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Yucca Mountain Site Characterization Project

Exploratory Studies Facility Alternatives Study: Final Report

Volume 1: Executive Summary, Supporting Information, and Study Conclusions

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EXPLORATORY STUDIES FACILITY ALTERNATIVES STUDY FINAL REPORT

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ABSTRACT

An Exploratory Studies Facility (ESF) is planned for use in the characterization of a potential site for a high-level nuclear waste repository at Yucca Mountain, NV. A comparative evaluation of ESF-repository design options was conducted for the Department of Energy's Yucca Mountain Site Characterization Project Office. The purposes of the evaluation were to identify and rank order ESF-repository options and to improve understanding of the favorable or unfavorable features of an ESF design. The evaluation relied on techniques from decision analysis, including decision trees and multiattribute utility analysis (MUA). Decision trees provided a means for evaluating decisions under uncertainty. MUA provided a means for evaluating decisions with multiple, possibly competing objectives. Thirty-four ESF-repository options were evaluated and ranked based on inputs provided by 11 panels composed of technical specialists and one panel composed of senior managers. With guidance from decision analysts, the technical specialists developed the measures for quantifying performance; identified, developed, and analyzed scenarios for the development and operation of the ESF and the potential repository; and provided estimates of the probabilities of uncertainties and the performance of each option against various performance measures. With similar guidance, the senior managers specified the objectives and criteria for the evaluation, the value tradeoffs among objectives, and the attitude toward risk used in the analysis.

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Design Investigation Memo 241, Selection of Evaluation Panel Members

Design Investigation Memo 242, Development of Preliminary Screening

Design Investigation Memo 243, Identification of Repository Access and ESF Options

Design Investigation Memo 244, Identification of Repository and ESF Design, Performance and Construction Requirements

Design Investigation Memo 245, Development of Influence Diagrams and Performance Measures for the ESF Alternatives Study

Design Investigation Memo 246, Exploratory Shaft Facility (ESF) Alternatives Evaluation Study - Task 7 Subtask-Testing

Design Investigation Memo 249, ESF Alternatives Study Task 1. Plan Management

Design Investigation Memo 250, ESF Alternatives Study Task 6. Final Report

Design Investigation Memo 251, Evaluation of Repository/ESF-Feature Performance Discriminators

Design Investigation Memo 252, Application of Management and Policy-Based Judgments to the ESF Alternatives Study

Design Investigation Memo 254, Scoring of Options for the ESF Alternatives Study

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TABLE OF CONTENTS

VOLUME 1

TABLE OF CONTENTS (continued)

VOLUME 1

TABLE OF CONTENTS (continued)

VOLUME 1

TABLE OF CONTENTS (concluded)

VOLUME 1

TABLE OF CONTENTS

VOLUME 2

TABLE OF CONTENTS (continued)

VOLUME 2

TABLE OF CONTENTS (concluded)

VOLUME 2

LIST OF FIGURES

VOLUME 1

LIST OF FIGURES

VOLUME 2

LIST OF FIGURES (concluded)

VOLUME 2

LIST OF TABLES

VOLUME 1

LIST OF TABLES

VOLUME 2

LIST OF TABLES (concluded)

VOLUME 2

VOLUME 1

EXECUTIVE SUMMARY, SUPPORTING INFORMATION, AND STUDY CONCLUSIONS

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EXECUTIVE SUMMARY

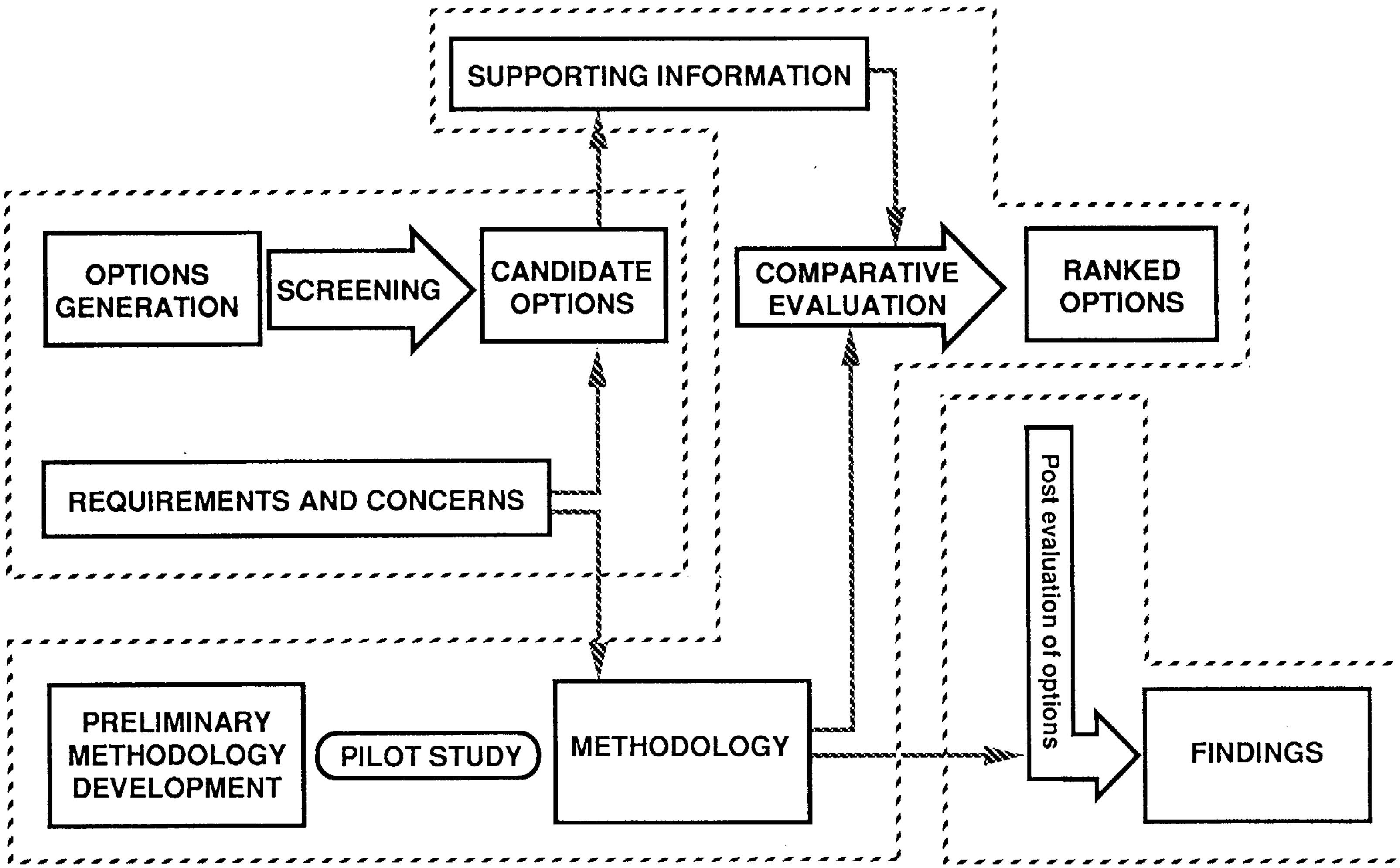

Figure 1. ESF Alternatives Study

EXECUTIVE SUMMARY

INTRODUCTION

The Yucca Mountain Site Characterization Project Exploratory Studies Facility Alternatives Study (ESF-AS) Implementation Plan directed Sandia National Laboratories (SNL) to lead a study that would identify various ESF-repository configurations and construction methods (together called options), identify all requirements and concerns applicable to the ESF and repository, and comparatively evaluate the options relative to those requirements and concerns. The Calico Hills Risk/Benefit Analysis, conducted parallel to and integrated with this study, addressed a Nuclear Regulatory Commission (NRC) objection to the draft Site Characterization Plan (SCP), and provided a recommendation to this study that the selected option should be able to support extensive drifting in the Calico Hills rock unit. The ESF-AS incorporated these recommendations and further evaluated the benefits to the test program, as well as the waste isolation impacts for the features of each complete ESF option. The evaluation of the options was completed and documented in the Findings of the ESF Alternatives Study (Stevens and Costin, 1991). This final report completes the documentation of the study.

The principal activities of the ESF-AS are illustrated in Figure 1, which is structured according to the flow of those activities. In the remainder of this summary, the evolutionary process that led to the selection of 34 ESF options is discussed, followed by the decision methodology that provided the framework for the comparative evaluation and the rank order of the 34 ESF options in terms of their relative desirability. A compilation of the principal evaluation factors and design features that were found to be influential in establishing the rank ordering of the options is described next. Finally, the findings of the Alternatives Study are summarized. The remainder of Volume I and Volume II of this report provide the details of the study.

ESF-REPOSITORY OPTIONS AND REQUIREMENTS

An option was defined as the combination of an ESF configuration and associated construction methods integrated with a repository configuration to provide compatible interfaces between the ESF and repository.

For each option, the accesses and other ESF interfaces with a repository were defined in the context of a total ESF-repository system so that ESF accesses were compatible with and had integral functions in the repository. In the sense used here, configuration refers to the conceptual physical layout of accesses and underground works.

In the initial part of the study, all previous ESF and repository conceptual configurations were reviewed and new ESF-repository configurations were generated. New configurations were developed to address regulatory and other requirements, as well as to address comments and concerns expressed by the Nuclear Waste Technical Review Board (NWTRB) and the NRC. Therefore, all options are expected to meet the requirements of 10 CFR Part 60. In addition, a number of major design features were addressed in various ways within the new options so that a direct comparative evaluation of features embedded in a number of different ESF-repository systems could be made.

After the previous ESF and repository configurations had been identified and new options prepared, a screening of options was conducted to reduce the number of possible options to a set that would be evaluated in detail. As a result of this screening process and the subsequent review, 17 options were identified for further evaluation.

A series of events then occurred that significantly altered the number and content of the options and required revision of the methodology used for comparative evaluation of the options. The events were:

(1) The Calico Hills Risk/Benefit Assessment Working Group provided input to the ESF-AS on June 30, 1990, that added extensive drifting in the Calico Hills unit to each of the ESF configurations.

(2) The NWTRB (in its First Report to Congress) confirmed its previous recommendation for the addition of an east-west drift in the Topopah Spring unit to detect potential north-south trending faults.

(3) At an ESF-AS Management Panel meeting on August 8, 1990, the Department of Energy (DOE) directed the ESF-AS to evaluate each option considering two alternative characterization-testing strategies. These were (a)

primary emphasis on early access to the Topopah Spring unit, and (b) primary emphasis on early access to the Calico Hills unit.

On the basis of the first two events, the design configurations for the 17 ESF options were updated to include 19,000 feet of exploratory drifting in the Calico Hills unit and an east-west drift in the Topopah Spring unit. The third event led to the development of 17 additional options to accommodate the two alternative characterization-testing strategies. The testing strategy for Options 1 through 17 consisted of the systematic progression of construction and site-characterization testing from the surface down the accesses to the Topopah Spring and then on down to the Calico Hills. In contrast, the testing strategy for Options 18 through 34 was to proceed to the Calico Hills as rapidly as possible to make an early determination of suitability (or unsuitability) of the principal natural barrier, while conducting only those tests in the accesses necessary to acquire site data that would be irrecoverable if not acquired during initial construction. An option was now defined as a physical configuration and construction method plus a testing strategy (two testing strategies per configuration). That is, under this definition, there are 17 pairs of options (1 and 18, 2 and 19, 3 and 20, etc.). In the case of a few pairs, the physical configuration was modified to better address the objective of the second strategy. Within each strategy, early and late testing phases were defined so that the relative value of early information from each test strategy could be assessed for the purpose of an early determination of suitability.

As indicated in Figure 1, requirements were a major component of this study. Requirements, as a category, includes such things as (1) federal, state, and local regulatory requirements, and (2) DOE orders, requirements documents, and guidance, as well as (3) concerns expressed by oversight agencies (e.g., NRC, NWTRB, State of Nevada). These requirements were cross-correlated with the factors that influence the probabilities and performance measures.

COMPARATIVE EVALUATION

The comparative evaluation was based on formal decision analysis and is discussed in detail in Volume 2 of this report. Prior to conducting the main analysis, a pilot study was conducted to test the feasibility of the approach and to identify the considerations that would be most important for the analysis to address. The pilot study results suggested that the choice of an ESF option might significantly affect future uncertainties, such as the likelihood of license approval, and could affect ultimate repository consequences, such as postclosure releases.

Accordingly, the main analysis consisted of two major components. First, the uncertain future events and decisions potentially impacted by the choice of an ESF option were identified. These uncertainties defined six alternative future scenarios, which were represented in a decision tree. The analysis included an assessment of how the probabilities of each possible scenario depended on the selected option. Second, the end consequences of each possible future scenario were estimated using multiattribute utility analysis (MUA).

The consequences for each scenario were estimated by expert panels. Scaling and weighting functions were applied to the estimated numerical value of each measure for a given option and scenario and then summed to obtain an aggregate measure of the net benefit of that scenario. Net benefit was defined as the benefit of getting to a particular end point in the tree (scenario), minus the consequences of getting there. The purpose of scaling the consequence measures was to allow them to be expressed in a common set of units and to weigh their relative value. In this analysis, all consequences were expressed as equivalent dollar amounts. Because the scaling factors represented a value judgment and not a technical judgment, a management panel, independent of the expert panels, was used to determine the scaling factors for each measure.

The assumed benefit of obtaining a closed repository was somewhat arbitrary, but was assumed to be larger than the total consequences; otherwise, the analysis would indicate that the best option would be the one that maximized the probability of doing nothing (which would produce the fewest consequences). A benefit of $50 billion was assumed for a closed repository. Waste retrieved, but kept at site, was assigned a benefit of $2 billion. A zero benefit was assumed for all other scenarios. The value of the benefits assumed was found not to affect the ranking of the alternatives as long as the total benefit is much larger than the total consequences.

The aggregate score for each option was determined by solving the decision tree. The solution was produced by multiplying the probability of each scenario through the tree by the net benefit of that scenario and summing over all scenarios. The overall score was then the expected net benefit of a particular option.

Because of insufficient data and large uncertainties in the numerical values that would be required to perform the actual quantitative evaluation, the estimates of probabilities and consequences were generated by expert panels. When estimating a given consequence measure or probability, each panel was asked to provide a best estimate value, a high estimate and a low estimate. The best estimate value was used as input to the model to determine the overall score. The high and low values were used as the extreme values for the measure in sensitivity studies. Before scoring, expert panels developed influence diagrams for each probability and consequence measure. This was done to determine the major factors that must be considered when evaluating an option with respect to a given performance measure.

In addition to the influence diagrams, the panels were provided with a substantial amount of reference information regarding the options, the applicable requirements, previous analytical results, and other guidance. The development of much of this supporting information is presented in Volume 1 of this report. Once the influence diagrams were completed for each criterion, a subset of the applicable regulations, requirements, and other concerns that were determined to be potentially discriminatory (i.e. would allow for discrimination) between options were cross-correlated with the factors on the influence diagrams. This was done for two purposes: first, to ensure that all applicable requirements, regulations, etc. were being taken into account in the assessments through evaluations against the criteria; and, second, to provide the evaluators with information as to exactly what regulations, requirements, etc. should be considered during an evaluation against a particular criterion.

Once the evaluations were complete, a series of sensitivity studies was performed to assess the sensitivity of the ranking to input judgments and other assumptions. Analyses were also performed to determine which of the evaluation criteria were the most important or influential to determining the ranking.

An overall rank ordering of the options, which are described in Section 5 of Volume I, is presented in Table 1. The relative value of the options is quantified by a normalized figure of merit. The figure of merit used was based on the expected net benefit of each option as calculated by solving the decision tree with the best estimate values of each probability and consequence estimate. The expected net benefit for each option was then normalized by scaling the highest ranked option to 100 points in dimensionless units rounded to the nearest point. It should be noted that this ranking was derived from consensus or majority views expressed by each panel. Alternative views (minority reports) were also recorded by several of the expert panels.

There were a number of cases in which panel consensus was not obtained when assessing the best judgment values for a measure. In some cases the differences between majority and minority views were a matter of degree. That is, the rationale leading to the assessment of a value was essentially the same, but the assigned value differed. In other cases, differences in rationale were sufficient to lead to considerably different results.

With the exception of the minority report on programmatic viability, the ranking was found to be largely insensitive to the disagreements that prevented panel consensus. The minority report on programmatic viability was provided by one member of the Programmatic Viability Panel who expressed a view that was considerably different from the remaining six-member majority. The minority view resulted in a large number of the options receiving a probability of 1.0, expressing the fact that he was certain any one of the number of options could be implemented. In addition, the minority view expressed concern that more emphasis should be given to the potential for early delays that might be caused by differences in options, and less emphasis given to other concerns. Resolution of NRC and NWTRB comments and concerns was important to the majority of panel members in assessing programmatic viability.

ANALYSIS OF PRINCIPAL FACTORS AND FEATURES

An initial objective of the ESF-AS was to comparatively evaluate design features, and as a result, identify those features that, if incorporated into a given option, would result in that option being more favorably rated. A list of potentially favorable features could then form the basis for developing new options, or altering existing options, to produce

TABLE 1

ESF-AS
RANK ORDER OF 34 ALTERNATIVE DESIGN OPTIONS

Option	Normalized Figure of Merit	Overall Ranking*
30	100	1st
23	96	2nd
24	94	3rd
13	93	4th
6	91	5th
7	90	6th
2	85	7th
19	84	8th
25	82	9th
4	81	10th
21	80	11th
28	79	12th
22	73	13th
29	69	14th
32	69	15th
27	67	16th
20	67	17th
8	66	18th
31	65	19th
15	63	20th
33	63	21st
5	59	22nd
12	56	23rd
3	56	24th
16	56	25th
11	56	26th
1	50	27th
14	47	28th
10	46	29th
18	45	30th
17	45	31st
34	40	32nd
26	31	33rd
9	25	34th

*Assumes benefit of a functioning repository is $50 B or more.

options that would rate better overall than any of the current options. The approach taken was to select options that displayed a wide range of specific features and different combinations of those features. Thus, the relative merit of trade-offs between design features (such as shafts versus ramps) could be evaluated in the context of their performance in the ESF-repository system. The five principal design features that were varied from option to option were (1) means of access, (2) location of access, (3) location of the main test level (MTL), (4) excavation methods used, and (5) total number of ESF-repository accesses.

It was also recognized that other features not previously identified as being of potential importance, but incorporated in a number of options, might be identified as being favorable (or unfavorable) as a result of the comparative evaluation. Several of these features were indeed identified, including (1) not having a constructed pathway for gravity flow of water from the repository to the Calico Hills, (2) increasing the elevation of the repository above the water table, (3) avoiding emplacement drifts crossing at the Ghost Dance Fault, (4) large exposure of rock during site characterization, and (5) flexibility for early exploration of both the Topopah Spring and Calico Hills units. In addition, comments from the NWTRB and the NRC resulted in the incorporation of several changes to the options as the study was being implemented. The features, such as a second crossing of the Ghost Dance Fault, were incorporated in different ways in different options. Therefore, even though all options contained some of these features, a comparison of how they were incorporated was performed.

An effort was made to verify potentially favorable features by analyzing the results of the comparative evaluation. As part of the sensitivity studies, measures that were demonstrated to affect the ranking and exhibit a high correlation to the overall ranking were judged to be the most influential in determining the overall ranking. The factors that significantly influenced the measures were identified from the influence diagrams, and, in turn, these factors were connected to the design features.

After the comparisons, both qualitative and quantitative, had resulted in identifying a set of potentially favorable features, the options were again examined to see if there was good correlation between the number of favorable features incorporated in the option and how well that option performed in the overall ranking.

The results of the comparative evaluation of features is summarized in Table 2. The features found to be favorable to an option's performance and overall rating in the comparative evaluation, are listed across the top of the table. The remainder of the table indicates how many of these favorable features were incorporated in the top-ranked options. It can be seen that none of the top ranked options contain all of the potentially favorable features. Approaches to refining or improving a selected option are addressed.

As part of the postanalysis of the scoring results, an effort was made to determine whether the addition of a favorable feature or the alteration of an existing feature, to make it more favorable, would have resulted in any of the highly ranked options being improved. Only qualitative assessments were performed in this effort.

Some modification of highly rated options could improve certain features without significant chance of degrading the option overall. One suggested modification was raising the repository relative to the water table. A second feature that was suggested was a repository design that reduced the drifting through the Ghost Dance Fault from the base case. Addition of major features would require detailed analyses to balance the favorable and adverse effects of the feature.

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 methods will be used to refine or improve all features of the selected baselined option. However, input from experts in testing, performance assessment, and other disciplines may be required for significant trade-offs. As an example, engineering trade-off studies may suggest that certain test areas of an option with a drill and blast MTL be excavated mechanically to minimize chemical or mechanical disturbance to the rock to be tested.

TABLE 2

IDENTIFICATION OF FAVORABLE FEATURES IN HIGHLY RATED OPTIONS

TOP-RANKED OPTIONS		1	2	3	4	5	6	7	8	9	10	11	12	13
RANK	OPTION	NUMBER OF RAMP(S)	NUMBER OF SHAFT(S)	NUMBER OF ACCESSES	MTL LOCATION FLEXIBILITY	MECHANICAL MINED ACCESSES	NO GRAVITY FLOW PATHWAY FROM TS UNIT TO CHn	MAXIMIZE DISTANCE FROM EMPLACEMENT LEVEL TO WATER TABLE	AVOID EMPLACEMENT DRIFTS CROSSING GHOST DANCE FAULT	MAXIMIZE EXPOSED ROCK -- ON AND OFF BLOCK	FLEXIBILITY FOR EARLY DRIFTING IN TS OR CH OR BOTH	2 INTERCEPTS OF GHOST DANCE FAULT IN TS	E-W DRIFT IN TS	LARGER MTL AREA TO AVOID INTERFERENCES
1	30	2	0	4	✓	✓	✓			✓	✓	✓	✓	✓
2	23	2	0	4		✓						✓	✓	✓
3	24	1	1	5		✓					✓	✓	✓	✓
4	13	2	0	4	✓	✓				✓	✓	✓	✓	✓
5	6	2	0	4		✓						✓	✓	✓
6	7	1	1	5		✓						✓	✓	✓
7	2	1	1	5								✓	✓	✓
8	19	1	1	5								✓	✓	✓
9	25	1	1	5		✓					✓	✓	✓	✓
10	4	1	2	5						✓	✓	✓	✓	✓
.	.													
.	.													
.	.													
20	15	1	1	4				✓	✓			✓	✓	✓

FINDINGS

The findings of the ESF-AS are summarized as follows:

1. The study considered and screened a large number of alternatives to produce 34 ESF-repository options that were then formally evaluated against a wide range of criteria.

2. The rank order of the options was determined primarily from the relative probabilities assessed for programmatic viability. Other key measures, such as regulatory approval, likelihood of repository closure, postclosure performance and characterization testing were considered in assessing programmatic viability.

3. The rankings under the majority and minority views are expressed in Table 1.

4. The top-ranked options indicated in Table 1 are consistent with the value judgments expressed by the Management Panel and the technical judgments expressed by all but three members of the technical panels. Only one technical panel member provided a view that produced a substantially different ranking. Even given this view, many of the same options remain highly rated.

5. A number of design features were identified that might potentially enhance the overall performance of particular options.

SUPPORTING INFORMATION AND STUDY CONCLUSIONS

1.0 INTRODUCTION

1.1 Description of the Study

The Department of Energy (DOE) has the responsibility for developing a mined geologic repository[1] for the disposal of spent nuclear fuel and other high-level radioactive waste. A site at Yucca Mountain Nevada has been tentatively identified as a possible location for a repository. If a repository is built at Yucca Mountain, it will consist of a system of tunnels and rooms excavated in rock formations approximately 300 meters below the surface. After waste has been placed in the repository rooms, called emplacement drifts, and the performance of the repository has been confirmed according to applicable regulatory requirements, the repository openings will be permanently sealed and the facility will be officially decommissioned.

A multiyear research program termed "site characterization" is to be conducted to investigate whether the proposed Yucca Mountain site is a suitable location for the repository. A critical decision for the characterization program is the selection of a design -- including a location, construction method, and testing strategy -- for the underground test facility central to the effort. This facility is known as the Exploratory Studies Facility (ESF).[2]

To assist the DOE in selecting an ESF design, the DOE's Yucca Mountain Site Characterization Project Office (YMPO) asked Sandia National Laboratories (SNL) to provide the department's Office of Civilian Radioactive Waste Management (OCRWM) with the information it required to make an informed decision regarding the selection of a preferred configuration for an ESF at Yucca Mountain, NV. It is the YMPO's intention to use the configuration selected by the OCRWM as a basis for the

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[1] The term "repository" appears throughout Volumes 1 and 2 and the appendices of this document. The use of the term "repository" to identify the facility that may be constructed and operated at Yucca Mountain is not intended to imply that such a facility will be constructed or operated at this site.

[2] In March 1991, the name of the underground exploration facility at Yucca Mountain was changed from Exploratory Shaft Facility to Exploratory Studies Facility. The new name will be used throughout this document, but documents generated prior to April 1, 1991 will not be revised to change the facility name. Thus the names Exploratory Shaft Facility and Exploratory Studies Facility have the same meaning in all supporting materials for this study.

design of the ESF. The scope of the Exploratory Studies Facility Alternatives Study (ESF-AS) was to obtain this information by identifying alternative ESF configurations and comparatively evaluating these alternative configurations. The goals of the comparative evaluation were to (1) establish an ordered preference list by rank ordering the options under consideration, and (2) identify individual features contained in some options that, if incorporated in other options, could be expected to improve the rank of the other options.

It was recognized that the results of the study might or might not confirm the design recommended in the Site Characterization Plan (SCP) (DOE, 1988). Thus, the study was envisioned to either (1) provide convincing evidence that the SCP ESF design was appropriate or (2) provide a basis for developing an alternative ESF design. The optimization of ESF configurations to achieve specific goals was not within the scope of this study; however, optimization of the ESF configuration can be addressed by the facility designer during the Title II phase of the ESF design.

The major elements of the study and their relationships are illustrated in Figure 1-1. These study elements include: (1) generating and screening alternative ESF-repository options, (2) identifying requirements and concerns and developing and testing a methodology for evaluating and comparing options, (3) applying the methodology to obtain a comparative evaluation of candidate options, and (4) developing study findings.

This document is the first volume of a two-volume report summarizing the ESF-AS. This volume, Volume 1, contains an Executive Summary of the full study, provides a description of the options evaluated, identifies regulatory requirements and concerns that discriminate among options, analyzes principal factors and features, and summarizes overall study conclusions. Volume 2 documents the comparative evaluation of candidate Exploratory Study Facility-repository (ESF-repository) options that provided the nucleus for the study. It summarizes the methodology used, describes the results of the comparative evaluation, and presents insights and conclusions.

1.1.1 Motivation for Study

In December 1988, DOE published a SCP for Yucca Mountain that included a recommended ESF design (DOE, 1988). The U.S. Nuclear Regulatory Commission (NRC), the agency that will ultimately be asked to grant a license to construct and

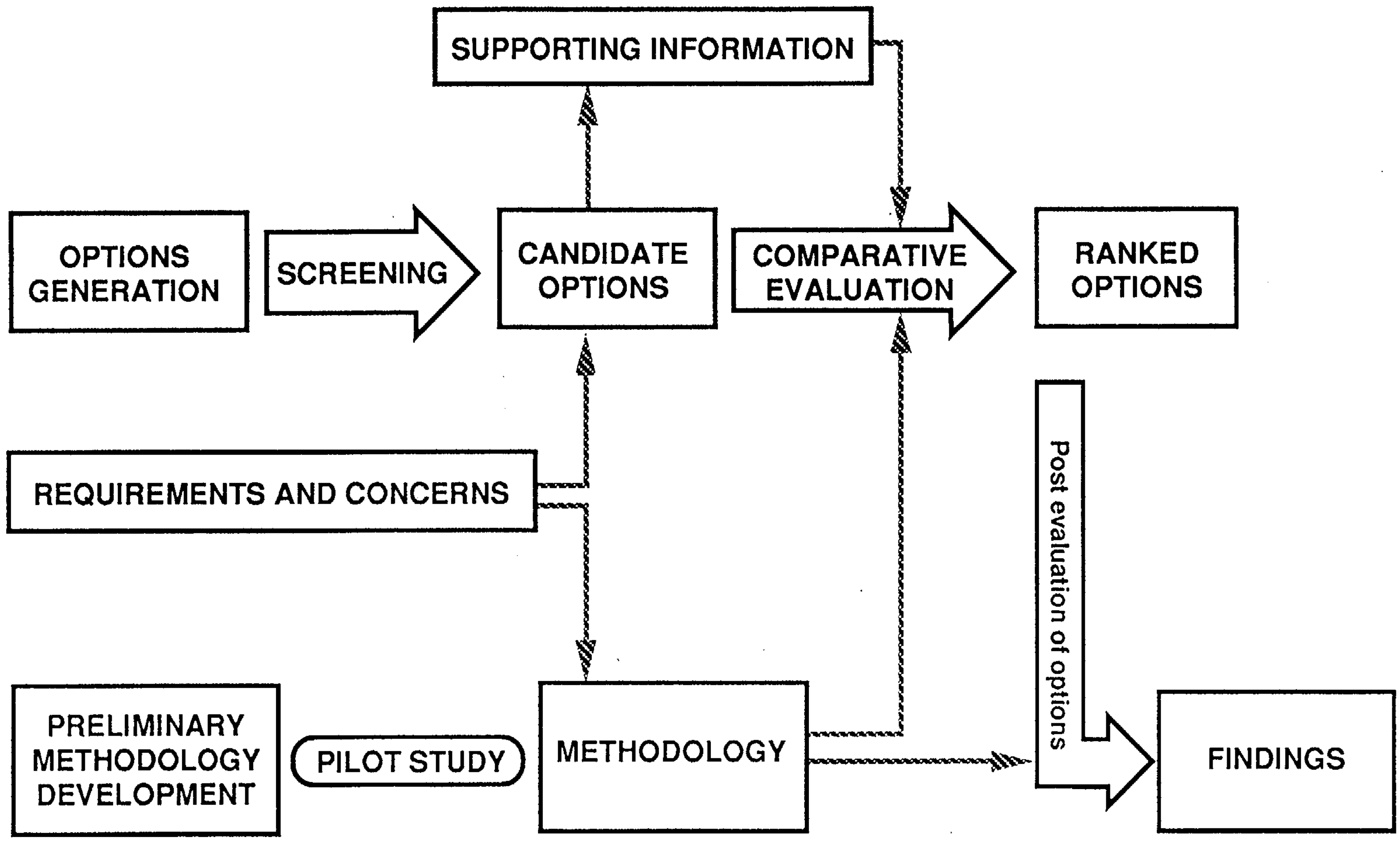

Figure 1-1. ESF Alternatives Study

operate the repository, objected to various features of the proposed ESF design and criticized DOE for failing to conduct a systematic evaluation of alternative designs (NRC, 1989). Concerns over the SCP ESF design were also expressed by the Nuclear Waste Technical Review Board (NWTRB), an independent oversight committee (NWTRB, 1989; NWTRB, 1990). Meanwhile, construction of the ESF was delayed when, in the fall of 1989, the DOE was unable to obtain the necessary permits for the continuation of the work. The OCRWM and the YMPO chose to use this delay to perform a single comprehensive analysis to address the NRC, State, and NWTRB concerns and suggestions. Thus, the ESF-AS was proposed by the DOE as a means of responding to the concerns expressed by the NRC, the State of Nevada, and the NWTRB, while making constructive use of the delay in ESF construction.

1.1.2 Study Scope and Objectives

The scope of this study was (1) the identification of and evaluation of alternative configurations and construction methods for the ESF-repository, (2) a documentation of findings resulting from the evaluation of these designs, and (3) the compilation of a set of ESF design requirements in the form of a draft report.

For the purpose of this study the ESF-repository configurations and construction methods include identification of the following items:

- for the ESF portion--the orientation, geometry, layout, and depth; the location in relation to the potential geologic repository operations area (GROA); the surface and underground locations of the accesses; and the construction methods for the GROA; and

- for the repository portion--the boundaries of the potential GROA, the surface and underground locations of the repository accesses, the general repository layouts, and the construction methods for the GROA.

In all cases the ESF and repository design concepts were developed as an integrated set to form an ESF-repository option. The strategy for and sequencing of the site characterization testing that would be conducted in the ESF was integrated into the development of each ESF-repository option. The selection of options that were evaluated and the development of the information necessary to support the evaluation of the options is presented in this volume (Volume 1).

Each of the ESF-repository options was evaluated by the use of expert judgement; recognized decision-aiding approaches were used to facilitate evaluation and to limit any possible impacts of bias on the part of the experts. Technical judgments were provided by eleven panels of technical specialists. Each panel was responsible for one or more of the following major technical areas:

- Aesthetics
- Biota
- Characterization Testing
- Cost and Schedule
- Historic Properties
- Postclosure Health
- Preclosure Nonradiological Safety
- Preclosure Radiological Health
- Program Viability
- Regulatory Considerations
- Socioeconomics

The inputs to the analysis dealing with values were provided by a Management Panel. The Management Panel consisted of senior managers familiar with the repository program. The evaluation of the ESF-repository options is discussed in detail in Volume 2 of this document.

1.1.3 Relationship to Other Studies

The YMPO conducted two other studies in parallel with this study. These studies were the Calico Hills Risk/Benefit Analysis and the study conducted by the Test Prioritization Task Force. At the meeting of August 8, 1990, the ESF Management Panel directed the ESF-AS to

- incorporate the recommended Calico Hills exploratory strategies into this study; and

- incorporate, within the ESF Alternatives Study, a means of evaluating or weighting the value of assigning a high priority to obtain early access to the Calico Hills unit and making the early access a factor in the ranking of options.

On September 4, 1990, the YMPO confirmed this direction.[3]

The preliminary results of the Calico Hills Risk/Benefit Analysis (CHRBA),[4] which were confirmed in the final report, were fully integrated into this study. The exploratory development within the Calico Hills unit, identified in the preliminary CHRBA, was the same in all ESF-AS options, but the method of accessing the Calico Hills unit was varied in this study. The results from the Testing Prioritization Task Force were not available for incorporation into this study (Mattson et al., 1991).

1.1.4 Chronological History of Key Events

A number of events were viewed as significant milestones by the participants in this study. These events are listed below to provide a time reference for the reader.

Study Implementation Plan, Rev. 0, approved by YMPO (technical activities initiated)	30-NOV-89
Identification of options for pilot study completed (pilot study evaluation activities initiated)	08-JAN-90
Guidance for development of new ESF options established (development of new options initiated)	11-JAN-90
Pilot study completed and results evaluated (confirmed applicability of decision tree-multiattribute utility analysis (MUA) methodology for the study)	12-FEB-90
Definition of ESF-repository testing requirements completed	07-MAR-90

[3] Letter to Thomas O. Hunter, SNL, from Carl P. Gertz, YMPO. Subject: Importance of Testing in the Calico Hills Unit (CHU), a Primary Natural Barrier, for Early Evaluation of Site Suitability, September 4, 1990.

[4] Letter to M. B. Blanchard, YMPO, and to T. O. Hunter, SNL, from John H. Nelson, T&MSS. Subject: Interface Control Input from Calico Hills Risk/Benefit Analysis (CHRBA), to the Exploratory Shaft Facility (ESF) Alternatives Study, June 30, 1990.

Management review of screening activity completed (provided the 17 ESF options initially selected for evaluation and ranking)	29-MAR-90
Conceptual design information for initial 17 options complete (Following completion of this milestone, study activities were placed on hold pending identification of Calico Hills exploration strategies)	30-APR-90
Calico Hills exploration strategies identified (work initiated to incorporate Calico Hills exploratory drifting in the initial 17 options)	30-JUN-90
ESF-AS Management Panel decision to include two testing strategies--one for early Topopah Spring testing and one for early Calico Hills testing--number of options increased from 17 to 34--need for programmatic viability panel identified (work initiated to identify supporting information for Options 18 through 34)	08-AUG-90
Scoring of options 50% complete	11-OCT-90
Scoring of options complete	19-NOV-90
Draft findings report submitted to YMPO	21-DEC-90
Final findings report submitted to YMPO (Stevens and Costin, 1991)	09-JAN-91
Findings submitted to OCRWM, RW-1	14-JAN-91

Many of these events are referred to in Volumes 1 and 2 of this report. This information should assist the reader in establishing a time frame within which each event occurred.

1.1.5 Supporting Organizations

The following organizations supported Sandia during the course of this study and made significant contributions to all aspects of this study.

- Los Alamos National Laboratory (LANL)
- Parsons Brinckerhoff Quade & Douglas, Inc. (PBQ&D)
- Raytheon Services Nevada (RSN)[5]
- Reynolds Electric & Engineering Co., Inc. (REECo)
- Technical and Management Support Services Contractor (T&MSS)
- U. S. Geological Survey (USGS)

1.1.6 Terminology

The term "repository" appears throughout Volumes 1 and 2 and the appendices of this document. The use of the term "repository" to identify the facility that may be constructed and operated at Yucca Mountain is not intended to imply that such a facility will be constructed or operated at this site. When the draft text, tables, and figures were developed for this document, it was not realized that the use of the word "repository" without the modifier "potential" had been interpreted by some individuals to mean that the DOE had prejudged the acceptability of the Yucca Mountain site. Because revision of the text, tables and figures to replace "repository" with "potential repository" would result in a delay in release of this document to the public, the DOE has elected to publish the document in its present form. The DOE and the authors apologize to the readers for any inconvenience this error in terminology may cause. An attempt has been made to include the modifier "potential" before "repository" when this could be accomplished without delaying the release of this document to the public.

1.2 Quality Assurance

The ESF-AS was conducted under the SNL quality assurance (QA) program which meets the requirements of 10 CFR 60, Subpart G (NRC, 1987). The SNL QA program

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[5] Participants from Raytheon Services Nevada were employed by Fenix and Scisson of Nevada (FSN) and Holmes and Narver (H&N) when this study was initiated.

has been approved by the YMPO and the OCRWM, and it has been accepted by the NRC. The application of the QA program controls to the input and conduct of the study provides confidence in the quality of the results presented.

All tasks conducted as part of this study were controlled by SNL QA implementing procedures. Personnel from other YMP participants that contributed to the study conducted their work under SNL QA implementing procedures. The entire study was conducted in accordance with the YMPO QA procedure (AP-5.19Q) that controls YMP participant (organizational) interfaces.

In subsequent sections and appendices of this report, references may be made to specific SNL QA implementing procedures called Design Investigation Memoranda (DIM). A DIM contains a statement of work for a specific block of work to be done. At least one DIM was used to control the work of each task of this design-related ESF-AS.

1.3 Report Organization

Figure 1-1 depicts the process used to implement the study. It is the intent that this report describe the process in sufficient detail for the reader to understand both the process and the results of the process. To that end, Figure 1-1 will be used to describe the apparent chronology of the activities shown in the figure and to provide a roadmap to the sections of the report that describe the specific activities in the figure. The reader should also consult Section 1.1.4 for a chronological list of key events during the course of the study.

Requirements include federal, state, and local regulatory requirements, DOE orders, and site characterization testing requirements. Concerns expressed by oversight agencies are included here in that they emphasize attention to regulatory requirements. Section 2 describes the process of identifying these requirements and concerns. Preliminarily identified requirements and concerns were used in the generation of new options and in the screening process.

The candidate options generated for the comparative evaluation were a combination of historical options recovered from YMP files and new options developed to more specifically address regulatory and functional concerns. Ninety-one options were generated by this activity, the details of which are described in Section 3. Section 4 describes the process that was used to screen this set down to the initial set of 17 ESF-repository options. Section 5 describes the final set of 34 options developed for the comparative evaluation.

An analysis of the principal factors and design features of the option is given in Section 6, and a summary of the study findings is in Section 7 of Volume 1. Development of the methodology for conducting the comparative evaluation is discussed in Volume 2 together with a complete description of the application of the evaluation process and the resulting ranked options.

Appendix 1A, a mandatory appendix, the inclusion which is required in all SNL Department 6310 SAND reports, provides database information. Seventeen other appendices have been included to provide more complete information on the topics of the various sections.

1.4 Release of Data to Parties Who Are Not Participants on the Yucca Mountain Project

Throughout this document references are made to records packages (RP). These RPs contain detailed records associated with specific areas of this study (for example, transcripts documenting the elicitation of the information used to construct the influence diagrams related to postclosure health and safety). These RPs, which are identified in each section, are available to the public. To obtain a copy of an RP, the requester should submit a request to the project manager of DOE's YMPO.[6]

[6] Carl P. Gertz
Project Manager
Yucca Mountain Site Characterization Project
U.S. Department of Energy
P.O. Box 98608
Las Vegas, NV 89193-8608

2.0 FACTORS THAT DISCRIMINATE BETWEEN ESF-REPOSITORY CONFIGURATIONS

A review of existing program requirements documents, comments, and concerns relating to the repository and ESF design and construction methods was performed to identify those requirements that might impact the evaluation of repository access configurations, ESF configurations, and construction methods. A working group with members from RSN, LANL, REECo, SNL, and T&MSS was formed to identify these applicable requirements, comments, and concerns. The requirements that were deemed useful in discriminating between options are presented in Section 2.1, and the comments and concerns that were deemed useful in discriminating between options are presented in Section 2.2.

2.1 Regulatory Requirements and Department of Energy Orders

2.1.1 Approach

2.1.1.1 Identification of Regulatory Requirements Documents, DOE Orders, and Other Documents--To arrive at a set of source documents for this task, the ESF Subsystems Design Requirements Document (SDRD) Title II, Rev. 2, Appendix E, "Applicable Regulations, Codes and Specifications" (DOE, 1990) was consulted. Of the 104 documents listed in Appendix E only nine were chosen for detailed review. The remaining 95 documents are applicable to the design of the ESF, but do not appear to offer significant potential for the identification of requirements that can be used to discriminate between ESF options. The following documents identified in Appendix E of the SDRD were selected for detailed review:

- Nuclear Waste Policy Act (1982) (NWPA) and Amendments (1987) (NWPAA),
- 10 CFR 20, Standards for Protection Against Radiation (NRC, 1987),
- 10 CFR 60, Disposal of High-Level Radioactive Waste in Geologic Repositories (NRC, 1987),

- 10 CFR 960, General Guidelines for Recommendation of Sites for Nuclear Waste Repositories (DOE, 1987),

- 30 CFR 57, Safety and Health Standards-Underground Metal and Nonmetal Mines (DOL, 1985),

- Nevada Mine Safety and Health Standards (NRS Title 46),

- DOE Order 5480.4, "Environmental Protection, Safety, and Health Protection Standards" (DOE, 1984),

- California Administrative Code Tunnel (CTSO Title 8) (CAC, 1981) and Mine (CMSO Title 8) (CAC, 1989) Safety Orders, as called out in DOE Order 5480.4, Attachment 2, pages 4 and 4a(8)(a) and (b) (DOE, 1984), and

- DOE Order 6430.1A, "General Design Criteria." (DOE, 1983)

Additional documents were identified for review based on the recommendation of YMP participants familiar with the scope of the ESF and repository needs. These documents are

- 29 CFR 1926, Subparts, Safety and Health Regulations for Construction, OSHA (DOL, 1989)

- 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-level and Transuranic Radioactive Wastes (EPA, 1987),

- Criteria from the Design Acceptability Analysis (DAA) of ESF Title I Design (YMP/89-3 1990)

- Generic Requirements Document (OGR/B-2) (DOE, 1986)

- Repository Design Requirements (RDR, Rev. D) (SNL, 1988)

- Subsystem Design Requirements Document (SDRD, Rev. 2) (DOE, 1990)

2.1.1.2 Identification of Requirements--Requirements that could be used during the evaluation to discriminate between and among options were identified using a three-step procedure. First, a matrix was formed to aid in the categorization of each requirement in the source documents identified above. The purpose of this was to identify individual requirements that might impact the evaluation of repository access configurations and ESF configurations and construction methods. It was recognized that some requirements address functional aspects of the ESF and repository facilities, while others address performance aspects of the site, facilities, or the total site-facilities system. The matrix categorized each requirement according to its relationship to the functions of the facilities, and further categorize the requirement with respect to postclosure or preclosure performance. The following column headings were identified.

Functional Requirements

- Design - engineering design-related tasks or functions
- Development - construction-related tasks or functions
- Operations - operations or maintenance-related tasks or functions
- Testing - site characterization testing and performance confirmation-related testing

Performance (Postclosure)

- Postclosure Performance - tasks and functions that may affect the nuclear waste-isolation capability of the potential geologic repository after closure

Performance (Preclosure)

- Preclosure Radiological Safety - tasks and functions related to radiological safety of the public and workers
- Preclosure Non-radiological Safety - tasks and functions related to worker industrial and non-radiological health and safety
- Environmental - tasks and functions related to environmental protection
- Socioeconomic - tasks and functions related to public social and economic issues
- Cost/Schedule - cost, schedule, management, procurement, and training tasks and functions

- Retrievability - tasks and functions related to retrieval strategy implementation for emplaced waste

In the second step, for each individual requirement listed in the left column of the matrix, a marker was placed in one or more of the right columns to identify the functional or performance category of the requirement. Finally, those regulatory criteria that would directly impact the ESF or repository and that, in the opinion of the reviewers, would provide factors that could be used to discriminate among various ESF and repository options were identified and ranked. The following scale was used to rank regulations, DOE Orders, and other requirements that had the potential to serve as discriminators.

Rank	Definition
1	A requirement, etc., which relates to or identifies a measure of performance (pre- or postclosure) that an item (or feature) or activity is obligated to attain, and for which the value of the performance measure is expected to depend strongly on the concept of the item (feature) or conduct of the activity. (That is, the performance measure is expected to depend strongly on the option.)
2	A requirement, etc., which relates to or identifies a measure of performance (pre- or postclosure) that an item (or feature) or activity is obligated to attain. While the requirement may be attainable for any alternative option, a higher value for the performance measure may be more easily attainable for certain alternatives.
3	A requirement, etc., that must be completely accommodated by any alternative option (or feature) or activity, and which can be included readily in the layout or activity for any option. As such, the requirement cannot be used to discriminate among alternatives (features) or activities.

A column was provided in the matrix to designate the rank of each requirement. Finally, a column was provided in which to explain the logic or rationale for the selection of category and discriminator rank. It should be noted here that, as described in Section 2.1.2.1 of this report, both Rank 1 and Rank 2 requirements were subsequently used in the evaluation of options.

Consistency in the identification and ranking of the requirements was ensured by discussions between reviewers during meetings, and by informal review of all requirements matrices by the Principal Investigator (PI). In addition, a formal review of the identification and ranking of requirements was conducted in accordance with Departmental (SNL 6310) Operating Procedure (DOP) 3-13 (Independent Technical and Management Reviews of Documents). A team of eight reviewers participated in the formal review of the requirements matrices.

The PI and SNL management met with the reviewers to resolve all comments. Copies of the original (pre-review) requirements matrices, the document review comment forms, and the final requirements matrices (matrices with comment resolutions incorporated) are available in the form of records packages. A complete listing of available records packages supporting the material in this section is contained in Appendix 2A of this document.

2.1.2 Requirements Identified

2.1.2.1 Federal Regulatory Requirements--The following requirements were identified as being either discriminatory (Rank 1) or potentially discriminatory (Rank 2). Because no differentiation was made during the evaluation process between discriminatory and potentially discriminatory requirements, these requirements are listed in order under their source documents. Generally, procedural requirements were not viewed as discriminatory.

Nuclear Waste Policy Act (NWPA) of 1982 and 1987 Amendments (NWPAA)

Sec. 113.(a) In General

The Secretary shall carry out, in accordance with the provisions of this section, appropriate site characterization activities beginning with the candidate sites that have been approved under section 112 and are located in various geologic media. The Secretary shall consider fully the comments received under sub-section(b)(2) and section 112(b)(2) and shall, to the maximum extent practicable and in consultation with the Governor of the State involved or the governing body of the affected Indian tribe involved, conduct site characterization activities in a manner that minimizes any significant adverse environmental impacts identified in such comments or in the environmental assessment submitted under subsection (b)(1).

Sec. 113.(c) Restrictions

(1) The Secretary may conduct at any candidate site only such site characterization activities as the Secretary considers necessary to provide the data required for evaluation of the suitability of such candidate site for an application to be submitted to the Commission for a construction authorization for a repository at such candidate site, and for compliance with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.).

10 CFR 20, Standards for Protection Against Radiation

There were no requirements identified in 10 CFR 20 believed to provide discrimination for ESF-repository options.

10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories

10 CFR 60.15 Site Characterization
10 CFR 60.15(c)(1)

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)(2)

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)(3)

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 operation or where large unexcavated pillars are planned.

10 CFR 60.15(c)(4)

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 60.21(c)

The safety analysis report shall include: (1) a description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment. (ii) The assessment shall contain:

10 CFR 60.21(c)(1)(ii)(D)

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)(E)

An analysis of the performance of the major design structures, systems, and components, both surface and subsurface, to identify those that are important to safety. For the purposes of this analysis, it shall be assumed that operations at the geologic repository operations area will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the application.

10 CFR 60.21(c)11

A description of design considerations that are intended to facilitate permanent closure and decontamination or dismantlement of surface facilities.

10 CFR 60.74(a)

DOE shall perform, or permit the Commission to perform, such tests as the Commission deems appropriate or necessary for the administration of the regulations of this part. These may include tests of: (1) radioactive waste, (2) 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(b)

The tests required under this section shall include a performance confirmation program carried out in accordance with Subpart F of this part.

10 CFR 60.111 Performance of the geologic repository operations area through permanent closure.

(a) Protection against radiation exposures and releases of radioactive material. The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency.

(b) Retrievability of waste. (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

10 CFR 60.112 Overall system performance objective for the geologic repository after permanent closure.

The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

10 CFR 60.113 Performance of particular barriers after permanent closure.

(a) General provisions. (1) Engineered barrier systems (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. For disposal in the saturated zone, both the partial and complete filling with groundwater of available void spaces in the underground facility shall be appropriately considered and analyzed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 60.113(b) provided that each period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

(2) Geologic setting. The geologic repository shall be located so that pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

10 CFR 60.122 Siting Criteria.

(a)(1) A geologic setting shall exhibit an appropriate combination of the conditions specified in paragraph (b) of this section so that, together with the engineered barriers system, the favorable conditions present are sufficient to provide reasonable assurance that the performance objectives relating to isolation of the waste will be met.

(2) If any of the potentially adverse conditions specified in paragraph (c) of this section is present, it may compromise the ability of the geologic repository to meet the performance objectives relating to isolation of the waste. In order to show that a potentially adverse condition does not so compromise the performance of the geologic repository the following must be demonstrated:

(i) The potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and

(ii) The effect of the potentially adverse human activity or natural condition on the site has been adequately evaluated using analyses which are sensitive to the potentially adverse human activity or natural condition and assumptions which are not likely to underestimate its effect; and

(iii)(A) The potentially adverse human activity or natural condition is shown by analysis pursuant to paragraph (a)(2)(ii) of this section not to affect significantly the ability of the geologic repository to meet the performance objectives relating to isolation of the waste, or

(B) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics so that the performance objectives relating to isolation of the waste are met, or

(C) The potentially adverse human activity or natural condition can be remedied.

(b) Favorable conditions. (1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(2) For disposal in the saturated zone, hydrogeologic conditions that provide -

(i) A host rock with low horizontal and vertical permeability;

(ii) Downward or dominantly horizontal hydraulic gradient in the host rock and immediately surrounding hydrogeologic units; and

(iii) Low vertical permeability and low hydraulic gradient between the host rock and the surrounding hydrogeologic units.

(3) Geochemical conditions that--(i) Promote precipitation or sorption of radionuclides: (ii) Inhibit the formation of particulates, colloids, and inorganic

and organic complexes that increase the mobility of radionuclides; or (iii) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(4) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(5) 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.)

(6) A low population density within the geologic setting and a controlled area that is remote from population centers.

(7) Pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years.

(8) For disposal in the unsaturated zone, hydrogeologic conditions that provide -

(i) Low moisture flux in the host rock and in the overlying and underlying hydrogeologic units;

(ii) A water table sufficiently below the underground facility such that fully saturated voids contiguous with the water table do not encounter the underground facility;

(iii) A laterally extensive low-permeability hydrogeologic unit above the host rock that would inhibit the downward movement of water or divert downward moving water to a location beyond the limits of the underground facility.

(iv) A host rock that provides for free drainage; or

(v) A climatic regime in which the average annual historic precipitation is a small percentage of the average annual potential evapotranspiration.

(c) Potentially adverse conditions. The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(1) 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.

(2) Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection or fluids, underground pumped storage, military activity or construction or large scale surface water impoundments.

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system.

(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(6) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

(7) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

(8) Geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system.

(9) Groundwater conditions in the host rock that are not reducing.

(10) Evidence of dissolutioning such as breccia pipes, dissolution cavities, or brine pockets.

(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(14) More frequency occurrence of earthquakes or earthquakes or higher magnitude than is typical of the area in which the geologic setting is located.

(15) Evidence of igneous activity since the start of the Quaternary Period.

(16) Evidence of extreme erosion during the Quaternary Period.

(17) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:

(i) Economic extraction is currently feasible or potentially feasible during the foreseeable future; or

(ii) Such materials have greater gross value or net value than the average for other areas of similar size that are representative of and located within the geologic setting.

(18) Evidence of subsurface mining for resources within the site.

(19) Evidence of drilling for any purpose within the site.

(20) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(21) Geomechanical properties that do not permit design of underground opening that will remain stable through permanent closure.

(22) Potential for the water table to rise sufficiently so as to cause saturation of an underground facility located in the unsaturated zone.

(23) Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment.

(24) Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment.

10 CFR 60.130 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 60.131(b)(1) General design criteria for the geologic repository operations area.

(b) Structures, systems, and components important to safety. (1) Protection against natural phenomena and environmental conditions.

The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.

10 CFR 60.133(a)(1) Additional design criteria for the underground facility.

(a) 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)(2)

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(b)

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(c)

Retrieval of waste. The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of 60.111.

10 CFR 60.133(e)(1)

Underground openings. Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.

10 CFR 60.133(e)(2)

Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surround rock.

