U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

Report of the Peer Review Panel on the Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada

January 1992

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REPORT OF THE PEER REVIEW PANEL ON THE EARLY SITE SUITABILITY EVALUATION OF THE POTENTIAL REPOSITORY SITE AT YUCCA MOUNTAIN, NEVADA

JANUARY 1992

CORE TEAM MEMBERS

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PEER REVIEW PANEL

STAN L. ALBRECHT, Brigham Young University, Provo, UT; WALTER J. ARABASZ, University of Utah, Salt Lake City, UT; JOHN H. BELL, University of Nevada, Las Vegas, NV; F. WILLIAM CAMBRAY, Michigan State University, East Lansing, MI; STEVEN W. CAROTHERS, SWCA, INC. Environmental Consultants, Flagstaff, AZ; JAMES I. DREVER, University of Wyoming, Laramie, WY; MARCO T. EINAUDI, Stanford University, Palo Alto, CA; DON E. FRENCH, Billings, MT; KIP V. HODGES, Massachusetts Institute of Technology, Cambridge, MA; ROBERT H. JONES, Los Gatos, CA; DAVID K. KREAMER, University of Nevada, Las Vegas, NV; WILLIAM G. PARISEAU, University of Utah, Salt Lake City, UT; THOMAS A. VOGEL, Michigan State University, East Lansing, MI; THOMPSON WEBB III, Brown University, Providence, RI.

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INTRODUCTION

The U.S. Department of Energy (DOE) Yucca Mountain Site Characterization Project Office (YMPO) assigned Science Applications International Corporation (SAIC), the Technical and Management Support Services (T&MSS) contractor to the YMPO, the task of conducting an Early Site Suitability Evaluation (ESSE) of the Yucca Mountain site as a potential site for a high-level radioactive waste repository. First, the assignment called for the development of a method to evaluate a single site against the DOE General Guidelines for Recommendation of Sites for Nuclear Waste Repositories, 10 CFR Part 960. Then, using this method, an evaluation team, the ESSE Core Team, of senior YMP scientists, engineers, and technical experts, evaluated new information obtained about the site since publication of the final Environmental Assessment (DOE, 1986) to determine if new suitability/unsuitability findings could be recommended. The Core Team members are identified in Table 1. Finally, the Core Team identified further information and analyses needed to make final determinations for each of the guidelines. The results of these efforts are contained in a companion document: "The Report of Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada" (Younker et al., 1992).

As part of the task, an independent peer review of the ESSE report has been conducted. Expertise was solicited that covered the entire spectrum of siting guidelines in 10 CFR Part 960 in order to provide a complete, in-depth critical review of the data evaluated and cited in the ESSE report, the methods used to evaluate the data, and the conclusions and recommendations offered by the report. Fourteen nationally recognized technical experts (Table 2) served on the Peer Review Panel. The comments from the Panel and the responses prepared by the ESSE Core Team, documented on formal Comment Response Forms, constitute the body of this document.

DIRECTION FOR THE ESSE PEER REVIEW

In his 1989 report to Congress, the Secretary of the U.S. Department of Energy committed to evaluate the suitability of the potential site for a high-level radioactive waste repository by focusing on a search for features that could indicate if the site is not suitable. Responding to this commitment, an activity plan (DOE, 1991a) was prepared under guidance from the Director, DOE Office of Civilian Radioactive Waste Management (OCRWM), to the Associate Director, Office of Geologic Disposal (OGD), to develop a general approach for evaluating site suitability.

The OGD activity plan described the background, defined the organization and management, and developed a general work plan for the task. The work plan described the nature of the work to be done and set forth strategies for developing the method and for conducting the evaluation. The strategy for preparing the ESSE included submitting the ESSE report to external peer review and revising the report based on the review comments.

In response to instructions from the Associate Director, OGD, to the T&MSS Project Manager, the ESSE Task Manager prepared an implementation plan (T&MSS, 1991a). The T&MSS implementation plan described the scope, schedule, and

Table 1. Members of Core Team for Early Site Suitability Evaluation

Name	Organization	Guideline Evaluation/ Area of Expertise
	VOTING CORE TEAM MEMBERS	
Jean L. Younker	Technical & Management Support Services (T&MSS)	Team Lead
Lynden B. Ballou; Michael A. Revelli	Lawrence Livermore National Laboratory	Postclosure Rock Characteristics
William W. Dudley	United States Geological Survey	Postclosure Tectonics Erosion Surface Characteristics
Dwight T. Hoxie	United States Geological Survey	Climatic Change
Richard J. Herbst; Edward A. Patera	Los Alamos National Laboratory	Geochemistry Dissolution Preclosure Rock Characteristics
Larry D. Rickertsen; Janet A. Docka	Weston Technical Support Team	Postclosure System Ease and Cost System Guideline
Arthur R. DuCharme	Sandia National Laboratories	Preclosure Hydrology Preclosure Tectonics
Les E. Shephard	Sandia National Laboratories	Postclosure Geohydrology
Steven R. Mattson	T&MSS	Natural Resources
William B. Andrews	T&MSS	Transportation Offsite Installations & Operations
Gregory A. Fasano	T&MSS	Preclosure Radiological Safety Environmental Quality Socioeconomic Impacts Population Density Meteorology Site Ownership & Control
C. Charles Herrington	T&MSS	Licensing

Table 1. Members of Core Team for Early Site Suitability Evaluation (continued)

Name	Organization	Guideline Evaluation/ Area of Expertise
	VOTING CORE TEAM MEMBERS (continued)	
Robert C. Murray	T&MSS	General Geology and Deputy Team Lead
	OTHER NONVOTING PARTICIPANTS AND OBSERVERS	
Bruce R. Judd	Decision Analysis Company	Decision Analysis
John F. Lathrop	Strategic Insights	Decision Analysis
K. Michael Cline	Woodward-Clyde Federal Services	Tectonics
Jeremy M. Boak; Jane R. Stockey	Office of Geologic Disposal	U.S. Department of Energy Observers

funding necessary to develop and execute a method for evaluating the suitability of a potential repository site against the siting guidelines in 10 CFR Part 960.

IMPLEMENTATION OF THE PEER REVIEW

A peer review serves as a formal mechanism for incorporating expert judgment in assessing the adequacy of work performed within or for the DOE, in this case the development and application of a method for evaluating site suitability. A procedure (T&MSS, 1991b) prescribes the process for performing peer reviews of work assigned to and performed by T&MSS, including designs, plans, test procedures, research reports, materials choices, or site exploration. This procedure is consistent with the U.S. Nuclear Regulatory Commission's generic technical position on peer reviews (Altman et al., 1988).

Under the T&MSS peer review procedure, the ESSE Task Manager received approval to initiate a peer review of the ESSE report from the T&MSS Project Manager and the Manager, Site Characterization Technical Support. The Task Manager then prepared a peer review plan (T&MSS, 1991c), as required by the peer review procedure, describing the ESSE task, the scope and objectives of the review, the necessary size and composition of the peer review panel, and the

Table 2. Peer Review Panel for the Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada

NAME	ORGANIZATION	SPECIALTY
Stan L. Albrecht	Brigham Young University Provo, UT	Socioeconomics
Walter J. Arabasz	University of Utah Salt Lake City, UT	Preclosure Tectonics
John H. Bell	University of Nevada Las Vegas, NV	Health Physics and Radiological Safety
F. William Cambray	Michigan State University East Lansing, MI	Structural Geology, Tectonics
Steven Carothers	SWCA, Inc. Environmental Consultants Flagstaff, AZ	Environmental Quality
James Drever	University of Wyoming Laramie, WY	Geochemistry
Marco T. Einaudi	Stanford University Stanford, CA	Economic Geology
Don E. French	Petroleum Geologist Billings, MT	Petroleum Geology
Kip V. Hodges	Massachusetts Institute of Technology, Cambridge, MA	Tectonics, General
Robert H. Jones	Hazardous Material Systems, Inc. Los Gatos, CA	Transportation Impacts
David K. Kreamer	University of Nevada Las Vegas, NV	Hydrology
William G. Pariseau	University of Utah Salt Lake City, UT	Rock Characteristics, Engineering Geology
Thomas A. Vogel	Michigan State University East Lansing, MI	Tectonics-Volcanology
Thompson Webb III	Brown University Providence, RI	Climatic Change

method and schedule for preparing the peer review report. The reviewers were asked (1) to evaluate the adequacy of the methods and results in the report and (2) to determine if it presents an objective and technically defensible view of the suitability of the Yucca Mountain site. The plan called for a minimum of 12 experts representing the spectrum of technical disciplines specified in the 10 CFR Part 960 guidelines to review the ESSE report. Figure 1 presents the schedule for conducting the peer review. It starts with the request for peer review, then moves through the assembly of the Panel to the actual review and working sessions, and, finally, to the comment response process and revision of the ESSE report.

