to deflect any possible uncontained flood waters. Due to the extreme volume of flow by a probable maximum precipitation, culverts and roadways do not back water more than a 6-foot depth to prevent flash flooding caused by retention failure.

The TS north and TS south portals and the optional shaft collar are protected from the probable maximum flood as defined in the U.S. Bureau of Reclamation Probable Maximum Flood Study GR-87-8. The 100, 50, 25, and 10-year floods are as defined in the current edition of the Clark County Regional Flood Control District, Hydrologic Criteria and Drainage Design Manual. All roads, parking areas, and related improvements shall be protected from the effects of a 25-year flood. All auxiliary sites shall be designed to handle potential runoff of a 100-year storm. The batch plant, lower storage sites, and borehole sites shall be protected from a 10-year event. The booster pump site and the compressor site shall be protected from a 50-year event. A site-specific USBR flood study is currently being conducted.

6.3 SURFACE FACILITIES

6.3.1 VENTILATION SYSTEM

The surface-based ventilation system will supply and exhaust adequate quantities of acceptable quality air to and from underground working areas, to provide personnel safety, health, and productivity in accordance with applicable federal and state regulations in support of the various phases of ESF construction, operation, and test characterization. System details are given in Section 3.3.1 of this report.

6.3.2 SURFACE BUILDINGS

Space requirements for surface buildings are based on staffing requirements projected by the participants. Their space and staffing projections are the basis of design for individual buildings. Space around the buildings is determined by the operational requirements of each facility to allow sufficient space for access to mechanical equipment, materials delivery and storage, limited vehicle parking, and pedestrian circulation.

For maximum efficiency and flexibility during the expected 15-year life of the ESF, a single pre-engineered steel building, located on the TS north portal site, has been designed to provide all the office and laboratory space required except that an office trailer (if required) will be located at the optional shaft collar site. Activities requiring special or unique features such as computer facilities, high ceilings, or heavy equipment repair are housed in other pre-engineered steel buildings, or in engineered steel or concrete block buildings. See Section 3.3 for building design details, including provisions for HVAC, plumbing, lighting, communications, and fire protection systems.

The architectural/structural criteria for all surface buildings are based on the Uniform Building Code requirements and minimum design loads for buildings and other structures, ASCE Std. 7-88.

6.4 ESF ACCESSES

6.4.1 TS NORTH RAMP

The TS north ramp (see Drawings No. YMP-025-2-MING-MI08 and YMP-025-2-MING-MI09) has a selected diameter of 25 feet, a size that permits efficient construction and drilling of test-related horizontal holes. The excavation method selected for ramp construction is the tunnel boring machine (TBM), based upon program requirements to use the latest industrially accepted methods, and also on the perception that the rock characteristics at the Yucca Mountain site are well suited to mechanical excavation techniques. The requirements of 10 CFR 60 have been interpreted to mean that the effects of excavation on the rock mass should be minimized, which influenced the decision to select mechanical excavation wherever possible. Mechanical excavation tends to create significantly less shock-related damage than drill-and-blast or other excavation methods, thereby minimizing any detrimental effects on porosity or permeability of the rock mass.

The TS north ramp involves a reinforced concrete structure only in the TS portal area near the surface. The remainder of the ramp is unlined, but is supported according to a predetermined support plan. This plan deals with each proposed rock type, and analyzes the opening relative to the rock strength characteristics in that particular stratigraphic section. In all areas some degree of rockbolting will be required as a minimum. As ground conditions change, the support methods will change accordingly. Additional support needed could include wire mesh, shotcrete, steel sets, concrete, or a suitable combination of methods. The extent of support will be determined by field inspection as the excavation process continues. Ample time will be allotted in the excavation cycle to accomplish this task. Rockbolts will be installed immediately after the TBM has opened new ground, and additional support will be installed as space becomes available behind the machine.

6.4.1.1 Ramp Sizing

Ramp sizing studies have been conducted to satisfy the requirements identified in the ESFDR. The 25-foot diameter ramp has been determined the appropriate size to meet the requirements of ventilation, flexibility, testing conditions, schedule, logistics, hardware, and practicality of the excavation process; and, as capable of repository incorporation at some future time if necessary. The final size will be confirmed during Title II design.

6.4.1.2 Design Loads

To evaluate the stresses for the TS north ramp, three major sources of loading are considered: ground pressure (geostatic load), seismic loads, and induced thermal loads.

Rock properties at the Yucca Mountain site indicate that the tuff can be treated as an elastic medium. Therefore, in the rock mass surrounding the opening, the loads resulting from the modification of the virgin stress field are determined using principles of the theory of elasticity. It should be noted, however, that the initial stresses concentrated around an excavation may undergo redistribution in time as a result of various phenomena occurring at interfaces between discontinuities and differences in properties of rock materials involved.

A seismic load, whether associated with an earthquake or an underground nuclear explosion (UNE), generates elastic waves that propagate outward from the source. The elastic waves from such a seismic event induce transient stresses and strains in a rock mass and hence in any embedded structure, such as a ramp.

Thermal loads are the result of thermal expansion of the rock as it is heated, either by artificial means associated with site characterization testing or by natural environmental conditions. It should be noted that the thermal loads are important in the full scale of future operations. Loads resulting from thermal effects are discussed in more detail in Section 6.5.2.3.

Pillar analysis is also used in design load evaluation. See Section 6.5.2.3 for details.

6.4.1.3 Ground Support

To determine ground support requirements for the ESF, a modified rock mass classification, based primarily on empirical rock mass classification and support selection guides, is being developed. Analytical methods (use of numerical codes) provide a check on empirical results and assist in providing information where empirical methods fall short. This information includes predicted stresses and stress states around openings induced by excavation, and stress changes resulting from thermal loads and seismic effects.

In particular, the Norwegian Geotechnical Institute (NGI) Tunnel Quality Index (Barton et al., 1974) and the South African Council for Scientific and Industrial Research Classification System (CSIR) (Bieniawski, 1974) are applied to obtain the rock mass characteristics of the emplacement horizon (Langkopf and Gnirk, 1986).

After emplacement, the thermally-induced loads are expected to be several times greater than the overburden loads; therefore, it is necessary to use thermomechanical models (see Section 6.5.2.3) to estimate the forces applied to the underground excavations. In this regard, advantage is taken of the various analyses performed to date in which thermal effects were investigated (see Appendix 5.7) to provide the ground support system necessary to accommodate these thermal effects.

Depending on the rock conditions encountered at various depths, a range of primary ground support techniques, including rockbolts of suitable lengths in combination with wire mesh and shotcrete, if necessary, is considered. The TS north ramp is used for in situ measurements associated with site characterization. The design of the ground support encompasses provisions for testing activities, including (1) the safety of personnel involved both in excavation and research activities; and (2) minimum interference with testing.

6.4.1.4 Transportation Methods and Provisions

Transportation in the TS north ramp is determined by functional requirements of the material being moved. Material is classified by personnel movement, equipment movement, movement of supplies, and transportation of broken rock. Systems for each classification work in conjunction with other systems to establish a balance.

Personnel, equipment, and supplies are transported in the ramp by means of diesel-powered, rubber-tired vehicles. The vehicles run on a roadway established with selected fill of crushed rock excavated by the TBM. The fill is well compacted and the roadway top finished to create a solid, dust-free road surface.

The TS north ramp is sufficiently wide to allow most vehicles to pass. Occasional passing areas are provided for large vehicles and equipment being transported underground.

Personnel are transported at shift change by diesel-powered "mantrip" vehicles designed specifically for that purpose. Each vehicle will accommodate about 20 people, and will minimize the time necessary for transfer to the work area.

Excavated rock removal is handled by conveyors installed as a semipermanent utility in the ramp. Initially the conveyor is installed behind the TBM as excavation progresses, and extended as development expands throughout the subsurface areas. These conveyors are installed as a main rock removal system only in the TS north ramp and the TS main drift running north and south. Lateral drifts may be serviced by temporary development conveyors which feed onto the main system in the TS main drift and north ramp. The conveyor is located off-side below the spring line of the ramp for easy maintenance. The conveyor is elevated overhead at the TS north portal entrance and at the TS main drift to allow vehicles freedom of passage in the roadway. Various transfer points for the conveyor exist at major intersections such as the Calico Hills (CH) north ramp and the entrance to the lateral drifts on each level. All transfer points are enclosed, and are fitted with a dust control system.

6.4.1.5 Tunnel Boring Machine Excavation

Details of the TBM method of excavation are given in Section 3.5.1.5 of this report.

6.4.2 TS SOUTH RAMP

The basic configuration of the TS south ramp (see Drawings No. YMP-025-2-MING-MI10 and YMP-025-2-MING-MI11) is similar to that of the TS north ramp as described in Section 6.4.1. Features peculiar to the TS south ramp are identified. One difference lies in the presence of a reinforced concrete airlock structure at the TS south portal near the surface.

6.4.2.1 Ramp Sizing

The ramp sizing study cited in Section 6.4.1.1 for the TS north ramp also applies to the TS south ramp.

6.4.2.2 Design Loads

The description of the design load sources (ground pressure or geostatic load, seismic loads, and induced thermal loads) in Section 6.4.1.2 for the TS north ramp also applies to the TS south ramp.

6.4.2.3 Ground Support

Determination of ground support requirements for the TS south ramp will be accomplished as described in Section 6.4.1.3 for the TS north ramp.

6.4.2.4 Transportation Methods and Provisions

Transportation methods and provisions for the TS south ramp are identical to those described in Section 6.4.1.4 for the TS north ramp.

6.4.2.5 Tunnel Boring Machine Excavation

TBM operations applicable to the TS south ramp are identical to those described for the TS north ramp in Section 6.4.1.5, which referenced Section 3.5.1.5.

6.4.3 OPTIONAL SHAFT

The optional shaft's recommended finished cross-section is 16 feet in diameter. Without liner, the excavated 18-foot diameter of the shaft permits efficient construction and drilling of test-related horizontal holes. A mechanical excavation method has been selected for shaft construction based upon program requirements to use industry-proven methods to minimize rock damage. The requirements of 10 CFR 60 have been interpreted to mean that the effects of excavation on the rock mass should be minimized. This influenced the decision to select a mechanical excavation technique. This method is intended to reduce overbreak, original crack dilation, new crack creation, and vibrations that could damage the wall rock.

The optional shaft ground support and liner design consider the various loads and construction-related requirements. The shaft collar and liner are designed on a competent rock foundation, allowing for thermal and seismic stresses and using authorized design input. Peak particle velocities generated by the collar excavation blasting are also considered.

During construction the separation of the liner bottom from the excavation bottom varies from 20 to 40 feet. This area of excavated rock wall may require temporary support to prevent loosened rock fragments from falling and injuring persons working at the shaft bottom. The method of support (short rockbolts and wire mesh) is selected because protection is required only from falling rock and because the rock is not stressed to a degree requiring structural support to prevent excavation collapse prior to placement of the concrete liner.

The thickness of the liner takes into consideration the stresses to which it is subjected and the methods available for concrete placement, embedment item clearances, and other working spaces indicated by testing needs. Resulting liner thickness is a nominal 12 inches.

If it is decided to incorporate the optional shaft into a potential repository, liner removability must be considered in that enlargement of the shaft would be required. The currently planned concrete liner would be difficult to remove. If an alternative method of rock support were used; e.g., fiberglass rockbolts, wire mesh, and shotcrete, removability would be much easier and shaft enlargement facilitated.

6.4.3.1 Shaft Sizing

Construction, ventilation, handling of materials and equipment, personnel hoisting capabilities, and site characterization test support were considered in sizing the optional shaft. Based upon the requirements, the results indicate that a finished shaft diameter of 16 feet satisfies all the considerations.

Adequacy of the 16-foot finished diameter size is confirmed in the following analyses (see Section 6.4.3.3), which were performed to determine the effects of predicted geostatic and seismic loads on the shaft. Preliminary results show that a 12-inch thick liner of unreinforced 5,000-psi strength concrete would be adequate for support. Because it is considered that the liner need not be watertight, and that it functions mainly to enhance ventilation qualities, prevent spalling of the rock wall, and support the shaft furnishings, the liner need consist only of the single 12-inch thickness. At a finished inside shaft diameter of 16 feet, the minimum total excavated diameter is 18 feet to allow for liner thickness.

Shaft station cross-sections at the Topopah Spring (TS) level meet the requirements of test configuration and configuration sizes necessary to accommodate shaft and station furnishings. Stability of the shaft brow is ensured by sizing the station in a manner that can be efficiently supported and satisfy the necessary testing program goals.

6.4.3.2 Design Loads

The three major sources of design load considered for the TS north ramp and TS south ramp (see Sections 6.4.1.2 and 6.4.2.2)--ground pressure (geostatic load), seismic loads, and induced thermal loads--were also used to evaluate the liner stresses for the optional shaft.

6.4.3.3 Analyses

Radial and shear tractions develop on the outer surface of a liner as it offers passive resistance to distortions of the surrounding rock mass. Tractions resulting from this interaction between the liner and the rock mass are often used as loads in liner calculations. However, they differ from classic engineering loads in that their magnitude depends on the liner-to-rock stiffness ratio. In the methodology used to calculate liner thickness, the free-field stresses, strains, and displacements are collectively termed loads.

The term free-field refers to effects in the ground that occur if the shaft opening is not present. By defining loads in this manner, they can be calculated independently without specifying opening shape, liner thickness and properties, and phenomena occurring at the interface of the liner and the rock.

Although numerous technical articles have been written about determining ground pressures on shaft and tunnel liners, there is no universally accepted method for calculating this component of liner load.

Design analyses of the shaft liner involve several steps. The first step includes calculations of the stresses and strains (or displacements) of the rock mass surrounding the liner. Two zones around the shaft are considered: the nonlinear (relaxed/plastic) zone adjacent to the opening, and the elastic zone extending further away from the shaft into the rock mass. Evaluation of the extent of the plastic zone is based on material properties assigned to the rock within this zone.

Material parameters for the nonelastic zone are derived by derating the Reference Information Base (RIB) data provided for an undisturbed rock mass at the horizon of interest, using a predetermined derating factor value. (See Appendix 5.4.)

Based on geostatic load calculations only, a derating factor value equal to 17.3 (Gleser, 1988) is required to generate rock failure at the depth corresponding to the TS level at 1,270 feet and rock mass properties given in the RIB for the Topopah Spring Member (TSw2). The recommended percentage of such calculated radial displacements of the rock face corresponding to the associated rock strength derating factors is used as an input (free-field load) to calculate stresses within the concrete liner. In general, liner stresses due to geostatic stresses are calculated according to the procedure used by Hustrulid (1984b).

Unlike surface structures such as buildings that tend to move and deform independently when excited by earthquake-induced ground motions, shaft liners move and distort compatibly with the ground in which they are embedded. Hence, static analysis is appropriate. Preliminary analyses involving calculation of seismic loads induced in the liner by earthquakes or UNEs are performed according to recommendations provided in the Report by the Exploratory Shaft Seismic Design Basis Working Group (1988). The results (Mrugala 1988a; Gleser, 1988) indicate that generally, liner stresses generated by seismic loads are higher than the loads induced by ground pressure. Combined effects of geostatic and seismic stresses are evaluated using the principle of linear superposition.

Because the optional shaft is designed for use during the operational phase, the load induced as a result of thermal expansion of the rock as it is heated is an important component of the total load on the shaft liner. Due to the complexities of the emplacement geometry relative to the shaft location, computer modeling is used to assess the induced thermal loads. Preliminary efforts in this field have been completed by Sandia National Laboratories (St. John, 1987). The general procedure for solution of the problem comprises the following four steps: (1) determination of the appropriate type of analysis; (2) preparation of the input data; (3) establishing boundary and initial conditions and model development; and (4) computation of temperature distribution and thermally-induced stresses (strains) at the shaft location.

An example of the analysis performed to investigate the long-term thermal effects resulting from emplacement is presented in Appendix 5.8. Synopses of various studies performed to assess the stability of underground excavations at Yucca Mountain are provided in Appendix 5.7.

6.4.3.4 Ground Support

Preliminary analysis to date (e.g., Hustrulid, 1984) indicates that a liner thickness of 12 inches of 5,000-psi concrete is adequate for the optional shaft. Installation of the final liner may be preceded by installation of the primary ground support.

Additional considerations related to ground support of the optional shaft are similar to those detailed in Section 6.4.1.3 for the TS north ramp.

6.4.3.5 Shaft Hoisting System

The shaft hoisting system provides safe and controlled access for personnel to the TS level. The primary function of the hoist system is to service site characterization in-shaft testing. The system is not intended for hoisting TS level development rock, nor for primary underground operations support.

The hoist to be used will be selected during Title II design.

The headframe is designed to accommodate all the operational phase requirements. The height of the headframe is determined by the arrangement of operational phase equipment. The headframe is a rigid space frame structure with backlegs and vertical columns located symmetrically to the shaft centerline.

The conveyance is a double-decked man cage sized to provide adequate capacity to transport personnel between the surface and subsurface levels. In addition, the cage is capable of evacuating all underground personnel to safety within one hour in the event of an emergency.

The design loads for the headframe must satisfy the requirements of the operations phase. The design loads acting on the headframe are dead load, floor live load, equipment live load, rope breaking load, wind load, and seismic load. In designing the overall headframe structure and its individual structural members, all the loads cited above are considered in whatever combination most unfavorably affects the headframe.

6.4.3.6 Sinking Arrangement

The design of the optional shaft sinking equipment, methods, and configurations will be based upon a shaft inside diameter of 16 feet, the expected conditions as expressed in the RIB, the planned activity that occurs in the shaft as described in the ESFDR, and other concerns created by proposed activity during the shaft construction period. The optional shaft dimensions are as follows:

Finished diameter	-	16 feet
Excavation diameter	-	18 feet (minimum)
Attitude	-	Vertical
Ground Support	-	Unreinforced concrete liner

A mechanical excavation method is anticipated for use in optional shaft sinking. The definitive construction and operating methods will be adopted during Title II design.

6.5 UNDERGROUND EXCAVATIONS

Underground excavations planned at the ESF include the TS north ramp, the TS south ramp, the TS main drift, the north and south TS/CH ramp intersections, the main test area off the TS north ramp, three exploratory drifts on the TS level, the CH north and CH south ramps, the CH main drift, and four exploratory drifts on the CH level. An optional shaft is also under consideration. Additionally, alcoves and stations will be excavated in the ramps and main drifts to accommodate a wide variety of site characterization tests and experiments. These test areas were developed as necessary to meet various requirements pertaining to the mission of the ESF. As the design matures through Title II, more detailed performance evaluations will be conducted, and a feedback established to assure that alternatives to such excavations are adequately addressed.

6.5.1 DEVELOPMENT AND EXCAVATION PLAN

Each ESF construction center is designed both to the individual requirements of the area and as part of an overall system. The "Plan for the Phased Approach to ESF Design Development and Implementation," YMP/91-13, describes the conduct of ESF design, construction, and test activities. This approach allows the program to consider newly obtained information, which may alter current designs, construction, or testing strategy.

The two TS ramps (north and south) are excavated by mechanical means (TBM) to minimize the alteration of the adjacent rock mass and the attendant hydrological system. Both ramps are dedicated to the support of planned site characterization testing in the various geologic units above the emplacement horizon. Testing is scheduled on a non-interference basis with ramp excavation progress unless perched water is encountered. Excavation on both ramps commences at approximately the same time, with the TS south ramp start delayed about three months from the start of TS north ramp excavation.

As the TS north or TS south ramp excavation passes the TS/CH north ramp or TS/CH south ramp intersection, the TBM proceeds about 200 feet beyond the intersection, stops, and waits for excavation of the CH north or CH south ramp TBM intersection and assembly chamber. The chamber is excavated using controlled drilling and blasting techniques to achieve the angular turnout and specific dimensions desired. The floors and special construction of launching area walls are finished and the concrete allowed to cure as the 18-foot diameter TBM parts are transported to the assembly area. Once all major components of the TBM are in place, excavation of the TS north or TS south ramp can proceed on a non-interference basis with the Calico Hills activity. After its assembly, the 18-foot diameter TBM proceeds with excavation of the CH north or CH south ramp to the Calico Hills level and beyond. **NOTE:** During Title II, use of an 18-foot diameter TBM versus use of a 25-foot diameter TBM in combination with other types of excavators will be evaluated.

On the Topopah Spring level, the TBM proceeds with excavation of the TS main drift until breakthrough is achieved in the central portion of the area of interest. Breakthrough occurs when meeting the TBM excavation which progressed down the TS south ramp similar to that in the north. As the TS north ramp TBM passes the entrance location to the main test area and reaches the imbricate fault zone, a side cutout is made to the east and a conveyor transfer point established. Excavation of the main test area and the TS imbricate drift proceeds at a normal pace using mechanical excavation wherever possible, and controlled drilling and blasting where necessary for construction of special room and spatial configurations. The purpose of continuing this excavation as soon as practical is to achieve early start of testing on a reasonable schedule, and to be ready to commence this testing when a second means of egress is established. Preparation for much of this testing takes considerable excavation effort and specialized attention to installation of instrumentation and data collection equipment.

Excavation of the CH north or CH south ramp to the Calico Hills level is a priority in the schedule and plan. All other excavation can take place simultaneously, but on a non-interference basis with Calico Hills work. The 18-foot diameter TBM proceeds with CH ramp excavation, then beyond in the CH main drift running the length of the area underlying the outline of the area of interest. Exploratory drifting is done as the TBM passes the points of intersection; roadheader machines are used to excavate those side drifts. (Rock strength on the Calico Hills level is considerably less than that on the Topopah Spring level; therefore, roadheaders are a reasonable choice for side drift excavation, although excavation equipment choices will be detail evaluated during Title II design.) Rock from these drifts is handled by temporary conveyor systems which feed into the main system in the TS main drift. Breakthrough to a second means of egress is established on this level by meeting a second TBM proceeding to the center of the level from the south. Size of drifting on the Calico Hills level is kept to a minimum, because the purpose of the level is to investigate site suitability, not to establish any large-scale permanent facilities.

Once breakthrough on either level (TS or CH) is achieved, a ventilation circuit is established and flow-through ventilation attained. Vent lines are removed in the main and lateral drifts where possible, and the airlock and main fans at the TS south portal are put into operation. All ventilation circuits are then tested and placed into operation along with all auxiliary fans and ventilation control devices necessary for the operational phase of the Project.

