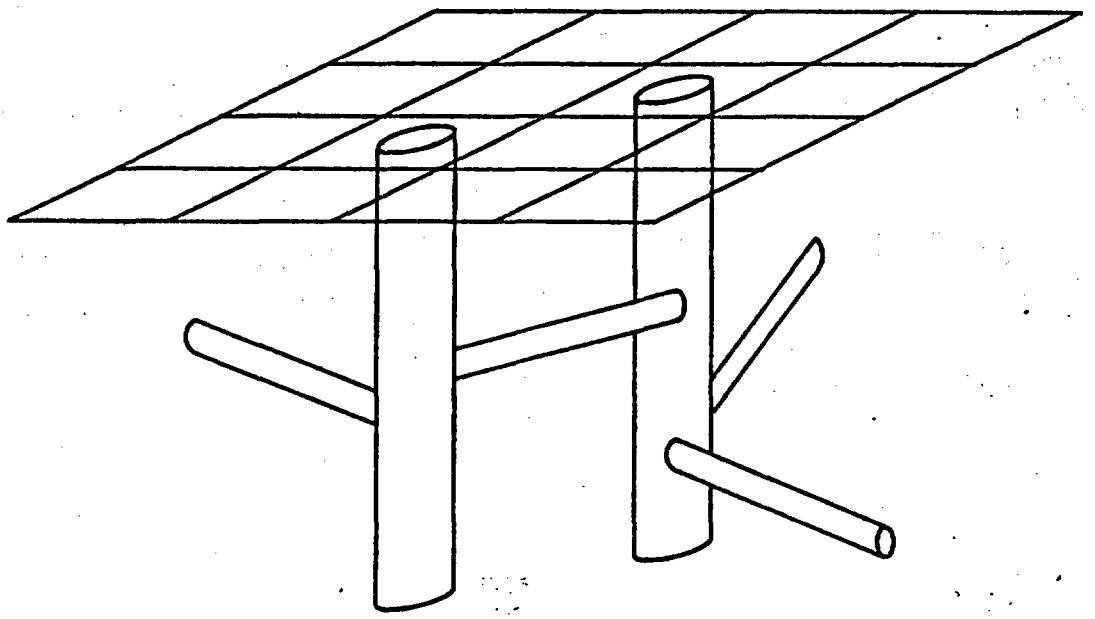
EXPLORATORY SHAFT FACILITY (ESF) SITE SELECTION PROCEDURE



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28 February, 1989

Mr. Robert R. Loux
Executive Director
Agency for Nuclear Projects
State of Nevada
Nuclear Waste Projects Office
Capitol Complex
Carson City, Nevada 89710

Re: ESF Site Selection Procedure

Dear Mr. Loux:

Attached herewith, please find the ESF Site Selection Procedure prepared by this office. This document outlines and gives specific procedural information that may be utilized for the selection of an ESF location at Yucca Mountain, Nevada.

We wish to thank you and the members of your staff for the provision of the information and thoughtful comments that were used in the preparation of this Procedure.

Should you require any further information or if I can be of any further service, please do not hesitate to contact me.

Very truly yours,

JAMES F. THOMPSON, P.E.
Vice President

JFT:tm
Attachments
cc: F797-5.1.3/C012
JFT File

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1.0 EXECUTIVE SUMMARY

This document depicts an ESF Site Selection Procedure that may be utilized for the determination of a location suitable for site characterization activities within an area proposed to host a high-level nuclear waste repository. The evaluation of each possible site is performed using a numerical analysis approach depending on the certain site-specific characteristics of each location being considered.

Although this procedure was prepared specifically for the Yucca Mountain Nevada site, currently under consideration by the Department of Energy (DOE), this procedure may be utilized on any site that may fall under consideration.

It is not the intent of this report to develop a procedure for ESF construction alternatives, methodologies, etc., but rather specifically ESF site selection.

2.0 INTRODUCTION

In order to fully understand the intent of this Site Selection Procedure, presented herein are the procedural concepts and assumptions utilized in the development of this report.