The fourteen invitees listed on Table 2 ultimately accepted positions on the Panel. Because of the diversity of the membership of the Panel, a nonvoting Chairman was appointed by the Task Manager to organize and coordinate the review and to fulfill the responsibilities of general secretary. The Panel was divided into two informal subpanels, which separated the geotechnical experts and those concerned mainly with environmental quality, transportation, socioeconomic impacts, and radiological safety. After accepting an invitation to participate in the peer review, the members of the Panel were placed under Consultant Agreements with SAIC. The Consultant Agreements were prepared and negotiated by the T&MSS Personnel and Contract Support Department and approved by the YMP Contract Officer.

The ESSE was designated non-quality-affecting in Quality Assurance Grading Report TESS-001. However, because the results of this effort, including the peer review, will be used by the DOE in public interactions and to assess future program planning, and because they may ultimately be used in the licensing process, the task is being subjected to the full rigor of all appropriate Quality Assurance controls. The Panelists were familiarized with the purpose and intent of the YMP Quality Assurance Program and maintained current training during the peer review through reading assignments for revisions to the relevant plans and procedures. Table 3 shows the revision schedule and status of these documents.

The formal YMP records package for this review contains copies of all comment resolution documentation in accordance with appropriate procedures (T&MSS, 1991b; 1991d). The records packages also include copies of the original request for peer review, the Peer Review Plan, and all other pertinent and appropriate documentation.

INDEPENDENCE AND TECHNICAL QUALIFICATIONS OF THE PEER REVIEW PANEL

Members of the Peer Review Panel were selected on the basis of two primary considerations: (1) their independence from the YMP and (2) their recognized technical expertise in their respective fields. Panel members were chosen mainly from university faculties so that their professional, intellectual, and political independence could be maintained throughout the review. Independent consultants were retained in instances where specific technical expertise (such as the petroleum geology of the Great Basin physiographic province) was required for a comprehensive review of information on the Yucca Mountain site. In other instances where the required expertise was genuinely unique to the high-level waste program, such as spent-fuel transportation, persons with selective prior

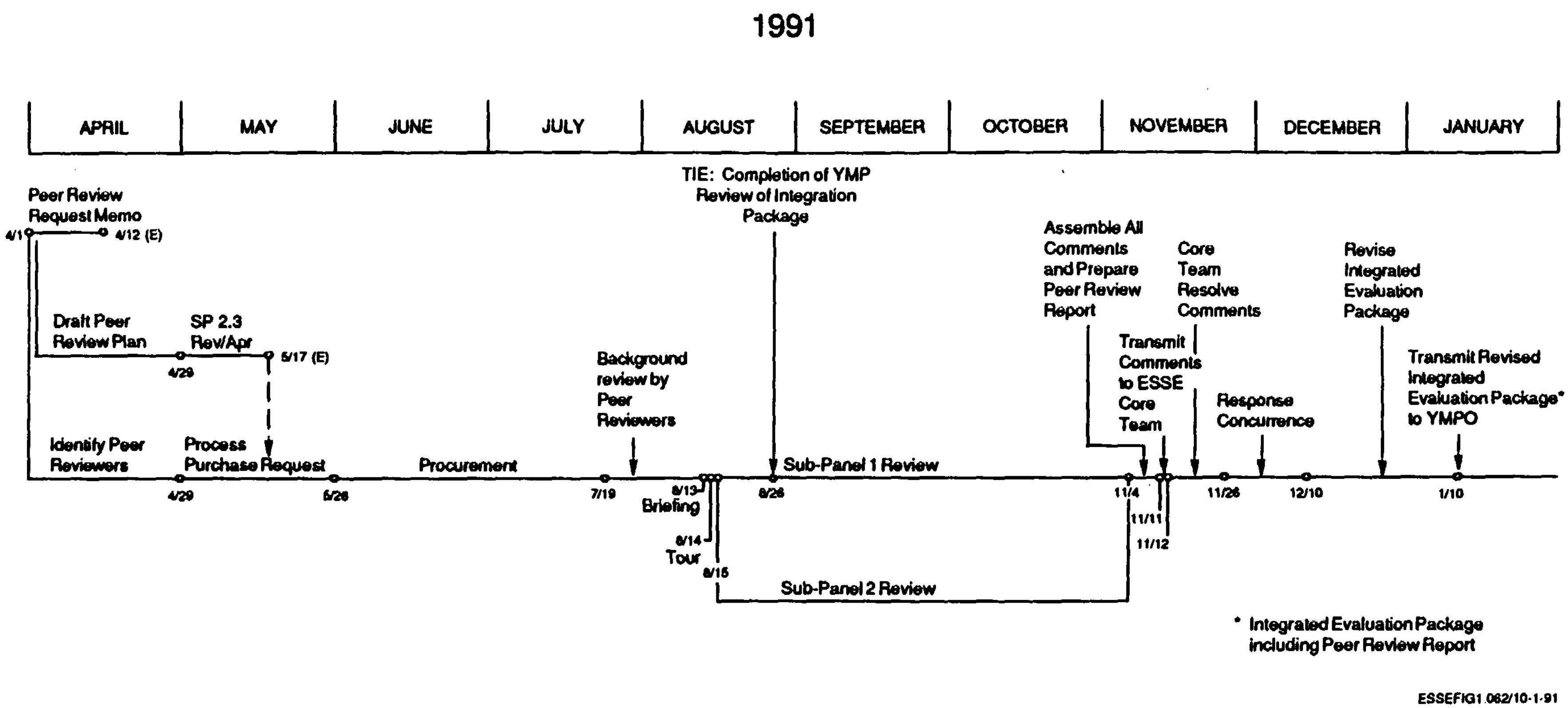

Figure 1. Early Site Suitability Evaluation (ESSE) Peer Review Schedule.

experience were asked to serve on the Panel. The technical qualifications and experience of the Panelists are documented in their resumes, which are presented in Appendix A of this report.

PEER REVIEW WORKING SESSIONS

From August 13 to 14, 1991, the Panel convened in Las Vegas, Nevada, for working sessions with the ESSE Core Team and a tour of the Yucca Mountain site. The working sessions began with formal introductions of all those involved in the task and with overview presentations on the YMP and the high-level waste program, the development and status of the ESSE task, and the structure of the peer review. These topics were followed by brief introductions for each of the 10 CFR Part 960 guidelines by the report section authors, who reviewed the qualifying and disqualifying conditions, explained the issues with respect to the Yucca Mountain site, and provided a summary of the Core Team's evaluation. On August 14, 1991, the Core Team led the Panel on a field trip to the Yucca Mountain site to familiarize them with the site and to continue individual discussions between members of the Core Team and the Panel. Field trip stops at the top of Yucca Mountain for a regional overview, at Trench-14 (the site of the calcite-silica fault deposits), and at Midway Valley (the proposed location for the potential repository surface facilities) included explanatory talks by Core Team members and YMP scientific investigators.

During these working sessions it was explained to the Panelists that they would conduct their review under the T&MSS peer review procedure (1991b), and that the purpose of the review would be to determine whether the ESSE report presents an objective and technically defensible view of the suitability of the Yucca Mountain site. The Panelists were asked to focus their review on their respective areas of expertise, but to submit comments on any of the guidelines, as they felt appropriate. They were also asked to review the Executive Summary, Section 1 (Introduction), and Section 4 (Summary and Recommendations). During their review, the Panelists and Core Team members were encouraged to work closely together to clarify issues and to answer questions raised during the review. Copies of all the references cited in the draft ESSE report and any YMP documents were made available to the Panel upon request. Finally, the Panelists were urged to contact anyone and to request any information that they felt might help them with their review.

On August 28, 1991, the draft ESSE report was transmitted to the members of the Panel along with copies of the review procedure and the formal Comment Response Forms. Following delivery of the report, the Panelists were contacted to schedule individual meetings with Core Team members, T&MSS ESSE staff, and supporting technical experts. These meetings were held intermittently between September 9 and October 4, 1991, to discuss the text of the report, to answer questions, and to ensure that all necessary supporting information was being provided. Figure 2 shows the schedule of working sessions.