Coordination of all development sequences in the manner described allows for economical use of planned utilities. Demand is series-oriented, thereby decreasing the physical sizes of certain systems such as water supply, underground waste water removal, and ventilation. Time-phased support assures an efficient, cost-effective development scheme.

The optional shaft (if required) will be sunk by mechanical excavation methods to avoid the possible alteration of the adjacent rock mass and the hydrological system. The optional shaft is dedicated to site characterization testing.

Considerations common to the underground test areas are discussed in Section 6.5.2.

6.5.2 COMMON TEST AREA CONSIDERATIONS

These considerations include the sizing of underground openings, design load factors, stability analyses, and ground support requirements.

6.5.2.1 Sizing

Sizes of underground openings and the general configurations of the test area layouts are based on three major criteria: (1) safety of operation, which dictates the minimum opening dimensions necessary to accommodate excavation equipment used in underground test area development and worker safety; (2) needs associated with testing and site characterization; and (3) consistency with the conceptual design of future openings (MacDougall et al., 1987).

A consistent methodology for the selection of rock support that accommodates a range of rock conditions anticipated underground is based on limiting the dimensions of underground openings. The openings range from 18 feet wide by 14 feet high to 25 feet in diameter.

The size of the larger openings is equal to the full-scale openings considered for future applications. In addition, the sizes of pillars separating various testing areas are based on testing requirements and the need to protect specific structures vital to operation of the ESF (e.g., TS ramp stations).

6.5.2.2 Design Loads

In general, three types of loads are considered during underground opening stability analyses: geostatic loads, seismic loads, and thermal loads.

Rock properties provided in the RIB indicate that the Topopah Spring (TSw2) tuff can be treated as an elastic medium. Therefore, in the rock mass surrounding the opening, the loads resulting from the modification of the virgin stress field are determined using the theory of elasticity. However, the initial stresses concentrated around the excavation may, in time, undergo redistribution as a result of various phenomena occurring at interfaces between discontinuities, and differences in properties of the rock materials. To account for these phenomena, the time-dependent properties of tuff must be considered.

Seismic loads of two different origins are considered: natural seismicity (earthquakes) and the underground nuclear explosions (UNEs) conducted periodically at the NTS. Preliminary calculations for seismic-induced stresses in the TS level drifts due to a design basis earthquake have been made by Ehgartner (1988).

Thermal loads from heating the rock are evaluated using numerical modeling techniques. The results of parameter sensitivity analyses reported by Ehgartner (1987) indicate that changes in rock strength and modulus affect the thermal loads exerted upon the opening and associated safety factors of the drift more than the thermal input variables.

Pillar loads are evaluated (Mrugala, 1988b) using a standard tributary area approach, where they are assumed to be equal to the weight of a rock column extending one half the entry size on each side of the pillar and up to the surface above the pillar.

6.5.2.3 Analyses

The concern in the design of the underground openings is that they be stable and usable for exploratory activities; and for those openings that may be incorporated into a potential repository, stable and usable for the lifetime of the project, including the retrievability period.

For personnel safety, stability implies that no localized rockfall of a size sufficient to cause serious personnel injuries occurs, and no catastrophic failure of the openings that could block personnel access and egress occurs. The following analyses apply to all underground openings excavated for test purposes.

Numerical methods provide the means by which the effects of long-term, time-dependent loading conditions can be investigated. These methods have been employed extensively in recent years to study the effects of static and thermal loads on the stability of underground openings in tuff formations.

The thermal and mechanical effects of underground openings on stability are the focus of 15 reports or studies published to date on this subject (e.g., Appendices 5.7 and 5.8). These analyses have used a variety of numerical and empirical approaches: finite-element methods, boundary-element methods, and tunnel-indexing methods. Similarly, differently constituted models are used: elastic models, ubiquitous-joint models, compliant-joint models, and elastic-plastic models. Other items that vary in the analyses include sizes and shapes of openings, depths, thermal and mechanical properties, and fracture properties under in situ conditions.

In general, these analyses point to the conclusion (Ehgartner, 1987; also Appendix 5.7) that underground openings, as currently designed, are predicted to remain stable. Additional effort is needed in two areas: adaptation of the rock mass classifications to tuff conditions, and verification and validation of the codes used in numerical analysis.

Evaluation of pillar stability is generally associated with the areal extraction ratio, which provides the basis for comparisons of various underground layout concepts. The overall extraction ratio calculated for the entire ESF, assuming a constant height of 14 feet for all the openings, is compared to several local extraction ratios calculated for the various sections of the ESF (e.g., station areas and other underground sections where more test activities are to be performed). It appears that for the ESF, in its current form, the overall areal extraction ratio is equal to 27 percent, whereas the local extraction ratios range from 25 percent to 32 percent for the four areas of activity considered in these analyses.

Considering gravity loading, a consistent method for stability assessment of pillars with different dimensions is used in which five commonly-used pillar sizing formulas are employed (Mrugala, 1988b). The recommended factor of safety for each formula assesses the long-term stability of the pillar.

Results of these analyses indicate that scaling rules, which relate the laboratory-determined strength properties of tuff to the strength of the rock mass in situ, need to be established more firmly. These preliminary analyses indicate that pillars of the minimum width of 35 feet to 40 feet appear to have a safety factor sufficient to satisfy long-term stability requirements.

6.5.2.4 Ground Support

In general, ground support needs are dictated by the rock mass class encountered at the particular location. To provide a uniform approach to the selection of ground support, a rock mass classification system is used. This system is applicable to all underground openings and is capable of accommodating the range of ground conditions anticipated at the ESF.

As stated, rock mass classifications (Barton et al., 1974; Bieniawski, 1974) provide the basis by which design analyses are translated into the design. The methods were developed through an extensive study of case histories of underground openings in many types of rock, including tuff. The methods, although developed for a variety of rock types, do not in their current version incorporate the effects of heat in the ground support recommendations.

The preliminary rock mass classification system defines five ground support categories for Yucca Mountain. The categories encompass the full range of conditions reported by Langkopf and Gnirk (1986) and Johnstone et al. (1984) in studies involving empirical rock mass classifications of the Yucca Mountain tuff.

Table 6-2 describes the ESF ground support categories in general geologic terms and presents a summary of the proposed ground support measures for each category. Observations and measurements made during excavation of the ESF ascertain the required ground support at any given location in accordance with predetermined standards.

6.6 UNDERGROUND SUPPORT SYSTEMS

6.6.1 POWER DISTRIBUTION SYSTEM

The 12,470V/4,160-2,400V underground power centers (see Section 3.8.1) are the main subsurface electrical power supplies for all TS level and CH level underground electrical loads. As the excavation and mechanical requirements are determined, the horsepower, kilovolt-amp (kVA), and/or kilowatt (kW) capacity is calculated for the ventilation, waste water, lighting, testing, and Integrated Data System (IDS) loads. The total connected load is utilized in determining the demand factor loading by using the average assumed values of actual run times of all loads divided by the diversity factor of one (1.0).

Table 6-2. ESF ground support categories

Ground Class NGI* Relative Description	A Very Good	B Good	C Fair	D Poor	E Very Poor
General Ground Condition Relative to Yucca Mountain	Massive, welded tuff; little or no jointing; dry or slightly damp.	Densely welded tuff with one to three joint sets; joints are tight with no alteration.	Densely welded tuff with multiple or random joint sets; little or no joint alteration.	Heavily jointed, welded tuff; typical of conditions at transition within flow units.	Fault zone; crushed tuff in a matrix of low-strength gouge; heavy alteration and possibly minor water.
Ground Support System Recommended for Conceptual Design	Untensioned, friction-type bolts on variable spacing, as needed; typical grid spacing of 6.5 to 10 ft.	Untensioned grouted dowels on a 5- to 6.5-ft grid spacing with wire mesh or chainlink fabric on ribs and crown.	Untensioned grouted dowels on a 5- to 6.5-ft spacing with welded wire mesh and 2 to 3 in. of shotcrete.	Initial support: friction bolts on a 5-ft spacing with 2- to 3-in. fiber-reinforced shotcrete; final support: welded wire mesh, grouted dowels with 3 in. of additional shotcrete.	Light steel ribs or lattice girders placed near face; fiber-reinforced shotcrete 3 to 4 in., followed by welded wire mesh, grouted dowels, and 2 in. of shotcrete.

* Norwegian Geotechnical Institute (Barton et al., 1974).

The 1.0 diversity factor allows a safety factor to be added to the loading. A cumulative total connected load of [TBD] kVA and a cumulative maximum demand factor load of [TBD] kVA exist for the TS, CH, and optional shaft underground areas.

The underground power center transformer kVA ratings are established using the maximum demand factor loading. The underground power center configuration, illustrated on Drawing No. YMP-025-2-ELEC-EL34, has been selected based on the ESFDR criterion that redundant 15kV armored power cables be installed down each entry feeding a substation or power center. Each cable will have adequate capacity to supply all construction, operations, and testing loads for site characterization, and adequate capacity for acceptable system reliability. Double-ended or secondary selective unit substation arrangements will be used in both the TS and CH areas.

6.6.2 COMMUNICATIONS SYSTEM

The system designed for subsurface communications and subsurface-to-surface communications is a dual-function dial/page type telephone system. It combines the capability of a conventional rotary dial-operated public telephone exchange with a page-all system.

Each station in the system is connected through an interface unit to a separate line of the telephone exchange switchboard. However, up to five parallel extension stations can be connected to the same line. Permanent stations and plug-in type telephone jacks in the TS and CH areas utilize this feature. Permanent stations are installed where operations, maintenance, or testing personnel are located such as IDS, shop, and ramp stations. Where personnel may be located for performing temporary work tasks, plug-in telephone jacks are spaced no greater than 200 feet apart. A portable dial/page telephone station can be connected to the jack and removed when the need no longer exists.

Permanent stations are also installed in strategic places important for emergency use. Exact locations of the dial/page stations will be determined during Title II design, after the underground layout is finalized. The underground dial/page phone system is designed as an alternative to the page phone system, which lacks privacy and multiple conversation capabilities. Advanced features of the system include a separate line for each station so that the number of independent, simultaneous conversations is limited only by the number of stations. Any station inside the subsurface area can call any telephone outside the area as well as any other dial/page station within the area.

Automated circuits answer incoming calls and permit the calling party to page desired persons via a self-contained horn-type loudspeaker. This voice page is preceded by a distinctive tone. A calling party may page a person at the location expected without disturbing people at other stations. A dial-access, all-station paging facility is provided for use in reaching people not at their normal location. This facility also reaches those stations using the system for normal conversations. A pushbutton-controlled, all-station page capability goes into operation automatically in the event of a telephone switchboard or connecting cable failure. The stations are equipped with an indicator light emitting bright, repetitive flashes during incoming voice page and waiting-for-an-answer periods. This aids in signaling a call in noisy areas or at stations located in remote areas. The underground dial/page phone system provides the convenience of a telephone station plus additional paging facilities in dusty locations where standard telephone equipment is considered unsuitable for the environment.

All these functions take place over a single pair of wires between the station and the interface, which is connected to the telephone switchboard with a corresponding pair of wires. Connection to the surface facilities is made by separate multipair telephone cables running in different ramps, and providing 100-percent redundancy to the subsurface communications system. In addition to the underground dial/page telephone system, the audio alarm communicators of the fire detection and alarm system are utilized as emergency communications speakers for the public address system.

Alternatives for the communications systems were investigated. It was concluded that the following would meet the needs of the users: expansion of the DOE/NV telephone system; one multichannel intercom system; and expansion of the DOE/NV microwave system. It was also decided that a closed-circuit television system for access operations would improve safety, that the communications system would be served by the uninterruptible power system, and that dust-proof enclosures would be used for all subsurface communications components.

6.6.3 LIGHTING SYSTEM

As mentioned in Section 3.8.3, the general subsurface TS and CH lighting systems consist primarily of incandescent, fluorescent, and emergency lighting. Because the desired incandescent lighting illumination level in the drift and test alcove areas is 3.0 fc on a horizontal plane 30 inches above the floor level, a lamp rating of 150 watts at 120VAC is utilized. The number of fixtures used is based on the largest drift size and length.

An Illumination Engineering Society and DOE Order 6430.1A requirement to use fluorescent lighting in shop areas at a recommended illumination level of 50 fc on a horizontal plane 30 inches above the floor level requires the use of 90-watt preheat fixtures. The number of fluorescent fixtures is also based on the drift size and length.

The ESFDR (see Appendix 5.3) also requires that emergency lighting be located underground in each shop area, test area, power center, ramp station, and access drift. In case of total power loss underground, the emergency lighting unit must be capable of illuminating these areas using a battery backup system. Each fixture consists of two lamp heads, 30 watts each, with an input voltage rating of 120VAC and a 12VDC, 90-minute rated battery.

At present the total connected underground lighting load is approximately [TBD] kVA.

6.6.4 VENTILATION DISTRIBUTION SYSTEM

When airways are established connecting the TS and CH north and south ramps, a flow-through ventilation system (north ramps intake, south ramps exhaust) will be made operational. The main exhaust fan is located on the surface at the TS south portal, and is provided with a 100 percent backup unit to assure continuous ventilation during emergency or scheduled preventive maintenance. The ventilation plan development sequence is shown on Drawing No. YMP-025-2-MING-MI53.

Pending flow-through ventilation, the ventilation features for both TS and CH north and south ramps will be combination intake and exhaust air systems. Each ramp is furnished with a vent line installed close to the working face and the exhaust airway. That is, the intake air flows down each ramp into the TS and CH levels and exhausts to the surface through the metal duct. Air distribution into the underground development and test areas is controlled by a combination of fans, ducts, regulators, and doors. The subsurface openings are subjected to the negative pressure of the ventilation system, generating an optimum airflow design capacity of about 400,000 cfm.

The total air quantity supports all the phases of development and site characterization scheduled in accordance with the requirements of the ESFDR.

Monitoring of air quality and quantity and primary fans is provided to indicate normal operating status of the system. Abnormalities activate an alarm or signal so that timely corrective actions can be instituted before serious ventilation problems can occur. Fan noise is controlled by providing appropriate attenuators to limit the sound pressure level to 85 dBA or less, the American Conference of Government Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for an 8-hour exposure within [TBD] feet of the work area.

Fire doors are provided at critical stations to isolate the ramps from the TS or CH level in case of an emergency. The use of fire doors will also be a part of the underground evacuation plan, which helps assure that at least one ramp is potentially useful as a fresh air base station. The primary fan is also provided with electrical controls to effect air flow reversal, if needed.

Airborne dust is controlled to concentrations below the TLVs issued by ACGIH. Dust suppression techniques include the use of water for mechanical excavation, drilling, bolting, and handling of excavated rock. Water and approved biodegradable, nontoxic chemical additives are applied to subsurface roadways. Where the use of water and other wetting agents is not feasible or is limited, appropriate dust collectors are provided.

6.6.5 UNDERGROUND WATER DISTRIBUTION SYSTEM

The underground supply water system design features (see Drawing No. YMP-025-2-MECH-PI01) all relate to the demand requirements, which vary with the fire protection needs and types of equipment required for various phases of construction, testing, and operation. The water distribution system incorporates an approved chemical tracer injection system. By evaluating the water usage for each equipment item and applying the value to the equipment complement, a total water demand for equipment can be determined. The equipment and fire protection demands can be summarized by area, establishing component flow rates. Pipe sizing determinations can then be made utilizing these flow rates and the design velocity limits.

Reliability and safety features of the underground water supply system include distribution looping, pressure regulators, line break valves, relief valves, and water hammer dampening. The water supply system piping develops in stages as construction of the ESF progresses.

6.6.6 UNDERGROUND WASTE WATER COLLECTION SYSTEM

The underground waste water system design (see Drawing No. YMP-025-2-MECH-PI03) must incorporate both collection and transfer features. The sources of underground waste water for collection include water from construction, testing, operation, and fire protection water runoff. Another possible source of waste water is naturally occurring ground water inflow. The ground water inflow is estimated for input into the demand summaries, because actual values cannot be calculated. The underground waste water demand is estimated by summarizing the possible sources such as water for drilling and coring, working face spray, dust suppression, sprinkler system runoff, and natural inflow of ground water.

These combined flow rates result in a peak demand value used for pump selection, sump design, and pipe sizing. The pumping system consists of various types of drift or ramp bottom pump units feeding into sumps at the TS and CH levels. The selection of waste water pumps capable of handling the flow rates, head pressures, and particulates present in this water is key to establishing a working waste water system. The TS and CH sumps settle out large particulates; high-pressure pumps transfer the waste water in stages to the surface disposal facility.

Many reliability and safety features are utilized in the underground waste water collection and transfer system. The system is fully redundant in that each of the two main sump pumps is capable of transferring the full design peak flow, as is each sump waste water pipe. Vacuum relief devices are utilized for riser pipe protection, and various design methods dampen the effects of water hammer, preventing damage from sudden flow reduction.

The underground waste water system piping develops in stages as construction of the ESF progresses.

6.6.7 COMPRESSED AIR DISTRIBUTION SYSTEM

The compressed air distribution system design features are developed to meet the demand requirements for ESF construction, testing, and operation (see Drawing No. YMP-025-2-MECH-PI05). The compressed air system demand varies with the equipment complement required at various phases of development. The equipment complements are determined from a review of the current schedules for construction and testing. The equipment utilizing compressed air includes such items as pneumatic rock drills, working face sprays, blowpipes, diaphragm pumps, pneumatic test drill equipment, tuggers, air door cylinders, and pneumatic wrenches. By evaluating the compressed air usage for each equipment item and applying the values to the equipment complement, a total compressed air demand can be determined.

The compressed air demands can then be summarized by area, and pipe size determinations made. Pipe sizes are determined by utilizing the flow rates and maximum allowable velocities. The total demand value must be corrected for onsite conditions characteristic of the ESF. Corrections for altitude and leakage must be made prior to compressor selection.

Reliability and safety features of the compressed air distribution system include distribution looping, allowing partial shutdown with continued use of compressed air elsewhere; relief valves; aftercoolers to limit the compressed air temperature to safe levels; moisture separators; and air receivers. The compressed air system piping develops in stages as construction of the ESF progresses.

6.6.8 FIRE PROTECTION SYSTEMS

The fire protection system design features are developed by RSN along with provisions for the fire protection water supply, system monitoring and control, fire doors, fire dampers, and portable extinguisher units. Additionally, fire protection emergency procedures and training programs as required are scheduled for implementation during all phases of ESF activity.

Automatic sprinkler systems are provided to meet the intent of improved risk as defined by DOE Order 5480.7, Fire Protection. The higher standard of protection is interpreted to pertain to all surface structures based on the Project's high public visibility, the potential effects on production, and the low incremental cost of the added protection. Sprinkler systems are provided in all occupied surface structures. Automatic fire protection systems are also provided for the electrical switchgear buildings and the electrical substation control buildings. Underground sprinkler systems will be provided in all areas where significant quantities of combustible materials are stored, and for underground facilities.

6.6.9 ROCK HANDLING SYSTEM

Broken rock is removed from the development headings of both mechanical excavation methods and drill and blast methods. In each case, this material is picked up, moved away from the face, and transported to a conveyor loading facility for removal to the surface.

When dealing with controlled drill and blast rounds, rock may be found in small pieces to large rocks greater than one foot square. For these headings, a Load Haul Dump (LHD) unit will be used to load the material and tram it to the nearest rock handling facility. Due to maneuverability of the LHD and drilling system, this method can be used for tight corners and limited space cutouts.

Mechanical excavation methods used in long lateral drifts and in the TS main test area utilize a mobile miner excavator. This machine picks up rock at the workface and loads it onto an integral loading conveyor for discharge at the back of the machine. Under the discharge is an LHD which fills to capacity, then trams the broken rock to a conveyor loading station.

The main haulage conveyor is that conveyor installed directly behind the 25-foot diameter TBM as it progresses down-ramp and across the TS level in the TS main drift. As development progresses, rock from lateral drifting is removed to either the TS north or TS south portal.

6.6.10 SANITARY FACILITIES

The sanitary facilities design includes portable toilet unit construction, location determinations, and maintenance/operating procedures. Units conform to accepted industry practice for underground operations, and are chosen for consistency in providing a safe and healthy work environment.

6.6.11 LIFE SAFETY SYSTEMS

The required features of the life safety monitoring and warning systems incorporate the applicable codes, standards, and regulations that apply to the ESF.

6.6.12 MONITORING AND WARNING SYSTEMS

Operational monitoring and control include power monitoring, ventilation monitoring and control, conveyor monitoring, air compressor monitoring, and water system monitoring. RSN is developing design criteria for sensors and actuators.

The automatic alarm system provides flexibility to add or delete monitor and control points as required during the design and development of the monitoring and warning systems. Monitor and control points are controlled by software and can be changed as criteria become better defined or as field operations change.

The life safety monitoring and alarm system allows for the subsurface monitoring of gases, including noxious and toxic gases. Gases monitored, according to the ESFDR, are carbon monoxide, carbon dioxide, nitric oxide, nitrous oxide, hydrogen sulfide, sulfur dioxide, and oxygen. Sensor-transmitters are strategically located throughout the drifts and in both TS portals, and are cabled to the signal gathering and processing stations.

Multiplexed signals from the stations are sent to the computer in the surface central control room (CCR) for monitoring and alarm. The setpoint limits for alarm are set at the sensor-transmitters so as not to exceed the ACGIH TLV. The design includes the system of sensor-transmitters, cabling system, and the field data stations.

Environmental monitoring consists of monitoring of temperature, relative humidity, and barometric pressure. Temperature and humidity are monitored on the surface in ventilation exhaust ducts at the TS portal areas, in ramp stations at the TS level and CH level areas, at the primary booster fans, and at various locations throughout the TS and CH drifts. Barometric pressure is monitored on the surface in the intake air flow at the TS north portal and in ramp stations at the TS and CH levels. Air velocity (and mass air flow as a derivative) is monitored for the intake air of ramp stations at the TS level and CH level areas and in the exhaust ducts at the TS portal areas. All the environmental parameters cited above are monitored continuously by respective sensor-transmitters connected at the data gathering multiplexer stations and to the computer in the CCR. Other environmental conditions such as dust pollution, noise level, presence of radon daughters in air, and gamma radiation background are monitored periodically by portable hand-held sensors and meters in various locations throughout the ramps and drifts.