2.1 Procedure Concept

2.1.1 This Procedure is basically a numerical analysis in which candidate sites are analyzed numerically for their suitability as an ESF location and/or regulatory compliance. A numerical analysis such as this proves quite favorable in terms of ascertaining which candidate site may prove best suited for the objectives of an ESF.

In addition to providing easy tabulation of results, this form of analysis also provides the ability to weight certain parameters of an

ESF that affect each particular or unique location.

2.1.2 Each site may be compared equally to one another. In other words, the numerical analysis is performed on a site-by-site basis while maintaining the same criteria and weighted parameters for each site. This reduces biased judgments on each site as the candidate sites may be compared competitively with one another. After the analysis is performed, the results are tabulated to provide a quality assurance check on the ranking of the various parameters.

2.1.3 This Site Selection Procedure is not dependent on certain types of construction or construction methodologies. It must be established at the onset of the Procedure whether a vertical shaft, for example, is to be analyzed versus a declined ramp facility. Once an analysis is performed for a given area and a given ESF type of construction, another analysis may be performed for yet another ESF construction type.

2.1.4 This Procedure is not dependent on intended investigations within the unsaturated or saturated zone. As with the construction methodology, this should be defined prior to the initiation of the analysis. However, once an analysis is performed for a given condition such as the unsaturated zone, another analysis across the repository area may be performed considering the saturated zone.

2.1.5 Within this Procedure, there are three key definitions that must be established to facilitate the analysis. It is extremely

important to understand that it is not the intent of this Procedure to manipulate word definitions, alter common technical phrases, etc. to yield results favorable or unfavorable to a particular region or site within the repository area. Rather, these three key definitions are established at the onset of this Procedure to aid in the consistent unbiased judgement and analysis of the various ESF candidate sites. The three key definitions are described below:

CATEGORY - A class division or field in a scheme of classification such as Geoscience, Environmental, or Engineering.

PARAMETER - An attribute whose characteristic may vary with the circumstances of its application.

CRITERIA - A standard rule or desirable characteristic by which a parameter can be judged or its value measured.

2.2 Assumptions

2.2.1 The primary assumption to this ESF Site Selection Procedure is that consistent data is available, or will be available, throughout the study area. In other words, a particular ESF candidate site is not given favorable consideration, as a result of ignorance of another ESF candidate site's physical characteristics or attributes.

3.0 PROCEDURAL PROCESS OVERVIEW

3.1 Role of ESF

The intended role of the ESF within the Site Characterization Program of the study area must be firmly

established. If the role of the ESF is not clearly defined, then the objectives of the ESF may be severely affected.

3.2 ESF Objectives

After the role of the ESF is established, the true objectives of the ESF should be defined such that any activities performed at a given site will yield the results and data necessary to facilitate the Site Characterization Program (SCP).

3.2.1 All regulatory requirements of the Nuclear Regulatory Commission, applicable Federal regulations, State regulations, and local and other Federal requirements shall be met.

3.2.2 Considering the SCP and the intended role of the ESF, all scientific and engineering requirements pertaining to the collection of data and the furtherance of site characterization activities shall be met.

3.2.3 All environmental requirements shall be met; and furthermore, the ESF should have very minimal impact on the environment at the site location.

3.3 ESF Categories

To facilitate the analysis within the Procedure, the major categories of study or interest to the ESF shall be determined. These categories shall be comprised of the major fields of endeavors proposed within the study area.

3.4 Parameters

For each category, parameters shall be established defining the major attributes that shall be analyzed within the Procedure. These parameters shall consist

of primary physical characteristics important to the success of the ESF.

3.5 Criteria

The criteria of each parameter within each category shall be established based upon the given proposed construction methodology, depth, and other constraints proposed for the ESF.

3.6 Weighting of Parameters

Based on the level of importance or contribution to the ESF objectives, given the role of the ESF, the parameters shall be weighted in a fashion suitable for analysis.

