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ITASCA Consulting Group, Inc.

David Tiktinsky - SS623
U.S. Nuclear Regulatory Commission
Division of Waste Management
Washington, D.C. 20555

Contract No. NRC-02-85-002
Task Order No. 1

Dear David:

Enclosed are document reviews for the two documents requested for review in your letter dated September 11, 1985:

(1) "Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation" (SAND-83-0372); and

(2) "NNWSI Exploratory Shaft Site and Construction Method Recommendation Report" (SAND-84-1003).

These reviews were conducted by Jaak Daemen with the assistance of Loren Lorig (in the review of thermomechanical analyses) and Margaret Asgian (in the review of hydrological analyses) for the first document. As you will notice, Dr. Daemen has performed a very extensive review, particularly of the second report, which he believes is a very important document for the ESF review. Dr. Daemen has identified several supporting documents which are essential references in the two reports and, thus, he recommends that these should be reviewed for supporting information.

Please call me if you have questions or comments concerning these reviews.

Sincerely,

Roger D. Hart
Program Manager

cc: J. Greeves
Director, NMSS
E. Wiggins
Document Control

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ITASCA DOCUMENT REVIEW

File No.: 001-02-1

Document: SAND83-0372: Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation by J. Keith Johnstone, Ralph R. Peters, and Paul F. Gnirk, June 1984.

Reviewer: Itasca Consulting Group, Inc. (J. Daemen, M. Asgian, L. Lorig)

Date Approved:

Date Review Completed: September 24, 1985

Significance to NRC Waste Management Program

The document reviewed is the basic reference used by DOE to justify the choice of the Topopah Spring welded tuff unit as the repository horizon. The choice appears to be justified on the basis of the data and analyses summarized here. It must be recognized that data base and analyses available at the time of writing this document were very limited.

The document also is frequently referenced in various sections of the Draft Environmental Assessment, Yucca Mountain Site, especially in sections dealing with rock, thermo-mechanical behavior, and travel time.

Summary of Document

The document presents a comparative evaluation of four potential repository units at Yucca Mountain. Two potential units (the welded, devitrified portions of the Bullfrog and Tram Members of the Crater Flat Tuff) are below the water table. The other two potential units (the welded, devitrified Topopah Spring Member of the Paintbrush Tuff and the non-welded, zeolitized Tuffaceous Beds of Calico Hills) are above the water table. In this report, Sandia National Laboratories and its subcontractors, Pacific Northwest Laboratory and RE/SPEC, Inc., present the results of a comparative study—and not of an absolute performance assessment of the four potential host units. Ranking criteria summarized are:

- mineability (ease of excavation)
- gross thermal loading
- excavation stability
  - near-field thermal/mechanical
  - rock mass/rock matrix properties
  - rock mass classification (NGI and CSIR)*
- far-field thermal/mechanical
- groundwater travel time (vertical)

Radionuclide migration is discussed briefly on the basis of water travel time and average sorption ratios.

The Topopah Spring unit ranks first (best repository unit) according to all but one (mineability) of the ranking criteria.

The authors recognize extreme uncertainty in some of the results, especially radionuclide migration and groundwater travel times but, in all cases, the minimum calculated groundwater travel times to the accessible environment exceeds 1,000 years even for the most conservative estimate and, usually, by one to two orders of magnitude for the most probable estimates.

The allowable repository gross thermal loadings determined from near-field calculations are nearly the same for all four units. These gross thermal loadings provide the heat source for subsequent studies that include thermal effects.

A large number of studies evaluate excavation stability. They include near-field mechanical and thermomechanical finite element calculations, rock matrix property evaluation, analytical pillar stress calculations, and rock mass classifications (NGI-Barton; CSIR-Bieniawski).

The final recommendation is to select the Topopah Spring as the target unit, followed by, in order, the Calico Hills, Bullfrog, and Tram.

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*NGI is Norwegian Geotechnical Institute; CSIR is Council for Scientific and Industrial Research.

Problems, Limitations, and Deficiencies

General Comments

The conclusions are drawn from an extremely limited data basis and from extremely limited and simplified hydrological and radionuclide migration modeling.

Very little detail is presented in the document, which mostly quotes results from other documents. Hence, detailed evaluation of the validity of the analyses is not entirely possible on the basis of the document itself.

Groundwater flow modeling is extremely simplistic, as recognized by the authors, and is based on highly uncertain input parameters. As a consequence, the sensitivity analyses result in an extremely wide range of travel times.

The effect of sorption on radionuclide migration is discussed only in an extremely simplified way—by multiplying water travel time by an average retardation factor based on average sorption ratios, rock mass bulk densities, and porosities.

Although the document was printed in June 1984, the unit evaluation was completed in February 1983, and no indication has been given (e.g., in the Draft Environmental Assessment) that it has been re-analyzed on the basis of additional information since the study was completed.

The decision to select the Topopah Spring as the target horizon was made in July 1982, in the midst of this unit evaluation study (p. 1, 3rd paragraph). No indication is given as to whether or not the unit evaluation study influenced the decision.

The authors repeatedly point out that the study is comparative, incomplete (i.e., not a comprehensive site performance assessment), and based on "a nearly complete absence of real data or by using very preliminary data" (p. 1). Notwithstanding these extensive caveats, this document is repeatedly referenced in the Draft Environmental Assessment without qualifiers.

Specific Comments

The thermomechanical evaluation of excavation stability uses a ubiquitous joint model to represent vertical jointing in the rock mass. The results are somewhat confusing and, at a cursory inspection, do not appear to be correct. For example, Fig. 11 does not indicate an extensive region of joint separation at mid-height of the excavation wall. The presence of the excavation will cause a reduction of horizontal stresses near the wall, and thermal loading will produce an increase in vertical stress in the wall. Thus, a large region of joint opening into the excavation would be expected.