10 CFR 60.133(f)

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(g)

Underground facility ventilation. The ventilation system shall be designed to - (1) Control the transport of radioactive particulates and gases within the releases from the underground facility in accordance with the performance objectives of 60.111(a).

(2) Assure continued function during normal operations and under accident conditions; and

(3) Separate the ventilation of excavation and waste emplacement areas.

10 CFR 60.133(h)

Engineered barriers. Engineered barriers shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure.

10 CFR 60.133(i)

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, and surrounding strata, groundwater system.

10 CFR 60.134 Design of seals for shafts and boreholes.

(a) 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.

(b) Selection of materials and placement methods. 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.

10 CFR 60.135(a) Criteria for the waste package and its components.

(a) High-level-waste package design in general. (1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

10 CFR 60.137

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 960, General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories

§ 960.4-2-1(d)

> *Disqualifying Condition.* A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.

§ 960.4-2-7(d)

> *Disqualifying Condition.* A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur.

§ 960.5-2-9(d)

> *Disqualifying Condition.* The site shall be disqualified if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause significant risk to the health and safety of personnel, taking into account mitigating measures that use reasonably available technology.

§ 960.5-2-11(d)

> *Disqualifying Condition.* A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.

29 CFR 1926, Occupational Safety and Health Standards (OSHA)

There were no requirements identified in 29 CFR 1926 believed to provide discrimination for ESF-repository options.

30 CFR 57, Chapter 1, Mine Safety and Health Administration (MSHA)

§ 57.3360 Ground support use.

Ground support shall be used where ground conditions, or mining experience in similar ground conditions in the mine, indicate that it is necessary. When ground support is necessary, the support system shall be designed, installed, and maintained to control the ground in places where persons work or travel in performing their assigned tasks. Damaged, loosened, or dislodged timber use for ground support which creates a hazard to persons shall be repaired or replaced prior to any work or travel in the affected area.

§ 57.4760(a)(3)

Evacuation. If used as an alternative, effective evacuation shall be demonstrated by actual evacuation of all persons underground to the surface in ten minutes or less through routes that will not expose persons to heat, smoke, or toxic fumes in the event of a fire.

§ 57.4761 Underground shops.

To confine or prevent the spread of toxic gases from a fire originating in an underground shop where maintenance work is routinely done on mobile equipment, one of the following measures shall be taken: use of control doors or bulkheads, routing of the mine shop air directly to an exhaust system, reversal of mechanical ventilation, or use of an automatic fire suppression system in conjunction with an alternate escape route. The alternative used shall at all times provide at least the same degree of safety as control doors or bulkheads.

§ 57.5001 Exposure limits for airborne contaminants.

Except as permitted by § 57.5005--

(a) Except as provided in paragraph (b), the exposure to airborne contaminants shall not exceed, on the basis of a time-weighted average, the threshold limit values adopted by the American Conference of Governmental Industrial Hygienists, as set forth and explained in the 1973 edition of the Conference's publication, entitled "TLV's Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1973," pages 1 through 54, which are hereby incorporated by reference and made a part hereof. This publication may be obtained from the American Conference of Governmental Industrial Hygienists by writing to the Secretary-Treasurer, P.O. Box 1937, Cincinnati, Ohio 45201, or may be examined in any Metal and Nonmetal Mine Safety and Health District or Subdistrict Office of the Mine Safety and Health Administration. Excursions above the listed thresholds shall not be of a greater magnitude than is characterized as permissible by the Conference.

§ 57.5003 Drill dust control.

Holes shall be collared and drilled wet, or other efficient dust control measures shall be used when drilling non-water-soluble material. Efficient dust-control measures shall be used when drilling water-soluble materials.

§ 57.5050 Exposure limits for noise.

(a) No employee shall be permitted an exposure to noise in excess of that specified in the table below. Noise level measurements shall be made using a sound level meter meeting specifications for type 2 meters contained in American National Standards Institute (ANSI) Standard S1.4-1971, "General Purpose Sound Level Meters," approved April 27, 1971, which is hereby incorporated by reference and made a part hereof, or by a dosimeter with similar accuracy. This publication may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018, or may be examined in any Metal and Nonmetal Mine Heath and Safety District or Subdistrict Office of the Mine Safety and Health Administration.

PERMISSIBLE NOISE EXPOSURES

Duration per day, hours of exposure	Sound level dBA, slow response
8	90
6	92
4	95
3	97
2	100
$1^1/_2$	102
1	105
$^1/_2$	110
$^1/_4$ or less	115

No exposure shall exceed 115 dBA. Impact or impulsive noises shall not exceed 140 dB, peak sound pressure level.

Note: When the daily exposure is composed of two or more periods of noise exposure at different levels, their combined effect shall be considered rather than the individual effect of each.

If the sum

$$(C_1T_1) + (C_2T_2) + \ldots (C_n/T_n)$$

exceeds unity, then the mixed exposure shall be considered to exceed the permissible exposure. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level. Interpolation between tabulated values may be determined by the following formula:

$$\log T = 6.322 - 0.0602 \text{ SL}$$

Where T is the time in hours and SL is the sound level in dBA.

(b) When employees' exposure exceeds that listed in the above table, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce exposure to within permissible levels, personal protection equipment shall be provided and used to reduce sound levels to within the levels of the table.

§ 57.11050 Escapeways and refuges.

(a) Every mine shall have two or more separate, properly maintained escapeways to the surface from the lowest levels which are so positioned that damage to one shall not lessen the effectiveness of the others. A method of refuge shall be provided while a second opening to the surface is being developed. A second escapeway is recommended, but not required, during the exploration or development of an ore body.

(b) In addition to separate escapeways, a method of refuge shall be provided for every employee who cannot reach the surface from his working place through at least two separate escapeways within a time limit of one hour when using the normal exit method. These refuges must be positioned so that the employee can reach one of them within 30 minutes from the time he leaves his workplace.

2.1.2.2 State Requirements--The State of Nevada and State of California codes regulating underground development activities were reviewed. The results of these reviews are presented below.

The State of Nevada, Title 46, Chapter 512, Health and Safety Standards for Open Pit and Underground Metal and Non-Metal Mines and Sand, Gravel, and Crushed Stone Operations (NRS, 1985), was reviewed to determine if it contained any requirements that were believed to be useful as discriminators between and among options. The requirements contained in NRS Title 46 are believed to be equally applicable to all options; no requirements that could be used to discriminate between and among options were identified.

The California codes related to mine safety (CAC, 1981) and to tunnel safety (CAC, 1981) were also reviewed.

7093 (5-3) Dust--Rock Drilling.

(b) Rock drilling in underground mines is prohibited unless the dust is controlled by wet drilling or other means acceptable to the Division.

7094 (5-4) Dust--Mucking and Transferring Rock

(a) The muck pile shall be wet down before mucking begins and shall be kept wet during the entire mucking operation to control the dust.

It is recommended that a continuous spray of water be maintained on muck piles where mucking machines are being operated.

(b) Water sprinklers shall be installed and used on all chutes from which dusty rock is taken, or other equally effective means acceptable to the Division shall be used to prevent harmful accumulations of dust in the atmosphere.

(c) Whenever a sprinkling device is installed at a chute, it shall be so placed that it can be operated by the workmen who operate the chute gates.

The spray shall be directed into the chute and away from the operator's position at the chute.

(d) To prevent spillage from loaded cars and trackless haulage vehicles from adding to the mine dust, the loaded car or vehicle shall not be moved away from the loading spot until the load has been trimmed and leveled so as to prevent spillage.

(e) Effective means shall be used to control the dust in manways, haulage-ways, and other parts of the mine.

It is recommended that dust on haulageways be controlled with water, treating with calcium chloride, or other equally effective means.

In areas of water scarcity, it is recommended that water for dust control be treated with a wetting agent to increase its efficiency.

7237. Misfires. This is the most hazardous operation associated with blasting operations.

(c) (6-104) (6-105) (6-177) In case of a detonator misfire, the shot area shall be made safe under competent supervision by one of the following means after a 30-minute wait following electric blasting, except where an electric blasting cap is visible on the surface, or a 60-minute wait following fuse cap blasting:

(1) Non-applicable
(2) Where the hole cannot be reblasted, the stemming and explosive shall be washed out with water, or . . . .
(3) Non-applicable

<u>8 CAC 4.20, Tunnel Safety Orders</u>

Article 12-8438 Rock Dust.

(a) The drilling of holes in rock or concrete underground by machines without the use of water or other effective methods of controlling the dust is prohibited.

Article 16-8458 Dust Control.

(a) Water sprays or other effective methods shall be used to control dust at the face, conveyor transfer points, and other dusty locations.
(b) Dust enclosures, dust collectors, and exhaust ventilation shall be used when necessary to control dust.

Article 16-8496 Shafts and Inclines.

(i) There shall be two safe means of access in shafts at all times. This may include the ladder and hoist.

2.1.2.3 Department of Energy Orders--Two Department of Energy Orders, 5480.4 (DOE, 1984) and 6430.1A (DOE, 1983) were reviewed and the following requirements were identified.

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

4. APPLICABILITY.

(c) In instances where both DOE and non-DOE ES&H standards are applicable and mandatory and there are conflicts between such standards, the ES&H standards providing greater protection shall govern. Similarly, where there are conflicts between the mandatory ES&H standards of this Order, or between those of this Order and other DOE Orders or requirements, the mandatory ES&H standards or requirements providing the greater protection shall govern.

5. BACKGROUND REGARDING EXEMPTIONS FROM MANDATORY ES&H STANDARDS.

a. General Information. Depending on the origin of ES&H standards, non-compliance with a requirement of these standards is referred to as an exemption, variance, exception, interim order, waiver, or deviation. In virtually all cases, the definition of such non-compliance is essentially the same: a temporary or permanent release from the requirements of a statute, code, directive, regulation, order, or manual. For the purposes of this Order, a temporary or permanent release from the mandatory ES&H standards of Attachments 1 and 2 is termed an "exemption." Since this term may conflict with terms used in other DOE Orders or requirements, which DOE organizations may be subject to, the purposes of this background paragraph are to provide guidance and clarification in determining applicability of this Order or other mandatory ES&H requirements and procedures to be followed in requesting releases from these mandatory ES&H requirements.

DOE Order 6430.1A, General Design Criteria

Division 1 - General Requirements

0110-6.2 Fire Protection Design Analysis

A *special* fire protection design analysis shall be made of each facility vital to DOE mission accomplishment. The analysis shall use time parameters established in accordance with DOE 5480.7. The analysis shall identify the special fire prevention and protection features and controls deemed by the cognizant DOE fire protection authority to achieve a level of fire protection for vital facilities and programs that meets or exceeds the "improved risk" level.

As a part of determining the "improved risk" level, the analysis shall address those conditions in a facility where:

- Large or unusual fire potential exists.
- There are special life-safety hazards.
- Toxic chemicals or biological agents exist.
- The consequences of fire include radioactive contamination of the facility, the site, or the public environment.
- National security is adversely affected by fire.

Special precautions for preventing the spread of fires, such as multiple fire suppression systems, rapid detection of incipient fires, confining fires, increased fire ratings of construction materials, and rapid-response fire departments shall be provided.

A *general* fire-protection design analysis shall be made of each facility to ascertain and limit the cost of future damage repair and replacement of facilities and their contents from fire. The analysis shall be made using those parameters established in DOE 5480.7. The analysis shall determine the special fire prevention and protection features and controls deemed by the cognizant DOE fire protection authority to achieve a level of improved risk fire protection that limits damage to an acceptable level. The analysis shall be documented in report form in the facility project files and referenced by the SAR.

Fire-protection design analysis shall be done as soon as possible and included as a portion of the Title I Design Summary document required by DOE 4700.1.

2.1.2.4 Additional Documents--Six additional documents were identified for review based on the recommendation of YMP participants. These are listed in subsection 2.1.1.1. Requirements found in 40 CFR 191 were determined to be potentially useful in the discrimination between ESF options. The other five documents are either generic in nature or project specific. After review of these documents it was decided that the requirements contained in these documents either (1) were directly related to regulatory requirements (federal and state) or to requirements that were imposed by DOE Orders, or (2) were design specific, for example, requiring that two 12-foot-diameter shafts be used as accesses for the exploratory shaft facility. After the document review was completed, it was decided that the discriminatory requirements contained in the additional documents (1) were too limiting to be acceptable as a basis for option evaluation, or (2) did not provide sufficiently distinct discriminatory requirements to justify their presentation in this report.

40 CFR 191, Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes

§ 191.13 Containment requirements.

(a) Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation, based upon performance assessments, that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall:

(1) Have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table 1 (Appendix A); and

(2) Have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1 (Appendix A).

(b) Performance assessments need not provide complete assurance that the requirements of § 191.13(a) will be met. Because of the long time period involved and the nature of the events and processes of interest, there will inevitably be substantial uncertainties in projecting disposal system performance. Proof of the future performance of a disposal system is not to be had in the ordinary sense of the word in situations that deal with much shorter time frames. Instead, what is required is a reasonable expectation, on the basis of the record before the implementing agency, that compliance with § 191.13(a) will be achieved.

§ 191.15 Individual protection requirements.

Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not cause the annual dose equivalent from the disposal system to any member of the public in the accessible environment to exceed 25 millirems to the whole body or 75 millirems to any critical organ. All potential pathways (associated with undisturbed performance) from the disposal system to people shall be considered, including the assumption that individuals consume 2 liters per day of drinking water from any significant source of ground water outside of the controlled area.

§ 191.16 Ground water protection requirements.

(a) Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not cause the radionuclide concentrations averaged over any year in water withdrawn from any portion of a special source of ground water to exceed:

(1) 5 picocuries per liter of radium-226 and radium-228;

(2) 15 picocuries per liter of alpha-emitting radionuclides (including radium-226 and radium-228 but excluding radon); or

(3) The combined concentrations of radionuclides that emit either beta or gamma radiation that would produce an annual dose equivalent to the total body or any internal organ greater than 4 millirems per year if an individual consumed 2 liters per day of drinking water from such a source of ground water.

(b) If any of the average annual radionuclide concentrations existing in a special source of ground water before construction of the disposal system already exceed the limits in § 191.16(a), the disposal system shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not increase the existing average annual radionuclide concentrations in water withdrawn from that special source of ground water by more than the limits established in § 191.16(a).

2.2 Comments and Concerns

2.2.1 Approach

2.2.1.1 Identification of Documents--Available comments and concerns related to repository or ESF design, construction, or performance generated by external agencies were reviewed for applicability. DOE correspondence with NRC and NWTRB was also reviewed, but determined to not provide any unique concerns. The documents used follow:

- NUREG 1347: NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada (SCA), 1989

- State of Nevada Comments on the U.S. Department of Energy Site Characterization Plan, Yucca Mountain Site, Nevada, September 1, 1989

- First Report to the U.S. Congress and the U.S. Secretary of Energy from the Nuclear Waste Technical Review Board, March 1990 (Recommendations A, B, C, D, E, and J)

- Transcript of DOE Briefing to Nuclear Waste Technical Review Board (NWTRB) (Structural Geology and Geoengineering Panel), April 11-12, 1989

2.2.1.2 Identification of Comments and Concerns--The NRC staff, the State of Nevada, and the Structural Geology and Geoengineering Panel of the NWTRB questioned specific items related to the configuration and construction methods proposed in the Title I and early Title II designs for the ESF. These questions have been expressed in the form of comments, concerns, and recommendations. Comments and concerns relating to the configuration and construction methods proposed in the Title I design and early Title II design of the ESF were identified in a manner that was similar to that used to identify requirements described in Section 2.1.1.2. The review of the comments and concerns identified by this activity was integrated with the review of the requirements and conducted in parallel with the review of the requirements.

2.2.2 Comments and Concerns Identified

2.2.2.1 NRC Comments and Concerns--The comments and concerns expressed by the NRC staff in NUREG 1347 (1989) were incorporated in this study in two forms: (1) those comments that were general in nature and were expressed in several sections of NUREG 1347 were summarized by the reviewer and (2) those comments that were specific in nature and expressed in a single location were quoted by the reviewer. In the text that follows, the summarized comments will be presented first and the quoted comments second.

Summarized Comments

SCA Sections 2.2.3, 3.2.3(1), 3.7.1(2), 4.1 Objection 1, last bullet, and 4.2 Comment 35.

Comment Summary--The program of drifting in the northern part of the repository block, combined with the surface-based test program, may not yield data representative of conditions and processes throughout the repository block because, based on existing information, geologic conditions in the area of the proposed ESF may not be characteristic of potentially adverse conditions elsewhere in that block.

SCA Sections 2.4, 3.4, and 4.1 Objection 1, bullet 1 b. (This objection is a roll-up of concerns expressed in Comments 72, 74, and 119 as well.)

Comment Summary--The DOE has proposed a seal design concept that relies primarily on an engineered drainage system and the assumption that such a system would be effective over the repository life time. There are uncertainties in the long-term performance of an underground drainage system, a concept not previously supported by any large scale tests. The result is that this concept, which would not be tested until after submittal of the license application, would necessarily be the basis of DOE's license application because, under the assumption seals are not needed, the strategy of and schedule for seal testing is not oriented toward providing necessary and sufficient data in support of the license application. Hence, available information may not be adequate to establish the acceptability of DOE's seal program. Accordingly, it is recommended that DOE start potentially important large scale in situ tests as early as practicable during site characterization and incorporate such test in the design of the ESF.

SCA Sections 2.5, 3.5, 3.7.1(2), 4.1 Objection 1, bullet 1 a and bullet 3, 4.2 Comments 82, 119 (in part) and 4.3 Question 58.

Comment Summary--The waste package testing program does not include substantive in situ testing. Laboratory testing is laid out in the SCP, but that testing by itself does not seem adequate to resolve the full range of waste package issues. Consequently, plans for in situ tests should be incorporated into the design of the ESF. In addition, the NRC recommends establishment of a long-term waste package performance confirmation program that recognizes the benefits that such a program can provide. In this regard, the relationship of long-term waste package performance confirmation with in-situ testing of waste packages should be considered.

SCA Sections 2.7, 3.7.1(2), and 4.1 Objection 1, bullet 3(a).

Comment Summary--Analyses have not been presented to demonstrate that the main test area layout and test durations will permit all currently identified tests to be conducted without construction and operational interference for the time periods required. Also, information in the SCP did not show that thermal tests can be conducted for sufficient lengths of time to gather necessary site characterization data without interference problems.

SCA Sections 4.1, second bullet item d and 4.2 Comment 132.

Comment Summary--The requirements of 10 CFR 60.21(c)(1)(ii)(D) (Consideration of Major Design Features) have not been adequately addressed in evaluating the acceptability of ESF Title I design. The following concerns have been identified:

1. Limited comparative evaluation of alternatives to major design features.

2. Insufficient evidence that differences among alternative shaft locations for currently expected conditions are not significant to waste isolation.

3. Insufficient supporting arguments that current shaft location is the only possible way to characterize the northeast part of the repository.

4. Questionable conclusion that shaft location is not expected to affect significantly the waste isolation capabilities of the site.

5. Inadequate consideration of the presence of an anomaly near the ESF with respect to 10 CFR 60.21(c)(1)(ii)(D) requirements.

6. Questionable conclusion that data from borehole USW G-4 supports representativeness of the ESF location.

7. Insufficient consideration of surface uplift/subsidence induced by waste emplacement surrounding the shafts.

8. Insufficient consideration of potential blockage of shaft sump drainage by geochemical changes.

SCA Section 4.1 Objection 1, third bullet, items f and g.

Comment Summary--The locations of several major tests identified in the SCP as well as other tests that are yet to be defined have not been specifically identified. These include some tests that could have a considerable zone of influence and some that require extensive test areas.

Quoted Comments

SCA Section 4.1, third bullet item d.

"It is not clear that uncertainties have been sufficiently considered in the calculation 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."

SCA Section 4.1 Objection 1, third bullet item e.

"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."

SCA Section 4.1 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 since some areas may not be suitable for use because of faults, lithophysal content, breccia, offsets from waste emplacement areas, and offsets from proposed multipurpose boreholes."

SCA Section 4.1 Objection 1, third bullet item i.

"The zone of influence of existing borehole USW G-4 located within the dedicated test area should be considered in evaluating the size of suitable available test space."

SCA Section 3.2.1 and 4.2, Comment 16.

"Plans to characterize the geohydrologic properties of the Calico Hills unit are not complete. It is currently hypothesized in the SCP that groundwater flow through fractures and faults within the Calico Hills nonwelded unit is negligible. As a result, the Calico Hills nonwelded unit has been designated the primary natural barrier to groundwater flow and radionuclide transport. However, current plans for characterizing the Calico Hills unit are limited to surface-based studies. Development of in-situ testing in the Calico Hills unit as part of the ESF is being held in abeyance because of a concern that penetration of the unit within the repository block may adversely affect the performance of the site. Because of the importance placed upon the Calico Hills unit in demonstrating compliance with the performance objectives of Part 60, the staff considers development and completion of an adequate testing plan for the unit to be a significant open item."

SCA Comment 56 (pg. 4-52).

"The validation of models should be a part of the overall test program. It is not clear that the aspects have been addressed by the test program."

SCA Section 4.2 Comment 57 (pg. 4-52).

"Studies relating to design verification do not consider investigating the effects of underground excavation in the tuff using alternate excavation methods."

SCA Comment 77 (pg. 4-65).

"In evaluating potential effects of credible accidents on projected preclosure radiological exposures, the SCP has not sufficiently considered retrieval operations. NRC staff considers that waste retrieval operations may have environmental effects including: (1) operational problems due to increased temperature of rock mass and disposal room; (2) potential physical deterioration of emplacement room and emplacement boreholes; (3) potential deterioration or breaching of waste packages."
SCA Comment 89 (pg. 4-71).

"Consider the effect of pH changes resulting from building materials in the repository on the corrosion of the metal waste containers and the leach rates of radionuclides from the glass."

SCA Comment 123 (pg. 4-92).

"The effects of ventilation of the exploratory shafts and the underground testing rooms may have been underestimated in the evaluation of the potential interference with testing and the potential for irreversible changes to baseline site conditions; also, there is not an adequate analysis of the effects of ventilation in the ESF on the ability of the site to isolate waste."

SCA Question 3 (pg. 4-103, 4-104).

"The SCP updates should address the total area requirements, including the area required for adequate flexibility in the repository development, in planning the site investigation program."

SCA Question 55 (pg. 4-125).

"An analysis of the effects of water handling facilities on testing and postclosure performance should be performed before these facilities are constructed, operated, and their ultimate disposition is decided."

SCA Question 57 (pg. 4-126).

"Evaluate the influence of the location of multi-purpose boreholes (MPBH) on (i) design flexibility of upper demonstration breakout room (UDBR) due to potential interference and (ii) interference with underground testing at the main test level."

SCA Section 4.1, third bullet item b, and Question 59.

"The zones of influence presented for thermal tests are based on short test durations (e.g., canister-scale heater experiment, heated block test, and heated room experiment are planned for 30 months, 100 days, and 36 months, respectively). Longer tests 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."

SCA Question 60 (pg. 4-127).

"Identify the potential interferences between the radial boreholes test and shaft construction/operations."

2.2.2.2 State of Nevada Comments and Concerns--The State of Nevada's comments contained in State of Nevada Comments on the U.S. Department of Energy Site Characterization Plan, Yucca Mountain Site, Nevada were reviewed. The State's comments contained in this document are believed to be equally applicable to all options; no comments from this document were identified that could be used to discriminate between and among options. The State of Nevada also commented on the DOE's Title I Design of the Exploratory Shaft Facilities[7]. The State's comments, that were within the scope of this study, were judged to be equivalent to specific NRC comments, NWTRB comments, regulatory criteria, or screening criteria. The State's comments[8] that were judged to be within the scope of this study were correlated with corresponding NRC and NWTRB comments, regulatory criteria, or ESF-AS Screening Criteria and are identified in the correlation matrix presented in Appendix 2B. The State comments that were judged to be outside the scope of this study are also identified in Appendix 2B.

2.2.2.3 NWTRB March 3, 1990 Comments and Concerns--In the NWTRB First Report to Congress, dated March 3, 1990, the Structural Geology and Geoengineering Panel identified six concerns that may be used to discriminate between and among options. These concerns are

1. Shaft Construction

"The DOE's program contemplated the excavation of two exploratory shafts, each about 1,100 feet deep, using conventional drill-and-blast techniques. These techniques can cause disturbance to the rock walls in two ways: (1) by introducing water into the

[7] A compilation of the State's comments is presented in a letter from C. P. Gertz, YMPO, to R. R. Loux, Jr., State of Nevada, titled: U.S. Department of Energy (DOE) Responses to Comments in the State of Nevada's May 30, 1989, Letter on the Exploratory Shaft Facility (ESF), dated Dec. 13, 1990, Accession Number 544-7590.

[8] In this table, the State's comments have been placed in generic categories. For example, all comments related to surface flooding are classified under that heading. Interested parties may request a copy of the YMPO's summary of the State's comments form the YMPO. The procedure for obtaining copies is described in Section 1.4.

unsaturated rock from the blast-hole drilling, and (2) by creating new fractures and opening up existing natural fractures by the dynamic blasting forces. By contrast, mechanical excavation techniques would reduce the disturbance to the rock walls of the shafts and also would provide the potential for faster and more economical excavation. The less disturbed rock walls for the shafts also would make the conduct and interpretation of in-situ testing more reliable."

2. Exploration of the Ghost Dance Fault

"The initial study plans of the DOE call for a number of exploratory drifts (tunnels) to be excavated from the bottom of the shafts to explore for specific geologic features. One of these is to cut the Ghost Dance Fault, which crosses the site in a north-south direction. The Board believes that this potentially important fault should be crossed at least twice by exploratory drifts, so that the fault zone may be inspected and characterized in different areas. One of these crossings should be made farther to the south, where the fault displacement is believed to be larger than in the vicinity of the exploratory shafts."

3. An East-West Exploratory Drift

"The Board believes that an additional exploratory drift should be driven over and above those proposed in the SCP. This drift would run east-west across the middle of the Yucca Mountain block and would facilitate the detection of any unknown north-south trending faults that might exist. Also, the additional drift would offer the opportunity to inspect and characterize a larger extent of the candidate repository host rock (welded tuff) closer to the center of the site and away from the shafts."

4. An Inclined Ramp into the East Side of the Yucca Mountain Block

"Consideration should be given to replacing one of the two exploratory shafts with an inclined tunnel (or ramp) driven from the surface into the east side of the Yucca Mountain geologic block. Such a ramp would cross a number of the known faults that occur between the surface facilities and the repository area in Yucca Mountain. The ramp would allow the faults to be inspected at some depth below the surface where they can be characterized better than at the surface. The ramp also would intersect most of the tuff units of interest and would allow for short exploratory rooms or drifts to be excavated at any point of special interest for detailed mapping or testing."

5. Geologic Mapping of Shafts and Tunnels

"The DOE and its contractors have emphasized the need to carefully map the shaft and tunnel walls, particularly the natural fractures or joints that occur in the different geologic units. The Board agrees that such mapping is important so that indexing of the fractures can be done for comparison with other geological units and with the same unit at other locations. Units can also be correlated with mechanical properties, such as permeability, deformability, and strength."

"Mapping of the shaft or tunnel walls that have been bored, rather than blasted, should provide the most reliable data because of the less disturbed conditions. Before mapping the rock, the surfaces must be cleaned of dust and perhaps stained by brushing or spraying on a liquid to enhance the recognition of the finer joints."

6. Exploration of the Softer Tuff Units

"Within the 1,100-foot-thick tuff units that occur between the repository level and the surface are a number of interbeds of softer, tuff units, which are much less fractured and thereby less permeable than the harder welded tuff units. These softer, less fractured units are important in impeding downward flow of surface infiltration. Also, below the repository level, the thick Calico Hills formation is a similar, softer, and less fractured tuff that will provide the main retardation of downward flow from the repository level to the deep groundwater table."

"The DOE exploratory program should include both borings and penetration by shafts, ramps, or tunnels of these softer, less permeable units, so that inspection, mapping, and testing can be conducted. The outcome of work on these units is critical to site characterization."

2.2.2.4 NWTRB April 11-12, 1989 Comments and Concerns--The concerns expressed by the NWTRB's Structural Geology and Geoengineering Panel at its April 11-12, 1990, meeting that could be used to discriminate between and among options were identified by reviewing the meeting transcripts. All concerns expressed by the panel at this meeting were subsequently identified by the panel in the NWTRB's March 3, 1990, report and are identified in Section 2.2.2.3.

2.3 <u>Crosswalk of Requirements</u>

In order to assure that the decision process took into account potentially discriminatory requirements, concerns, etc., each requirement was cross-correlated to the decision factors expressed in the influence diagrams. (The influence diagrams are discussed in Volume 2). This process assured that the essence of each discriminatory requirement, as expressed by a specific decision factor (bubble on an influence diagram), would be considered by one or more of the expert panels as they evaluated each option. The draft copy of the crosswalk, similar to that presented in Appendix 2C for each set of regulations or requirements (a set being the requirements from one document source), was made available to the panels during the evaluation of options.

A summary of the crosswalk for the 10 CFR 60 requirements is presented in Table 2-1. An "X" in a box in Table 2-1 indicates that the requirement is relevant to at least one factor listed in the indicated influence diagram. The exact factors to which the requirement applies can be found in the detailed crosswalk matrix. A complete set of summary sheets and the detailed crosswalk matrix for each requirement set is provided in Appendix 2C.

2.4 <u>Testing Requirements</u>

Chapter 8 of the Site Characterization Plan for the Yucca Mountain site, Nevada Research and Development Area, Nevada (SCP) (DOE, 1988) provided the basis for all site characterization testing to be conducted at the Yucca Mountain site. Thirty-five tests were defined in the SCP to be conducted in the ESF; these tests are listed in Table 2-2, with reference to the Section of the SCP in which they are described.

The objective of these tests was to acquire specific site data for use in design and performance assessment. At the time the SCP was prepared, the reference design for the ESF included two shafts but no ramps. The ESF options to be evaluated used either shafts or ramps or a combination. As the testing basis for this study, each option was required to provide the capability for acquiring the site data identified in the 35 tests listed in Table 2-2. In particular, where the SCP defined tests to acquire site data in a shaft, this study required that some data be acquired in all accesses.

TABLE 2-1
10 CFR 60 SUBSECTIONS DETERMINED TO BE DISCRIMINATORS FOR ESF-REPOSITORY

10 CFR 60 REFERENCES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
60.15 (c) (1)	X						X	X		X	X	X	X	X	
60.15 (c) (2)	X			X			X	X		X	X	X	X	X	
60.15 (c) (3)	X			X			X	X		X	X	X	X	X	
60.15 (c) (4)	X			X			X	X		X	X	X	X	X	
60.21 (c) (1) (ii) (D)	X							X		X	X	X	X		X
60.21 (c) (1) (ii) (E)	X														
60.21 (c) (11)	X			X			X	X							
60.74 (a)	X	X	X				X	X			X	X	X	X	
60.74 (b)	X						X	X						X	
60.111 (a)* & (b)*	X		X												X
60.112	X													X	
60.113 (a) (1) & (a) (2)	X									X	X	X	X	X	
60.122 (a) (2) & (b) (1)	X									X	X			X	
60.130	X			X										X	
60.131(b) (1)	X														
60.133 (a) (1) & (a) (2)	X			X			X							X	
60.133 (b)	X													X	
60.133 (c)															X
60.133 (e) (1) & (e) (2)	X			X			X			X	X	X	X	X	X
60.133 (f)	X						X							X	
60.133 (g)	X			X			X							X	
60.133 (h)	X													X	
60.133 (i)	X													X	
60.134	X														
60.135 (a) (1) & (2)	X	X	X				X					X	X		
60.137	X							X							

*Elevated to discriminator during review

LEGEND

The following titles relate to the *INFLUENCE DIAGRAM NUMBERS.

Postclosure Health	1 Health Effects Portion Transport Through Natural Barriers Portion Engineered Barrier System Portion Scenario Portion
Preclosure Health and Safety	2 Radiological Worker Health 3 Radiological Public Health 4 Nonradiological Worker Safety
Environment	5 Aesthetics 6 Historical Properties
Cost - Direct	7 Total System Life Cycle Cost Repository Life Cycle Cost ESF Cost
Schedule - Indirect	8 Schedule - Indirect Costs Schedule - Indirect Costs
Programmatic Viability	9 Probability of Programmatic Viability
Characterization Testing	10 Probability of Early False Positive 11 Probability of Late False Positive 12 Probability of Early False Negative 13 Probability of Late False Negative (Page 1 of 2) Probability of Late False Negative (Page 2 of 2)
Regulatory Authorization	14 Likelihood of Construction/Operation Approval
Closure	15 Likelihood of Retrieval

TABLE 2-2

EXPLORATORY STUDIES FACILITY (ESF) EXPERIMENTS AS DESCRIBED IN THE SITE CHARACTERIZATION PLAN (SCP)

SCP Activity Title	SCP Section Reference	ESF Testing Location
Shaft Convergence	8.3.1.15.1.5.1	Access
Demonstration Breakout Rooms	8.3.1.15.1.5.2	Access/MTL
Sequential Drift Mining	8.3.1.15.1.5.3	MTL
Heater Experiment in Unit TSw1	8.3.1.15.1.6.1	Access
Canister-Scale Heater Experiment	8.3.1.5.1.6.2	MTL
Yucca Mountain Heated Block	8.3.1.5.1.6.3	MTL
Thermal Stress Measurements	8.3.1.15.1.6.4	MTL
Heated Room Experiment	8.3.1.15.1.6.5	MTL
Development and Demonstration of Required Equipment	8.3.2.5.6	MTL
Plate Loading Tests	8.3.1.15.1.7.1	MTL/Long Drifts
Rock-Mass Strength Experiment	8.3.1.15.1.7.2	MTL/Long Drifts
Evaluation of Mining Methods	8.3.1.15.1.8.1	Access/MTL/Long Drifts
Monitoring of Ground Support Systems	8.3.1.15.1.8.2	Access/MTL/Long Drifts
Monitoring Drift Stability	8.3.1.15.1.8.3	MTL/Long Drifts
Air Quality and Ventilation Experiment	8.3.1.15.1.8.4	Access/MTL/Long Drifts

TABLE 2-2 (continued)

EXPLORATORY STUDIES FACILITY (ESF) EXPERIMENTS AS DESCRIBED IN THE SITE CHARACTERIZATION PLAN (SCP)

SCP Activity Title	SCP Section Reference	ESF Testing Location
In-Situ Testing of Seal Components	8.3.3.2.2.3	MTL
Overcore Stress Experiments in the Exploratory Shaft Facility	8.3.1.15.2.1.2	Access/MTL/Long Drifts
Engineered Barrier System Field Tests	8.3.4.2.4.4	MTL
Laboratory Tests (Thermal and Mechanical) Using Samples Obtained from the ESF	8.3.1.15.1.1.4	Access/MTL/Long Drifts
Geologic Mapping of the Exploratory Shaft and Drifts	8.3.1.4.2.2.4	Access/MTL/Long Drifts
Mineralogy and Petrology of Candidate Host Rock	8.3.1.3.2.1.1 8.3.1.3.2.1.3 8.3.1.3.2.2.1	Access/MTL/Long Drifts
Seismic Tomography/ Vertical Seismic Profiling	8.3.1.4.2.2.5	Access
Matrix Hydrologic Properties Testing	8.3.1.2.2.3.1	Access/MTL/Long Drifts
Intact-Fracture Test in the Exploratory Shaft Facility	8.3.1.2.2.4.1	Access/MTL
Percolation Tests in the Exploratory Shaft Facility	8.3.1.2.2.4.2	MTL
Bulk-Permeability Test in the Exploratory Shaft Facility	8.3.1.2.2.4.3	MTL

TABLE 2-2 (concluded)

EXPLORATORY STUDIES FACILITY (ESF) EXPERIMENTS AS DESCRIBED IN THE SITE CHARACTERIZATION PLAN (SCP)

SCP Activity Title	SCP Section Reference	ESF Testing Location
Radial Borehole Tests in the Exploratory Shaft Facility	8.3.1.2.2.4.4	Access
Excavation Effects Test in the Exploratory Shaft Facility	8.3.1.2.2.4.5	Access
Calico Hills Test in the Exploratory Shaft Facility	8.3.1.2.2.4.6	Calico Hills
Perched-Water Test in the Exploratory Shaft Facility	8.3.1.2.2.4.7	Access/MTL/Long Drifts
Hydrochemistry Tests in the Exploratory Shaft Facility	8.3.1.2.2.4.8	Access/MTL/Long Drifts
Diffusion Tests in the Exploratory Shaft Facility	8.3.1.2.2.5.1	MTL
Chloride and Chlorine -36 Measurements of Percolation at Yucca Mountain	8.3.1.2.2.1	Access/MTL/Long Drifts
Multipurpose-Borehole Testing Near the ESF	8.3.1.2.2.4.9	N/A
Hydrologic Properties of Major Faults Encountered in Main Test Level of the Exploratory Shaft Facility	8.3.1.2.2.4.10	Access/MTL/Long Drifts

3.0 HISTORICAL AND NEW ESF-REPOSITORY OPTIONS FOR PRELIMINARY SCREENING

The identification and development of ESF options had been underway for a period of 9 to 10 years when this study was initiated. The exploratory facilities had progressed from a single-access blind-drilled shaft, 8 feet in diameter, through the Title I ESF Design to the initial studies supporting resumption of Title II Design. In this section, historical information relating to the development of the conceptual design of the ESF and the repository is presented. The development of new ESF-repository concepts is also discussed in this section. Both the historical concepts and the new concepts were screened to obtain a set of options for use in this study. The screening process used to develop these options is discussed in the following section, Section 4.0, of this report.

3.1 Identification of Historical Configurations

A literature search was conducted to identify the ESF configurations and separate repository configurations that had been considered in the past. The literature search covered the period from February 1981 through December 1989 and was focused principally on the records and files of architects/engineers (A/E) that were involved in the ESF and repository design efforts during that period. The literature search was conducted under the control of SNL QA procedures (DIM 243). A list of documents identified as relevant to the historical ESF and repository configurations is provided in Appendix 3A.

3.1.1 Identification of Historical ESF Configurations

The literature search for ESF configurations focused on records found in the REECo and RSN files. REECo served as the ESF A/E prior to the start of ESF Title I design. RSN (formerly FSN and H&N) led the ESF Title I and early Title II design efforts.

For each of the ESF layouts identified in the literature search, data sheets were developed to provide the following information, if available on the records:

- Number, type, size, and location of the accesses
- Construction method

- Constructability
- MTL description and test rationale
- Cost estimates
- Construction schedules
- Non-radiological health and safety evaluations
- Needs for development and testing of new equipment
- Representative sketches
- Other information

In addition, the data sheets identified (if available from the records) how each of the identified layouts was evaluated at the time it was developed and the process (if any) used to review each layout. The data sheets included the following information:

- Scope of the evaluation
- Methodology used to conduct the evaluation
- Results of the evaluation
- Recommendations
- QA procedures under which the evaluation was conducted
- Other information

As expected, some configurations were better documented in the records than others. Information that was not found in the records was noted as "Not Available" on the data sheets.

During the course of the literature review, a system to identify the different historical ESF configurations was developed. The configurations were identified in terms of a construction and access method, a configuration subset, an underground test-level configuration, and a design time line. Construction method and access methods were identified for single or multiple-access ESF configurations. Configuration subsets were identified for all options by providing a description of the underground-access sizing, depth or length of the accesses, and method of ground support. Underground test-level descriptions were identified for each ESF configuration. The Time Line was developed for the period January 1981, to December 1989, utilizing fixed points for recognized Project documents associated with A/E design studies, Conceptual, and Title I and Title II Designs. Miscellaneous ESF configurations associated with the project, but not necessarily associated with the formal A/E design process, were fit into the Time Line by calendar time or by association. The use of the Time Line was to provide continuity between the formal A/E-associated ESF configurations and those that were not part of a similar A/E design process.

Thirteen unique construction and access methods (1 through 13) were identified which, combined with the identified configuration subsets (1 through 15), produced a total of 52 historical ESF configurations. In addition, a total of 9 underground test-level configurations (A through I) were identified and were included as part of each of the 52 identified ESF configurations. Each configuration was therefore capable of being described by a unique identifier such as 2-11B, where the first number (2) is associated with a construction and access method, the second number (11) describes a configuration subset, and the letter (B) describes an underground test-level configuration. Table 3-1 lists the complete set of 52 historical ESF configurations, provides dates on the Time Line, and provides a brief description of each of the configuration subsets. A records package containing data sheets for all 52 configurations is identified in Appendix 3A. This records package includes a bibliography of reports used to identify the historical ESF configurations. A description of the 13 construction and access methods and their associated subsets is included in Appendix 3B. A description of the nine underground test-level configurations is provided in Appendix 3C.

3.1.2 Identification of Historical Repository Configurations

Next, a literature search for historical repository configurations considered in the past was conducted by PBQ&D. PBQ&D made a thorough review of applicable project literature available in its library and from the personal working files of staff engineers who were involved in the repository design. After examining the available material, SNL and PBQ&D personnel agreed to consider the start of the historical sequence for repository configurations as the date of passage of Nuclear Waste Policy Act of 1982. The designs from the reviewed material were then categorized into similar groups of historical repository configurations. Out of the categorized groups, 15 configurations that represented the design at different historical phases were chosen, based on the emphasis in the documentation and the distinctive features of each concept, such as mining method differences, major changes in access locations, and different repository orientations.

TABLE 3-1

HISTORICAL ESF CONFIGURATIONS AND CONFIGURATION SUBSET SUMMARY LIST

Construction and Access Method	Configuration Subset	Time Line Date	Subset Description	Underground Test Level Configuration
(1) Single Access, Blind Drilled Shaft	1	02/26/81	2-stage, 98-in. I.D., TD 2000 ft; 74-in. I.D., TD 3500 ft.	A
	2	02/26/81	74-in. I.D., TD 3500 ft.	A
	3	05/07/81	2-stage, 122-in. I.D., 2200 ft.; 100-in. I.D., TD 3500 ft.	A
	4	10/29/81	2-stage, 122-in. I.D., 2200 ft.; 100-in. I.D., TD 3500 ft.	A
	5	03/18/82	144-in. I.D., TD 1200 ft.	A
	6	03/18/82	144-in. I.D., TD 1600 ft.	A
	7	03/18/82	144-in. I.D., TD 3100 ft.	A
	8	03/22/82	122-in. I.D., TD 1700 ft.	A
	9	05/04/82	96-in. I.D., TD 2000 ft.	A
	10	05/14/82	122-in. I.D., TD 3500 ft.	A
	11	05/14/82	122-in. I.D., TD 1800 ft.	A
	12	05/14/82	2-stage, 122-in. I.D., 1800 ft., characterize; drill TD 3500 ft.	A
	13	06/11/82	2-stage, 98-in. I.D., 1800 ft.; 74-in. I.D., TD 3500 ft.	A

*Time Line Milestone (Reference Exhibit 1-1)

TABLE 3-1

HISTORICAL ESF CONFIGURATIONS AND CONFIGURATION SUBSET SUMMARY LIST (continued)

Construction and Access Method	Configuration Subset	Time Line Date	Subset Description	Underground Test Level Configuration
(1) Single Access, Blind Drilled Shaft (continued)	14	06/30/82	2-stage, 98-in. I.D., 1800 ft.; 74-in. I.D., TD 3500 ft.	A
	15	06/30/82	72-in. I.D., TD 1700 ft.	A
(2) Single Access, Conventionally Sunk Shaft	1	10/15/81	12-ft. concrete shaft, TD 3500 ft.	B
	2	03/18/82	12-ft. concrete shaft, TD 1200 ft.	B
	3	03/18/82	12-ft. concrete shaft, TD 1600 ft.	B
	4	03/18/82	12-ft. concrete shaft, TD 3100 ft.	B
	5	05/04/82	14-ft. concrete shaft, TD 2000 ft.	B
	6	05/14/82	12-ft. concrete shaft, TD 1800 ft.	A
	7	05/14/82	12-ft. concrete shaft, TD 3500 ft.	A
	8	05/14/82	2-stage, 12-ft. concrete shaft, characterize, 1800 ft.; 12-ft. concrete shaft, TD 3500 ft.	B
	9	06/30/82	12-ft. finished shaft, TD 1600 ft.	B
	10	*04/11/83 08/05/83	12-ft. concrete shaft, TD 1530 ft.	B B
	11	08/05/83	12-ft. concrete shaft, TD 1520 ft.	B

*Time Line Milestone (Reference Exhibit 1-1)

TABLE 3-1

HISTORICAL ESF CONFIGURATIONS AND CONFIGURATION SUBSET SUMMARY LIST (continued)

Construction and Access Method	Configuration Subset	Time Line Date	Subset Description	Underground Test Level Configuration
(2) Single Access, Conventionally Sunk Shaft (Continued)	12	08/01/83	12-ft. concrete shaft, TD 1600 ft.	B
	13	03/11/84	12-ft. concrete shaft, TD 1480 ft.	C
	14	12/01/84	12-ft. concrete shaft, TD 1480 ft.	C
(3) Single Access, Conventionally Mined Ramp	1	05/04/82	Decline, 14 ft. x 14 ft., 7728 ft. long	A
	2	05/14/82	Decline, total depth 1800 ft.	A
(4) Single Access Conventionally Mined Ramp and Conventionally Sunk Shaft Combination	1	05/14/82	2-stage, drive decline to 1800 ft. depth, characterize; sink vertical shaft to TD 3500 ft. (12-ft. finished)	A
(5) Single Access, Conventionally Mined Ramp and Blind Drilled Shaft Combination	1	05/14/82	2-stage, drive decline to 1800 ft. depth, characterize; drill shaft to TD 3500 ft.	A
(6) Single Access, Blind Drilled Shaft and Blind Drilled Shaft Combination	1	05/14/82	2-stage, drill shaft to 1800 ft., characterize; complete drilled shaft to TD 3500 ft.	A

*Time Line Milestone (Reference Exhibit 1-1)

TABLE 3-1

HISTORICAL ESF CONFIGURATIONS AND CONFIGURATION SUBSET SUMMARY LIST (continued)

Construction and Access Method	Configuration Subset	Time Line Date	Subset Description	Underground Test Level Configuration
(7) Single Access, Conventionally Sunk Shaft and Conventionally Sunk Shaft Combination	1	05/14/82	2-stage, sink shaft to 1800 ft. (12-ft. finished), characterize; continue shaft to TD 3500 ft. (12-ft. finished)	A
(8) Single Access, Blind Drilled Shaft and Conventionally Sunk Combination	1	05/14/82	2-stage, drill shaft to 1800 ft., characterize; sink shaft to TD 3500 ft. (12-ft. finished)	A
(9) Single Access, Conventionally Sunk Shaft and Blind Drilled Shaft Combination	1	05/14/82	2-stage, sink to 1800 ft., characterize; drill shaft to TD 3500 ft.	A
(10) Single Access, Conventionally Mined Ramp and Conventionally Mined Ramp Combination	1	05/14/82	2-stage, drive to 1800 ft. depth, characterize; continue decline to 3500 ft. depth	A
(11) Multiple Access, Two Conventionally Sunk Shafts	1	12/01/84	#1 shaft, 12-ft. concrete shaft, TD 1480 ft.; #2 shaft, 25-ft. concrete lined, TD 1110 ft.	C

*Time Line Milestone (Reference Exhibit 1-1)

TABLE 3-1

HISTORICAL ESF CONFIGURATIONS AND CONFIGURATION SUBSET SUMMARY LIST (continued)

Construction and Access Method	Configuration Subset	Time Line Date	Subset Description	Underground Test Level Configuration
(11) Multiple Access, Two Conventionally Sunk Shafts (continued)	2	12/01/84	#1 shaft, 16-ft. concrete shaft, TD 1480 ft.; #2 shaft, 25-ft. concrete shaft, TD 1110 ft.	C
	3	02/14/86	#1 shaft, 12-ft. concrete shaft, TD 1480 ft.; #2 shaft, 15-ft. concrete shaft, TD 1480 ft. (ESF Location Change)	F
	4	11/29/86	ES-1 shaft, 12-ft. concrete shaft, TD 1400 ft.; ES-2 shaft, 12-ft. concrete shaft, TD 1100 ft.	G
		04/15/87		G
		•04/26/88		G
	5	06/16/89	ES-1 shaft, 12-ft. concrete shaft, TD 1105 ft.; ES-2 shaft, 12-ft. concrete shaft, TD 1153.5 ft.	H I
		•08/01/88		H
		•10/25/88		H
		•09/29/89		I
	6	06/16/89	ES-1 shaft, 14-ft. concrete shaft, TD 1105 ft.; ES-2 shaft, 14-ft. concrete shaft, TD 1153.5 ft.	H
	7	06/16/89	ES-1 shaft, 16-ft. concrete shaft, TD 1105 ft.; ES-2 shaft, 16-ft. concrete shaft, TD 1153.5 ft.	H

•Time Line Milestone (Reference Exhibit 1-1)

TABLE 3-1

HISTORICAL ESF CONFIGURATIONS AND CONFIGURATION SUBSET SUMMARY LIST (continued)

Construction and Access Method	Configuration Subset	Time Line Date	Subset Description	Underground Test Level Configuration
(12) Multiple Access, One Conventionally Sunk Shaft and One Tunnel Boring Machine Ramp	1	12/01/84	#1 shaft, 12-ft. concrete shaft, TD 1480 ft.; TBM ramp, 19-ft. dia., -15% grade, 4700 ft. long	C
	2	12/01/84	#1 shaft, 16-ft. concrete shaft, TD 1480 ft.; TBM ramp, 19-ft. dia., -15% grade, 4700 ft. long	C
	3	12/01/84	#1 shaft, 12-ft. concrete shaft, TD 1480 ft.; TBM ramp, 24-ft. dia., -8% grade, 6725 ft. long	C
	4	12/01/84	#1 shaft, 16-ft. concrete shaft, TD 1480 ft.; TBM ramp, 24-ft. dia., -8% grade, 6725 ft. long	C
(13) Multiple Access, One Conventionally Sunk Shaft and One Raised Bore Shaft	1	12/01/84	#1 shaft, 12-ft. concrete shaft, TD 1480 ft.; #2 shaft, 6-ft. dia., raised bored shaft, TD 1200 ft.	C
		*04/08/85		D
		12/02/85		E
	2	12/01/84	#1 shaft, 16-ft. concrete lined shaft, TD 1480 ft.; #2 shaft, 6-ft. dia. bored shaft, TD 1200 ft.	C

*Time Line Milestone (Reference Exhibit 1-1)

TABLE 3-1

HISTORICAL ESF CONFIGURATIONS AND CONFIGURATION SUBSET SUMMARY LIST (concluded)

Construction and Access Method	Configuration Subset	Time Line Date	Subset Description	Underground Test Level Configuration
(13) Multiple Access, One Conventionally Sunk Shaft and One Raised Bore Shaft (continued)	3	*03/14/86	ES-1 shaft, 12-ft. concrete shaft, TD 1480 ft.; ES-2 shaft, 6-ft. dia. raise bored shaft, TD 1200 ft.	E
		12/02/85		E
		05/07/85		E

*Time Line Milestone (Reference Exhibit 1-1)

Data sheets were developed using a common format to present the information gathered during the literature search of historical repository configurations. For each of the repository layouts identified by the literature search, the following information (where available in the records) was to be provided in the data sheets.

- Number, type, size, and location of the accesses
- Construction method
- Constructability
- Cost estimates
- Construction schedules
- Non-radiological health and safety evaluations
- Needs for development and testing of new equipment
- Representative sketches
- Other information

The following additional information was provided (if available from the records) in the data sheets:

- Scope of the evaluation
- Methodology used to conduct the evaluation
- Results of the evaluation
- Recommendations
- QA procedures under which the evaluation was conducted
- Other information

The 15 historical repository configurations represent the evaluation of a number of disposal concepts and available technology. Table 3-2 lists the 15 historical repository configurations identified during the literature search (identified as R1 through R15). The table lists the number of subsets and provides a brief description of each configuration. Some of the layouts are predicated on drill and blast mining techniques, others on tunnel boring machines (TBM), and some on a combination of both techniques. Some of the configurations take potential fault zones into consideration, by developing the underground openings to avoid such structural features.

The first two historical repository configurations (R1, R2) are based on early designs produced by Dravo Engineering, Inc. These two designs provided a basis for

TABLE 3-2

HISTORICAL REPOSITORY CONFIGURATIONS SUMMARY

No.	Alternative No.	No. of Subsets*	Descriptions
1	R1	11	Initial Preconceptual - Horizontal Emplacement
2	R2	11	Initial Preconceptual - Horizontal Emplacement
3	R3	53	Two-Stage Repository Development
4	R4	1	SCP Conceptual Design - Complete Separation of DHLW from SF
5	R5	63	SCP/CDR Reference Layout
6	R6	6	SCP/CDR Based Design, Raised to New TSw1/TSw2 Interface**
7	R7	1	TBM Layout 2, 4 Blocks
8	R8	1	TBM Layout 2, 3 Blocks, Avoids Emplacement Drifts Across Ghost Dance Fault
9	R9	3	TBM Layout 3, SCP/CDR Outline and Elevation
10	R10	0	TBM Layout 4, SCP/CDR Outline, Raised to New TSw1/TSw2
11	R11	0	TBM Layout 5, SCP/CDR Outline and Elevation - Mining from South Access
12	R12	1	TBM Layout 6, Two Blocks Integrated with ESF
13	R13	0	TBM Layout 7, 4 Panels within SCP/CDR Area
14	R14	3	TBM Layout 8, 1984 Version
15	R15	1	Preconceptual Horizontal Emplacement

*Subsets shown are the number of combinations identified and not intended to define all the possible combinations potentially available.
**TSw1, Upper Topopah Spring Member, TSw2, Middle Topopah Spring Member.

development of alternative underground configurations R3 and R4 designed by PBQ&D. These configurations, R3 and R4, evolved into historical configuration R-5, the design presented in the Site Characterization Plan-Conceptual Design Report (SCP-CDR, SNL, 1987). This conceptual design, R-5, has become the standard reference base for the YMP. Additional layouts were developed parallel with and subsequent to the development of the SCP-CDR configuration. TBMs were to be used sparingly in the SCP-CDR design, but more recent designs use TBMs to develop almost the entire repository. Some of the configurations take advantage of a recently revised estimate for the elevation of the Upper Topopah Spring Member-Middle Topopah Spring Member (TSw1-TSw2) contact. The repository configuration subsets listed in Table 3-2 are also described in the data sheets for each option (see Appendix 3A for a listing of records packages containing a complete set of historical repository configurations).