3.6.1 The numeric sum of the ranked parameters must equal unity (1.0).

3.7 Grid System

A grid system for the Procedure must be established. Each grid block within the system shall constitute a potential ESF candidate site location. The grid system itself should be comprised of the entire repository study area.

3.7.1 An origin of the grid system, to remain constant, shall be defined.

3.7.2 An orientation of the grid system, to remain constant, shall be defined.

3.7.3 Given the geographic location of the study area, a map projection shall be determined that will best suit the study area. Which map projection is utilized, Lambert or Mercator for example, is not important, but rather that the map projection remains constant for the study area throughout the ESF Site Selection Procedure. It is recommended that the map

projection recommended by the USGS for the particular geographic region under investigation be utilized.

3.7.4 A grid size defining the various grid blocks within the system shall be determined considering the construction methodology, depth, etc. proposed.

3.8 Ranking of Parameters

Considering the objectives of the ESF and all of the criterions previously established, the parameters shall be ranked depending on the level of positive contribution towards the ESF objectives.

3.8.1 On a grid block-by-grid block basis, all of the defined and previously weighted parameters shall be ranked. The ranking of all parameters shall be based on established criteria.

3.8.2 Any parameter that does not meet specific criteria shall be ranked numerically as zero (0).

3.9 Overall Grid Block Weight

For each grid block, the overall grid block weight shall be established.

3.9.1 Considering the ranking of the various parameters of each grid block, the sum of all of the parameter's rankings multiplied by the parameters weights shall be calculated to establish an overall grid block weighted ranking or grid block weight.

3.9.2 Any grid block that has received a parameter ranking equal to zero, as defined in 3.8.2, shall be dropped from consideration as a possible ESF candidate site.

3.9.3 The results of the grid block's ranking shall be tabulated in a fashion such that the overall grid block weights can be viewed and checked for particular biased rankings, miscellaneous errors, etc.

3.10 Further Iterations

Further iterations in the procedural process can be performed to provide further analyses of the study area.

3.10.1 To account for various types of construction, changes in the ESF size or depth, etc., the grid block size and the specific criteria may be altered to facilitate the changed ESF Plan. This, however, should not affect the role of the ESF or the objectives of the ESF, as this would not constitute a further iteration of the Procedure.

4.0 SUMMARY OF PROCEDURE

Figure 1 depicts a flow chart illustrating the Procedure in a simplistic manner.