On p. 23, the assertion is made that small thermal gradients suggest that thermal impact on flow behavior is minor. However, temperatures, rather than temperature gradients, can have a significant impact on the groundwater flow rates. The hydraulic conductivity (permeability), k, of a porous medium increases with a temperature increase—i.e., it is inversely proportional to the viscosity, μ, of the pore fluid:

$$\frac{k_1}{k2} = \frac{\mu 2}{\mu 1}$$

For water at 170°F, the viscosity equals 0.372 centipoise[1], while at 50°F it equals 1.31 centipoise. For such a groundwater temperature decrease, the hydraulic conductivity decreases 350%. Such a temperature change, and hence permeability change, can be significant because (1) the infiltration capacity of unsaturated porous media is directly related to the saturated hydraulic conductivity (c.f., Groundwater, R. A. Freeze and J. A. Cherry, Prentice-Hall, New Jersey, 1979) and (2) flow rates are proportional to hydraulic conductivity.

The conceptual infiltration model given in Figs. 64 and 65 uses a global mass balance approach. This is a very reasonable first step in the assessment of groundwater travel times and, hence, of radionuclide transport times. However, the authors should jus-

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[1]Max Peters. Elementary Chemical Engineering, p. 294. New York: McGraw-Hill, 1954.

tify the use of effective porosity in their model. Under partially-saturated conditions, the mobile groundwater in soil or rock occupies less space than the effective porosity. It occupies the space defined by the effective porosity times the degree of saturation. Shown in the attached Fig. 1 is a relationship between degree of saturation and water suction pressures. The curves are for a variety of rocks and soils. They indicate that, at high suction pressures (which may be expected in the unsaturated zones at Yucca Mountain), the residual degree of saturation can be as low as 5% and as high as 50%. An estimate of the residual saturation for the tuffs at Yucca Mountain could be made from field measurements of moisture content, dry density, and specific gravity. If the residual degree of saturation times the effective porosity of the tuffs is less than 0.10, then the travel times given in Table 7 are NOT conservative estimates.

A (minor) discrepancy exists between the emplacement hole geometries for various plots (e.g., compared Figs. 27 and 29).

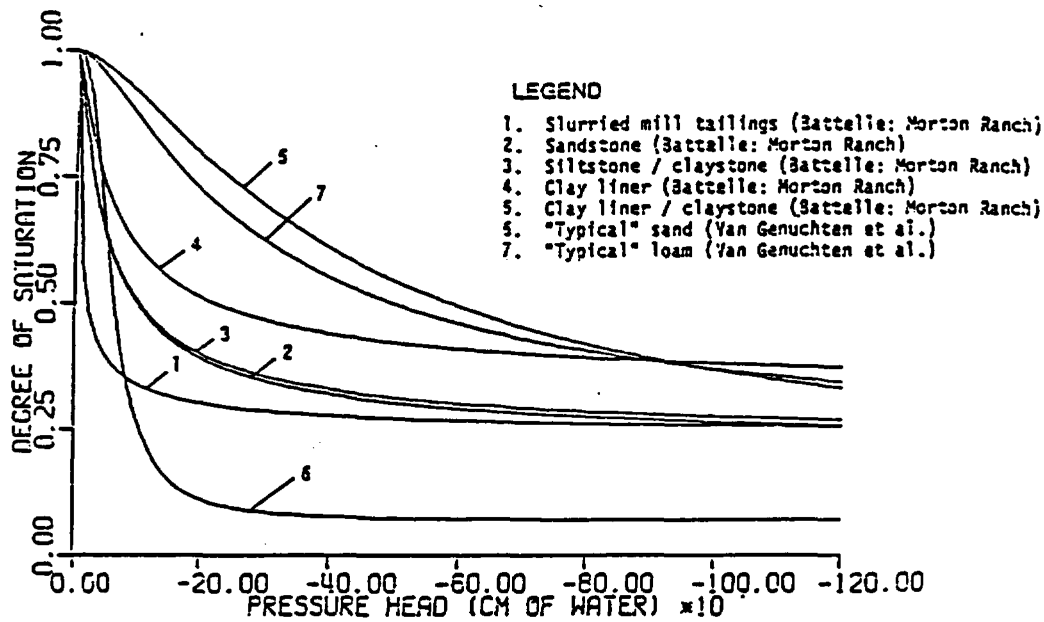

Fig. 1 Relationship Between Degree of Saturation and Pressure Head for Various Rocks and Soils (from D. Sharma, "Fluid Dynamics and Mass Transfer in Variably-Saturated Porous Media: Formulation and Applications of a Mathematical Model," Proceedings of the Symposium on Unsaturated Flow and Transport Modeling (Seattle, Washington, March 1982). E. M. Arnold, G. W. Ghee, and R. W. Nelson, Eds. NUREG/CP-0030; PNL-SA-10325, 1982.

Recommended Action

No evidence is available to suggest that the Topopah Spring is not the preferred target horizon at Yucca Mountain. Most ranking criteria are not very discriminatory. Extremely discriminatory is the opening stability criterion; although the authors underemphasize it, strong indications are given that maintaining stability in all three units not selected could be difficult—hence, greatly complicating retrieval and probably resulting in a much larger disturbed zone than for a repository in the Topopah Spring unit. Therefore, from a rock mechanics/underground excavation design/stability viewpoint, the recommendation to propose the Topopah Spring as the repository horizon appears fully warranted. This suggests that the need for follow-up action in this particular area would be minimal.