From October 23 to 24, 1991, in conjunction with the annual national meeting of the Geological Society of America, geotechnical subpanel working sessions were held in San Diego, California. A meeting of all those able to attend on October 23 was followed on October 24 by two separate discussions: one focused on seismic risk, tectonics, and rock properties and the other on geohydrology and geochemistry.

Table 3. Revisions to Peer Review Planning Documents

Document	Document Number	Revision	Effective Date
Yucca Mountain Site Characterization Project Activity Plan for Development and Implementation of a Method for Early Evaluation of Site Suitability	YMP/91-1	0 1 2	1/31/91 10/3/91 In final signature
T&MSS Plan, "Implementation Plan for Developing and Implementing a Method for Early Evaluation of Site Suitability"	T&MSS/PM-91/001	0 1 2 3	1/30/91 6/13/91 7/31/91 10/17/91
T&MSS Plan, "Peer Review Plan for Early Site Suitability Evaluation"	None	0 1 2	6/14/91 8/23/91 10/15/91
T&MSS Procedure, "Peer Review"	T&MSS SP-1.62	1	5/21/91

No formal subpanel working session was scheduled for the Panelists covering socioeconomic impacts, environmental quality, transportation, and radiological safety because these Panelists were concentrating on technically distinct guidelines. However, they were encouraged to communicate informally among themselves, as appropriate. Because of inevitable schedule conflicts, not all the Panelists were able to attend each of the appropriate working sessions. In these instances, special arrangements were made for them to come to Las Vegas and the Yucca Mountain site or to meet elsewhere.

RESULTS OF THE PEER REVIEW

This peer review differed from several others conducted within the YMP in that no effort was made to reach formal consensus of the Peer Review Panel on the results and recommendations of the review. Because of the diversity of expertise needed on the Panel to provide a thorough examination of the method and substance of the 10 CFR Part 960 guideline evaluations in the ESSE report, it was determined that no comprehensive set of comments could be made in any one technical area. Numerous informal cross-disciplinary conversations occurred,

ESSE MEETINGS
SEPTEMBER - OCTOBER 1991

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
2 *LABOR DAY HOLIDAY*	3	4	5	6
9	10 CAROTHERS (Flagstaff) - Fasano - Murray	11	12 OCRWM & EEI (DC) - Younker - Murray - Fogdall	13 FRENCH (Billings) - Mattson
16 BELL (LV) - Fasano - Andrews HODGES (Cambridge) - Mattson - Dudley - Younker - Stockey - Cline	17 CAMBRAY & VOGEL (Lansing) - Mattson - Dudley - Murray - Younker	18 KREAMER (LV) - Hoxie - DuCharme - Hopkins - Murray	19	20 ARABASZ (LV) - DuCharme - Cline - Gibson - Younker - Stockey ALBRECHT (LV) - Fasano - Kimble - Murray
23	24 DREVER (Laramie) - Herbst - Canepa - Murray	25	26	27 WEBB (Providence) - Hoxie - Murray
30	1 EINAUDI (Stanford) - Mattson - Stockey - Younker	2 JONES (Los Gatos) - Andrews - Younker	3	4 PARISEAU (SLC) - Ballou - Revelli - Herbst - Younker

ESSECAL.075/1-24-92

Figure 2. Schedule of individual working sessions between Peer Review Panelists and Core Team authors and technical experts, September - October, 1991.

and common concerns arose during each of the working sessions. So, while the reviewers were free to comment on any section of the ESSE report as they felt appropriate, the comment record constituting the body of this report is largely the result of reviews by the fourteen independent technical experts. The focus of the ESSE task remains with the ESSE report itself, and the substantial points raised in this review have been incorporated into the final ESSE report.

The charter of each of the Panelists was to examine the method developed to evaluate the Yucca Mountain site against the siting guidelines in 10 CFR Part 960 and then to determine the adequacy of the technical information presented and the conclusions advanced on the basis of that information. The final ESSE report (Younker et al., 1992) has been modified on the basis of negotiated resolutions to these review comments. However, some of the responses to the comments included recommendations for future action beyond the scope of the ESSE task. These recommendations include specific commitments to modify test plans or strategies and more general commitments related to planning and decision-making by the DOE. At DOE direction, these commitments will be tracked through the appropriate administrative procedure (DOE, 1991b).

At the working sessions in San Diego, it became apparent that the geotechnical subpanel members, working independently, had identified several common concerns with the site characterization program. A brief consensus statement citing three concerns was prepared, circulated, and reviewed within the subpanel. Nine of the ten geotechnical subpanel members concurred with the statement (with one providing additional comments). The remaining panel member did not choose to participate in developing the consensus position. The statements were then submitted under signatures from each of the nine subpanel members to the ESSE Task Manager. They recommended (1) a comprehensive test prioritization to focus site characterization on determining if the site is in any way unsuitable, (2) a greater emphasis on interdisciplinary communication and coordination, and (3) a risk-based approach to quantify residual uncertainties associated with technical issues at the site. The full text of this statement is presented in Appendix B.

NOTES ON THE CONTENTS OF THIS REPORT

The following general notes on organization, structure, and content of this report are provided to facilitate readability. The contents of this report are as follows:

- Introduction section
- Fourteen sections (one for each peer reviewer) each containing
  - Signed Comment Resolution Records
  - Formal Comment Response Forms, each containing the comment offered by the Peer Reviewer, the response developed by Core Team authors, and the comment resolution statement
  - List of references cited in comments and responses
- Appendices
  - Geotechnical Subpanel Consensus Statement
  - General Comments from Peer Reviewers
  - Resumes/Curricula Vitae for Peer Reviewers

In each of the sections containing comments offered by Peer Reviewers, the Comment Resolution Record is presented first to provide the reader with the summary concurrence/verification that the the reviewer's comments have been resolved. In reading each reviewer's section, please note that the text of a comment may continue to subsequent pages. An "END OF TEXT" statement will be found at the conclusion of each comment. Likewise, the response may continue on subsequent pages but begins after the end of the comment section. For each reviewer, a list of references cited in the text of the comments and responses is provided at the end. The page citations in these references refer to the August 1991 draft of the ESSE Report that was submitted to the Peer Review. As the ESSE Report has now been revised (Younker et al., 1992), these page citations may no longer be appropriate.

The Appendices contain the following additional materials:

- Geotechnical consensus statement (Appendix A)
- General comments (Appendix B) from some of the reviewers. (Note that the Peer Reviewers have agreed that these are general comments or opinions concerning the review and/or the program and are not submitted as comments to be resolved by the ESSE Core Team)
- Collection of resumes or curricula vitae for each of the Peer Reviewers (Appendix C)

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	1-24	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	1-24	

Comments 1 through 24 are attached.

Peer Reviewer Stan L Albrecht Date 12-13-91

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ______ The following comments have not been adequately addressed:

Peer Reviewer Stan L Albrecht Date 12-13-91

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-13-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 1.2.4
7. Page 1-12
8. Paragraph Figure 1-2

9. Comment

On the disqualifying condition portion where you ask if the conclusion could change, I would substitute "possibly" for "likely." You really don't believe the conclusion will change but, because it possibly could, additional data are called for.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The reviewer makes a good point, which was also made in Dr. Hodges' Comment #2. The figure and its caption will be changed as shown on the attached figure (will be Figure 1-3).