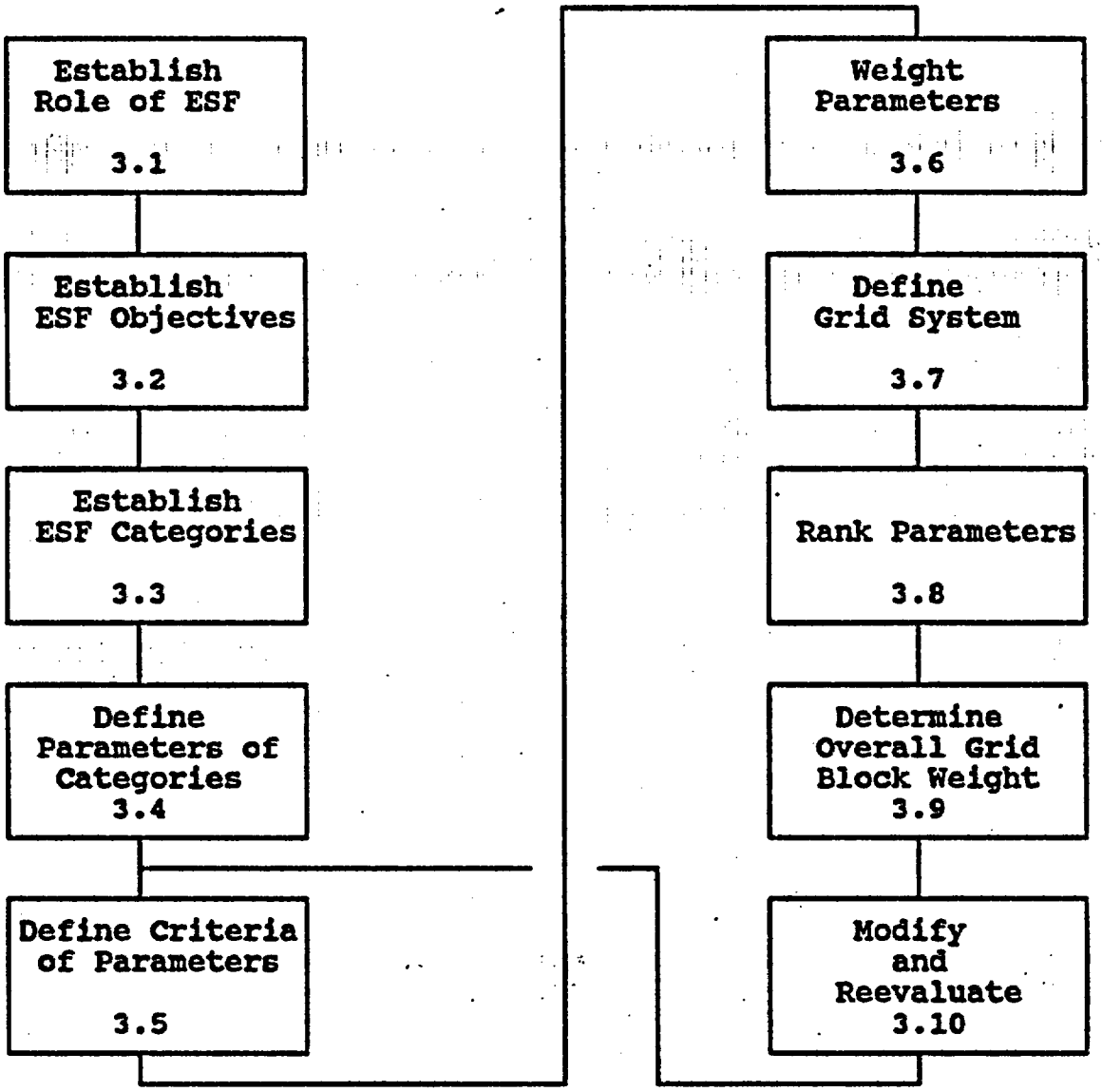
Establish Role of ESF 3.1
Establish ESF Objectives 3.2
Establish ESF Categories 3.3
Define Parameters of Categories 3.4
Define Criteria of Parameters 3.5
Weight Parameters 3.6
Define Grid System 3.7
Rank Parameters 3.8
Determine Overall Grid Block Weight 3.9
Modify and Reevaluate 3.10

Figure 1

5.0 ROLE OF ESF WITHIN SITE CHARACTERIZATION PROGRAM

5.1 Programmatic Considerations

5.1.1 An Exploratory Shaft Facility (ESF) shall provide access for detailed study of the potential host rock and physical characteristics and attributes of a potential high-level nuclear waste repository location. While providing access for detailed site characterization study, the ESF must also demonstrate the site's compliance with all applicable Federal, State, and local regulations pertaining to the construction, operation, and subsequent closure of a deep geologic high-level nuclear waste repository.

5.1.2 The ESF shall establish the geologic conditions and ranges of the parameters of a candidate site relevant to the location of a repository within a given study area. By means of in situ testing, the suitability of a candidate site shall be ascertained in terms of its ability to host a repository.

5.1.3 An ESF is not to be utilized to determine whether site characterization activities should be undertaken or extended.

5.1.4 The ESF's extents shall be limited to an extent practical and consistent with obtaining the required information needed for proper site characterization of the study area.

5.2 Functional Considerations

5.2.1 An ESF should provide site-specific data, pertinent to site characterization, to substantiate or justify a license application for a high-level nuclear waste repository.

5.2.2 The ESF should provide access for in situ exploration and testing at an elevation where wastes would be implaced.

5.2.3 An ESF shall be placed in a location where shafts or ramps are planned for underground facility construction and operation, such that the ESF may be efficiently and safely incorporated into an overall repository layout.