In all subsurface areas where required by code, the power, control, and communications cables are placed in metal cable trays with solid bottoms and solid covers to comply with NFPA-70, NEC Art. 300-22(c). All branch connections to local devices are made of rigid or flexible metal conduit.

Power, control, and lighting cable trays and IDS instrumentation cable trays run on the opposite sides of the ramps and drifts. The crossovers between cable trays are made as close to right angles as possible. The cable tray supports are trapeze type hangers attached to the back, or wall brackets. A minimum distance of [TBD] feet is provided between the bottom of the tray and the drift floor.

6.6.13 INTEGRATED DATA SYSTEM (IDS)

The IDS is designed as a separate task by RSN under the technical direction of Los Alamos National Laboratory, and is not a part of this Title I report. See Section 3.8.12 for a brief description of the IDS.

6.7 TESTING

Test constraints are requirements imposed on the ESF design that must be satisfied to ensure that the test can be located properly. Constraints impacting the underground layout can be categorized into three types: sequencing constraints; physical location constraints; and construction and operational constraints.

The zone of influence also becomes an important consideration because of the requirement to separate tests sufficiently so there is no unacceptable test-to-test interference and the requirement to limit, as much as possible, the construction influence on the dedicated testing area.

Selection of specific design features to accommodate the planned testing in the ESF is the result of work performed by the ICWG and incorporated into the ESFDR. The test plans are the result of several years of work by the ESF Test Plan Committee, and are documented in the Site Characterization Program Baseline (SCPB) and the ESFDR. Section 8.4 of the SCPB and Appendix B of the ESFDR discuss the ESF testing with respect to the facility design. A brief description of each test is provided in Section 3.9 of this report. See Section 7.5, Provision 10 CFR 60.15(c)(4), for specific requirements, related NRC concerns, discussion, and specific constraints applicable to design features and test considerations.

REFERENCES

Barton, N., R. Lien and J. Lunde, 1974, "Engineering Classification of Rock Masses for the Design of Tunnel Support," Rock Mechanics, Vol. 6, No. 4, 1974, pages 189-236. Original published as Analysis of Rock Mass Quality and Support Practice in Tunneling, Norwegian Geotechnical Institute, Report No. 54206, June 1974, 74 pages.

Bieniawski, Z. T., 1974, Geomechanics Classification of Rock Masses and its Application in Tunneling, Proc. Third International Congress on Rock Mechanics, ISRM, Denver, Vol. 11A.

Ehgartner, B. L., 1987, Sensitivity Analyses of Underground Drift Temperature, Stresses, and Safety Factors to Variation in the Rock Mass Properties of Tuff for a Nuclear Waste Repository Located at Yucca Mountain, Nevada, SAND86-1250, Sandia National Laboratories, Albuquerque, NM.

Ehgartner, B. L., 1988, Free Field Load Calculations for ESF Drifts, Manuscript dated 9/30/88, 4 pages.

Gleser, H., 1988, Design of Shaft Liner, Fenix and Scisson, FS-CA-0004.

Hustrulid, W., 1984, Preliminary Stability Analysis for the Exploratory Shaft, Contractor Report, SAND83-7069, for Sandia National Laboratories, Albuquerque, NM.

Johnstone, J. K., R. R. Peters and P. F. Gnirk, 1984, Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation, Sandia National Laboratories, Albuquerque, NM, SAND83-0372.

Langkopf, B. S., and P. F. Gnirk, 1986, Rock-Mass Classification of Candidate Repository Units at Yucca Mountain, Nye County, Nevada, SAND82-2034, Sandia National Laboratories, Albuquerque, NM, February, 1986.

MacDougall, H. R., L. W. Scully, and J. R. Tillerson (eds.), 1987. Site Characterization Plan Conceptual Design Report, SAND84-2641, Sandia National Laboratories, Albuquerque, NM.

Mrugala, M. J., 1988a, Seismic Design Analysis, Fenix and Scisson, TI-ST-0053, 98 pages.

Mrugala, M. J., 1988b, Pillar Stability Analysis, Fenix and Scisson, TI-ST-0054, 77 pages.

St. John, C. M., 1987, Thermomechanical Analysis of Underground Excavations in the Vicinity of a Nuclear Waste Isolation Panel, NNWSI Project, Contractor Report, SAND84-7208, for Sandia National Laboratories, Albuquerque, NM.

CHAPTER 7

ESF/POTENTIAL REPOSITORY INTERFACES, DESIGN CRITERIA AND REQUIREMENTS, AND NRC CONCERNS

7.1 ESF/POTENTIAL REPOSITORY INTERFACES

7.1.1 THE ROLE OF THE ESF IN SUPPORT OF A POTENTIAL REPOSITORY

The Yucca Mountain Site Characterization Plan encompasses scientific testing for the Exploratory Studies Facility and the potential repository. Based on the results of the scientific testing program, decisions will be made regarding construction of the repository.

The ESF facilities would support a potential repository in several ways: (1) the TS north and TS south ramps provide access to the underground levels; (2) the TS north and TS south ramps and the TS main drift provide the conduit for ventilation air to support waste emplacement operations; and (3) the exploratory drifts on the TS level penetrate waste emplacement areas.* If the site has been determined suitable, the NRC has licensed the construction of a

* For drawings that depict how the ESF and potential repository interface, see PB Dwgs. No. MND-A201-101 through MND-A201-105 developed by Parsons Brinckerhoff Quade & Douglas, Inc. For purposes of this report, the term "repository" shall include the Geological Repository Operations Area (GROA). Tolerances at the interfaces will be established during Title II design based on generally accepted mining practices.

repository, and all other pre-construction obligations have been met, the TS north and TS south ramps and underground drifts could represent the initial construction phase of a potential repository.

The various surface facilities described in Chapter 3 provide for worker comfort, surface and underground utilities, storage of excavated materials from underground, communications, and scientific test data collection facilities.

The underground facilities, also described in Chapter 3, provide shop facilities, drifts for scientific testing, and paths for ventilation air. The most important underground activity is conducting the scientific tests and experiments. This is true for both the Topopah Spring level and the Calico Hills level.

If Yucca Mountain is licensed by the NRC for use as a repository, the ESF shops will be used to support initial development of the repository until the permanent repository shops are commissioned. The utility systems used for the Topopah Spring level development will be used for initial repository development until the permanent repository utilities are installed. The dedicated main test area will be modified to provide space as a training area for waste emplacement, emergency, and mine rescue activities.

The ESF may also include an optional shaft. Whether the vertical shaft will be included in the ESF design will not be determined until scientific data from the ramps is available. The optional shaft would not be considered a permanent item in the proposed repository, but as a pilot shaft to be enlarged later. The 16-foot diameter presently planned is not adequate for use in a repository.

7.1.2 ESF PERMANENT ITEMS

Permanent items are items or facilities constructed or installed as part of the ESF that are converted for operational use by the repository.

The majority of the excavations between the surface and the Topopah Spring level would become permanent items in the proposed repository. These items would include the TS north and TS south ramps and all openings and drifts at the Topopah Spring level. The exception is any lateral exploratory drifts excavated undersized. All undersized drifts would need to be reworked to be made adequate for repository use, and are therefore not considered permanent items.

Permanent items would also include: ground support items used to reinforce rock and/or control the movement of rock, except for items of support which may be removed or replaced if the ESF is incorporated into the repository; and operational seals, which may be defined as any engineered structure including the material placed in an underground opening and/or the peripheral rock for the purpose of controlling the flow of water and/or gas during the life of the ESF and through the preclosure phase of the repository if the site is approved.

7.2 BACKGROUND AND SUMMARY

The remainder of Chapter 7 presents the history of NRC concerns about the ESF and the manner in which DOE addresses those concerns. This information is provided because it explains the evolution of the design, and demonstrates the advances DOE has made in response to concerns about the design. As such, rather than describing a complete and integrated design, this section describes how particular concerns are met by particular design aspects. A significant portion of this chapter is devoted to listing the NRC concerns and the Project requirements which implement a solution to the concern.

Since 1980 the staff of the U.S. Nuclear Regulatory Commission (NRC) and other parties have been interacting with the U.S. Department of Energy (DOE) on the Exploratory Studies Facility (ESF). Beginning with the NRC's Waste Confidence Proceedings (April, 1980) and continuing through the DOE's design authorization (February, 1991), the concept of an ESF evolved through the chronology of events summarized in Table 7-1.

As the ESF evolved, it became increasingly more difficult to track commitments resulting from DOE/NRC interactions and reviews. In many cases commitments and open items were overtaken by events or subsumed by new advice. Recognizing this dilemma, the NRC staff consolidated its past concerns in one document, the Site Characterization Analysis (SCA) (NRC, 1989). According to the staff's guidance, the SCA should "... be the vehicle by which the NRC staff's concerns over the past several years ... are brought together into one trackable set of open items ..." (NRC, 1988a).

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions.

DATE	EVENT	DESCRIPTION
Apr 15, 1980	Waste Confidence Rulemaking	ESF would be developed after site characterization and then only if needed
Feb 25, 1981	10 CFR Part 60 Licensing Procedures Final Rule	NRC stated that testing at depth ("at the base of a shaft at the depth of the proposed repository") is essential. Noted DOE planned an extensive facility but noted a facility consisting of two shafts and up to 1000 feet of tunnels is more practical and believes $30 million is an upper limit to the cost
Jun 1982	Conceptual Design Report ESF Phase I LA-9179-MS	Two-phase ES (suitability for test facility and for repository); assumed location (H-1) and depth; blind drilled (conventional not ruled out). Single 98-in. ID steel liner; two rooms 85 kft^3 excavated
Oct 26, 1982	Conceptual Test Plan for the NNWSI Exploratory Shaft	From the ES CDR. Single 8-ft finished diameter, conventionally mined shaft, into Calico Hills but not to water table. Lateral drill holes
Mar 31, 1983	Orange Draft SCR	Single 12-ft diameter, conventionally mined shaft; total depth 465 m; bottomed 30 m below Topopah - Calico Hills contact (80 m above water table)
Nov 27, 1983	Test Plan for Exploratory Shaft at Yucca Mountain	More detail in test program; test depth is 451 m, 23 m below TSM-CH contact, 85 m above water table
Aug 1984	NNWSI Exploratory Shaft Site and Construction Method Recommendation Report	Documented the formal Figure of Merit (FOM) studies to select the construction method (looked at drill/conventional and vertical/decline) and the location for a single shaft. Documentation needed to support the Environmental Assessment (EA)

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions (Continued).

DATE	EVENT	DESCRIPTION
Dec 1984	Recommendation for a Second Access for the Yucca Mountain Exploratory Shaft Facility	DOE position on consistency between the characterization programs at the nine sites (i.e., two accesses for emergency egress) necessitated the development of a second access at the Yucca Mountain site. The report recommended a ramp; DOE concluded that as the sites would be compared in the selection process, the configurations needed to be consistent
Dec 1984	Draft Environmental Assessment	12-ft diameter, conventionally mined shaft to Calico Hills; second shaft 6-ft diameter raise bored for emergency egress. Location of second shaft not firm
Jun 1985	Mission Plan	ESF at each site would be two exploratory shafts; DOE intends to use the ES's in the repository (cost effective). NRC commented on the draft on the size of the shafts; DOE answered that they were in compliance with the applicable regulations
Aug 1985	NNWSI Exploratory Shaft Test Plan	Details on duration of tests
May 1986	Environmental Assessment	Secondary egress shaft location established and diameter noted as 5.9 ft
Jul 30, 1986	10 CFR Part 60 Final Rule Amendments to Licensing Procedures	Amended to reflect the NWPA. DOE to defer shaft sinking until it has solicited and considered pertinent comments on the ESF; noted that 60.21(c)(1)(ii)(D) provisions must be addressed prior to sinking
Dec 22, 1986	NRC Comments on EA	No exploratory shaft-related comments provided
Jan 1987	Draft Mission Plan Amendment	Noted that DOE was planning to increase the second shaft diameter and the extent of horizontal drifting

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions (Continued).

DATE	EVENT	DESCRIPTION
Apr 14, 1987	DOE-NRC Meeting on Proposed Changes to the ESF	In answer to NRC and state concerns, DOE proposed to relocate the shafts above floodplains, raise the MTL to 1020 ft, construct 5600 ft of drifting to explore faults, add 2500 ft of drifts to the MTL, and increase second shaft diameter to 12 ft. NRC concurred or supported the proposed changes; requested additional performance analyses. (Meeting summary dated 5/29/87)
Jun 1987	Mission Plan Amendment	Reaffirmed that ESF would be part of the GROA and noted that the ES's would be two 12-ft diameter, conventionally mined shafts
Jan 1988	Consultation Draft SCP	The second exploratory access would be a 12-ft diameter, conventionally mined shaft. The characterization plans stated that details of the Calico Hills test program would be developed following a decision about the appropriate degree of allowable penetration. Section 8.4, however, indicated plans to penetrate the Calico Hills
May 11, 1988	NRC Point Papers on CD SCP	Three Objections related to the Exploratory Shaft Facility design. 1. CDSCP does not contain sufficient information to allow evaluation of interference between investigations or operations. 2. The CDSCP does not adequately address the impacts from erosion and flooding at the proposed locations. 3. The proposed Calico Hills penetration may have negative impacts and the DOE has not evaluated this
Jun 1988	Draft Mission Plan Amendment	Neither shaft penetrates the Calico Hills
Jul 18, 1988	DOE-NRC Meeting on ESF Issues	DOE explained how the Design Process considers and implements 10 CFR 60 Requirements and responded to ESF Objections

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions (Continued).

DATE	EVENT	DESCRIPTION
Oct 19, 1988	DOE-NRC Meeting on ESF Open Items	DOE presented information that described how ESF Objections were being addressed in the SCP
Nov 3, 1988	Meeting w/NRC on Design Control	NRC presents 8-step approach to demonstrate adequacy of design control approach
Nov 23, 1988	Meeting w/NRC on DAA	NRC recommends DOE define major features and consider alternatives
Dec 8, 1988	Meeting w/NRC on ESF Design	NRC recommends DOE include certain 10 CFR 60 requirements; alternatives analysis should consider all major ESF features
Dec 21, 1988	Exploratory Shaft Location Documentation Report	Historical Summary of activities related to selection of exploratory shaft locations. Prepared to respond to NRC questions; also discussed implicit treatment of performance impact considerations
Dec 21, 1988	Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report	Design report and drawings for facility as previously described, but with reserve capacity to support excavation in the Calico Hills following decision on acceptability of impacts
Dec 1988	Site Characterization Plan	Detailed description of Exploratory Shaft Facility (two 12-ft conventionally mined shafts); no Calico Hills penetration, and comprehensive evaluations of test, construction, and operational interference. Figure 1.40 indicated inferred fault that was not shown on USGS compiled structure map; NRC concluded design control was lacking

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions (Continued).

DATE	EVENT	DESCRIPTION
Jan 1989	**Selected Analyses to Evaluate the Effect of the Exploratory Shafts on Repository Performance at Yucca Mountain. SAND85-0598**	Compilation of scientific analyses to determine whether the construction of two shafts can significantly influence the long-term isolation capabilities of a high-level waste repository at Yucca Mountain
Feb 3, 1989	**Design Acceptability Analysis Report (YMP/89-3)**	Addressed NRC concerns in the Design Control process used to develop the Title I Design by developing a set of requirements that explicitly addressed isolation impacts, and evaluated alternative Exploratory Shaft Facility locations with respect to waste isolation potential
Apr 11, 1989	DOE-NWTRB Meeting on ESF	NWTRB SUGGESTIONS: 1. DATA QUALITY Consider the use of mechanical mining methods (raise bore or v-mole) alone, or sequenced with conventional mining methods to improve data quality by limiting the amount of rock fracturing and drill fluid and blast gas intrusion during exploratory shaft mining. 2. SCHEDULE Consider the use of mechanical mining methods and deferral or relocation of non-critical in-line ESF tests to expedite exploratory shaft construction. 3. REPRESENTATIVENESS Consider exploratory drifts to the south to intersect Ghost Dance fault, at additional locations, to obtain additional information for characterizing the fault; and consider additional exploratory drifting to the west across proposed repository block, to identify and characterize significant north-south trending faults which may exist in this area
Jul 1989	**Evaluation of Additional Drifting for Site Characterization at Yucca Mountain**	**Report prepared by Weston to address NWTRB recommendations**

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions (Continued).

DATE	EVENT	DESCRIPTION
Aug 1989	Site Characterization Analysis NUREG-1347 (SCA)	NRC Objection on ESF: Incompatibility of some tests with construction operations; longer test durations necessary, may affect sequencing; space likely to be inadequate. Recommended: Use acceptable QA process; number/location of shafts should reduce uncertainty; investigate PAC in vicinity of shafts; present bases for test durations; layout should account for uncertainties
Aug 1989	Alternative Strategies to ESF Design	Identify major problems in the ESF design/design process that need resolution for: a) complete compliance with Subpart G; b) improving the design with respect to site characterization, safety; c) interface with early surface-based program start
Aug 1989	Evaluation of Alternative ESF Shaft Construction Methods and Test Sequences for Yucca Mountain Project Office	Report prepared by Golder Associates to address NWTRB recommendations
Sep 1989	Management Assessment of Alternative Methods for Exploratory Shaft Construction/Testing Sequences and Additional Exploratory Drifting	Report prepared by DOE to address the recommendations of the NWTRB
Jan 1990	Structural Geology in Vicinity of proposed ESF: TAR (YMP/90-2)	Found no evidence of significant faulting in vicinity of proposed ESF location; could not rule out possibility of small fault

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions (Continued).

DATE	EVENT	DESCRIPTION
Mar 1990	NWTRB First Report to Congress	NWTRB ISSUE 1. Shaft construction disturbance: (a) by introducing water into rock from blast-hole drilling, and (b) by creating or opening existing or natural fractures. RECOMMENDATION: Maximize the use of the most modern mechanical excavation techniques in the recently initiated studies of alternative shaft and tunnel construction methods. NWTRB ISSUE 2. Exploration of the Ghost Dance fault at least twice by exploratory drifts; one farther south. RECOMMENDATION: Cross the Ghost Dance fault with an exploratory drift at more than one location. NWTRB ISSUE 3. An east-west exploratory drift to facilitate the detection of north-south trending faults and characterize a larger extent of rock away from the shafts. RECOMMENDATION: Definitively plan an additional early exploratory drift in an east-west direction across the Yucca Mountain geologic block to reduce uncertainties and increase confidence as early as possible that potentially disqualifying geologic features do or do not occur. NWTRB ISSUE 4. Inclined ramp into the east side of the Yucca Mountain block to replace one exploratory shaft, faults to be inspected at depth, intersect most of the tuff units, and allow exploratory rooms at points of interest. RECOMMENDATION: Continue studies for incorporating an exploratory ramp entering the Yucca Mountain geologic block from the east. NWTRB ISSUE 5. Geologic mapping of shafts and tunnels that have been bored should provide most reliable data. RECOMMENDATION: Develop innovative ways of coordinating and sequencing the excavation and scientific testing so that both programs can be executed in a timely manner without sacrificing the scientific validity of the testing. NWTRB

Table 7-1. Chronology of Significant ESF Development and Regulatory Interactions (Continued).

DATE	EVENT	DESCRIPTION
Mar 1990 (continued)	NWTRB First Report to Congress	ISSUE 6. Exploration of the softer tuff units that occur above and below the repository level are important in impeding downward flow of surface infiltration. RECOMMENDATION: Include in the DOE exploratory program ample penetration of the softer, less permeable tuff units by borings, shafts, ramps, or tunnels so inspection, mapping, and testing of these critical units can be conducted, both above and below the repository level
Jul 17, 1990	DTP on Regulatory Considerations in the Design and Construction of the Exploratory Shaft Facility	Two and one-half years after DOE issues the CDSCP the NRC issues draft guidance on regulatory considerations in the design and construction of the ESF
Nov 1990	DOE/NWTRB Interaction on ESF Alternatives Study	Presentation to Structural Geology and Geoengineering Panel of the NWTRB on preliminary results of the ESF Alternatives Study. Six options presented as ranked high
Dec 21, 1990	Findings of the ESF Alternatives Study, SAND90-3232	Report documenting the results of ESF Alternatives Study. Findings supported by multi-attribute decision aiding methodology; report reviewed by independent NAS and USNCTT members
Jan 29, 1991	DOE-NRC Meeting on CHRBA and ESF Alternatives	DOE presentations to NRC describing the results of the CHRBA and ESFAS
Feb 12, 1991	Direction for proceeding with ESF Design	Letter from Bartlett to Gertz providing guidance for the completion of the ESF design. Authorizes design study but places hold point for check on content of final products

With regard to the ESF, all the NRC staff's concerns (past and recent) are consolidated in SCA Objection 1 which is summarized in Section 7.3. For continuity, Section 7.3 also briefly recounts the staff's concerns (NRC, 1988b) with the Consultation Draft SCP (DOE, 1988a). Underlying the staff's concerns was the perception that in designing the ESF the DOE was not considering requirements in 10 CFR 60. Section 7.4 lists the provisions from 10 CFR 60 that were considered in the ESF design. Here, the provisions that do not discriminate one design from another are distinguished from the provisions that do discriminate. In Section 7.5 the discriminating provisions and related segments of SCA Objection 1 are quoted and cited. This section also presents the ESF design criteria that correspond to each provision and an updated response to Objection 1.

7.3 CDSCP AND SCA OBJECTIONS, QUESTIONS, AND COMMENTS RELEVANT TO ESF DESIGN

SCA Objection 1, with its related questions and comments, is complex and addresses a number of concerns ranging from quality assurance to implementation of a design control process that specifically addresses 10 CFR Part 60 requirements. Further, the complex history of evolving regulatory requirements, developing guidance, and design concepts resulted in the capture of a number of specific and detailed NRC concerns within the context of Objection 1.

In general, Objection 1 is a compendium of many concerns related to ESF design activities. The full text of Objection 1 and an updated response are provided in Section 7.5. A summary of the issues raised in the objection follows:

- Adequacy of the ESF Title I design control process.

- Integration of currently available information into the shaft location decision process.

- Consideration of applicable 10 CFR Part 60 provisions.

- Test interference relative to facility adequacy and test durations.