It is recommended that:

- any NRC reviewer of a document referencing this one (e.g., draft and probably final Environmental Assessment) be made aware of the severe simplifications underlying most analyses summarized.

- DOE update its performance analysis for the Topopah Spring target horizon.

- NRC perform a review of the essential documents from which results are used here. The following documents are identified for the NRC to consider for review if not yet reviewed.

  B. S. Langkopf, Sandia National Laboratories, to Distribution, "Discussion of Thermomechanical Cross-Section C-C" as given to RE/SPEC for Far-Field Unit Selection Calculations," Memorandum dated July 23, 1982.

  J. L. Ash and W. E. Craig, Scott-Ortech, Inc., to J. K. Johnstone, Sandia National Laboratories, "Mineability of Four Candidate Lithologic Units in Yucca Mountain," Letter Report dated September 1982.

P. F. Gnirk and J. L. Ratigan, RE/SPEC Inc., to J. K. Johnstone, Sandia National Laboratories, "Constructibility Analysis of Welded and Nonwelded Tuff Members at Yucca Mountain," Technical Letter Memorandum RSI-0078 dated October 20, 1982.

W. A. Hustrulid, Colorado School of Mines, to J. K. Johnstone, Sandia National Laboratories, "Constructibility of a Nuclear Waste Disposal Facility at Yucca Mountain," Letter Report dated October 18, 1982.

R. L. Johnson, "NNWSI Unit Evaluation at Yucca Mountain, Nevada Test Site: Near Field Thermal and Mechanical Calculations Using the SANDIA ADINA Code," SAND83-9939, Albuquerque, Sandia National Laboratories, in preparation.

R. K. Thomas. "NNWSI Unit Evaluation at Yucca Mountain, Nevada Test Site: Near Field Mechanical Calculations Using a Continuum Jointed Rock Model in the JAC Code," SAND83-0070, Albuquerque, Sandia National Laboratories, in preparation.

A. Melo and D. K. Parrish, "NNWSI Unit Evaluation at Yucca Mountain, Nevada Test Site: Near Field Thermal-Rock Mechanics Analysis," RSI-0205, Rapid City, RE/SPEC Inc., in preparation.

R. R. Peters and A. R. Lappin, Sandia National Laboratories, To T. Brandshaug, RE/SPEC Inc., "Revised Far Field Thermomechanical Calculations for Four Average Property Cases," Memorandum dated August 17, 1982.

R. R. Peters and A. R. Lappin, Sandia National Laboratories, To T. Brandshaug, RE/SPEC Inc., "Revised Far Field Thermomechanical Calculations for Four "Limit" Property Cases," Memorandum dated September 22, 1982.

R. R. Peters to R. K. Thomas, Sandia National Laboratories, "Thermomechanical Calculations for Unit Evaluation," Memorandum dated October 25, 1982.

R. R. Peters, Sandia National Laboratories, to S. W. Key, RE/SPEC Inc., "Thermomechanical Calculations for Unit Evaluation," Memorandum dated October 25, 1982.

R. R. Peters to R. D. Krieg, Sandia National Laboratories, "Near Field Thermomechanical Calculations in the Welded, Devitrified Portion of the Grouse Canyon Member of the Belted Range Tuff (G-Tunnel Tuff)," Memorandum dated November 29, 1982.

R. H. Price, "Analysis of Rock Mechanics Properties of Volcanic Tuff Units from Yucca Mountain, Nevada Test Site," SAND82-1315, Albuquerque, Sandia National Laboratories, in preparation.

A. R. Lappin, Sandia National Laboratories, to Distribution, "Bulk and Thermal Properties of the Functional 'Tuffaceous Beds', Here Defined to Include the Basal Topopah Spring, All of the Tuffaceous Beds of Calico Hills, and the Upper Portion of the Prow Pass," Memorandum dated March 26, 1982.

A. R. Lappin, Sandia National Laboratories, to Distribution, "Bulk and Thermal Properties for the Welded, Devitrified Portions of the Bullfrog and Tram Members, Crater Flat Tuff," Memorandum dated April 19, 1982.

A. R. Lappin, Sandia National Laboratories, to Distribution, "Bulk and Thermal Properties of the Potential Emplacement Horizon Within the Densely Welded, Devitrified Portion of the Topopah Spring Member of the Paintbrush Tuff," Memorandum dated June 30, 1982.

J. K. Johnstone and P. F. Gnirk, "Preliminary Technical Constraints for a Repository in Tuff," SAND82-2147, Albuquerque, Sandia National Laboratories, in preparation.

B. S. Langkopf, Sandia National Laboratories, to Distribution, "Suggested Bounds for In Situ Stress Ratios for Use in Yucca Mountain Unit Selection Calculations," Memorandum dated March 26, 1982.

J. H. Healy, S. H. Hickman, M. D. Zoback, and W. L. Ellis, "Deep-Borehole Stress Measurements at the Nevada Test Site," (abs.), EOS, Vol. 63, no. 45, p. 1099, 1982.

R. M. Zimmerman and W. C. Vollendorf, "Geotechnical Field Measurements, G-Tunnel, Nevada Test Site," SAND81-1971, Albuquerque, Sandia National Laboratories, May 1982.

B. S. Langkopf and P. F. Gnirk, "Preliminary Rock Mass Classification Ratings of Four Potential Repository Units at Yucca Mountain," SAND82-2034, Albuquerque, Sandia National Laboratories, in preparation.

T. Brandshaug, "NNWSI Unit Evaluation at Yucca Mountain, Nevada Test Site: Far Field Thermal-Rock Mechanics Analyses," RSI-0209, Albuquerque, RE/SPEC, Inc., in preparation.