The choice of shafts versus ramps for various repository functions and of the locations of these openings is different not only for the various historical repository configurations but also for the subsets of the configurations. The number of openings varies as well between configurations and subsets. Most of the configurations show a particular portion of the layout as dedicated to the ESF, with either one or two openings. In many historical configurations, the ESF is simply acknowledged, with space allotted, but there is no true integration or consideration of how the ESF and the repository designs interact. In each of the historical repository configurations, waste and muck are transported through separate openings. Each configuration can accommodate at least the mandated amount of waste (70,000 metric tons uranium [MTU]). A complete set of the configuration data sheets is included in the records packages identified in Appendix 3A. A brief description of each of the 15 historical repository configurations is included in Appendix 3D.

3.2 Identification of Preliminary New Options

3.2.1 Approach

The basic approach was to develop combinations of ESF and future repository elements into option configurations that would satisfy regulatory and testing requirements and the comments and concerns of the overview organizations (i.e., NRC and NWTRB). The method used to develop a set of new options involved a process of making rough layouts of accesses and ESF core test panels on a base Primary Area Boundary and

SCP-CDR defined repository block. This process was performed by a group of experienced engineers and scientists appointed to the task from the various participating organizations. The option development process also included the specification of various excavation methods, the size of various access openings, the functional assignments, the interfaces with the repository, and the tentative locations for various components of the configurations.

When the participants reached a consensus with respect to the feasibility, the conformity to guidelines, and the reasonableness of a concept configuration, the result was identified as a "preliminary new option." This process resulted in the development of 24 new options. Particular attention was paid to such items as alternative excavation methods, location of access entries above the possible maximum flood levels, need for additional exploratory drifting, and flexibility to characterize the site in areas below the main test level (MTL).

In addition, the 24 Preliminary New Options were developed considering the following major design "features":

- Means of access--shaft, ramp, or combinations
- Location of Accesses--northeast, southeast combinations
- Location of main (core) MTL--northeast, south combinations
- Excavation method of openings--mechanical, drill and blast, combination
- Total number of repository accesses--ESF accesses are an integrated subset of the total number of accesses needed for the repository

A simple classification scheme was developed to uniquely describe each of the 24 Preliminary New Options. This scheme included the following designations; A1-A10, B1-B9, and C1-C5 where the letter A describes a single level drill and blast repository, the letter B describes a single level TBM-excavated repository, and the letter C describes a step block (multiple level) TBM-excavated repository. The numbers following each letter refer to subsets. Table 3-3 summarizes the 24 Preliminary New Options.

TABLE 3-3

SUMMARY OF PRELIMINARY NEW OPTIONS

ACCESS SUMMARY

GROUP A. DRILL & BLAST, SINGLE LEVEL REPOSITORY

	DESCRIPTIVE TITLE	ESF ACCESSES			REPOSITORY ACCESSES *		
		SHAFTS	RAMPS	SUBTOTAL	SHAFTS	RAMPS	TOTAL
A1	MTL N., SHAFT/TUFF RAMP	1	1	2	3	2	5
A2	MTL N., SHAFT/SHAFT	2	-	2	4	2	6
A3	MTL N., SHAFT/WASTE RAMP	1	1	2	3	2	5
A4	MTL N., SHAFT/SHAFT/TUFF RAMP	2	1	3	3	2	5
A5	MTL S., SHAFT/TUFF RAMP	1	1	2	3	2	5
A6	MTL S., SHAFT/WASTE RAMP	1	1	2	3	2	5
A7	MTL N., TUFF RAMP/WASTE RAMP	-	2	2	2	2	4
A8	MTL S., TUFF RAMP/WASTE RAMP	-	2	2	2	2	4
A9	MTL S., SHAFT/TUFF RAMP	1	1	2	2	3	5
A10	MTL S., SHAFT/TUFF RAMP	1	1	2	3	2	5

GROUP B. TBM, SINGLE LEVEL REPOSITORY

	DESCRIPTIVE TITLE	ESF ACCESSES			REPOSITORY ACCESSES *		
		SHAFTS	RAMPS	SUBTOTAL	SHAFTS	RAMPS	TOTAL
B1	MTL N. SHAFT/TUFF RAMP	1	1	2	3	2	5
B2	MTL N. SHAFT/SHAFT	2	-	2	3	2	5
B3	MTL N. SHAFT/WASTE RAMP	1	1	2	3	2	5
B4	MTL S., SHAFT/TUFF RAMP	1	1	2	3	2	5
B5	MTL S., SHAFT/WASTE RAMP	1	1	2	3	2	5
B6	MTL N., TUFF RAMP/WASTE RAMP	-	2	2	2	2	4
B7	MTL S., TUFF RAMP/WASTE RAMP	-	2	2	2	2	4
B8	MTL S., SHAFT/TUFF RAMP	1	1	2	2	3	5
B9	MTL S., SHAFT/TUFF RAMP	1	1	2	3	2	5

GROUP C. TBM, STEP BLOCK REPOSITORY

	DESCRIPTIVE TITLE	ESF ACCESSES			REPOSITORY ACCESSES *		
		SHAFTS	RAMPS	SUBTOTAL	SHAFTS	RAMPS	TOTAL
C1	MTL N. SHAFT/TUFF RAMP	1	1	2	2	2	4
C2	MTL N. SHAFT/SHAFT	2	-	2	3	2	5
C3	MTL N. SHAFT/WASTE RAMP	1	1	2	2	2	4
C4	MTL S., SHAFT/TUFF RAMP	1	1	2	3	2	5
C5	MTL N., TUFF RAMP/WASTE RAMP	-	2	2	2	2	4

*INCLUDES ESF ACCESSES,VENT., M/M, TUFF, AND WASTE

3.2.2 Test Program Requirements

In addition, the preliminary new options (and all subsequent options) developed had to be capable of supporting the test program described in the SCP. This test program included 35 experiments listed in Section 2, Table 2-2. These experiments were to be conducted in the accesses, MTL, and in exploratory drifts that intersect each of the three known faults or suspected faulting in the northeast repository block. These fault areas were Ghost Dance, Drill Hole Wash, and imbricate structures. The SCP test program required that the access tests be performed (in general) as the accesses were excavated. Therefore, access construction would stop whenever there was a potential for interference between testing and construction activities. While no effort was made to define additional tests not already described in Sections 8.3 and 8.4 of the SCP (DOE, 1988), the different configurations considered did, in fact, lead to expanded test programs for many of the options considered. A significant concern of the NRC SCA (NRC, 1989) was related to a perceived lack of sufficient area devoted to testing and a related lack of flexibility to accommodate all testing; accordingly a larger test area was defined in all preliminary new options. This test area would allow expansion of the testing program in the future.

3.2.3 Description

A brief description of each of the 24 Preliminary New Options is given below. The following descriptions include three paragraphs for each of the 24 Preliminary New Options. The first paragraph describes the physical configuration of the ESF for each option (access size, access type, access function during ESF, access location, excavation method(s), MTL description, exploratory drifting description). The second paragraph describes access function during repository development and operation. The third paragraph provides a physical description of the repository. The 24 Preliminary New Options sketches and data sheets, developed through the process described, appear in Appendix 3E.

Option A1

The MTL for this option would be constructed by drill-and-blast methods and located in the northeast corner of the potential repository block; access from above would be a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp from the north. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash and Ghost Dance Fault and imbricate faults.

During potential repository development, the shaft would be used for ventilation and personnel; the ramp would be used for ventilation, muck handling, and personnel. The function of the ESF accesses during potential repository operations would be for ventilation and tuff removal for the shaft and ramp, respectively.

The potential repository would be constructed with a TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. Additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), a 25-foot-diameter mechanically mined emplacement exhaust shaft (off of the potential repository block), and a 25-foot-diameter TBM-driven waste ramp. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and the total number of accesses is five.

Option A2

The MTL for this option would be constructed by drill-and-blast methods and located in the northeast corner of the potential repository block, and would be accessed from above by two 16-foot-diameter drill-and-blast shafts. Both ESF accesses would function in science, ventilation, and emergency egress capacities; one shaft would provide men-and-materials service and the other would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development, both shafts would be used for ventilation and personnel; one would also be used for muck handling. The functions of the ESF accesses during potential repository operations would be to provide ventilation and emergency egress.

The potential repository would be constructed with a TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. The additional potential repository accesses are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), a 25-foot-diameter mechanically mined emplacement exhaust shaft (off of the potential repository block), a 25-foot-diameter TBM-driven waste ramp, and a 25-foot-diameter TBM-driven tuff ramp. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of six accesses.

<u>Option A3</u>

The MTL for this option would be constructed by drill-and-blast methods and located in the northeast corner of the potential repository block; access from above would be by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp from the north. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development, the shaft would be used for ventilation and personnel; the ramp would be used for ventilation, muck handling, and personnel. The function of the ESF accesses during potential repository operations would be for ventilation and nuclear waste handling for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. Additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), a 25-foot-diameter mechanically mined emplacement exhaust shaft (off of the potential repository block), and a 25-foot-diameter TBM-driven waste ramp. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and the total number of accesses is five.

Option A4

The MTL for this option would be constructed by drill-and-blast methods and located in the northeast corner of the potential repository block and would be accessed from the north by two shafts, one 16-foot-diameter drill-and-blast shaft, one 10-foot-diameter drill-and-blast shaft, and a 25-foot-diameter TBM ramp from the north. The three ESF accesses would all function in science, ventilation, and emergency egress capacities; however, the 10-foot shaft would be the primary science shaft and its sinking schedule would be independent of other ESF construction activities. The 16-foot shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development both shafts would be used for ventilation, personnel would be hoisted in Access 1, and the ramp would be used for ventilation, muck handling, and personnel. The 10-foot shaft would be mechanically enlarged to 25 feet for potential repository use. The function of the ESF accesses during potential repository operations would be ventilation and tuff removal for the shafts and ramp, respectively.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. The additional accesses for the potential potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), and a 25-foot-diameter TBM-driven waste ramp. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option A5

The MTL for this option would be constructed by drill-and-blast methods and located in the southern corner of the potential repository block, and would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp driven from the southeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. An exploratory drift would run the length of the potential repository block from the MTL to intersect the Drill Hole Wash Fault in the north.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and tuff removal for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. Emplacement drifts would be developed from the north, mining across the full potential repository width, with a southern retreat. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south, a 25-foot-diameter mechancially mined emplacement exhaust shaft in the north, and a 25-foot-diameter TBM-driven waste ramp in the northeast corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option A6

The MTL for this option would be constructed by drill-and-blast methods and located in the southern corner of the potential repository block and would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp driven from the northeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. An exploratory drift would run the length of the potential repository block from the MTL to intersect the Drill Hole Wash Fault in the north.

During potential repository development both MTL accesses would be used for ventilation and personnel and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and waste handling for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. Emplacement drifts would be developed from the north, mining across the full potential repository width, with a southern retreat. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south, a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north, and a 25-foot-diameter TBM-driven waste ramp in the northeast corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option A7

The MTL for this option would be constructed by drill-and-blast methods and located in the northeast corner of the potential repository block and would be accessed by two 25-foot-diameter TBM ramps from the north. Both ESF accesses would function in science, ventilation, and emergency egress capacities; one ramp would provide men-and-materials service and the other ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development both ramps would be used for ventilation and personnel, one of which would also be used for muck handling. The function of the ESF accesses during potential repository operations would be as a tuff ramp and waste ramp.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. The additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block) and a 25-foot-diameter mechanically mined emplacement exhaust shaft (off of the potential repository block). The single level of the potential repository and ESF ACS is the same as that for the SCP-CDR and has a total of four accesses.

Option A8

The MTL for this option would be constructed by drill-and-blast methods and located in the southern corner of the potential repository block and would be accessed from above by a 25-foot-diameter TBM ramp driven from the southeast and by a 25-foot-diameter TBM ramp driven from the northeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the waste handling ramp would provide men-and-materials service and the tuff ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. An exploratory drift would run the length of the potential repository block from the MTL to intersect the Drill Hole Wash Fault in the north.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the tuff ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be waste and tuff removal.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. Emplacement drifts would be developed from the north, mining across the full potential repository width, with a southern retreat. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south and a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of four accesses.

Option A9

The MTL for this option would be constructed by drill-and-blast methods and located in the southern corner of the potential repository block and would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp driven from the southeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. An exploratory drift would run the length of the potential repository block from the MTL to intersect the Drill Hole Wash Fault in the north.

During potential repository development both MTL accesses would be used for ventilation and personnel and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and tuff removal for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. Emplacement drifts would be developed from the north, mining across the full potential repository width, with a southern retreat. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials ramp in the south, a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north, and a 25-foot-diameter TBM-driven waste ramp in the northeast corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option A10

The MTL for this option would be constructed by drill-and-blast methods and located in the southern corner of the potential repository block and would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 16-foot-diameter TBM ramp driven from the southwest. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the TBM and drill-and-blast-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. An exploratory drift would run the length of the potential repository block from the MTL to intersect the Drill Hole Wash Fault in the north.

During potential repository development both MTL accesses would be used for ventilation and personnel and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and tuff removal for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for the mains and perimeter drift; the panel access and emplacement drifts would use drill-and-blast construction methods. Emplacement drifts would be developed from the north, mining across the full potential repository width, with a southern retreat. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south, a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north, and a 25-foot-diameter TBM-driven waste ramp in the northeast corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option B1

The MTL for this option would be constructed by mechanical methods and located in the northeast corner of the potential repository block and would be accessed from above by a 16-foot-diameter drill-and-blast mined shaft and by a 25-foot-diameter TBM ramp from the northeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development the shaft would be used for ventilation and personnel and the ramp would be used for ventilation, muck handling, and personnel. The function of the ESF accesses during potential repository operations would be ventilation and muck handling for the shaft and ramp, respectively.

The potential repository would be constructed using TBM for mains, perimeter drift, and emplacement drifts (no panel access drifts). The additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), a 25-foot-diameter mechanically mined emplacement exhaust shaft, and a 25-foot-diameter TBM-driven tuff ramp from the north. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option B2

The MTL for this option would be constructed by mechanical methods and located in the northeast corner of the potential repository block and would be accessed from above by one 16-foot-diameter drill-and-blast shaft and one 25-foot-diameter mechanically mined shaft. Both ESF accesses would function in science, ventilation, and emergency egress capacities; one shaft would provide men-and-materials service and the other would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the mechanically-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development both shafts would be used for ventilation and personnel and one would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and emplacement exhaust for the 25-foot-diameter shaft.

The potential repository would be constructed with TBM for mains and perimeter drift; the emplacement drifts would also use TBM construction methods. The additional potential repository accesses are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), a 25-foot-diameter mechanically mined emplacement exhaust shaft a 25-foot-diameter TBM-driven waste ramp, and a 25-foot-diameter TBM-driven tuff ramp. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of six accesses.

Option B3

The MTL for this option would be constructed by mechanical methods and located in the northeast corner of the potential repository block and would be accessed from above by a 16-foot-diameter mechanically mined shaft and by a 25-foot-diameter TBM ramp from the northeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development the shaft would be used for ventilation and personnel and the ramp would be used for ventilation, muck handling, and personnel. The function of the ESF accesses during potential repository operations would be ventilation and waste emplacement ramp for the shaft and ramp, respectively.

The potential repository would be constructed using TBM for mains, perimeter drift, and emplacement drifts (no panel access drifts). The additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), a 25-foot-diameter mechanically mined emplacement exhaust shaft, and a 25-foot-diameter TBM-driven tuff ramp from the north. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option B4

The MTL for this option would be constructed by mechanical methods and located in the southern corner of the potential repository block and would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp from the southeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. A mechanically developed exploratory drift would run the length of the potential repository block from the MTL to intersect the Drill Hole Wash Fault in the north.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and tuff removal for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for mains, perimeter drift, and emplacement drifts (no panel access drifts). The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south, a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north, and a 25-foot-diameter TBM-driven waste ramp in the northeast corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

<u>Option B5</u>

The MTL for this option would be constructed by mechanical methods and located in the southern corner of the potential repository block and would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp from the northeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. A mechanically developed exploratory drift would run the length of the potential repository block from the MTL.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and waste handling for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for mains, perimeter drift, and emplacement drifts (no panel access drifts). The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south, a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north, a 25-foot-diameter TBM-driven tuff ramp in the southwest corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option B6

The MTL for this option would be constructed by mechanical methods and located in the northeast corner of the potential repository block and would be accessed by two 25-foot-diameter TBM ramps from the north. Both ESF accesses would function in science, ventilation, and emergency egress capacities; one ramp would provide men-and-materials service and the other ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the mechanically-developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development both ramps would be used for ventilation and personnel, one of which would also be used for muck handling. The function of the ESF accesses during potential repository operations would be as a tuff ramp and waste ramp.

The potential repository would be constructed with TBM for mains and perimeter drift; the emplacement drifts (no panel access drifts) would use TBM construction methods. The additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block) and a 25-foot-diameter mechanically mined emplacement exhaust shaft (off of the potential repository block). The single level of the potential repository and ESF is the same as that for the SCP-CDR and has a total of four accesses.

Option B7

The MTL for this option would be constructed by mechanical methods and located in the southern corner of the potential repository block and would be accessed from the southeast by a 25-foot-diameter TBM ramp and by a 25-foot-diameter TBM ramp driven from the northeast originating in the northeast corner of the block. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the ramp from the northeast would also provide men-and-materials service and the southeast ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the southeastern ramp would also be used for muck handling. The function of the ESF accesses during potential potential repository operations would be waste emplacement for the northeast ramp and tuff removal for the southeast ramp.

The potential repository would be constructed with TBM for mains, perimeter drift, and emplacement drifts (no panel access drifts). The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south and a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of four accesses.

Option B8

The MTL for this option would be constructed by mechanical methods and located in the southern corner of the potential repository block and would be accessed from the southwest by a 25-foot-diameter TBM-driven ramp and from above by 16-foot-diameter drill-and-blast shaft. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the ramp would also be used for muck handling and the shaft would be used for men-and-materials service. The MTL elevation would correspond with that of the potential repository and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults via a northeast-southwest drift extending the length of the potential repository.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be tuff removal for the ramp and ventilation for the shaft.

The potential repository would be constructed with TBM for mains, perimeter drift, and emplacement drifts (no panel access drifts). The additional accesses for the potential repository consist of a 25-foot-diameter mechanically developed men-and-materials ramp in the southwest, a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north, and a 25-foot-diameter TBM-driven waste ramp from the northeast corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option B9

The MTL for this option would be constructed by mechanical methods and located in the southern corner of the potential repository block and would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp driven from the southwest. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with that of the potential repository and the TBM and drill-and-blast exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. An exploratory drift would run the length of the potential repository block from the MTL to intersect the Drill Hole Wash Fault in the north.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the ramp would also be used for muck handling. The function of the ESF accesses during potential repository operations would be ventilation and tuff removal for the shaft and ramp, respectively.

The potential repository would be constructed with TBM for mains and perimeter drift; the emplacement drifts would use TBM construction methods. Emplacement drifts would be developed from the north, mining across the full potential repository width, with a southern retreat. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south, a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north, and a 25-foot-diameter TBM-driven waste ramp from the northeast corner of the block. The single level of the potential repository and ESF MTL is the same as that for the SCP-CDR and has a total of five accesses.

Option C1

The MTL for this option would be constructed by mechanical methods and located in the northeast corner of the potential repository block and would consist of two levels corresponding to the two levels of the potential potential repository. The MTL would be accessed from above a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp driven from the north. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevation would correspond with those of the potential repository and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development both MTL accesses would be used for ventilation and personnel, and the ramp would be used for ventilation, muck handling, and personnel. The shaft would be increased in diameter of 25 feet for potential repository use. The function of the ESF accesses during potential repository operations would be emplacement exhaust and tuff removal for the shaft and ramp, respectively.

The potential repository and ESF MTL would be developed at two levels to take advantage of the new higher pick of the TSw1-TSw2 contact, and to allow for near one-degree grades for the potential repository. Mains, accesses, and drifts would all be developed by TBM. The additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential potential repository block), and a 25-foot-diameter TBM-driven waste ramp. This option contains a total of four accesses.

Option C2

The MTL for this option would be constructed by mechanical methods and located in the northeast corner of the potential repository block and would consist of two levels corresponding to the two levels of the potential potential repository. The MTL would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter mechanically mined shaft. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the 25-foot-diameter shaft would provide men-and-materials service and the other would be used for muck handling. The MTL elevations would correspond to those of the potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash and Ghost Dance Faults and imbricate faults.

During potential repository development the shafts would be used for ventilation, personnel, and muck handling. The first shaft would be increased in diameter to 25 feet for potential repository use. The function of the ESF accesses during potential repository operations would be emplacement exhaust and ventilation.

The potential repository and ESF MTL would be developed at two levels to take advantage of the new higher pick of the TSw1-TSw2 contact, and to allow for near one-degree grades for the potential repository. Mains, accesses, and drifts would all be developed by TBM. The additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential potential repository block), a 25-foot-diameter TBM-driven waste ramp, and a 25-foot-diameter TBM-driven tuff ramp. This option contains a total of five accesses.

Option C3

The MTL for this option would be constructed by mechanical methods and located in the northeast corner of the potential repository block and would consist of two levels corresponding to the two levels of the potential repository. The MTL would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp from the north. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevations would correspond to those of the potential repository and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development the shaft would be used for ventilation and personnel, and the ramp would be used for ventilation, muck handling, and personnel. The shaft would be increased in diameter to 25 feet for potential repository use. The function of the ESF accesses during potential repository operations would be emplacement exhaust and waste handling for the shaft and ramp, respectively.

The potential repository and ESF MTL would be developed at two levels to take advantage of the new higher pick of the TSw1-TSw2 contact, and to allow for near one-degree grades for the potential repository. Mains, accesses, and drifts would all be developed by TBM. The additional accesses for the potential repository are all in the north and consist of a 25-foot-diameter mechanically mined men-and-materials shaft (off of the potential repository block), and a 25-foot-diameter TBM-driven tuff ramp. This option contains a total of four accesses.

Option C4

The MTL for this option would be constructed by mechanical methods and located in the southern corner of the potential repository block and would consist of two levels corresponding to the two levels of potential repository. The MTL would be accessed from above by a 16-foot-diameter drill-and-blast shaft and by a 25-foot-diameter TBM ramp from the southeast. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the shaft would provide men-and-materials service and the ramp would be used for muck handling. The MTL elevations would correspond to those of the potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults. As such an exploratory drift would extend the length of the potential repository, running adjacent to and through the Ghost Dance Fault.

During potential repository development the shaft would be used for ventilation and personnel, and the ramp would be used for ventilation, muck handling, and personnel. The function of the ESF accesses during potential repository operations would be ventilation and tuff removal for the shaft and ramp, respectively.

The potential repository and ESF MTL would be developed at two levels to take advantage of the new higher pick of the TSw1-TSw2 contact, and to allow for near one-degree grades for the potential repository. Mains, accesses, and drifts would all be developed by TBM. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the south, a 25-foot-diameter TBM-driven waste ramp in the north, and a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north. This option contains a total of five accesses.

<u>Option C5</u>

The MTL for this option would be constructed by mechanical methods and located in the northeastern corner of the potential repository block and would consist of two levels corresponding to the two levels of the potential repository. The MTL would be accessed from above by two 25-foot-diameter TBM ramps from the north. Both ESF accesses would function in science, ventilation, and emergency egress capacities; the waste ramp would provide men-and-materials service and the tuff ramp would be used for muck handling. The MTL elevations would correspond to those of the potential potential repository, and the mechanically developed exploratory drifting would include that to the Drill Hole Wash Fault and the Ghost Dance Fault and imbricate faults.

During potential repository development the waste ramp would be used for ventilation and personnel, and the tuff ramp would be used for ventilation, muck handling, and personnel. The function of the ESF ramp accesses during potential repository operations would be waste handling and tuff removal.

The potential repository and ESF MTL would be developed at two levels to take advantage of the new higher pick of the TSw1-TSw2 contact, and to allow for near one-degree grades for the potential repository. Mains, accesses, and drifts would all be developed by TBM. The additional accesses for the potential repository consist of a 25-foot-diameter mechanically mined men-and-materials shaft in the north, and a 25-foot-diameter mechanically mined emplacement exhaust shaft in the north. This option contains a total of four accesses.

3.3 Historical Configurations and New Options Identified for Preliminary Screening

The package prepared for the Screening Panel consisted of the following items:

1. Historical ESF configurations with subsets totaling 52 configurations described in detail in Section 3.1.1 and Appendices 3A, 3B, and 3C;

2. The 15 Historical Repository configurations submitted for screening described in detail in Section 3.1.2 and Appendices 3A, and 3D; and

3. The 24 Preliminary New Options submitted for screening described in Section 3.2.2 and in Appendices 3E and 3F.

4.0 SELECTION OF OPTIONS FOR EVALUATION

4.1 ESF-Repository System

Two approaches were considered in developing a method for defining and evaluating ESF configurations. The first approach considered evaluating a number of repository configurations and selecting a preferred repository configuration. This would be followed by considering a number of ESF configurations that were compatible with the preferred repository configuration and that used a subset of the repository accesses for access to the ESF. A second approach considered dividing the problem into a number of pieces based on major design features. A range of options for each major feature would be evaluated to determine the preferred feature within that range. This approach could be considered a more direct application of 10 CFR 60.21(c)(1)(ii)(D), which requires a comparison and evaluation of major design features for their ability to contain and isolate waste. For example, if the feature being considered was "ESF accesses," then combinations of shafts and ramps of different sizes would constitute the set of options for a decision leading to a preferred set of accesses. Separate evaluations would be done for each feature, and the preferred features would be combined into a single configuration.

Both of these approaches were rejected in favor of an approach that defines an option as a combined ESF-repository system. This was considered necessary because the goal of the exploratory studies is to conduct appropriate site characterization activities at the candidate site while insuring that the investigations to obtain the required information are conducted in such a manner that adverse effects on the long-term performance of any potential geologic repository that might be constructed and operated at that candidate site are limited (to the extent practical). Experience suggests that the interrelationship among various major features is such that if they were evaluated individually and then combined into a system, the system would not be an optimum system. For example, the optimum locations and type of accesses for a repository might not support the need to conduct appropriate site characterization activities. Conversely, access means and locations determined when considering only the ESF might not support the need to limit adverse effects (to the extent practical) on the long-term performance of any potential geologic repository that might be constructed and operated at the candidate site. Thus evaluation of configurations and construction methods should consider the ESF and repository as a total system.

The findings of this study may influence the decision that will determine the configuration and construction method for the ESF. Thus, the options evaluated in this study should not be chosen so that they would unduly limit future repository design concepts, yet they must be sufficiently comprehensive to identify the interface aspects between the ESF and the potential repository. Only those elements that would constitute the interface between the ESF and repository should be fixed by the ESF design and construction, for example, ESF access means and locations. Therefore, a conceptual configuration for a potential repository was necessary for each option to ensure that a repository configuration could be made compatible with the ESF configuration. In addition, using the ESF-repository system as a basis for the evaluation should ensure that the subsequent evaluations conducted in this study will address the requirements of 10 CFR 60.21 (c)(1)(ii)(D) to the degree appropriate at this point in the design process.

It was necessary to define more precisely what distinguishing features constitute an option in order to define what made two given alternatives different. Each option would be composed of a unique set of major features. These features are discussed in the next section. Also given in the next section is the range of each feature that was allowed. Because the decision process would be applied to options that would be defined in terms of major features, minor differences in one configuration versus another would not be considered as distinguishing. For example, two configurations differing by only a small difference in shaft size would be considered to be the same configuration for the purposes of the evaluation.

4.2 Major Features

This section presents a set of major features that were determined to be relevant to the scope of the ESF Alternatives Study and that could be used to define what distinguishes one option from another.

The following major features were identified to be distinguishing and relevant to the scope of the ESF Alternatives Study:

- access means,
- location of access to the ESF and the MTL,

- test area configuration,
- construction method, and
- repository-ESF interface.

These features are discussed in more detail in the following sections.

4.2.1 Access Means

Access means were defined as the set of shafts and/or ramps that would be used for repository development and operational needs, and the subset of those accesses used for initial development and operation of the ESF. Options with different numbers and combinations of the basic types of accesses were required for the evaluation set. In addition, options with different subsets of accesses used for initial development of the ESF were required.

4.2.2 Location of Access to ESF and MTL

One distinguishing feature of the possible configurations was the location of the accesses used for the repository and, in particular, the subset of accesses used for the initial development of the ESF and MTL. Options with different access locations and ESF locations were required to span the range of alternatives needed. Repository options needed to show a variety of access locations that were compatible with functional requirements and other requirements that might be unique to the construction method, and that would be compatible with surface terrain and overburden requirements.

4.2.3 Test Area Configuration

The ESF configuration current at that time was defined by the SCP (Section 8.4) and the Title I design. The testing program was specified to obtain the information needed to address those "Key Issues," "Issues," and "Information Needs" identified in the SCP that required information from an underground test program. The underground test program that was proposed in response to this need contained a suite of 35 tests.

For the purposes of the ESF Alternatives Study, test area configuration referred to the underground area where testing might be conducted as part of the ESF. This included accesses to the underground, the MTL, and other drifts that might be constructed to explore specific geologic features or other portions of the site. Many different configurations compatible with the testing program defined in the SCP were possible. The test area configuration would depend somewhat on the construction method, accesses chosen for the ESF, and location of the ESF within the repository area. It was desirable to have a range of test area configurations in the alternatives set used for the evaluation. This range of configurations should include different accesses and different uses of those accesses within the testing program, different MTL-layout concepts, different exploratory drifting concepts, and different locations for the MTL.

An additional feature of the ESF configuration was that sufficient area had to be provided to accommodate the testing program. This needed to include a minimum area for each test and appropriate standoff distances. Additional area would have to be provided in the event that unexpected geologic conditions were encountered, that tests required relocation, and that additional tests needed to be conducted. Options with differing area available to the test program would need to be included in the evaluation set.

4.2.4 Construction Methods

Alternative repository and ESF construction methods had to be considered. Options featuring different construction methods needed to be included in the final set. In some cases, the layout of the ESF or repository would be dependent on the construction method used. Therefore, some coupling would be expected between construction method and repository and/or ESF configuration. The construction methods to be considered included drill and blast, machine excavation, and various combinations of the two.

4.2.5 Repository-ESF Interface

This feature was defined by the degree to which the ESF would be integrated into the initial repository development and subsequent operations. It was illustrated by an ESF ramp or shaft that would later be used for material handling, personnel, ventilation, or repository operations. The potential range of this feature ran from a totally isolated ESF to one in which all ESF accesses would be used for initial repository development. Between these extremes would be options in which a set of accesses would be devoted to the ESF through the initial period of repository construction and operation and then converted to repository accesses or ventilation openings. The principal characteristic of this feature was the total number of accesses that were required for the ESF and repository. Options with different concepts of repository-ESF interface were required for the evaluation set.

4.3 Method for Preliminary Screening

The mechanics of implementing the proposed decision process suggested that the number of options be limited to a number compatible with comprehensive as well as efficient treatment. In addition, it was desirable to ensure that the options evaluated covered the widest possible range of alternatives so that reasonable ranges and combinations of major design features would be considered. In order to satisfy these two conditions, an initial screening of available alternatives was implemented. A preliminary screening process was developed with the goals of (1) reducing the number of alternatives to a suitable number for the final evaluation process, (2) defining the ranges of major design features that could reasonably be considered when defining option possibilities, and (3) ensuring that the set of options considered in the final evaluation spanned the range of possibilities. This work was conducted under DIM 242.

The process of preliminary screening involved the following four-step program in which two actual screening functions occurred:

- Screening out of configurations that could be shown to be in noncompliance with applicable regulations or requirements;
- Consolidation and/or grouping of the remaining configurations into classes using major features as an organizing principle;
- Choice of a representative configuration from each class;
- Recommendation of additional configurations to be developed, if necessary, to form a complete set for final evaluation.

The final product of preliminary screening was a set of options that represented all reasonable permutations of global concepts or ranges of major design features relevant to the scope of the decision.

The screening process is briefly discussed in the following sections. A complete report on the screening method is given in SNL Letter Report (SLTR) 90-4001 (Appendix 4A).

4.3.1 Screening Noncomplying Configurations

Screening of noncomplying options was considered a higher level, or preliminary screening activity, and was based on criteria that could be derived from the following:

- testing and site characterization requirements (SCP), and
- regulatory and nonregulatory design and performance requirements, including functional design requirements.

The main thrust of the ESF program was to characterize the site through a comprehensive testing program. The individual interpretation of testing needs changed and matured as the requirements for performance modeling became more clearly defined. It was likely that ESF configurations developed early in the program would not accommodate the required tests then outlined in the SCP, and therefore should be dropped from further consideration.

Regulatory and design requirements provided a second classification for screening. These requirements were derived from federal, state, and local laws pertinent to the development of a mined geologic repository for nuclear waste, as well as DOE orders and design documents applicable to the ESF and repository. Section 2 of this report discusses the requirements. These requirements were evaluated to determine which, if any, could be used in preliminary screening. Those selected had to be useable by an informed evaluator to determine to a high degree of assurance, and without substantial analysis or calculation, that a particular option did or did not meet the requirement.

By applying a preliminary screening process based on the two major areas of consideration discussed above, configurations which were obviously noncompliant were eliminated from further considerations and the reasons for elimination were completely documented. The remaining configurations constituted a viable set of possibilities, all of which conform to basic requirements without any definitive nonfunctional features.

4.3.2 Consolidation of Options

After the initial screening, it was expected that a substantial number of configurations would still remain. These configurations were to be consolidated into classes of configurations that were defined according to differences in major distinguishing features relevant to this study. A discussion of these features is given in Section 4.2. In order to define this set of classes, the potential range of each reasonable alternative feature was defined.

Based on the expected ranges of features, twelve classes were defined. The number and definition of the classes required was based on the principle that the options selected for the final evaluation must represent a sufficiently broad range of alternatives for each major feature so that they spanned the spectrum of reasonable alternatives. Each class included a particular range of one of the distinguishing features defined in Section 4.2. Most configurations fell into more than one class. Based on this principle, classes were defined for grouping the options as given in Table 4-1, and each alternative was placed in one or more of the 12 classes.

4.3.3 Representative Options

After the alternatives were assigned to classes, an option representative of each class was selected. This option was representative of the range of the particular distinguishing feature for which that class was defined. That is, configurations in the same class might not be similar in all aspects, but were similar to or the same relative to the particular feature used to define the class. The criteria for selection of a representative option from each class were defined as follows:

- If any class had only one alternative, that configuration was selected to represent the class.

- If more than one alternative was available in each class for which an option had yet to be selected, one alternative at a time was examined and an option chosen. The option chosen was selected by a majority vote of the screening committee.

TABLE 4-1

OPTION CLASSES

Class	Feature	Definition
1	Location	Location of the accesses and ESF approximately in the SCP-CDR configuration
2	Location	ESF and at least one ESF access in a substantially different location than Class 1
3	Access Means	Total number of accesses less than SCP-CDR
4	Access Means	ESF access by two or more shafts
5	Access Means	ESF access by two or more ramps
6	Access Means	ESF access by at least one shaft and one ramp
7	Construction Method	Construction of the repository and ESF substantially by drill and blast. This would include options with machine-mined ramps and mains but with the emplacement areas developed by drill and blast
8	Construction Method	All construction (including ESF and accesses except for some testing alcoves, etc.) by mechanical mining
9	Construction Method	Combination of mechanical and drill and blast methods, e.g., one shaft and ESF constructed by drill and blast, with the remainder constructed by mechanical mining (including the second ESF access)
10	Test Area Configuration	ESF layout (including exploratory drifting and designated test area) similar to the Title I or early Title II concepts
11	Test Area Configuration	ESF layout substantially different from Class 10, which may include size or scope of designated test areas
12	ESF-Repository Interface	Options that integrate repository and ESF accesses

- After an alternative was selected from one class, it was eliminated from consideration in any other class. Thus, after several selections had been made, if some classes were reduced to a single member, the first criterion applied.

- If there was a class with no alternatives, an alternative could be developed and assigned to that class.

After an option was selected from each class, an evaluation was done to ensure that the ranges of distinguishing features necessary to have a complete set were covered by the options selected. If not, additional options would be recommended for development and inclusion in the final evaluation set.

To accomplish this, the selected set of options was checked against the list of distinguishing features and their desired ranges to ensure that each feature and its range was properly represented and the final set was complete.

The representative option from each class was then further developed, if necessary, to provide sufficient information about the alternative for scoring the option against objectives. Only the representative options from each class participated in the final evaluation and ranking process.

4.3.4 Recommended Additional Options

The classes of options defined as a result of the activity described in the preceding sections represented as complete a set of options as possible within the restrictions placed on the total number of classes defined. However, if it was later discovered (as a result of the checking process already described, or as a result of technical and management reviews) that the options remaining after initial screening did not represent a complete set, the screening committee was able to recommend that options with the required features or characteristics be developed for inclusion into the evaluation set.

4.4 Preliminary Screening

The initial screening of configurations was conducted under DIM 242, using the screening described in the preceding section. A more detailed description of the method is given in SLTR90-4001 (Appendix 4A). This section describes the application of the screening process used to arrive at the set of options to be evaluated. A list of the records associated with the screening process is provided in Appendix 4B.

An initial screening of the available configurations was considered appropriate for the following reasons:

- A large number of ESF and repository alternatives had been identified during the search of historical records (13 major ESF options with up to 15 subsets and nine different MTL configurations, and 15 major repository options).

- Twenty-four additional ESF-repository configurations had been developed as part of the ESF-AS.

- The methodology developed for the study required an extensive evaluation of each option.

- An extensive amount of information about each option was required for the evaluation process.

The decision methodology developed for the ESF-AS also requires that an option consist of a repository configuration with an imbedded ESF configuration. Many of the ESF and repository configurations identified during the search of historical records were developed as independent entities. No direct match of each ESF and repository configuration to form a well-defined option was possible. In addition, many of the historic configurations were developed prior to the current state of definition of regulatory and site characterization requirements; therefore, it was thought likely that they could not meet current requirements.

As a result of the above considerations, the screening process was developed to accomplish the following:

- consider all configurations identified;

- screen out those configurations or options that clearly could not meet the current regulatory and site characterization requirements, as defined in the SCP;

- identify a limited, yet comprehensive, set of options that could be used for the more extensive evaluation; and

- ensure that the set of options contained a sufficient range of major features so that a wide variety of options would be considered during the final evaluation.

To accomplish these goals a four-step process was used to screen, consolidate, select, and review the options for completeness. A panel was formed to conduct the screening and document the results and rationale for the options selected. A list of all documentation related to these panel meetings, including verbatim transcripts of the proceedings, is provided in Appendix 4B.

4.4.1 Screening Panel

The Screening Panel was selected under criteria developed as part of DIM 241. The panel consisted of personnel from J. F. T. Agapito and Associates, RSN, LANL, PBQ&D, and SNL.

The panel was assisted by facilitators from the methodology group and the options group. These members were from PBQ&D, RSN, REECo, and SNL.

4.4.2 Step 1: Screen Out Noncomplying Options

The ESF and repository configurations identified from a search of the historic records were reviewed against selected regulatory and site characterization requirements. The ESF options and repository options were screened separately because they were developed somewhat independently of each other. Except for the SCP-CDR and more recent integrated ESF-repository configurations, there was not a strong interface between the repository and ESF. It was the intent of the screening process to evaluate these options and then take those that passed the initial compliance screening and join matched ESF-repository systems that could then be considered further in Step 2 of the screening process.

The requirements or criteria used in the initial screening were developed from the set of requirements identified by the Requirements Task under DIM 244. As part of DIM

242, the Requirements Task Group provided a list of regulatory and programmatic requirements that could be used for screening. These requirements had to be such that it could be determined easily whether or not an option was in compliance. In addition, the TMO at LANL provided an estimate of the minimum area necessary to conduct the test program currently envisioned for the MTL of the ESF. From the results of the above efforts, six criteria were identified as a screening set for regulatory and programmatic compliance, and two criteria were developed for screening against site characterization needs. The requirements for each set were put on evaluation sheets, and each ESF and repository option was evaluated against the appropriate requirements. A sample set of evaluation sheets is included as Appendix 4C.

- Screening of Historical ESF Configurations--The historical ESF configurations (Section 3.1.1) were first screened against the regulatory/programmatic requirements. The ESF configurations were described by an option number, a subset number, and a configuration letter. (See Section 3.1.1 and Table 3-1 for a complete description.) Subsets of an option differed from the main option in shaft size, depth, construction method, etc. The configuration referred to the configuration of the MTL. A list of each option/subset/configuration considered in the screening is given in Table 4-2. Because of similarities in option subsets for some options, several or all subsets of an option were evaluated together on one evaluation sheet. A negative evaluation against any of the six requirements resulted in the option being dropped from further consideration. All negative evaluations were explained on the evaluation sheets and entered into the record (Appendix 4C).

  The historical ESF options remaining after the regulatory/programmatic screening were evaluated against the two site characterization criteria. In some instances, a calculation of MTL area for a configuration was required to check for compliance with the minimum area requirement.

  Table 4-2 summarizes the result of the initial screening of historical ESF options.

TABLE 4-2

SUMMARY OF INITIAL SCREENING OF HISTORICAL ESF OPTIONS

ESF Option	Subset	Configuration	Regulatory Screening Result	Testing Screening Result	Status
1	1-15	A	Fail (2, 3)*	N/A**	Dropped
2	1-14	B	Fail (2, 3)	N/A	Dropped
2	6-7	A	Fail (2, 3)	N/A	Dropped
2	14	C	Fail (2, 3)	N/A	Dropped
3	1-2	A	Fail (2, 3)	N/A	Dropped
4	1	A	Fail (2, 3)	N/A	Dropped
5	1	A	Fail (2, 3)	N/A	Dropped
6	1	A	Fail (2, 3)	N/A	Dropped
7	1	A	Fail (2, 3)	N/A	Dropped
8	1	A	Fail (2, 3)	N/A	Dropped
9	1	A	Fail (2, 3)	N/A	Dropped
10	1	A	Fail (2, 3)	N/A	Dropped
11	1-2	C	Pass	Fail (1)	Dropped
11	3	F	Pass	Fail (1)	Dropped
11	4	G	Pass	Fail (2)	Dropped
11	5	H	Pass	Fail (2)	Dropped
11	5	I	Pass	Pass	Passed
11	6-7	H	Pass	Fail (2)	Dropped
12	1-4	C	Pass	Fail (1)	Dropped
13	1-2	D	Fail (2)	N/A	Dropped
13	3	E	Fail (2)	N/A	Dropped

*Numbers in parentheses indicate the criteria number on which the option failed (see Appendix 4E for criteria used).
**N/A indicates that screening was not done for test requirements because the option failed the regulatory/programmatic screening.

- Initial Screening of Historical Repository Options--The 15 historical repository configurations (Section 3.1.2 and Table 3-2) were screened using the two sets of criteria described above. Criterion 1, dealing with site characterization (testing), was not applied because it was applicable to the ESF only. Any configuration receiving a negative evaluation was dropped from further consideration. The rationale for the evaluation was recorded on the evaluation sheet and in the transcript record (Appendix 4C). Table 4-3 gives a summary of the repository screening results.

- Preliminary New Options--The panel decided that it was not necessary to screen the preliminary new options (Section 4.3). These options were developed as part of the Options Development Task of the ESF Alternatives Study, under guidance provided in DIM 243 which made it almost certain that none of the options would have been dropped. At worst, some of the options would have received an uncertain rating for one or more of the criteria, which would have resulted in their being passed on to the next phase.

4.4.3 Step 2: Classification of Remaining Options

The alternatives passed on to the second phase of the screening process consisted of seven historical repository options and 24 preliminary new options. For the final evaluation, an option must consist of a repository configuration with an imbedded ESF configuration. Therefore, the historical repository options were matched with ESF interfaces and Configuration I MTL, the only ESF configuration that passed the initial screening. For repository options R-7 through R-11 and R-13, the ESF option that best matched the interface with the repository was ESF Option 11. Therefore, an ESF option/subset/configuration "like" 11-5-I was chosen as the proper mate for these repository options. For repository Option R-12, ESF Option 11 would not provide a good interface. However, it was decided that ESF Option 12-4 should be mated with configuration I to provide an ESF that would interface with repository Option R-12 and that would pass the initial screening. Therefore, repository Option R-12 was mated with an ESF option/subset/configuration "like" 12-4-I. The term "like" is used because some modifications to the ESF were deemed necessary to complete the integration with the matching repository. These modifications were to be performed as part of subsequent options developed should any of the historic ESF-repository option

TABLE 4-3

SUMMARY OF THE INITIAL SCREENING OF HISTORICAL REPOSITORY OPTIONS

Option	Regulatory Screening Result	Testing Screening Result	Status
R1	Fail (3)*	N/A**	Dropped
R2	Fail (3)	N/A	Dropped
R3	Fail (2)	N/A	Dropped
R4	Fail (2)	N/A	Dropped
R5	Fail (2)	N/A	Dropped
R6	Pass	Fail (2)	Dropped
R7	Pass	Pass	Passed
R8	Pass	Pass	Passed
R9	Pass	Pass	Passed
R10	Pass	Pass	Passed
R11	Pass	Pass	Passed
R12	Pass	Pass	Passed
R13	Pass	Pass	Passed
R14	Fail (2)	N/A	Failed
R15	Fail (2)	N/A	Failed

*Number in parentheses indicates the requirement which the option failed (see Appendix 4E).
**N/A indicated requirements were not considered because option had failed previous screening.

combinations pass the subsequent screening phase. The new options did not have a specific MTL layout but did have an area blocked out for the MTL. This was deemed acceptable by the panel.

The second step in the screening process was to identify to which of the 12 classes defined in Table 4-1 each option could be assigned. An option could fall in several of the classes, which were defined so that they represented the desirable ranges of the five major distinguishing features of one option. Those five features were: (1) location of the ESF accesses and MTL, (2) access means, (3) construction method, (4) test area configuration, and (5) ESF integration in the repository. Assignment of classes to each option resulted in the option class matrix presented in Table 4-4.

4.4.4 Step 3: Selection of an Option from Each Class

Once the option class matrix (Table 4-4) was filled in, one option was selected from each class as representative of that class. Selection was done according to the guidelines provided in Section 4.3.3. If several options were in a class, each panel member voted for the option he preferred. Then each panel member was given the opportunity to defend his choice. When one option in the class received four or more votes, it was designated as the option selected from that class. The option selected from each class and the vote tally were recorded on a form and verified by each panel member. The rationale and procedure for selection were recorded in the meeting transcript. As a result of this process, twelve options were selected for further evaluation. These are given in Table 4-5.

4.4.5 Step 4: Review of Options

Step 3 of the screening process resulted in 12 options being identified for the final evaluation set. Because one option was selected from each of 12 specially defined classes, it was highly probable that the range of major features would be covered. To check this assumption, and possibly identify any holes that might need to be filled by additional options, the range of each option for each of the five major features was identified and recorded on a form. This allowed the panel to review the available range within the options set for each of the five features.

TABLE 4-4

OPTION CLASS MATRIX FOR SCREENED ALTERNATIVES

Option Designator	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12
R-7/ESF (LIKE) 11-5-I	X			X					X	X		
R-8/ESF (LIKE) 11-5-I	X			X					X	X		
R-9/ESF (LIKE) 11-5-I	X			X					X	X		X
R-10/ESF (LIKE) 11-5-I	X			X					X	X		X
R-11/ESF (LIKE) 11-5-I	X			X					X	$\boxed{X}$		X
R-12/ESF (LIKE) 12-4-I (Long Drifts Not Shown)	X		X			X			X	X	X	X
R-13/ESF (LIKE) 11-5-I	X			X					X	X		X
A-1	X		X			X	X			X		$\boxed{X}$
B-1	X		X			X			X		X	X
C-1	X					$\boxed{X}$			X		X	X
C-5	X		X		X			X			X	X
A2	X			$\boxed{X}$			X			X		X
A3	X		X			X	X			X		X
A4	X		X	X		X	$\boxed{X}$			X		X
A5		X	$\boxed{X}$			X	X			X	X	X
A6		X	X			X	X			X	X	X
A7	X		X		$\boxed{X}$		X			X		X
A8		X	X		X		X			X	X	X
A9		X	X			X	X			X	X	X
A10		X	X			X	X			X	X	X
B2	X		X	X					X		X	X
B3	$\boxed{X}$		X			X			X		X	X
B4		$\boxed{X}$	X			X			X		X	X
B5		X	X			X			X		X	X
B6	X		X		X			X			X	X
B7		X	X		X			$\boxed{X}$			X	X
B8		X	X			X			$\boxed{X}$		X	X
B9		X	X			X			X		X	X
C2	X		X	X					X		X	X
C3	X		X			X			X		X	X
C4		X	X			X			X		$\boxed{X}$	X

X = Assigned to category class.
$\square$ = Select option from class.

TABLE 4-5

OPTION CLASSES

Class	Option Selected By Class	Definition
1	B3	Location of the accesses and ESF approximately in the SCP-CDR configuration
2	B4	ESF and at least one ESF access in a substantially different location than Class 1
3	A5	Total number of accesses less than SCP-CDR
4	A2	ESF access by two or more shafts
5	A7	ESF access by two or more ramps
6	C1	ESF access by at least one shaft and one ramp
7	A4	Construction of the repository and ESF substantially by drill and blast. This would include options with machine-mined ramps and mains but with the emplacement areas developed by drill and blast
8	B7	All construction (including ESF and accesses except for some testing alcoves, etc.) by mechanical mining
9	B8	Combination of mechanical and drill and blast methods, e.g., one shaft and ESF constructed by drill and blast, with the remainder constructed by mechanical mining (including the second ESF access)
10	R11/ESF 11-5-I	ESF layout (including exploratory drifting and designated test area) similar to the Title I or early Title II concepts
11	C4	ESF layout substantially different from Class 10, which may include size or scope of designated test areas
12	A1	Options that integrate repository and ESF accesses

The panel identified three potential problems, two of which were corrected by slight revisions of an option to allow it to better fit the feature range. The third required the addition of a 13th option to the set. The review is summarized as follows:

1. There was no option in the set that had a shaft/ramp or two-shaft access to the ESF where the shaft was constructed by mechanical excavation. It was thought necessary to have such an option to address directly NWTRB comments regarding the desirability of a mechanically excavated science shaft.

   Resolution: Option B3 (shaft/ramp access to an ESF in the northern part of the repository block) was revised to change the method of shaft construction from drill and blast to machine mined. This change did not affect the range of drill and blast ESF access because other options had drill and blast constructed shafts. The new option was designated Option B3 Rev. 1.

2. Option A4 had two shafts and one ramp access to the ESF MTL. The shaft that was designated as the primary science shaft was outside the repository block. The second shaft directly accessed the MTL but was intended to be constructed quickly for rapid access to the MTL. The panel thought that it was not appropriate to have a main science shaft outside the repository block.

   Resolution: This option was revised to specify that the 16-foot diameter shaft to the MTL be designated the primary science shaft and the 10-foot diameter shaft (outside the repository block) be constructed quickly to provide rapid access, via a connecting drift, to the MTL. This modified option was designated Option A4 Rev. 1.

3. The decision methodology used for the final evaluation requires a "base case" option to be designated. Probabilities for various scenarios are estimated for the base case during the scoring process. All other options are scored

relative to the base case. It is highly advantageous to select a very well developed option as a base case, one in which most of the relevant design information has already been developed. None of the options selected fit this requirement.

Resolution: A 13th option was added to the set and was designated as Option Base Case. This option is essentially the SCP-CDR repository with the updated interface drawings to allow two 12-foot diameter shafts for the ESF. The ESF configuration would be the Title II general arrangement (Historical Configuration I).

4.4.6 Management Review of Options

Thirteen ESF-repository options were identified for final evaluation as a result of the initial screening exercise. These options were described in a letter report forwarded to the YMP Office for management review. The management review was conducted using SNL QA procedures, and included reviewers from both the YMPO and DOE Headquarters (HQ). In accordance with SNL QA procedures, the resolution of any comments that required a change to the options required concurrence of the screening panel to make the change. Only one such comment was addressed. This comment suggested that the options did not address all possible mechanical construction methods for shafts. In options that had one or more shafts, the construction method was only designated as mechanical or drill and blast. In addition it was desirable to make a direct comparison of construction methods so that the best method could be selected. As a result of this comment, the screening panel was requested to add additional revisions of Option B3 so that there would be five B3 options, differing only by the construction method used in the shaft. The Screening Panel concurred in this and recommended that Option B3 be revised to form five options, one each for a shaft constructed by shaft boring machine, V-Mole, blind boring, raise boring, and drill and blast. These options were designated as Option B3 Revs. 2, 3, 4, 5, and 6, respectively. Option B3 Rev. 1 was then eliminated from the set. Thus, after the management review seventeen options were designated for complete evaluation. A summary description of the 17 options is given in Table 4-6.

4.5 **Initial Set of Options for Evaluation**

Following the screening activity, the 17 options selected for comparative evaluation were numbered 1 through 17 consecutively. This new identification system was used consistently throughout the remainder of the study; however, many of the study participants continued to use the old letter-number designation when they referred to the options and, of course, the old letter-number designations remain in the records. For convenience both identifications systems are shown in Table 4-6. For example, Option 17 will be identified as, "Option 17 (R11)." With the exception of Option 4 (A4, Rev. 1) and Options 7 through 11 (B3, Rev. 2 through B3, Rev. 6) the descriptions of the options are the same as those presented in Section 3.2.2 (Preliminary New Options) and Appendix 3G (Historical Repository Configurations). A brief description of changes in Option 4 and Options 7 through 11 made during the screening process is presented below. Sketches of the initial 17 options are provided in Appendix 4D.

Option 4 (A4 Rev. 1)

In this option, the 16-foot shaft will be the primary science shaft and its sinking schedule will be independent of other ESF construction activities. After its completion, the 16-foot shaft will provide men-and-materials service.

Option 7-11 (B3 Rev. 2, 3, 4, 5, 6)

In these options, the 16-foot-diameter shaft will be excavated by one of the following methods: shaft boring machine (Option 7), V-Mole mined (Option 8), blind bored (Option 9), raise bored (Option 10), or drill-and-blast mined (Option 11).