The bases for these issues are summarized below:

- The SCP describes an acceptable approach for assessing the potential for test-to-test and construction-to-test interference, but does not establish that the design has been appropriately implemented.

- The DAA did not consider certain concerns critical to NRC acceptance of DAA conclusions, including applicability of certain 10 CFR 60 requirements and adequacy of data.

- Some of the ESF design criteria were not sufficiently justified.

- The SCP did not clearly show that thermal tests can be conducted without interference.

- Potential impacts of long-term performance confirmation testing on ESF design have not been addressed.

- The SCP has not demonstrated that in situ waste package testing will not be needed during site characterization. If such testing is found necessary, an analysis of the impact on ESF design should be presented.

- The proposed drifting and underground exploration will not yield the data needed for repository design and licensing.

To resolve these issues, the NRC staff recommended:

- An acceptable baselined Quality Assurance (QA) process should be used during Title II design.

- The Title II design should follow an adequate design process, and the number of shafts and their locations in the final repository contribute to reduce uncertainty with respect to waste isolation.

- The DOE should evaluate existing technical data with respect to the ESF location and, if necessary, the DOE should consider additional geological and geophysical surface-based tests.

- The ESF Title II design should present the basis for the duration of selected tests.

- The ESF Title II design should provide a complete conceptual layout of the main test level and related test schedules.

- The ESF Title II design should recognize the potential need for additional underground testing areas and demonstrate sufficient flexibility to accommodate likely contingencies.

Prior to the SCA and Objection 1, the NRC staff reviewed the Consultation Draft SCP (CDSCP) (DOE, 1988a) and provided numerous objections, major questions and comments (NRC, 1988b). Those relevant to the ESF are summarized below:

- Potential impacts of the penetration of the Calico Hills unit had not been evaluated in terms of negative impacts to the isolation capability of the site (CDSCP Objection 2).

- There was inadequate conceptual design information to allow evaluation of test and construction interference (CDSCP Objection 3).

- The CDSCP did not adequately consider potentially adverse impacts "that could result from the proposed locations of the exploratory shafts -- in areas that may be subject to flooding and erosion" (CDSCP Objection 4).

Objections, comments, and concerns not resolved in the SCP or DAA were "rolled up" into Objection 1 of the SCA.

7.4 10 CFR 60 REQUIREMENTS APPLICABLE TO THE ESF

The Exploratory Studies Facility Design Requirements (ESFDR) (DOE, 1991c) is a compilation of all requirements that directly affect the Title I and II designs of the Exploratory Studies Facility (ESF). Included in the ESFDR are 10 CFR 60 requirements that must be considered in the ESF design. All of these requirements were considered in the sense that the ESF would not be designed in a manner that would later preclude the DOE's complying with 10 CFR 60. Some of the 10 CFR 60 requirements, which will be discussed later, provided a basis for numerous design criteria. Requirements considered include the following:

1. The 10 CFR 60 requirements that regulate the handling and control of radioactive material do not directly influence the ESF design because radioactive waste will not be used during ESF testing. These requirements include:

   10 CFR 60.111(a), Protection against radiation exposures and releases of radioactive material

   10 CFR 60.131, General design criteria for the geologic repository operations area (a) Radiological protection

10 CFR 60.143, Monitoring and testing waste packages

Should the DOE decide to transport radioactive waste to the ESF and test it, the above requirements plus others from 10 CFR 72, Section 113 of the NWPA, and appropriate state regulations will be added to the ESFDR.

DOE considers that 10 CFR 60.74, Tests, could affect the ESF design, therefore this requirement has been incorporated into the ESFDR. This requirement that DOE conduct (or permit NRC to conduct) certain tests (e.g., tests of HLW) has been addressed in Title I design via the features listed in Table 6-1 under 10 CFR 60.74. The approach taken in this design is to incorporate features with flexibility, such that HLW tests could be performed if DOE's position changes.

2. Similarly, the 10 CFR 60 requirements for structures, systems, and components that protect the public's radiological health and safety do not directly influence the ESF design because such structures would not be needed where there is no radioactive material. These requirements include:

   10 CFR 60.21, Content of License Application. The requirements for an assessment of alternative design features, 10 CFR 60.21(c)(1)(ii)(D), were addressed in an Exploratory Studies Facility Alternatives Study (ESFAS).

The ESFAS provided comparisons of features only as appropriate for this conceptual design stage. The process of considering alternatives will continue through Title II design. Selected key features that may be considered for change will be the subject of engineering trade-off studies during the design phase. It is expected that conventional engineering and mine design methodologies, along with performance assessment, will be used to refine or improve all features of the selected baseline option.

10 CFR 60.131, General design criteria for the geologic repository operations area. (b) Structures, systems, and components important to safety with the exception of (b)(9) Compliance with mining regulations.

10 CFR 60.133(g), Underground Facility Ventilation (ventilation when radioactive particles are present underground).

10 CFR 60.133(h), Engineered Barriers (none will be present).

While these requirements do not directly affect the design of the ESF, they will be directly addressed in the ESF/repository interface design effort. That design effort is preliminary at present, but ultimately will be responsive to requirements of the YMP Mined Geologic Disposal System (MGDS) Repository Design Requirements (RDR) document.

3. The following administrative requirements of 10 CFR 60 do not directly impact the ESF design. The intent of these administrative requirements is implemented through various existing plans and procedures (e.g., OCRWM Quality Assurance Requirements, YMPO Regulatory Compliance Plan).

10 CFR 60.4 Communications and records. (b) Retention of records.

10 CFR 60.16 Site characterization plan required (These requirements have been satisfied.)

10 CFR 60.17 Contents of the Site Characterization Plan (These requirements have been satisfied.)

10 CFR 60.24(a) Updating of application and environmental report

10 CFR 60.131(b)(9) Compliance with mining regulations

10 CFR 60.151 Quality Assurance applicability and 10 CFR 60.152

Quality Assurance Implementation (The NRC staff has accepted the DOE's overall QA program and has lifted their objection to the specific programs associated with Midway Valley Trenching and Calcite-Silica Activities (NRC, 1991). The DOE, in turn, has approved most of its participants' quality programs. The NRC staff may continue to participate in quality verification activities, as well as conduct independent surveillances or audits.)

4. The following 10 CFR 60 requirements will be evaluated as construction and testing activities proceed during Title II design.

   Although these requirements may not be addressed during ESF Title I design, other phases of the ESF design will address them. As the design matures during the Title II phase and as performance assessment results become available, designers will have more information with which to meet requirements such as the postclosure performance standards.

   The portion of design relating to ESF/repository interfaces (Section 7.1) addresses requirements related to retrievability. This portion of the design is in its preliminary (conceptual) phase.

   10 CFR 60.111(b), Retrievability of Waste

   10 CFR 60.112, Performance Objective of Geologic Repository after Permanent Closure

10 CFR 60.113(a)(1), Performance Objectives of Engineered Barrier Systems

10 CFR 60.113(a)(2), Requirements for the minimum groundwater travel time to the accessible environment

10 CFR 60.113(b),(2),(3) and (4), Factors that may persuade the Commission to specify or approve some other radionuclide release rate, containment period or groundwater travel time.

10 CFR 60.122, Siting Criteria (Requirements of 10 CFR 60.122 (c)(1), are used to constrain drainage and surface water impoundments. Requirements of 10 CFR 60.122(b)(5)) are used to justify a minimum depth of 300 meters from the ground surface.)

10 CFR 60.133(c), Retrieval of Waste

10 CFR 60.133(e)(1), Underground openings (design is to support the retrievability option).

5. Performance confirmation requirements do not directly influence the ESF design, but they do influence Performance Confirmation Plans and the Site Characterization Program Baseline (SCPB). The ESF design accommodates the plans and baseline but does not directly address the following performance confirmation requirements:

10 CFR 60.140, Performance Confirmation Program, General requirements

10 CFR 60.141, Performance Confirmation Program, Confirmation of geotechnical and design parameters

10 CFR 60.142, Performance Confirmation Program, Design Testing

As stated earlier, the Title I and Title II designs of the ESF will not preclude the DOE from complying with the above requirements. However, the requirements themselves do not dictate any particular design.

Certain 10 CFR 60 requirements provide a basis for design criteria. These requirements include:

60.15(b)	site characterization program
60.15(c)(1)-(4)	conduct of site characterization
60.72(a), (b)	construction records (These requirements do not discriminate any particular design but were included anyway.)
60.74	tests performed by the Commission

60.130	design basis must be consistent with the results of site characterization
60.122(c)(1)	constrain drainage and surface water impoundments
60.122(b)(5)	a minimum depth of 300 meters from the ground surface is required for preferred favorable conditions of a site
60.131(b)(9)	compliance with the Federal Mine Safety and Health Act of 1977
60.133(a)(1), (2)	general design criteria for the underground facility
60.133(b)	flexibility of design
60.133(d)	control of water and gas
60.133(e)(2)	underground openings
60.133(f)	rock excavation
60.133(i)	thermal loads
60.137	general requirements for performance confirmation
60.134	design seals for shafts and boreholes

10 CFR 60.137, the overall requirement to conduct a performance confirmation program, applies to the ESF. It was specifically considered by the ESFAS as a means of selecting the highest-ranked option. Table 6-1 of this report lists the design features which address that requirement.

Whenever the ESFDR addresses a topic that ultimately will be subject to NRC regulation, one or more of the above 10 CFR 60 provisions is quoted and cited. Next, a series of design criteria orients the provision to the regulated topics, such as control the use of water or avoid damaging the host rock. These design criteria tend to be more specific than related 10 CFR 60 provisions. Both the Design Acceptability Analysis (DAA) (DOE, 1989a) (as incorporated in the ESFDR) and the ESFDR consider the applicable 10 CFR 60 requirements qualitatively. In the past, the NRC staff objected to the DAA because:

> "The approach adopted in the DAA raises questions about completeness and rigor of the design acceptability analysis, as detailed design criteria were not developed for all applicable requirements." (NRC, 1989, page 4-98).

Detailed design criteria will be further refined as the design matures, as underground exploration proceeds, and as requirements are modified and verified. Prior to underground exploration, most design criteria will be qualitative but more detailed than the 10 CFR 60 requirements upon which they are based. These criteria will be developed through continued interactions among design, testing, and performance assessment personnel to evaluate each ESFDR requirement related to a specific lower-level 10 CFR 60 requirement in a manner that can be used collectively to address the higher level 10 CFR 60 requirements in the design process. This will be an ongoing iterative process (i.e., incorporate revised conceptual understanding of the site as testing and construction proceed and include sensitivity and uncertainty analyses as appropriate or necessary) that will continue throughout the Title II design process.

7.5 RESPONSES TO THE NRC OBJECTION AND IMPLEMENTATION OF 10 CFR 60

As stated in Section 7.3, SCA Objection 1 is complex and addresses concerns ranging from quality assurance to test interference. In the letter that transmitted the SCA (NRC, 1989) to the DOE, the NRC staff stated that their concerns could be resolved in parallel with completion of the final ESF Design. The DOE believes that, subject to NRC agreement, about half of these concerns are resolved by this report, the Exploratory Studies Facility Alternatives Study (ESFAS), the Design Acceptability Analysis (DAA) (DOE, 1989a), and the Calico Hills Risk/Benefit Analysis (CHRBA) (DOE, 1991b). It is DOE's intent to satisfactorily resolve the remaining portions of the Objection and related comments by the end of Title II design. Although the NRC staff prefers that DOE not start the ESF until its concerns are resolved, 10 CFR Part 60 states that the DOE may sink shafts after considering, but not necessarily resolving, the NRC Objection.

The balance of this section presents, in a matrix-like format, the strategy for resolving Objection 1. An explanation of the format follows:

Provision: ONE OF THE 10 CFR 60 PROVISIONS THAT APPLIES TO AN ESF DESIGN IS QUOTED AND CITED IN BOLD CAPITAL LETTERS.

Related NRC Concern: A segment of the NRC staff's objection that, to the extent possible, relates to the above provision is quoted and cited. In some cases several concerns relate to the same provision.

Response: These responses to the NRC concern are more specific and current than those given in "Responses to the Nuclear Regulatory Commission (NRC) Site Characterization Analysis (YMPO/90-107)" (DOE, 1990a).

Closure Date and Mechanism: On this date, the NRC concern has been or will be resolved. The closure mechanism constitutes a document or an endeavor that closes the concern.

Implementation: The above 10 CFR 60 provision will be implemented by the listed design criteria. The criteria were taken nearly verbatim from the ESFDR and will be used throughout the Title I and Title II phases of the ESF design. ESFDR citations follow each design criterion. The ESFDR also repeats verbatim the applicable 10 CFR 60 provision in each applicable subsystem chapter. However, for the sake of brevity these repetitious provisions are not included in Section 7.5. As noted in Section 7.4 Item 4, the list of applicable requirements, and their implementing requirements, may change as performance assessment results become available throughout design.

The Yucca Mountain Site Characterization Project has identified the 10 CFR 60 and attendant ESFDR requirements which may require specific performance assessment (PA) support. Specific types of PA have been defined and assigned to each of the identified requirements. PA is an iterative process which incorporates design enhancements as the design of the ESF matures. It is expected that the analyses conducted in support of the design will impact the design and result in changes in ESFDR performance criteria.

The PA logic is based on the flowdown of requirements from 10 CFR 60 through the ESFDR to a set of performance-based analyses. The results of these analyses will be used to provide performance assessment input into the design and to demonstrate that the design complies with the requirements. The flowdown logic also provides the ability to track each analysis and clearly identify the requirements to which it applies.

Provision:

UNLESS THE COMMISSION DETERMINES WITH RESPECT TO THE SITE DESCRIBED IN THE APPLICATION THAT IT IS NOT NECESSARY, SITE CHARACTERIZATION SHALL INCLUDE A PROGRAM OF IN SITU EXPLORATION AND TESTING AT THE DEPTHS THAT WASTES WOULD BE EMPLACED (10 CFR 60.15(b)).

Related NRC Concerns: (Objection 1, second bullet, item e; also comment 131)

"The Design Acceptability Analysis (DAA) undertaken by DOE in response to NRC concerns for evaluating the acceptability of the ESF Title I design did not consider certain concerns critical to NRC acceptance of DAA conclusions.

DAA did not thoroughly check the adequacy of data used in the ESF Title I design. For example, several key documents which were part of ESF Title I design were not reviewed."

Response:

A study was performed (SAIC, 1991) to evaluate the favorable features of the highest-ranked options identified in the ESF Alternatives Study (SNL, 1991). Based on the results of this study, the A/E was directed by DOE (DOE, 1991f) to incorporate the recommended favorable features into its Title I design study to enhance construction and performance of the underground test facility. The Title I design study will use DOE-controlled requirements documents to develop a preliminary (reference) design that is consistent with the controlled site characterization testing program. The Title I design study will form the basis for a revised Title I design.

The DOE has already responded to the NRC concern that the DAA did not thoroughly check the adequacy of the data (see SCA Comment Response Package) (DOE, 1990a). A summary of that response follows.

Design basis documents are being established for the Title II design, which will identify design input sources and intended applications. These documents should provide a complete set of appropriate data, including average values, expected ranges, and values selected for specific purposes. It is a design responsibility to evaluate, select, and justify the appropriateness of design inputs for specific uses. These data will be obtained from various sources, including the Reference Information Base (RIB) (DOE, 1991e), the Site Engineering Properties Data Base (SEPDB), and other appropriate sources.

Data values submitted to the RIB and the SEPDB are subjected to review for adequacy, per the appropriate Yucca Mountain Site Characterization Project (YMP) procedures. This will ensure that future applications of these data in design are using adequate or reasonable values.

. . RIB and SEPDB are potential sources of design inputs, but should not be viewed as compilations of design data. For all YMP activities, those involved in design and analysis may use any source of input that can be adequately justified. The selection of design inputs will be appropriately documented and reviewed.

Closure Date and Mechanism: N/A; this is a continuous process that is controlled by Administrative Procedures AP-5.1Q and AP-5.2Q and by quality assurance audits.

Related NRC Concern: (Objection 1, fifth bullet; see also Comments 121 and 124, Questions 27 and 24)

"Some of the ESF design criteria are not sufficiently justified. These include:

(a) Seismic design basis;

(b) ES-1 drainage volume and long-term drainage reliability; and

(c) effect of liner removal at closure."

Response:

Design criteria are justified by the requirements (e.g., 10 CFR Part 60) from which they originate. In the cases of items b and c, the significantly new ESF configuration will be designed to different criteria that will be developed during Title II design. Detailed criteria will not be developed until the time of underground testing.

Generally, the process of developing and justifying numerical design criteria involves submission of these values to the RIB. Acceptance of values into the RIB is a technically reviewed and documented process. This documentation would be available for examination.

Closure Date and Mechanism: 5/91, Exploratory Studies Facility Design Requirements (ESFDR) (DOE, 1991c)

Implementation:

1. Ramp or shaft design and construction shall provide access for site characterization activities to be performed at the planned waste emplacement horizon. 1264, PC 1a (i); 1265, PC 1a (i)

2. For planning purposes, the breakout for the main test area shall be at an elevation identified in the RIB. 1264, PC 1a (ii); 1265, PC 1a (ii)

3. Selection of the horizon for the main test area shall be based on evaluation of stratigraphic information sources available during construction (e.g., from the geologic mapping of the ramp, and a probe hole drilled ahead of the ramp face in portions of the ramp) with respect to explicit horizon criteria. 1264, PC 1a (iii); 1265, PC 1a (iii)

4. The flexibility to construct the shaft, and/or drift, into the Calico Hills formation shall be maintained without adversely affecting other testing that may be ongoing. Such flexibility shall consider aspects of hoisting capacity, underground utilities, ground support, and excavated materials handling. 1264, PC 1a (iv)

5. Develop underground openings in welded high lithophysal/low lithophysal tuff for in situ site characterization construction, operations, and maintenance. 1266, PC 1a (i)

6. The ESF main test area shall be constructed at the planned repository horizon, which currently is the TSw2 rock unit, although TSw1 can be considered. 1266, PC 1a (ii)

7. The proposed main test area floor shall be within the Topopah Spring Member of the Paintbrush Tuff. 1266, PC 1a (iii)

8. The underground design shall not preclude the ability to access the Calico Hills formation. 1266, PC 1a (iv)

Provision:

INVESTIGATIONS TO OBTAIN THE REQUIRED INFORMATION SHALL BE CONDUCTED IN SUCH A MANNER AS TO LIMIT ADVERSE EFFECTS ON THE LONG-TERM PERFORMANCE OF THE GEOLOGIC REPOSITORY TO THE EXTENT PRACTICAL (10 CFR 60.15(c)(1)).

Related NRC Concern: (CDSCP Objection 2)

"... the proposed shaft (ES-1) penetration into the Calico Hills unit and the proposed horizontal drifting through it may have significant negative impacts on the waste isolation capability of the site. The Calico Hills unit is an important barrier between the repository horizon level and the groundwater table, and DOE has not evaluated whether the activities proposed may irreparably damage its ability to function as a barrier." (NRC, 1988b)

Response:

A risk/benefit analysis of testing within the Calico Hills unit has been completed (DOE, 1991b). Conceived to address the NRC objection to penetrating the Calico Hills (CDSCP Objection 2), this analysis presents cumulative distribution functions for cumulative 10,000-year aqueous releases to the accessible environment. These functions indicate that aqueous releases will likely be well within the U.S. Environmental Protection Agency standards, regardless of whether the ESF penetrates the Calico Hills unit. The risk/benefit analysis was sent to the NRC in January, 1991.

Closure Date and Mechanism: 1/91, Calico Hills Risk/Benefit Analysis (CHRBA)(DOE, 1991b)

Related NRC Concern: (Objection 1, second bullet, item f)

"The Design Acceptability Analysis (DAA) undertaken by DOE in response to NRC concerns for evaluating the acceptability of the ESF Title I design did not consider certain concerns critical to NRC acceptance of DAA conclusions.

The DAA has not demonstrated that DOE has considered information that indicates the presence of an anomaly in the immediate vicinity of the proposed locations of exploratory shaft 1 and 2. (Comment 127) By not considering this readily available information in reaching decision on the locations of ES-1 and ES-2, uncertainties regarding the design control process are further heightened. The design itself is further questioned since the comparative evaluation of the major design features (i.e., ES-1 and ES-2) with respect to waste isolation did not assess the impact of the anomaly."

Response:

A Technical Assessment Review (TAR) (DOE, 1990b) was performed to address the validity and significance of this specific anomaly to design and performance of the ESF. Results of the TAR were reported to the NRC. Recommendations regarding further work on this anomaly and on YMP practices (to preclude future problems of this nature) were made, and will be factored into YMP activities as described below.

The new ESF configuration has ramp accesses in new locations. Consistent with the TAR recommendations, these locations are being assessed for potentially adverse features such as faults, which could have design or performance impacts on the ESF openings. Results will be reported to Raytheon Services Nevada and incorporated into the Preliminary Siting Analysis Report.

Another recommendation of the TAR which will be implemented concerns the improved entry of data into a Graphic Information System (GIS). This practice will improve data management practices, such that future information on geologic features of interest would be incorporated, and available to users.

These activities reflect an in-place design control process. A final demonstration of acceptability must await the completion of Title II design.

Closure Date and Mechanism: During Title II Design

Related NRC Concern: (Objection 1, fourth bullet, first paragraph; also Comment 119)

"Potential impacts of long-term performance confirmation testing on ESF design have not been addressed."

Response:

The impacts of performance confirmation testing on repository operation will not be assessed until licensing. For the purpose of ESF construction and operations, the DOE has assessed the most critical disturbances (i.e., penetrating the Calico Hills) and could foresee no impacts on the repository's long-term performance (DOE, 1991b). Consistent with the response to this NRC concern in DOE's SCA response document (Comment 119, DOE 1990a), more information on the characteristics of the site, the waste package, and the configuration of the proposed underground repository is needed before the details of a program to confirm performance predictions can be determined.