5.2.4 In situ exploration and testing within the ESF shall provide site-specific data pertinent to repository design and construction.

6.0 ESF OBJECTIVES

6.1 Regulatory Objectives

6.1.1 The ESF shall be in compliance with the NWPA and all NRC, State, and local regulations.

6.1.2 The ESF shall provide an adequate margin for compliance with all established safety criteria at the Federal and local level.

6.1.3 The ESF shall provide achievement of its intended use within the site characterization activities, including technical integrity, cost effectiveness, and project schedule.

6.2 Scientific/Engineering Objectives

6.2.1 The ESF shall aid in supplying data and information pertinent to the development of a detailed description of a proposed repository to be located at the site, including all preliminary engineering specifications required for the facility.

6.2.2 The ESF shall aid in the development of an understanding of the relationship between the

waste form packaging and the geologic host median.

6.2.3 Data related to the safety of the site in terms of construction and waste isolation shall be developed from tests conducted within the ESF.

6.2.4 Adequate flexibility shall be provided within the ESF design for both construction and operation to accommodate the site characterization activities and any potential work required within the ESF for testing in the future.

6.2.5 All ESF activities, including design and construction, shall provide near-term cost effectiveness.

6.2.6 Construction methodologies, reasonably and functionally related to the objectives of geologic investigations proposed within the site characterization activities, shall be provided for within the ESF.

6.2.7 The ESF shall provide access to the subsurface at an elevation proposed to host the waste containers for all geologically-related tests necessary for the site characterization of the site.

6.2.8 The ESF shall provide safe and adequate transportation of people and equipment to the test locations proposed within the underground networks.

6.2.9 Adequate surface facilities shall be provided to accommodate all tests proposed for site characterization within the ESF.

6.2.10 Demonstration that large diameter shafts and ramps are feasible and practical for incorporation into a deep geologic repository shall be provided by the ESF.

6.2.11 All investigations, tests, and studies proposed for site characterization activities shall be able to be conducted within an ESF in such a manner as to limit adverse effects on the long-term performance of a geologic repository at the site.

6.2.12 The ESF must provide information necessary to aid in the determination of the orientation, geometry, layout, and depth of an underground facility, including the design of any engineered barriers that may contribute to the containment and isolation of radionuclides.

6.2.13 The ESF shall provide access to areas necessary to demonstrate the ability of retrieval of waste containers in accordance with the other performance projectives.

6.2.14 The design of the ESF shall incorporate methods of construction that will limit the potential for creating preferential pathways for groundwater or radioactive waste migration to the accessible environment.

6.2.15 The ESF shall provide information and data necessary to determine if engineered barriers will assist the geologic setting in prohibiting waste migration following permanent closure.

6.2.16 Data necessary to predict the thermomechanical, geochemical, and other responses of the host rock and surrounding strata shall be provided

by tests and other activities conducted within the ESF.

6.2.17 The ESF shall aid in the determination as to whether seals and plugs will aid the waste isolation integrity of a deep geologic repository at the site.

6.2.18 The ESF shall provide access to an environment that will demonstrate the geologic capabilities of the host setting as a potential site for a deep geologic repository.

6.2.19 The ESF shall adequately demonstrate that a geologic repository at the site is feasible, constructible, and will meet all regulatory requirements.

6.3 Environmental Objectives

6.3.1 The ESF shall be placed in a location such that all site characterization activities conducted at the facility can be conducted in a manner that does not have any significant adverse environmental impacts.

6.3.2 The ESF shall be located, constructed, and operated such that, when closed, it will not have any long-term environmental impacts to the site area.

7.0 ESF CATEGORIES

7.1 Science

7.1.1 The category of Science includes all disciplines and areas of studies pertinent to scientific endeavors concerned with establishing facts, principles, and theories related to the physical characteristics at and around

the site. This category includes climatology, geology, hydrogeology, etc.

7.2 Engineering

7.2.1 This category is comprised of disciplines and endeavors concerned with putting scientific knowledge and data to practical uses. This category primarily revolves around interests pertaining to man-made occurrences, facilities, and the physical nature of the site pertinent to engineered facilities.