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

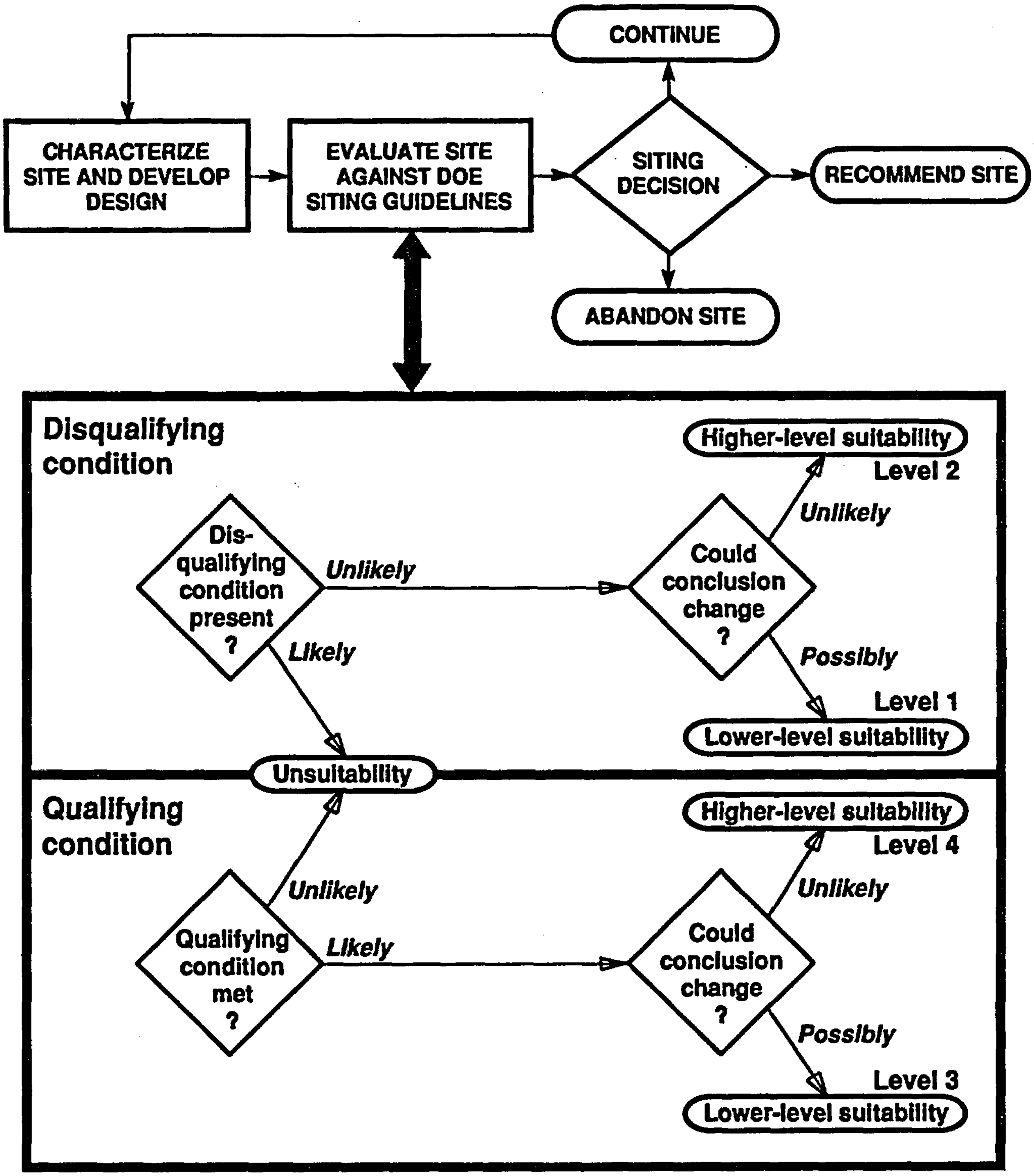

Figure 1-3. Decision logic for suitability and unsuitability findings, based on DOE Siting Guidelines. The primary distinction between lower- and higher-level suitability findings is the likelihood that further information will change conclusions about the suitability of the site for repository development. A higher-level suitability finding is supported when it is unlikely that additional data will change current conclusions; a lower-level suitability finding is supported when additional information could possibly change current conclusions.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.2
7. Page 3-3
8. Paragraph 3, sentence 3

9. Comment

Reference is made here to measures that are available to mitigate unacceptable impacts. Should more be said about the kinds of measures that DOE has in mind?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

While the discussion of potential environmental, socioeconomic, and transportation-related impacts and mitigation measures in Section 3.2 is general, the sentence in question will be modified to read as follows: "...the measures available to mitigate unacceptable impacts, such as avoiding the impacts altogether, minimizing impacts, rectifying impacts, and compensating for the impacts."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.1.1
7. Page 3.3.1-2
8. Paragraph 2

9. Comment

Will pre-site characterization data continue to be collected to establish a baseline for project monitoring and mitigation efforts? I understand that regular monitoring reports are being prepared to document any project-related changes in the employment and population base. It might be helpful to note this in the ESSE document. The importance of the monitoring reports is increased because of the density of population issue that is raised in the disqualifying condition (10 CFR 960.5-2-1(d)), though it is extremely unlikely that this would ever become a factor.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Data collection for the socioeconomic monitoring program will continue through the site characterization phase, but the information developed for the socioeconomic monitoring program is not sufficiently detailed to address the population density and distribution factors specified in the guidelines. However, demographic information developed in support of the radiological monitoring program does address the ongoing need to evaluate population density and distribution factors.

In response to comments from Dr. Bell, a paragraph will be added to the review of information obtained since the Environmental Assessment in Section 3.3.1.1.3 (page 3.3.1-4). That paragraph will include population density and distribution information from the radiological monitoring program to address the concern raised in this comment. (See proposed response to Dr. Bell's Comment #1.)

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.4
7. Page 3.3.1-4
8. Paragraph 4

9. Comment

It will be important, of course, to confirm this with 1990 census data.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The discussion in the second paragraph of Section 3.3.1.1.4 indicates that data from the 1990 census will have to be evaluated in relationship to the population density and distribution factors incorporated in the disqualifying conditions.

Additionally, in response to this comment and comments from Dr. Bell, a paragraph will be added to the review of information obtained since the Environmental Assessment in Section 3.3.1.1.3 (page 3.3.1-4). That paragraph will include an evaluation of the preliminary information from the 1990 census in terms of the closest highly populated area and the closest 1 mile by 1 mile area with a population of 1,000 or more individuals. (See proposed response to Dr. Bell's Comment #1.)

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2
7. Page 3.3.2-1
8. Paragraph 1

9. Comment

Since reference is made to protecting the public and the environment from all potential impacts, it seems that a case can be made for greater reference to specifically social and perception-based concerns that might flow from the project. Even if such work is not done by the SAIC team in this phase of the project, relevant work done by others should be acknowledged.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The third, fourth, and fifth sentences in the third paragraph of Section 3.3.2.2.3 (page 3.3.2-13) will be replaced with the following text: "The State of Nevada has initiated a comprehensive socioeconomic assessment program, which includes evaluation of potential economic and demographic effects, as well as potential effects on public services and facilities. A major focus of the State's socioeconomic program is on potential sociocultural impacts and on potential perception-based impacts on tourism and economic development. While the complete results of these assessments are not yet available, the State of Nevada has produced reports regarding particular components of its program and an interim report (Mountain West Research, 1989) that summarizes the results of its entire socioeconomic program. In those reports, the State of Nevada has indicated that population-related impacts on public infrastructure and fiscal capacity are expected. The reports also suggest that perception-based impacts on tourism and economic development are anticipated,

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 5 of 24

2. Page 2 of 2

3. Name Stan L. Albrecht
(Print Name)

4. Date November 10, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

but the extent of those effects is not yet fully understood."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2
7. Page 3.3.2-1
8. Paragraph last

9. Comment

When will the types of impacts that are to be addressed be defined?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The discussion in Section 3.3.2 (last paragraph) indicates that the "...types of impacts that will need to be evaluated for this group of guidelines have not yet been fully defined..." The discussion in the previous paragraph also indicates that while those impacts have not been defined, "...the impacts that are likely to be of concern can be identified." For clarification, the following text will replace the last sentence on page 3.3.2-1: "The ongoing programs to address environmental quality, socioeconomic, and transportation issues and concerns indicate that some types of impacts have been identified and are being assessed. However, additional information concerning the environmental characteristics of the site and repository design, as well as ongoing input from State and local officials and from residents of Nevada, is necessary to fully define the types of impacts that are to be addressed."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2
7. Page All
8. Paragraph

9. Comment

In a typical study of large-scale developments, demographic change is perceived as the prime drive of social impacts associated with the project. It is important to acknowledge that demographically-driven changes are important, as are the social infrastructure impacts that follow from the demographic changes, but it is also important not to ignore or downplay other categories of impacts, such as perceptions of the hazards and risks associated with nuclear waste storage.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified to include (following the first sentence): "Typically the socioeconomic impact assessment for a project of this magnitude includes an evaluation of potential local and regional economic and demographic effects and the resulting changes in public infrastructure requirements, as well as the social effects that may occur both as a direct result of the project and as a result of the involvement of special interest groups. An evaluation of the potential effects that may result from public response to the controversial nature of the project and the public perception of the risks associated with the transportation and storage of high-level nuclear waste may also be necessary because the extent and duration of many economic, demographic, and social changes are related to public perception. The possibility that many of these potential social and economic effects could be long term and may extend beyond the operational life of a repository will need to be addressed in the final assessment of