NWTS Working Group on Far Field Performance Constraints, "Repository Performance Constraints in the Far Field Domain," NWTS-25, Washington, D.C., NWTS Program Office and U.S. Department of Energy, in draft form, 1981.

<u>For Review by Hydrologists</u>

R. R. Peters and J. K. Johnstone to L. D. Tyler, Sandia National Laboratories, "Bounding Calculations for Radionuclide Movement in the Unsaturated Zone," Memorandum dated September 13, 1982.

F. H. Dove, W. A. Rice, J. L. Devary, F. W. Bound, and P. G. Doctor, "Hydrologic and Transport Considerations for Horizon Selection at Yucca Mountain, Nevada," Richland, Pacific Northwest Laboratory, in preparation.

J. H. Robinson and F. E. Rush, "Hydrologic Site Characterization of Yucca Mountain, Nevada," U.S. Geological Survey, presented at the 1982 NWTS Program Information Meeting, Las Vegas, Nevada, December 1982.

F. E. Rush, U.S. Geological Survey, to J. K. Johnstone, Sandia National Laboratories, "Preliminary Hydraulic Conductivities in Wells USW-H1 and UE25a-B1," Personal Communication, January 21, 1983.

ITASCA DOCUMENT REVIEW

FILE NO.: 001-02-2

DOCUMENT: Sandia Report SAND 84-1003, NNWSI Exploratory Shaft Site and Construction Method Recommendation Report, by Sharla G. Bertram. Printed August 1984.

REVIEWER: Itasca Consulting Group, Inc. (J. Daemen)

DATE APPROVED:

DATE REVIEW COMPLETED: September 24, 1985

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM

The document summarizes the decision making process that has been followed to arrive at two important decisions for the Yucca Mountain Site:

- Exploratory Shaft (ES) construction by means of conventional mining (drilling, blasting, etc.)
- Location of the Exploratory Shaft (ES)

The importance of the document is illustrated by the fact that the site selection procedures and the shaft construction method selection procedure as described at the DOE-NRC NNWSI ES meeting (Willste Building, Silver Spring, MD, 8-27/28-85) closely follow the document. Even though this document is not referenced in the Yucca Mountain Site Draft Environmental Assessment, it remains highly relevant.

The work reported on in this document has been performed during April through June, 1982, and some significant changes have taken place since that time (e.g., exploratory shaft depth), and additional information about the site has become available.

The ES construction method selection has not included any consideration of the potential impact the ES might have on repository performance, an explicit NRC concern. Nevertheless, when read in conjunction with the Exploratory Shaft Performance Analysis Study (letter from D. L. Veith, DOE, Nevada, to J. J. Linehan, NRC, July 15, 1985, with attachments), the decision to conventionally mine the ES appears justified.

Only very limited detail is given in this document about the information on which the ES site selection has been based. It appears that ease of construction of the Exploratory Shaft Test Facility (ESTF) has been a major, possibly driving, consideration. The extent to which the ESTF will allow true comprehensive site characterization remains highly uncertain.

SUMMARY OF DOCUMENT

The document consists of three main parts. Chapter II, following the Introduction, outlines the Figure of Merit Technique, the decision methodology that has been followed to derive the conclusions. The Figure of Merit (FOM) Technique allows a numerical ranking of alternatives based on the sum of a series of numbers assigned to each alternative for each particular criterion that has initially been defined as being important for the comparison between the alternatives being considered. In sum, the selection process is a numerically quantified expert judgment procedure.

Detailed evaluation has been performed of five shaft construction procedures, three for the unsaturated zone (to an 1800 ft. depth): drill (bore) a vertical shaft, conventionally mine a vertical shaft, mine a declined shaft (slope, ramp), and of two alternatives for the saturated zone (3500 ft.): drill or mine a vertical shaft. Criteria applied for the selection, in order of weight assigned, are: site characterization (weight 2.25), shaft constructibility (1.50), cost and schedule (0.75), environment (0.25), health and safety (during construction) (weight 0.25). Conventionally mining a vertical shaft is the clearly preferred choice based on these criteria.

Site selection has been based on three sets of criteria: 1) Scientific, 2) Engineering, 3) Environmental, with weights of 2.75, 1.50, and 0.75 respectively. The scientific criteria include: a) subsurface facilities in good rock, b) maximum vertical thickness of target units, c) distance to potentially adverse structures-sufficiently close to allow exploration, d) volume explored: largest possible. Engineering criteria are: a) cost, b) avoidance of flash flooding, c) waste rock disposal, d) maximize future use of ES in repository. Environmental criteria include: a) archaeological, b) effluents and emissions, c) reclamation, d) surface disturbance. The FOM evaluation clearly identifies the ultimately selected site, in Coyote Wash on the North East flank of Yucca Mountain, as the preferred one. The selection is accompanied by firm recommendations for detailed geological site characterizations prior to finalizing this decision.

PROBLEMS, LIMITATIONS, AND DEFICIENCIES

The main limitation of the document is that the work has been performed in 1982, based on the assumption that ES construction was to start on March 31, 1983 (page 16), and apparently never has been updated in light of information and insight gained since that time. It is improbable that the shaft construction method selection would be affected significantly by information gained since this exercise has been performed. It is far from obvious that the same holds true for the ES site selection. Only a comprehensive analysis of the presently available information from an ES site selection point of view would allow making a judgment as to whether the site selection procedure followed in 1982 would be confirmed by a similar analysis performed today.

Shaft (ES) Construction Method Selection

The main deficiency of the ES construction method selection is that no attention has been paid, and not even mention made, of the potential impact the ES might have on repository performance, especially isolation and containment. This is particularly disturbing in view of the strong emphasis in the selection procedure on assuring that the ES can become effectively integrated as a useful part of an eventual repository.