7.3 Environmental

7.3.1 The Environmental category contains the areas of study necessary to determine any impacts on the environment of the host site. Included within this category are interest of vegetation, water quality, destruction of wildlife, etc.

7.4 Other

7.4.1 This category is comprised of other interests that do not pertain to the categories outlined in Sections 7.1, 7.2, and 7.3.

8.0 PARAMETERS OF ESF CATEGORIES

8.1 Science Parameters

8.1.1 Rock Mass Character

8.1.2 Geologic Processes

8.1.3 Climatological Events

8.1.4 Hydrological Events

8.1.5 Thermal/Chemical Behavior

8.1.6 Geomorphic Character

8.2 Engineering Parameters

8.2.1 Rock Volume

8.2.2 Rock Mass Integrity

8.2.3 Topographic Suitability

8.2.4 Flood Control

8.2.5 Engineered Barriers

8.2.6 Dynamic Stability

8.2.7 Constructibility

8.2.8 Cost Effectiveness

8.3 Environmental Parameters

8.3.1 Groundwater Protection

8.3.2 Atmospheric Quality

8.3.3 Surface Protection

8.3.4 Human Isolation/Protection

8.4 Other Parameters

8.4.1 Social and Economic Impacts

9.0 CRITERIA OF PARAMETERS

The criteria presented herewith is generic and general in nature. Once a construction methodology and ESF type is determined, the criteria may be modified and elaborated upon, as per Sections 2.1.3 and 3.10.1.

9.1 Science Criteria

9.1.1 Rock Mass Character Criteria

9.1.1.1 The ESF shall provide access to the rock environment proposed to host a repository for complete study and characterization.

9.1.1.2 The ESF shall provide access to a host rock setting that is representative

of the geologic setting of the site. It is preferable to provide access to a rock setting that provides information necessary to ascertain the fastest pathway of waste migration to the accessible environment.

9.1.1.3 Alternative horizons must be able to be investigated from the ESF.

9.1.1.4 The ESF location shall have minimal effects on the inability to characterize the site.

9.1.2 Geologic Processes Criteria

9.1.2.1 The ESF shall be located such as to aid in the characterization of the geologic processes within the study area.

9.1.2.2 Future changes in the natural geologic processes at the site must not adversely affect the characterization activities within the ESF.

9.1.2.3 The geologic processes must not have adverse effects on the waste isolation integrity of the ESF should the ESF be incorporated into a repository.

9.1.3 Criteria Pertaining to Climatological Events

9.1.3.1 The ESF shall be located such as not to be adversely impacted by major climatological events.

9.1.3.2 The ESF shall aid in the determination of the impacts of major events such as storm events on repository design and waste isolation.

9.1.4 Hydrogeologic Character Criteria

9.1.4.1 The ESF shall allow measurement and detection of the groundwater flow volumes and rates through the setting.

9.1.4.2 Access to a representative geohydrologic setting shall be provided, which will adequately aid characterization activities in determining the hydrologic regime of the site.

9.1.4.3 The ESF shall allow access to sufficient environs such as to provide data pertinent to adequately model the site.

9.1.4.4 The hydrogeologic impacts of seals shall be assessed within the ESF.

9.1.5 Thermal/Chemical Behavior Criteria

9.1.5.1 The ESF shall provide complete access to a representative rock setting, such that the thermal and chemical effects of waste containment may be characterized.