TABLE 4-6

DESCRIPTION OF INITIAL SET OF OPTIONS

OPTION #		ESF								REPOSITORY				
		ACCESS-1		ACCESS-2		MAIN TEST LEVEL				ACCESSES		CONSTRUCTION METHOD		
		SIZE	CONST. METHOD	SIZE	CONST. METHOD	LAYOUT	CONST. METHOD	LOCATION	ELE-VATION	SHAFTS	RAMPS (TBM)	RAMPS & DRIFTS	EMPL. AREA	TOTAL ACCESSES
1	BASE CASE	12 ' SHAFT	DRILL & BLAST	12 ' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2 - 20 '	1 - 25 ' 1 - 23 '	TBM	DRILL & BLAST	6
2	A1	16 ' SHAFT	--- " ---	25 ' RAMP	TBM	MODIFIED T II G.A.	--- " ---	--- " ---	--- " ---	2 - 25 '	1 - 25 ' + ESF	--- " ---	--- " ---	5
3	A2	16 ' SHAFT	--- " ---	16 ' SHAFT	DRILL & BLAST	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	2 - 25 '	--- " ---	--- " ---	6
4	A4 REV. 1	16 ' SHAFT	--- " ---	12 ' SHAFT 25 ' RAMP	DRILL & BLAST TBM	--- " ---	--- " ---	--- " ---	--- " ---	1 - 25 ' ENLARGE ES - 2 25 '	1 - 25 ' + ESF	--- " ---	--- " ---	5
5	A5	16 ' SHAFT	--- " ---	25 ' RAMP	TBM	--- " ---	--- " ---	S	--- " ---	2 - 25 '	--- " ---	--- " ---	--- " ---	5
6	A7	25 ' RAMP	TBM	25 ' RAMP	--- " ---	--- " ---	--- " ---	NE	--- " ---	--- " ---	IN ESF	--- " ---	--- " ---	4
7	B3, REV. 2 ---	16 ' SHAFT	· SBM	--- " ---	--- " ---	--- " ---	MECH.	--- " ---	--- " ---	--- " ---	1 - 25 ' + ESF	--- " ---	TBM	5
8	B3, REV. 3 ---		· V-MOLE											
9	B3, REV. 4 ---		· BLIND BORE											
10	B3, REV.5 ---		· RAISE BORE											
11	B3, REV. 6 ---		· DRILL/BLAST											
12	B4	16 ' SHAFT	DRILL & BLAST	--- " ---	--- " ---	--- " ---	--- " ---	S	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	5
13	B7	25 ' RAMP	TBM	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	IN ESF	--- " ---	--- " ---	4
14	B8	16 ' SHAFT	DRILL & BLAST	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	1 - 25 '	2 - 25 ' + ESF	--- " ---	--- " ---	5
15	C1	16 ' SHAFT	--- " ---	--- " ---	--- " ---	TWO LEVEL	--- " ---	NE	TWO LEVELS SAME AS REPOS.	2 - 25 ' ENLARGE ES - 1 25 '	1 - 25 ' + ESF	--- " ---	--- " ---	4
16	C4	16 ' SHAFT	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	S	--- " ---	2 - 25 '	--- " ---	--- " ---	--- " ---	5
17	R11	12 ' SHAFT	--- " ---	12 ' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2 - 25 '	2 - 25 '	--- " ---	--- " ---	6

12411/AW07049171 of 1

5.0 ESF-REPOSITORY OPTIONS

5.1 Final Set of Options

5.1.1 Transition From 17 to 34 Options

The screening process, described in Section 4, resulted in 17 options being selected for subsequent evaluation by the evaluation panels. A summary description of the 17 options is given in Section 4, Table 4-6. At that time, an option was defined as the combination of an ESF configuration and associated construction method integrated with a repository configuration. That is, for each option the accesses and other ESF interfaces with a repository were defined in the context of a total ESF-repository system so that ESF accesses were compatible with and had integral functions in the repository. A series of events occurred subsequent to identification of the initial 17 options that significantly altered the number and content of the options and required revision of the methodology used for evaluation of the options. These events are described below.

1. The CHRBA delivered a preliminary product to the ESF-AS on June 30, 1990 (listed as a source document in Appendix 5A) that recommended provisions be made for an extensive amount of drifting in the Calico Hills unit to each of the initial 17 options.

2. The NWTRB (in its First Report to Congress) strongly recommended that the Ghost Dance Fault be intercepted in at least two locations and that an east-west drift be added in the Topopah Spring unit to detect potential north-south trending faults.

3. At an ESF-AS Management Panel meeting on August 8, 1990, the DOE directed the ESF-AS to evaluate each option considering two different testing strategies. The first strategy emphasized early site-characterization testing in the Topopah Spring Unit and gave priority to testing within the Topopah Spring unit over testing in the Calico Hills unit. The second strategy reversed these priorities; that is, it gave priority to early site-characterization testing in the Calico Hills Unit over site-characterization

testing in the Topopah Spring Unit. This direction affected the study in two areas. First, the sequence of site-characterization tests had to be revised to accommodate early testing in either unit; and second, the ESF construction schedules, cost estimates and, in some cases, the design concept sketches had to be revised to support the changes in the testing program. This resulted in two sets of 17 options being defined for further study, or 34 options total (see Table 5-1).

The first event (CHRBA) required configurations for the initial 17 options to be updated to include up to 19,000 feet of exploratory drifting in the Calico Hills unit and a definition of the means of access to the Calico Hills unit. In addition, a list of the experiments that were expected to be conducted in the Calico Hills access/drifts was developed so that cost and schedule estimates could be made. Table 5-2 lists the set of tests considered for Calico Hills exploration.

The second event (NWTRB Report) resulted in the addition of an east-west drift across the repository block on the Topopah Spring Horizon. This east-west drift would serve two purposes. First, it would allow a determination of any heretofore undetected north-south trending faults in the repository horizon. Second, it would allow two intersections of the Ghost Dance Fault in the repository horizon, including an intercept in the south where fault displacement was thought to be greater. The one exception to the additional drifting on the TSw2 was in the Base Case (Option 1) where the east-west drift was not added. This allowed a clear comparison between all other options and the Base Case.

The third event (ESF-AS Management Panel Meeting on August 8, 1990) required the development of a testing strategy that could accommodate project goals for (1) Strategy 1, Early Access and Characterization of TSw2; and (2) Strategy 2, Early Access and Characterization of the Calico Hills unit. An option was now re-defined as a physical configuration and construction method (17 configurations) plus a testing strategy (two strategies per configuration). The first strategy (Options 1-17) consisted of the systematic progression of construction and site-characterization testing from the surface, down the accesses to the Topopah Spring, and then on down to the Calico

TABLE 5-1

DESCRIPTION OF FINAL SET OF OPTIONS

OPTION #			E.S.F.								REPOSITORY				
			ACCESS-1		ACCESS-2		MAIN TEST LEVEL				ACCESSES		CONSTRUCTION METHOD		
			SIZE	CONST. METHOD	SIZE	CONST. METHOD	LAYOUT	CONST. METHOD	LOCATION	ELE-VATION	SHAFTS	RAMPS (TBM)	RAMPS & DRIFTS	EMPL. AREA	TOTAL ACCESSES
18	1	BASE CASE	12' SHAFT	DRILL & BLAST	12' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2 - 20'	1 - 25' 1 - 23'	TBM	DRILL & BLAST	6
19	2	A1	16' SHAFT	--- " ---	25' RAMP	TBM	MODIFIED T II G.A.	--- " ---	--- " ---	--- " ---	2 - 25'	1 - 25' + ESF	--- " ---	--- " ---	5
20	3	A2	16' SHAFT	--- " ---	16' SHAFT	DRILL & BLAST	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	2 - 25'	--- " ---	--- " ---	6
21	4	A4 REV. 1	16' SHAFT	--- " ---	12' SHAFT 25' RAMP	DRILL & BLAST TBM	--- " ---	--- " ---	--- " ---	--- " ---	1 - 25' ENLARGE ES - 2 25'	1 - 25' + ESF	--- " ---	--- " ---	5
22	5	A5	16' SHAFT	--- " ---	25' RAMP	TBM	--- " ---	--- " ---	S	--- " ---	2 - 25'	--- " ---	--- " ---	--- " ---	5
23	6	A7	25' RAMP	TBM	25' RAMP	--- " ---	--- " ---	--- " ---	NE	--- " ---	--- " ---	IN ESF	--- " ---	--- " ---	4
24	7	B3, REV. 2 —	16' SHAFT	· SBM	--- " ---	--- " ---	--- " ---	MECH.	--- " ---	--- " ---	--- " ---	1 - 25' + ESF	--- " ---	TBM	5
25	8	B3, REV. 3 —		· V-MOLE											
26	9	B3, REV. 4 —		· BLIND BORE											
27	10	B3, REV.5 —		· RAISE BORE											
28	11	B3, REV. 6 —		· DRILL/BLAST											
29	12	B4	16' SHAFT	DRILL & BLAST	--- " ---	--- " ---	--- " ---	--- " ---	S	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	5
30	13	B7	25' RAMP	TBM	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	IN ESF	--- " ---	--- " ---	4
31	14	B8	16' SHAFT	DRILL & BLAST	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	1 - 25'	2 - 25' + ESF	--- " ---	--- " ---	5
32	15	C1	16' SHAFT	--- " ---	--- " ---	--- " ---	TWO LEVEL	--- " ---	NE	TWO LEVELS SAME AS REPOS.	2 - 25' ENLARGE ES - 1 25'	1 - 25' + ESF	--- " ---	--- " ---	4
33	16	C4	16' SHAFT	--- " ---	--- " ---	--- " ---	--- " ---	--- " ---	S	--- " ---	2 - 25'	--- " ---	--- " ---	--- " ---	5
34	17	R11	12' SHAFT	--- " ---	12' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2 - 25'	2 - 25'	--- " ---	--- " ---	6

12411/AWD/0391/1 of 1

TABLE 5-2

EXPERIMENTS ASSUMED TO BE CONDUCTED IN CALICO HILLS ACCESS/DRIFTS

Experiment	Location
Geologic Mapping	Access and Drifts
Mineralogy and Petrology	Access and Drifts
MPB	Access (only Shaft Access)
Radial Boreholes	Access (short radial boreholes only)
Exploratory Drilling (excavation effects?)	Drifts
Hydrologic Tests of Major Faults	Access & Drifts (only if encountered)
Bulk Permeability Test	Drifts
Percolation Test	Drifts
Laboratory and In-Situ Geochemistry Test	Access & Drifts

Hills. In contrast, the second strategy (Options 18-34) was to proceed to the Calico Hills as rapidly as possible to obtain data to make an early determination of suitability (or unsuitability) of the principal natural barrier, while conducting only those tests in the accesses necessary to acquire site data that would be irrecoverable if not acquired during initial construction. In some cases, the physical configuration was modified to better address the objective of the second strategy. Within each strategy, early and late testing phases were to be defined so that the relative value of early information from each test strategy could be assessed for the purpose of an early determination of site suitability. A list of documents and records relevant to the development of the 34 ESF-Repository options is included as Appendix 5A.

The test program for all 34 options continued to be based on conducting 35 tests. The test that will be conducted as early test in Strategies 1 and 2 are listed in Tables 5-3 and 5-4 respectively. The tests that will be conducted as late tests in Strategies 1 and 2 are

TABLE 5-3

OPTIONS 1 THROUGH 17; EARLY TESTS*

EARLY TESTS	1(Base Case)	2(A1)	3(A2)	4(A4-Rev1)	5(A5)	6(A7)	7(B3,R2) 5 BM	8(B3,R3) V-MOLE	9(B3,R4) BORED	10(B3,R5) RAISED	11(B3,R6) D&B	12(B4)	13(B7)	14(B8)	15(C1)	16(C4)	17(R11)	Const. Impact (Days) R = Ramp S = Shaft Const. Supp.	Testing
ACCESSES:																			
Geo. Mapping	shaft, shaft	shaft ramp	shaft shaft	2 shafts, ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft,shaft		17(R),32(S)
Min/Pet Sam.	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	0	0
Hydrol. Prop.	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	0	0
Intact Frac.	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	16(R),16(S)	0
Sht. Rad. Bh.	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	56(R),56(S)	105(R),105(S)
Exc. Effects	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	ramp	ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	68(R),68(S)	35(R),35(S)
Shaft Conver.	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	36(R),36(S)	60(R),60(S)
Per. Water	shaft shaft	shaft ramp	shaft shaft	2 shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	unknown	unknown
Hydrochem.	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	7(R),7(S)	0
Chlorine-36	shaft(1)	shaft ramp	shaft(1)	shaft(1) ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	ramp	ramp	shaft ramp	shaft ramp	ramp ramp	shaft ramp	shaft ramp	shaft ramp	shaft(1)	0	0
Fault Prop.	-	ramp	-	ramp	ramp	ramp ramp	ramp	ramp	ramp	ramp	ramp	ramp	ramp,ramp	ramp	ramp	ramp	-	N/A	N/A
Lab Tests	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
MPBH:																			
MPBH	shaft shaft	shaft	shaft shaft	shaft shaft	shaft	-	shaft	shaft	shaft	shaft	shaft	shaft		shaft	shaft	shaft	shaft shaft	pre-const.	pre-const.
EXP. DRFTS:																			
Fault Prop.	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	N/A	N/A
Bulk Perm.	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	N/A	N/A
Geo. Map.	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	N/A	N/A
Per. Water	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	N/A	N/A
Others	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	drifts	N/A	N/A

Notes:

1. Table does not include previously deferred tests: UDBR, Heater Exp. in TSw1.
2. Table does not include construction support for Long Radial Boreholes and Vertical Seismic Profiling, although these support durations are included in construction schedule for Options 1-17 developed by FSN. These access tests will be conducted after construction is complete. Estimated schedule for support during construction is 60 days in shaft for LRBTs (6 locations) and 37 days in shaft for VSP (37 locations).
3. N/A implies that the test and support durations have not been specifically calculated for the Alternatives Study schedule. These tests do not generally impact initial construction schedules, with exception of fault properties testing in ramp accesses.
4. Construction impact (days) includes only testing in accesses between surface and MTL. Radial Boreholes and Excavation Effects Tests between MTL and Calico are not included.

*Per revised SNL Guidance (9-07-90), Early test for Options 1-17 are those tests conducted in accesses, replicated in shaft/ramp and ramp/ramp options, and testing in long exploratory drifts on the Topopah (MTL) horizon.

TABLE 5-4

OPTIONS 18 THROUGH 34; EARLY TESTS*

Per Revised SNL Guidance (9-7-90), Early Tests for this scenario are critical, irretrievable site suitability tests in the accesses and Calico Hills Exploration Testing. Tests will not be replicated in the accesses, with the exception of Geologic Mapping, Perched Water, and Vertical Seismic Profiling.

EARLY TESTS	18(Base Case)	19(A1)	20(A2)	21(A4-Rev1)	22(A5)	23(A7)	24(B3,R2) SBM	25(B3,R3) V-Mole	26(B3,R4) Bored	27(B3,R5) Raised	28(B3,r6) D&B	29(B4)	30(B7)	31(B8)	32(C1)	33(C4)	34(R11)	Const. Impact (Days) R = Ramp S = Shaft Const. Supp.	Testing
ACCESSES:																			
Geo. Mapping	shaft,shaft	shaft,ramp	shaft shaft	shafts(2), ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	ramp	ramp	shaft,ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	shaft,ramp	shaft,shaft		17(R)32(S)
Min/Pet	shaft(1)	shaft,ramp	shaft(1)	shaft(1) ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	ramp	ramp	shaft,ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	shaft,ramp	shaft(1)	0	0
Hydrol. Prop.	shaft(1)	shaft,ramp	shaft(1)	shaft(1) ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	ramp	ramp	shaft,ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	shaft,ramp	shaft(1)	0	0
Sht. Rad. Bh.	shaft(1)	shaft	shaft(1)	shaft(1)	shaft	ramp(1)	shaft	shaft	ramp	ramp	shaft	shaft	ramp (1)	shaft	shaft	shaft	shaft(1)	56(R),56(S)	105(R),105(S)
Per. Water	shaft,shaft	shaft,ramp	shaft,shaft	shafts(2) ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	ramp	ramp	shaft,ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	shaft,ramp	shaft,shaft	unknown	unknown
Hydrochem.	shaft(1)	shaft	shaft(1)	shaft(1)	shaft	ramp (1)	shaft	shaft	ramp	ramp	shaft	shaft	ramp (1)	shaft	shaft	shaft	shaft(1)	7(R),7(S)	0
Chlorine-36	shaft(1)	shaft,ramp	shaft(1)	shaft(1) ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	ramp	ramp	shaft,ramp	shaft,ramp	ramp,ramp	shaft,ramp	shaft,ramp	shaft,ramp	shaft(1)	0	0
Fault Prop.	-	ramp	-	ramp	ramp	ramp,ramp	ramp	ramp	ramp	ramp	ramp	ramp	ramp,ramp	ramp	ramp	ramp	-	N/A	N/A
Lab Tests	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
MPBH:																			
MPBH's	shaft,shaft	shaft	shaft,shaft	shafts(2)	shaft	-	shaft	shaft	shaft	shaft	shaft	shaft		shaft	shaft	shaft	shaft,shaft	pre-const.	pre-const.
CALICO HILLS:																			
(See Note)	CH	CH	CH	CH	CH	CH	CH	CH	CH	Ch	CH	CH	CH	CH	CH	CH	CH	See Note	See Note

Notes:

1. Calico Hills Test Program for the CH scenario (#2 & #5) recommended by the CH Study Group has not been fully developed. Testing will include a suite of hydrologic, geologic, and geochemical tests, including mapping and perched water. No CH testing schedule has been developed for the Alternatives Study, but initial testing duration will include drift construction period and two years following construction. Long-term test monitoring will continue after this period.
2. Early access tests include sampling programs for tests not impacting construction schedule. These tests are min/pet, matrix hydrologic properties, and Chlorine-36.
3. For this scenario (Options 18-34), tests which impact access construction schedules will be confined to one access (i.e., -not replicated), with the following exceptions: Geological mapping, perched water and fault properties in ramp/ramp options. In addition, non-schedule impactive sampling (see note 2) and VSP will be conducted in all accesses, if possible. Wherever possible, science access will be a shaft.
4. No support drilling for deferred tests (VSP, LRBT) will be conducted during access construction for this scenario.
5. Construction impact (days) includes only testing in accesses between surface and MTL. Radial Boreholes and Excavation Effects Tests between MTL and Calico are not included.
6. N/A implies that the test and support durations have not been specifically calculated for the Alternatives Study schedule. These tests do not generally impact initial construction shcedules, with exception of fault properties testing in ramp accesses.

listed in Tables 5-5 and 5-6 respectively. The late testing strategies are based on deferring those tests that can be deferred until after gaining access to the Calico Hills unit without an appreciable loss in the quality of data obtain during the site characterization program.

5.1.2 Description of Final ESF-Repository Options

The modification of the initial 17 options to accommodate the Early/Late Testing Program resulted in the formation of 34 options. The 17 options that were selected through the screening process were, in effect, doubled by assigning the alternative test strategies to the options. The result was pairs of options which, with 5 exceptions, differed only in schedule emphasis. Table 5-7 identifies the changes in configuration and the reasons for such changes. Figures 5-1 through 5-34 contain isometric sketches of the physical configurations of the final 34 options developed for the ESF-AS.

5.2 **Supporting Information**

A complete list of data and information packages was prepared in support of the scoring activities. These are listed in Appendix 5A. Major areas in which information and data packages were developed included test data sheets, and cost and schedule information. In addition, other information relating to facility layouts, materials, construction methods, etc. was developed for each option. Each of these major areas of supporting information are described below.

5.2.1 Test Data Sheets

Test data sheets were prepared in support of the Scoring Panel for Site Characterization. The PIs responsible for each of the 35 tests evaluated each of the various configurations (Options 1-17) with regard to the impact of the configuration on the ability to conduct each experiment. Because Options 18 through 34 have essentially the same configuration as Options 1 through 17, the evaluations in both cases are assumed to be the same. The PIs rated each option as "inferior," "equivalent" or "superior" to the Base Case (Option 1) and provided justification on test data sheets for their ranking. Table 5-8 summarizes these preliminary ratings. The preliminary

TABLE 5-5

OPTIONS 1 THROUGH 17; LATE TESTS*

LATE TESTS	CONSTRUCTION AND TEST SCHEDULE
MTL: Geologic Mapping Min/Pet Demonstr. Breakout (L) Seq. Drift Mining Canister Heater Heated Block Thermal Stress Heated Room Equip./Devel. Plate Loading Rock Mass Strength Eval. Mining Meth. Grnd. Support Mon. Mon. Drift Stab. Air Qual./Ventil. Seals Overcore Stress Hydrol. Prop. Percolation Bulk Permeability Perched Water Diffusion Chlorine-36 Eng. Barrier Fault Properties	The MTL Test Program is initiated after access testing and drift development to faults on Topopah Spring have been initiated or completed (early testing). MTL development will not be allowed to impact the schedule for early testing, but will be initiated as soon as possible. Specific durations for construction support and testing have not been developed for these tests as part of the Alternative Studies Schedule. A block of time, 5 years in duration, will be use to provide total estimate for mining, construction, and primary testing. Long-term monitoring for some tests, and performance confirmation testing, will continue beyond the 5-year period.
CALICO HILLS: Suite of Geologic, hydrol., and geochem. tests, including mapping and perched water	Drift development and testing in the Calico Hills will begin as soon as practical, but not to impact the schedule for conducting early tests. No defined test program or schedule for the Calico facility proposed by the Calico Study Group has been developed. Testing will coincide with drift development, and will continue after drift development is completed.
ACCESSES: Vertical Seismic Prof. Demonstr. Breakout (U) Heater Exp. in TSw1 Long Rad. Boreholes	This suite of deferred access tests will be conducted on an as-available schedule, after early testing and possibly in conjunction with MTL and Calico Hills testing. Drilling support for vertical seismic profiling and long radial boreholes was performed during access construction and early testing (See Table 1 notes). Later Excavation of UDBR could impact activities on MTL and/or Calico Hills, but the ability to replicate the UDBR in shaft/ramp or ramp/ramp options will be maintained.
LAB TESTS	These tests will be initiated during early testing phase and continue through late testing. No schedule impacts are associated with these tests.

*Per revised SNL guidance (9-07-90), Late Tests are those conducted in the MTL, the Calico Hills and previously deferred access tests.

TABLE 5-6

OPTIONS 18 THROUGH 34; LATE TESTS*

LATE TESTS	CONSTRUCTION AND TEST SCHEDULE
EXPLOR. DRIFTS: Test Suite (See Table 1)	The TS exploratory drifts excavation and testing program will be initiated as soon as practical following CH drifting and test development. Topopah drifting will not be allowed to impact CH development and testing schedules. Testing will coincide with drift development, and will continue at the faults after construction is complete.
MTL: Geologic Mapping Min/Pet Demonstr. Breakout (L) Seq. Drift Mining Canister Heater Heated Block Thermal Stress Heated Room Equip./Devel. Plate Loading Rock Mass Strength Eval. Mining Meth. Grnd. Support Mon. Mon. Drift Stab. Air Qual./Ventil. Seals Overcore Stress Hydrol. Prop. Percolation Bulk Permeability Perched Water Diffusion Chlorine-36 Eng. Barrier Fault Properties	The MTL test program in this Strategy will be initiated after critical testing in accesses and CH test program implementation (early testing). As practical, MTL development and testing will occur concurrent with long exploratory drifting on the Topopah horizon. MTL development will not be allowed to impact the schedule for early testing, but will be initiated as soon as possible. Specific durations for construction support and testing have not been developed for these tests as part of the Alternatives Studies Schedule. A block of time, 5 years in duration, will be used to provide total estimate for mining, construction, and primary testing. Long-term monitoring for some tests, and performance confirmation testing, will continue beyond the 5-year period.
ACCESSES: Intact Fractures Demonst. Breakout (U) Long Rad. Boreholes Excav. Effects Shaft Convergence Vertical Seismic Prof. Heater Exp. in TSw1	The suite of deferred access tests will be conducted on an as-available schedule, after early testing and possibly in conjunction with MTL, exploratory drifting, and CH testing. Later excavation of UDBR and support drilling for deferred tests could impact activities on the MTL and/or CH. These tests will not be replicated in shaft/ramp or ramp/ramp options.
LAB TESTS	These tests will be initiated during early testing phase and continue through late testing. No schedule impacts are associated with these tests.

*Per revised SNL guidance (9-07-90), Late Tests for this Strategy include Exploratory Shaft drifting on Topopah (MTL) horizon, MTL tests, and deferred tests in accesses.

TABLE 5-7

COMPARISON OF OPTIONS 1 THROUGH 17 WITH OPTIONS 18 THROUGH 34

Option No.	Configuration Change	Reason
1 & 18 (Base Case)	E-W Exploratory Drift (Option 18 only)	Response to NWTRB concern
2 & 19 (A1)	No change	--
3 & 20 (A2)	No change	--
4 & 21 (A4 Rev. 1)	No change	--
5 & 22 (A5)	No change	--
6 & 23 (A7)	Ramp to Calico Hills started from waste ramp in 23	Expedite access to Calico Hills
7 & 24 (B3 Rev. 2)	No change	--
8 & 25 (B3 Rev. 3)	Ramp to Calico Hills started from waste ramp in 25; V-Mole shaft from surface to Calico Hills in 25 to eliminate delay to Calico Hills in 2nd entry	Expedite access to Calico Hills
9 & 26 (B3 Rev. 4)	No change	--
10 & 27 (B3 Rev. 5)	Ramp to Calico Hills started from waste ramp to expedite access to Calico Hills in 27; raise bored shaft from surface to Calico Hills to eliminate delay to Calico Hills 2nd entry	Expedite access to Calico Hills
11 & 28 (B3 Rev. 6)	No change	--
12 & 29 (B4)	No change	--
13 & 30 (B7)	Ramps to Calico Hills started from Ramps in 30. Internal shaft eliminated in 30	Expedites access to Calico Hills. Not required with 2nd ramp access
14 & 31 (B8)	No change	--
15 & 32 (C1)	No change	--
16 & 33 (C4)	No change	--
17 & 34 (R13)	No change	--

Note: The UDBR's (upper demonstration breakout rooms) were removed in Options 18 through 34 wherever they appeared in their counterparts in Options 1 through 17. This was done to expedite access to the Calico Hills. The tests involved in these UDBR's were given in "deferred" status (see Table 5-4, 5-5, 5-6 and 5-7).

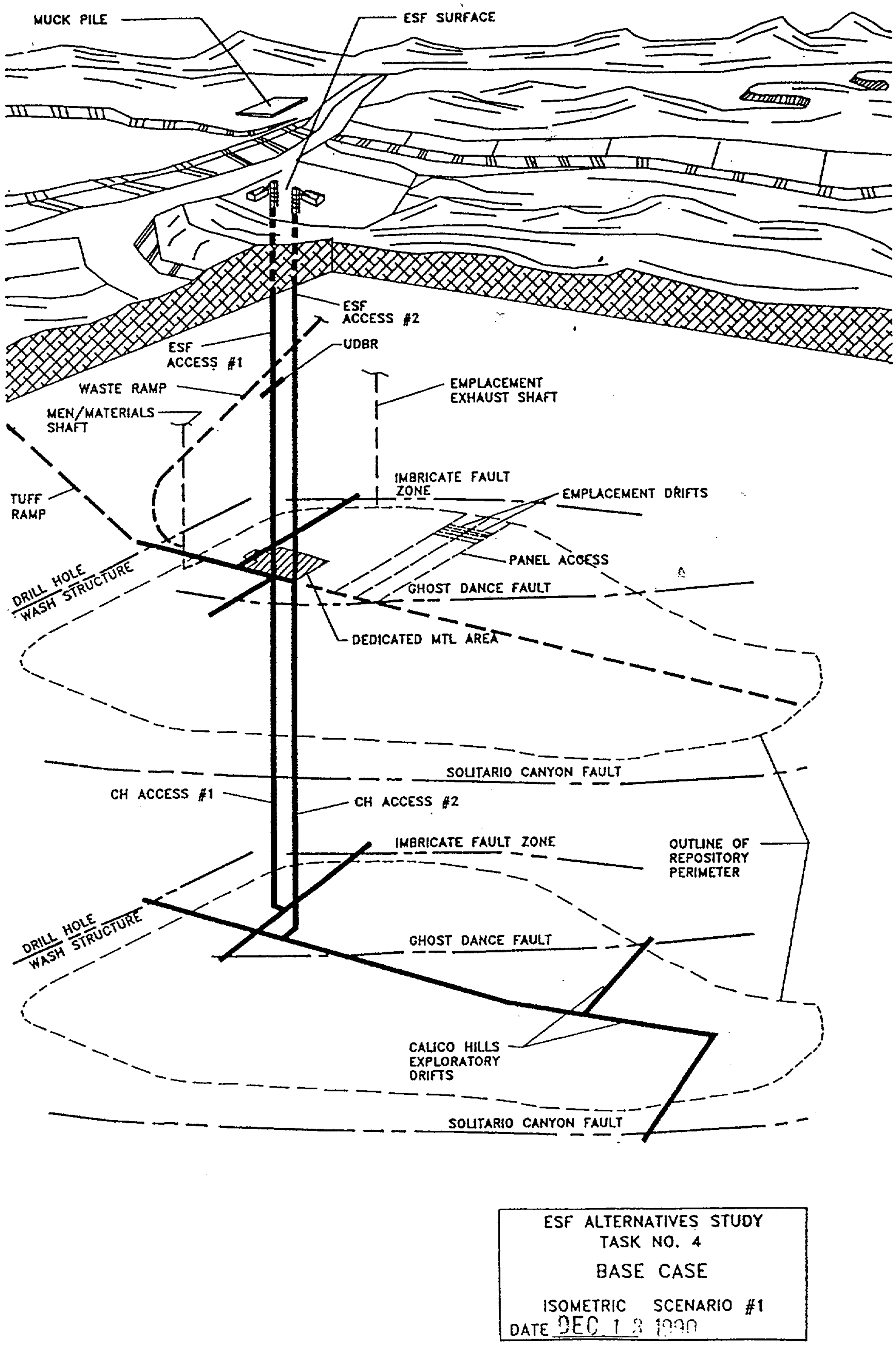


Figure 5-1. Option 1 (Base Case Scenario)

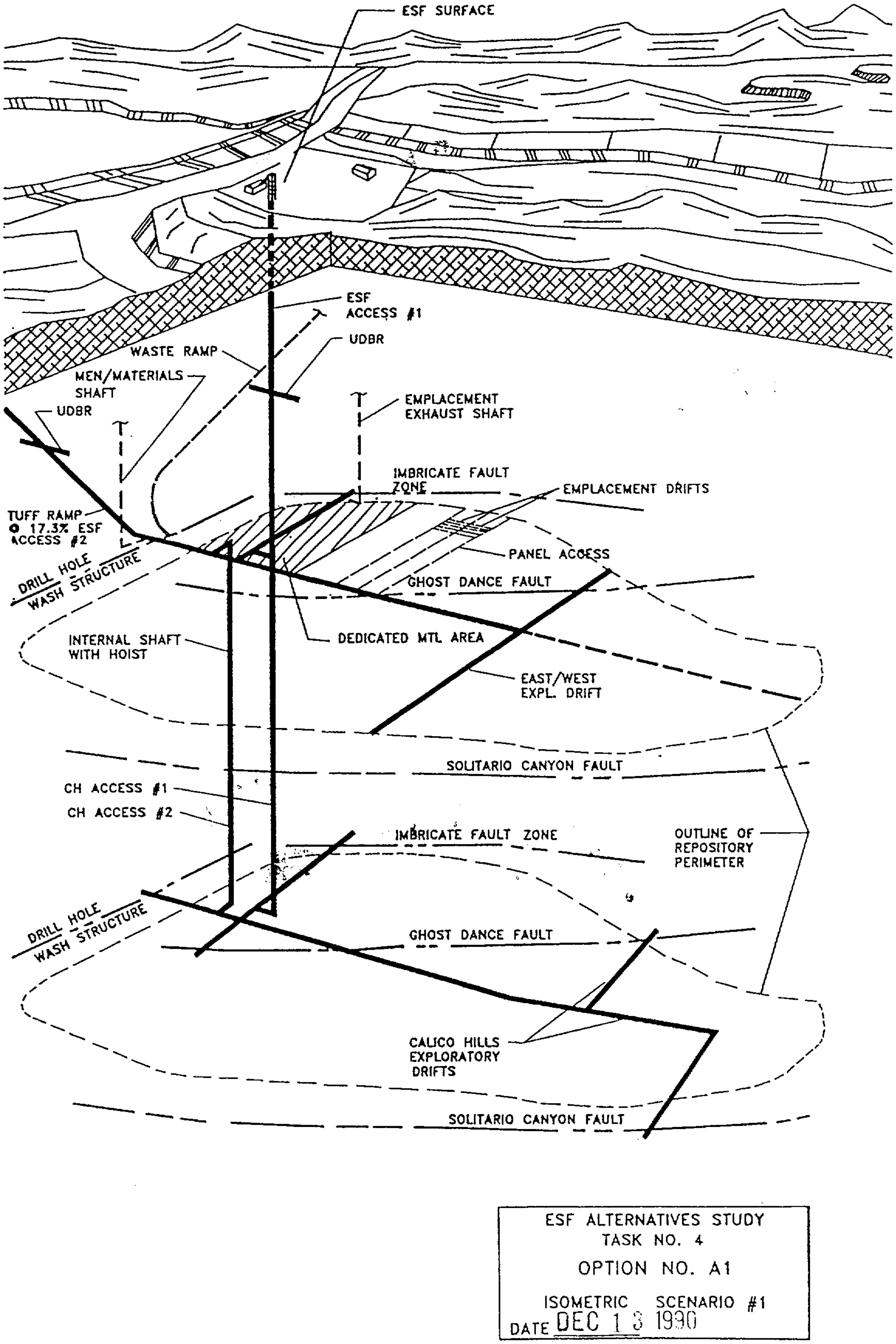


Figure 5-2. Option 2 (A1)

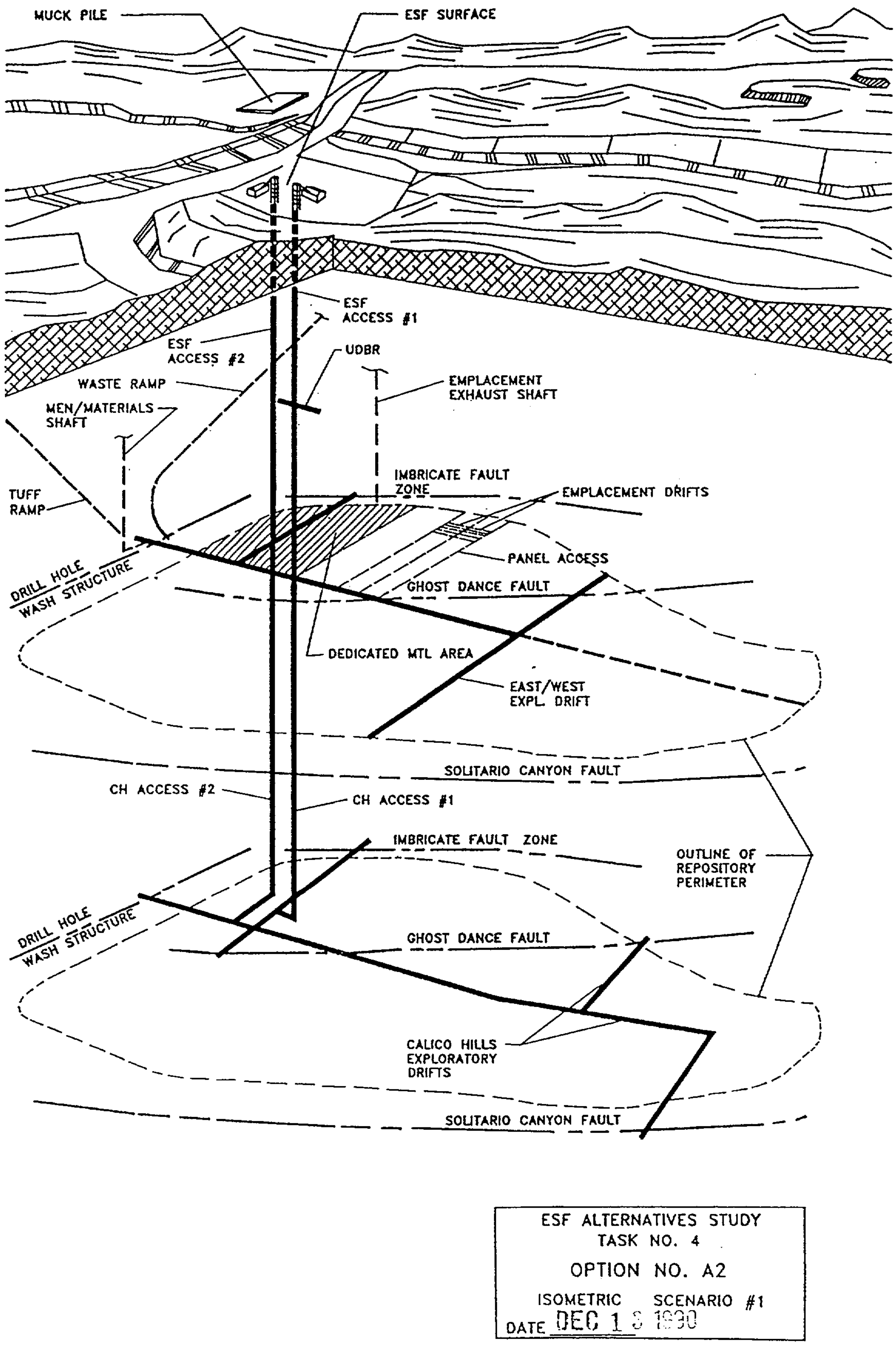
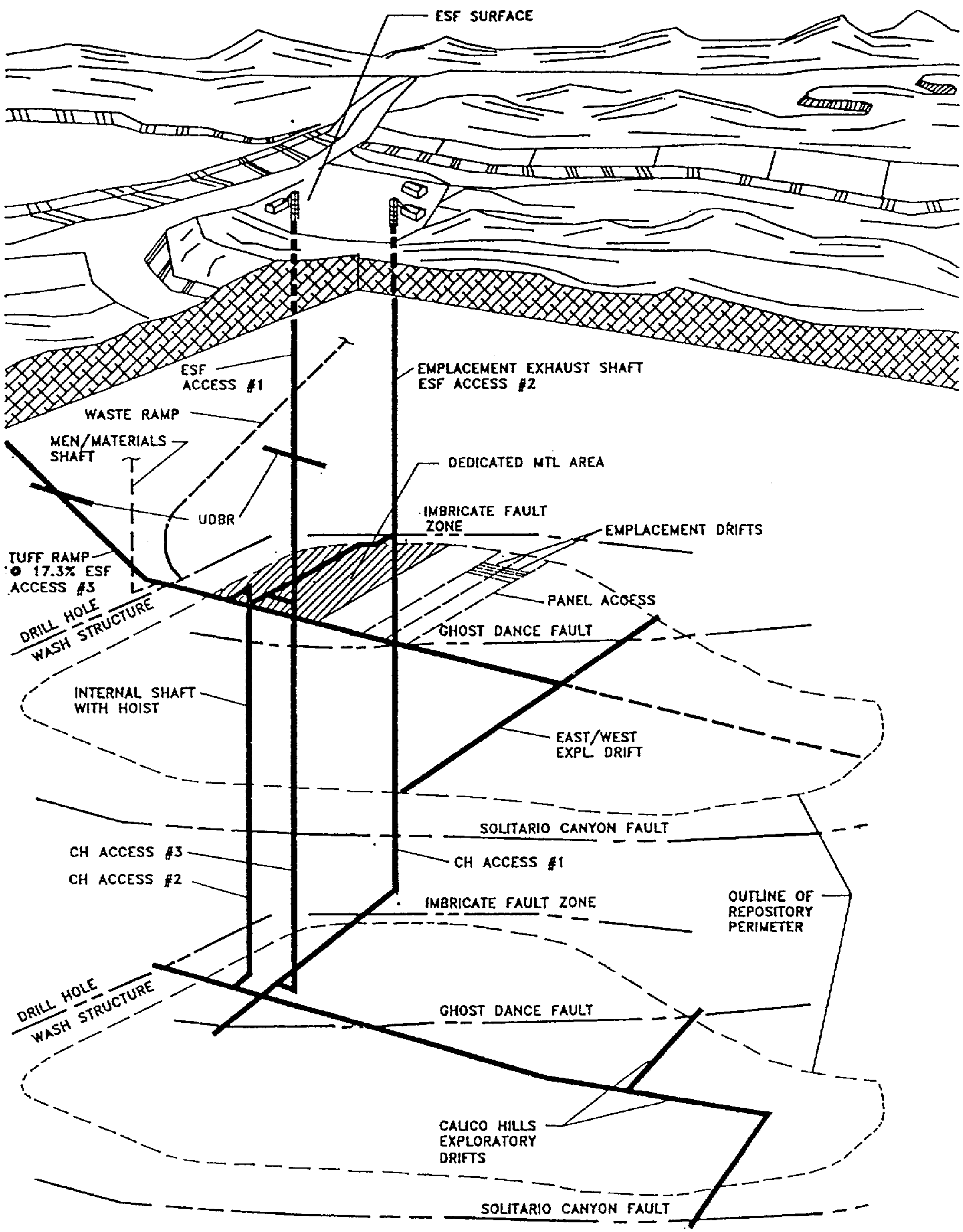
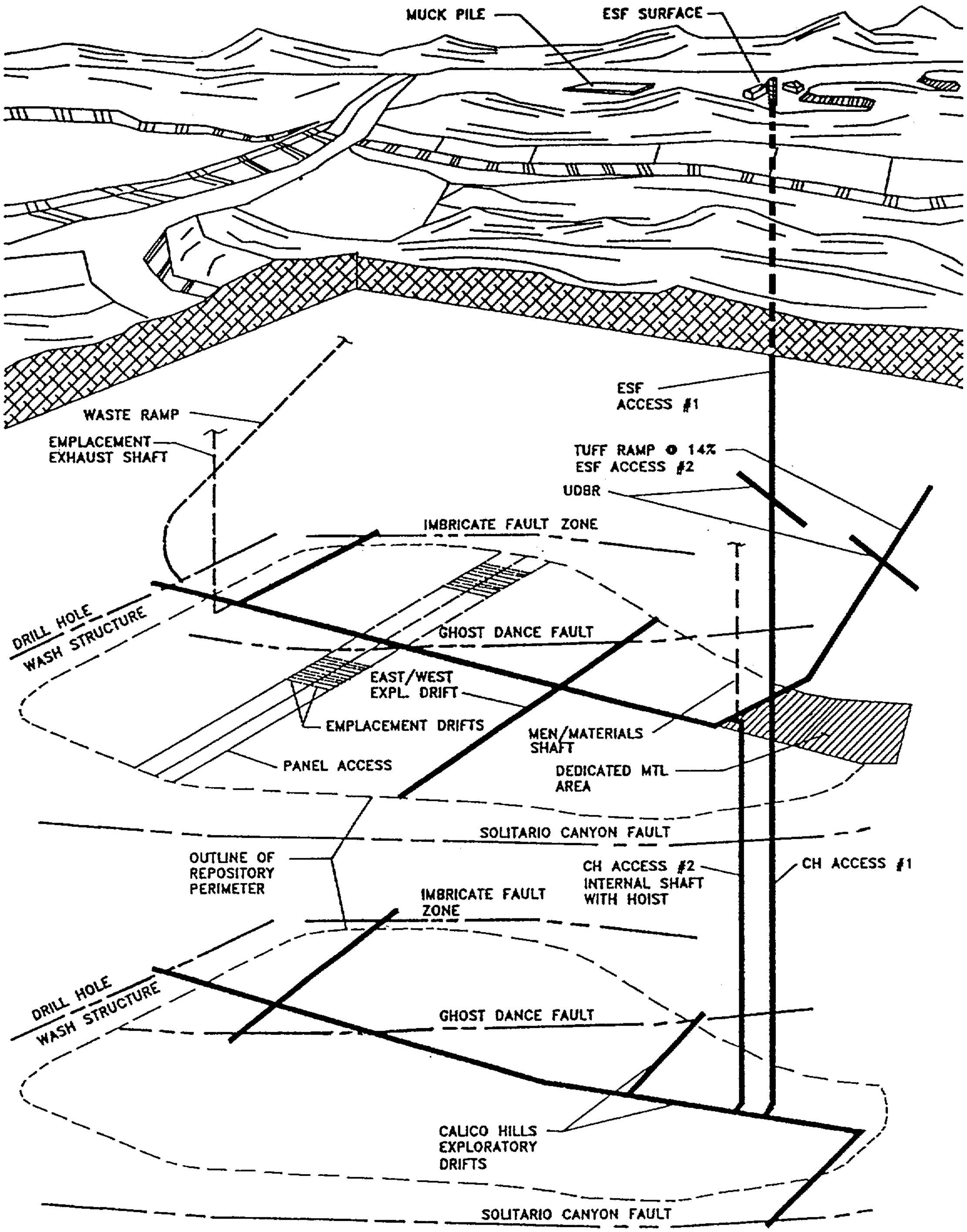


Figure 5-3: Option 3 (A2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. A4 REV. 1
ISOMETRIC SCENARIO #1
DATE DEC 13 1990

Figure 5-4. Option 4 (A4, Rev. 1)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. A5
ISOMETRIC SCENARIO #1
DATE DEC 1 3 1990

Figure 5-5. Option 5 (A5)

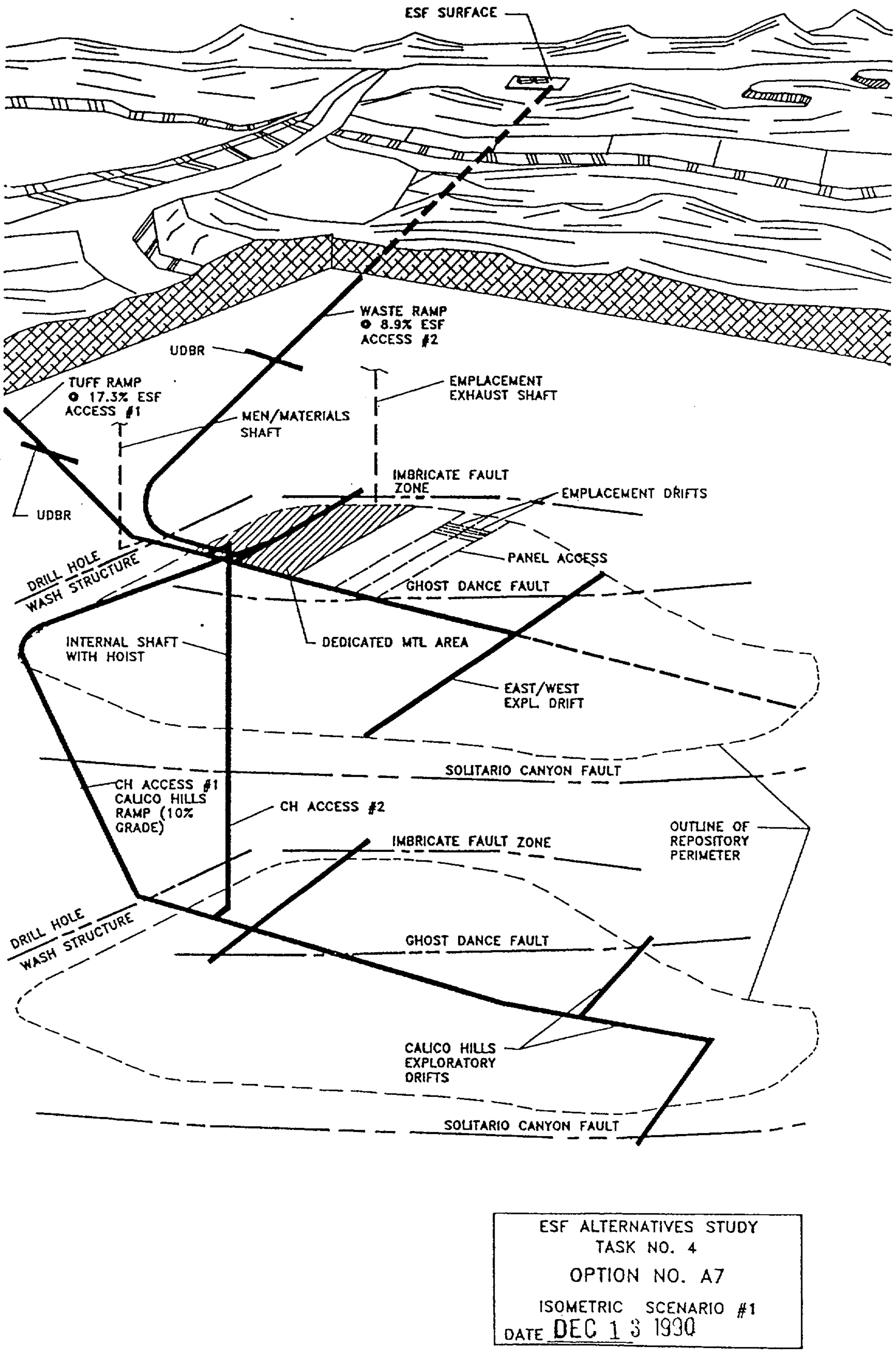


Figure 5-6. Option 6 (A7)

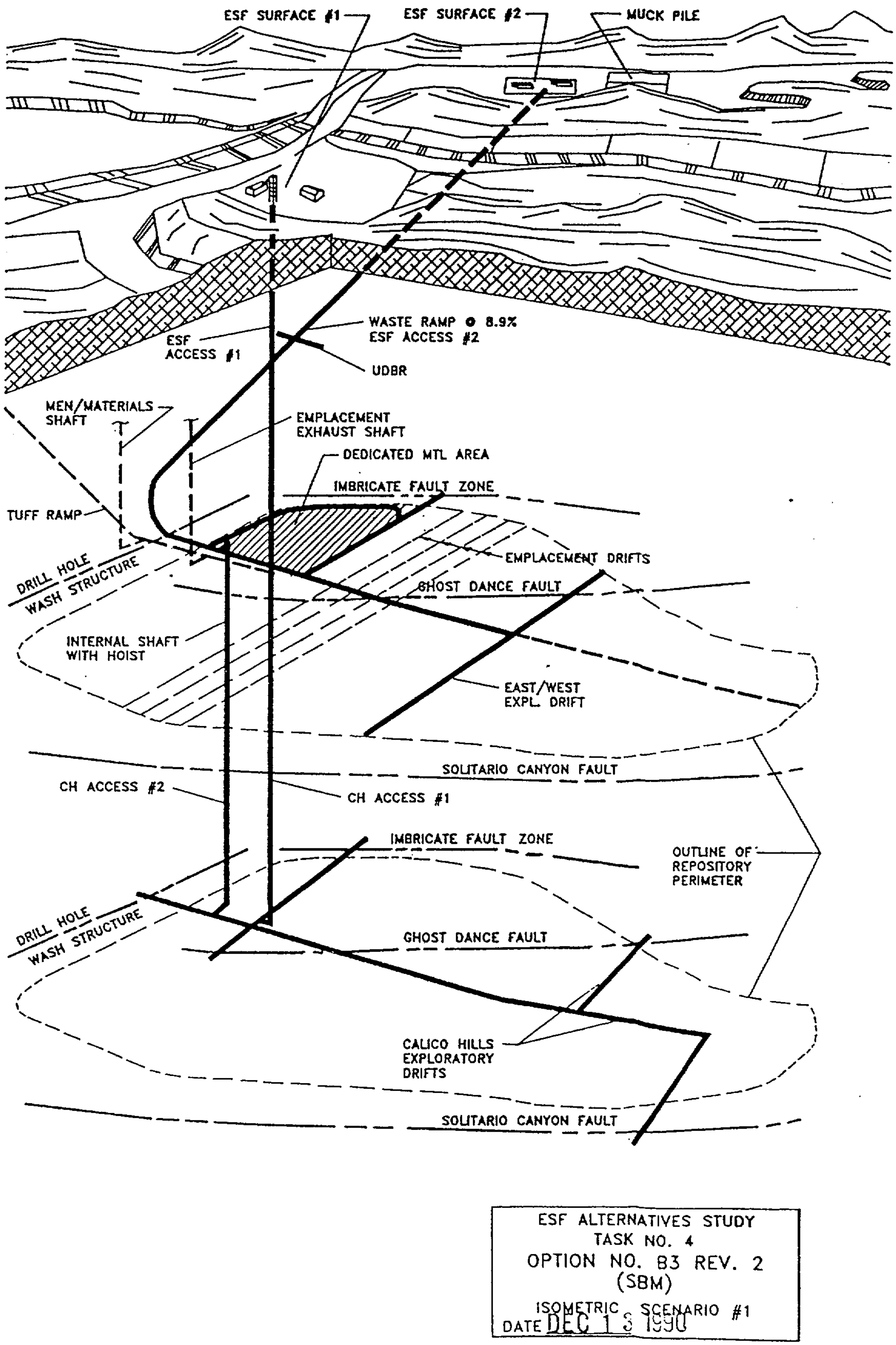


Figure 5-7. Option 7 (B3, Rev. 2)