Closure Date and Mechanism: At the time of license application and, for the purposes of the ESF, during Title II Design

Implementation:

1. In accordance with 10 CFR 60.15(c)(1), the location, design, construction, and operation of the main sites and auxiliary sites shall incorporate aspects specifically directed at limiting the potential for adverse effects on the long-term performance of the repository. 1261, Con A

2. In accordance with 10 CFR 60.15(c)(1), the design, construction, and operation of the surface utilities, including the wastewater ponds and water handling system, shall incorporate aspects specifically directed at limiting the potential for adverse impacts on the long-term performance of the repository, to the extent practical. 1262, Con A

3. All materials or substances to be used underground shall first be reviewed for potential effects on engineered barriers and waste isolation. They may be used only following review and approval, and only in those areas where use has been approved, and subject to whatever controls are established. Such materials or substances include, but are not limited to, the following:

   a. Concrete and other cementitious materials, such as shotcrete and grout.

   b. Ground support materials, including chemical/resin anchorages.

   c. Water (pH and organic content) and any additives to water for identification (tracers) or construction, operation, or testing.

   d. Hydrocarbons and solvents.

   e. Organic materials.

f. Explosives and blasting ancillaries, including the introduction of pressurized drilling water into the rock, and the chemical residues that are the products of blasting. 1264, PC 2a (ii); 1265, PC 2a (ii); 1266, PC 2a (ii)

4. To the extent feasible or practical, lining and grouting material selection shall consider material chemistry and take into account potential chemical interactions with groundwater that could affect waste package corrosion and radionuclide solubility. 1264, PC 2a (iii); 1265, PC 2a (iii)

5. A materials control program shall be implemented to enable establishment of limits on the inventory of materials left after decommissioning. 1264, PC 2a (iv); 1265, PC 2a (iv); 1266, PC 2a (iii)

6. Shafts, ramps, and underground excavations shall be designed with construction controls that enable flexibility in closure, such as the location of seals, so that a seismic event is unlikely to compromise the ability of the facility to isolate wastes. 1264, PC 2a (v); 1265, PC 2a (v); 1266, PC 2a (iv)

7. The design, construction, and operation of the ramp shall incorporate aspects specifically directed at limiting the potential for adverse impacts on the long-term performance of the repository. 1264, PC 2a (i); 1265, PC 2a (i)

8. The design, construction, and operation of the main test area shall incorporate aspects specifically directed at limiting the potential for adverse impacts on the long-term performance of the repository. 1266, PC 2a (i)

9. The design of the underground utilities shall incorporate aspects specifically directed at limiting, to the extent practicable, adverse effects on the repository's long-term performance, and construction and operation of the underground utilities shall be performed in a manner that limits, to the extent practicable, adverse effects on the repository's long-term performance. 1267, Con B (i)

Provision:

THE NUMBER OF EXPLORATORY BOREHOLES AND SHAFTS SHALL BE LIMITED TO THE EXTENT PRACTICAL CONSISTENT WITH OBTAINING THE INFORMATION NEEDED FOR SITE CHARACTERIZATION (10 CFR 60.15(c)(2)).

Related NRC Concern: (Objection 1, sixth bullet, also Comment 35)

"The subsurface drifting and exploration planned in the SCP have not been shown to be sufficient to yield the data needed for repository design and site suitability demonstration at license application."

Response:

The ESFAS evaluated a range of options for various considerations, including representativeness. Several highly-ranked options offered more drifting than the base case, including Option 30, the highest-ranked ESFAS option.

Beyond the present configuration, the extent of the necessary subsurface exploration will be revealed in phases. To that end, the DOE has prepared a plan (DOE, 1991d) that shows how the ESF design, construction, and test activities will be conducted using a phased approach. With a phased approach, DOE considers the most recent data as underground exploration proceeds. The nature of the data dictates the scope of future exploration.

Closure Date and Mechanism: 1991, ESF Alternatives Study Final Report (pending)

Implementation:

1. The number of connections between the underground excavations developed for the ESF and eventual repository drifting shall be kept to the minimum required to provide personnel safety and functional efficiency. 1266, PC 1b (i)

2. The area of the ESF underground excavations shall be limited to that necessary for conducting the needed site characterization and performance confirmation tests. 1266, PC 1b (ii)

Provision:

TO THE EXTENT PRACTICAL, EXPLORATORY BOREHOLES AND SHAFTS IN THE GEOLOGIC REPOSITORY OPERATIONS AREA SHALL BE LOCATED WHERE SHAFTS ARE PLANNED FOR UNDERGROUND FACILITY CONSTRUCTION AND OPERATIONS OR WHERE LARGE UNEXCAVATED PILLARS ARE PLANNED (10 CFR 60.15(c)(3)).

NRC Recommendation: (Objection 1, Recommendations, third bullet)

"The DOE should evaluate existing technical data (e.g., geophysical, geological) with respect to ESF location decisions and criteria; and, if deemed necessary, the DOE should consider additional geological and geophysical surface based tests in the vicinity of the exploratory shafts to investigate potentially adverse features and conditions."

Response:

A Technical Assessment Review (TAR), the results of which were reported to the NRC staff, evaluated current data and potentially adverse conditions. Recommendations regarding further work on adverse conditions, specific anomalies, and YMP practices (to preclude future problems of this nature) will be factored into Title II design.

Consistent with the TAR recommendations, the new ESF configuration will take into account potentially adverse conditions such as faults, which could affect the design or stability of the excavation. Appropriate design requirements have been added to the ESFDR, ensuring that such tests and data evaluations are performed before or during Title II design.

A review of existing geologic and geophysical data around access locations is being conducted. Results of this review will be included in the Preliminary Siting Analysis Report.

Closure Date and Mechanism: 9/91, ESF Title I Design Summary Report, Rev 1

Implementation:

1. ESF ramps or shafts shall be located, to the extent practicable, where such are planned for the repository facility. 1264, PC 2b (i)

2. Borehole alignments and locations shall be monitored, surveyed, and the results included on all underground working maps. 1264, PC 2b (ii); 1265, PC 2b (ii)

3. The centerline coordinate location of the ramps and shafts shall be as listed in the RIB and defined by the Nevada Coordinate System. 1264, PC 2b (iii)

4. The nominal finished inside diameter of the shafts and ramps shall be as listed in the RIB. 1264, PC 2b (iv); 1265, PC 2b (iv)

5. Ramps shall be located, to the extent practicable, where accesses are planned for the repository facility. 1265, PC 2b (i)

6. The portal coordinate location of a ramp shall be as listed in the RIB and defined by the Nevada Coordinate System. 1265, PC 2b (iii)

7. Exploratory boreholes drilled from the ground surface may intersect openings within the ESF dedicated testing areas, which are to be defined in ESFDR Appendix A. The number of boreholes should be kept to the minimum required to perform the experiments needed. The location of any such boreholes must be identified on the "as-built" maps of the ESF. 1266, PC 2b (i)

8. In areas outside the ESF dedicated testing areas which are to be defined in ESFDR Appendix A, no portion of an exploratory borehole drilled from the ground surface shall be located within 15 m of any underground opening. 1266, PC 2b (ii)

9. Horizontal boreholes, drilled from the main test area level for installation of experiments or instrumentation systems, that penetrate areas where waste could eventually be stored, shall not be permitted unless performance evaluations have been completed and approved indicating such holes shall be acceptable. Unless alternate constraints are approved, all such horizontal holes are subject to the following restrictions: 1266, PC 2b (iii)

   a. The holes shall be collared no less than 3 feet above the floor of the drift or alcove from which they are drilled. 1266, PC 2b (iii,a)

b. The holes shall be biased upward from the collar sufficiently to assure that any liquid that may enter the hole will drain toward the hole collar. 1266, PC 2b (iii,b)

c. All borehole alignments and locations shall be monitored, surveyed, and included on all underground as-built maps. 1266, 2b (iii,c)

10. Multipurpose boreholes (MPBHs) shall be located in pillars, to the extent practicable. 1268, Con D (i)

11. MPBHs should be surveyed as drilling proceeds and the option to cease drilling may be invoked if insufficient separation from the proposed access location is observed. 1268, Con D (ii)

12. Boreholes drilled from the main test area level shall not penetrate significantly below the base of the TSw2 host rock, unless the impacts on the waste isolation performance of the site have been evaluated and found to be acceptable. 1268, Con D (iii)

13. The maintainable design life for those nonpermanent ESF structures, systems, and components that are necessary for initial repository construction shall be 15 years. 1260, PC (vi)

14. To the extent practical, exploratory boreholes and shafts (and ramps) in the geologic repository operations area shall be located where shafts (and ramps) are planned for underground facility construction and operation or where large unexcavated pillars are planned. 1260, Con C(3); 12611, Con A

Provision:

SUBSURFACE EXPLORATORY DRILLING, EXCAVATION, AND IN SITU TESTING BEFORE AND DURING CONSTRUCTION SHALL BE PLANNED AND COORDINATED WITH GEOLOGIC REPOSITORY OPERATIONS AREA DESIGN AND CONSTRUCTION (10 CFR 60.15(c)(4)).

Related NRC Concern: (Objection 1, first paragraph)

"The Exploratory Shaft [sic] Facility (ESF) is intended to become an integral part of the repository if the site is found acceptable. However, the SCP and its references do not demonstrate the adequacy of ESF Title I design control process, and the adequacy of the ESF Title I design which is the basis for the SCP. For example, neither the design nor the subsequent Design Acceptability Analysis (DAA) considers some of the applicable 10 CFR Part 60 requirements. Also, the process used to integrate currently available technical data into decisions regarding shaft location appears to have overlooked evidence of a potential fault near the location of the exploratory shafts. In addition, it has not been demonstrated that the underground test facility and currently identified test durations will permit all tests to be conducted for the time periods required without interference. Furthermore, resolution of the problems identified with the Title I design may result in considerable corresponding modifications to the SCP."

Response:

The Exploratory Studies Facility Alternatives Study (ESFAS) examined 34 shaft/repository configurations. Options 1 through 17 would systematically characterize the shallow (Topopah Spring) and then the deep (Calico Hills) strata, while options 18 through 34 would proceed as quickly as possible to the Calico Hills and, thereby, provide early investigation of a major natural barrier. From these alternatives, the DOE management will select one ESF design.

A study was performed (SAIC, 1991) to evaluate the favorable features of the highest-ranked options identified in the ESF Alternatives Study (SNL, 1991). Based on the results of this study, the A/E was directed by DOE (DOE, 1991f) to incorporate the recommended favorable features into its Title I design study to enhance construction and performance of the underground test facility. The Title I design study will use DOE-controlled requirements documents to develop a preliminary (reference) design that is consistent with the controlled site characterization testing program. The Title I design study will form the basis for a revised Title I design.

This process will be done under design control, wherein specific procedures ensure that the design, testing, and performance assessment communities are all active participants in an interactive design process. This process will ensure that the design complies with the applicable 10 CFR 60 requirements.

Closure Date and Mechanism: 9/91, ESF Title I Design Summary Report, Rev 1

Implementation:

1. Underground ESF construction shall not adversely affect in situ site characterization. 1260, Con C(4) (i)

2. All ESF activities shall be monitored frequently for the purpose of assessing the effects of those activities on the future suitability of the site for a repository. 1260, Con C(4) (ii)

3. All substances and tracers intended to be added to water and compressed air to be used underground for such purposes as drilling and dust control shall first be reviewed for potential to affect site characterization testing, repository testing or monitoring, and waste isolation. They may be added only following review and approval. (See Test 2.2.29, ESFDR, Appendix B.) 1260, Con C(4) (iii)

4. The use of hydrocarbons and solvents underground shall comply with criteria to be determined by performance assessment. 1260, Con C(4) (iv)

5. Precautions shall be taken to avoid and/or control spills of hydrocarbons, solvents, and cementitious materials. Spills which do occur shall be cleaned up to the extent practicable. Spilled and contaminated material (including soil) shall be disposed of in

accordance with federal and state requirements. Specifically, this means the following regarding cleanup: 1260, Con C(4) (v)

a. Liquid spills-- all puddles and all soil that are nearly saturated with the spilled material shall be removed.

b. Powder spills-- all spilled material shall be removed. Final cleanup from solid surfaces shall be by sweeping; final cleanup from soil surfaces shall include removal of soil in contact with the spilled material.

6. Testing instrumentation shall be removed, to the extent practicable, following its final use. 1260, Con C(4) (vi)

7. To the extent practicable, drilling with water into known large-aperture fractures shall be avoided. 1260, Con C(4) (vii)

8. ESF items and activities shall not affect overall system performance objectives for the MGDS as required by 10 CFR 60.112. 1260, Con C(4) (viii)

9. Location of the underground facility shall stay within the conceptual perimeter drift boundary, except as needed to characterize areas outside that boundary, taking into account any potential impacts on the waste isolation capabilities of the site. 1266, PC 2c (i)

10. The facilities constructed to support the experimental program on the main test area level of the ESF, with the exception of the drifts driven laterally to investigate geological features, shall be within the boundary defined in ESFDR Appendix A. No drifting shall be closer than 75 feet from this boundary. Small diameter boreholes are exempted, provided they meet the requirements pertaining to boreholes. 1266, PC 2c (ii)

11. The line, grade, cross sections, and other features of the drift driven on the main test area level to investigate the Drill Hole Wash structures, the suspected imbricate fault zone, and the Ghost Dance Fault shall be as shown on drawings in ESFDR Appendix A. 1266, PC 2c (iii); 1266, PC 2c (iv); 1266, PC 2c (v)

12. The Dedicated Test Area and the Dedicated Shop Area openings, as defined in ESFDR Appendix A, shall be maintained for future use during repository operation (future uses include utilization as waste emplacement support shops, ventilation airways, access to performance confirmation areas, etc.). 1266, PC 2c (vi)

13. The future repository access drifts shown crossing the ESF Dedicated Shop Area which are to be shown on drawings in ESFDR Appendix A may be incorporated into the design of the ESF support shop facility. 1266, PC 2c (vii)

14. The long exploratory drifts laterally extended from the central portion of the ESF on the main test area level shall be constructed in locations that will permit them to be used to support repository operations. 1266, PC 2c (viii)

15. The ESF shall be designed to be consistent with the repository design goal to limit the extraction ratio to less than 30 percent unless otherwise governed by test requirements. [TBV] 1266, PC 2c (ix)

16. ESFDR Appendix A will show the interface between the ESF and the repository conceptual design. New or revised drawings will be prepared to show future design changes (if any) as they are approved. 1266, PC 2c (x)

Provision:

DOE SHALL MAINTAIN RECORDS OF CONSTRUCTION OF THE GEOLOGIC REPOSITORY OPERATIONS AREA IN A MANNER THAT ENSURES THEIR USABILITY FOR FUTURE GENERATIONS IN ACCORDANCE WITH SECTION 60.51(A)(2).

THE RECORDS REQUIRED UNDER PARAGRAPH (A) SHALL INCLUDE AT LEAST THE FOLLOWING:

(1) SURVEYS OF THE UNDERGROUND FACILITY EXCAVATIONS, SHAFTS, AND BOREHOLES REFERENCED TO READILY IDENTIFIABLE SURFACE FEATURES OR MONUMENTS;

(2) A DESCRIPTION OF THE MATERIALS ENCOUNTERED;

(3) GEOLOGIC MAPS AND GEOLOGIC CROSS SECTIONS;

(4) LOCATIONS AND AMOUNT OF SEEPAGE;

(5) DETAILS OF EQUIPMENT, METHODS, PROGRESS, AND SEQUENCE OF WORK;

(6) CONSTRUCTION PROBLEMS;

(7) ANOMALOUS CONDITIONS ENCOUNTERED;

(8) INSTRUMENT LOCATIONS, READINGS, AND ANALYSIS;

(9) LOCATION AND DESCRIPTION OF STRUCTURAL SUPPORT SYSTEMS;

(10) LOCATION AND DESCRIPTION OF DEWATERING SYSTEMS; AND

(11) DETAILS, METHODS OF EMPLACEMENT, AND LOCATION OF SEALS USED (10 CFR 60.72(a) and (b)).

Related NRC Concern: None

Closure Date and Mechanism: None

Implementation:

All geotechnical information used to locate and design the accesses and underground features (including seismic criteria) shall be consistent with information contained in the Reference Information Base (RIB), Yucca Mountain Site Characterization Project controlled documents, or standard reference information (e.g., standard handbooks). Records of the ESF design, construction, operation, and in situ testing shall be maintained sufficient to satisfy the requirements of 10 CFR 60.72. 1260, PC 1f

Provision:

DOE SHALL PERFORM, OR PERMIT THE COMMISSION TO PERFORM, SUCH TESTS AS THE COMMISSION DEEMS APPROPRIATE OR NECESSARY FOR THE ADMINISTRATION OF THE REGULATIONS IN THIS PART. THESE MAY INCLUDE TESTS OF: (1) RADIOACTIVE WASTE, (2) THE GEOLOGIC REPOSITORY INCLUDING ITS STRUCTURES, SYSTEMS, AND COMPONENTS, (3) RADIATION DETECTION AND MONITORING INSTRUMENTS, AND (4) OTHER EQUIPMENT AND DEVICES USED IN CONNECTION WITH THE RECEIPT, HANDLING, OR STORAGE OF RADIOACTIVE WASTE (10 CFR 60.74(a)).

THE TESTS REQUIRED UNDER THIS SECTION SHALL INCLUDE A PERFORMANCE CONFIRMATION PROGRAM CARRIED OUT IN ACCORDANCE WITH SUBPART F OF THIS PART (10 CFR 60.74(b)).

Related NRC Concern: (Objection 1, first bullet, item a)

"In planning the underground test facility, the overall performance confirmation testing program and the need for starting certain performance confirmation tests (e.g., waste package testing) as early as practicable during site characterization should be considered."

Response:

The ESFAS specifically addressed the underground test facility and its use for the conduct of certain performance confirmation tests in scoring the 34 options. Option 30, which ranked highest, has been selected to provide the basis for the ESF design.

Closure Date and Mechanism: ESF Alternatives Study Final Report (pending) and 9/91, ESF Title I Design Summary Report, Rev 1

Related NRC Concern: (Objection 1, fourth bullet, second paragraph; also Comment 82 and Question 58)

"The SCP has not provided sufficient demonstration that in situ waste package testing will not be needed during site characterization to reduce uncertainties associated with long-term waste package performance prediction for license application and closure. If such testing is found necessary, an analysis of the impact on ESF design is not presented."

Response:

The NRC defines waste package as "...the waste form and any containers, shielding, packing and other absorbent materials immediately surrounding an individual waste container." (10 CFR 60.2). The DOE does not plan to bring any form of high-level radioactive waste to Yucca Mountain during site characterization. Should the DOE change its mind, we will request the NRC's approval, consider the above objection, and take the necessary precautions.

Closure Date and Mechanism: N/A, HLW will not be brought to Yucca Mountain during site characterization.

Implementation:

1. The subsurface structures, systems, components, and operation of the shaft and ramp breakouts and main test area level of the ESF shall be designed to accommodate additional tests that may be required by the NRC for site characterization and performance confirmation without interruption of, or interference with, testing in progress or planned testing. 1264, Con A (i); 1265, Con A (i); 1266, Con A (i); 1267, Con C (i)

2. The area set aside for future site characterization and performance confirmation testing shall be representative of the overall designated test area with respect to rock characteristics and control. This determination shall be based on reasonable interpretation of available information on the variability of host rock characteristics throughout the ESF site area. 1266, Con A (ii)

Provision:

POTENTIAL FOR FLOODING OF THE UNDERGROUND FACILITY, WHETHER RESULTING FROM THE OCCUPANCY AND MODIFICATION OF FLOODPLAINS OR FROM THE FAILURE OF EXISTING OR PLANNED MAN-MADE SURFACE WATER IMPOUNDMENTS (10 CFR 60.122(c)(1)).

Related NRC Concern: (CDSCP Objection 4)

"... the CDSCP does not adequately consider the potentially adverse impacts that could result from the proposed locations of the exploratory shafts (and other shafts and ramp portals) in areas that may be subject to erosion and flooding." (NRC, 1988b)

Response:

Following their review of the DOE's final Site Characterization Plan (SCP) (DOE, 1988b) and Design Acceptability Analysis (DAA) (DOE, 1989a), the NRC staff lifted Objection 4.

Closure Date and Mechanism: 2/89, Design Acceptability Analysis (DAA) (DOE, 1989a)

Implementation:

In accordance with 10 CFR 60.122(c)(1), drainage shall be controlled to reduce the potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments. 12614, Con A

Provision:

CONDITIONS THAT PERMIT THE EMPLACEMENT OF WASTE AT A MINIMUM DEPTH OF 300 METERS FROM THE GROUND SURFACE. (THE GROUND SURFACE SHALL BE DEEMED TO BE THE ELEVATION OF THE LOWEST POINT ON THE SURFACE ABOVE THE DISTURBED ZONE) (10 CFR 60.122(b)(5)).

Related NRC Concern: None

Implementation:

1. Overburden shall be greater than 200 meters for the main test area level of the ESF. 1266, PC 2e (i)

2. The spacing between adjacent ESF drifts shall be a minimum of two drift diameters (using the maximum diameter of either opening and considering the closest proximity of any part of each opening) consistent with obtaining reliable and adequate information from site characterization, except where required otherwise by specific test requirements. 1266, PC 2e (ii)

3. The location of openings for handling excavated materials shall be selected to minimize effects on the integrity of any other openings. 1266, PC 2e (iii)

4. Rock support and other structural anchoring materials shall be compatible with waste isolation and shall neither interfere with radionuclide containment nor enhance radionuclide migration. 1266, PC 2e (iv)

5. The underground facility configuration (drift locations, orientation, geometry, and sizes) shall contribute to or not detract from the isolation capability of the site. 1266, PC 2e (v)

Provision:

SCOPE OF DESIGN CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREA. SECTIONS 60.131 THROUGH 60.134 SPECIFY MINIMUM CRITERIA FOR THE DESIGN OF THE GEOLOGIC REPOSITORY OPERATIONS AREA. THESE DESIGN CRITERIA ARE NOT INTENDED TO BE EXHAUSTIVE, HOWEVER. OMISSIONS IN 60.131 THROUGH 60.134 DO NOT RELIEVE DOE FROM ANY OBLIGATION TO PROVIDE SUCH SAFETY FEATURES IN A SPECIFIC FACILITY NEEDED TO ACHIEVE THE PERFORMANCE OBJECTIVES. ALL DESIGN BASES MUST BE CONSISTENT WITH THE RESULTS OF SITE CHARACTERIZATION ACTIVITIES (10 CFR 60.130).