9.1.6 Geomorphic Character Criteria

9.1.6.1 The ESF shall not be located such as to contribute to the erosion potential of the surrounding environment.

9.1.6.2 Complete geomorphic processes, as affected by the ESF, shall be characterized.

9.2 Engineering Criteria

9.2.1 Rock Volume Criteria

9.2.1.1 Multiple volumes must be accessed from the ESF.

9.2.1.2 The ESF shall provide access to thick target units.

9.2.1.3 Exploration of maximum subsurface volumes shall be performed.

9.2.1.4 The ESF shall provide access to maximum thickness of units of interest.

9.2.1.5 The ESF shall provide ultimate compatability with a repository layout.

9.2.2 Rock Mass Integrity Criteria

9.2.2.1 Rock character shall be fully characterized within the ESF.

9.2.2.2 The ESF shall have sound and stable rock conditions.

9.2.2.3 The ESF shall allow minimization of construction rock damage.

9.2.2.4 The rock mass accessed by the ESF shall demonstrate minimal disturbances from mining, excavation, or operational activities.

9.2.2.5 The rock setting of the ESF shall have favorable rock conditions for construction.

9.2.2.6 The rock mass must have the potential for suitability in determining seal performance.

9.2.3 Topographic Suitability Criteria

9.2.3.1 The ESF shall be located where the terrain can be minimally impacted by surface activities.

9.2.3.2 The topography shall provide adequate natural drainage away from the ESF shafts or ramps.

9.2.4 Flood Control Criteria

9.2.4.1 The ESF shall be located such as to have minimal surface flooding potential.

9.2.4.2 The ESF shall be located such that water infiltration can be minimized.

9.2.5 Engineered Barriers Criteria

9.2.5.1 The ESF must have the potential for determining the effective performance of engineered barriers such as seals and plugs.

9.2.5.2 The geologic setting's waste isolation integrity shall not be affected by seal emplacement.

9.2.6 Dynamic Stability Criteria

9.2.6.1 The ESF shall have the ability to resist seismic loads from earthquake events.

9.2.6.2 The ESF shall have the ability to resist seismic loads from NTS events.

9.2.7 Constructibility Criteria

9.2.7.1 The ESF shall be of a nature as to allow utilization of available

technologies, resources, and potential contractors.

9.2.7.2 The ESF location shall accommodate construction access.

9.2.7.3 Utility availability shall exist.

9.2.7.4 Waste rock materials shall have nearby surface accommodation.

9.2.8 Cost Criteria

9.2.8.1 Considering the proposed construction methodology and ESF type (i.e. shaft or ramp), the ESF shall be located to provide proper cost efficiency.

9.3 Environmental Criteria

9.3.1 Groundwater Protection

9.3.1.1 ESF construction, operation, or activities shall not endanger the groundwater quality.

9.3.1.2 Groundwater supply, locally and regionally, shall not be impacted by the ESF.

9.3.1.3 Proper monitoring of the groundwater system shall be maintained throughout the ESF activities.

9.3.2 Atmospheric Quality

9.3.2.1 ESF construction, operation, or activities shall not endanger the local or regional air quality. Any emissions, as a result of ESF activities, shall remain within applicable air quality standards.

9.3.2.2 Proper monitoring of the air quality shall be maintained throughout the ESF activities.

9.3.3 Surface Protection Criteria

9.3.3.1 Minimal vegetation disturbances shall result from ESF activities.

9.3.3.2 The ESF location must allow minimal surface reclamation efforts.

9.3.3.3 There shall be minimal wildlife impact at the site as a result of ESF activities.

9.3.3.4 There shall be no long-term impacts to wildlife around the ESF site.

9.3.3.5 The ESF shall have minimal effects on surface biological species of concern.

9.3.3.6 The ESF shall have minimal effects on surface archeological resources.

9.3.4 Human Isolation/Protection

9.3.4.1 The ESF shall be located such as to prevent future public intrusion or possible contamination as a result of any form of waste migration.

9.3.4.2 The ESF shall be a suitable distance from the site boundaries.

9.3.4.3 The ESF activities shall not affect the safety of the local or regional public.

9.4 Other Criteria

9.4.1 Social and Economic Impacts

9.4.1.1 The ESF shall have minimal negative social impacts on the surrounding areas.

9.4.1.2 The ESF shall have minimal negative economic impacts on the surrounding areas.

10.0 PROCEDURAL ANALYSIS EXAMPLE

A very small study area has been divided into four (4) grid blocks of equal size. Each grid block is a potential ESF site. Consistent data has been obtained across the site.