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 7 of 24

2. Page 2 of 2

3. Name Stan L. Albrecht
(Print Name)

4. Date November 10, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)
socioeconomic impacts."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2
7. Page All
8. Paragraph

9. Comment

This project is quite unlike anything that has ever been done before. The uniqueness of the project--its focus, size, timeframe, and national scope--really demands an assessment process that may be quite unlike the kinds of things that normally are done in social assessment efforts. Much of the methodology that is drawn on is designed for more "normal" development projects rather than for very highly sensitive projects which will continue to attract national and even international attention. Part of the challenge is not the adjustment of a community--local residents and their governmental infrastructure--to an influx of new workers, but local, county, and state reaction to the federal government and its various representatives, and to the prospect of siting an extremely controversial repository for highly dangerous materials.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified to better explain the socioeconomic impact assessment for the potential repository. The changes to that paragraph (see response to Dr. Albrecht's Comment #7) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2
7. Page All
8. Paragraph

9. Comment

Important social psychological, interpersonal, and psychological factors come into play in this arena. While most of the [work] on these issues is apparently being delayed until the EIS process, I would at least acknowledge the fact that these issues will require some attention before the project is completed. An "accident" at the site or along a transportation route would have very substantial implications. In addition, it is a very long-term project with possible impacts that extend well past construction, operation, and even closure. The implications of this for the social assessment process should be noted.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified to better explain the socioeconomic impact assessment for the potential repository. The changes to that paragraph (see response to Dr. Albrecht's Comment #7) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 10 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2
7. Page All
8. Paragraph

9. Comment

Where will regional consequences be addressed? If they are to be addressed in a format other than the EA process or the ESSE summary (Younker et al., 1992), this should be noted.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified to better explain the socioeconomic impact assessment for the potential repository. The changes to that paragraph (see response to Dr. Albrecht's Comment #7) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 11 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2
7. Page All
8. Paragraph

9. Comment

In recognition of the fact that there will be some very active interest groups following the progress of the project, it might be a good idea to acknowledge their potential role in the public participation phase of the effort. The environmental and anti-nuclear social movements are likely to play a very active role before all is said and done. To the extent to which this is the case, the whole political process associated with nuclear waste storage becomes a legitimate focus of the social assessment process.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified to better explain the socioeconomic impact assessment for the potential repository. The changes to that paragraph (see response to Dr. Albrecht's Comment #7) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 12 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2
7. Page 3.3.2-11
8. Paragraph 1 & 2

9. Comment

I find the disconnection between the qualifying and the disqualifying conditions to be interesting. In most other instances in the report, disqualifying conditions are typically the obverse of the qualifying conditions. Here the qualifying conditions are quite specifically socioeconomic in nature, while the disqualifying condition has to do with water quality. Should this receive further explanation in the body of the report?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following sentence will be inserted in the second paragraph of Section 3.3.2.2.1 (page 3.3.2-11) (following the second sentence): "The discussion in 10 CFR Part 960 indicates that the disqualifying condition could have been included in the guideline for natural resources, but was added here because the DOE believes that the most serious effects of a significant degradation of major water sources would be socioeconomic effects."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 13 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2
7. Page 3.3.2-11
8. Paragraph 5

9. Comment

Substantial work has been completed since the Environmental Assessment. It is my impression that significantly more attention has been given to that work in other parts of the ESSE than in the socioeconomic section. It is noted in the Peer Review Plan, for example, that "Non-DOE efforts have... contributed to this information base, including studies supported by the State of Nevada..." I have reviewed the very extensive list of studies and reports prepared by the State of Nevada Nuclear Waste Projects Office and believe that a number of them are relevant to the issues at hand. Most of these studies have now been released for public consumption and so are readily accessible. At the least, it would seem important to acknowledge the existence of this body of work and to summarize the major findings that are relevant to the conclusions reflected in the ESSE. For example, might it not be a good idea to cite the attitudinal and community studies conducted by the State? While you may be operating under the assumption that DOE is not required by statute to do this kind of work, at least until the EIS process begins, I think it would be a mistake to ignore the

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to Dr. Albrecht's Comment #5, the third paragraph of Section 3.3.2.2.3 (page 3.3.2-13) will be modified to indicate that the State of Nevada has initiated a comprehensive socioeconomic program, which includes evaluations of potential sociocultural effects and perception-based impacts on tourism and economic development. That response also addresses the concerns expressed in this comment (see response for the modification).

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 13 of 24
2. Page 2 of 2
3. Name Stan L. Albrecht (Print Name)
4. Date November 10, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

fact that a significant amount of work is being done on socioeconomic issues independent of the SAIC effort.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 14 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.1
7. Page 3.3.2-11
8. Paragraph 1

9. Comment

It is important to emphasize that while demographic changes will drive many of the other socioeconomic changes that occur, particularly the infrastructure needs, there are other types of impacts that are also important. These should not be ignored. This seems particularly relevant since Section 3.1.2 notes that lifestyle, social and esthetic values are pertinent areas of concern in the project.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified to better explain the socioeconomic impact assessment for the potential repository. The changes to that paragraph (see response to Dr. Albrecht's Comment #7) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 15 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.1
7. Page 3.3.2-11
8. Paragraph 3

9. Comment

Impacts can result from project-driven changes in the social environment, as well as from public perceptions of possible impacts. In this case, the latter may be equally as important as the former. In fact, public response will likely be affected as much by perceived impacts as by actual changes that are linked to the project. This deserves at least some mention.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified to better explain the socioeconomic impact assessment for the potential repository. The changes to that paragraph (see response to Dr. Albrecht's Comment #7) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 16 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.2
7. Page 3.3.2-11 & 3.3.2-12
8. Paragraph para. 1 of 3.3.2.2.2

9. Comment

Should more be said about the kind of negotiation process that will occur with affected political entities? This will be such an important part of the decision-making process that it may deserve some further, if only brief, mention.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be modified by replacing the second sentence with the following new paragraph:

"The guideline indicates that the qualifying condition will be addressed through '...a process of analysis, planning, and consultation among the DOE, affected State and local government jurisdictions, and affected Indian tribes.' The DOE has continued efforts to accomplish this coordination with affected parties by developing the Yucca Mountain Site Characterization Project Socioeconomic Plan (DOE, 1991e). That document, which was prepared in consultation with the State of Nevada and affected counties, specifies a process of consultation, communication, and coordination between the DOE and the affected parties to ensure that socioeconomic issues and concerns are identified, potential socioeconomic effects are evaluated, and appropriate impact mitigation strategies are developed and

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 16 of 24
2. Page 2 of 2
3. Name Stan L. Albrecht (Print Name)
4. Date November 10, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

implemented. The process of interaction between the affected parties and the DOE requires coordination of their respective socioeconomic programs to avoid unnecessary duplication of efforts and is designed to be sufficiently flexible to respond to changes in social and economic issues associated with the project."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 17 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.2
7. Page 3.3.2-11
8. Paragraph 5

9. Comment

It is important to recognize that this is not a "study" using an approved "method." Rather, it is an ongoing process that must be flexible and adaptive to a changing social and political environment. The project will change as it develops, as will the public reaction to it. This makes the task of the social science researcher even more difficult than it might otherwise be.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second sentence in the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be expanded into a new paragraph that explains the process of analysis, planning, and coordination specified in the qualifying condition. The changes to that paragraph (see response to Dr. Albrecht's Comment #16) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 18 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.2
7. Page 3.3.2-12
8. Paragraph 1

9. Comment

Should there be more on the kinds of coordination that has occurred and that will occur with the state, tribes and communities as specified in NWPA?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second sentence in the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be expanded into a new paragraph that explains the process of analysis, planning, and coordination specified in the qualifying condition. The changes to that paragraph (see response to Dr. Albrecht's Comment #16) address this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 19 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.2
7. Page 3.3.2-12
8. Paragraph 2

9. Comment

It should be noted that if further socioeconomic analysis is delayed until the EIS, the baseline for the EIS will be a characterized site. A great deal of consequence will obviously have happened prior to that point. It will be important that a good baseline be established prior to any impacts associated with the project, particularly in a socioeconomic environment that is changing as rapidly as it is in the Clark County area.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The third paragraph of Section 3.3.2.2.3 (page 3.3.2-13) will be modified to better explain the socioeconomic study area and to address the temporal issues raised by this comment. (See the response to Dr. Albrecht's Comment #21.)