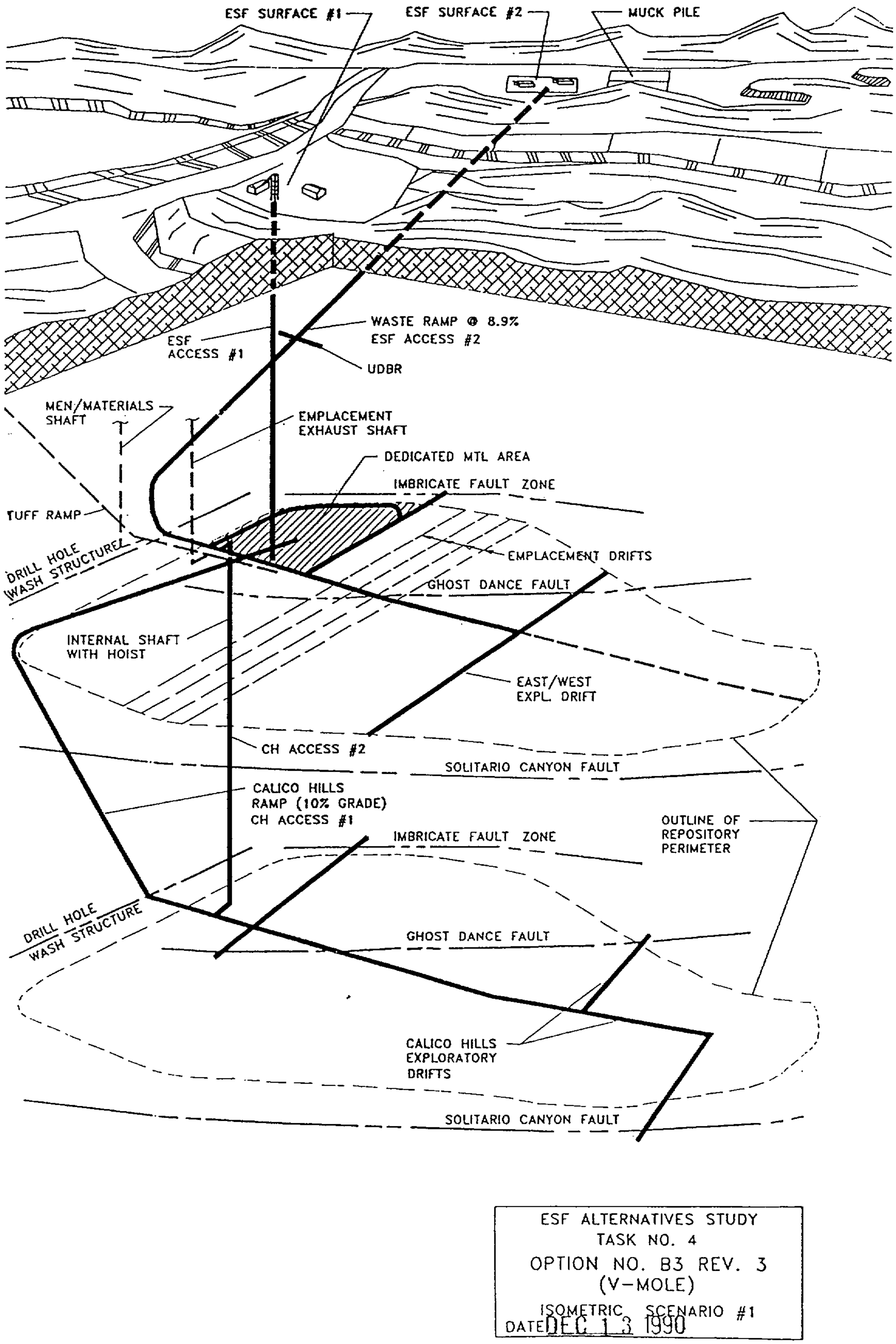


Figure 5-8. Option 8 (B3, Rev. 3)

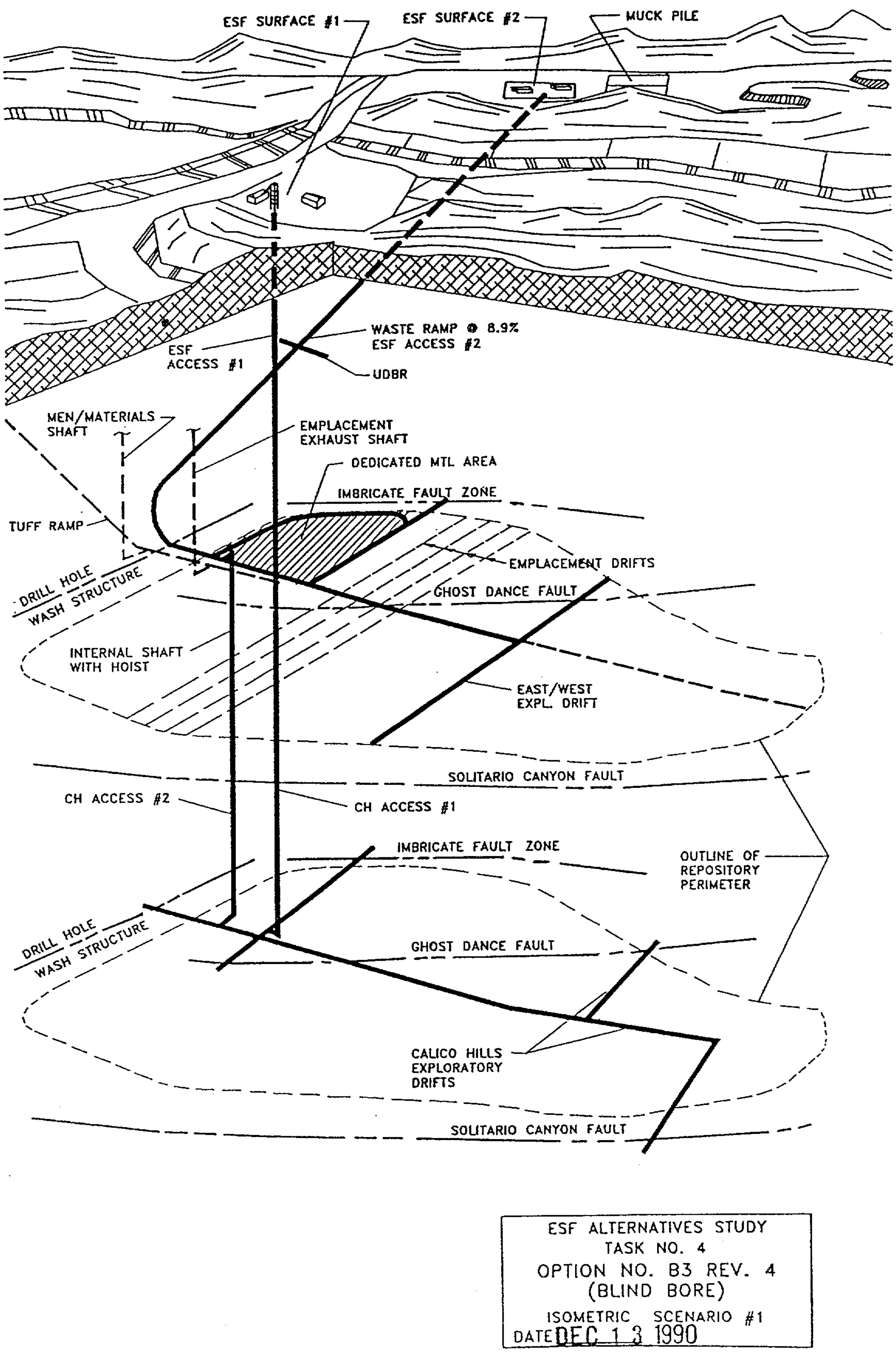


Figure 5-9. Option 9 (B3, Rev. 4)

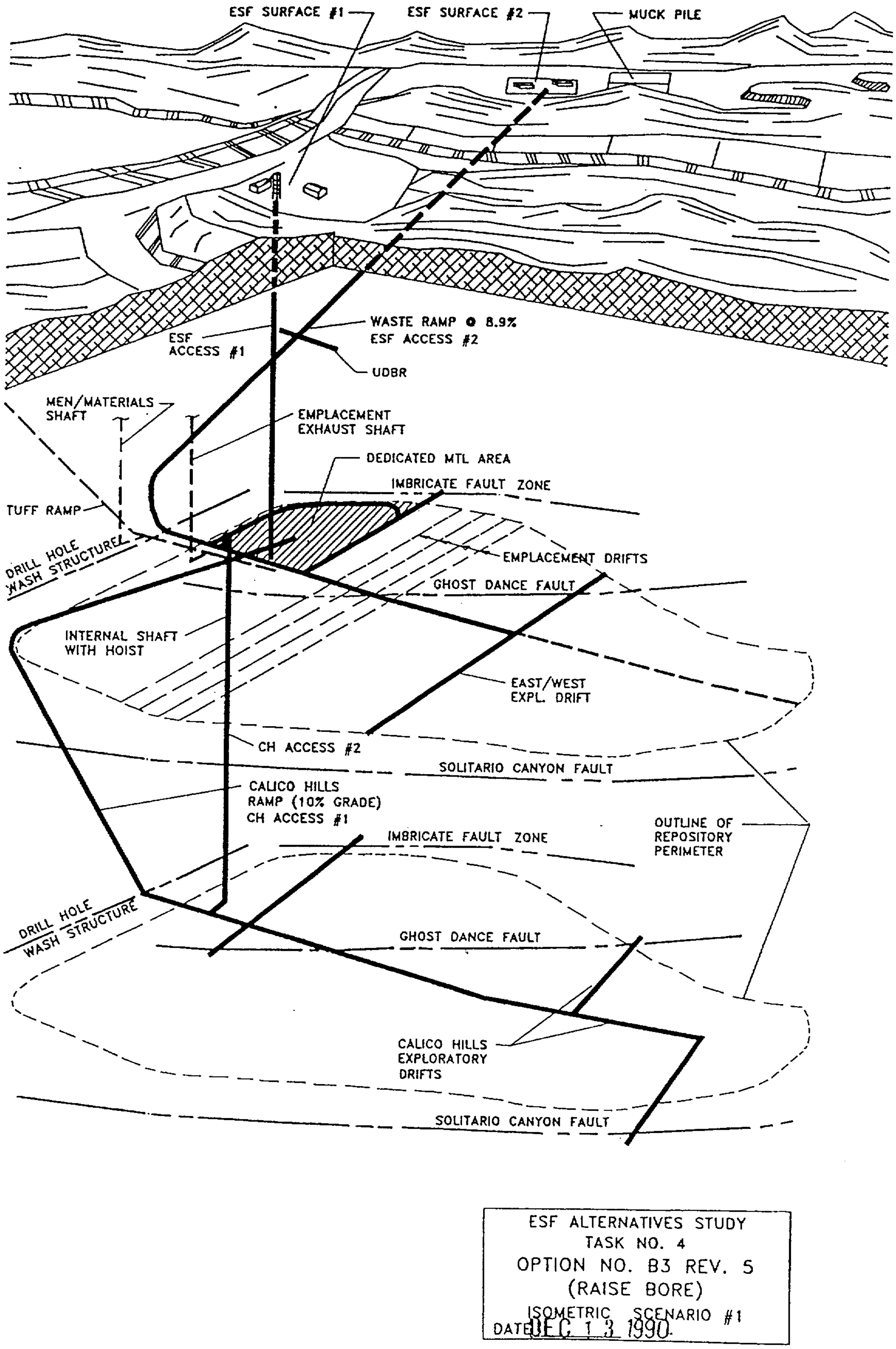


Figure 5-10. Option 10 (B3, Rev. 5)

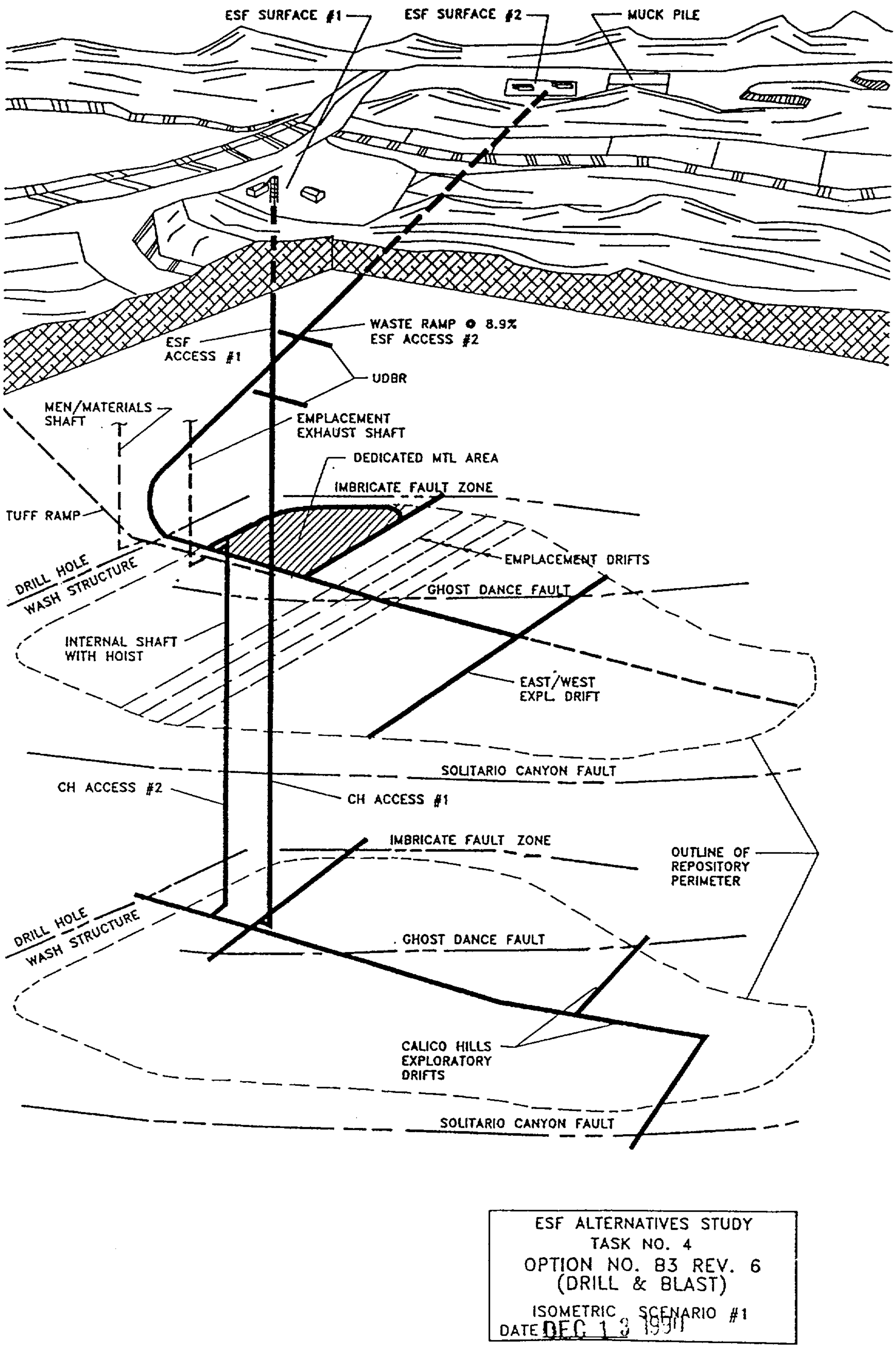
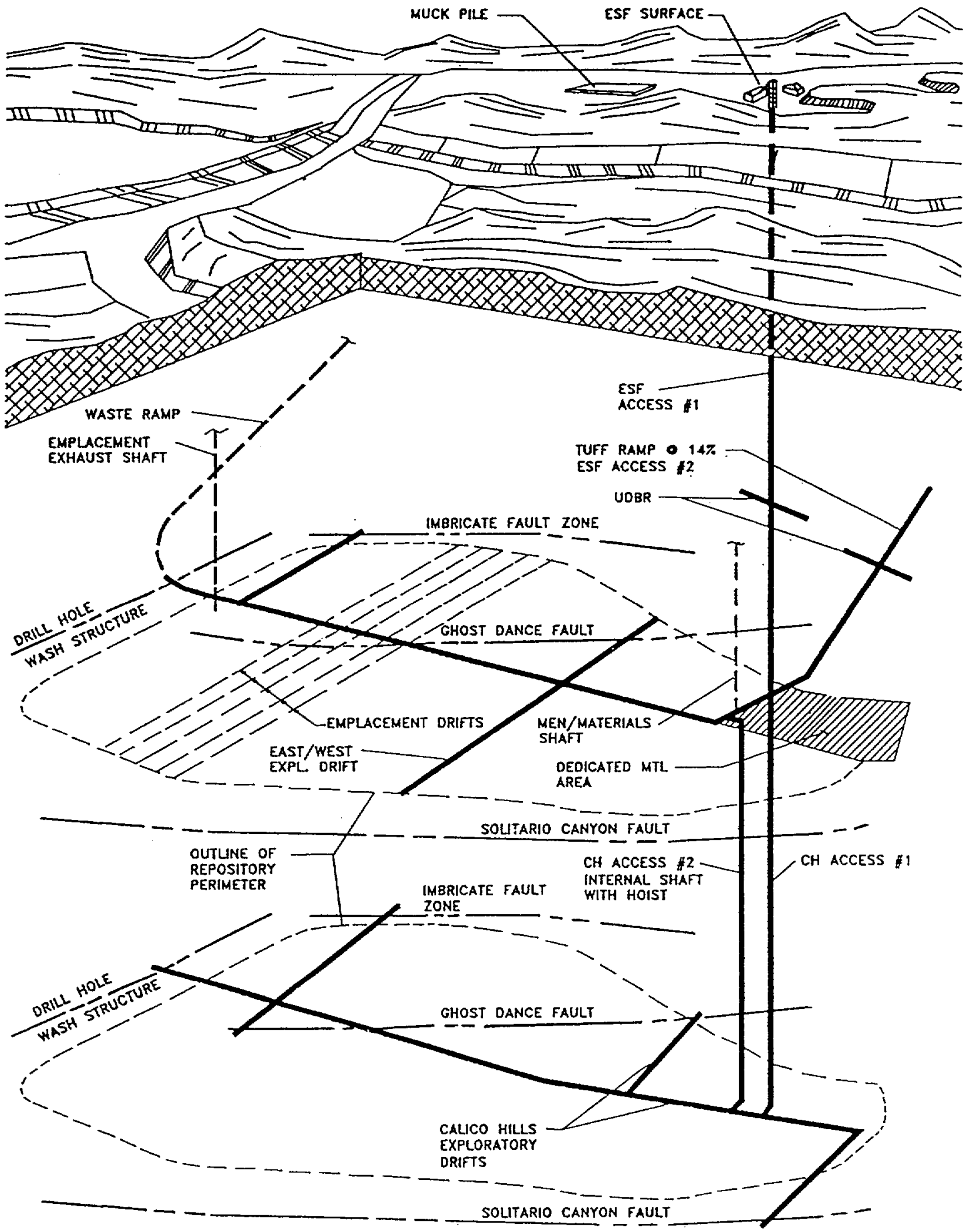


Figure 5-11. Option 11 (B3, Rev. 6)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. B4
ISOMETRIC SCENARIO #1
DATE DEC 13 1990

Figure 5-12. Option 12 (B4)

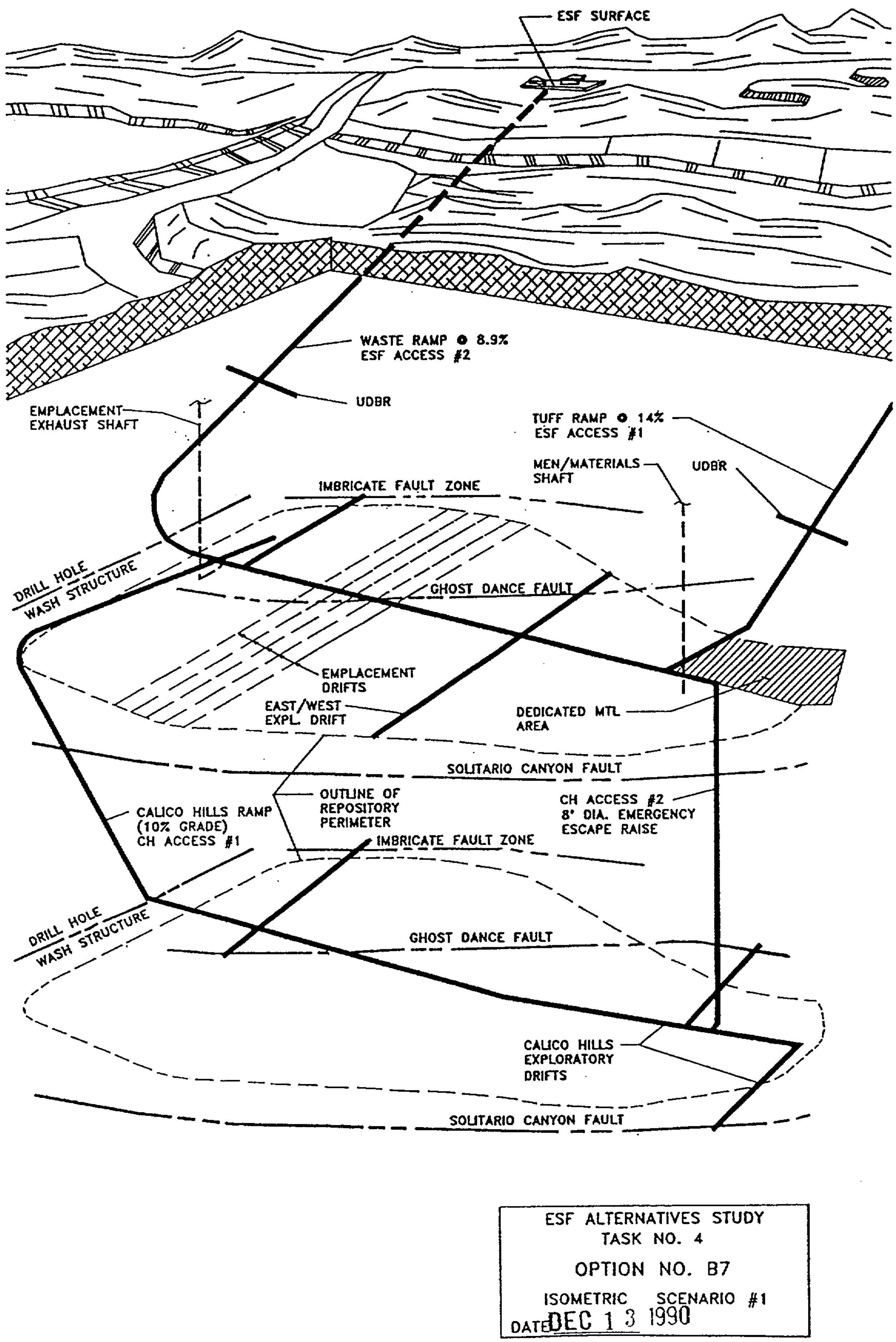
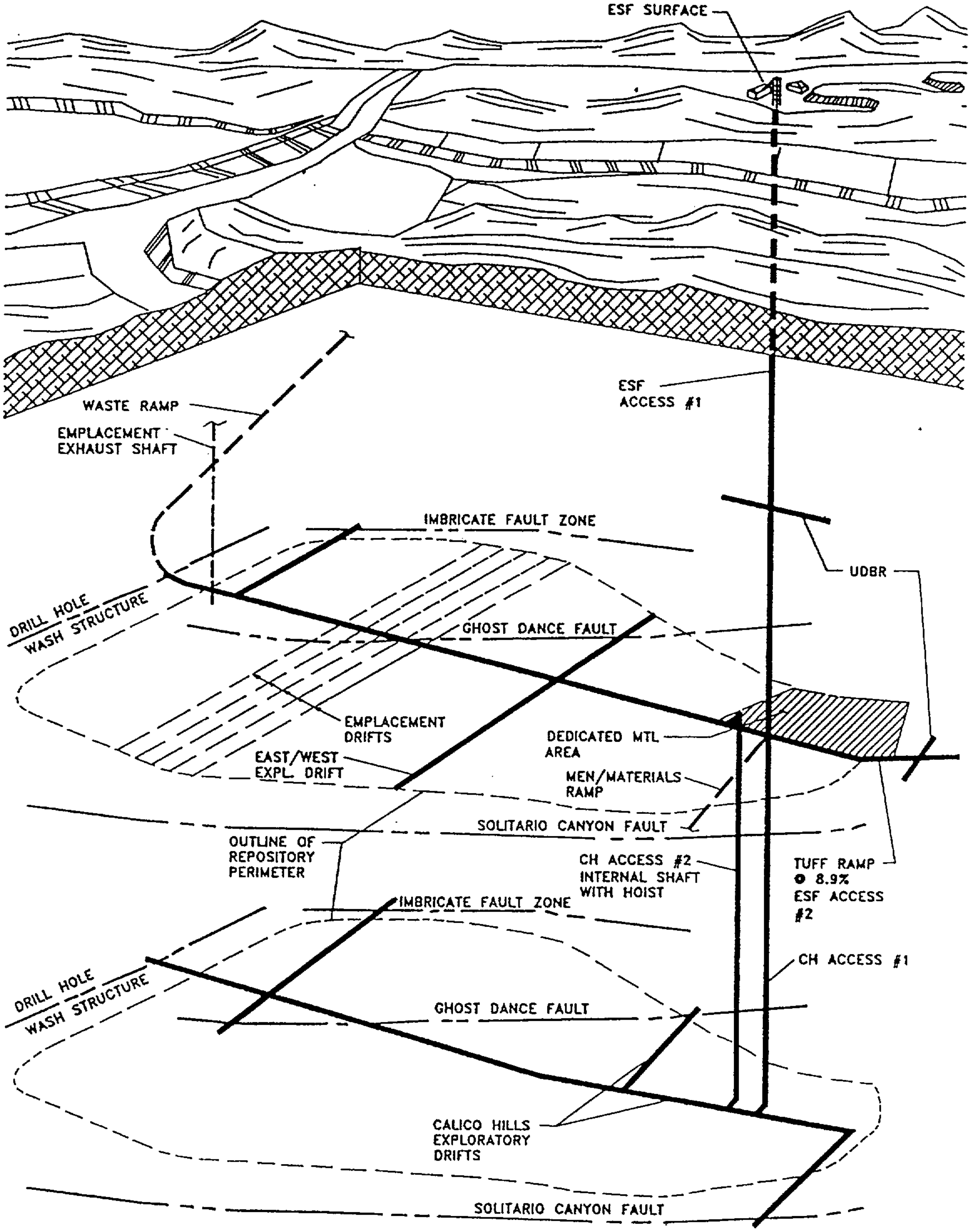


Figure 5-13. Option 13 (B7)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. B8
ISOMETRIC SCENARIO #1
DATE DEC 1 3 1990

Figure 5-14. Option 14 (B8)

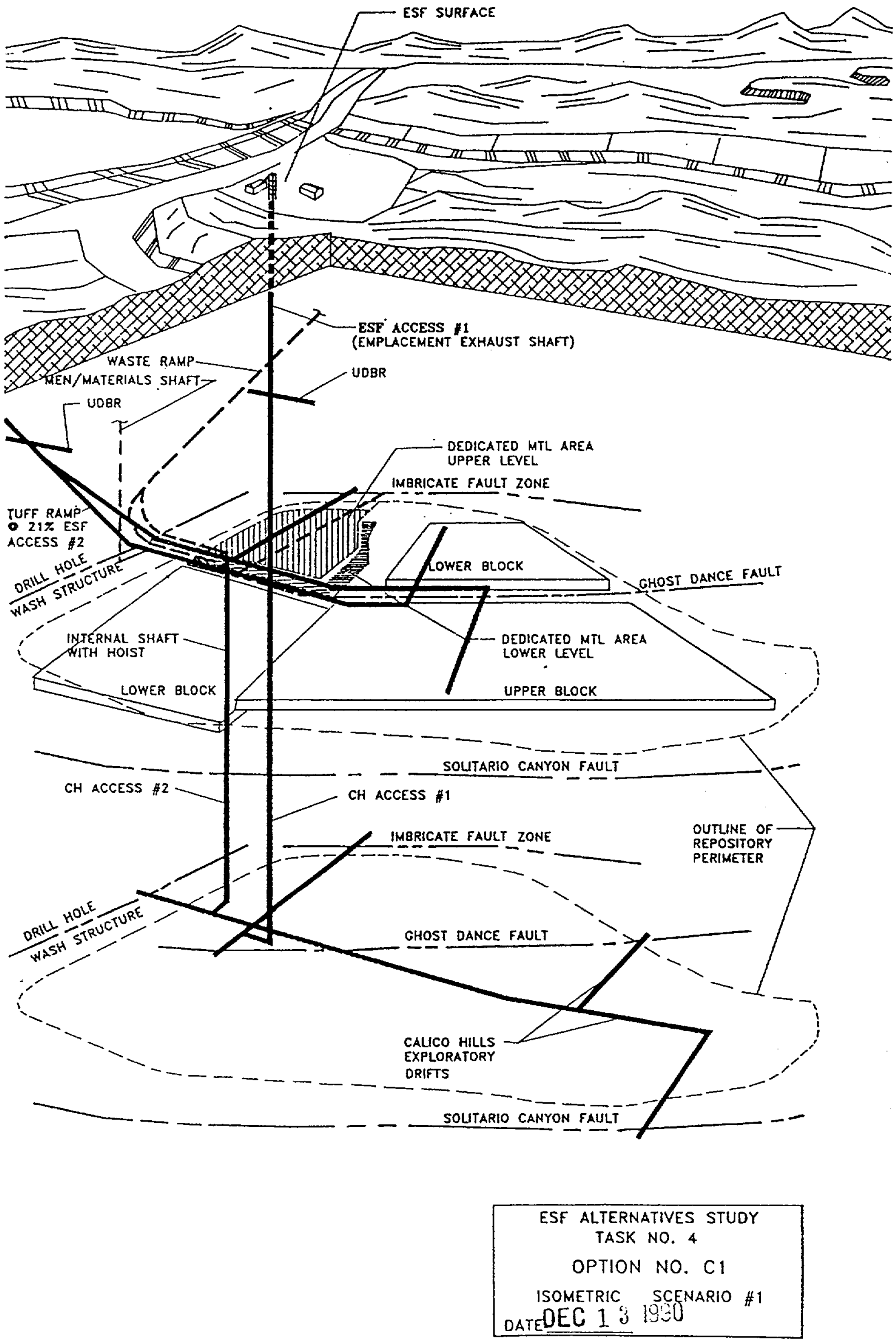


Figure 5-15. Option 15 (C1)

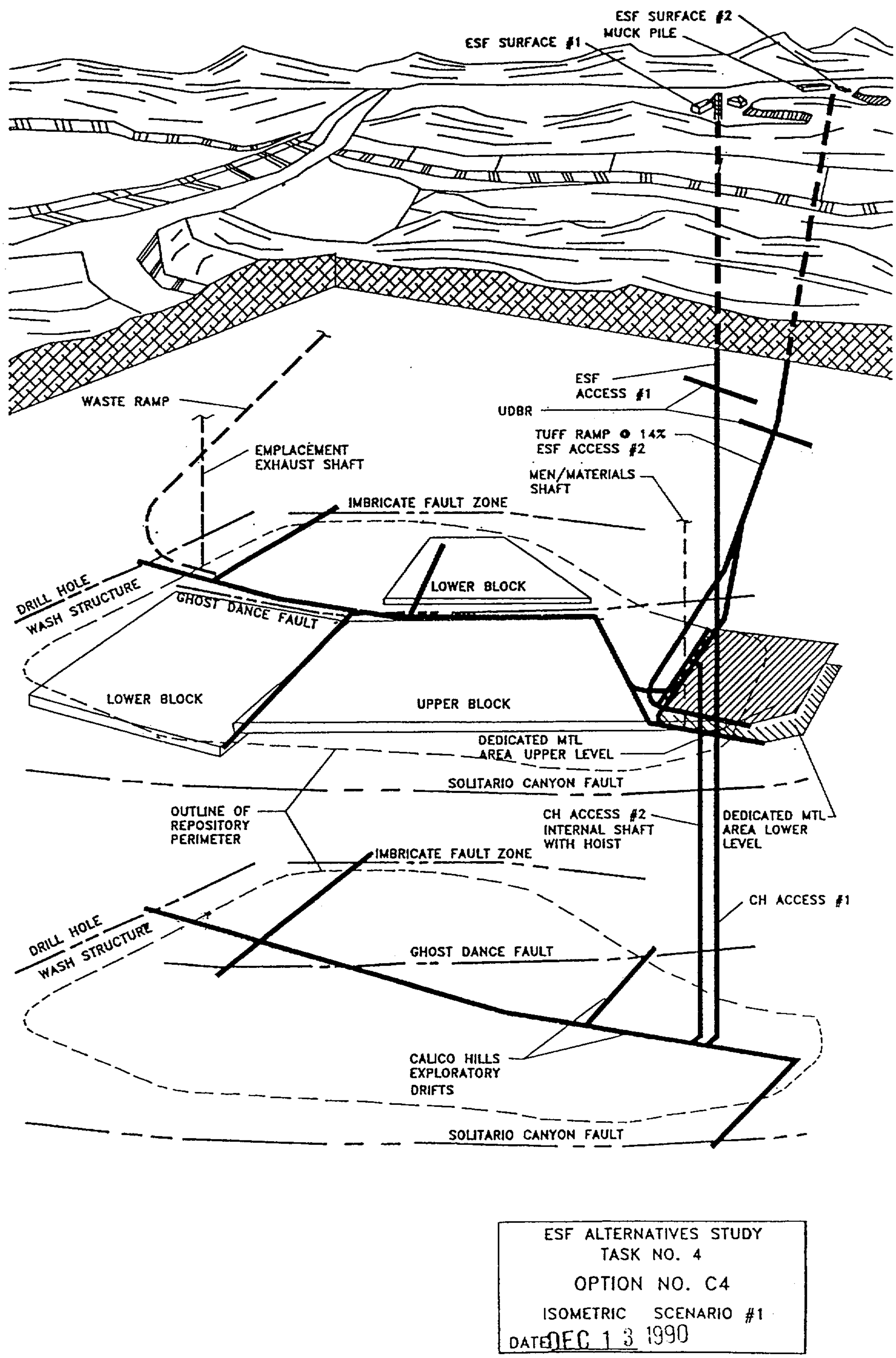
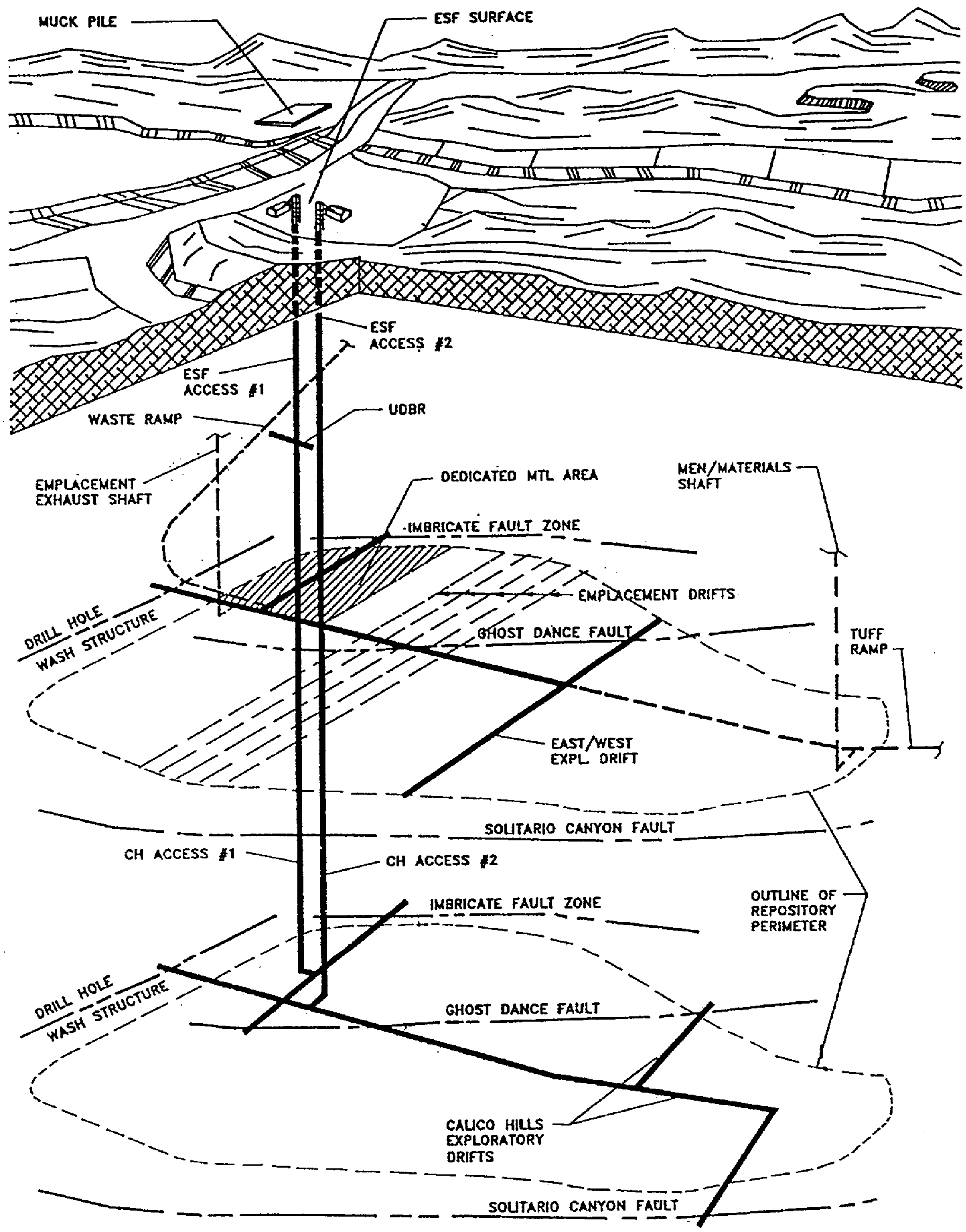


Figure 5-16. Option 16 (C4)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. R-11
ISOMETRIC SCENARIO #1
DATE DEC 13 1990

Figure 5-17. Option 17 (R-11)

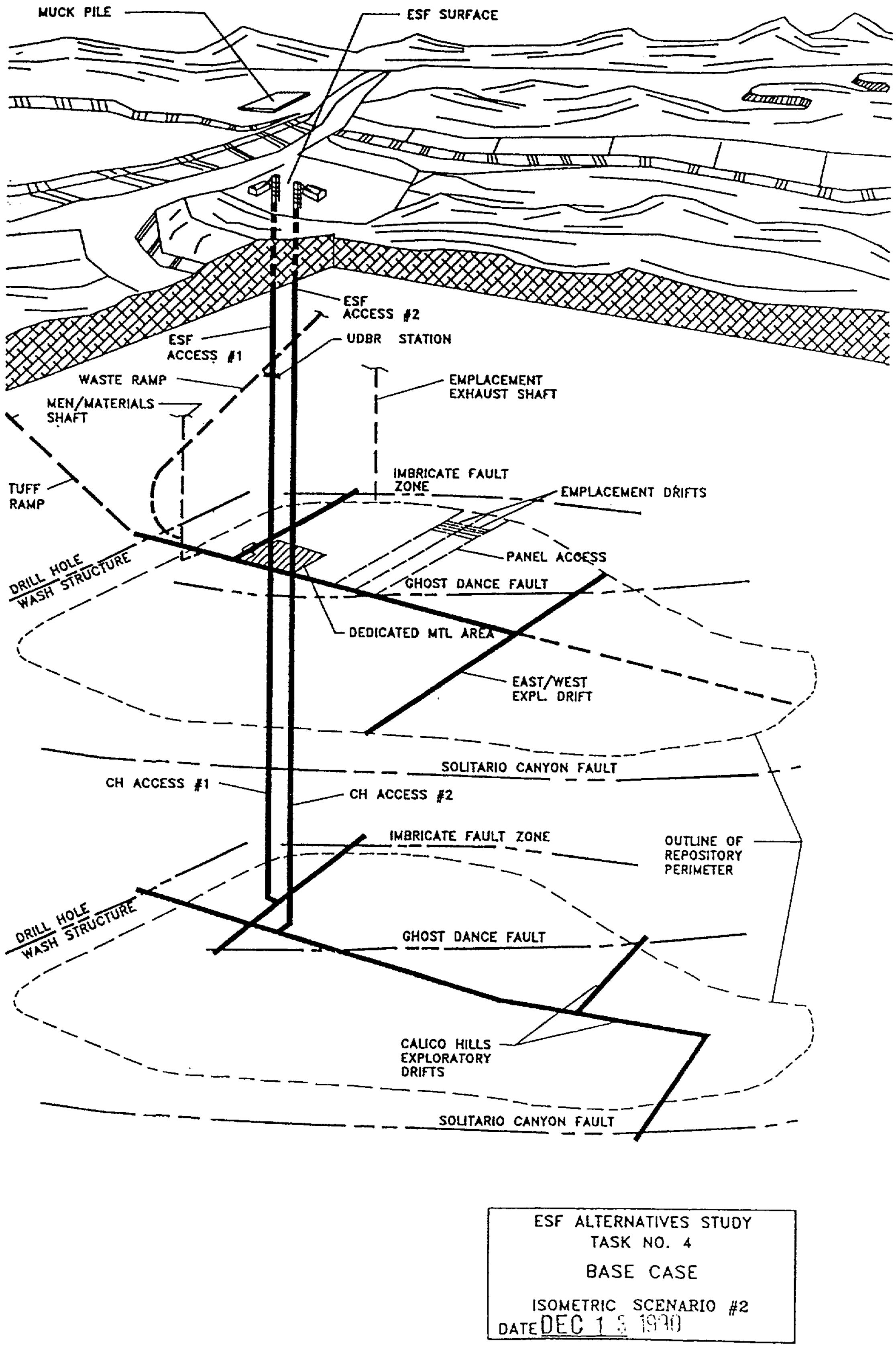
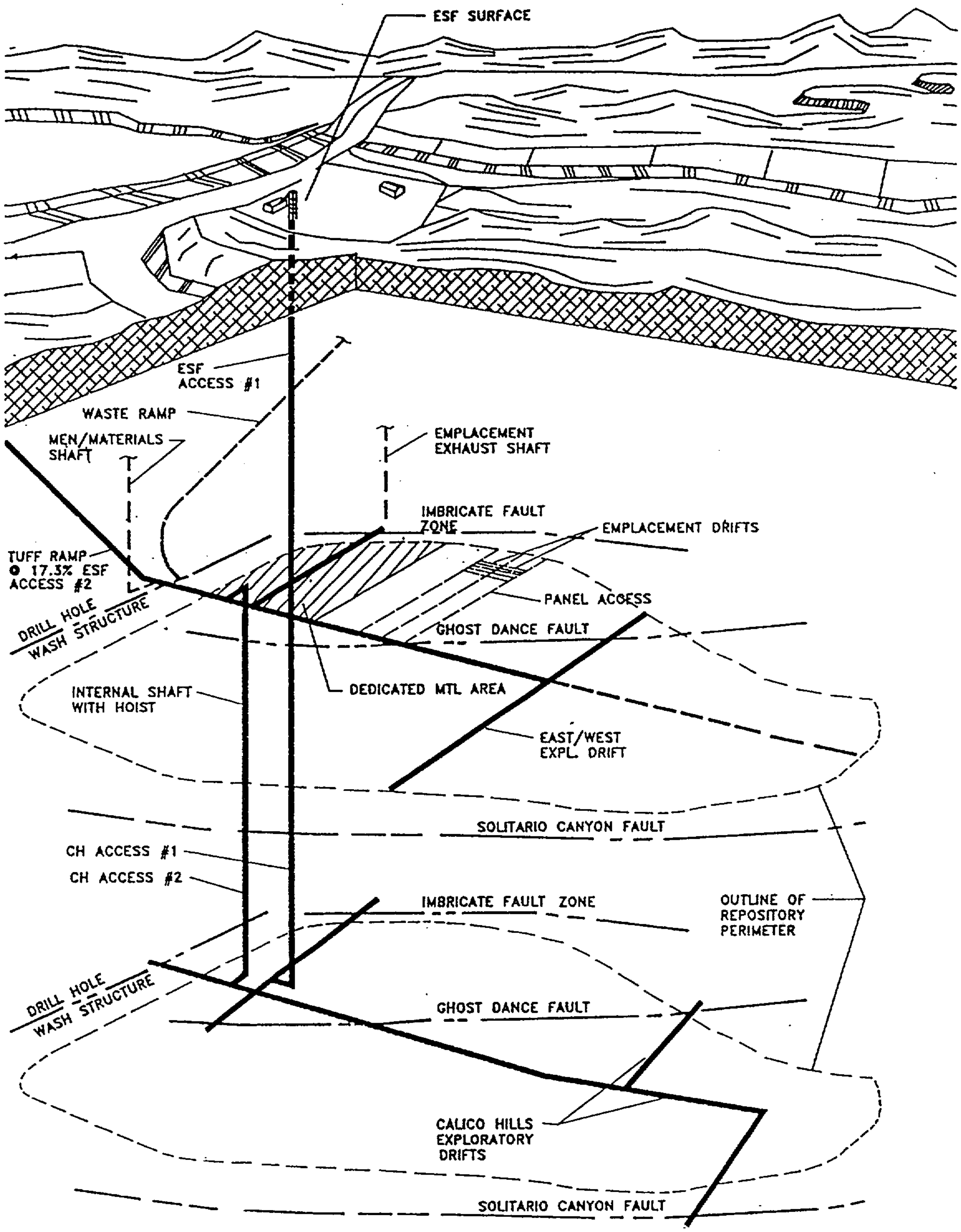
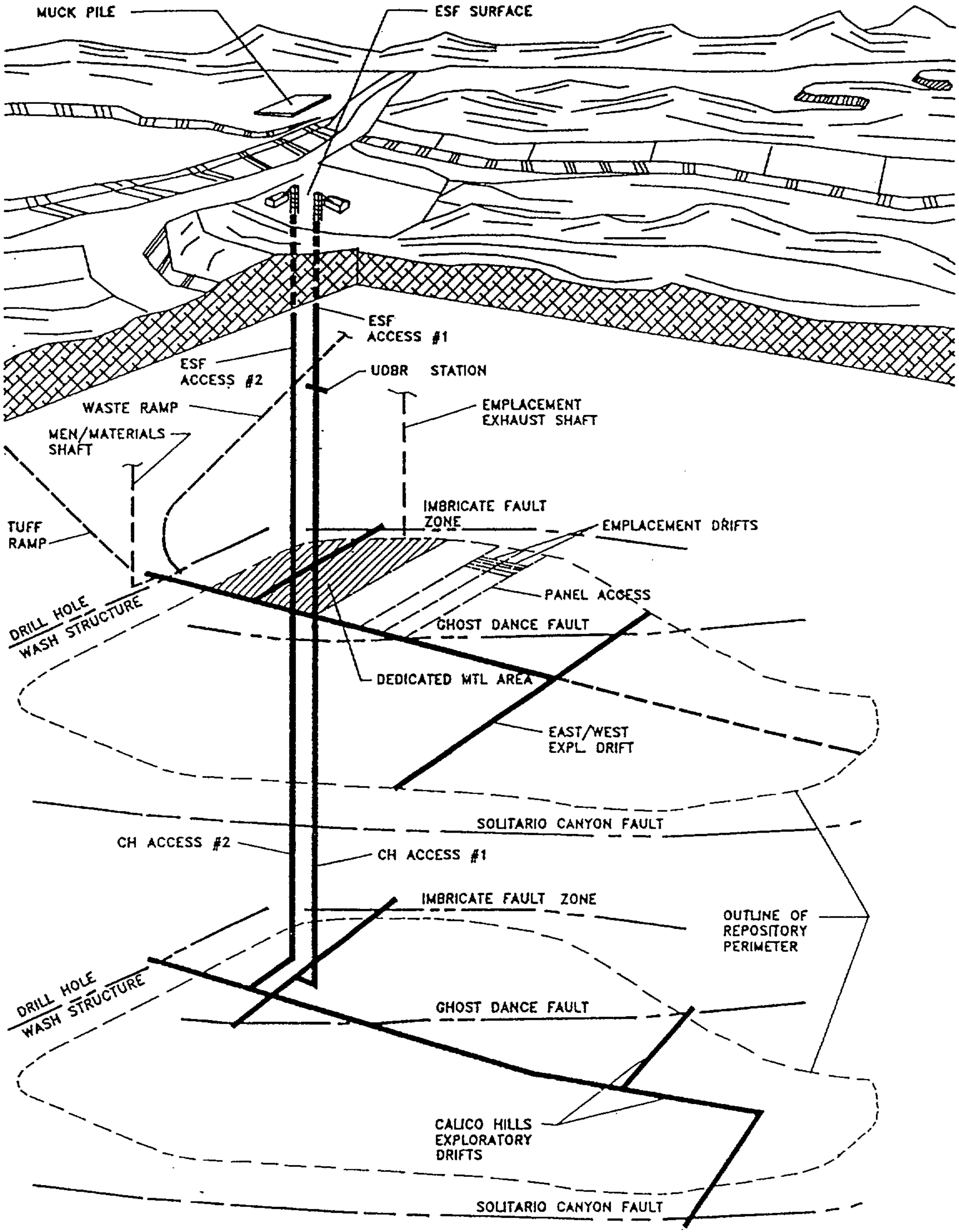


Figure 5-18. Option 18 (Base Case - Scenario 2)



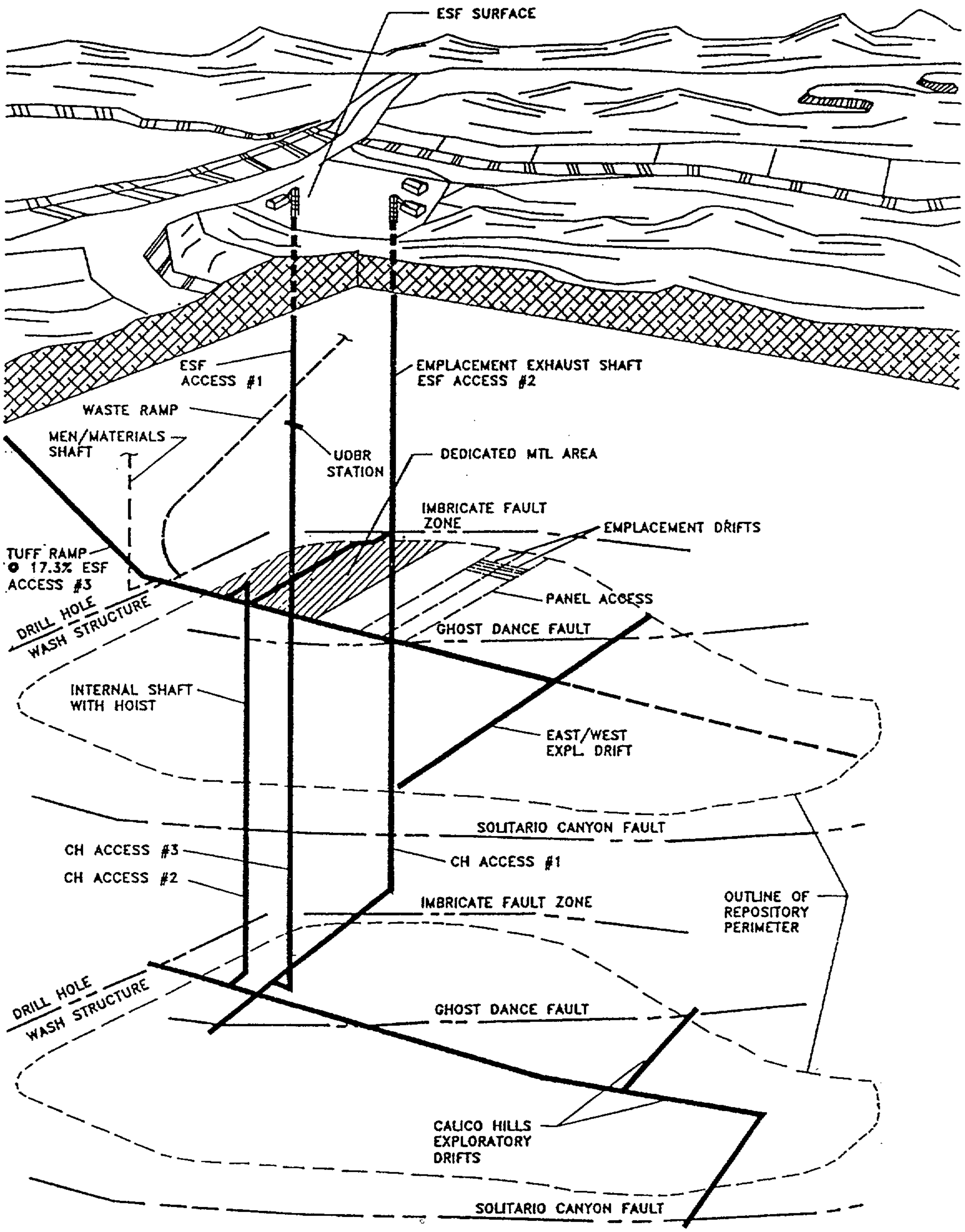
ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. A1
ISOMETRIC SCENARIO #2
DATE DEC 1 1990

Figure 5-19. Option 19 (A1 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. A2
ISOMETRIC SCENARIO #2
DATE DEC 1 3 1990

Figure 5-20. Option 20 (A2 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. A4 REV. 1
ISOMETRIC SCENARIO #2
DATE DEC 1 2 1990

Figure 5-21. Option 21 (A4, Rev. 1 - S2)