The main positive aspect of the construction method selection procedure is the high priority assigned to the site characterization function of the ES.

A number of detailed deficiencies can be identified in the shaft construction method selection, but they are unlikely to affect the final conclusion significantly.

Examples of shortcomings:

- The selection postulates the depth of an ES for the unsaturated zone to be 1800 ft.; it now appears (e.g., July 15, 1985 letter from D. Veith, DOE Nevada Operations Office to J. J. Linehan, NRC, with Appendices), that the ES will have a total depth of 1480 ft., with main breakout (test facility) at the 1200 ft. depth. This difference obviously would impact such selection criteria as cost and schedule, comparisons between vertical and inclined shafts, and possibly site characterization and constructibility.

- Very little if any evidence is presented in support of the claim near the bottom of page 4 that mining a vertical shaft is far superior, from a constructibility point of view, than drilling a shaft.
- The "Purpose of Shaft" statement on page 15 emphasizes strongly access to the underground test facilities, but omits mention of site characterization along the shaft. (However, this omission is fully compensated for in later discussions outlining a significant commitment to characterization along the shaft.)
- It would be desirable to provide a justification for the rather strong statement on pages 17-18 that "The extensive shaft construction experience for other locations on the NTS cannot be transferred unambiguously to the Yucca Mountain areas." Even though an unambiguous transfer might not be possible, considerable benefit could be gained from documenting and making available NTS experience.
- It was not realistic of the committee to "consider it unrealistic to erect either a drill rig or a headframe at the end of the decline" (pages 19-20). Erecting drill rigs and/or hoists at great depth is standard practice in multi-level very deep mines. Hence, the conclusion drawn at the end of the first paragraph on page 20 that such an approach would double cost and time is not warranted.

- The statement in the third paragraph on page 36 that drilling fluid loss in the saturated zone should be minimal is based on the assumption that the drilling fluid column will be very short and the drilling fluid light. Experience from NTS shaft drilling might indicate whether this is a reasonable working assumption.
- Have any calculations been made to justify the assumption made in the last paragraph on page 36 that most of the drilling water would be removed with the broken rock?
- The middle paragraph on page 38 makes extremely strong negative statements about shaft drilling. It is highly probable that shaft drillers would argue exactly the opposite case, i.e., that caving can be controlled better with drilling. Certainly a blunt statement that caving would cause a loss of the shaft or at least require a major fishing operation is an excessive generalization, even though the risk exists. Only a comprehensive geotechnical analysis would allow making any firmer statements.
- It is unclear why the authors state (top, page 39), that an unanticipated change in the depth of the breakout zones would be very difficult to accommodate during drilling of a shaft (unless it were a major deepening of the shaft).
- The statement in the middle of page 39 that "The potential for overbreak does not exist with drilling, unless caving occurs" is questionable in light of the implication on page 38 that caving is a major catastrophic event. Local sloughing and erosion is highly likely, especially in the upper part of a drilled shaft, and probably should be expected in light of the considerable hole enlargement logged in core hole USWG-4

(Spengler, et al., 1984, Stratigraphic and Structural Characteristics of Volcanic Rocks in Core Hole USWG-4, Yucca Mountain, Nye County, Nevada, USGS-OFR-84-789, 1984, last two pages-logs).

- The statement on page 40 that "No outside contractors were identified who had the drilling equipment. . ." is surprising in that at least two very well-known contractors have the equipment.
- The last paragraph on page 40 contains several questionable statements. No reason is given for an upper limit slope inclination of 14 degrees. Eighteen (18) degrees is the limit usually quoted for coal mines, based on belt conveyor limits, which, presumably do not apply here. Bullock (Bullock, R. L., General Mine Planning, pages 113-137, Underground Mining Methods Handbook, Society of Mining Engineers of AIME, New York, 1982) quotes 15° as an average value, and a range of 10° to 20°. Considering that the required maximum depth has been reduced significantly, this suggests that costs and time have been overestimated in this method selection. This is not insignificant in this case because an inclined shaft (ramp, slope) would provide considerably better site characterization than a vertical shaft, especially with regard to vertical structural features (and thus, for example, vertical hydraulic conductivity).
- The statement in the last sentence of the first paragraph on Environment (page 41) that "because no site had been selected, the influence of topography could not be considered" seems peculiar, in that presumably typical extremes (e.g., on the mountaintop vs. in a wash) could readily have been considered.
- The second paragraph on page 41, stating that "the surface disturbance associated with drilling the shaft was assumed to be less than for

mining the shaft" is questionable. The comments appear to imply that the mud pit will replace the muck pile, rather than be in addition to it.

- The first sentence on page 43 that "Mining a declined shaft would be less hazardous than mining a vertical shaft" is questionable. Construction of a decline would take considerably longer, resulting in a larger exposure time. Working in declines is dangerous. This statement needs to be supported by evidence, e.g., accident statistics.
- Pages 45, 46, 47, Tables 5 through 7.
  - It is difficult to understand why hydrologic observation in an inclined shaft is deemed less desirable than in a vertical shaft.
  - It is difficult to understand why water and ground control is deemed so significantly better in a vertical mined shaft than in a drilled shaft or an inclined shaft.
  - It is difficult to understand the dramatically lower ranking of drilling with respect to shaft size, given the relatively small shaft diameter (14 ft.) being considered, or why an inclined shaft ranks higher in this regard than a vertical shaft.
  - Experience for sinking inclined shafts definitely is less than for sinking vertical shafts.
  - It is difficult to see why reclamation and surface disturbance would be so significantly better for a drilled shaft than for a mined shaft.
  - The arguments presented in favor of reduced industrial hazards and improved working conditions in an inclined shaft as compared to a vertical shaft are not convincing.