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 20 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.3
7. Page 3.3.2-12
8. Paragraph 1

9. Comment

The guiding legislation requires that any socioeconomic impacts associated with the project can be mitigated. I believe that this will be the case. Unless there are impacts substantially greater than those identified in the Environmental Assessment, in the Section 175 report, or in other studies that have been done, I believe that the requirements for mitigation can be met. However, it will be important to make it clear that the mitigation package will be a negotiated package with significant involvement from state and local officials, as well as DOE. Strategies for mitigating typical impacts associated with demographically-driven infrastructure needs are well-known. Strategies for dealing with potential impacts on tourism and economic development are less-well understood. It might be a good idea to acknowledge this fact.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Section 3.3.2.2.2 (page 3.3.2-12) will be modified to include the following paragraph (prior to the last paragraph of the section):

"The guideline also requires that socioeconomic impacts '...induced in communities and surrounding regions by repository siting, construction, operation, closure, and decommissioning can be offset by reasonable mitigation or compensation...' The Nuclear Waste Policy Act (NWPA, 1983) requires the DOE to avoid or minimize adverse socioeconomic impacts to the maximum extent practicable and gives the DOE the authority to provide financial and technical assistance to mitigate unavoidable impacts. The Section 175 Report (DOE, 1988) and the Socioeconomic Plan for the Yucca Mountain Site Characterization Project (DOE, 1991) both indicate that the process of identifying socioeconomic impacts and developing appropriate mitigation strategies requires communication and cooperation between the DOE and

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 20 of 24
2. Page 2 of 2
3. Name Stan L. Albrecht (Print Name)
4. Date November 10, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

the affected parties. While the strategies for mitigating population-related impacts on public services and facilities are relatively well known, methods for addressing potential social impacts and perception-based impacts are less clearly understood. The DOE will need to work with the affected parties to determine which socioeconomic effects are considered adverse impacts and how they can most efficiently be addressed with reasonable mitigation or compensation."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 21 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.3
7. Page 3.3.2-13
8. Paragraph 1

9. Comment

I continue to have questions about what constitutes the study area. I acknowledge that political factors may force the inclusion of counties that would, on the basis of empirical data, not normally be included. Nevertheless, I recommend that most of the effort be concentrated on Nye and Clark counties and, to the extent that something must be done beyond that, that it be limited to contiguous counties. Exceptions might occur when looking at potential impacts along major transportation routes.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The third paragraph of Section 3.3.2.2.3 (page 3.3.2-13) will be modified to include (following the first sentence): "Because of the rapidly changing socioeconomic environment of the area, particularly in Clark County, and the need to develop a complete data base of information for use in preparation of the Environmental Impact Statement, the DOE has already initiated many components of the socioeconomic program for the Yucca Mountain Site Characterization Project. The socioeconomic studies conducted by the DOE primarily have focused on Nye, Clark, and Lincoln counties, and on the State of Nevada as a whole (See Section 3.3.2.1.3.1 for a description of the program to address Native American concerns). As circumstances require, socioeconomic studies will be needed to examine other potentially affected areas, such as counties or communities that may experience socioeconomic effects related to potential rail and highway access routes to the Yucca Mountain site."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 22 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.4
7. Page 3.3.2-14
8. Paragraph (Discussion)

9. Comment

A significant and quite unique feature of the Nuclear Waste Policy Act is the requirement for coordination and consultation between the federal government and the affected states, Indian Tribes, and communities. It would be helpful if some additional information on just how this is to be done is included, at least in a footnote to the report. For example, I know that SAIC and its consultants have been involved in quite extensive work with Native American groups. I would urge that this work be reviewed and summarized. As I understand it, some of this work is designed to assess the meaning and value the study area holds for Native Americans. It is my impression that this is an important effort and should be reflected in the ESSE, at least in summary form. While there are no Native American reservations that will be directly affected, the sensitivity to these concerns that is reflected in the work that is being done should be demonstrated in the report.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and several of the other comments provided by this reviewer, the second sentence in the second paragraph of Section 3.3.2.2.2 (page 3.3.2-12) will be expanded into a new paragraph that explains the process of analysis, planning, and coordination specified in the qualifying condition. The changes to that paragraph (see response to Dr. Albrecht's Comment #16) address this comment.

The DOE has an extensive program to involve Native American groups in the evaluation of the Yucca Mountain site. However, those studies are components of the environmental program and are addressed in Section 3.3.2.1.3.1. A parenthetical reference to the Native American work has been included in the paragraph added in response to Dr. Albrecht's Comment #21.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 23 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.2.4
7. Page 3.3.2-14
8. Paragraph 2

9. Comment

Should there be more detail on the types of mitigation that might occur? I agree with the Core Team that impacts that are likely to be associated with the project will be mitigatable. This is particularly true of the typical infrastructure impacts that follow from demographic change in the affected communities. As noted earlier, it is less clear that effective mitigation mechanisms are available for addressing the more social and perception-based impacts.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to Dr. Albrecht's Comment #20, Section 3.3.2.2.2 (page 3.3.2-12) will be modified to include a paragraph that describes the process of identifying socioeconomic impacts and developing appropriate mitigation strategies. That response also addresses this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 24 of 24
2. Date November 10, 1991
3. Reviewer Stan L. Albrecht
4. Organization Brigham Young University
5. Revision Draft/Date August 1991
6. Section 3.3.2.3
7. Page 3.3.2-15
8. Paragraph All OF 3.3.2.3

9. Comment

It is important for someone to be examining the socioeconomic impacts that might be associated with transportation of waste materials to the site. It is not clear that that is being done.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to Dr. Albrecht's Comment #21, the third paragraph of Section 3.3.2.2.3 (page 3.3.2-13) will be modified to include a discussion of the geographic scope of DOE's socioeconomic studies, including the assessment of potential socioeconomic effects resulting from development of transportation access routes. The modified text is given in that response which also addresses this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

REFERENCES FOR DR. STAN L. ALBRECHT

ALBRECHT

DOE (U.S. Department of Energy), 1986. Final Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada, 3 volumes DOE/RW-0073 Office of Civilian Radioactive Waste Management, Washington, DC.

DOE (U.S. Department of Energy), 1988b. Section 175 Report: Secretary of Energy's Report to the Congress Pursuant to Section 175 of the Nuclear Waste Policy Act, As Amended, DOE/RW-0205, Office of Civilian Radioactive Waste Management, Washington, DC.

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Dr. Walter J. Arabasz

PRECLOSURE TECTONICS

University of Utah
Salt Lake City, UT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.†
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	15, 16, 21, 26, 29	1-14, 17, 20, 22-25, 27, 28, 30 † *Most of these comments are minor or editorial.* — *WJA*
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	18, 19, 31	

Comments 1 through 31 are attached.

Peer Reviewer Walter J. Arabasz Date November 12, 1991
Walter J. Arabasz

Comment Resolution Record

Yes ✓ The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ____ The following comments have not been adequately addressed:

Peer Reviewer Walter J. Arabasz Date December 8, 1991
Walter J. Arabasz

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-8-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section Executive Summary
7. Page E-6 ff.
8. Paragraph

9. Comment

(editorial)

The section entitled, "Findings Based on Site-suitability Evaluations," outlines the logic for the designation of findings in a confusing way for the executive summary. The confusion stems from describing higher and lower levels only for suitability findings. Appendix III of 10 CFR Part 960 outlines higher and lower levels for unsuitability findings too (as later explained in section 1.2.2 of the Introduction). The concept of higher versus lower level is distinct from, and should be explained separately from, the concept of suitability versus unsuitability.

In Tables E-3 and E-4, the reader encounters "Lower-level finding" and "Higher-level finding"--dissociated from the word suitability, as earlier connected at the top of page E-7. Hence, initial confusion results in trying to understand the seemingly contradictory meaning of a "higher-level (suitability) finding" for a "disqualifying (unsuitable) condition." A better

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Text of the executive summary will be substantially revised.

To clarify the logic for the designation of findings, the text beginning with the fourth paragraph on page E-6 will be revised to read as follows:

"The Siting Guidelines specify two levels of suitability findings, depending on the likelihood that new information could change current conclusions about the site. These levels are designated "lower-level" and "higher-level" suitability findings in this report and are defined as follows:

Lower-level Suitability Finding	A lower-level suitability finding can be supported when (1) a disqualifying condition does not appear to be present, but additional information could change the conclusion; or (2) a qualifying condition appears to be present,

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

introductory summary of the complicated logic will help many readers unfamiliar with Appendix III of 10 CFR Part 960. (See also Comment 4.)