Related NRC Concern: (Objection 1, second bullet, item b; also Comment 128)

"The Design Acceptability Analysis (DAA) undertaken by DOE in response to NRC concerns for evaluating the acceptability of the ESF Title I design did not consider certain concerns critical to NRC acceptance of DAA conclusions.

Neither the ESF Title I design nor the subsequent DAA considers (qualitatively or quantitatively) all of the applicable 10 CFR 60 requirements."

Response:

All applicable regulations are now being considered. Appendix E of the Waste Management Systems Requirements (WMSR), Volume IV (DOE, 1991a) provides a complete list of the 10 CFR 60 requirements that apply to the ESF. The list includes some 52 provisions originally identified by DOE, plus 11 provisions identified by the NRC. The WMSR sets forth specific, top-level requirements that the repository program must fulfill.

Closure Date and Mechanism: 1/91, Waste Management Systems Requirements (WMSR) Volume IV (DOE, 1991a) and 5/91, Exploratory Studies Facility Design Requirements (ESFDR) (DOE, 1991c)

Related NRC Concern: (Objection 1, Second bullet, item c, also Comment 130)

"The Design Acceptability Analysis (DAA) undertaken by DOE in response to NRC concerns for evaluating the acceptability of the ESF Title I design did not consider certain concerns critical to NRC acceptance of DAA conclusions.

Of the 52 requirements considered by DOE to be applicable to the ESF design, only 22 were considered quantitatively. The remaining were said to have been considered qualitatively. Included in the remaining 30 are the requirements of Subpart F (Performance Confirmation Program) which according to 10 CFR 60.140(b), "shall have been started during site characterization." Several of these 30 requirements are potentially important in evaluating the acceptability of the ESF Title I design."

Response:

Appendix E of the WMSR Volume IV lists all applicable regulations that are implemented in subordinate documents. In the case of the ESF, the ESFDR (DOE, 1991c) converts regulations into general criteria. For example, whenever the ESFDR addresses a topic that is regulated by 10 CFR 60, the appropriate provision is first quoted and cited. Next, design criteria and constraints adopt the provision to the circumstances under which it will be applied, such as prevent test interference, ensure mine safety, or avoid impacts on waste isolation.

The ESFDR does not convert all of the applicable 10 CFR Part 60 requirements into quantitative design criteria. Although DOE promised that the Title II design would utilize specific design criteria (DOE, 1990a, p. 312), the DOE does not consider it prudent to develop quantitative design criteria prior to underground exploration. Moreover the National Academy of Sciences warned,

> "In a project where adherence to predetermined specifications is paramount, the inherent variability of the geologic environment will result in endless changes in the specifications, with resultant delays, frustration for field personnel, high overhead costs, and loss of public confidence in both the suitability of the site and the competence of the professionals working on the project." (NAS, 1990, page 28).

Closure Date and Mechanism: 5/91, Exploratory Studies Facility Design Requirements (ESFDR) (DOE, 1991c)

Implementation:

1. Design basis events for the ESF shall be those natural, credible disruptive events likely to occur at the ESF site during both pre-closure and post-closure periods. Natural, credible disruptive events shall be identified by the design organization (DO) and reviewed and approved by the Project Office. Analysis shall conform to procedures for determining items important to safety and items important to waste isolation. The magnitude, duration, and severity used for each of these design basis events shall be as described in the RIB. 1260, Con E (i)

2. Design basis accidents and operational occurrences for the ESF shall be those credible disruptive events likely to occur at the ESF site during pre-closure construction, operations, and testing. An initial comprehensive list of construction, operations, and testing related credible disruptive events shall be identified by the DO and reviewed and approved by the Project Office. Analysis shall conform to procedures for determining items important to safety and items important to waste isolation. The magnitude, duration, and severity used for each of these events shall be developed by the responsible DO and included in their design basis documentation. 1260, Con E (ii)

3. The use of hydrocarbons, solvents, and chemicals shall be controlled during construction and operation of shaft(s)/ramp(s)/surface site(s) to limit adverse chemical changes. 1261, Con E

4. Fluids and materials planned for use in a shaft, ramp, or underground facility shall be evaluated with respect to intended use and possible effects on site characterization or other testing, and appropriate controls shall be implemented. 1264, PC 1d (vi); 1265, PC 1d (vi); 1266, PC 1d (ix)

5. The capability to enhance postclosure performance by removing ramp linings shall be retained. 12652, Con C

Provision:

TO THE EXTENT THAT DOE IS NOT SUBJECT TO THE FEDERAL MINE SAFETY AND HEALTH ACT OF 1977, AS TO THE CONSTRUCTION AND OPERATION OF THE GEOLOGIC REPOSITORY OPERATIONS AREA, THE DESIGN OF THE GEOLOGIC REPOSITORY OPERATIONS AREA SHALL NEVERTHELESS INCLUDE SUCH PROVISIONS FOR WORKER PROTECTION AS MAY BE NECESSARY TO PROVIDE REASONABLE ASSURANCE THAT ALL STRUCTURES, SYSTEMS, AND COMPONENTS IMPORTANT TO SAFETY CAN PERFORM THEIR INTENDED FUNCTIONS. ANY DEVIATION FROM RELEVANT DESIGN REQUIREMENTS IN 30 CFR, CHAPTER I, SUBCHAPTERS D, E (SUBCHAPTERS D AND E COVER PARTS 18-36 IN THE CURRENT VERSION), AND N WILL GIVE RISE TO REBUTTABLE PRESUMPTION THAT THIS REQUIREMENT HAS NOT BEEN MET. (10 CFR 60.131(b)(9))

Related NRC Concern: None

Implementation:

If the subsurface facility is classified as a gassy mine, appropriate requirements of 30 CFR Part 57 in effect at the time of design shall be applicable. 1260, Con G (i)

Provision:

GENERAL CRITERIA FOR THE UNDERGROUND FACILITY. (1) THE ORIENTATION, GEOMETRY, LAYOUT, AND DEPTH OF THE UNDERGROUND FACILITY, AND THE DESIGN OF ANY ENGINEERED BARRIERS THAT ARE PART OF THE UNDERGROUND FACILITY SHALL CONTRIBUTE TO THE CONTAINMENT AND ISOLATION OF RADIONUCLIDES (10 CFR 60.133(a)(1)).

Related NRC Concern: (Objection 1, Recommendation, second bullet)

"The Title II design should ensure that the design process, which appears to have overlooked key regulatory requirements and information about the suitability of exploratory shaft locations during Title I design, is adequate and that the number of shafts and their locations in the final repository contribute to reduce uncertainty with respect to waste isolation."

Response:

The concerns expressed by this comment have been formulated into design requirements and added to the ESFDR. In carrying out the design process, designers will address these aspects, interpret them, and factor them into the design. Design reviews will ensure compliance with these requirements.

Closure Date and Mechanism: 2/91, Waste Management Systems Requirements (WMSR) Volume IV (DOE, 1991a) and 9/91, **ESF** Title I Design Summary Report, **Rev 1**

Implementation:

1. Rock support and other structural anchoring materials shall be compatible with waste isolation. 1264, PC 2d (i); 1265, PC 2d (i)

2. Rock support and other structural anchoring materials shall neither interfere with radionuclide containment nor enhance radionuclide migration. 1264, PC 2d (ii); 1265, PC 2d (ii)

3. Shaft configuration (shaft location, shaft diameter, shaft separation, and shaft depth) shall contribute to or not detract from the isolation capability of the site. 1264, PC 2d (iii)

4. The locations of openings for handling excavated materials shall be selected to minimize effects on the integrity of any other openings. 1264, PC 2d (iv); 1265, PC 2d (iv)

5. ESFDR Appendix A will show the interface between the ESF and the repository conceptual design. New or revised drawings will be prepared to show future design changes (if any) as they are approved. 1264, PC 2d (v); 1265, PC 2d (v)

6. Ramp configuration (access location, access size, access separation, and access depth) shall contribute to or not detract from the isolation capability of the site. 1265, PC 2d (iii)

Provision:

THE UNDERGROUND FACILITY SHALL BE DESIGNED SO THAT THE EFFECTS OF CREDIBLE DISRUPTIVE EVENTS DURING THE PERIOD OF OPERATIONS, SUCH AS FLOODING, FIRES AND EXPLOSIONS, WILL NOT SPREAD THROUGH THE FACILITY (10 CFR 60.133(a)(2)).

Related NRC Concern: None

Implementation:

1. A shaft or ramp shall be designed so that the effects of credible disruptive events (e.g., flooding, fires, and explosions) shall not spread through the facility. 1264, PC 2e (i); 1265, PC 2e (i)

2. A shaft collar shall be designed to prevent significant water inflow from a flooding event during site characterization and the planned period of repository operation, such that testing in the underground portion of the ESF and waste emplacement are not adversely affected. 1264, PC 2e (ii)

3. A ramp portal shall be designed to prevent significant water inflow from a flooding event during site characterization and the planned period of repository operation, such that testing in the underground portion of the ESF and waste emplacement are not adversely affected. 1265, PC 2e (ii)

4. The ESF shall be designed so that the effects of credible disruptive events (e.g., flooding, fires, and explosions) shall not spread through the facility. 1266, PC 2f (i)

5. Materials shall be selected such that effects of fire do not produce geochemical effects that impact waste isolation capabilities of the site. 1266, PC 2f (ii)

6. The underground facility shall be designed such that effects of fire, which could produce geochemical effects that adversely affect future repository operations, shall not spread. 1266, PC 2f (iii)

7. The drainage plan for underground work shall be consistent with repository operations and postclosure sealing concerns, be designed to control and limit the impact of a credible flood on testing in the ESF, and not impact the capability to characterize the site. 1266, PC 2f (iv)

8. Utility systems, including the water distribution and underground wastewater collection systems, shall be designed so that, in the event of seismic activity, safe operation is ensured. 1267, Con D (i)

9. The underground utility system shall be designed to control and limit the impact of utility system failures caused by credible disruptive events such as fire, explosion, or seismic events, on site characterization and other testing. 1267, Con D (ii)

10. Fire suppression agents shall be selected for their compatibility with their intended use. These agents shall be approved for use based on their impacts on underground safety (i.e., they do not produce adverse geochemical effects), the in situ site characterization testing program, and performance objectives as stated in 10 CFR 60. 12678, Con A

11. Shaft and shaft-collar and ramp and ramp-portal areas shall be located and/or graded to protect them, and prevent water inflow to the underground facilities, from the probable maximum flood. 1261, PC 1b

12. Water storage tanks shall be located, or protection provided, to preclude water inflow to the ESF following a possible tank failure. 1262, Con C

13. Piping shall be designed to preclude or limit possible water inflow to the ESF following a pipe rupture. 1262, Con D

14. Water intrusion, if any, into the underground openings shall be monitored and controlled by suitable measures such that the effects of expected water inflows (i.e., water, heat, gases) will not endanger worker safety and in situ site characterization. 1266, PC 1d (iii)

15. Excess water shall be removed to preclude interference with tests. 1266, PC 1d (iv)

16. Operational seals shall be provided where necessary to control the intrusion of water into the facility. 1266, PC 2h (vii)

17. Piping shall be designed to preclude or limit water inflow into the ESF following a pipe rupture. 1267, Con J

18. Water handling and control underground shall be designed for all credible inflows, including inflow from penetration of fault structures or from perched water horizons, use of fire protection sprinklers, and from water line breakage. 12676, PC 1b (i)

19. The underground portion of the ESF shall incorporate a fire protection system to control and limit the impact of credible fires in the ESF. 12678, PC 1a

20. The underground wastewater collection system shall have full operating redundancy or shall have storage capacity to allow installation of spares in order to limit possible impacts on the isolation capability of the site. 12676, PC 1b (v)

Provision:

FLEXIBILITY OF DESIGN. THE UNDERGROUND FACILITY SHALL BE DESIGNED WITH SUFFICIENT FLEXIBILITY TO ALLOW ADJUSTMENTS WHERE NECESSARY TO ACCOMMODATE SPECIFIC SITE CONDITIONS IDENTIFIED THROUGH IN SITU MONITORING, TESTING, OR EXCAVATION (10 CFR 60.133(b)).

Related NRC Concern: None

Implementation:

1. Probe or pilot holes shall be drilled, if required, in advance of drifting to detect and provide for control of possible anomalous geological conditions which may affect ESF development or ability to obtain data for site characterization. 1266, PC 2g (i)

2. The ESF shall be designed so as not to interfere with the flexibility of the repository to accommodate specific site conditions. 1266, PC 2g (ii)

3. A contingency plan shall be established for underground excavation to accommodate unexpected or site-specific conditions that may be encountered, such as highly fractured zones, lithophysae-rich zones, perched water, or pathways for significant water movement. 1266, PC 2g (iii)

4. Underground utilities for the ESF shall be designed to accommodate expansion of the main test area level for additional testing and exploratory drifting from the main test area level, if necessary, up to approximately 10,000 feet to other parts of the repository block. 1267, Con E (i)

5. The underground utilities for the ESF shall not preclude monitoring and investigation of in situ conditions, and shall be designed to accommodate site-specific conditions, construction, and operation of the ESF. 1267, Con E (ii)

6. The design of the underground utilities shall provide the flexibility needed to support the uncertainty in the design of the shafts and ramps, shaft and ramp breakouts, and the layout of the main test area level of the ESF. 1267, Con E (iii)

7. Shaft or ramp design shall have the flexibility needed to ensure that the location, orientation, geometry, and configuration of each planned test can be modified, as necessary, to meet specific test location acceptance criteria for each test in a shaft or ramp, in response to actual site conditions encountered during construction. 1264, PC 1c (i); 1265, PC 1c (i)

8. The configuration of a shaft or ramp shall be adequate to support site characterization testing and future testing that may be reasonably expected for site characterization. This shall include an allowance to accommodate site-specific conditions encountered in the shaft or ramp without adversely affecting testing that is planned or ongoing. 1264, PC 1c (ii); 1265, PC 1c (ii)

9. The design of shaft or ramp breakouts, and the layout of the main test area of the ESF, shall have the flexibility to ensure that the location, orientation, geometry, and configuration of each planned test can be modified, as necessary, to meet specific test location acceptance criteria, in response to actual site conditions encountered during construction. 1266, PC 1c (ii)

10. The ESF underground excavation shall be of adequate size to support site characterization testing and future testing that may be reasonably expected for site characterization. This shall include: (1) an allowance to accommodate site-specific conditions encountered in the dedicated test area without adversely affecting testing that is planned or ongoing; and (2) capacity to extend an exploratory drift from the main test area, if necessary, up to approximately 10,000 feet to other parts of the potential repository block, taking care that potential repository openings are not adversely impacted by random exploratory drift extensions. 1266, PC 1c (iii)

11. The design of shaft or ramp breakouts and the main test area shall have sufficient flexibility to: (1) relocate experiments as necessary to limit interference between tests and aid in ensuring that test location acceptance criteria are met; (2) incorporate additional tests, as needed, in the dedicated test area; (3) allow development and testing in other areas as needed (e.g., southern portion of repository block or Calico Hills formation); (4) accommodate schedule changes as needed; and (5) limit interference between ESF construction and operations activities and testing activities. 1266, PC 1c (iv)

12. The ESF shall be designed so that testing areas are separated from possible repository shop, training, operations, or waste emplacement areas, to limit adverse effects from activities in those areas on future testing, including performance confirmation, in the dedicated test area. 1266, PC 1d (xiv)

Provision:

CONTROL OF WATER AND GAS. THE DESIGN OF THE UNDERGROUND FACILITY SHALL PROVIDE FOR CONTROL OF WATER OR GAS INTRUSION (10 CFR 60.133(d)).

Related NRC Concern: (Objection 1, third bullet, item i)

"The zone of influence from the drilling activities of existing borehole USW G-4 located within the dedicated test area should be considered in evaluating the size of suitable available test space. In calculating the zone of influence for USW G-4 it should be considered that a total of 342,255 gallons of water were lost to various formations. Over 81,000 gallons of soap were used in the operation; however, how much soap was lost is unknown."

Response:

DOE will implement a phased approach towards ESF design, construction, and test activities, in order to allow the program to consider newly obtained information (e.g., high water saturations associated with water loss from USW G-4), which may alter or change current designs, construction, or testing strategies. The phased approach is described in the PFPA (DOE, 1991d).

Closure Date and Mechanism: 5/91, Exploratory Studies Facility Design Requirements (ESFDR) (DOE, 1991c)

Implementation:

1. The amount of water used in site preparation and operations should be limited to that required for sanitation, dust control, compaction of engineered fill material, and proper equipment operation so as to limit the effects on the containment and isolation capability of the site. 1261, Con F (i)

2. Construction of the shaft(s)/ramp(s) surface sites shall be performed in a manner to avoid blockage of natural surface water drainageways and avoid creation of surface water impoundments that could impact post-closure performance. 1261, Con F (ii)

3. Multipurpose boreholes (MPBHs) or other surface drilled exploratory boreholes associated with the ESF shall be drilled dry. 1261, Con F (iii); 1268, Con E (iv)

4. Any MPBHs drilled at ESF sites shall incorporate a standpipe or other measures appropriate and adequate for protection against the effects of maximum credible floods during the period when MPBHs are accessible prior to borehole plugging and sealing. The location of the maximum credible flood in relation to MPBHs shall be determined by the DO. 1261, Con F (iv)

5. Excess water shall be removed. 1261, Con F (v); 1268, Con E (vi)

6. The amount of water used in construction and operations shall be limited to that required for dust control and proper equipment operation so as to limit the effects on the containment and isolation capability of the site. The maximum quantity of water (based on use during construction) shall not exceed 15 gallons per ton of rock excavated. 1264, PC 2g (i); 1265, PC 2g (ii); 1266, PC 2h (iv)

7. Water use in shaft and ramp construction and in testing shall be generally consistent with repository design goals to limit the increase in average percent saturation of the repository horizon to less than [TBD] percent and to limit the increase in local percent saturation to less than [TBD] percent in waste emplacement areas. 1264, PC 2g (ii); 1265, PC 2g (iii); 1266, PC 2h (v); 1268, Con E (iii)

8. Water entering the ESF shall be managed appropriately, including quantity, location, and water balance. 1264, PC 2g (iii); 1265, PC 2g (iv); 1266, PC 2h (vi); 1268, Con E (viii)

9. Operational seals shall be provided where necessary to control the intrusion of water into the facility. 1264, PC 2g (iv); 1265, PC 2g (v); 1266, PC 2h (vii)

10. The drainage plan for underground work shall be consistent with repository operations and postclosure sealing concerns. Drainage in the dedicated test area shall be as defined on drawings in ESFDR Appendix A.2. Drainage in long drifts shall be compatible with repository grades. 1265, PC 2g (i)

11. Facilities for plugging or grouting water inflow areas shall be available if water is known to exist in the vicinity of subsurface workings. 1266, PC 2h (i)

12. The drainage plan for the ESF and long exploratory drifts shall be consistent with repository operations and postclosure sealing concerns. Specifically, drainage in the dedicated test area, as defined in ESFDR Appendix A.2, shall be toward the nearest shaft (or ramp, if no shaft is readily available) and drainage in long drifts shall be compatible with repository grades. 1266, PC 2h (ii)

13. The general drainage design for the main test area level shall preclude water entering the lateral exploratory drifts or the dedicated ESF support area as defined on drawings (ESFDR Appendix A) from flowing into the dedicated testing area defined on the same drawing. Construction provisions to ensure this preferential drainage pattern after closure are shown on drawings in ESFDR Appendix A.2. 1266, PC 2h (iii)

14. Appropriate gravity drainage and/or pumping systems shall be incorporated into the shaft, ramp, and underground facilities for draining water away from testing and other working areas to suitable collection point(s) for further treatment and/or disposal. 1264, PC 1d (ii); 1265, PC 1d (ii); 1267, Con F (i)

15. Structures, systems, and components shall be provided for effective water and ground control. 1267, Con F (ii)

16. The design of the ESF underground utility system, including ventilation, shall facilitate monitoring of moisture influx to the ESF from the rock mass and from ventilation, and moisture afflux from waste water removal and ventilation exhaust to limit possible impacts on the capability to adequately characterize the site. 1267, Con F (iii)

17. Fluids and materials planned for use in testing in the ESF shall be evaluated with respect to intended use and possible effects on site characterization or other testing, and appropriate controls implemented. 1268, Con E (i)

18. The amount of water used in testing and operations shall be limited so as to limit the effects on the containment and isolation capability of the site. 1268, Con E (ii)

19. Fluids recovered during testing operations shall be disposed in such a way as to avoid potential for performance impacts. 1268, Con E (v)

20. Any cleaning of ESF walls to facilitate photogrammetry, mapping, or other testing shall be done using compressed air/mist and control procedures to limit water saturation. 1268, Con E (vii)

21. Gaseous products used in characterization shall not produce geochemical effects that impact waste isolation capabilities of the site. 1268, Con E (ix)

22. Water entering the ESF shall be managed appropriately, including quantity, location, and water balance. 1261, Con O

23. Fluids recovered from sanitary uses or construction operations shall be disposed in such a way as to avoid potential performance impacts. 1262, Con E

24. The accesses (shafts, ramps) shall be separated to maintain reasonable distances for power and instrument cabling and water piping as well as to provide for redundancy in waste water discharge. 1264, PC 1i (iii)

25. Excess water shall be removed to preclude interference with tests. 1264, PC 1d (i); 1265, PC 1d (i)

26. The amount of water used in the construction and operation of the shaft or ramp shall be limited to preclude interference with tests. 1264, PC 1d (iii); 1265, PC 1d (iii)

27. Appropriate gravity drainage and/or pumping systems shall be incorporated in underground openings for draining water away from testing and other working areas to suitable collection point(s) for further treatment and/or disposal. 1266, PC 1d (v)

28. The amount of water used in construction and operations of the underground facility shall be limited to preclude interference with tests. 1266, PC 1d (vi)

29. Methods for dust control and cleaning of walls in the underground portion of the ESF shall be designed to limit adverse effects on the adequacy and reliability of information from site characterization. 1266, PC 1d (vii)

30. Construction methods shall be designed and implemented so that the fluids, gases, or other materials used do not adversely affect the adequacy or reliability of information from site characterization. 1266, PC 1d (viii)

31. Fluids and materials planned for use in the ESF underground facility shall be evaluated with respect to intended use and possible effects on site characterization or other testing, and appropriate controls shall be implemented. 1266, PC 1d (ix)

32. Fluids, gases, and other materials used in underground construction and operations, and/or injected into the rock mass, shall be appropriately tagged. Selection of approved tracers shall consider, but not be limited to: (1) the possible future need to account for the mobility and disposition of all such materials as part of site characterization, and (2) the effects of tracers on site characterization. 1266, PC 1d (x)

33. The presence of combustible materials in the underground facility shall be controlled and limited such that testing in the ESF is not adversely affected. 1266, PC 1d (xi)

34. The use of blasting agents and explosives shall be controlled to preclude adverse effects on in situ site characterization. 1266, PC 1d (xii)

35. The chemical content of the blasting agents and explosives shall be evaluated during their selection process and the chemical content of the blasts sampled, recorded, and the data used as necessary to preclude adverse effects on in situ site characterization. 1266, PC 1d (xiii)

36. The storage and pumping system shall have the capacity to accommodate a peak rate of 250 gpm or a steady flow of 20 gpm. 12676, PC 1b (ii)

Provision:

OPENINGS IN THE UNDERGROUND FACILITY SHALL BE DESIGNED TO REDUCE THE POTENTIAL FOR DELETERIOUS ROCK MOVEMENT OR FRACTURING OF OVERLYING OR SURROUNDING ROCK (10 CFR 60.133(e)(2)).