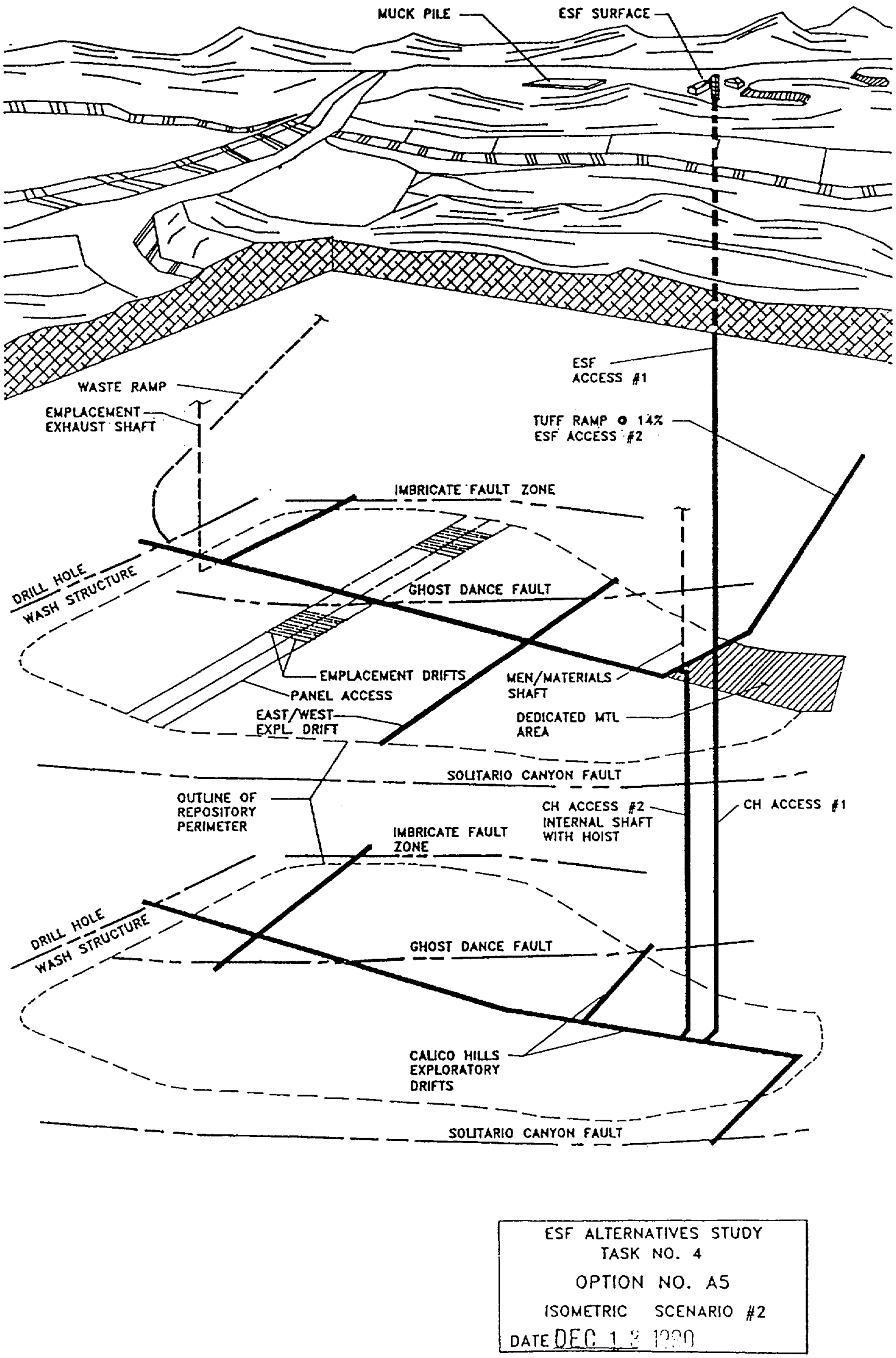
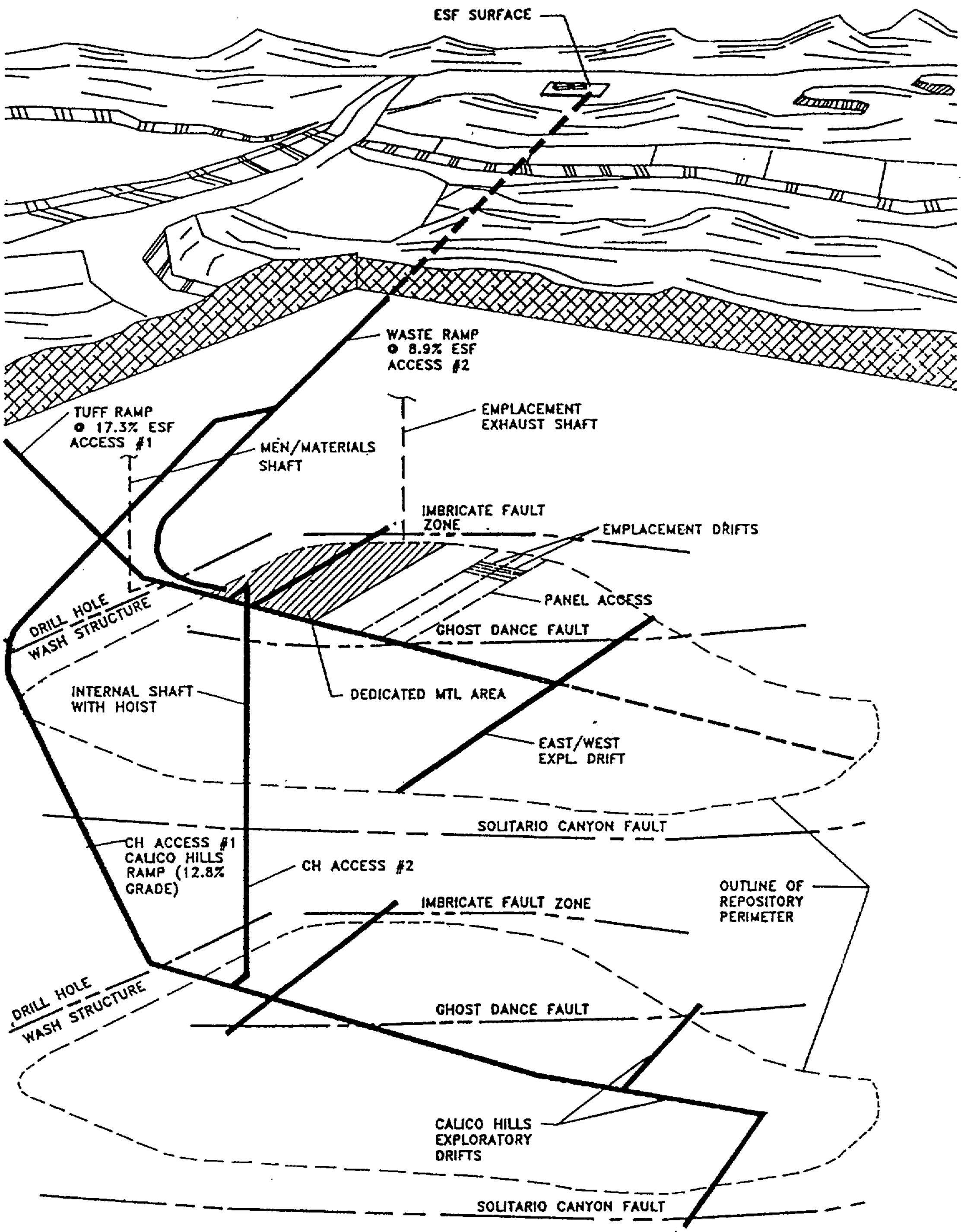


Figure 5-22. Option 22 (A5 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. A7
ISOMETRIC SCENARIO #2
DATE DEC 1 [illegible] 1990

Figure 5-23. Option 23 (A7 - S2)

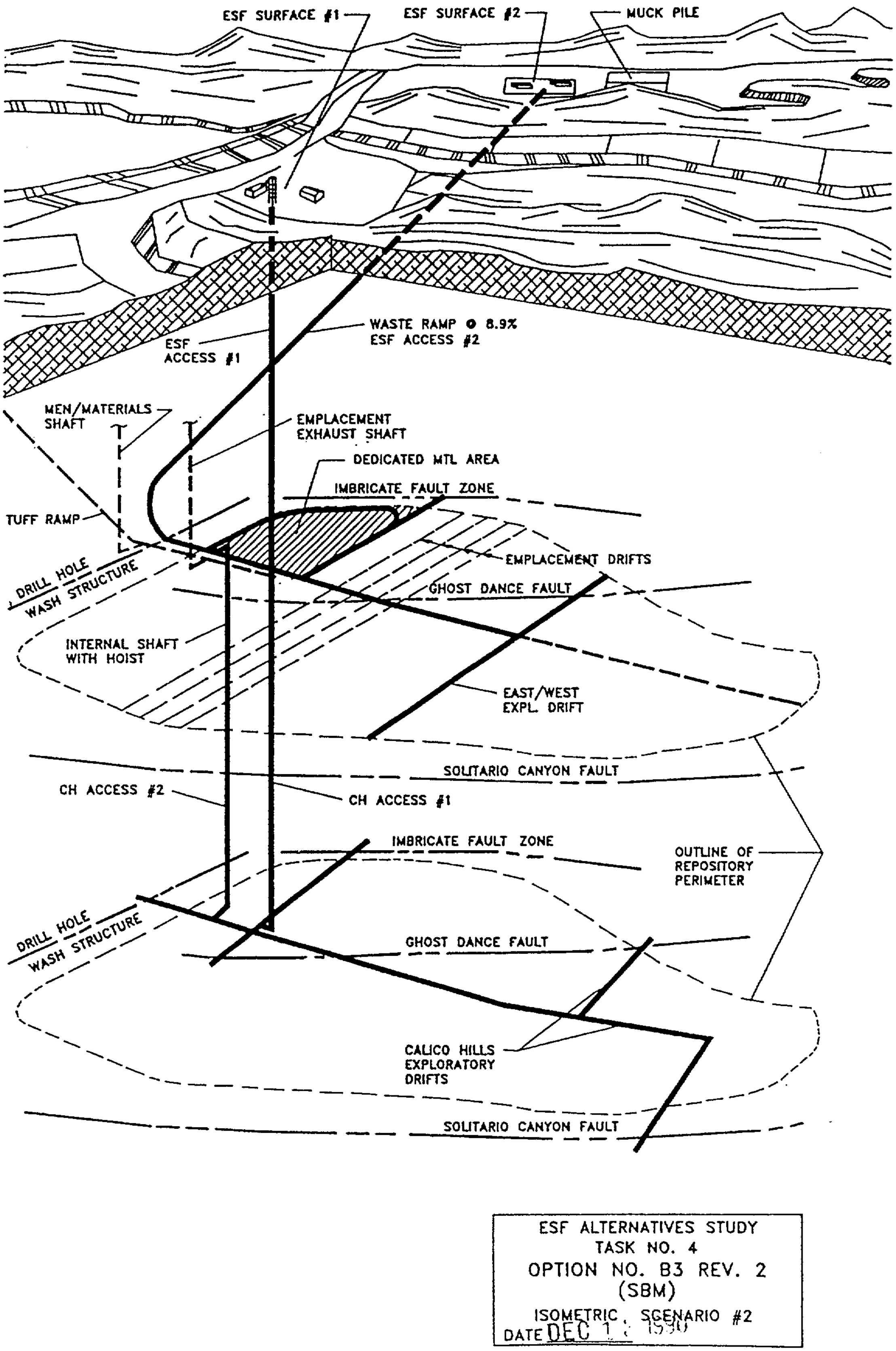


Figure 5-24. Option 24 (B3, Rev. 2 - S2)

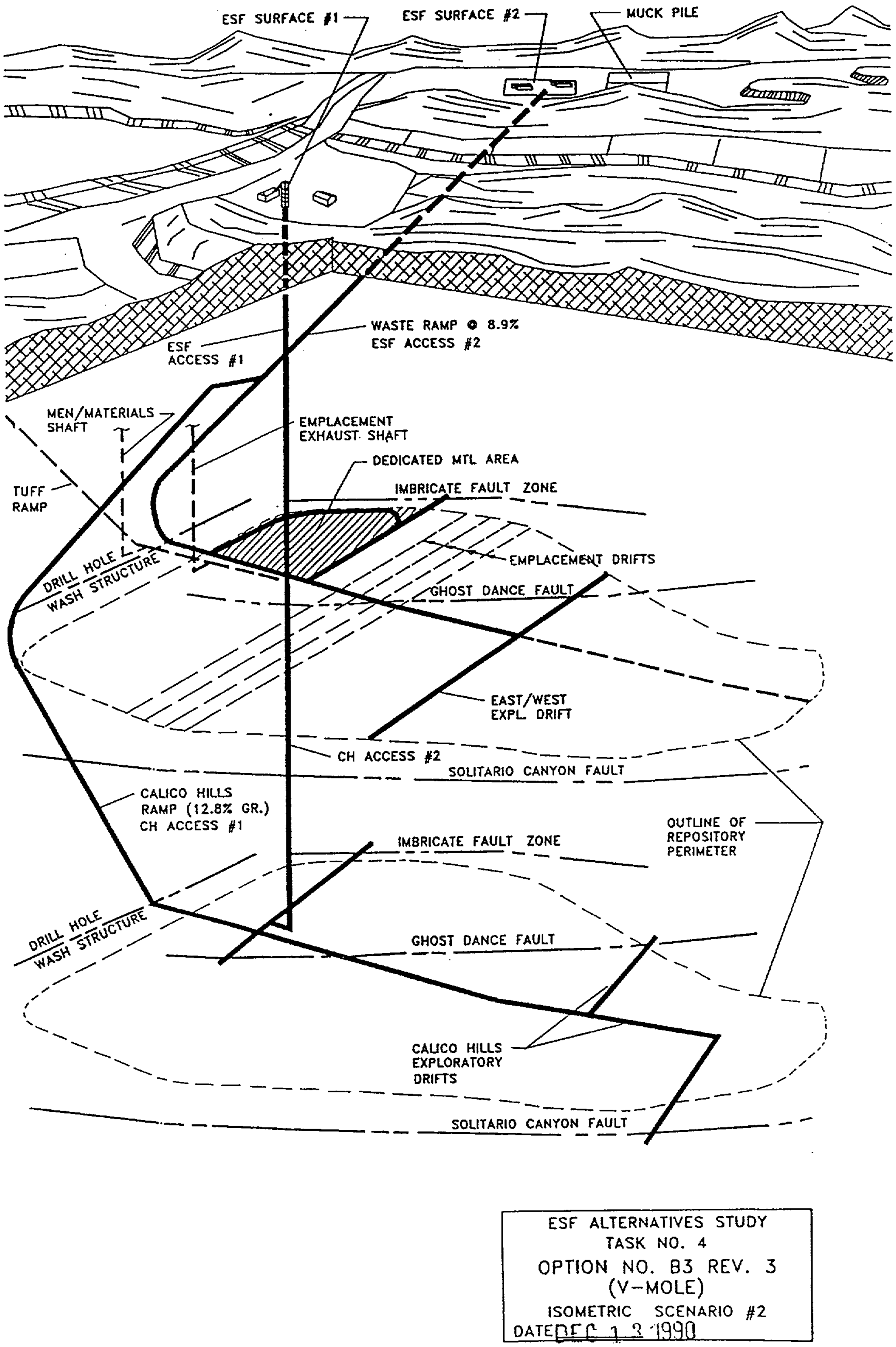
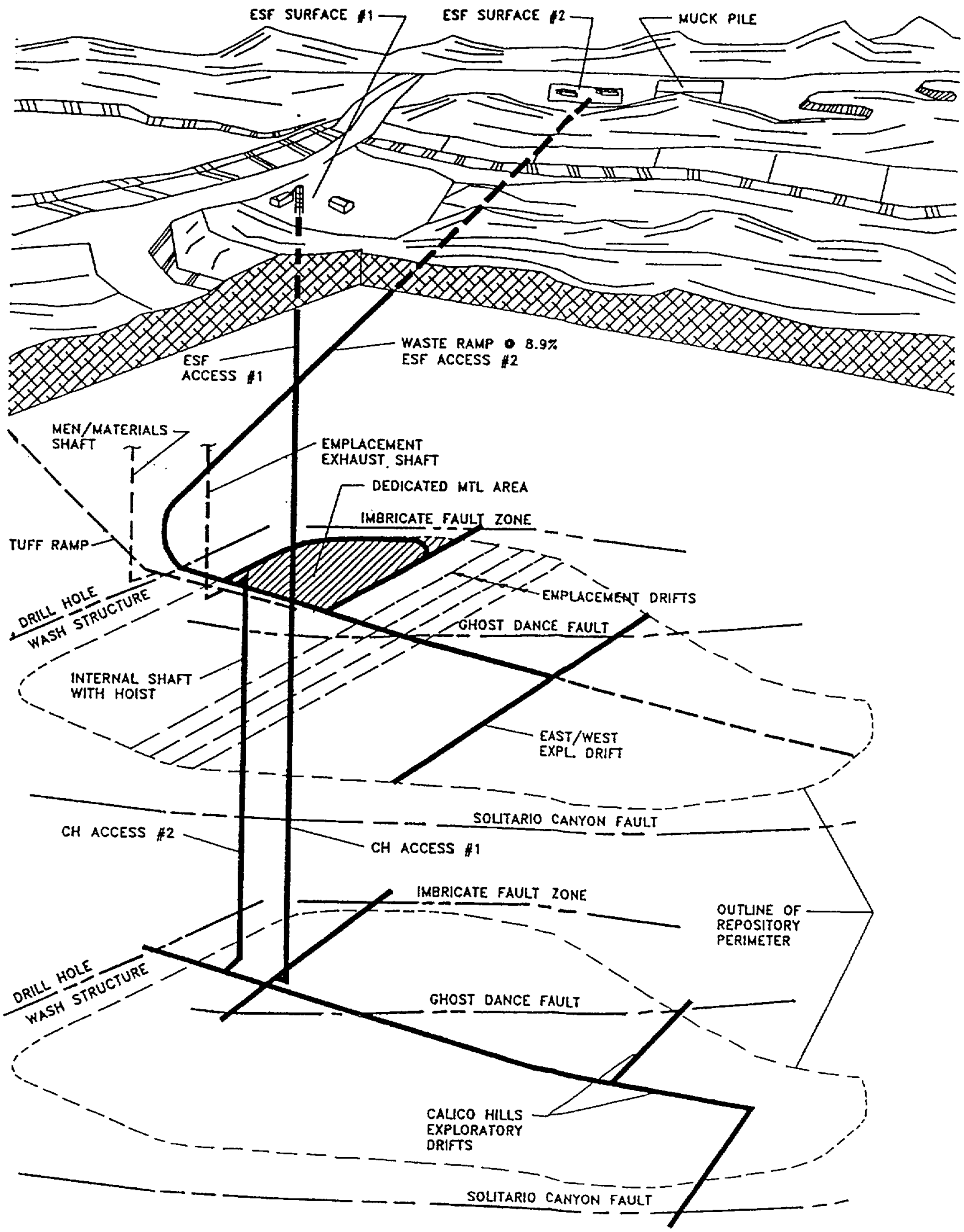
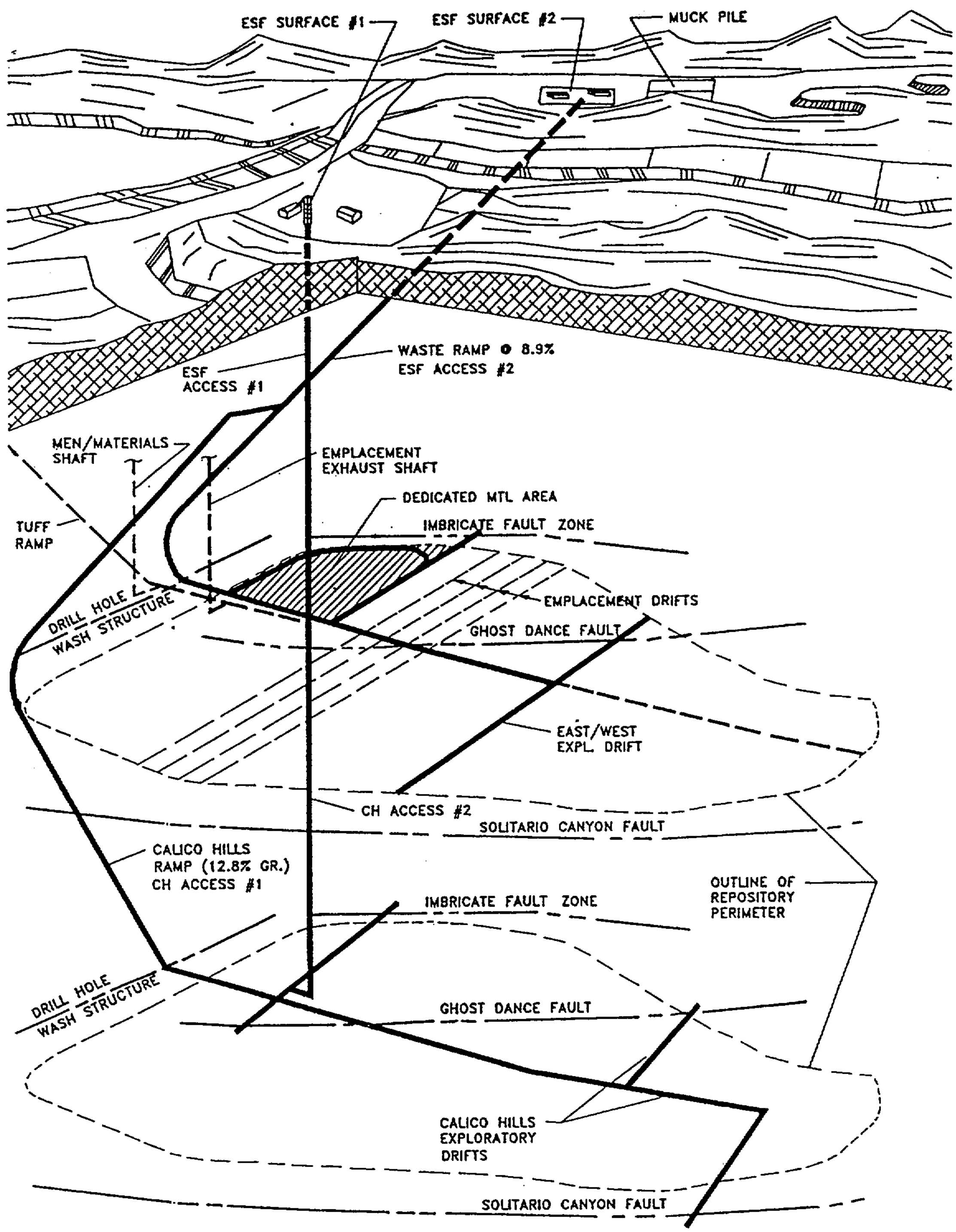


Figure 5-25. Option 25 (B3, Rev. 3 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. B3 REV. 4
(BLIND BORE)
ISOMETRIC SCENARIO #2
DATE DEC 1 3 1990

Figure 5-26. Option 26 (B3, Rev. 4 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. B3 REV. 5
(RAISE BORE)
ISOMETRIC SCENARIO #2
DATE DEC 1 3 1990

Figure 5-27. Option 27 (B3, Rev. 5 - S2)

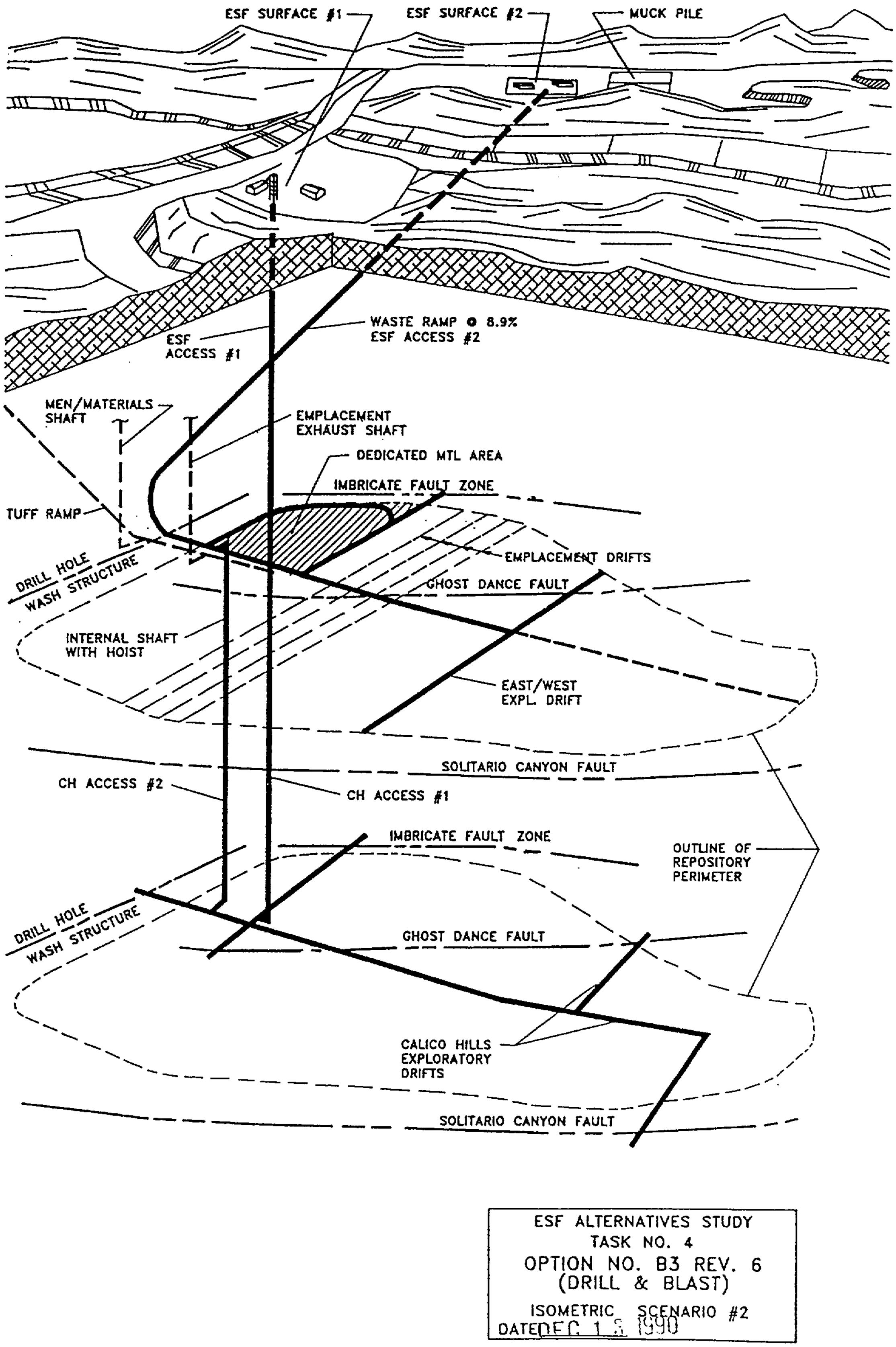


Figure 5-28. Option 28 (B3, Rev. 6 - S2)

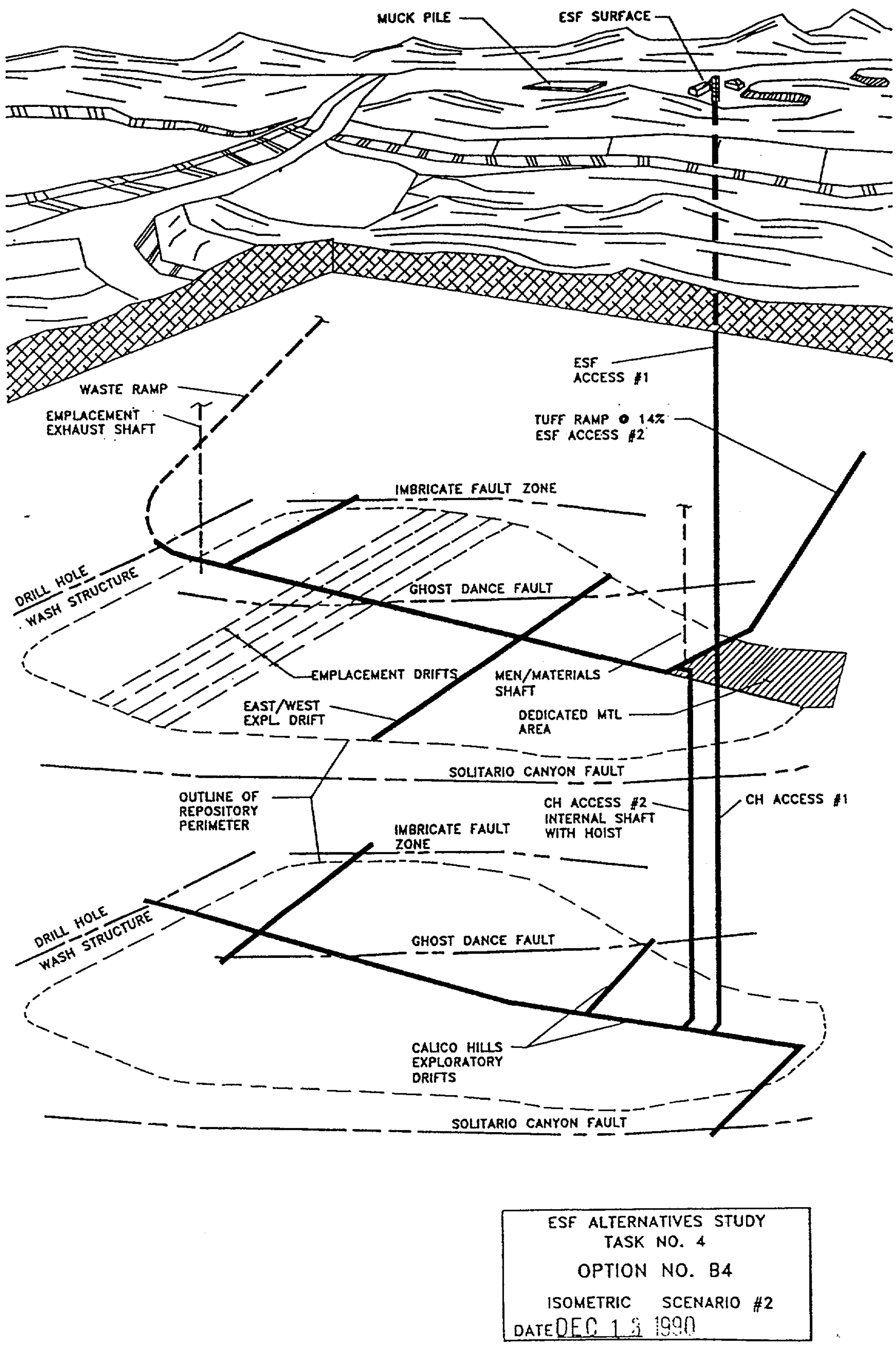
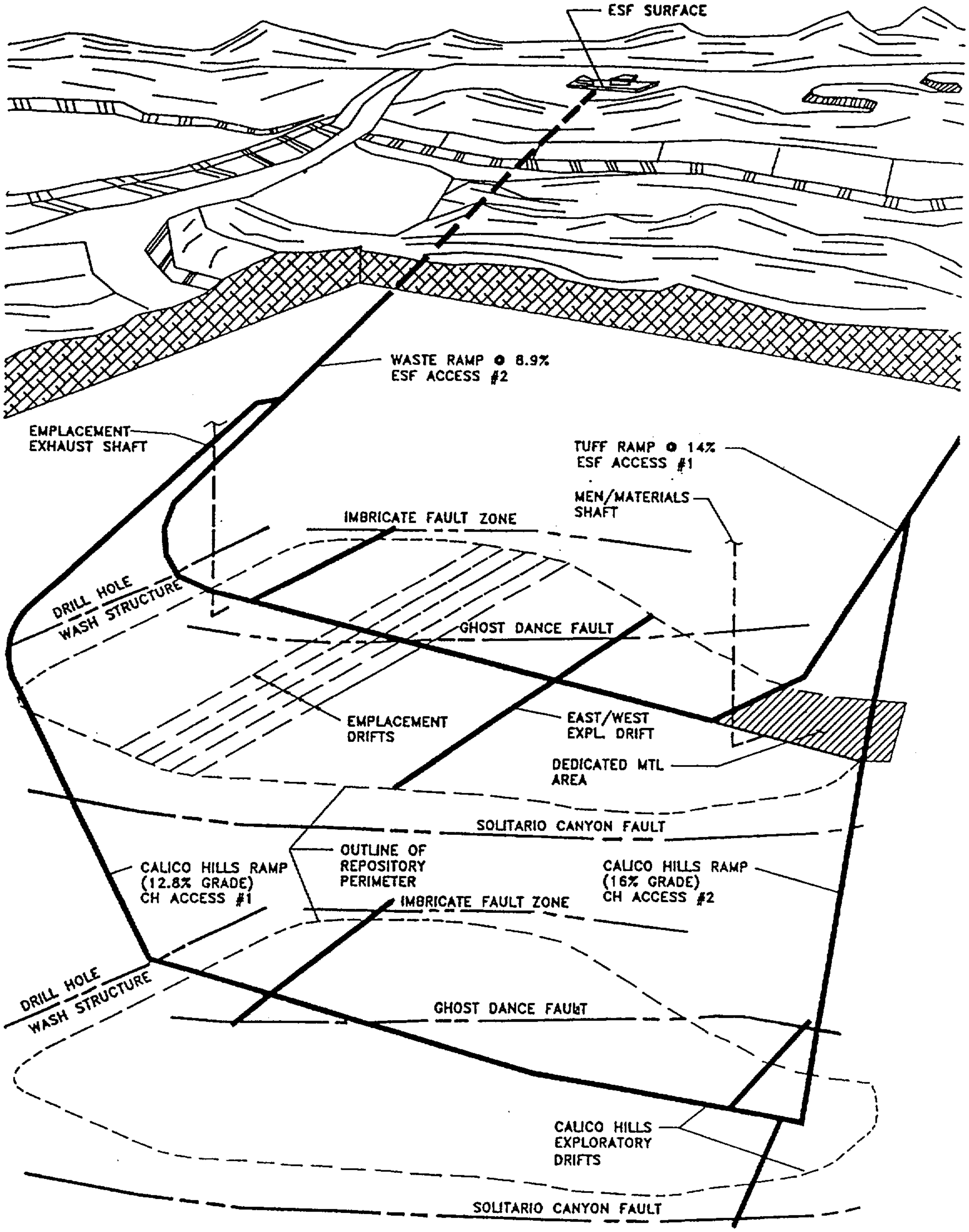


Figure 5-29. Option 29 (B4 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. B7
ISOMETRIC SCENARIO #2
DATE DEC 13 1990

Figure 5-30. Option 30 (B7 - S2)

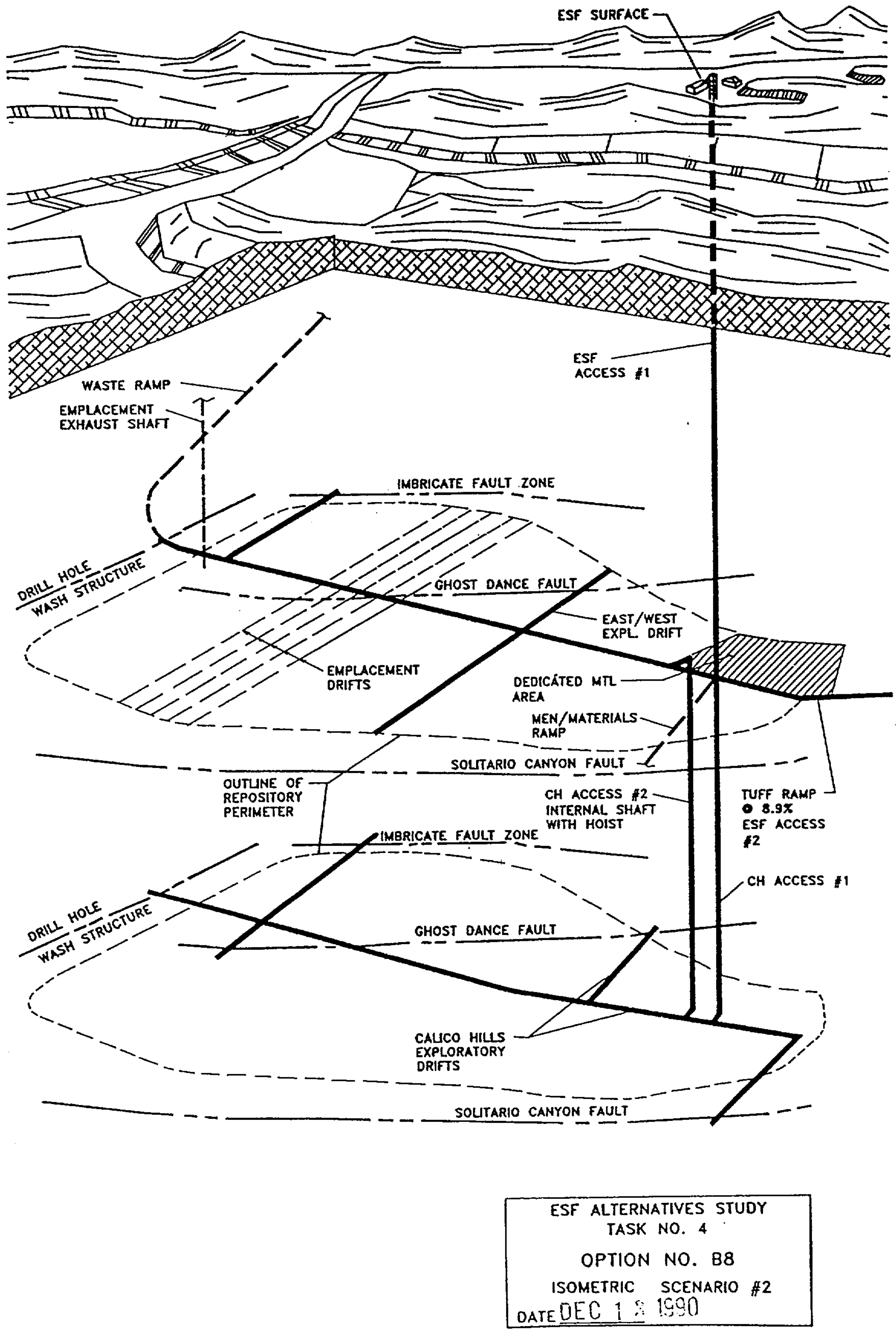
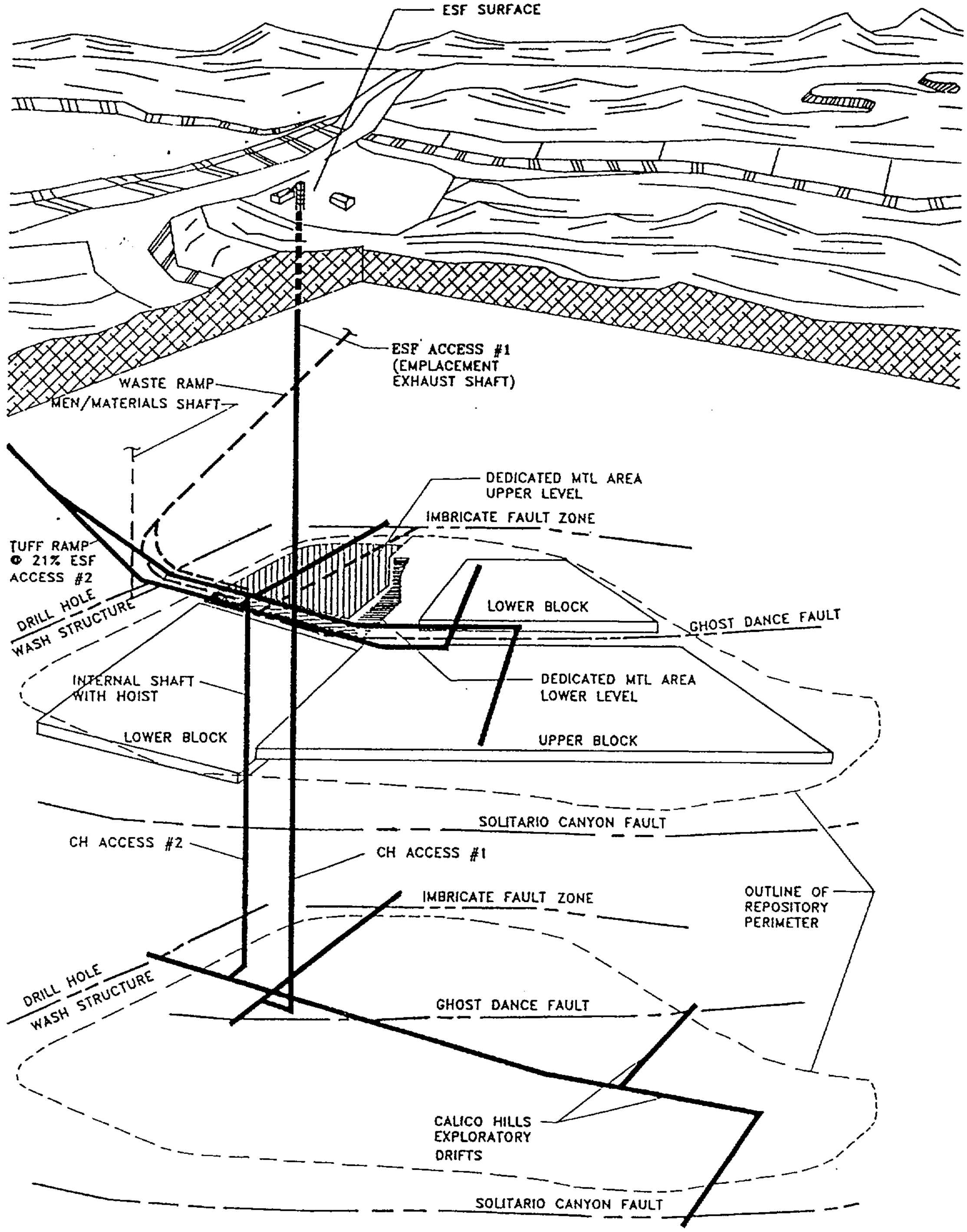
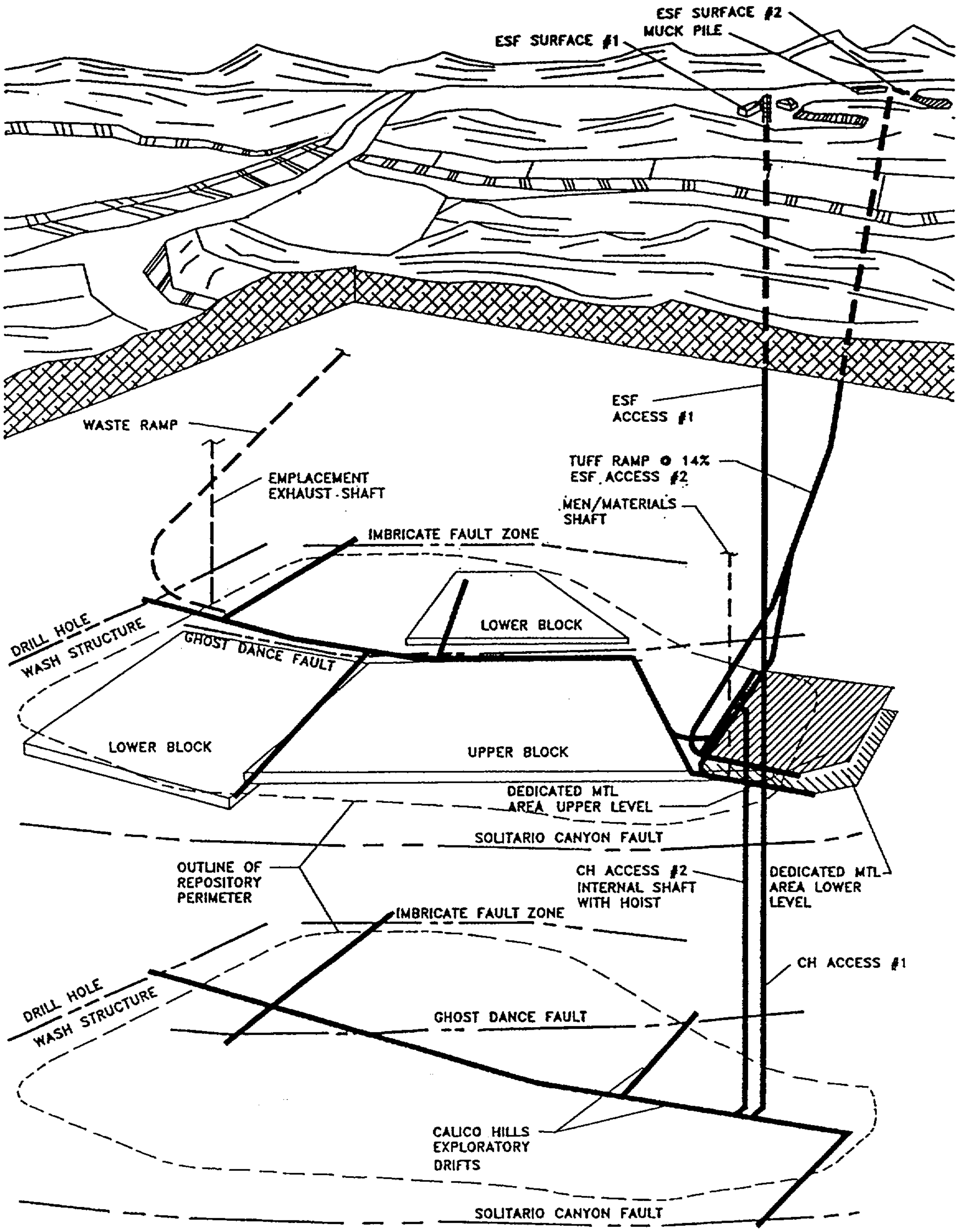


Figure 5-31. Option 31 (B8 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. C1
ISOMETRIC SCENARIO #2
DATE DEC 13 1990

Figure 5-32. Option 32 (C1 - S2)



ESF ALTERNATIVES STUDY
TASK NO. 4
OPTION NO. C4
ISOMETRIC SCENARIO #2
DATE DEC 1 3 1990

Figure 5-33. Option 33 (C4 - S2)

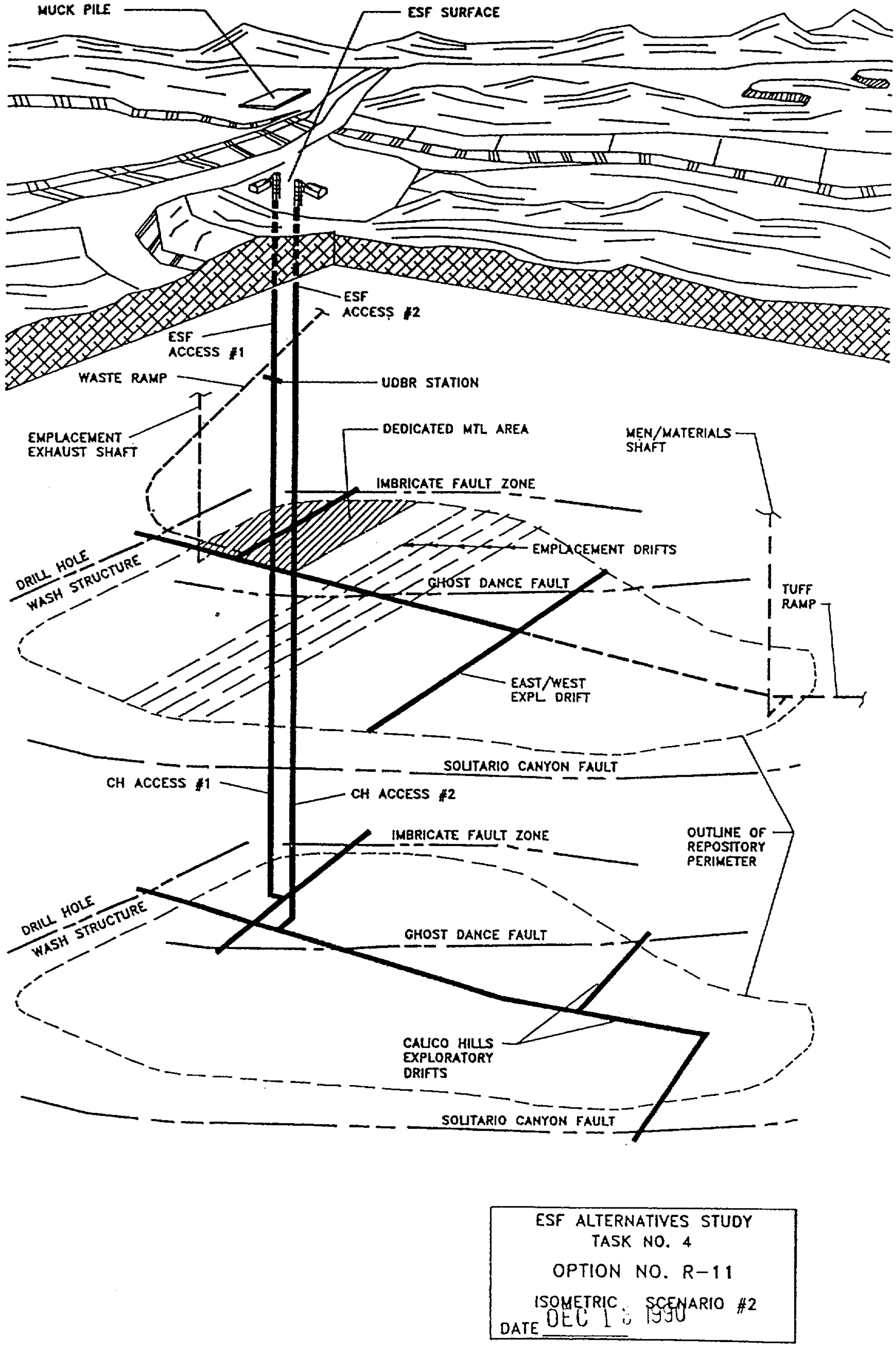


Figure 5-34. Option 34 (R11 - S2)

TABLE 5-8
SUMMARY ESF-AS TEST INPUT/TEST FEASIBILITY DATA QUALITY BY OPTION

	Option 1 (Base Case)	Option 2 (A1)			Option 3 (A2)			Option 4 (A4 Rev 1)		
Test Name	I E S	I	E	S	I	E	S	I	E	S
Shaft Conv.				X			X			X
Demon.BO Rooms			X			X			X	
Seq.DriftMine.			X			X			X	
HeaterExp/TSw1			X			X			X	
Canister Scale			X			X			X	
Heated Block			X			X			X	
Thermal Stress			X			X			X	
Heated Room			X			X			X	
Equip/Develop				X		X				X
Plate Loading				X		X				X
Rock-Mass Str.			X			X			X	
Eval.Min.Meth.				X		X				X
Grnd.Sup.Monit				X		X				X
Monit.Dri.Stab				X		X				X
AirQual/Ventil			X			X			X	
In Situ/Seals				X		X				X
Lab Tests				X		X				X
Geolog. Mappng		X				X				X
Overcore Stres			X			X			X	
Perched Water	NOT			X		X				X
Calico Hills	APPLICABLE									
Percolation			X			X			X	
Excav. Effts.				X			X			X
Hydrochemistry				X			X			X
Intact Fract.			X				X			X
Bulk Perm.		X			X			X		
Radial Boreho.				X			X			X
MultiPur.Boreh			X			X			X	
Prop/MajorFaul			X			X			X	
Matrix/HydProp				X		X				X
Seismic Tomo.				X		X				X
Eng. Barrier				X			X			X
Min/Pet				X		X				X
Chlor&Chlor36				X		X				X
Diffusion			X			X			X	
IDS			X			X			X	
TOTALS		2	17	17	1	28	6	1	15	20

I - Test Capability Inferior to Base Case
E - Test Capability Equivalent to Base Case
S - Test Capability Superior to Base Case

TABLE 5-8 (continued)
SUMMARY ESF-AS TEST INPUT/TEST FEASIBILITY DATA QUALITY BY OPTION

	Option 5 (A5)			Option 6 (A7)			Option 7 (B3 Rev 2-)			Option 8 (B3 Rev 3-)		
Test Name	I	E	S	I	E	S	I	E	S	I	E	S
Shaft Conv.			X	X				X		X		
Demon.BO Rooms		X		X				X			X	
Seq.DriftMine.		X			X			X			X	
HeaterExp/TSw1		X		X				X			X	
Canister Scale		X			X			X			X	
Heated Block		X			X			X			X	
Thermal Stress		X			X			X			X	
Heated Room		X			X			X			X	
Equip/Develop			X			X			X			X
Plate Loading			X			X			X			X
Rock-Mass Str.		X			X			X			X	
Eval.Min.Meth.			X			X		X			X	
Grnd.Sup.Monit			X			X			X			X
Monit.Dri.Stab			X			X			X			X
AirQual/Ventil		X			X			X			X	
In Situ/Seals			X			X			X			X
Lab Tests			X			X			X			X
Geolog. Mappng	X			X			X			X		
Overcore Stres		X			X			X			X	
Perched Water			X	X			X			X		
Calico Hills												
Percolation		X			X				X			X
Excav. Effts.			X			X			X			X
Hydrochemistry			X	X			X			X		
Intact Fract.		X		X			X			X		
Bulk Perm.	X			X			X			X		
Radial Boreho.	X			X					X	X		
MultiPur.Boreh		X		X				X			X	
Prop/MajorFaul			X		X			X			X	
Matrix/HydProp			X			X			X			X
Seismic Tomo.			X			X			X			X
Eng. Barrier			X			X			X			X
Min/Pet			X			X			X			X
Chlor&Chlor36			X	X					X			X
Diffusion		X			X			X			X	
IDS		X			X			X			X	
TOTALS	3	16	17	11	13	12	5	17	14	7	16	13

I - Test Capability Inferior to Base Case
E - Test Capability Equivalent to Base Case
S - Test Capability Superior to Base Case

TABLE 5-8 (continued)
SUMMARY ESF-AS TEST INPUT/TEST FEASIBILITY DATA QUALITY BY OPTION

	Option 9 (B3 Rev 4-)			Option 10 (B3 Rev 6-)			Option 11 (B3 Rev 6-)			Option 12 (B4)		
Test Name	I	E	S	I	E	S	I	E	S	I	E	S
Shaft Conv.	X			X					X			X
Demon.BO Rooms		X			X			X			X	
Seq.DriftMine.		X			X			X			X	
HeaterExp/TSw1		X			X			X			X	
Canister Scale		X			X			X			X	
Heated Block		X			X			X			X	
Thermal Stress		X			X			X			X	
Heated Room		X			X			X			X	
Equip/Develop			X			X			X			X
Plate Loading			X			X			X			X
Rock-Mass Str.		X			X			X			X	
Eval.Min.Meth.		X			X				X			X
Grnd.Sup.Monit			X			X			X			X
Monit.Dri.Stab			X			X			X			X
AirQual/Ventil		X			X			X			X	
In Situ/Seals			X			X			X			X
Lab Tests			X			X			X			X
Geolog. Mappng	X			X			X			X		
Overcore Stres		X			X			X			X	
Perched Water	X				X				X			X
Calico Hills												
Percolation			X			X			X			X
Excav. Effts.		X				X			X			X
Hydrochemistry	X			X					X			X
Intact Fract.	X			X			X			X		
Bulk Perm.	X			X			X			X		
Radial Boreho.	X			X					X	X		
MultiPur.Boreh		X			X			X			X	
Prop/MajorFaul		X			X			X				X
Matrix/HydProp			X			X			X			X
Seismic Tomo.			X			X			X			X
Eng. Barrier			X			X			X			X
Min/Pet			X			X			X			X
Chlor&Chlor36		X				X			X			X
Diffusion		X			X			X			X	
IDS		X			X			X			X	
TOTALS	7	18	11	6	17	13	3	15	18	4	14	18

I - Test Capability Inferior to Base Case
E - Test Capability Equivalent to Base Case
S - Test Capability Superior to Base Case

TABLE 5-8 (continued)
SUMMARY ESF-AS TEST INPUT/TEST FEASIBILITY DATA QUALITY BY OPTION

	Option 13 (B7)			Option 14 (B8)			Option 15 (C1)			Option 16 (C4)		
Test Name	I	E	S	I	E	S	I	E	S	I	E	S
Shaft Conv.	X					X			X			X
Demon.BO Rooms	X				X			X			X	
Seq.DriftMine.		X			X			X			X	
HeaterExp/TSw1	X				X			X			X	
Canister Scale		X			X			X			X	
Heated Block		X			X			X			X	
Thermal Stress		X			X			X			X	
Heated Room		X			X			X			X	
Equip/Develop			X			X			X			X
Plate Loading			X			X			X			X
Rock-Mass Str.		X			X			X			X	
Eval.Min.Meth.		X				X			X			X
Grnd.Sup.Monit			X			X			X			X
Monit.Dri.Stab			X			X			X			X
AirQual/Ventil		X			X			X			X	
In Situ/Seals			X			X			X			X
Lab Tests			X			X			X			X
Geolog. Mappng	X			X			X			X		
Overcore Stres		X			X			X			X	
Perched Water	X					X			X			X
Calico Hills												
Percolation			X			X			X			X
Excav. Effts.			X			X			X			X
Hydrochemistry	X					X			X			X
Intact Fract.	X			X			X			X		
Bulk Perm.	X			X			X			X		
Radial Boreho.	X			X					X	X		
MultiPur.Boreh	X				X			X			X	
Prop/MajorFaul			X			X			X			X
Matrix/HydProp			X			X			X			X
Seismic Tomo.			X			X			X			X
Eng. Barrier			X			X			X			X
Min/Pet			X			X			X			X
Chlor&Chlor36	X					X			X			X
Diffusion		X			X			X			X	
IDS		X			X			X			X	
TOTALS	11	12	13	4	14	18	3	14	19	4	14	18

I - Test Capability Inferior to Base Case
E - Test Capability Equivalent to Base Case
S - Test Capability Superior to Base Case

TABLE 5-8 (concluded)
SUMMARY ESF-AS TEST INPUT/TEST FEASIBILITY DATA QUALITY BY OPTION

	Option 17 (R11)											
Test Name	I	E	S	I	E	S	I	E	S	I	E	S
Shaft Conv.		X										
Demon.BO Rooms		X										
Seq.DriftMine.		X										
HeaterExp/TSw1		X										
Canister Scale		X										
Heated Block		X										
Thermal Stress		X										
Heated Room		X										
Equip/Develop		X										
Plate Loading		X										
Rock-Mass Str.		X										
Eval.Min.Meth.		X										
Grnd.Sup.Monit	X											
Monit.Dri.Stab	X											
AirQual/Ventil		X										
In Situ/Seals		X										
Lab Tests		X										
Geolog. Mappng		X										
Overcore Stres		X										
Perched Water		X										
Calico Hills												
Percolation		X										
Excav. Effts.			X									
Hydrochemistry	X											
Intact Fract.			X									
Bulk Perm.		X										
Radial Boreho.		X										
MultiPur.Boreh		X										
Prop/MajorFaul		X										
Matrix/HydProp		X										
Seismic Tomo.		X										
Eng. Barrier			X									
Min/Pet		X										
Chlor&Chlor36		X										
Diffusion		X										
IDS		X										
TOTALS	3	30	3									

I - Test Capability Inferior to Base Case
E - Test Capability Equivalent to Base Case
S - Test Capability Superior to Base Case

ratings were provided to the expert panel on site characterization testing. These ratings were part of the information supplied to the panel to assist in their evaluation of the options.