END OF TEXT

10 Proposed Resolution (continued)

	but additional information could change the conclusion, and thus, the site could subsequently be found to be unsuitable.
Higher-level Suitability Finding	A higher-level suitability finding can be supported when (1) a disqualifying condition is not present and additional information is unlikely to change the conclusion; or (2) a qualifying condition is present and additional information is unlikely to change the conclusion. This finding would be supported if there is high confidence in the conclusion based on current information.

A higher-level suitability finding for a particular disqualifying or qualifying condition does not necessarily mean that all remaining uncertainties regarding the conditon have been resolved. Rather, a higher-level suitability finding means that gaining additional information to resolve the remaining uncertainties is unlikely to change the present conclusion about the suitability of the site."

The footnotes to Tables E-3 and E-4 will be revised as follows:

Table 3:

LLF: Lower-level suitability finding is supported
HLF: Higher-level suitability finding is supported

Table E-4:

HLF: Higher-level suitability finding is supported
LLF: Lower-level suitability finding is supported

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section Executive Summary
7. Page E-7
8. Paragraph 3

9. Comment

(minor)

The section entitled, "Summary of Evaluation Results," may be an appropriate place for the authors to elaborate on the concept of "consensus" and their team approach to reaching agreement on qualifying versus disqualifying conditions.

It was particularly helpful for me (1) to understand that a higher-level finding required absolute unanimity among the technical specialists making up the core team (explained later on p. 1-16 of the Introduction) and (2) to be informed that the team was more conservative in voting on qualifying conditions than on disqualifying conditions.

I was given to understand that--consistent with language in 10 CFR Part 960--disqualifying conditions were held to be less important than qualifying conditions and were perceived to be intended as a tool for site screening. If

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text at the end of the first paragraph in the section entitled "Summary of Evaluation Results" will be modified to read as follows:

"... The consensus of the Core Team is that the new information corroborates the findings of the EA that the site is suitable for characterization. In some cases, the evidence supports stronger findings regarding suitability for repository development. The consensus findings by the Core Team are summarized in Tables E-3 and E-4."

In addition, text will also be added to the previous section (two paragraphs earlier) to explain that a "consensus" has a special meaning with regard to support for a higher-level suitability finding. In this instance, consensus means that the conclusions are supported by every member of the Core Team.

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

true, this perspective is important for readers to be aware of when considering, say, the relative merits of a higher-level finding for a disqualifying condition when only a lower-level finding is supported for the corresponding qualifying condition.

END OF TEXT

10 Proposed Resolution (continued)

A response to the reviewer's remark about understanding that "the team was more conservative in voting on qualifying conditions than on disqualifying conditions" is included in the following response to paragraph 3 of this comment. See also the perspective given in the response to Dr. Arabasz's Comment #3, where the intent of disqualifying and qualifying conditions, respectively, is described.

There may have been a miscommunication or misunderstanding between the ESSE Core Team members and the reviewer on this issue. The Core Team did not give greater importance to qualifying conditions relative to disqualifying conditions.

The intent of 10 CFR Part 960, as described in Section IV(A), was that disqualifying conditions should be conditions that are "so adverse as to constitute sufficient evidence to conclude, without further consideration, that a site is disqualified." The text further states that the presence or absence of 10 of 17 of the disqualifying conditions can be verified at a site without extensive data gathering or complex analysis, and thus, can be applied early in the siting process. A site must also be disqualified if it fails to meet any one of the qualifying conditions. However, according to Section IV(A), failure to meet a qualifying condition can usually only be determined after site characterization and concurrent environmental and socioeconomic investigations.

Rather than reflecting relative importance of the qualifying and disqualifying conditions as suggested in this comment, the distinction appears to be related to the amount of site-specific information needed to determine if the condition is present. Because more site data and analysis are required for some of the qualifying conditions compared to 10 of the 17 disqualifying conditions, Core Team members may have been "more conservative" on those qualifying conditions.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section Executive Summary
7. Page E-12, -13
8. Paragraph NA

9. Comment

(editorial)

The section entitled, "Ease and Cost of Siting, Construction, Operation, and Closure," includes seemingly contradictory statements that can be better worded to avoid confusion. Regarding disqualifying conditions and higher-level findings, the report first states that, "Hazards due to...seismic conditions...are not expected to require engineering measures that have not been applied and proven elsewhere in similar facilities." In terms of qualifying conditions, the same section goes on to say (p. E-13, paragraph 2), "However, uncertainty exists about the ability to accommodate seismic conditions at the site using reasonable available technology. Specifically, ground-motion or surface-rupture conditions on which repository designs are based are not yet known well enough to support a higher-level suitability finding."

Suggestion: Underline "expected" in the first part (last sentence of

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised as suggested in this comment. This comment illustrates a difficulty faced by the ESSE Core Team in evaluating qualifying and disqualifying conditions with very similar wording. The background material for 10 CFR Part 960 explains that disqualifying conditions were intended to be evaluated earlier in the siting process, and thus, on the basis of less complete site information. Conversely, qualifying conditions were intended to be evaluated later in the siting process and, thus, more stringent requirements for a thorough data base would be applied. On this basis, the Core Team concluded that a higher-level suitability finding could be supported for the disqualifying condition, but not for the qualifying condition. However, the confusing wording identified by the reviewer resulted from this conclusion. We believe the revised text greatly improves the clarity of the presentation of this section.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 31
2. Page 2 of 2

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4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

paragraph 4 on p. E-12). Reword paragraph 2 on p. E-13 to read: "Current evidence also continues to support the lower-level suitability finding for the qualifying condition for Preclosure Tectonics. Although ground-motion and surface-rupture conditions on which repository designs are to be based are not expected to exceed the ability of reasonably available technology to accommodate them, those seismic conditions are not yet known well enough to support a higher-level suitability finding."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 1.2.2 (general comment)
7. Page 1-9 ff.
8. Paragraph

9. Comment

(minor)

The authors have made commendable efforts to simplify the logical propositions spelled out in Appendix III of 10 CFR Part 960 (referred to hereafter as Appendix III). However, because Appendix III provides the definitive regulatory guidelines for site qualification or disqualification, rigor demands that serious readers be able to correlate conclusions in the ESSE Report with the original propositions outlined in Appendix III. It would be straightforward--and greatly helpful--in this section to relate the simplified logic about types of findings to the original propositions in Appendix III---indexed as 1(a), 1(b),...4(b).

Because the logic of 10 CFR Part 960 permeates the ESSE Report, it seems appropriate to reproduce the original propositions of Appendix III <u>verbatim</u>. Admittedly, Table 1-3 makes some attempt in this direction, but the language represents "translation," and tracing back to the original propositions of

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team will modify Table 1-3 to cross-reference the original eight propositions. This is in lieu of reproducing the wording of Appendix III verbatim or including the cross-reference indices in Figure 1-2. We believe that cross-referencing Table 1-3 will provide the needed link for readers who are thoroughly familiar with Appendix III, without unnecessarily complicating the picture for those with a less thorough knowledge of that appendix. The proposed Table 1-3 is reproduced at the end of this comment response.

To help clarify the table, the following sentence will be added at the end of first paragraph of Section 1.2.2 on page 1-9: "Each level is further subdivided into parts (a) and (b). Part (a) of each level specifies conditions for a suitability finding. Part (b) specifies conditions for an unsuitability finding."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

Table 1-3. Definitions of Findings Specified by DOE's Siting Guidelines

Conclusion	Suitability Finding	Suitability Level[a]
	DISQUALIFYING CONDITIONS	
Condition is present or likely to be present	Unsuitability	1(b) or 2(b)
Condition is not present but additional information could change conclusion	Lower-level suitability	1(a)
Condition is not present and it is unlikely that the conclusion will change with additional information	Higher-level suitability	2(a)
	QUALIFYING CONDITIONS	
Site cannot meet the condition or is not likely to meet the condition	Unsuitability	3(b) or 4(b)
Site is likely to meet the condition but additional information could change the conclusion	Lower-level suitability	3(a)
Site meets the condition and it is unlikely that the conclusion will change with additional information	Higher-level suitability	4(a)

[a]As defined in Appendix III, 10 CFR Part 960

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 4 of 31

2. Page 2 of 2

3. Name Walter J. Arabasz
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

Appendix III requires effort.