Related NRC Concern: None

Closure Date and Mechanism: None

Implementation:

1. Shafts, ramps, and underground structures shall be designed and constructed to withstand the effects of seismic events. Seismic criteria to be used to design the shaft are in the RIB. 1264, PC 2h (i); 1265, PC 2h (i); 1266, PC 2i (iii)

2. An adequate distance between accesses shall be provided to limit potential mechanical and hydrological interference between the accesses and to reduce the potential for deleterious rock movement so they do not impact the capability to reliably and adequately characterize the site. 1264, PC 2h (ii); 1265, PC 2h (ii)

3. The openings for rock handling shall be constructed in such a way as to minimize effects on the integrity of any other openings. 1264, PC 2h (iii); 1265, PC 2h (iii)

4. Underground excavated areas shall be designed for safe and maintainable ground support and control where required. 1266, PC 2i (i)

5. Facilities and equipment shall be available to deal effectively with subsurface ground control including emergencies such as rock falls, rock bursts, and squeezing and swelling rock. 1266, PC 2i (ii)

6. The main test area level of the ESF shall be designed to limit overall response to excavation, including rock fall, considering all planned drifts and future drifting that may be performed in the dedicated test area, consistent with obtaining adequate and reliable information from site characterization. 1266, PC 2i (iv)

7. The design of underground openings and their supports in the ESF shall utilize pillar and opening geometries that limit stress concentration, changes in rock mass permeability, and changes in rock mass deformability to levels consistent with acquiring adequate and reliable information from site characterization. 1266, PC 2i (v)

8. The ESF shall be designed to be consistent with the repository design goal to limit the extraction ratio to less than 30 percent unless otherwise governed by test requirements. 1266, PC 2c (ix)

9. Test areas shall be separated so they are not affected by the excavation disturbed zone and any thermal, mechanical, chemical, and hydrological interactions. See ESFDR Appendix B for specifics. 12662, Con A

Provision:

ROCK EXCAVATION. THE DESIGN OF THE UNDERGROUND FACILITY SHALL INCORPORATE EXCAVATION METHODS THAT WILL LIMIT THE POTENTIAL FOR CREATING A PREFERENTIAL PATHWAY FOR GROUNDWATER TO CONTACT THE WASTE PACKAGES OR RADIONUCLIDE MIGRATION TO THE ACCESSIBLE ENVIRONMENT (10 CFR 60.133(f)).

Related NRC Concern: None

Closure Date and Mechanism: None

Implementation:

1. The design and construction of the site civil improvements for the permanent and nonpermanent ESF structures, systems, and components shall not significantly increase the preferential pathways for groundwater or radioactive waste migration to the accessible environment or otherwise significantly reduce the ability of the site to meet the performance objectives as stated in the approved SCP. 1261, Con C (i)

2. Foundations for equipment, buildings, and structures shall be constructed using excavation methods such as controlled blasting to limit damage to the underlying rock mass, to the extent that it could

affect the adequacy or reliability of information from site characterization. Methods shall be designed by the responsible organization to facilitate investigation and monitoring of such effects during and after construction. 1261, Con C (ii)

3. The ESF equipment, buildings, and foundations for structures shall be designed and constructed so that their excavation does not lead to creation of pathways that compromise the repository's capability to meet the performance objective of 10 CFR Part 60.112. 1261, Con C (iii)

4. Techniques used for shaft and ramp excavation shall control overbreak of rock and minimize disturbance to the integrity of the adjoining rock mass. 1264, PC 2i (i); 1265, PC 2i (i)

5. Shafts and ramps shall be designed to provide stability and to minimize the potential for deleterious rock movement or fracturing that may create a pathway for radionuclide migration or could impact the capability to reliably and adequately characterize the site. 1264, PC 2i (ii); 1265, PC 2i (ii)

6. The following are design goals relating to shaft and ramp stability. These design goals may be modified pending information obtained during site characterization or from future analyses:

   a. In areas not affected by thermal load, diametrical closure rate decreasing at all times after construction.

b. In areas affected by thermal load, closure rate no greater than three times that predicted by thermoelastic models.

c. In accesses not lined with concrete, no rockfalls will be greater than a [TBD] size.

d. Access shall be maintainable. 1264, PC 2i (iii); 1265, PC 2i (iii)

7. Mechanical excavation methods shall be used when feasible and practical; however, in those circumstances where drill and blast excavation may be determined to be more effective (safety, ease of construction, readily available technology, schedule, or cost), the design of blasting rounds shall:

a. Limit the disturbance of the surrounding rock mass.

b. Provide fragmentation of tuff into sizes compatible with removal equipment.

c. Provide flexible blasting techniques to compensate for changes in the lithophysal content of the tuff and in local joint patterns.

d. Provide methods to control sudden inflows of water. 1264, PC 2i (iv); 1265, PC 2i (iv); 1266, PC 2j (v)

8. The magnitude and extent of blast-induced changes in permeability shall be limited by blast control. Limitations on blast-induced changes and excavation overbreak are as follows. The limitations are design goals which may be changed based on results of site characterization or future analyses.

   a. Blast-induced changes to the average in situ permeability of the rock beyond a dimension (into the rock) equal to one half of the maximum opening dimension shall be less than one order of magnitude.

   b. Excavation overbreak is to average less than 12 inches. This overbreak limit is additive to the dimensional tolerances applied to the location and runout of the drill holes used for excavation explosives. This limit may be exceeded for short intervals where blast designs are being adjusted. 1264, PC 2i (v); 1265, PC 2i (v); 1266, PC 2j (vi)

9. Drill and blast specifications should include controls related to types and amounts of explosives, shot patterns, and hole depth in order to limit the magnitude and extent of blast-induced permeability. 1264, PC 2i (vi); 1265, PC 2i (vi)

10. If drill and blast construction techniques are used, then controlled blasting will be utilized to limit overbreak and damage to the surrounding rock mass which could affect the adequacy or reliability of information from site characterization. The methods shall be

designed to provide for the requirements of specific site characterization tests, such as limitations on the extent of excavation-induced damage, or the type of ground support that may be installed. The methods shall be designed to facilitate investigation and monitoring of excavation effects during and after construction. 1264, PC 2i (vii)

11. The shaft construction method shall be selected, consistent with other goals of site characterization, to limit impacts on isolation. 1264, PC 2i (viii)

12. The typical cross-section of an ESF ramp shall be constructed using a tunnel boring machine to limit the damage to the surrounding rock mass which could affect the adequacy or reliability of information from site characterization. Ramp stations and other secondary excavation may be developed by controlled drilling and blasting methods. The excavation methods shall be designed to provide for the requirements of specific site characterization tests, such as limitations on the extent of excavation-induced damage, or the type of ground support that may be installed. The methods shall be designed to facilitate investigation and monitoring of such effects during and after construction. 1265, PC 2i (vii)

13. The ramp construction method shall be selected, consistent with other goals of site characterization, to limit impacts on isolation. 1265, PC 2i (viii)

14. Excavation techniques shall control overbreak of rock and minimize disturbance to the integrity of the adjoining rock mass. 1266, PC 2j (i)

15. Underground openings shall be designed to provide stability and to minimize the potential for deleterious rock movement or fracturing that may create a pathway for radionuclide migration or could impact the capability to reliably and adequately characterize the site. 1266, PC 2j (ii)

16. The following are design goals relating to underground opening stability. These design goals may be modified pending information obtained during site characterization or from future analyses:

    a. In areas not affected by thermal load, closure rate decreasing at all times after construction [rate TBD].

    b. In areas affected by thermal load, closure rate no greater than three times that predicted by theoretical thermoelastic models [rate TBD].

    c. In openings not lined with concrete, no rockfalls greater than a size of [TBD].

    d. Openings shall be maintainable. 1266, PC 2j (iii)

17. Conventional drill and blast excavation may not be the final preferred method of excavation for the emplacement drifts. Alternately, the construction of test alcoves and other short drifts in the ESF may not be amenable to the use of mechanical excavation methods. The term "mechanical excavation" is open to interpretation. The following paragraph includes definitions and elaborates on the above:

    Mechanical excavation methods with machines that break the rock with disc cutters or picks (e.g., tunnel boring machines, roadheaders, or variations of these machines) should be used when feasible and practical. However, controlled drill-and-blast excavation may be used in circumstances where it is determined to be more effective (maneuverability, flexibility, cost, and schedule), and provided that pressurized drill water usage and the chemical byproducts of blasting do not disturb site characteristics related to waste isolation. 1266, PC 2j (iv)

18. Mechanical excavation methods may be used if technically feasible and economically justified. 1266, PC 2j (vii)

19. The design, construction, and operation of the underground excavation shall incorporate aspects specifically directed at limiting, to the extent practicable, adverse effects on the repository long-term performance. 1266, PC 2j (viii)

20. If drill and blast methods are used, specifications shall include controls related to types and amounts of explosives, shot patterns, and hole depth in order to limit the magnitude and extent of blast-induced permeability. 1266, PC 2j (ix)

21. If the shaft or ramp breakouts and main test area level of the ESF are constructed using controlled drilling and blasting methods to limit overbreak and damage to the surrounding rock mass, the methods shall be designed to provide for the requirements of specific site characterization tests, such as limitations on the extent of excavation-induced damage, or the type of ground support that may be installed. The methods shall be designed to facilitate investigation and monitoring of excavation effects during and after construction. 1266, PC 2j (x)

Provision:

THERMAL LOADS. THE UNDERGROUND FACILITY SHALL BE DESIGNED SO THAT THE PERFORMANCE OBJECTIVES WILL BE MET TAKING INTO ACCOUNT THE PREDICTED THERMAL AND THERMOMECHANICAL RESPONSE OF THE HOST ROCK, SURROUNDING STRATA, AND GROUNDWATER SYSTEM (10 CFR 60.133(i)).

Related NRC Concern: (Objection 1, third bullet)

"The analysis presented did not demonstrate that the underground test area layout can accommodate currently identified tests in the ESF while avoiding interference between tests and between test and construction operations. Also, information presented in the SCP did not clearly show that thermal tests can be conducted for sufficient lengths of time to gather necessary site characterization data without interference problems."

Response:

See responses to the following concerns.

Closure Date and Mechanism: During Title II Design

Related NRC Concern: (Objection 1, third bullet, item b)

"The zones of influence presented for thermal tests are based on short test durations. Thermal tests such as the canister-scale heater experiment, heated block test, and heated room experiment are planned to run for relatively short durations (30 months, 100 days, 36 months). The staff considers that longer durations will very likely be necessary. The need to obtain additional site characterization data beyond the planned time periods may result in larger zones of influence."

Response:

ESFAS Option 30, the basis for this ESF design configuration, offers flexibility in main test area layout and greater separation of tests than the SCP ESF design, thereby reducing the potential for test interferences.

In addition, the ESFDR contains requirements for designers to minimize test-to-test interferences.

Closure Date and Mechanism: During Title II Design

Related NRC Concern: (Objection 1, third bullet, item e)

"The location of the canister-scale heater test shown in Figure 8.4.2-39 (p. 8.4.2-209) has been erroneously indicated on the layout. As a result, its zone of influence apparently overlays the heated block test. In addition, the SCP gives the following two constraints for locating the canister scale heater test (p. 8.4.2-120):

located greater than 9 m from drifts or alcoves running parallel to the axis of the heater.

located in a "low traffic" area.

Neither of these constraints has apparently been met."

Response:

During Title II design, the main test area layout will be re-evaluated for test interferences. At that point, the configuration is likely to change, obviating the need to change this particular figure.

Closure Date and Mechanism: During Title II Design

Implementation:

1. The subsurface facilities shall be designed considering the predicted thermal and thermomechanical response of the host rock, surrounding strata, and groundwater system so that the performance objectives of the repository can be met. 1264, PC 2j (i); 1265, PC 2j (i); 1266, PC 2k (i)

2. The predicted loads imposed on shafts, ramps, and underground excavations by heating of the repository waste disposal formation are defined in ESFDR Appendix A.4. These loads shall be considered in the analyses performed to predict the long-term response of the shafts, ramps, and underground excavations. 1264, PC 2j (ii); 1265, PC 2j (ii); 1266, PC 2k (ii)

3. The shaft, ramp, and underground excavation linings shall withstand pressures exerted along their length and around the entire perimeter under anticipated conditions, including reaction to thermally-induced stresses resulting from thermal loads. The provisions [TBD] for thermally-induced stresses can be installed at a later date. 1264, PC 2j (iii); 1265, PC 2j (iii)

4. The ESF shall be designed such that the thermal and thermomechanical effects of ESF operations and testing do not produce failure of intact rock, nor gross rock mass failure, along potential pathways from the repository to the accessible environment and do not significantly increase the saturation of the host rock in the waste emplacement area. 1266, PC 2k (iii)

5. The underground excavation support system shall be designed to withstand pressures under anticipated conditions, including reaction to thermally-induced stresses resulting from thermal loads. 1266, PC 2k (iv)

6. The ESF shall be designed so that the thermal effects of ESF testing do not result in temperatures in excess of 115°C in either the TSw3 or CHn units, compatible with the performance measure for the repository listed in Table 8.3.2.2-4 in Volume III of the Site Characterization Program Baseline (SCPB) for the Yucca Mountain site. 1266, PC 2k (v)

Provision:

GENERAL REQUIREMENTS FOR PERFORMANCE CONFIRMATION. THE GEOLOGIC REPOSITORY OPERATIONS AREA SHALL BE DESIGNED SO AS TO PERMIT IMPLEMENTATION OF A PERFORMANCE CONFIRMATION PROGRAM THAT MEETS THE REQUIREMENTS OF SUBPART F OF THIS PART (10 CFR 60.137).

Related NRC Concern: (Objection 1, third bullet, item a)

"The SCP does not clearly address the potential incompatibility of some of the tests with construction operations. It has not been demonstrated that operational requirements (e.g., storage of mobile equipment, drill steel, blasting materials, vent pipes, water pipes, support/reinforcement, disabled equipment, etc.) will not encroach on some of the identified test locations. For example, sequential drift mining test, heated block test and canister-scale heater experiment are currently shown to be located adjacent to the first loop access drifts to the shafts and therefore subject to potential operational interference."

Response:

Several tests that could be incompatible with the construction of the north ramp will be deferred until after construction. These tests include:

1. Upper Demonstration Breakout Room
2. Heater Experiment in TSw1

3. Overcore Stress
4. Vertical Seismic Profiling
5. Long Radial Boreholes Test
6. Intact Fractures
7. Excavation Effects
8. Shaft Convergence

The only tests proposed during the construction of the TS south ramp are Geologic Mapping, Perched Water (if encountered), and Hydrologic Properties of Major Faults (if encountered). A large main test area is specified for better isolation of tests; more detailed analyses will be conducted during Title II design. In addition, the ESFDR contains requirements for designers to minimize construction-to-test interferences and a Plan for a Phased Approach (PFPA) (DOE, 1991d) describes the testing sequence.

Closure Date and Mechanism: After underground testing begins

Related NRC Concern: (Objection 1, third bullet, item e)

"It is stated in the SCP that in some cases the same space can be used for more than one test by sequencing the tests. However, it is not clear if it has been fully considered that delays during initial testing could affect the timing for the tests to be followed in the same space."

Response:

This concern will be more fully addressed during Title II design. As part of the Title II design effort, the Los Alamos National Laboratory (LANL) Test Manager's Office will provide a test planning package for each test, including a detailed description of the test, the test/design requirements, and schedule/network information relevant to that test. The planning packages will address such things as delays in tests resulting in schedule interferences, and controls to prevent such interferences.

Closure Date and Mechanism: During Title II Design

Related NRC Concern: (Objection 1, third bullet, item d)

"It is not clear that uncertainties have been sufficiently considered in the calculations of zones of influence for various tests. For example, uncertainties associated with the numerical models and material properties have not been considered in calculating zones of influence."

Response:

A test's zone of influence cannot be calculated prior to underground exploration. The uncertainty in the calculation cannot be considered prior to underground testing. Generally, the NRC should not expect any detailed calculations or numerical criteria until after underground exploration begins (see NAS, 1990).

Closure Date and Mechanism: After underground testing begins

Related NRC Concern: (Objection 1, third bullet, item f)

"The locations of several major tests identified in the SCP have not been specifically identified. These include some tests that could have a considerable zone of influence (e.g., heated room experiment) and some that require extensive test area (e.g., horizontal drilling demonstration test). Examples of other tests for which specific locations have not been identified include thermal stress measurements, development and demonstration of required equipment, three of the four diffusion tests identified on p. 8.4.2-140, seal tests and other performance confirmation tests."

Response:

During Title II design, the main test area layout will be re-evaluated. At that point, more specific information, such as test locations, will be provided.

To address NRC's general concern regarding test-to-test interference in the ESF, the ESFDR contains requirements addressing the need for designers to position tests to avoid test-to-test interference. Likewise, the PFPA sequences the tests to avoid test-construction interference.

Closure Date and Mechanism: During Title II Design

Related NRC Concern: (Objection 1, third bullet, item g)

"Page 8.3.2.1-14 of the SCP states that "there are other tests that have not yet been completely defined that will investigate coupled interactions." Information has not been presented to indicate if any of these undefined tests will be in the main test area."

Response:

Until the tests for coupled interactions are more fully defined, the DOE will not know where they will be located. Test Planning Packages, compiled during Title II design, will provide this information. Generally the main test area can accommodate most any type of testing including tests that the NRC may want to conduct.

Closure Date and Mechanism: During Title II Design

Related NRC Concern: (Objection 1, third bullet, item h)

"The space designated for tests within the underground test area layout is very likely to be inadequate. DOE assumes that all the space within the dedicated test area may be or is usable. This is unlikely to be the case. For example, some areas may not be suitable for use because of faults, lithophysal content, breccia, etc. In addition, offsets from waste emplacement areas (30 m) and from proposed multipurpose boreholes (two drift diameters) may further reduce the available test area."

Response:

The specific design, construction, and test packages, as well as the tests described in the SCP, may change during the trade-off studies being performed in preparation for start of Title II design. Before Title II design begins, those aspects of the test program which may be affected by a change in ESF configuration will be identified and documented in the Site Characterization Program Baseline.

Closure Date and Mechanism: 9/91, ESF Title I Design Summary Report, Rev 1

Related NRC Concern: (Objection 1, Recommendations, fourth bullet)

"The ESF Title II Design should present the basis for selected test durations, address the suitability of established test durations, and assess their impact on the testing program."

Response:

This concern will be more fully addressed during Title II design. As part of the Title II design effort, the LANL Test Manager's Office will provide a test planning package for each test, including a detailed description of the test, the test/design requirements, and schedule/network information relevant to that test. The planning packages will address such things as the bases for test durations, delays in tests resulting in schedule interferences, and controls to prevent such interferences. This work is controlled by AP-5.32Q, Test Planning and Implementation Requirements.

Closure Date and Mechanism: Continuous

Implementation:

1. In accordance with 10 CFR 60.137, the ESF site shall be designed to facilitate appropriate performance confirmation measurement and monitoring to obtain adequate and reliable information about the site. The performance confirmation program shall include measurement and monitoring of the performance of the ESF site to the extent that aspects of the site are part of the geologic setting that could contribute to the waste isolation performance of a repository. 1261, Con D

2. The underground excavations shall be designed to accommodate the performance confirmation tests required by 10 CFR 60.141 and 10 CFR 60.142, taking into account any potentially adverse impacts these excavations could have on the waste isolation capabilities of the site. 1264, Con B (i); 1265, Con B (i); 1266, Con B (i)

3. The configuration of a shaft and ramp shall be adequate to support performance confirmation testing, and future testing that may be reasonably expected for performance confirmation. This shall include an allowance to accommodate site-specific conditions encountered in the shaft without adversely affecting planned or ongoing testing. 1264, Con B (ii); 1265, Con B (ii)

4. The accesses to the ESF underground facility shall be designed to facilitate performance confirmation testing to obtain adequate and reliable information about the site, during and after construction, as required for the geologic repository by 10 CFR 60, Subpart F. 1264, Con B (iii); 1265, Con B (iii)

5. The ESF underground excavation shall be of adequate size to support performance confirmation testing and future testing that may be reasonably expected for performance confirmation. This shall include an allowance to accommodate site-specific conditions encountered in the dedicated test area. 1266, Con B (ii)

6. The access breakouts and main test area level of the ESF shall be designed to permit performance confirmation testing to obtain adequate and reliable information about the site, during and after construction, as required for the geologic repository by 10 CFR 60, Subpart F. 1266, Con B (iii)

7. The design of underground utilities for the ESF shall be capable of supporting the performance confirmation testing. 1267, Con G (i)

8. The design of shaft or ramp breakouts and main test area shall have sufficient flexibility to: (1) relocate experiments as necessary to limit interference between tests and aid in ensuring that test location acceptance criteria are met; (2) incorporate additional tests, as needed, in the dedicated test area; (3) allow development and testing in other areas as needed (e.g., southern portion of repository block or Calico Hills formation); (4) accommodate schedule changes as needed; and (5) limit interference between ESF construction and operation activities and testing activities. 1266, PC 1c (iv)

9. The underground utilities for the ESF shall not preclude monitoring and investigation of in situ conditions, and shall be designed to accommodate site-specific conditions, construction, and operation of the ESF. 1267, Con E (ii)

Provision:

GENERAL DESIGN CRITERION. SEALS FOR SHAFTS AND BOREHOLES SHALL BE DESIGNED SO THAT FOLLOWING PERMANENT CLOSURE, THEY DO NOT BECOME PATHWAYS THAT COMPROMISE THE GEOLOGIC REPOSITORY'S ABILITY TO MEET THE PERFORMANCE OBJECTIVES FOR THE PERIOD FOLLOWING PERMANENT CLOSURE (10 CFR 60.134(a)).