Site Selection

Discussion Summary

The main deficiency of the site selection procedure followed for the ES is that it appears to be driven extremely strongly by ease of construction and cost considerations. A second important deficiency is that very little consideration appears to have been given as to whether or not the selected ES site is representative of a significant part of the potential repository site. A third significant deficiency of the ES site selection is that it might have been dominated by ease of construction considerations at the 3200 ft. level, considerations which clearly are irrelevant at the 1200 ft. (main breakout) and 1500 ft. (maximum ES depth) levels. This comment is based on the application of the screening (exclusion area) criterion with respect to potentially adverse structures (Figure 2). A fourth major deficiency is that many critical screening parameters are not explicitly identified or indicated on the figures (e.g., structures to which exclusion area criteria have been applied) nor specifically referenced. This makes cross-checking of the data base on which the conclusions rely extremely cumbersome and time-consuming, as it requires a reviewer to dig out relevant information from the extensive literature on the Yucca Mountain Site.

The assumption that potentially adverse structures can be explored by means of 2000 ft. long horizontal holes significantly influences the site selection. Presumably the document uses the term "explore" to recognize that no such structures will be characterized, a very regrettable decision. Moreover, no evidence is presented as to the feasibility of drilling such holes in the target horizon rock.

In sum, the site selection procedure presented here is highly questionable.

It is driven by construction considerations, with only very limited consideration given to site characterization. The location of the site ultimately selected will require extensive drifting, well beyond what presently appears to be planned, to characterize potentially adverse structures. However, the location of the site ultimately selected will not preclude characterizing some potentially adverse structures. Therefore, it does not appear that an argument can be developed that the selected site cannot be considered acceptable.

A more detailed discussion of specific problems, limitations and deficiencies follows.

Detailed Discussion of Major Concerns

Ease of construction and minimizing construction costs appears to have been the driving force behind ES site selection. This conclusion is based on the following observations:

- Large areas of the repository block have been excluded from ES site consideration based on set backs from potentially adverse structures (Figure 4).
- Construction costs are assigned the largest merit value for the selected site among all criteria, with the requirement that subsurface facilities be in good rock a close second. The sum of these two is over 30% of the total merit value of the selected site.
- Frequent emphasis on the need to have the underground facilities in "favorable rock conditions" (page 5, first scientific criterion, page 51), in "good rock" (page 74). It is clear from the context that intended is "good" rock, not necessarily "representative" rock. (The latter substitution, i.e., "representative" for "good" was made during the presentation

on the ES site selection at the NNWSI DOE/NRC technical meeting, Silver Spring, MD, August 27-28, 1985.)

- An exclusion criterion has been applied to assure that the ES itself would not be affected by fractures associated with potentially adverse structures (pages 52-54).
- Both primary scientific criteria stress the need to have the subsurface facilities in good rock (e.g., for the second scientific criterion, last paragraph on page 55). While it is reasonable and expected that engineering criteria would consider cost and ease of construction as dominant criteria, it is difficult to see how these could be dominant scientific criteria.

Virtually no attention appears to have been paid to the question as to whether the small rock volume that will be characterized in detail is likely or not to be representative of the exploration block. In fact, the areas that have been eliminated on the basis of structural geology criteria are so large (Figures 2, 4) that a question arising naturally is whether the remaining areas still could be representative, especially with regard to faults, presumably a dominant geological, hydrological, and geomechanical concern at this site. Similarly, the site has been selected with the objective to maximize the probable repository horizon thickness (page 55, last paragraph--last sentence is incomplete, but suggests a potentially significant comment in this context), not to locate the ESTF in a "representative" ("average"?) thickness. Critical selection criteria variables have been based on unreferenced (undocumented?) discussions with USGS personnel (page 52, last paragraph). No mention is made anywhere of lateral or vertical variations in lithology, mineralogy, hydrological, mechanical, geochemical properties.

The selection procedure is strongly influenced by constructibility and cost considerations at the 3200 ft. level, as well as by the application of the scientific criteria at the 3200 ft. level. Because the analyses for the 1600 ft. and 3200 ft. are so intimately intertwined, it is very difficult to separate out these effects. Topics of particular concern in this regard are the exclusion zones (Figures 3, 4, 5) and the assignment of merit values, performance measures, and weighting factors (Tables 13 through 15). Any exclusion areas at the 3200 ft. depth are double the exclusion areas at the 1600 ft. depth (Figure 2, Figure 4?) and/or are offset from areas at the 1600 ft. depth (Figures 4 and 5?).

Detailed Comments

This section lists a series of comments, generally of secondary importance, listed sequentially and referring to specific pages or sections in the document reviewed. Many "comments" actually are requests for clarification or back-up information.

Page 5, Scientific Criteria. It remains entirely unclear why scientific criteria should include location in favorable rock conditions, and in thick target units.

Page 6, Engineering Criteria. Although shaft constructibility is listed here as the primary criterion, it is not discussed in the detailed section on engineering criteria (pages 75-76), nor listed among engineering criteria (Tables 10, 11, 13, 14, and, especially, 15). It is understood that as a criterion it has been addressed explicitly in the exclusion criteria discussion (pages 52, 54).

Page 50, A. Objectives. Although the objectives claim that emphasis will be placed on the unsaturated zone (see also page 5, second scientific criterion), it appears that the saturated zone horizon, because of its greater depth, has dominated the exclusion procedure, and thus might very well have received most emphasis in the actual selection procedure.