5.2.2 Cost and Schedule Information for 34 Options

Information on cost and schedules was prepared in support of several scoring panel sessions, primarily the Cost and Schedule Panel and Programmatic Viability Panel. Schedules were prepared for each of the 34 options and reflect major ESF and repository events and durations. Important events for the ESF included the beginning and end of early and late testing, already defined in Section 5.1. For the purpose of this study, the beginning of the NRC Review for License Application was assumed to be coincident with the end of late testing. Schedules also included durations for the major phases of repository construction and operations; initial construction, emplacement operations, caretaker operations, and backfill and closure. Figure 5-35 illustrates the schedules for the completion through late testing (that is, through submittal of license application) for all 34 options.

Costs in 1990 dollars, were also developed for each of the 34 options. Figure 5-36 illustrates total costs for each of the 34 options through the completion of late testing. In addition, costs were combined with the detailed schedules to develop annual costs for each of the 34 options over the complete ESF-repository life cycle. An example is given in Table 5-9 for Option 30.

Costs and schedules were developed for all options using common assumptions. A more detailed description of the costs and schedules and the assumptions used in developing them are included in Appendix 5B.

5.2.3 Other Supporting Information

Additional information was prepared to support the various scoring sessions. This information included concept sketches that illustrate the physical layout of the options, materials usage, construction methods, etc. The accelerated schedule for conducting scoring sessions required that this supporting information be developed on a phased basis. Therefore several data packages were developed that included information specific to the particular scoring activity. The final data package, including all

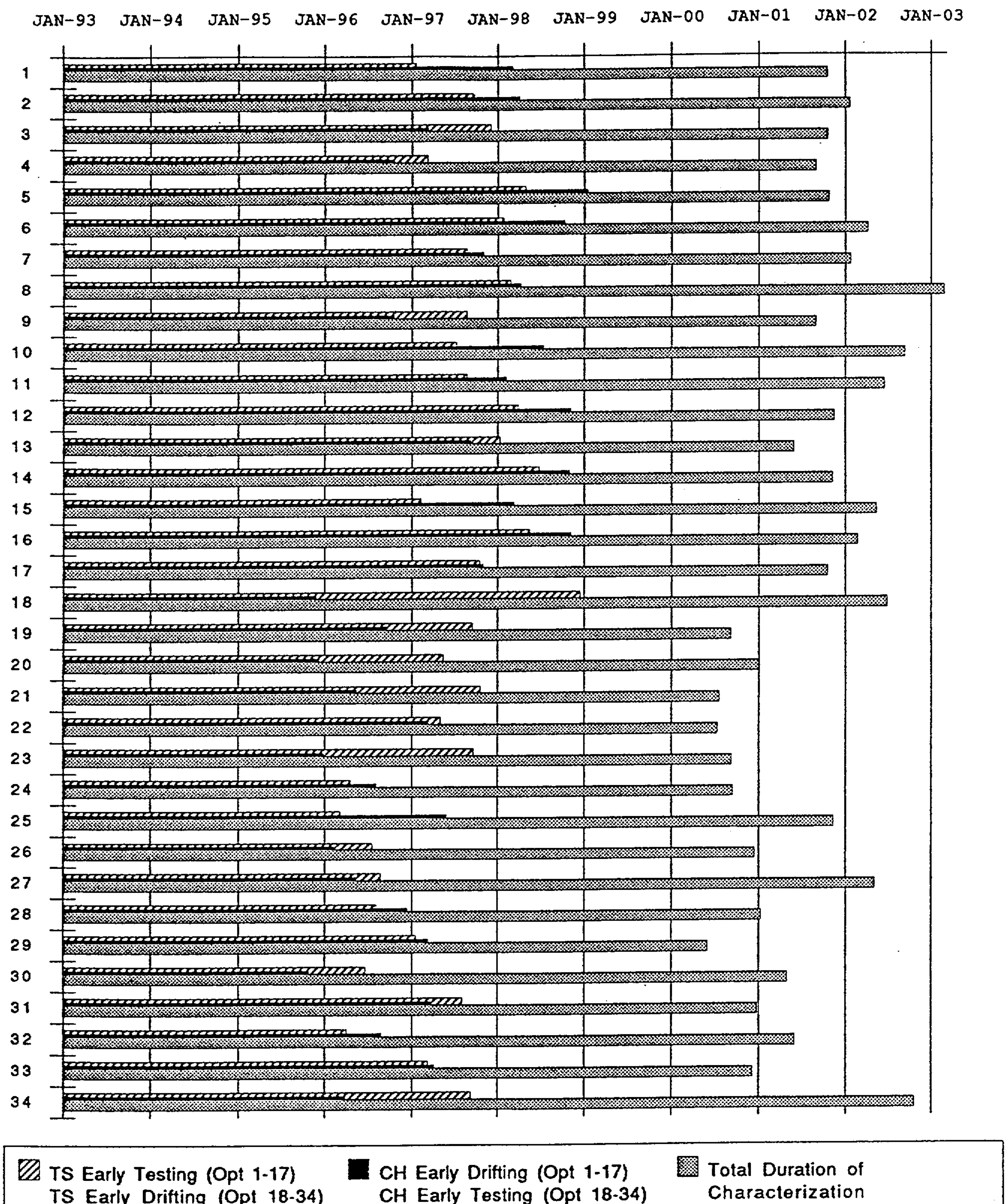


Figure 5-35. Bar Diagram Showing ESF Durations Through End of Late Testing

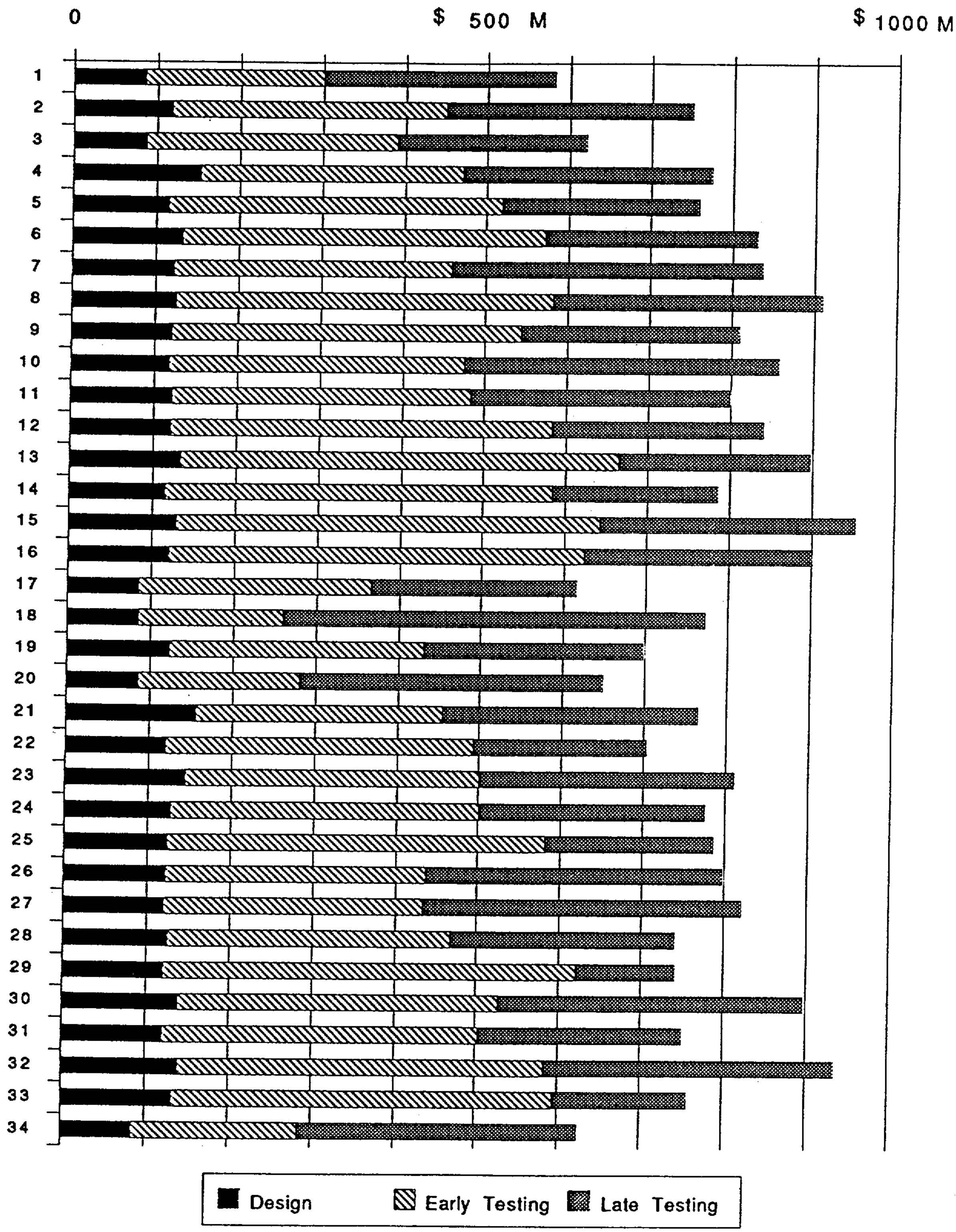


Figure 5-36. Bar Diagram Showing ESF Costs Through End of Late Testing

TABLE 5-9

ANNUAL COSTS FOR OPTION 30

25-Apr-91 COSTS and SCHEDULE Scoring Data Sheets for OPTION # 30 B7

10:26:30 Annualized Costs by Calendar Year:

Scenarios F, E, D, C & A

	|-Note 1				|-Note 2						|-Note 3			|-Note 4									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
High Est.	24	56	170	198	232	138	37	36	92	88	60	41	41	82	270	270	270	270	287	376	376	376	376
Best Est.	20	47	142	163	190	114	31	29	74	71	48	33	33	66	216	216	216	216	230	297	297	297	297
Low Est.	19	44	133	148	173	105	29	27	65	62	42	29	29	57	184	184	184	184	197	263	263	263	263

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
High Est.	376	376	376	376	376	376	376	376	376	376	376	376	376	376	376	376	376	376	376	376	319	30	30
Best Est.	297	297	297	297	297	297	297	297	297	297	297	297	297	297	297	297	297	297	297	297	252	25	25
Low Est.	263	263	263	263	263	263	263	263	263	263	263	263	263	263	263	263	263	263	263	263	223	23	23

	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059
High Est.	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	35
Best Est.	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	29
Low Est.	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	27

	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082
High Est.	65	65	65	65	65	65	65	65	65	65	65	65	54										
Best Est.	52	52	52	52	52	52	52	52	52	52	52	52	43										
Low Est.	48	48	48	48	48	48	48	48	48	48	48	48	40										

Scenario B

	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081
High Est.	10	58	58	58	58	58	58	58	58	66	109	109	109	109	109	109	109	109	109	109	109	109	109
Best Est.	8	46	46	46	46	46	46	46	46	53	84	84	84	84	84	84	84	84	84	84	84	84	84
Low Est.	7	44	44	44	44	44	44	44	44	50	80	80	80	80	80	80	80	80	80	80	80	80	80

																			|-Note 5				
	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104
High Est.	109	109	109	109	109	109	109	109	109	109	109	100	53	53	53	53	53	53	44				
Best Est.	84	84	84	84	84	84	84	84	84	84	84	77	41	41	41	41	41	41	34				
Low Est.	80	80	80	80	80	80	80	80	80	80	80	73	39	39	39	39	39	39	32				

Scenario Code	Description		Total Cost-Note 6		Restoration Cost		Duration (Months)
	TOTAL THRU BEGINNING		%	$M	%	$M	
	OF EARLY TESTING	High	120	165	35	58	
F	(Note 1)	Best	100	137	20	27	28
		Low	95	130	10	13	
	TOTAL THRU END OF		%	$M	%	$M	
	EARLY TESTING	High	121	642	35	225	
E	(Note 2)	Best	100	529	20	106	56
		Low	92	489	10	49	
	TOTAL THRU END OF		%	$M		$M	
	LATE TESTING	High	122	1092	E+10M	235	
D	(Note 3)	Best	100	897	E+10M	116	122
		Low	91	820	E+10M	59	

Scenario Code	Description		Total Cost-Note 6		Restoration Cost		Duration (Months)
	TOTAL THRU NRC		%	$M		$M	
	DECISION	High	122	1282	Same	235	
C	(Note 4)	Best	100	1050	as	116	164
		Low	91	954	D	59	
	TOTAL THRU END OF		%	$M			
	RETRIEVAL, DECOM.,	High	126	16401	(Included		
B	& CLOSURE	Best	100	12986	in Total)		1316
	(Note 5)	Low	90	11684			
	TOTAL THRU END OF		%	$M			
	DECOM., BACKFILL,	High	126	13595	(Included		
A	& CLOSURE	Best	100	10827	in Total)		980
		Low	89	9616			

NOTES:
1) START OF CONSTRUCTION, 24 JUN 1993 (START OF EARLY TESTING).
2) END OF EARLY TESTING, 1 NOV 1995.
3) END OF LATE TESTING, 9 MAY 2001.
4) NRC DECISION, 7 NOV 2004 (42 MONTHS AFTER END OF LATE TESTING).
5) END OF RETRIEVAL, 7 NOV 2100.
6) TOTAL COST EXCLUDES RESTORATION COST UNLESS OTHERWISE STATED.

information developed in support of all scoring sessions, underwent a DOP 3-13 review during December 1990 and January 1991. Table 5-10 lists the information provided in each complete data package, and Appendix 5C provides a complete data package for Option 30 (B7) as an example.

In addition to the engineering data packages, other information was developed and provided to the panel on postclosure performance. This included a summary and review of previous performance assessment analyses with applications to the comparison of major design features. This review (discussed in detail in Section 6.5.1), provided some guidance as to which major features (e.g., shafts versus ramps) might provide some discrimination in terms of postclosure performance.

5.3 Reference Material

During the evaluation process, it was expected that panel members would require some reference or resource material in order to make informed evaluations regarding certain factors. To provide a library of reference materials for the expert panels, selected members of each panel were requested to identify key resource material that should be available for the panel meetings. The key materials were collected and made available to the panels. A bibliography of general resource material (for all panels) and other materials made available to each specific panel is given in Appendix 5D.

The bibliography in Appendix 5D represents the minimum set of material available to panel members. All panel members were encouraged to bring any additional reference material they desired. In some cases, panel members requested copies of reports that were not on the initial list. These were provided to the panels.

TABLE 5-10

INFORMATION/DATA/SKETCHES TO BE PROVIDED FOR SCORING

SKETCHES:

- Concept sketch
- Concept isometric
- Calico Hills concept
- ESF-repository interface
- MTL layout
- Stratigraphic column(s)
- Stratigraphic section
- Surface disturbance

CONCEPT DATA SHEETS:

ESF-REPOSITORY

Summary of selected ESF-repository data including:

- Access Summary (e.g., type, size, location, construction method)
- MTL Layout Features (e.g., location, elevation, construction method)
- Calico Hills Layout Features (e.g., drifting length, construction method)
- Repository Layout Features (e.g., drift orientation, elevation, construction method(s))
- Test Program Implications (e.g., test descriptions)
- Disturbed Surface Area (ESF, repository)
- Peak Manpower (ESF, repository)
- Costs (ESF, repository, Calico Hills)

MTL/CH DATA SHEET

Summary of selected MTL/CH data including:

- Access Features (e.g., ESF/CH access type, dimensions, construction method, location, elevation, grades, bearing, lengths, units transected, and access function in the ESF)

- Concept Features (e.g., MTL/CH location, elevation, dist to water table, MTL area, MTL expansion area, construction method, extent of exploratory drifting) - Also includes constructability/operability comments and sequence of construction

- Materials (e.g., estimate of water, concrete, steel used for construction/operation of ESF including accesses)

ESF SURFACE FACILITIES DATA SHEET

- Location, Size/Quantity, Disturbed Area for Ramp Pad, Topsoil Storage Pad, Borrow Area, Auxiliary Pads, Roads, Drainage Management, and Utilities

TABLE 5-10 (continued)

INFORMATION/DATA/SKETCHES TO BE PROVIDED FOR SCORING

REPOSITORY DATA SHEET(S)

- Repository Description (surface underground)
- Repository Constructability and Operability Comments
- The Role of the ESF Openings in Repository Construction and Operations
- Impact of MTL Movement
- Base Case Design Deficiency Comments

REPOSITORY ACCESS - PHYSICAL FEATURES

- Type of Access (e.g., shaft/ramp)
- Size
- Lining Type
- Construction Method
- Length of Access
- Grade and Bearing
- Location (surface/underground)
- Access Function in Repository-ESF

REPOSITORY LAYOUT - PHYSICAL FEATURES

- Type of Repository Opening (e.g., emplacement drifts, waste, tuff, and service mains, ventilation, and perimeter drift)
- Approximate Size
- Lining Type
- Construction Method
- Typical Length
- Grade and Bearing
- Elevation
- Distance from Waste Canister to Water Table

REPOSITORY SURFACE DISTURBANCE DATA SHEET

Disturbed surface area for:

- Central Surface Facilities
- Men and Materials Access
- Emplacement Exhaust Shaft
- Repository Ramp(s)

REPOSITORY MATERIALS AND WATER USAGE DATA SHEET

- Steel and concrete quantities for underground facilities for all time phases of the repository
- Water quantities for both repository surface and underground for all time phases of the repository

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TABLE 5-10 (continued)

INFORMATION/DATA/SKETCHES TO BE PROVIDED FOR SCORING

REPOSITORY QUANTITIES-EXCAVATION LENGTHS AND AREAS

Excavation lengths for:

- Shafts
- Ramps
- Mains
- Emplacement drifts and entrys
- Emplacement holes
- Perimeter drifts
- Shops, offices, other drifts

Excavated areas:

- Within ESF-AS boundary
- Emplacement
- Layout losses
- ESF test area
- Net area

COST AND SCHEDULE PERFORMANCE PROJECTIONS

- ES Construction Cost Estimate (plus high-low)
- CH Construction Cost Estimate (plus high-low)
- ES Construction Schedule Duration (plus high-low)
- CH Construction Schedule Duration (plus high-low)
- Face Man Hours for ESF/CH Construction/Operations
- Peak Staff for ESF/CH Construction/Operations
- Repository Underground Construction Cost Estimate (plus high-low)
- Repository Underground Emplacement/Operations Cost Estimate (plus high-low)
- Repository Underground Caretaker Operations Cost Estimate (plus high-low)
- Repository Underground Decommissioning Cost Estimate (plus high-low)
- Repository Underground Construction Schedule Duration (plus high-low)
- Repository Underground Emplacement/Operations Schedule Duration (plus high-low)
- Repository Underground Caretaker Operations Schedule Estimate (plus high-low)
- Repository Underground Decommissioning Schedule Estimate (plus high-low)
- Repository Surface Facilities Cost/Schedule Estimate (plus high-low)
- Waste Disposal Container Costs (plus high-low)
- Repository Peak Staff

TABLE 5-10 (continued)

INFORMATION/DATA/SKETCHES TO BE PROVIDED FOR SCORING

ESF-REPOSITORY CASH FLOW DATA SHEETS

Cash expenditures on a year-by-year basis from 1991-2075. Costs include:

- ESF construction support
- ESF REECo operations
- ESF lab test support
- ESF FSN/H&N design
- ESF site construction
- ESF first entry construction
- ESF second entry construction
- ESF third entry construction
- ESF entry tests
- ESF MTL construction
- ESF exploratory drifting
- ESF MTL test drilling
- CH design
- CH first entry construction
- CH second entry construction
- CH exploratory drifting
- CH testing
- Repository surface facilities
- Repository waste disposal containers
- Repository construction
- Repository emplacement operations
- Repository caretaker operations
- Repository decommissioning

ESF/CH CONSTRUCTION SCHEDULE

ESF/CH MILESTONE SCHEDULE

ESF/CH PROCUREMENT SCHEDULE

ESF/CH SCHEDULE ACTIVITY REPORT

Activity start/finish dates and durations for:

- Operations and testing
- Procurement
- Design
- Accesses
- ESF underground facility
- Project milestones
- CH facility

TABLE 5-10 (concluded)

INFORMATION/DATA/SKETCHES TO BE PROVIDED FOR SCORING

REPOSITORY COST AND STAFFING DATA SHEET

Repository cost and staffing (plus high-low) for:

- Initial construction
- Emplacement operations
- Caretaker operations
- Backfill and closure

Repository surface facilities costs
Repository waste disposal containers cost

REPOSITORY SCHEDULE DATA SHEET

Repository underground facilities schedule estimates (plus high-low) for:

- Initial construction
- Emplacement operations
- Caretaker operations
- Backfill and closure

Repository surface facilities schedule estimates

6.0 ANALYSIS OF PRINCIPAL FACTORS AND FEATURES

6.1 Introductory Remarks

An initial objective of the ESF-AS was to evaluate design features comparatively, and as a result, to identify those features that, if incorporated into a given option, would result in that option having a better overall performance. A list of potentially favorable features could then form the basis for developing new options, or altering existing options, to produce options that would perform better overall than any of the current options. The approach taken was to select options that displayed a wide range of special features and different combinations of those features. Thus, the relative merit of trade-offs between design features (such as shafts versus ramps) could be evaluated in the context of their performance in the total ESF-repository system.

In part, the purpose of the comparison of features, as discussed in this section, was to address the requirements of 10 CFR 60.21(c)(1)(ii)(D) to the degree appropriate at that point in the design process. The above regulation requires that, for the repository design, a comparison of alternatives to major design features be conducted, specifically considering their ability to contain and isolate waste. Within the ESF-AS, the ability of options to contain and isolate waste (postclosure performance) was considered explicitly as one of 16 principal measures of the evaluation. However, at this early stage in the definition of the ESF and repository configurations, DOE recognized that other factors must also be considered. Thus, the comparison of features extracted from the study results was a comparison of features based on a number of important criteria. Postclosure performance was one of these criteria. The process of evaluating design alternatives to identify major design features that would provide longer radionuclide containment and isolation was expected to continue throughout the design process for the ESF and the potential repository.

Potentially favorable features were identified through a qualitative assessment of their impact on the comparative evaluation. Features were identified through the expert panel discussions on a number of measures used in the evaluation process, and by examining the features incorporated in a number of the highly ranked options. As a result of the preliminary screening process, the five principal design features that were incorporated into the set of 34 ESF-repository options. These are listed in Table 6-1. As a result of the comparative evaluation, it was recognized that other features not previously identified as being of potential importance, but incorporated in a number of options, might be identified as being favorable (or unfavorable). Also as noted in Section 5, comments from the NWTRB resulted in the incorporation of several changes to the options as the study was being implemented. These changes, such as a second crossing of the Ghost Dance Fault, were incorporated in different ways in different options. Therefore, even though all options contained some of these new features, a comparison of how they were incorporated was performed and provided an additional source of identification of potentially favorable features. These features are discussed in Section 6.2.

An effort was made to validate the potentially favorable features identified through the process described above by analyzing the results of the comparative evaluation, which is presented in detail in Volume 2 of this report. As part of the sensitivity studies, the ranking of the options with respect to each individual performance measure was correlated with the aggregate ranking of the options. The factors that significantly influenced the ranking were identified from the influence diagrams, and, in turn, these factors were connected to the design features. This process and the results are discussed in Section 6.3.

After the qualitative and quantitative evaluations had identified a set of potentially favorable features, the options were again examined to see if there was good correlation between the number of favorable features incorporated in the option and how well that option performed in the overall ranking. This comparison is presented in Section 6.4.

As part of the evaluation of options for postclosure performance, a substantial body of existing data and analyses relevant to performance of features was reviewed and summarized for use by the expert panel on postclosure performance. This summary evaluation included feature comparisons that could provide some discrimination among the options for postclosure performance. It represented a more direct application of 10 CFR 60.21(c)(1)(ii)(D). An assessment was, also, made of how to proceed with alteration or modification of highly ranked options to improve overall performance, based on the favorable features identified in this study. This assessment is discussed in Section 6.5.

TABLE 6-1

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 Level (MTL) Core Area in Topopah Spring (TS)	Northeast South	
4. Excavation Method of Openings	Shafts	- Drill and Blast - Shaft Boring Machine - Blind Hole Drill - V-Mole - Raise Bore
	Ramps	- Tunnel Boring Machine (TBM) - Road Header - Drill and Blast
	MTL(TS) core area	- Drill and Blast - Mobile Miner - TBM*
	Exploratory drifting in TS & CH	- Drill and Blast - Mobile Miner - TBM - Road Header
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 MTL excavation but is expected to be an acceptable alternative.

6.2 Comparison of Features Included in the Options

The options that were developed for evaluation included a range of configurations in response to the list of major design features presented in Table 6-1. Details of the configuration of each option are given in Section 5. A qualitative evaluation of the major features was accomplished by assessing the relative merit of the individual forms of the major design features (Table 6-1) in conjunction with expert panel discussions and the rank order of the options resulting from the detailed evaluation presented in Volume 2. In addition to the major design features identified in Table 6-1, the comparative evaluation showed that other design features incorporated into various options were also important in the ranking of the options. In the following sections, the most favorable configurations for both the major design features and the additional design features are discussed.

6.2.1 Major Design Features

Means of Access - The ranking of options (Table 6-2) indicates that options with two ramps were preferred (in the majority view). Ramp accesses have the advantage of providing site characterization data off the main block as well as providing exposure of the predominately vertical geologic structures in the Yucca Mountain area. On the other hand, the desirability of obtaining site characterization data in a column (shaft configuration) within the main block cannot be ignored; this would provide a continuous vertical profile of the relevant hydrologic information at the site. Configurations with two ramps and with a ramp-shaft combination were well represented in the top-ranked options. Options 4 and 21 had three accesses (with one dedicated to site characterization testing), and they ranked high from the perspective of site characterization by itself.

Location of Accesses - Surface features of Yucca Mountain encouraged location of accesses at either the northeastern part of the main block, the southern part, or both. The surface features also encourage access in the center of the block from the east side, but potential repository operational considerations preclude it. The ranking of options from the testing perspective indicated that accesses which permit the broadest spatial distribution of exposed rock enhance the value of site characterization data by allowing for large spatial coverage of data, ensuring reduced potential for test interferences, and

TABLE 6-2

ESF-AS
RANK ORDER OF 34 ALTERNATIVE DESIGN OPTIONS

Option	Normalized Figure of Merit	Overall Ranking*
30	100	1st
23	96	2nd
24	94	3rd
13	93	4th
6	91	5th
7	90	6th
2	85	7th
19	84	8th
25	82	9th
4	81	10th
21	80	11th
28	79	12th
22	73	13th
29	69	14th
32	69	15th
27	67	16th
20	67	17th
8	66	18th
31	65	19th
15	63	20th
33	63	21st
5	59	22nd
12	56	23rd
3	56	24th
16	56	25th
11	56	26th
1	50	27th
14	47	28th
10	46	29th
18	45	30th
17	45	31st
34	40	32nd
26	31	33rd
9	25	34th

*Assumes benefit of a functioning repository is $50 B or more.

providing for collection of locationally representative data. Preliminary analysis, based on Squires and Young (1984), indicated that the location of openings on the surface were outside potential regional maximum flood areas.

Location of (Core) MTL - Some options include flexibility for location of the MTL at either end of the main block, as well as the ability to distribute tests along the long drift in the Topopah Spring unit. This flexibility may be useful during the design process and test development.

Excavation Method of Openings - The overall ranking clearly indicates that options using mechanical excavation (as opposed to drill-and-blast excavation) of the accesses and drifts ranked highest. The ranking appears to show that the excavation method for the MTL could be either drill and blast or mechanical mining. For instance, mechanical mining might be required in certain test areas to minimize mechanical or chemical disturbance to the rock.

Total Number of Repository Accesses - The overall ranking of the options clearly indicated that options with fewer repository accesses ranked highest. Four of the top six ranked options had four accesses. The ranking of options for release consequences shows a similar trend. From the repository operations perspective, four accesses appeared to be the minimum acceptable number of openings for a viable repository that requires two separate ventilation systems (one for development mining and one for the emplacement area).

6.2.2 Additional ESF-Repository Design Features

A number of additional design features were considered by the expert panels to be of importance in relation to the ESF-repository option selection. These follow, with a descriptive sentence introducing each one.

"No Constructed Pathway for Gravity Flow of Water from the Repository (TS) Level to the Calico Hills (CH) Level" - Option 30 was designed with no shaft or internal ramp providing a direct-gravity flow pathway from the repository waste-emplacement level to the underlying Calico Hills exploration level. This feature appears to be very favorable from the viewpoint of postclosure releases, and could be added to some other options.

"Maximize the Distance from the Waste-Emplacement Level to the Water Table" - The "step-block" configurations of the waste-emplacement areas of four options (15, 16, 32, and 33) were such that the distance from the waste-emplacement horizon to the water table was nominally 50 percent greater for these options than for others. This feature was present in the highest-ranked options under the measure for postclosure releases. The ability to realize the advantages of this feature depends upon early surface-based borehole data confirming the elevation of the interface (contact) between the waste-emplacement host rock unit (TSw2) and the overlying rock unit (TSw1). If this elevation is confirmed, this feature may be incorporated into any of the repository designs.

"Avoid Emplacement Drifts Crossing the Ghost Dance Fault" - The "step-block" configurations of the waste-emplacement area of four options (15, 16, 32, and 33) were such that no waste-emplacement drifts were designed to cross the Ghost Dance Fault. The importance depends on characteristics of the fault discovered during site exploration and testing. This feature may be incorporated into the repository design after site characterization is completed.

"Large Exposure of Rock, Both On and Off the Main Block" - A few options (30, 13, and 4, for example) offered the advantage of providing exploration and testing of a large amount of the main block and adjacent blocks during both the early and the total site characterization program. This was judged to result in increasing the amount of information about the site and reducing the likelihood of false indications about the conditions on the site (according to the majority opinion expressed by the Characterization Testing Panel).

"Flexibility for Early Exploration of Both the Topopah Spring and the Calico Hills Units" - A number of options (4, 13, 24, 25, and 30 from among the top-ranked options) offered the advantage of providing early completion of a suite of extensive underground tests and exploration of the major faults on both the Topopah Spring and Calico Hills levels simultaneously. This advantage would accrue to those configurations that offer access construction with minimum testing interference, and with ventilation configurations capable of supporting operations at both levels.

6.2.3 Features Included By Guidance

The following three features were included in all options (except the Base Case, Option 1) as a result of guidance issued for the development of options. The guidance was developed in response to concerns of the NRC and the NWTRB.

"Two Intercepts of the Ghost Dance Fault in the Topopah Spring" - This feature recognizes that the displacement of the Ghost Dance Fault changes with position along the fault within the main block. One intercept is located toward the north end of the block, the other toward the south end, to permit characterization of at least two displacements.

"East-West Drift in the Topopah Spring" - This feature of the ESF configuration is included in the options to expose any yet undiscovered north-south trending faults within the Topopah Spring in the main block.

"Larger Dedicated MTL to Avoid Interferences in Testing" - This feature was included in the options to permit all tests, including extended duration tests and any future performance confirmation tests, to be separated by sufficient distance to avoid any test-to-test or construction-test interferences.

6.3 **Validation of Feature Performance**

The previous section describes, in a qualitative way, how certain features were related to the ranking of options. This section describes a more systematic analysis that was performed to validate that the features were clearly related to an option's ability to perform better on the most important performance measures.

6.3.1 Key Measures

As part of the sensitivity analysis, the ranking of options with respect to their evaluation against each performance measure was correlated with the aggregate ranking of the options. This was done to determine which of the measures were the most influential in determining the overall ranking. In this exercise, it was assumed that the magnitude of the correlation coefficient between a measure and the aggregate ranking was an indicator of the importance of that measure in the overall decision process. The highest correlation for any measure was for programmatic viability (correlation coefficient of 0.91), which was extremely high. Other key measures are given in Table 6-3. The correlation factors for other key measures are given in Volume 2, Section 6, Table 6-2.

6.3.2 Important Factors Related to the Key Measures

The influence diagrams and other reference material (e.g. costs, schedules, etc.) used during scoring were consulted to identify important factors related to the key measures that were considered when assessing the options against those measures. In the influence diagrams, important factors are highlighted by being enclosed by double lines. Table 6-3 lists the principal factors associated with each of the key measure given in Section 6.3.1.

6.3.3 Design Features Related to Key Measures

Based on the factors identified as being important to the evaluation of options relative to key measures (Table 6-3), design features (from Section 6.2) were identified that, if incorporated into an option, would likely cause that option to be more favorably rated when considering one or more of the specific factors identified in Table 6-3. These design features are listed in Table 6-4. Table 6-4 should not be considered a complete listing of all design features that were identified as potentially favorable. In any design process, important factors, such as those given in Table 6-3, can be addressed in a multitude of ways. Table 6-4 contains features that could be identified in specific options as having resulted in the option being rated more favorably against one or more of the key measures (Table 6-3). The relationship of design features to the important performance measures from which they were identified is provided in the last column of Table 6-3. The numbers listed in that column correspond to the numbers assigned to the design features listed in Table 6-4. For example, reading across the second entry in Table 6-3 and then to Table 6-4, the following can be understood: achievement of regulatory approval was principally influenced by the ability of an option to support early site suitability tests, extended duration tests, and high-level waste tests; it was also influenced by an option's ability to reduce releases, residual uncertainty in characterization testing, and environmental impacts. Those six factors were better satisfied by options that had a ramp (Feature 1), flexibility of MTL location (Feature 4), mechanical mined accesses (Feature 5), etc.

TABLE 6-3

KEY MEASURES, PRINCIPAL FACTORS, AND DESIGN FEATURES

Key Measure	Principal Factors	Feature Number*
Programmatic Viability	• List of NWTRB Concerns from First Report • Meets NRC Concerns from SCA • Rapid Schedule for Testing in Both TS and CH	1, 3, 5, 6, 8, 9, 10, 11
Regulatory Approval	• Early Site Suitability Tests • Capability for Extended Duration Tests • Ability to Conduct High Level Waste Tests • Releases • Residual Uncertainty in Characterization Testing • Environmental Factors	1, 4, 5, 9, 10, 11
Repository Closure	• Large Exposure of Rock (Real Estate) Both On and Off the Block • Residual Uncertainty in Characterization Testing	9, 11
Postclosure Performance	• Repository Configuration - Avoidance of Potentially Adverse Feature • Repository Location - Distance to Water Table • Number and Type of Accesses • Nature and Extent of Calico Hills Penetration	3, 6, 7, 8
Characterization Testing	• Location Representativeness • Ability to Characterize Units Above CH • Large Spatial Coverage • Adequate Space for Test Flexibility • Low Potential for Test Interference	1, 2, 4, 5, 9, 11

*Numbers in this column correspond to the numbers assigned to the design features listed in Table 6-4.

TABLE 6-4

POTENTIALLY FAVORABLE DESIGN FEATURES

Feature Number	Description	Source Descriptor
1	Inclusion of a Ramp(s)	MF
2	Inclusion of a Shaft(s)	MF
3	Minimization Repository Accesses (including ESF openings)	MF
4	Flexibility of MTL Location (NE or S)	MF
5	Emphasis on Mechanical Excavation of Accesses and Drifts	MF
6	No Direct "Gravity Line" Between Emplacement Area (TSw2) and the CH Unit	P
7	Maximization of Distance Between Repository and Water Table (a repository feature)	P
8	Avoidance of Emplacement Drifts Intersecting Ghost Dance Fault (a repository feature)	P
9	Large Exposure of Rock	R, T
10	Flexibility to Drift Early in Either the TSw2 or CH	T, V
11	Inclusion of Major Features Identified From SCA and NWTRB First Report: a. Two Intercepts of Ghost Dance Fault at Repository Horizon b. E-W Drift Across Block at Repository Horizon c. Larger Dedicated MTL for Avoidance of Interference and to Allow Possible Replication and Confirmation Testing	G

NOTE: Descriptors are:
Major Feature - MF
Postclosure Panel - P
Testing Panel - T
Programmatic Viability Panel - V
Regulatory Panel - R
Design Guidance - G

The specific features listed in Table 6-4 were identified from several sources described in Section 6.2. The first source was the specific major features that were intentionally varied from option to option (Table 6-1). These features are identified in the table by descriptor MF. Other features were identified by members of expert panels as being important to the evaluations performed by that panel (discussed in Section 6.2.2). These features are given a panel name descriptor, P for Performance Assessment Panel, etc. Finally, features with a descriptor G were incorporated in all options, except the Base Case, because of guidance to satisfy specific concerns of the NRC and NWTRB (discussed in Section 6.2.3).

Caution is recommended when trying to reach conclusions regarding combinations of preferred features based on those identified in Table 6-4. For example, the fact that the inclusion of a shaft and a ramp were both considered individually favorable does not imply that a shaft-ramp combination could be judged the most favorable for an ESF configuration. The fact that a feature was determined to be favorable depended heavily on how that feature was integrated with the system. Further discussion of the potential for improving options based on the features identified in Table 6-4 is given in Section 6.5.2.

6.4 Comparison of Features Included in Options

The features identified in Table 6-4 were compared with the top-ranked options as a means of checking whether the features did appear consistently in the options that seemed to be most favorably evaluated. Table 6-5 is a correlation of the potentially favorable features with a number of top-ranked options. It can be seen that none of the top-ranked options contained all of the potentially favorable features. Approaches developed for refining or improving a selected option are addressed in Section 6.5.2.

6.5 Additional Analysis

6.5.1 Summary of Performance Assessments to Support the Postclosure Panel and the 10 CFR 60.21 Comparative Evaluations

As part of the preparation for the evaluation of options with regard to postclosure performance, a review was performed of existing analyses and assessments of

TABLE 6-5

IDENTIFICATION OF FAVORABLE FEATURES IN HIGHLY RATED OPTIONS

		1	2	3	4	5	6	7	8	9	10	11a	11b	11c
RANK	TOP-RANKED OPTIONS OPTION	NUMBER OF RAMP(S)	NUMBER OF SHAFT(S)	NUMBER OF ACCESSES	MTL LOCATION FLEXIBILITY	MECHANICAL MINED ACCESSES	NO GRAVITY FLOW PATHWAY FROM TS UNIT TO CHn	MAXIMIZE DISTANCE FROM EMPLACEMENT LEVEL TO WATER TABLE	AVOID EMPLACEMENT DRIFTS CROSSING GHOST DANCE FAULT	MAXIMIZE EXPOSED ROCK -- ON AND OFF BLOCK	FLEXIBILITY FOR EARLY DRIFTING IN TS OR CH OR BOTH	2 INTERCEPTS OF GHOST DANCE FAULT IN TS	E-W DRIFT IN TS	LARGER MTL AREA TO AVOID INTERFERENCES
1	30	2	0	4	✓	✓	✓			✓	✓	✓	✓	✓
2	23	2	0	4		✓						✓	✓	✓
3	24	1	1	5		✓					✓	✓	✓	✓
4	13	2	0	4	✓	✓				✓	✓	✓	✓	✓
5	6	2	0	4		✓						✓	✓	✓
6	7	1	1	5		✓						✓	✓	✓
7	2	1	1	5								✓	✓	✓
8	19	1	1	5								✓	✓	✓
9	25	1	1	5		✓					✓	✓	✓	✓
10	4	1	2	5						✓	✓	✓	✓	✓
.	.													
.	.													
.	.													
20	15	1	1	4				✓	✓			✓	✓	✓

performance impacts that could result from various features. The purpose of this review was to evaluate repository features to determine whether the features would be discriminators for performance. The term "discriminator" was used in this context to indicate a feature that, when changed between options, might have a discernible effect on the performance of the repository. A feature was not considered a discriminator if (a) the present state of knowledge of the site and its performance was insufficient for a meaningful evaluation of the effect of a feature on performance, or (b) an evaluation of the effect of a feature indicated no clear-cut advantage for one use/design of a feature versus others under consideration. Complete details of the evaluation and the results are contained in the records identified in Appendix 6A.

The results of this review were supplied to the expert panel on postclosure performance to use in the evaluation of options. The results were also used as a guide to identify features that, if included in an option, could result in better overall performance of that option. This latter application of the results represents a direct application of the type of evaluation called for in 10 CFR 60.21(c)(1)(ii)(D). The results of this review are summarized in this section.

The features compared are shown in Table 6-6. These features represented essentially the same set of features that was used in the overall feature comparison (Table 6-1). The review was performed by a number of analysts familiar with performance assessment methods. The analysts first identified existing analyses and data germane to the features in Table 6-6. Based on the best information available, a determination was made as to whether the feature was a discriminator for repository performance and, if so, the degree to which the discriminator might influence performance. If existing analyses and data were insufficient for an evaluation (but new analyses using existing data might lead to an evaluation) the analysts were directed to perform the additional analyses. The details of the evaluations performed and the results are included in the records packages identified in Appendix 6A.

The results of the review are summarized in Tables 6-7 and 6-8. The features (with the exception of lateral extent of the repository) identified in Tables 6-7 and 6-8 as being potentially significant or minor discriminators, respectively, are included in the set of features identified as potentially favorable based on the overall evaluation of the

TABLE 6-6

POTENTIAL REPOSITORY FEATURE PERFORMANCE DISCRIMINATORS

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1. Location, number, and size of openings
   a. Location outside flood channels
   b. Location near major site features - fracture flow
   c. Number and size - fluid flow
   d. Number and size - gas flow
   e. Calico Hills penetration/drifting
2. Means of access
   a. Shaft vs. ramp - uniform gas or liquid flow
   b. Shaft vs. ramp - flow along faults
   c. Shaft vs. ramp - sealing effectiveness
3. Construction method - mechanical vs. drill & blast
   a. Permeability and fluid flow
   b. Introduction of fluids and chemicals
4. Configuration of layout
   a. Vertical location - surface, water table, zeolites (heat)
   b. Lateral location
   c. Ghost Dance Fault penetrations

TABLE 6-7

POTENTIALLY SIGNIFICANT DISCRIMINATORS

Feature	Factor	Comments
Configuration of layout	Vertical location	Favor flexibility to move the eastern portion of the underground repository upward and western downward.
	Lateral location	Favor flexibility to limit the western extent of the underground repository.
	Ghost Dance Fault penetrations	Favor options with significantly fewer penetrations of the Ghost Dance Fault.

Notes:
1. Adequate drainage for a shaft or a ramp is an additional factor that may be significant, but it can probably be provided for any option.
2. The uncertainty of the importance of these discriminators is very high.

TABLE 6-8

MINOR DISCRIMINATORS

Feature	Factor	Comments
Means of access (ramp or shaft)	Flow along faults or other discontinuities	Favor ramps if seals expected to be effective; favor shafts if seals ineffective.
	Seal effectiveness	Favor ramps for sealing effectiveness.
	Overall	Given both of the above, slight favoring of ramps.

options (Table 6-4). The analysts concluded that no additional analyses could be performed that would provide additional discriminating ability. The information shown in Tables 6-7 and 6-8, along with the details of the rational behind the conclusions (Appendix 6A), was provided to the Postclosure Performance Panel for their use in evaluating overall performance of each option.

6.5.2 Modifications to Improve Options

In Sections 6.2 through 6.4, a number of factors were identified that were highly correlated with the rank order of the options. How well an option rated against each of these factors depended somewhat on whether the option contained certain design features. As a result of that analysis, a number of design features were identified that were considered to be potentially favorable and could enhance an option's performance in the overall comparative analysis. As part of the postanalysis of the scoring results, an effort was made to determine whether the addition of a favorable feature or the alteration of an existing feature to make it more favorable would have resulted in any of the highly ranked options being improved. Only qualitative assessments were performed in this effort.

Some modification of highly rated options could improve certain features without significant chance of degrading the option overall. One modification suggested was raising the repository emplacement level 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 the favorable and adverse effects of the feature.

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 methods will be used to refine or improve all features of the selected baselined option. However, input from experts in testing, performance assessment, and other disciplines may be required for significant trade-offs. As an example, trade-off studies may suggest that certain test areas of an option with a drill-and-blast MTL should be excavated mechanically to minimize chemical or mechanical disturbance to the rock to be tested.

7.0 SUMMARY OF FINDINGS

The findings of the ESF-AS are as follows:

- The study considered and screened a large number of alternatives to produce 34 ESF-repository options (discussed in Volume 1) that were then formally evaluated against a wide range of criteria (discussed in Volume 2).

- The rank order of the options was determined primarily from the relative probabilities assessed for programmatic viability. Other key measures, such as regulatory approval, likelihood of repository closure, postclosure performance and characterization testing were considered in assessing programmatic viability.

- The rankings under the majority and minority views are expressed in Table 7-1.

- The top ranked option indicated in Table 7-1 is consistent with the value judgments expressed by the Management Panel and the technical judgments expressed by all but three members of the Technical Panels. Only one Technical Panel member provided a view that produces a substantially different ranking. Even under this view, many of the same options are concluded to be highly rated.

- A number of design features were identified that appear to enhance the overall performance of particular options.

TABLE 7-1

ESF-AS
RANK ORDER OF 34 ALTERNATIVE DESIGN OPTIONS

Option	Normalized Figure of Merit	Overall Ranking*
30	100	1st
23	96	2nd
24	94	3rd
13	93	4th
6	91	5th
7	90	6th
2	85	7th
19	84	8th
25	82	9th
4	81	10th
21	80	11th
28	79	12th
22	73	13th
29	69	14th
32	69	15th
27	67	16th
20	67	17th
8	66	18th
31	65	19th
15	63	20th
33	63	21st
5	59	22nd
12	56	23rd
3	56	24th
16	56	25th
11	56	26th
1	50	27th
14	47	28th
10	46	29th
18	45	30th
17	45	31st
34	40	32nd
26	31	33rd
9	25	34th

*Assumes benefit of a functioning repository is $50 B or more.

ACRONYMS FOR VOLUME 1

A/E	architect/engineer
ADA	Applied Decision Analysis, Inc.
APD	areal power density
BNI	Bechtel National, Inc.
CFR	Code of Federal Regulations
CH	Calico Hills
CHRBA	Calico Hills Risk/Benefit Analysis
CMSO	California Mine Safety Orders
CTSO	California Tunnel Safety Orders
DAA	Design Acceptability Analysis
DIM	Design Investigation Memo
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DOP	Department (6310 SNL) Operating Procedure
ES&H	Environment, Safety, and Health
EPA	Environmental Protection Agency
ESF	Exploratory Studies Facility
ESF-AS	ESF Alternatives Study
FSN	Fenix and Scissin of Nevada
GR	Generic Requirements Document
GROA	geologic repository operations area
H&N	Holmes and Narver
HQ	headquarters
LANL	Los Alamos National Laboratory
MPBH	multi-purpose boreholes
MSHA	Mine Safety and Health Administration
MTL	main test level
MTU	metric tons uranium
MUA	multiattribute utility analysis
NRC	Nuclear Regulatory Commission
NRS	Nevada Revised Statutes
NWPA	Nuclear Waste Policy Act
NWPAA	Nuclear Waste Policy Amendments Act
NWTRB	Nuclear Waste Technical Review Board

OCRWM	Office of Civilian Radioactive Waste Management
OGR	Office of Geologic Repositories
OSHA	Occupational Safety and Health Administration
PBQ&D	Parsons Brinckerhoff Quade & Douglas, Inc.
PI	Principal Investigator
QA	Quality Assurance
RDR	Repository Design Requirements
REECo	Reynolds Electric Engineering Co, Inc.
RP	records package
RSN	Raytheon Services Nevada
SAIC	Science Applications International Corp.
SCA	Site Characterization Analysis; also NUREG 1347
SCP	Site Characterization Plan
SCP-CD	Site Characterization Plan Consultation Draft
SCP-CDR	Site Characterization Plan-Conceptual Design Report
SDRD	Subsystem Design Requirements Document
SLTR	Sandia Letter Report
SNL	Sandia National Laboratories
TAR	Technical Assessment Review
TBM	tunnel boring machine
T&MSS	Technical and Management Support Services
TMO	Test Manager's Office
TS	Topopah Spring
TSw1	Upper Topopah Spring Member
TSw2	Middle Topopah Spring Member
USGS	U.S. Geological Survey
WAS	Work Authorization Schedule
YMP	Yucca Mountain Site Characterization Project
YMPO	YMP Office

REFERENCES FOR VOLUME 1

CAC (California Administrative Code), 1981. Title 8, "Industrial Relations," Part 1, "Department of Industrial Relations," Chapter 4, "Division of Industrial Safety," Subchapter 17, "Mine Safety Orders." (NNA.900702.0009)

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SAND91-0025

EXPLORATORY STUDIES FACILITY ALTERNATIVES STUDY FINAL REPORT

APPENDICES VOLUME 1

APPENDIX 1A

DATABASE INFORMATION

Information from the Reference Information Base Used in this Report

This report contains no information from the Reference Information Base.

Candidate Information for the Reference Information Base

This report contains no candidate information for the Reference Information Base.

Candidate Information for the Site & Engineering Properties Data Base

This report contains no candidate information for the Site and Engineering Properties Data Base.