SELECTION OF MATERIALS AND PLACEMENT METHODS. MATERIALS AND PLACEMENT METHODS FOR SEALS SHALL BE SELECTED TO REDUCE, TO THE EXTENT PRACTICABLE, THE POTENTIAL FOR CREATING A PREFERENTIAL PATHWAY FOR GROUNDWATER TO CONTACT THE WASTE PACKAGES OR FOR RADIONUCLIDE MIGRATION THROUGH EXISTING PATHWAYS (10 CFR 60.134(b)(1) and (2)).

Related NRC Concern: (Objection 1, first bullet, item b)

"The design of the ESF should take into account the need for preliminary information from in situ seal testing to be available in the License Application submittal."

Response:

The ESFAS addressed this concern in ranking the 34 options. Should the DOE decide to perform in situ seal testing earlier than currently planned, the ESF main test area layout now contains additional space beyond the base case to accommodate such testing.

Closure Date and Mechanism: ESF Alternatives Study Final Report (pending) and 9/91, ESF Title I Design Summary Report, Rev 1

Implementation:

1. Access design and construction shall allow for future sealing in shafts, declines, or drifts to ensure that they do not become preferential pathways for groundwater or radioactive waste migration. In addition, techniques used to seal aquifers during access construction should not preclude use, or reduce the effectiveness, of future access seals. 1264, PC 2k (i); 1265, PC 2k (i); 1266, PC 2l (i)

2. To prevent complications of seal evaluations and emplacement and limit chemical alteration in future seal environments, no pressure grouting shall take place during the construction period of the shaft at locations of potential seal testing or emplacement. Specifically, no pressure grouting shall be performed within 50 feet of the original ground surface and within 50 feet (above and below) the contact of the Pah Canyon and Topopah Spring tuffs, or below the main test area level. 1264, PC 2k (ii); 1265, PC 2k (ii)

3. Design, construction, and materials used in the construction of shafts and ramps (e.g., epoxies and lean grouts need to be evaluated prior to use) shall not significantly interfere with or prevent the eventual

installation of the features required to effect postclosure repository sealing. Specific banned items and activities are to be determined at the direction of the Yucca Mountain Site Characterization Project Office. The major areas in which these limitations apply are as follows:

a. Immediately below the shaft collar or the TS portal structure in the area where an anchor-to-bedrock seal installation is planned to be installed at the time of shaft closure.

b. At the interface between the nonwelded tuff (PTn) and the Topopah Spring tuff (TSw).

c. In the extension of the shaft below the ESF main test area level. 1264, PC 2k (iii)(a-c); 1265, PC 2k (iii)(a-c)

NOTE: The above limitations are not intended to apply to the locations of the radial borehole tests.

4. Pressure grouting during or after construction shall not be permitted in a zone extending 50 feet above and below locations planned for installation of anchor-to-bedrock seals or below the main test area level. 1264, PC 2k (iv); 1265, PC 2k (iv)

5. Materials and placement methods for shaft, ramp, and borehole seals shall be selected to reduce, to the extent practicable, the potential for creating preferential pathways for groundwater to contact the waste packages or to reduce radionuclide migration through existing pathways. 1264, PC 2k (v); 1265, PC 2k (v)

6. Any fill or other construction materials used in the floors of the drifting within the ESF in areas that may adversely impact implementation of post-closure sealing shall be removable. 1266, PC 21 (ii)

7. The 150-foot long, full-sized portion of the drift driven toward the Ghost Dance fault shall be excavated consistent with the requirements imposed by the sealing program. 1266, PC 21 (iii)

8. The ESF underground facility operational seals shall be designed, consistent with other goals of site characterization, to limit impacts on isolation. If the seals are determined to be important to waste isolation, a comparative evaluation of alternatives shall be performed. 1266, PC 21 (iv)

9. Operational seals shall be provided where necessary to control the spread of water through the facility. [10 CFR 60.134(a)(2)] 1266, PC 21 (v)

10. Grouting during ESF construction shall have the following limitations:

a. Pressure grouting is not permitted during or after construction in the ESF dedicated test area connection drifts and access station drifts for a distance of 50 feet from the panel access drift as shown in ESFDR Appendix A.2.

b. In the drift excavated to investigate the Drill Hole Wash structure, no pressure grouting is to be performed during or after construction in the fault or within the limits of the enlarged drift (approximately 150 ft.) driven through the fault (see drawings in ESFDR Appendix A.2).

c. No pressure grouting is to be performed in the 150-ft long full-sized portion of the drift driven toward the Ghost Dance fault.

d. In the drift excavated to investigate the Ghost Dance fault, no pressure grouting is to be performed during or after construction in the fault or within the limits of the enlarged drift (approximately 126 ft.) driven through the fault (see drawings in ESFDR Appendix A.2). 1266, PC 21 (vi)(a-d)

11. Seals for shaft or ramps and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure. Materials and placement methods for seals shall be selected to reduce, to the extent practicable, (1) the potential for creating a preferential pathway for groundwater to contact the waste packages or (2) for radionuclide migration through existing pathways. 1260, Con H

Provision:

THE QUALITY ASSURANCE PROGRAM APPLIES TO ALL SYSTEMS, STRUCTURES AND COMPONENTS IMPORTANT TO SAFETY, TO DESIGN AND CHARACTERIZATION OF BARRIERS IMPORTANT TO WASTE ISOLATION AND TO ACTIVITIES RELATED THERETO. THESE ACTIVITIES INCLUDE: SITE CHARACTERIZATION, FACILITY AND EQUIPMENT CONSTRUCTION, FACILITY OPERATION, PERFORMANCE CONFIRMATION, PERMANENT CLOSURE, AND DECONTAMINATION AND DISMANTLING OF SURFACE FACILITIES (10 CFR 60.151).

Provision:

DOE SHALL IMPLEMENT A QUALITY ASSURANCE PROGRAM BASED ON THE CRITERIA OF APPENDIX B OF 10 CFR 50 AS APPLICABLE, AND APPROPRIATELY SUPPLEMENTED BY ADDITIONAL CRITERIA AS REQUIRED BY SECTION 60.151 (10 CFR 60.152).

Provision:

MEASURES SHALL BE ESTABLISHED TO ASSURE APPLICABLE REGULATORY REQUIREMENTS AND THE DESIGN BASIS, AS DEFINED IN §50.2 AND AS SPECIFIED IN THE LICENSE APPLICATION, FOR THOSE STRUCTURES, SYSTEMS, AND COMPONENTS TO WHICH THIS APPENDIX APPLIES ARE CORRECTLY TRANSLATED INTO SPECIFICATIONS, DRAWINGS, PROCEDURES, AND INSTRUCTIONS... (10 CFR 50.2, Appendix B, III. Design Control)

Related NRC Concern: (Objection 1, second bullet, item a)

"The Design Acceptability Analysis (DAA) undertaken by DOE in response to NRC concerns for evaluating the acceptability of the ESF Title I design did not consider certain concerns critical to NRC acceptance of DAA conclusions.

Independence of the reviewers is in question. Five reviewers who were certified not to have significantly contributed to the ESF Title I design and SDRD (sub-system design requirements) are identified as authors, reviewers, and/or contributors to specific documents which were input documents to the ESF design." (Question 63)

Response:

DOE believes that the standard of independence for Technical Assessment Review (TAR) (DOE, 1990b) team members that was established for the review of ESF Title I design was appropriate and that the standard was met. The Quality management procedure that governs the TAR process, QMP-02-09 (DOE 1), specifies that it is the responsibility of the TAR chairperson to establish minimum qualifications for review team members, including independence, to accomplish the scope and purpose of the review. In this case, the standard for sufficient independence that was established by the chairperson was that review team members must not have been principal contributors to the ESF Title I design or the Exploratory Shaft [sic] Design Requirements (ESFDR) document that was used as the basis for the ESF Title I design. In the judgment of the TAR chairperson, none of the review team members had sufficient prior involvement with the Title I design to feel that they were reviewing their own work. Furthermore, the DOE believes that the quality of the review would have suffered had the team been comprised only of people who had no prior connection with, and knowledge of, the ESF Title I design.

Closure Date and Mechanism: N/A, Project procedures ensure independence of reviewers.

Related NRC Concern: (Objection 1, Recommendations, first bullet)

"An acceptable baselined QA process should be used during Title II design."

Response:

The NRC staff has accepted the DOE's overall QA program and has lifted their objection to the specific programs associated with Midway Valley Trenching and Calcite-Silica Activities (NRC, 1991). The DOE, in turn, has approved most of its participants' quality programs. The NRC staff may continue to participate in quality verification activities, as well as conduct independent surveillances or audits.

Closure Date and Mechanism: Date is [TBD]; NRC may continue to audit and surveil the program.

Provision:

THE SAFETY ANALYSIS REPORT SHALL INCLUDE AN ASSESSMENT OF:...THE EFFECTIVENESS OF ENGINEERED AND NATURAL BARRIERS, INCLUDING BARRIERS THAT MAY NOT BE THEMSELVES A PART OF THE GEOLOGIC REPOSITORY OPERATIONS AREA, AGAINST THE RELEASE OF RADIOACTIVE MATERIAL TO THE ENVIRONMENT. THE ANALYSIS SHALL ALSO INCLUDE A COMPARATIVE EVALUATION OF ALTERNATIVES TO THE MAJOR DESIGN FEATURES THAT ARE IMPORTANT TO WASTE ISOLATION, WITH PARTICULAR ATTENTION TO THE ALTERNATIVES THAT WOULD PROVIDE LONGER RADIONUCLIDE CONTAINMENT AND ISOLATION. (10 CFR 60.21(c)(1)(ii)(D)).

Related NRC Concern: Objection 1, second bullet, item d; also Comment 132)

"The Design Acceptability Analysis (DAA) undertaken by DOE in response to NRC concerns for evaluating the acceptability of the ESF Title I design did not consider certain concerns critical to NRC acceptance of DAA conclusions.

Of the 22 requirements that were considered quantitatively, some inadequacies have been identified. For example, in considering the regulatory requirements related to alternatives to major design features important to waste isolation (60.21(c)(1)(ii)(D)), the analysis presented was limited and incomplete. As a result, comparative evaluation of alternatives to the major design features was limited to comparative evaluation of five alternative ESF locations. Hence other comparative evaluations such as the number of man-made openings were not considered." (Comment 132)

Response:

The requirement to analyze alternative designs (10 CFR 60.21(c)(1)(ii)(D)) was addressed in the ESFAS. The following material is an abbreviated description of that study. Refer to the ESF Alternatives Study Final Report (SNL, 1991) for a complete description of the study.

This study examined 34 ESF/repository configurations, each consisting of an assembly of different major design features (see Table 7-2). Options 1 through 17 would systematically characterize the shallow (Topopah Spring) then the deep (Calico Hills) strata, while options 18 through 34 would proceed as quickly as possible to the Calico Hills and, thereby, provide early investigation of a major natural barrier. The comparison process focused on the ability of major design features, presented as elements of influence diagrams, to meet important ESF/repository influence diagram objectives. Influence diagrams presented the series of related factors and judgments that influenced a particular objective. Objectives included important performance aspects such as:

- Limit postclosure releases to the accessible environment;
- Provide preclosure worker and public safety;
- Provide a characterization testing program;
- Obtain regulatory approval; and
- Others.

Evaluation of each option against the set of influence diagrams was done by expert panels and produced a probability of meeting that objective. These probabilities were then factored into a series of two decision trees to obtain a final "score" for each option. The options were ranked on the basis of final score and presented to DOE. From the ranked alternatives, DOE selected option 30, with modifications, to form the basis for Title I design.

The designers of the ESFAS consider that the study met the intent of 10 CFR 60.21(c)(1)(ii)(D) to the degree appropriate at this phase of the design process. During Title II design, additional comparisons of design features will be required. This process is reflected in ESFDR requirements which originated from the DAA and which call for comparative analysis of items important to waste isolation for each ESF physical subsystem. In addition, in Appendix I of the ESFDR SNL has acknowledged that this requirement will require performance assessment support during Title II design.

Table 7-2. Alternatives of Major Design Features.

Major Design Feature	Alternatives
1. Means of Access	Shafts only Ramps only Shaft/ramp combination
2. Location of Accesses	All in northeast All in south Combination of locations
3. Location of Main Test Area (MTA) Core Area in Topopah Spring (TS)	Northeast South

4.	Method of Excavating Openings	Shafts	-Drill and Blast -Shaft Boring Machine -Blind Hole Drill -V-mole -Raise Bore
		Ramps	-Tunnel Boring Machine (TBM) -Roadheader -Drill and Blast
		MTA (TS) core area	-Drill and Blast -Mobile Miner -TBM*
		Exploratory drifting in TS & CH	-Drill and Blast -Mobile Miner -TBM -Roadheader
5.	Total Number of Accesses	ESF accesses are an integrated subset of the total number of accesses for the repository	

*TBM not specifically considered for MTA excavation but is expected to be an acceptable alternative.

Closure Date and Mechanism: 1991, ESF Alternatives Study Final Report (pending)

Implementation:

DOE has directed its architect/engineer contractor, Raytheon Services of Nevada (RSN), to incorporate the highest-ranked option, Option 30 of the ESFAS, into the ESF Title I design.

Some modifications have been made to Option 30. For example, the main test area has been moved to the northeast portion of the area of interest. Some additional modification of the highest-ranked option could improve certain features without significantly degrading the option overall. One modification suggested during the ESFAS was raising the repository relative to the water table. A second modification suggested was a repository design that reduces the drifting through the Ghost Dance fault from the base case. The addition of major features would require detailed analyses to balance their favorable and adverse effects.

Although future modifications of a selected option were not the subject of this study, any such modifications may be accomplished in accordance with the design control process. Selected key features that may be considered for change will be subject to engineering trade-off studies during the design phase. It is expected that conventional engineering and mine design methodologies, along with performance assessment, will be used to refine or improve all features of the selected baselined option. As an example, trade-off studies may suggest that certain test areas of an option with a drill-and-blast main test area should be excavated mechanically to minimize chemical or mechanical disturbance to the rock to be tested.

REFERENCES

Bertram, S.G., 1984. NNWSI Exploratory Shaft Site and Construction Method Recommendation Report, SAND84-1003, Sandia National Laboratories, Albuquerque, NM

DOE (U.S. Department of Energy), 1980. In the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking), DOE/NE-0007, Washington, D.C.

DOE (U.S. Department of Energy), 1984. Draft Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0012, Washington, D.C.

DOE (U.S. Department of Energy), 1986. Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0073, 3 vols., U.S. Department of Energy, Washington, D.C.

DOE (U.S. Department of Energy), 1987. OCRWM Mission Plan Amendment with Comments on the Draft Amendment and Responses to the Comments, DOE/RW-0128, Washington, D.C.

DOE (U.S. Department of Energy), 1988a. Consultation Draft Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Office of Civilian Radioactive Waste Management, Washington, D.C., January, 1988

DOE (U.S. Department of Energy), 1988b. Draft 1988 Mission Plan Amendment, DOE/RW-0187, Office Of Scientific and Technical Information, Oak Ridge, TN

DOE (U.S. Department of Energy), 1988c. Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report, YMP/88-02, U.S. Department of Energy, Nevada Operations Office, Yucca Mountain Project Office, Las Vegas, NV

DOE (U.S. Department of Energy), 1988d. Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area (DOE/RW-0199), Office of Civilian Radioactive Waste Management, Washington, D.C., December, 1988

DOE (U.S. Department of Energy), 1989a. Design Acceptability Analysis, Yucca Mountain Site, Nevada Research and Development Area, Office of Civilian Radioactive Waste Management, Washington, D.C., February, 1989

DOE (U.S. Department of Energy), 1989b. The Department of Energy Management Assessment of Alternative Methods for Exploratory Shaft Construction/Testing Sequences and Additional Exploratory Drifting in Response to Suggestions from the Structural Geology and Geoengineering Panel of the Nuclear Waste Technical Review Board, Office of Civilian Radioactive Waste Management, Washington, D.C., August, 1989

DOE (U.S. Department of Energy), 1990a. Responses to the Nuclear Regulatory Commission (NRC) Site Characterization Analysis (YMPO/90-107), Yucca Mountain Site Characterization Project, Las Vegas, Nevada, December, 1990

DOE (U.S. Department of Energy), 1990b. Yucca Mountain Project Technical Assessment Review (TAR) Review Record Memorandum (RRM), Geologic and Geophysical Evidence Pertaining to Structural Geology in the Vicinity of the Proposed Exploratory Shaft (YMP/90-2), Yucca Mountain Site Characterization Project, Las Vegas, Nevada, January, 1990

DOE (U.S. Department of Energy), 1991a. Waste Management Systems Requirements, Volume IV: Mined Geologic Disposal System, Revision I, Office of Civilian Radioactive Waste Management, Washington, D.C., January, 1991

DOE (U.S. Department of Energy), 1991b. Record Memorandum Risk/Benefit Analysis of Alternative Strategies for Characterizing the Calico Hills Unit at Yucca Mountain (YMP/91-6), Yucca Mountain Site Characterization Project, Las Vegas, Nevada, January, 1991

DOE (U.S. Department of Energy), 1991c. Exploratory Studies Facility Design Requirements, YMP/CC-0013, Yucca Mountain Site Characterization Project, Las Vegas, Nevada, May 1991

DOE (U.S. Department of Energy), 1991d. Plan for the Phased Approach to ESF Design, Development and Implementation (YMP/91-13), Yucca Mountain Site Characterization Project, Las Vegas, Nevada, February, 1991

DOE (U.S. Department of Energy), 1991e. Reference Information Base (YMP/CC-0002), Yucca Mountain Site Characterization Project, Las Vegas, Nevada, January, 1991

DOE (U.S. Department of Energy), 1991f. Letter, Gertz to Bullock, February 2, 1991, "Authorization for Conducting a Design Study to Develop a Reference Exploratory Shaft Facility (ESF) Design to be used as Input to Title I Design Summary Report (Work Breakdown Structure 1.2.6).

DOE (U.S. Department of Energy) 1. Yucca Mountain Site Characterization Project Administrative Procedures, Vol. 2 of 3.

DOE (U.S. Department of Energy) 2. Yucca Mountain Site Characterization Project Office Quality Management Procedures.

Fernandez, J.A., T.E. Hinkebein, and J.B. Case, 1988. Selected Analyses to Evaluate the Effect of the Exploratory Shafts on Repository Performance at Yucca Mountain, SAND85-0598, Sandia National Laboratories, Albuquerque, NM.

Golder Associates, Inc., 1989. "Evaluation of Alternative ESF Shaft Construction Methods and Test Sequences," report number 833-1017.116, Redmond, WA. Prepared for U.S. DOE, Office of Civilian Radioactive Waste Management.

NAS (National Academy of Sciences), 1990. Rethinking the High-Level Radioactive Waste Disposal, National Academy Press, Washington, D.C., July, 1990

NRC (U.S. Nuclear Regulatory Commission), 1981. "Disposal of High-Level Radioactive Wastes in Geologic Repositories: Licensing Procedures," Federal Register, Vol. 46, pp. 13971-13987

NRC (U.S. Nuclear Regulatory Commission), 1986. "Disposal of High-Level Radioactive Wastes in Geologic Repositories; Conforming Amendments," Federal Register, Vol. 51, Washington, D.C., pp. 22288-22300

NRC (U.S. Nuclear Regulatory Commission), 1988a. Review Plan for NRC Review of DOE's Site Characterization Plan, Division of High-Level Waste Management, Washington, D.C., December 12, 1988

NRC (U.S. Nuclear Regulatory Commission), 1988b. NRC Staff Review of the Department of Energy's January 8, 1988 Consultation Draft Site Characterization Plan for the Yucca Mountain Site, Division of High-Level Waste Management, Washington, D.C., May, 1988

NRC (U.S. Nuclear Regulatory Commission), 1989. NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada (NUREG-1347), Division of High-Level Waste Management, Washington, D.C., August, 1989

NRC (U.S. Nuclear Regulatory Commission), 1990. Draft Technical Position on Regulatory Considerations in the Design and Construction of the Exploratory Shaft Facility, Division of High-Level Waste Management, Washington, D.C., June, 1990

NRC (U.S. Nuclear Regulatory Commission), 1991. May 11, 1991 letter from John J. Linehan (NRC) to Dwight E. Shelor (DOE)

NWTRB, 1990. First Report to the U.S. Congress and the U.S. Secretary of Energy from the Nuclear Waste Technical Review Board, Washington, D.C.

SAIC (Science Applications International Corporation), 1991. Letter, King to Gertz, dated July 29, 1991, "Selection of Reference Design Concept Which Includes Favorable Features of the Highest Ranked Options from Exploratory Shaft Facility Alternatives Study (ESFAS), Contract No. DE-AC08-87NV10576"

SNL (Sandia National Laboratories) and Parsons Brinckerhoff Quade & Douglas, Inc., 1984. Recommendation for a Second Access for the Yucca Mountain Exploratory Shaft Facility, Sandia National Laboratories, Albuquerque, NM

SNL, 1987. Site Characterization Plan Conceptual Design Report, SAND84-2641, 6 vol. Sandia National Laboratories, Albuquerque, NM

SNL, 1990. Findings of the ESF Alternatives Study, SAND90-3232. Sandia National Laboratories, Albuquerque, NM

SNL, 1991 (pending). Exploratory Studies Facility Alternatives Study (ESFAS) Final Report, SAND91-0025. Sandia National Laboratories, Albuquerque, NM

Weston, Roy F., Inc., 1989. Evaluation of Additional Drifting for Site Characterization at Yucca Mountain, Washington, D.C., July, 1989. Prepared for U.S. DOE Office of Civilian Radioactive Waste Management.