Page 51, First Scientific Criterion. The objective of the first criterion is stated as ". . .so that the subsurface facilities would be within favorable rock conditions judged typical of the. . .". The requirement to be "typical" is a sound and high priority scientific objective. However, the addition of the "favorable rock conditions" results in the immediate elimination of what appears to be over half the repository block area (Figure 3). This invites the question as to how "typical" the remaining area really is.

Pages51-55, First Scientific Criterion. This entire discussion is extremely revealing as to the extent to which the emphasis on avoiding construction problems has driven the elimination of large areas from ES site location considerations. It also reveals the extent to which potential problem areas have been excluded from possible characterization. This section could be clarified considerably if each of the structures mentioned would be plotted on a figure, together with its associated exclusion zone.

Page 55, Vertical Thickness of Target Units. The prime objective of the second scientific criterion is to locate "maximum vertical thickness of target units in the unsaturated zone," and heavy emphasis is placed here also on constructibility. "Maximum thickness" implies non-representativeness. Weight has been assigned to thickness of the target units in the saturated zone also, but no indication is given as to how significantly this has influenced the final ratings (Tables 10, 11, 12-bottom section, and particularly 13 through 15).

Page 55, Last Paragraph. Incomplete.

Page 56, Third Scientific Screening Criterion. The stated objective of this criterion is to allow exploration of adverse structures, yet the detailed criteria emphasize staying sufficiently far away from the structures (preferably more than 1000 feet) to assure that detailed exploration (i.e., drifting through them) would be difficult, time-consuming and expensive. Both here and in the executive summary (page 5, third scientific criterion), an explicitly stated scientific criterion is that no subsurface facilities (excluding horizontal holes) should come closer than 100 feet to a potentially adverse structure. It is difficult to envision a scientific rationale for excluding detailed characterization of those features most likely to have an adverse impact on repository performance. In the final analysis, this point becomes rather moot, as none of the five sites selected for detailed comparative evaluation comes closer than 800 feet to an adverse structure (Table 12, 1600 ft. depth). The site ultimately selected is at 1200 feet, suggesting that any characterization of any potentially adverse structure will require horizontal holes at least 1000 feet long, a technique, assuming it is successful, clearly not amenable to detailed characterization.

According to the last sentence of this criterion, preference would be given to those structures expected to influence repository performance. While a highly laudable objective, it is not mentioned anywhere else, and does not appear to have influenced site selection.

Page 57, Volume Explored. The detailed implementation of the fourth scientific criterion, i.e., a site at least one radius away from the block boundary, especially when combined with the boundary set-back (Figure 3) appears to be based on an underlying assumption that boundary faults will not affect repository performance, and therefore do not need to be characterized.

This is far from obvious, and would need extensive justification.

Page 57, Engineering, First Criterion. The last sentence of the discussion, "Highly transmissive zones, major fault rubble zones, and areas of squeezing clay should be avoided" once more points out the extent to which cost and constructibility considerations have driven ES site selection, and raises the issue as to whether any potentially adverse conditions can be characterized in the ESTP as planned.

Page 57, Engineering, Terrain Effects. Terrain effects, although assigned limited weight in the final evaluation (Table 15) take on an extreme importance because they have been used to eliminate virtually all of the repository block from consideration for the ES site (Figure 6). The justification and discussion given (here and on page 66) are totally inadequate to support such a major decision. Considerably more detail is needed in this section before this decision step can be considered acceptable.

Page 58, Repository Compatibility. This third engineering criterion, especially when read in conjunction with section a starting on page 80, clearly confirms the plans to incorporate the ES within an eventual repository. This points out the necessity to consider potential ES impacts on repository performance.

Page 63, Top line. The statement that "all structures shown were treated equally" confirms that the decision process followed contradicts the stated objective of the second scientific criterion that "Preference would be given to those structures expected to influence repository performance."

Page 63, Second paragraph. This paragraph, and, to a lesser extent, the next one, indicate the extent to which exclusion at the 3200 ft. depth, as well as constructibility, have influenced site selection. Because 1600 ft.

and 3200 ft. exclusions are not plotted separately, it is not readily apparent what the results would be if only an unsaturated target horizon were considered.

Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Scales would be very helpful.

Page 66, Third paragraph. It would be very helpful, for an independent assessment, both for the comparative evaluation of the five sites and for the previously applied surface terrain exclusion, to have available the conceptual designs of the surface facilities mentioned here.

Pages 72-80, Evaluation Subcriteria, Weight of Criteria and Subcriteria, Performance Comparison. It is difficult to assess the validity of the site comparisons because of the lack of detail given with regard to numerical ranking for each site and for each parameter.

Page 74, Scientific Facilities in Good Rock. Particularly the last sentence ". . .homogeneous target zones, minimal groundwater in-flow, adequate rock mechanical properties, and absence of faults and adverse fractures" once again confirms the emphasis on constructibility and costs, and raises the representativeness issue.

Page 74, Vertical Thickness of Target Units. Confirms the objective to locate the ES at a site with maximum repository target horizon thickness, rather than representative thickness.

Pages 74-75, Distance to Potentially Adverse Structures. Although "Preference will be given to (explore) those structures that might influence repository performance. . .", it is obvious that the overwhelming majority of those have been eliminated from consideration at this stage.

Page 78, Table 11. Three of the first four subcriteria relate to cost and constructibility, and their cumulative weighting exceeds 40% of the total weight.

Pages 80-82, Repository Compatibility. It appears that the repository as presently conceived (access, shafts) will be drastically different from the possible repository layout (Figure 10) used for this discussion, and presumably for the repository compatibility merit values obtained in Table 15 (e.g., compare Figure 10 with repository lay-outs shown in the Draft Environmental Assessment, pages 5-3, 5-7, or with Figure 6, page 37, and Figure 3, page 10, of Appendix B, Response to Questions from Los Alamos National Laboratory Regarding Quality Assurance Levels for Exploratory Shaft Design and Construction Features, to the D. L. Veith letter of July 15, 1985, to J. J. Linehan, an "Exploratory Shaft Performance Analysis Study"). Although repository compatibility merit values are not strongly discriminatory (Table 15), they constitute between 5 and 15% of the total merit figure for the different sites, and could be altered drastically as a result of different repository designs.