APPENDIX 2A

RECORDS PACKAGE LIST OF DOCUMENTS FOR EVALUATION

SUPPORTING DOCUMENTATION FOR
SAND91-0025 - RECORDS PACKAGES, SECTION 2

	Records Management System Number (RMS)	Title	Date	Source/ Org.	File Code
1.	027146	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, NWPA 1982 (PL97-425) and Amendment 1987 (PL100-203), Application to Repository and ESF, (Nuclear Waste Policy Act)	4/29/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
2.	027147	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, 10 CFR 60 ESF and Repository		AW Dennis 6311	100/12611/ SAND91-0025/ NQ
3.	027148	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, 10 CFR 960 ESF and Repository		AW Dennis 6311	100/12611/ SAND91-0025/ NQ
4.	027149	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, 10 CFR 20 ESF and Repository	4/29/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
5.	027150	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, 40 CFR 191 ESF and Repository	4/29/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
6.	027151	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, Criteria from the Design Acceptability Analysis, Application to ESF		AW Dennis 6311	100/12611/ SAND91-0025/ NQ

SUPPORTING DOCUMENTATION FOR SAND91-0025 - RECORDS PACKAGES, SECTION 2 (continued)

	Records Management System Number (RMS)	Title	Date	Source/ Org.	File Code
7.	027152	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, NRC Comments		AW Dennis 6311	100/12611/ SAND91-0025/ NQ
8.	027153	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, State of Nevada Comments on the SCP, Application to Repository and ESF		AW Dennis 6311	100/12611/ SAND91-0025/ NQ
8.	027154	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, DOE Order 6430.1, General Design Criteria Manual, issued on 12/12/83, Application to Repository and ESF		AW Dennis 6311	100/12611/ SAND91-0025/ NQ
8.	027155	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, 30 CFR 57 (MSHA)	4/10/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
9.	027156	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, California Code 8 CAC 4.20, Tunnel Safety Orders (7/81), (California Tunnel Safety Orders)	4/10/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ

SUPPORTING DOCUMENTATION FOR SAND91-0025 - RECORDS PACKAGES, SECTION 2 (continued)

Records Management System Number (RMS)	Title	Date	Source/ Org.	File Code
10. 027157	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, California Code 8 CAC 4.17, Mine Safety Orders (7/89), Application to Repository and ESF, (California Mining Code)	4/29/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
11. 027158	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, State of Nevada Code, Part 1, Title 46, Chapter 512, Application to Repository and ESF, (Nevada Mining Code)	4/29/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
11. 027159	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, DOE Order 5480.4 Requirement, Application to Repository and ESF (DOE Order Design)	4/29/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
12. 027160	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, OSHA (29 CFR Part 1926)	4/10/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
13. 027161	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, Nuclear Waste Technical Review Board (NWTRB)	4/10/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ

SUPPORTING DOCUMENTATION FOR SAND91-0025 - RECORDS PACKAGES, SECTION 2 (continued)

Records Management System Number (RMS)	Title	Date	Source/ Org.	File Code
14. 027162	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, Generic Requirements (GR)	4/10/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
15. 027163	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, Repository Design Requirements (RDR)	4/10/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ
16. 027164	Contents of Record Package, Exploratory Shaft Facility Alternatives Study (ESF-AS), Task 3, Requirements Matrices, Subsystem Design Requirements Document (SDRD)	4/10/91	AW Dennis 6311	100/12611/ SAND91-0025/ NQ

APPENDIX 2B

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
1. ESF construction activities may compromise capability of site to isolate waste	1. 10 CFR 60.15(c)(1)
2. A north-south trending fault may be present in the vicinity of the ESF Title I shaft locations	2. NWTRB Comment 3
3. Potential for surface water flooding	3. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
4. Sealing	4. SCA Sections 2.4, 3.4, and Objection 1, bullet 1b. (This objection is a roll-up of concerns expressed in SCA Comments 72, 74, and 119 as well.)
5. Multipurpose boreholes	5. SCA Question 57
6. A north-south trending fault may be present in the vicinity of the ESF Title I shaft locations	6. NWTRB Comment 3
7. A north-south trending fault may be present in the vicinity of the ESF Title I shaft locations	7. NWTRB Comment 3
8. Multipurpose boreholes	8. SCA Question 57
9. ESF construction activities may compromise capability of site to isolate waste	9. 10 CFR 60.15(c)(1)
10. Location of ESF Title I facilities	10. SCA Sections 4.1, second bullet item d and 4.2 Comment 132

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS (continued)

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
11. Location of ESF Title I facilities	11. SCA Sections 4.1, second bullet item d and 4.2 Comment 132
12. Potential for surface water flooding	12. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
13. Representativeness	13. SCA Sections 2.2.3
14. Location of ESF Title I facilities	14. SCA Sections 4.1, second bullet item d and 4.2 Comment 132
15. Location of ESF Title I facilities	15. SCA Sections 4.1, second bullet item d and 4.2 Comment 132
16. Location of ESF Title I facilities	16. SCA Sections 4.1, second bullet item d and 4.2 Comment 132
17. Location of ESF Title I facilities	17. SCA Sections 4.1, second bullet item d and 4.2 Comment 132
18. A north-south trending fault may be present in the vicinity of the ESF Title I shaft locations	18. NWTRB Comment 3
19. Location of ESF Title I facilities	19. SCA Sections 4.1, second bullet item d and 4.2 Comment 132

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS (continued)

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
20. Characterization of Calico Hills unit	20. SCA Section 3.2.1 and 4.2, Comment 16; and NWTRB Comment 6
21. Sealing	21. SCA Sections 2.4, 3.4, and Objection 1, bullet 1b. (This objection is a roll-up of concerns expressed in SCA Comments 72, 74, and 119 as well.)
22. ESF construction activities may compromise capability of site to isolate waste	22. 10 CFR 60.15(c)(1)
23. Environmental concerns	23. The assessment of adverse consequences presented in Volume 2 of this report addresses environmental impacts.
24. Multipurpose boreholes	24. SCA Question 57
25. Independence of Technical Assessment Review (TAR) participants	25. This topic was not within the scope of this study.
26. ESF construction activities may compromise capability of site to isolate waste	26. 10 CFR 60.15(c)(1)
27. TEST-to-test and test-to-construction compatibility	27. SCA Sections 2.7, 3.7.1(2), and 4.1 Objection 1, bullet 3(a)
28. Location of ESF Title I facilities and potential for surface water flooding	28. SCA Section 4.1, second bullet item d and 4.2 Comment 132. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS (continued)

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
29. Location of ESF Title I facilities	29. SCA Sections 4.1, second bullet item d and 4.2 Comment 132
30. Floodplains/Wetlands Environmental Review	30. This comment is being addressed by other YMPO activities and was not included in this study.
31. Floodplains/Wetlands Environmental Review	31. This comment is being addressed by other YMPO activities and was not included in this study.
32. Floodplains/Wetlands Environmental Review	32. This comment is being addressed by other YMPO activities and was not included in this study.
33. Floodplains/Wetlands Environmental Review	33. This comment is being addressed by other YMPO activities and was not included in this study.
34. Clean Water Act	34. This comment is being addressed by other YMPO activities and was not included in this study.
35. Floodplains/Wetlands Environmental Review	35. This comment is being addressed by other YMPO activities and was not included in this study.
36. Floodplains/Wetlands Environmental Review	36. This comment is being addressed by other YMPO activities and was not included in this study.
37. Potential for surface water flooding	37. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS (continued)

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
38. Potential for surface water flooding	38. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
39. Potential for surface water flooding	39. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
40. Potential for surface water flooding	40. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS (continued)

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
41. Potential for surface water flooding	41. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
42. Potential for surface water flooding	42. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
43. Potential for surface water flooding	43. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
44. Potential for surface water flooding	44. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
45. Potential for surface water flooding	45. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
46. Potential for surface water flooding	46. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS (continued)

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
47. Potential for surface water flooding	47. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
48. ESF Title I design details	48. Design concepts were addressed by this study. Design details will be addressed by the facility designers after ESF Title II design activities are resumed.
49. ESF Title I design details	49. Design concepts were addressed by this study. Design details will be addressed by the facility designers after ESF Title II design activities are resumed.
50. ESF Title I design details	50. Design concepts were addressed by this study. Design details will be addressed by the facility designers after ESF Title II design activities are resumed.
51. ESF Title I design details	51. Design concepts were addressed by this study. Design details will be addressed by the facility designers after ESF Title II design activities are resumed.
52. Floodplains/Wetlands Environmental Review	52. This comment is being addressed by other YMPO activities and was not included in this study.
53. Floodplains/Wetlands Environmental Review	53. This comment is being addressed by other YMPO activities and was not included in this study.
54. Floodplains/Wetlands Environmental Review	54. This comment is being addressed by other YMPO activities and was not included in this study.

CORRELATION OF STATE OF NEVADA COMMENTS WITH RELATED REGULATORY REQUIREMENTS OR NRC/NWTRB COMMENTS (concluded)

Central Issue Addressed by State of Nevada Comment	Related Regulatory Requirement or NRC/NWTRB Comment
55. Potential for surface water flooding	55. The study recognized the importance of protection of facilities from surface water flooding (see Requirement 1, Screening Criteria, Appendix 4C). However, the thrust of this comment and several similar comments is that the basis for evaluation of the surface flooding potential in and around the Yucca Mountain area (Squires and Young, 1984) may not be sufficient to support facility siting activities. The evaluation of this basis and/or the development of a new basis for surface water flooding was not within the scope of this study.
56. Floodplains/Wetlands Environmental Review	56. This comment is being addressed by other YMPO activities and was not included in this study.
57. Floodplains/Wetlands Environmental Review	57. This comment is being addressed by other YMPO activities and was not included in this study.
58. Floodplains/Wetlands Environmental Review	58. This comment is being addressed by other YMPO activities and was not included in this study.

APPENDIX 2C

CROSSWALK OF ALL IDENTIFIED REQUIREMENTS

The following titles relate to the *INFLUENCE DIAGRAM NUMBERS.

Postclosure Health	1 Health Effects Portion Transport Through Natural Barriers Portion Engineered Barrier System Portion Scenario Portion
Preclosure Health and Safety	2 Radiological Worker Health 3 Radiological Public Health 4 Nonradiological Worker Safety
Environment	5 Aesthetics 6 Historical Properties
Cost - Direct	7 Total System Life Cycle Cost Repository Life Cycle Cost ESF Cost
Schedule - Indirect	8 Schedule - Indirect Costs Schedule - Indirect Costs
Programmatic Viability	9 Probability of Programmatic Viability
Characterization Testing	10 Probability of Early False Positive 11 Probability of Late False Positive 12 Probability of Early False Negative 13 Probability of Late False Negative (Page 1 of 2) Probability of Late False Negative (Page 2 of 2)
Regulatory Authorization	14 Likelihood of Construction/Operation Approval
Closure	15 Likelihood of Retrieval

Diagram ID	Diagram Name
1	Health Effects Portion [9/5/90]

Element ID	Element Name	Requirement	Rank
14	Releases to atmosphere		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
16	Concentrations in surface and ground water		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
17	Mixing volume of surface water and ground water		
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
19	Releases to groundwater that people may use		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
20	Release to surface water		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
21	Subsurface transport through accessible environment		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1

Diagram ID	Diagram Name
1	Health Effects Portion [9/5/90]

Element ID	Element Name	Requirement	Rank
22	Releases to the accessible environment		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
		NWPA Sec. 113(a)	1
71	Direct releases		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1

Diagram ID	Diagram Name
2	Transport through Natural Barriers Portion [8/15/90]

Element ID	Element Name	Requirement	Rank
23	Saturated zone ground water pathway		
		10 CFR 60.112	1
		10 CFR 60.137	2
		10 CFR 60.74(b)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
30	Saturated zone retardation		
		10 CFR 60.122(b)(1)	2
31	Saturated zone ground water velocity distribution (including GWTT)		
		10 CFR 60.113(a)(2)	1
		10 CFR 60.122(a)(2)	2
		10 CFR 960.4-2-1(d)	1

Diagram ID	Diagram Name
2	Transport through Natural Barriers Portion [8/15/90]

Element ID	Element Name	Requirement	Rank
32	Ground water transport through saturated zone		
		10 CFR 60.133(i)	2
33	Unsaturated zone ground water pathway		
		10 CFR 60.112	1
		10 CFR 60.137	2
		10 CFR 60.74(b)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
40	Unsaturated zone retardation		
		10 CFR 60.122(a)(2)	2
41	Unsaturated zone ground water velocity distribution (including GWTT)		
		10 CFR 60.113(a)(2)	1
		10 CFR 60.122(a)(2)	2
		10 CFR 960.4-2-1(d)	1
42	Ground water transport through unsaturated zone		
		10 CFR 60.112	1
		10 CFR 60.133(i)	2
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
45	Release to unsaturated zone		
		10 CFR 60.133(h)	1
47	Gas phase transport through unsaturated zone		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1

Diagram ID	Diagram Name
3	Engineered Barrier System Portion [8/15/90]

Element ID	Element Name	Requirement	Rank
48	Gas phase transport through engineered barrier system and seals		
		10 CFR 60.112	1
		10 CFR 60.113(a)(1)	1
		10 CFR 60.133(h)	1
		10 CFR 60.134(a)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
49	Gas phase releases		
		10 CFR 60.112	1
		10 CFR 60.137	2
		10 CFR 60.74(b)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
51	Ground water transport through engineered barrier system and seals		
		10 CFR 60.113(a)(1)	1
		10 CFR 60.134(a)	1
53	Waste package releases		
		10 CFR 60.112	1
		10 CFR 60.113(a)(1)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
54	Retardation in engineered barrier system and seals		
		10 CFR 60.112	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1

Diagram_ID	Diagram Name
3	Engineered Barrier System Portion [8/15/90]

Element ID	Element Name	Requirement	Rank
55	Ground water velocity distribution through engineered barrier system and seals		
		10 CFR 60.112	1
		10 CFR 60.74(b)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
57	Waste form dissolution		
		10 CFR 60.113(a)(1)	1
		10 CFR 60.135(a)(1)	2
		10 CFR 60.135(a)(2)	2
58	Volume of water contacting waste		
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
59	Container degradation		
		10 CFR 60.112	1
		10 CFR 60.113(a)(1)	1
		10 CFR 60.135(a)(1)	2
		10 CFR 60.135(a)(2)	2
		10 CFR 60.137	2
		10 CFR 60.74(a)	1
		10 CFR 60.74(b)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
62	Ground water chemistry		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1

Diagram ID	Diagram Name
4	Scenario Portion [5/14/90]

Element ID	Element Name	Requirement	Rank
44	Post-waste-emplacement characteristics of natural barriers		
		10 CFR 60.112	1
		10 CFR 60.137	2
		10 CFR 60.74(b)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
56	Post-waste-emplacement characterization of engineered barrier system and seals		
		10 CFR 60.112	1
		10 CFR 60.130	2
		10 CFR 60.133(a)(1)	1
		10 CFR 60.133(a)(2)	2
		10 CFR 60.135(a)(1)	2
		10 CFR 60.135(a)(2)	2
		10 CFR 60.21(c)(1)(ii)(D)	2
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
63	Pre-waste-emplacement characterization of natural barriers		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
64	Changes in state of disposal system		
		10 CFR 60.112	1
		10 CFR 60.122(a)(2)	2
		10 CFR 60.21(c)(1)(ii)(E)	2
		10 CFR 60.74(a)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1

Diagram ID	Diagram Name			
4	Scenario Portion [5/14/90]			
	Element ID	Element Name	Requirement	Rank
	66	ESF repository-induced changes		
			10 CFR 60.112	1
			10 CFR 60.133(a)(1)	1
			10 CFR 60.15(c)(1)	1
			10 CFR 60.21(c)(1)(ii)(E)	2
			10 CFR 60.74(a)	1
			40 CFR 191.13(a)	1
			40 CFR 191.15	1
			40 CFR 191.16	1
			SCA, Comment 123	2
	67	Faulting		
			10 CFR 960.4-2-7(d)	1
			SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
	72	Repository design		
			10 CFR 60.112	1
			10 CFR 60.122(a)(2)	2
			10 CFR 60.130	2
			10 CFR 60.131(b)	2
			10 CFR 60.133(a)(1)	1
			10 CFR 60.133(a)(2)	2
			10 CFR 60.133(b)	1
			10 CFR 60.133(e)(1)	2
			10 CFR 60.133(e)(2)	1
			10 CFR 60.133(f)	1
			10 CFR 60.133(g)	1
			10 CFR 60.133(h)	1
			10 CFR 60.133(i)	2
			10 CFR 60.134(a)	1
			10 CFR 60.137	2
			10 CFR 60.21(c)(1)(ii)(E)	2
			10 CFR 60.21(c)(11)	2
			10 CFR 60.74(a)	1
			40 CFR 191.13(a)	1

Diagram ID	Diagram Name			
4	Scenario Portion [5/14/90]			
	Element ID	Element Name	Requirement	Rank
			40 CFR 191.15	1
			40 CFR 191.16	1
	73	ESF configuration		
			10 CFR 60.112	1
			10 CFR 60.113(a)(2)	1
			10 CFR 60.122(a)(2)	2
			10 CFR 60.130	2
			10 CFR 60.131(b)	2
			10 CFR 60.133(a)(1)	1
			10 CFR 60.133(a)(2)	2
			10 CFR 60.133(b)	1
			10 CFR 60.133(e)(1)	2
			10 CFR 60.133(e)(2)	1
			10 CFR 60.133(f)	1
			10 CFR 60.133(g)	1
			10 CFR 60.133(h)	1
			10 CFR 60.133(i)	2
			10 CFR 60.134(a)	1
			10 CFR 60.137	2
			10 CFR 60.15(c)(1)	1
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1
			10 CFR 60.15(c)(4)	1
			10 CFR 60.21(c)(1)(ii)(E)	2
			10 CFR 60.21(c)(11)	2
			10 CFR 60.74(a)	1
			40 CFR 191.13(a)	1
			40 CFR 191.15	1
			40 CFR 191.16	1
			SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
			SCA, 3.2.1	1
			SCA, 3.7.1(2), 4.1 Obj. 1	1
			SCA, 4.1 Obj. 1, 3rd bullet items f and g	1

Diagram ID	Diagram Name
4	Scenario Portion [5/14/90]

Element ID	Element Name	Requirement	Rank
74	Main Test Level location		
		SCA, 3.2.1	1
75	ESF connection with repository		
		10 CFR 60.15(c)(1)	1
76	Nature and extent of Calico Hills penetration		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(4)	1
77	Fluid and material usage		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(4)	1
		SCA, Comment 89	2
		SCA, Question 55	2
78	ESF construction method		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(4)	1
		SCA, Comment 57	1
79	Extent of exploratory drifting at the repository horizon		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(4)	1
		SCA, 3.2.1	1
80	ESF access		
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(4)	1
		10 CFR 60.74(a)	1
83	ESF access location		
		10 CFR 60.15(c)(3)	1

Diagram ID	Diagram Name
4	Scenario Portion [5/14/90]

Element ID	Element Name	Requirement	Rank
84	Repository construction method		
		10 CFR 60.133(f)	1
85	Areal power density		
		10 CFR 60.133(i)	2
		10 CFR 60.74(a)	1
86	Waste age		
		10 CFR 60.74(a)	1
87	Number and types of accesses		
		10 CFR 60.15(c)(2)	1
88	Repository location		
		10 CFR 60.133(a)(1)	1
89	Rock support system		
		10 CFR 60.133(e)(1)	2
		10 CFR 60.133(e)(2)	1
90	Repository configuration		
		10 CFR 60.112	1
		10 CFR 60.133(a)(1)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.21(c)(11)	2
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
91	Change in water table level		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1

Diagram ID	Diagram Name
5	Radiological Worker Health [5/14/90]

Element ID	Element Name	Requirement	Rank
3	Worker population dose from accidents		
		10 CFR 60.111(a)	2
		10 CFR 60.135(a)(1)	2
		10 CFR 60.135(a)(2)	2
		10 CFR 60.74(a)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
5	Drift collapse		
		10 CFR 960.5-2-9(d)	1
8	Frequency of collapse		
		10 CFR 960.5-2-11(d)	1
		10 CFR 960.5-2-9(d)	1
10	Transporter collision/fire exposure		
		DOE Order 6430.1a 0110-6.2	2

Diagram ID	Diagram Name
6	Radiological Public Health [6/18/90]

Element ID	Element Name	Requirement	Rank
3	Public population dose from accidents		
		10 CFR 60.111(a)	2
		10 CFR 60.135(a)(1)	2
		10 CFR 60.135(a)(2)	2
		10 CFR 60.74(a)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
8	Frequency of collapse		
		10 CFR 960.5-2-11(d)	1

Diagram ID	Diagram Name			
6	Radiological Public Health [6/18/90]			
	Element ID	Element Name	Requirement	Rank
	10	Transporter collision/fire exposure		
			DOE Order 6430.1a 0110-6.2	2

Diagram ID	Diagram Name			
7	Nonradiological Worker Safety [5/14/90]			
	Element ID	Element Name	Requirement	Rank
	5	Hazard (fatalities/man-hour)		
			10 CFR 60.133(e)(2)	1
			10 CFR 960.5-2-9(d)	1
	7	Other hazard (fatalities/man-hour)		
			DOE Order 6430.1a 0110-6.2	2
	8	Horizontal openings		
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1
	9	Ramp (Tunnel Boring Machine)		
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(4)	1
	10	Vertical shaft		
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1
	14	Mining technique (Tunnel Boring Machine/drill and blast)		
			8CAC4.17 7237 (c) (2)	2
			8CAC4.20 8438 (a)	1
	22	Horizontal openings		
			10 CFR 60.133(e)(2)	1
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1

Diagram ID	Diagram Name			
7	Nonradiological Worker Safety [5/14/90]			
	Element ID	**Element Name**	**Requirement**	**Rank**
	23	Ramp (Tunnel Boring Machine)		
			10 CFR 60.133(e)(2)	1
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(4)	1
	24	Vertical shaft		
			10 CFR 60.133(e)(2)	1
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1
	39	Orientation with respect to natural rock stratigraphy and structure		
			10 CFR 960.5-2-11(d)	1
	40	Ventilation system design		
			10 CFR 60.130	2
			10 CFR 60.133(a)(2)	2
			10 CFR 60.133(g)	1
	42	Materials handling system		
			10 CFR 60.133(e)(2)	1
	43	Number of ramps and/or shafts		
			30 CFR 57.11050	1
			8CAC4.20 8496 (i)	1

Diagram ID	Diagram Name			
10	Total System Life Cycle Cost [8/1/90]			
	Element ID	**Element Name**	**Requirement**	**Rank**
	14	ESF cost		
			10 CFR 60.15(c)(1)	1
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(4)	1

Diagram ID	Diagram Name
11	Repository Life Cycle Cost [8/1/90]

Element ID	Element Name	Requirement	Rank
18	Costs of closure and decommissioning (60-70)		
		10 CFR 60.21(c)(11)	2
24	Ventilation and cooling requirements		
		10 CFR 60.133(a)(1)	1
		10 CFR 60.133(a)(2)	2
		10 CFR 60.133(g)	1
25	Rock treatment		
		10 CFR 60.133(e)(2)	1
36	Excavation method		
		10 CFR 60.133(e)(2)	1
		10 CFR 60.133(f)	1
38	Number of ESF openings		
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		30 CFR 57.11050	1
		8CAC4.20 8496 (i)	1
67	Cost of emplacement containers		
		10 CFR 60.135(a)(1)	2
		10 CFR 60.135(a)(2)	2

Diagram ID	Diagram Name
12	ESF Cost [8/1/90]

Element ID	Element Name	Requirement	Rank
14	ESF cost		
		10 CFR 60.15(c)(1)	1
44	Number and location of underground accesses		
		10 CFR 60.15(c)(2)	1

Diagram ID	Diagram Name
12	ESF Cost [8/1/90]

Element ID	Element Name	Requirement	Rank
		10 CFR 60.15(c)(3)	1
		30 CFR 57.11050	1
		8CAC4.20 8496 (i)	1
45	Underground accesses (shafts, ramps)		
		10 CFR 60.133(e)(1)	2
		10 CFR 60.133(e)(2)	1
		30 CFR 57.11050	1
		8CAC4.20 8496 (i)	1
46	Main Test Level configuration and extent		
		10 CFR 60.133(e)(1)	2
		10 CFR 60.133(e)(2)	1
		SCA, 3.2.1	1
		SCA, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 4.1 Obj. 1, 3rd bullet item e	2
		SCA, 4.1 Obj. 1, 3rd bullet item h	1
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1
		SCA, 4.1 Obj. 1, 3rd bullet, Item d	2
47	Cost of exploratory drifting		
		SCA, 3.2.1	1
48	Schedule		
		SCA, 4.1 Obj. 1, 3rd bullet, Item c	2
50	Installation of Main Test Level testing		
		SCA, 4.1 Obj. 1, 3rd bullet, Item d	2
51	Extent of exploratory drifting		
		SCA, 3.2.1	1
52	Number and duration of underground access testing		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1

Diagram ID	Diagram Name
12	ESF Cost [8/1/90]

Element ID	Element Name	Requirement	Rank
		10 CFR 60.15(c)(3)	1
		10 CFR 60.15(c)(4)	1
54	Method of construction		
		10 CFR 60.133(f)	1
		SCA, Comment 57	1
58	Flexibility of construction method		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.15(c)(4)	1
59	Modifications to Main Test Level testing		
		SCA, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
		SCA, 4.1 Obj. 1, 3rd bullet item e	2
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1
		SCA, Comment 119	1
61	Adequacy of test program		
		SCA, Comment 72, Question 28	1
63	Configuration of Main Test Level		
		SCA, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
		SCA, 4.1 Obj. 1, 3rd bullet item e	2
		SCA, 4.1 Obj. 1, 3rd bullet item h	1
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1

Diagram ID	Diagram Name			
14	Schedule p. 2 [1/4/91]			
	Element ID	Element Name	Requirement	Rank
	5	ESF construction duration		
			10 CFR 60.15(c)(1)	1
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1
			10 CFR 60.15(c)(4)	1
			30 CFR 57.11050	1
			8CAC4.20 8496 (i)	1
			SCA, 3.7.1(2), 4.1 Obj. 1	1
			SCA, 3.7.1(2), Comment 82, Question 58, 118	2
	8	Title II design duration		
			30 CFR 57.11050	1
			8CAC4.20 8496 (i)	1
	11	Construction method		
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(4)	1
			SCA, Comment 57	1
	12	Test program		
			30 CFR 57.11050	1
			8CAC4.20 8496 (i)	1
			SCA, 3.7.1(2), Comment 82, Question 58, 118	2
	14	Decommissioning and closure duration		
			10 CFR 60.21(c)(11)	2
	16	Regulatory requirements		
			10 CFR 60.21(c)(1)(ii)(D)	2
			DOE Order 5480.4 Sec. 4 Item c	1
			DOE Order 5480.4 Sec. 5	1

Diagram ID	Diagram Name
14	Schedule p. 2 [1/4/91]

Element ID	Element Name	Requirement	Rank
18	Calico Hills characterization		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(4)	1
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
		SCA, 3.2.1	1
20	Test requirements		
		10 CFR 60.74(a)	1
21	Main Test Level		
		SCA, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 4.1 Obj. 1, 3rd bullet item h	1
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1
22	Exploratory footage		
		SCA, 3.2.1	1
		SCA, 3.2.1	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
23	Test plan		
		10 CFR 60.74(a)	1
25	Additional requirements for NWTRB/NRC/NV testing		
		10 CFR 60.137	2
		10 CFR 60.74(a)	1
		10 CFR 60.74(b)	1
		SCA, 3.2.1	1
		SCA, 3.2.1	1
		SCA, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2

Diagram ID	Diagram Name
14	Schedule p. 2 [1/4/91]

Element ID	Element Name	Requirement	Rank
		SCA, Comment 72, Question 28	1
27	Construction and test sequencing		
		SCA, 4.1 Obj. 1, 3rd bullet, Item c	2

Diagram ID	Diagram Name
15	Probability of Early False Negative [8/14/90]

Element ID	Element Name	Requirement	Rank
2	Inaccurate models/analyses		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
3	Inaccurate data		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 4.1 Obj. 1, 3rd bullet Item e	2
4	Insufficient data		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
6	Inability to obtain data to refute erroneous observation and interpretation		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.74(a)	1
7	Non-representative data		
		SCA, 3.2.1	1
9	Inadequate amount of data		
		SCA, 3.2.1	1
		SCA, Comment 72, Question 28	1
11	Inability to understand interference		
		10 CFR 60.15(c)(1)	1
12	Test interference		
		10 CFR 60.15(c)(1)	1

Diagram ID	Diagram Name			
15	Probability of Early False Negative [8/14/90]			
	Element ID	Element Name	Requirement	Rank
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1
			10 CFR 60.15(c)(4)	1
			8CAC4.17 7093 (b)	1
			8CAC4.17 7094 (a)	1
			8CAC4.17 7237 (c) (2)	2
			8CAC4.20 8438 (a)	1
			8CAC4.20 8458 (a)	1
			SCA, 2.7, 3.7.1(2), 4.1 Obj. 1	2
			SCA, 4.1 Obj. 1, 3rd bullet Item e	2
			SCA, 4.1 Obj. 1, 3rd bullet Items f and g	1
			SCA, 4.1 Obj. 1, 3rd bullet, Item i	2
			SCA, Comment 123	2
			SCA, Question 55	2
			SCA, Question 60	2
	13	Test to test		
			SCA, 4.1 Obj. 1, 3rd bullet Item e	1
			SCA, 4.1 Obj. 1, 3rd bullet, Item d	2
	14	Adverse influence of construction on test		
			10 CFR 60.15(c)(1)	1
			10 CFR 60.15(c)(2)	1
			10 CFR 60.15(c)(3)	1
			10 CFR 60.15(c)(4)	1
			8CAC4.17 7093 (b)	1
			8CAC4.17 7237 (c) (2)	2
			8CAC4.20 8438 (a)	1
			8CAC4.20 8458 (a)	1
	16	Adverse construction sequencing		
			10 CFR 60.15(c)(4)	1
	17	Construction method		
			10 CFR 60.21(c)(1)(ii)(D)	2

Diagram ID	Diagram Name			
15	Probability of Early False Negative [8/14/90]			
	Element ID	Element Name	Requirement	Rank
			8CAC4.17 7093 (b)	1
			8CAC4.17 7094 (a)	1
			8CAC4.17 7237 (c) (2)	2
			8CAC4.20 8438 (a)	1
			8CAC4.20 8458 (a)	1
			SCA, Comment 57	1
	18	Inability to design or conduct engineered barrier system tests		
			10 CFR 60.135(a)(1)	2
			10 CFR 60.135(a)(2)	2
			10 CFR 60.15(c)(1)	1
			SCA, 3.7.1(2), Comment 82, Question 58, 118	2
	19	Inability to design or conduct natural barrier tests		
			10 CFR 60.15(c)(1)	1
	20	Inability to adequately characterize the Calico Hills unit		
			10 CFR 60.113(a)(2)	1
			10 CFR 60.15(c)(1)	1
			10 CFR 60.15(c)(4)	1
			10 CFR 60.74(a)	1
			SCA, 3.2.1	1
	21	Location representativeness		
			10 CFR 60.15(c)(3)	1
	22	Shaft versus ramp/number and location		
			10 CFR 60.133(e)(2)	1
			10 CFR 60.15(c)(1)	1
			10 CFR 60.15(c)(3)	1
			10 CFR 60.21(c)(1)(ii)(D)	2
			30 CFR 57.11050	1
			8CAC4.20 8496 (i)	1

Diagram ID	Diagram Name
15	Probability of Early False Negative [8/14/90]

Element ID	Element Name	Requirement	Rank
23	Repository horizon elevation		
		10 CFR 60.113(a)(2)	1
25	Poor timing of test		
		SCA, 4.1 Obj. 1, 3rd bullet, Item c	2
26	Inability to adequately characterize rock units above Calico Hills		
		10 CFR 60.74(a)	1
27	Option requires changing test configuration		
		10 CFR 60.15(c)(4)	1
28	Inadequate duration for early tests		
		SCA, Comment 119	1
		SCA, Question 59	2

Diagram ID	Diagram Name
16	Probability of Late False Negative-p. 1 [8/14/90]

Element ID	Element Name	Requirement	Rank
2	Inaccurate models/analyses		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
3	Inaccurate data		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 4.1, 3rd bullet item e	2
4	Insufficient data		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, Comment 72, Question 28	1
6	Inability to obtain data to refute erroneous observation and interpretation		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.74(a)	1

Diagram ID	Diagram Name
16	Probability of Late False Negative-p. 1 [8/14/90]

Element ID	Element Name	Requirement	Rank
7	Non-representative data		
		SCA, 3.2.1	1
8	Inability to satisfy add. information needs beyond those obtained from 35 tests		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.74(a)	1
9	Inadequate amount of data		
		SCA, 3.2.1	1
11	Inability to understand interference		
		10 CFR 60.15(c)(1)	1
12	Test interference		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.15(c)(4)	1
		8CAC4.17 7093 (b)	1
		8CAC4.17 7094 (a)	1
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
		8CAC4.20 8458 (a)	1
		SCA, 2.7, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 4.1 Obj. 1, 3rd bullet, Item i	2
		SCA, 4.1, 3rd bullet item e	2
		SCA, 4.1, 3rd bullet items f and g	1
		SCA, Comment 123	2
		SCA, Question 55	2
		SCA, Question 60	2
13	Test to test		
		SCA, 4.1 Obj. 1, 3rd bullet, Item d	2
		SCA, 4.1, 3rd bullet item e	1

Diagram ID	Diagram Name
16	Probability of Late False Negative-p. 1 [8/14/90]

Element ID	Element Name	Requirement	Rank
14	Adverse influence of construction on test		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.15(c)(4)	1
		8CAC4.17 7093 (b)	1
		8CAC4.17 7094 (a)	1
		8CAC4.17 7094 (a)	1
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
		8CAC4.20 8458 (a)	1
16	Adverse construction sequencing		
		10 CFR 60.15(c)(4)	1
17	Construction method		
		10 CFR 60.21(c)(1)(ii)(D)	2
		8CAC4.17 7093 (b)	1
		8CAC4.17 7094 (a)	1
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
		8CAC4.20 8458 (a)	1
		SCA, Comment 57	1
18	Inability to design or conduct engineered barrier system tests		
		10 CFR 60.135(a)(1)	2
		10 CFR 60.135(a)(2)	2
		10 CFR 60.15(c)(1)	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
19	Inability to design or conduct natural barrier tests		
		10 CFR 60.15(c)(1)	1

Diagram ID	Diagram Name		
16	Probability of Late False Negative-p. 1 [8/14/90]		

Element ID	Element Name	Requirement	Rank
25	Poor timing of test		
		SCA, 4.1 Obj. 1, 3rd bullet, Item c	2
26	Insufficient ability to change and expand testing program		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.74(a)	1
27	Option requires changing test configuration		
		10 CFR 60.15(c)(4)	1

Diagram ID	Diagram Name		
17	Probability of Late False Negative, p. 2 [8/14/90]		

2C-26

Element ID	Element Name	Requirement	Rank
20	Inability to adequately characterize the Calico Hills unit		
		10 CFR 60.113(a)(2)	1
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(4)	1
		10 CFR 60.74(a)	1
		SCA, 3.2.1	1
21	Location representativeness		
		SCA, 3.2.1	1
22	Shaft versus ramp/number and location		
		10 CFR 60.133(e)(2)	1
		10 CFR 60.15(c)(1)	1
		10 CFR 60.21(c)(1)(ii)(D)	2
		30 CFR 57.11050	1
		8CAC4.20 8496 (i)	1
23	Repository horizon elevation		
		10 CFR 60.113(a)(2)	1

Diagram ID	Diagram Name
17	Probability of Late False Negative, p. 2 [8/14/90]

Element ID	Element Name	Requirement	Rank
	ate duration of early tests		
		SCA, Comment 119	1
		SCA, Question 59	2

Diagram ID	Diagram Name
18	Probability of Early False Positive [8/14/90]

Element ID	Element Name	Requirement	Rank
2	Inaccurate models/analyses		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
3	Misjudged global characteristic		
		10 CFR 60.15(c)(2)	1
4	Missed adverse feature		
		10 CFR 60.122(a)(2)	2
		10 CFR 60.15(c)(2)	1
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
5	Systematic biased data obscures problem		
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1
		SCA, Obj. 1, 3rd bullet Item e	2
6	Non-representative data		
		10 CFR 60.15(c)(2)	1
		SCA, 3.2.1	1
7	Inadequate amount of data		
		10 CFR 60.15(c)(2)	1
		SCA, Comment 72, Question 28	1

Diagram ID	Diagram Name
18	Probability of Early False Positive [8/14/90]

Element ID	Element Name	Requirement	Rank
8	Inadequate spatial coverage of data		
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		SCA, 3.2.1	1
9	Experimental design error		
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1
		SCA, 4.1 Obj. 1, 3rd bullet, item c	2
		SCA, 4.1 Obj. 1, 3rd bullet, Item d	2
10	Test interferences		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.15(c)(4)	1
		8CAC4.17 7093 (b)	1
		8CAC4.17 7094 (a)	1
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
		8CAC4.20 8458 (a)	1
		SCA, 2.7, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 4.1 Obj. 1, 3rd bullet, Item i	2
		SCA, Comment 123	2
		SCA, Obj. 1, 3rd bullet Item e	2
		SCA, Obj. 1, 3rd bullet Items f and g	1
		SCA, Question 55	2
		SCA, Question 60	2
11	Precludes ability to do realistic tests		
		10 CFR 60.15(c)(1)	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
		SCA, Obj. 1, 3rd bullet Item e	2

Diagram ID	Diagram Name
18	Probability of Early False Positive [8/14/90]

Element ID	Element Name	Requirement	Rank
12	Construction method		
		10 CFR 60.15(c)(1)	1
		8CAC4.17 7093 (b)	1
		8CAC4.17 7094 (a)	1
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
		8CAC4.20 8458 (a)	1
		SCA, Comment 57	1
13	Inadequate physical space		
		10 CFR 60.15(c)(1)	1
		SCA, 2.7, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 4.1 Obj. 1, 3rd bullet item h	1
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1
14	Inability to design or conduct natural barrier tests		
		10 CFR 60.15(c)(1)	1
15	Shaft versus ramp/number and location		
		10 CFR 60.133(e)(2)	1
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.21(c)(1)(ii)(D)	2
		30 CFR 57.11050	1
		8CAC4.20 8496 (i)	1
16	Repository horizon elevation		
		10 CFR 60.113(a)(2)	1
17	Location representativeness		
		10 CFR 60.15(c)(3)	1
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1

Diagram ID	Diagram Name
18	Probability of Early False Positive [8/14/90]

Element ID	Element Name	Requirement	Rank
18	Inability to adequately characterize the Calico Hills unit		
		10 CFR 60.113(a)(2)	1
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(4)	1
		SCA, 3.2.1	1
21	Drill and blast versus mechanical mining		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.21(c)(1)(ii)(D)	2
22	Inadequate duration for early tests		
		SCA, Comment 119	1
		SCA, Question 59	2

Diagram ID	Diagram Name
19	Probability of Late False Positive [8/14/90]

Element ID	Element Name	Requirement	Rank
2	Inaccurate models/analyses		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
3	Misjudged global characteristic		
		10 CFR 60.15(c)(2)	1
4	Missed adverse feature		
		10 CFR 60.122(a)(2)	2
		10 CFR 60.15(c)(2)	1
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
5	Systematic biased data obscures problem		
		SCA, 4.1 Obj. 1, 3rd bullet Item e	2

Diagram ID	Diagram Name		
19	Probability of Late False Positive [8/14/90]		

Element ID	Element Name	Requirement	Rank
		SCA, 4.1 Obj. 1, 3rd bullet Items f and g	1
6	Non-representative data		
		10 CFR 60.15(c)(2)	1
		SCA, 3.2.1	1
7	Inadequate amount of data		
		10 CFR 60.15(c)(2)	1
		SCA, Comment 72, Question 28	1
8	Inadequate spatial coverage of data		
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		SCA, 3.2.1	1
9	Experimental design error		
		SCA, 4.1 Obj. 1, 3rd bullet Items f and g	1
		SCA, 4.1 Obj. 1, 3rd bullet, Item c	2
		SCA, 4.1 Obj. 1, 3rd bullet, Item d	2
10	Test interferences		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.15(c)(4)	1
		8CAC4.17 7093 (b)	1
		8CAC4.17 7094 (a)	1
		8CAC4.17 7237 (c) (2)	2
		8CAC4.20 8438 (a)	1
		8CAC4.20 8458 (a)	1
		SCA, 2.7, 3.7.1(2), 4.1 Obj. 1	1
		SCA, 4.1 Obj. 1, 3rd bullet Item e	2
		SCA, 4.1 Obj. 1, 3rd bullet Items f and g	1

Diagram ID	Diagram Name			
19	Probability of Late False Positive [8/14/90]			
	Element ID	**Element Name**	**Requirement**	**Rank**
			SCA, 4.1 Obj. 1, 3rd bullet, Item i	2
			SCA, Comment 123	2
			SCA, Question 55	2
			SCA, Question 60	2
	11	Precludes ability to do realistic tests		
			10 CFR 60.15(c)(1)	1
			10 CFR 60.74(a)	1
			SCA, 3.7.1(2), Comment 82, Question 58, 118	2
			SCA, 4.1 Obj. 1, 3rd bullet Item e	2
	12	Construction method		
			10 CFR 60.15(c)(1)	1
			8CAC4.17 7093 (b)	1
			8CAC4.17 7094 (a)	1
			8CAC4.17 7237 (c) (2)	2
			8CAC4.20 8438 (a)	1
			8CAC4.20 8458 (a)	1
			SCA, Comment 57	1
	13	Inadequate physical space		
			10 CFR 60.15(c)(1)	1
			SCA, 2.7, 3.7.1(2), 4.1 Obj. 1	1
			SCA, 4.1 Obj. 1, 3rd bullet item h	1
			SCA, 4.1 Obj. 1, 3rd bullet Items f and g	1
	14	Inability to design or conduct natural barrier tests		
			10 CFR 60.15(c)(1)	1
			10 CFR 60.74(a)	1
	15	Shaft versus ramp/number and location		
			10 CFR 60.133(e)(2)	1
			10 CFR 60.15(c)(1)	1
			10 CFR 60.15(c)(2)	1

Diagram ID	Diagram Name		
19	Probability of Late False Positive [8/14/90]		

Element ID	Element Name	Requirement	Rank
		10 CFR 60.15(c)(3)	1
		10 CFR 60.21(c)(1)(ii)(D)	2
		30 CFR 57.11050	1
		8CAC4.20 8496 (i)	1
16	Repository horizon elevation		
		10 CFR 60.113(a)(2)	1
17	Location representativeness		
		10 CFR 60.15(c)(3)	1
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
18	Inability to adequately characterize the Calico Hills unit		
		10 CFR 60.113(a)(2)	1
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(4)	1
		SCA, 3.2.1	1
21	Drill and blast versus mechanical mining		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.21(c)(1)(ii)(D)	2
22	Inadequate duration for late tests		
		SCA, Comment 119	1
		SCA, Question 59	2
24	Inability to adequately characterize the rock units above the Calico Hills		
		10 CFR 60.15(c)(2)	1

Diagram ID	Diagram Name
20	Likelihood of Construction/Operation Approval [11/1/90]

Element ID	Element Name	Requirement	Rank
2	Technical confidence		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 3.2.1	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
		SCA, 4.1 Obj. 1, 3rd bullet item e	2
		SCA, 4.1 Obj. 1, 3rd bullet items f and g	1
3	Procedural confidence		
		DOE Order 5480.4 Sec. 4 Item c	1
		DOE Order 5480.4 Sec. 5	1
		NWPA Sec. 113(a)	1
15	Releases		
		10 CFR 60.112	1
		10 CFR 60.113(a)(1)	1
		40 CFR 191.13(a)	1
		40 CFR 191.15	1
		40 CFR 191.16	1
17	Option facilitates tests by NRC [10 CFR 60.74(a)]		
		10 CFR 60.74(a)	1
19	Option promotes confidence for impl. of perf. conf. plan [10 CFR 60.140-143]		
		10 CFR 60.74(b)	1
		SCA, Comment 119	1
		SCA, Comment 72, Question 28	1
20	Option facilitaties demonstration of compliance with [60.15(c)1-4]		
		10 CFR 60.15(c)(1)	1
		10 CFR 60.15(c)(2)	1
		10 CFR 60.15(c)(3)	1
		10 CFR 60.15(c)(4)	1

2C-34

Diagram ID	Diagram Name
20	Likelihood of Construction/Operation Approval [11/1/90]

Element ID	Element Name	Requirement	Rank
21	Option facilitates comparative evaluation of alternatives [60.21(c)(1)(ii)(D)]		
		10 CFR 60.21(c)(1)(ii)(D)	2
		SCA, Comment 132	2
22	Option facilitates compliance with [10 CFR 60.133]		
		10 CFR 60.130	2
		10 CFR 60.133(a)(1)	1
		10 CFR 60.133(a)(2)	2
		10 CFR 60.133(b)	1
		10 CFR 60.133(e)(1)	2
		10 CFR 60.133(e)(2)	1
		10 CFR 60.133(f)	1
		10 CFR 60.133(g)	1
		10 CFR 60.133(h)	1
		10 CFR 60.133(i)	2
24	Capability for extended-duration tests		
		10 CFR 60.74(b)	1
25	Option allows high-level waste test		
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2

Diagram ID	Diagram Name
21	Likelihood of retrieval [8/2/90]

Element ID	Element Name	Requirement	Rank
2	Insufficient technical confidence		
		10 CFR 60.133(e)(1)	2
3	Insufficient procedural confidence		
		10 CFR 60.111(b)	2

Diagram ID	Diagram Name
21	Likelihood of retrieval [8/2/90]

Element ID	Element Name	Requirement	Rank
16	Option promotes insufficient conf. for impl. of perf. conf. plan [60.140-143]		
		SCA, Comment 119	1
		SCA, Comment 72, Question 28	1
17	Option allows high-level waste test		
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
18	Ramps versus shafts		
		10 CFR 60.21(c)(1)(ii)(D)	2
21	Capability for extended-duration tests		
		SCA, Question 59	2

2C-36

Diagram ID	Diagram Name
22	Probability of Programmatic Viability [8/28/90]

Element ID	Element Name	Requirement	Rank
15	Insufficient technical credibility		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 2.7, 3.7.1(2), 4.1 Obj. 1 3rd bullet item a	1
		SCA, 3.2.1	1
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
		SCA, 4.1 Obj. 1, 3rd bullet Item e	2
		SCA, 4.1 Obj. 1, 3rd bullet Item h	1
		SCA, 4.1 Obj. 1, 3rd bullet Items f and g	1
17	Unclear evidence of information gathering for		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1

Diagram ID	Diagram Name
22	Probability of Programmatic Viability [8/28/90]

Element ID	Element Name	Requirement	Rank
22	Planned schedule		
		SCA, 3.7.1(2), Comment 82, Question 58, 118	2
23	TRB/NRC acceptance		
		SCA, 2.2.3, 3.7.1(2), 4.1, Comment 35	1
		SCA, 2.7, 3.7.1(2), 4.1 Obj. 1 3rd bullet item a	1
		SCA, 3.2.1	1
33	Need to redo Title I, conceptual design or EA		
		10 CFR 60.21(c)(1)(ii)(D)	2

APPENDIX 3A

LIST OF DOCUMENTS AND RECORDS RELEVANT TO THE IDENTIFICATION OF HISTORICAL ESF AND REPOSITORY CONFIGURATIONS

SUPPORTING DOCUMENTATION FOR SAND91-0025 - RECORDS PACKAGES, SECTION 3

Records Management System Number (RMS)	Title	Date	Source/ Org.	File Code
1. 017230	DIM-243 Rev. A	5/15/90	E.R. Gruer	60/12611/ DIM243/1.0/QA
2. 021496	Identification of Exploratory Shaft Facility Historical Configuration Options and Construction Methods Rev. 2 April 1990 (Data Sheets for 52 Historical ESF Configurations)	4/1/90	E.R. Gruer/ REECO	60/12611/ DIM243/1.1/QA
3. 021508	Deliverables for DIM-243, Rev. 0, Identification of Repository Access and ESF Options (Data Sheets for 15 Historical Repository Configurations)	3/15/90	E.R. Gruer, Harig/ PBQ&D	60/12611/ DIM243/1.1/QA

APPENDIX 3B

CONSTRUCTION AND ACCESS METHODS (1 - 13) IDENTIFIED FROM THE REECo LITERATURE SEARCH FOR THE HISTORICAL ESF CONFIGURATIONS

This appendix provides a brief verbal description of the 13 identified construction and access methods (and their associated configuration subsets) that were identified by REECo during the literature search for historical ESF configurations.

Construction and Access Method 1 - Single Access, Blind Drilled Shaft

Fifteen configuration subsets of Construction and Access Method 1 were reviewed and evaluated from 2/26/81 through 6/30/82. The shafts were located within the repository boundary in the northeast quadrant. These single access, blind drilled shafts ranged from 1200 feet to 3500 feet deep with internal diameters varying from 6 feet to 12 feet. The accesses were to be steel cased and backfilled with concrete.

Construction and Access Method 2 - Single Access, Drill and Blast Shaft

Fourteen configuration subsets of Construction and Access Method 2 were reviewed and evaluated from 10/15/81 through 12/1/84. The shafts for these subsets were located within the repository boundary in the northeast quadrant. The depth of the shafts ranged from 1200 feet to 3500 feet deep. The shafts varied from 12 feet to 14 feet diameter and were lined with concrete. The shaft construction method used drill and blast techniques.

Construction and Access Method 3 - Single Access, Drill and Blast Ramp

Two configuration subsets of Construction and Access Method 3 were reviewed and evaluated on 5/4/82 and 5/14/82. The ramp portal location was not defined. The breakout elevations of the ramps (approximately 1800-feet depth) were located within the repository boundary in the northeast quadrant. The ramps were driven using drill and blast techniques.

Construction and Access Method 4 - Single Access, Drill and Blast Ramp and Drill and Blast Shaft Combination

One configuration subset of Construction and Access Method 4 was presented to SNL on 5/14/82 for technical review and evaluation. This configuration subset entailed driving a ramp using drill and blast techniques to a depth of 1800 feet in an attempt to characterize the unsaturated zone. An internal shaft was then sunk, using drill and blast techniques, from the 1800-foot level to a depth of 3500 feet. The internal shaft was to be concrete lined. The access location was not defined.

Construction and Access Method 5 - Single Access, Drill and Blast Ramp and Blind Drilled Shaft Combination

One configuration subset of Construction and Access Method 5 was presented to SNL on 5/14/82 for technical review and evaluation. This configuration subset involved driving a ramp, using drill and blast techniques, to a depth of 1800-feet in an attempt to characterize the unsaturated zone. An internal shaft was then sunk, using a blind drilling technique, from the 1800-foot level to a depth of 3500 feet. The access location was not defined.

Construction and Access Method 6 - Single Access, Blind Drilled Shaft and Blind Drilled Shaft Combination

One configuration subset of Construction and Access Method 6 was presented to SNL on 5/14/82 for technical review and evaluation. This configuration subset involved blind drilling a 142-inch-diameter shaft to a depth of 1800 feet, installing steel casing and backfilling with concrete. The 1800-foot depth would then be used to attempt to characterize the unsaturated zone. Subsequently, a 120-inch diameter blind drilled shaft would be developed to a depth of 3500 feet. The shaft would be steel cased and backfilled with concrete. The access location was undefined.

Construction and Access Method 7 - Single Access, Drill and Blast Shaft and Drill and Blast Shaft Combination

One configuration subset of Construction and Access Method 7 was presented to SNL on 5/14/82 for technical review and evaluation. This configuration subset involved sinking a 12-foot-diameter concrete-lined shaft to a depth of 1800 feet using drill and blast techniques. The 1800-foot level was to be used to characterize the unsaturated zone. After the unsaturated zone characterization was completed, a shaft would be mined to a depth of 3500 feet using drill and blast techniques. The access location was undefined.

Construction and Access Method 8 - Blind Drilled Shaft and Drill and Blast Shaft Combination

One configuration subset of Construction and Access Method 8 was presented to SNL on 5/14/82 for technical review and evaluation. This configuration subset consisted of blind drilling a shaft 142 inches in daimeter to a depth of 1800 feet, installing steel casing, and backfilling with concrete. The 1800-foot level was to be used to characterize the unsaturated zone. After the unsaturated zone characterization was completed, a mined shaft 12 feet in diameter would be sunk to a depth of 3500 feet using drill and blast techniques and would be concrete-lined. The access location was undefined.

Construction and Access Method 9 - Single Access, Drill and Blast Shaft and Blind Drilled Shaft Combination

One configuration subset of Construction and Access Method 9 was presented to SNL on 5/14/82 for technical review and evaluation. This configuration subset consisted of sinking a 12-foot-diameter concrete-lined shaft to a depth of 1800 feet using drill and blast techniques. The 1800-foot level was to be used to characterize the unsaturated zone. After the unsaturated zone characterization was completed, a blind-drilled shaft would be sunk to a depth of 3500 feet. This shaft would be steel cased and backfilled with concrete. The access location was undefined.

Construction and Access Method 10 - Single Access, Drill and Blast Ramp and Drill and Blast Ramp Combination

One configuration subset of Construction and Access Method 10 was presented to SNL on 5/14/82 for technical review and evaluation. This configuration subset consisted of a ramp excavated to a depth of 1800 feet using drill and blast techniques. The 1800-foot level was to be used to characterize the unsaturated zone. After the unsaturated zone characterization was completed, the ramp would be continued to a depth of 3500 feet using drill and blast techniques. The access location was undefined.

Construction and Access Method 11 - Multiple Access, Two Drill and Blast Shafts

Seven configuration subsets of Construction and Access Method 11 were developed from several studies including: SAND84-1261, by G. K. Beall; a shaft sizing study by Ralph M. Parsons Co.; an action memorandum from D. L. Vieth of DOE/NV; and a FSN shaft sizing study. These subsets included two drill and blast concrete-lined shafts varying from 1053.5 feet to 1480 feet in depth. The design time line associated with these subsets ranged from December, 1984 to September, 1989. This was from the beginning of Title I design up to and including Title II design. During this time period the depth of the MTL was decided. Also, the number of MTL accesses and the option of accessing the Calico Hills Unit was retained as a requirement of the SCP-Consultation Draft (CD). The accesses and the MTL were in the northeast quadrant of the repository boundary.

Construction and Access Method 12 - Multiple Access, One Drill and Blast Shaft and One Tunnel Bored Ramp

Four configuration subsets of Construction and Access Method 12 were developed from SAND84-1261 by G. K. Beall. These subsets included concrete-lined drill-and-blast shafts excavated to diameters ranging from 12 feet to 16 feet, and ramps excavated by tunnel boring machine from 19 feet to 24 feet in diameter. The design time line associated with these subsets was December, 1984. The shafts and ramps were located within the northeast quadrant of the repository boundary.

Construction and Access Method 13 - Multiple Access, One Drill and Blast Shaft and One Tunnel Bored Ramp

Three configuration subsets of Construction and Access Method 13 were developed from SAND84-1261 by G. K. Beall and a DOE letter from V.F. Witherill, Director of NTSO. These subsets included one drill and blast concrete-lined shaft and one 6-foot-diameter steel-cased raise-bored shaft. The drill and blast shafts ranged from 12 feet to 16 feet in diameter and were 1480 feet deep to provide access to the Calico Hills Unit. The Design Time Line ranged from December, 1984 to May, 1985. The accesses and the MTL were located in the northeast quadrant of the repository boundary.