The results of the analysis are tabulated in Table 1. As can be seen, the sum of all of the weights of the parameter's equal unity.

Site No. 3 has been dropped from consideration because the rock mass integrity of the site failed to meet specific criteria.

Of the three remaining sites, No. 2 has the overall highest grid block weight (0.668) and is the best site considering the intended construction methodology and ESF type and the resultant criteria.

11.0 REFERENCES

NWPA (Nuclear Waste Policy Act), 1983. "Nuclear Waste Policy Act of 1982," Public Law 97-425, 42 USC 10101-10226, Washington, D.C.

10 CFR Part 60 (Code of Federal Regulations), 1987. Title 10, "Energy," Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," U.S. Government Printing Office, Washington, D.C., pp. 627-658.

		GRID BLOCK							
		1		2		3		4	
	weight	rank	rank x weight	rank	rank x weight	rank	rank x weight	rank	rank x weight
SCIENCE									
Rock Mass Character	0.09	0.30	0.027	0.60	0.054	0.20	-	0.5	0.045
Geologic Processes	0.05	0.70	0.035	0.70	0.035	0.30	-	0.7	0.035
Climatological Events	0.02	0.50	0.010	0.50	0.010	0.50	-	0.5	0.010
Hydrologic Character	0.05	0.80	0.040	0.60	0.030	0.40	-	0.6	0.030
Thermal/Chem. Behavior	0.05	0.80	0.040	0.50	0.025	0.20	-	0.5	0.025
Geomorphic Character	0.02	0.40	0.008	0.60	0.012	0.70	-	0.6	0.012
ENGINEERING									
Rock Volume	0.05	0.10	0.005	0.30	0.015	0.50	-	0.7	0.035
Rock Mass Integrity	0.09	0.30	0.027	0.70	0.063	0.00	-	0.7	0.063
Topographic Suitability	0.05	0.50	0.025	0.80	0.040	-	-	0.6	0.030
Flood Control	0.08	0.70	0.056	0.70	0.056	-	-	0.5	0.040
Engineered Barriers	0.05	0.80	0.040	0.60	0.030	-	-	0.8	0.040
Dynamic Stability	0.05	0.70	0.035	0.60	0.030	-	-	0.7	0.035
Constructibility	0.05	0.80	0.040	0.80	0.040	-	-	0.5	0.025
Cost Effectiveness	0.01	0.80	0.008	0.80	0.008	-	-	0.7	0.007
ENVIRONMENTAL									
Groundwater Protection	0.10	0.30	0.030	0.70	0.070	-	-	0.6	0.060
Atmospheric Quality	0.10	0.80	0.080	0.80	0.080	-	-	0.6	0.060
Surface Protection	0.05	0.40	0.020	0.80	0.040	-	-	0.7	0.035
Human Isolation/Protec	0.02	0.70	0.014	0.70	0.014	-	-	0.6	0.012
OTHER									
Soc. & Eco. Impacts	0.02	0.80	0.016	0.80	0.016	-	-	0.7	0.014
	1.00		0.556		0.668		-		0.613

TABLE 1

10 CFR Part 960 (Code of Federal Regulations), 1987. Title 10, "Energy," Part 960, "General Guidelines for the Recommendations of Sites for Nuclear Waste Repositories," U.S. Government Printing Office, Washington D.C., pp. 518-551.

40 CFR Part 191 (Code of Federal Regulations), 1986. Title 40, "Protection of Environment, "Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," U.S. Government Printing Office, Washington, D.C., pp.7-16.

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1988 GAO: GAO, 1988, Fourth Annual Report on DOE's Nuclear Waste Program, (GAO/RCED-88-131), United States General Accounting Office, September 1988.

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1964 L&C: Lewis, R. S., and Clark, G. B., 1964, Elements of Mining, New York, John Wiley & Sons, Inc.

1984 SAND: Bertram, S. G., 1984, "NNWSI Exploratory Shaft Site and Construction Method Recommendation Report," SAND84-1003, 95p.