Pages 80-81, Repository Compatibility. The last paragraph of this section reinforces the importance assigned to assuring that the ES can be incorporated within an eventual repository.

Pages 82-84, Engineering Considerations. As no detailed site maps are provided, and no basis given for cost estimates, this section cannot be assessed.

Page 87, Relative Performance. The first assumption, "All potentially adverse structures treated equally", explicitly contradicts the third scientific evaluation subcriterion that "Preference will be given to (explore) those structures that might influence repository performance." (Unless it is assumed that all structures have equal influence.)

Pages 87-88, Relative Performance. It would be of considerable value to have access to the detailed evaluations performed by the Committee, especially for those cases where a consensus initially did not exist.

Page 89, Table 13. It remains very unclear how some of the measures listed in this table have been arrived at. This is particularly true for the (very discriminatory) "good rock" measure. Limiting consideration to the 1600 ft. depth level might change significantly the "Distance to Potentially Adverse Structures" measures, at least for the sites with intermediate rank (S2, S3, S4). The "Volume Explored" measures, strongly discriminatory, appear inconsistent with the radial distances listed in Table 12. According to the last sentence in the discussion of Site 5, page 84, "The repository compatibility would be the same as for Site 4." In Table 13 Site 5 is given a significantly lower "Repository Compatibility" measure than Site 4.

Page 91, Recommendations. Have the recommendations been followed, and are the results available?

RECOMMENDED ACTION

ES Construction Method Selection

It is recommended that the calculations in Tables 5, 6, 7 and 8 be repeated on the basis of differing expert judgments, e.g., in light of previously listed detailed comments, and that sensitivity analyses be performed in order to evaluate whether the final conclusion, a recommendation for a mined vertical shaft, could be affected by reasonable changes in the judgmental input parameters.

It is recommended that a number of the statements discussed in the detailed criticisms be justified better, e.g., by citing specific experience or performing back-up analysis, or that they be modified.

It is recommended that the selection be revisited in light of the significantly reduced ES depth (1480 ft.) compared to the depth (1800 ft.) used in this analysis.

ES Site Selection

It is recommended that the potentially adverse structures to which the exclusion area criteria have been applied (Figures 2, 4, 5) be individually identified and indicated on the figures, and that references be provided in which their characteristics are described. It would be desirable for the NRC to compare the potentially adverse structures, and make an assessment as to whether the potentially adverse structures that can readily (?) be characterized from the ES, i.e., that are within 1000 to 2000 feet from the ES, are likely to be representative of adverse structures.

It is recommended that the exclusion area criteria maps (Figures 2, 4, 5, and all subsequent figures including these) be reconstructed based only on likely repository and ES depths (i.e., omitting all information at the 3200 ft. depth).

It is recommended that scales be provided on all maps and figures.

It is recommended that the entire site selection procedure be updated, i.e., be repeated on the basis of all presently available site information and on the basis of the presently selected probable repository horizon.

It is recommended that a detailed evaluation be made of the adequacy of the decision to eliminate the overwhelming majority of the repository block from consideration for an ES site on the basis of adverse terrain effects for surface construction (Figure 6).

It is recommended that back-up details be obtained on the site comparison evaluation subcriteria (Section D, pages 72-77), weights (pages 77, 78) and performance comparison (pages 77, 79-80), and that NRC perform an independent assessment of the validity of the assigned parameters.

It is recommended that NRC check all site dimensions listed in Table 12.

It is recommended that NRC obtain a copy of the most recent repository layout (especially shaft and access ramp locations), and evaluate the repository compatibility discussion (pages 80-82) and merit values (Table 15) in light of current repository concepts.

It is recommended that NRC obtain and review the detailed Committee evaluations (page 87, last paragraph).

It is recommended that NRC perform its own independent derivation of Tables 13, 14 and 15.

NRC might give consideration to performing its own entirely independent ES site selection, including site characterization, particularly of potentially adverse structures, and with emphasis on those with likely influence on repository performance, as a heavily weighted subcriterion. Alternatively, a recommendation for performing such an analysis could be made to DOE.

It is recommended that the following supporting documents be reviewed to evaluate the statements made in SAND 84-1003:

1. Nelson, D. C., T. J. Merson, P. L. McGuire, and W. L. Sibbet. Conceptual Design Report, Exploratory Shaft Phase I, Nevada Nuclear Waste Storage Investigations, Los Alamos National Laboratory (LA-9179-MS), 1982.

2. Pippin, L. C. May 1982 Letter to S. G. Bertram. Subject: Effects and potential adverse impacts of NNWSI Exploratory Shaft construction.

3. Sandia National Laboratories, SAND82-0436. "Preliminary Repository Configurations for the Nevada Nuclear Waste Storage Investigations, January 31, 1982. Draft.

4. Sinnock, S. and J. A. Fernandez. Summary and Conclusions of the NNWSI Area-to-Location Screening Activity, SAND82-0650, NVO-247, Sandia National Laboratories, Albuquerque, New Mexico, 1982.

5. Spengler, R. W., F. N. Byers, Jr., and J. B. Warner. Stratigraphy and Structures of Volcanic Rocks in Drill Hole USW-G1, Yucca Mountain, Nye County, Nevada. US Geological Survey Open-File Report 81-1349, 1981.