Ideally, I would prefer to see Table 1-3 list each original proposition, together with its index--1(a), 1(b),...4(b)--and a descriptor in the language of the ESSE Report (e.g., 1(a) would be "lower-level suitability"; 1(b), "unsuitability" or "lower-level finding of unsuitability"; etc.). This would allow the easiest tracking and a convenient basis for discussing conclusions about findings throughout the report.

Alternatively, I suggest incorporating into Table 1-3 cross-reference to the original eight propositions of Appendix III. For example, the first entry in Table 1-3 reads: "(Disqualifying) Condition is present or likely to be present." This conclusion relates either to proposition 1(b) or 2(b) of Appendix III. Such index numbers could also be incorporated into Figure 1-2 to link the logic to Appendix III. Each arrow in the flow chart of the enlarged box could be labeled with one or two indexes. For example, in the case of the decision-node "Qualifying condition met?" the "Unlikely" branch is linked either to proposition 3(b) or 4(b) and leads to "Unsuitability."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 1.2.2
7. Page 1-9
8. Paragraph 5

9. Comment

(minor)

The text states that "A lower-level suitability finding is the converse of the unsuitability finding...." I believe a more precise statement would be, "A lower-level suitability finding results from the negation of an unsuitability finding..." In logic, the "converse" results from interchanging the subject and the predicate of a proposition. I purposely use the article "an" rather than "the" before "suitability finding," because, in fact, a lower-level suitability finding results from negating either proposition 1(b) or 3(b) or 4(b) in Appendix III of 10 CFR Part 960.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The intent of this suggested improvement will be incorporated in the revised executive summary. The executive summary will be revised to make it more readable to a general audience. The revised text in the section describing the findings will read as follows:

"In accordance with the Siting Guidelines, conclusions about the site can be either that current information supports an unsuitability finding or a suitability finding. An unsuitability finding means that (1) a disqualifying condition is present, or (2) a qualifying condition is not present. A suitability finding means that (1) a disqualifying condition is not present, or (2) a qualifying condition is present."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 31
2. Date November 12,1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 1.2.6
7. Page 1-18
8. Paragraph 2

9. Comment

(editorial)

Consistent with tense usage elsewhere, change "Peer reviewers will be asked" to "Peer reviewers were asked" and "Individual peer reviewers will be asked" to "Individual peer reviewers were asked..."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The tense usage will be revised as suggested.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 1.3.1
7. Page 1-21
8. Paragraph 4

9. Comment

(minor)

The tectonic history summarized at the beginning of this paragraph is incomplete and confusing, and I'm uncertain whether the individual descriptions were intended indeed to refer to the "region" or to Yucca Mountain. Mesozoic deformation isn't mentioned among the major phases of tectonism. The text refers to "extensional faulting associated with silicic volcanism that occurred from about eleven to about seven million years ago...." The syntax is ambiguous. If the dates refer to silicic volcanism, silicic and volcaniclastic rocks at and near Yucca Mountain, derived from the Timber Mountain-Oasis Valley caldera complex, are described as 9.5 to 16 million years old in the SCP (DOE, 1988a, p.1-89), and the ages of the four major ash-flow tuffs at Yucca Mountain are described by Scott (1990, p. 253) as ranging from about 15 to 11.5 million years old. The SCP (DOE, 1988a, p. 1-110) describes extensional faulting around Yucca Mountain "contemporaneous with early volcanic activity, around 14 to 16 million years ago" and implies continued contemporaneity of extensional

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and to Dr. Hodges's Comment #6, we will replace the third and fourth paragraphs of page 1-21 with the following new text:

"The Timber Mountain-Oasis Valley caldera complex, to the north of the potential repository site, erupted these ash-flow tuffs, between 16 and 9.5 million years ago (mya), with deposition of the Paintbrush tuff occurring about 13 mya. Several episodes of basaltic volcanism occurred since the late Miocene, and some activity may be younger than 140,000 years. While silicic volcanism has ceased in the area, there is evidence of more recent basaltic volcanism and cinder cones less than 2 million years old in the area. North-trending extensional faulting in the area started at about the same time as the silicic volcanism, between 16 to 14 mya, with most of the offset in the vicinity of the site occurring between 12.9 and 11.6 mya (DOE, 1988a), after deposition of the Paintbrush tuff. Continued extensional faulting, associated with development

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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1. Comment 7 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

faulting and silicic volcanism at about 11 million years ago and later. The text further refers to "basin-and-range style faulting that occurred in the past seven million years...." The SCP (DOE, 1988a, p. 1-110) does indicate that "Faulting has been nearly continuous since about 7 million years ago..." but it also describes other aspects of basin-range faulting in the region dating from about 15 million years ago.

END OF TEXT

10 Proposed Resolution (continued)

of the Basin-and-Range province during the last 7 million years dominates the modern topography at the site. Yucca Mountain is composed of a series of north-trending structural blocks that have been tilted eastward along west-dipping, high-angle normal faults. The underground facility for the potential repository would be located in one of these structural blocks. This block is bounded on the west by the Solitario Canyon fault, on the northeast by an inferred fault in the Drill Hole Wash, and on the east and southeast by a hypothesized series of imbricate normal faults. One of the north-trending faults, the Ghost Dance fault, transects the potential repository layout within this block."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 1.3.1
7. Page 1-21
8. Paragraph 5

9. Comment

(minor)

In describing the setting of the Yucca Mountain site with respect to regional seismicity, the text states, "The Yucca Mountain site is about 100 miles to the east of the Nevada-California seismic belt and about 150 miles to the northwest of the Intermountain seismic belt." This description fails to note that the site lies "on the southern margin of the southern Nevada East-West Seismic Belt" (DOE, 1986, p. 3-20; see also DOE, 1988a, p. 1-151 and Fig. 1-51). Also, the description should correctly read: "...150 miles to the southwest of the Intermountain seismic belt."

The text in this place also states, "However, the area immediately surrounding Yucca Mountain (including the eastern Mojave Desert and the southwest quadrant of the Nevada Test Site) has been relatively quiet seismically during the past 150 years." In order to be more informative for those unfamiliar with historical seismicity, and to preclude the inference that

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised as suggested in the comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 8 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

seismicity prior to the mid-1800's may have been different, I suggest the wording: "...has been relatively quiet seismically since the 1850's, when the historical earthquake record for the region began."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 1.3.2 (general comment)
7. Page 1-24 ff.
8. Paragraph NA

9. Comment

(editorial)

The technical and regulatory concepts of containment, isolation, and engineered barrier system are fundamentally important in the ESSE Report. I believe an explanation of these concepts should be given at least by the end of the Introduction, and this section seems an appropriate place to do so.

Another reason for this suggestion is that I was given to understand that the terms "containment" and "isolation" are used slightly differently by the EPA and in 10 CFR Part 960. (In 10 CFR 960.2, only a very general definition is given for "containment.") Finding explanations of these terms in a readily-identifiable place would be greatly helpful.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following text will be added to the end of Section 1.3.2 to describe the meaning of the terms "containment," "isolation," and "engineered barrier system," as requested in this comment:

"Containment is the term used by the NRC to describe confinement of the radioactive waste within the waste package for a period of 300-1,000 years. According to the NRC, the containment period is the first several hundred years following permanent closure of a geologic repository, when radiation and thermal levels are high and the uncertainties in assessing repository performance are large. During this time, "special emphasis is placed upon the ability to contain the wastes by waste packages within an engineered barrier system." In 10 CFR Part 960, DOE more generally describes containment as "...confinement of radioactive waste within a designated boundary." In 40 CFR Part 191, the EPA used the term containment to describe their 10,000-year cumulative release requirements.

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 9 of 31

2. Page 2 of 2

3. Name Walter J. Arabasz
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

Isolation is defined in 10 CFR Part 960 as "inhibiting the transport of radioactive material so that the amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits." The NRC uses the phrase "Isolation of Waste" (10 CFR 60.102 (e) to include both containment by the engineered barrier system and "isolation of wastes by virtue of the characteristics of the geologic repository." The EPA only uses the term isolation to describe "Disposal" as "permanent isolation of spent nuclear fuel or radioactive waste from the accessible environment with no intent of recovery.

The EPA describes a "barrier" as any material or structure that prevents or substantially delays movement of water or radionuclides toward the accessible environment." The engineered barrier system is defined in 10 CFR Part 960 as "the manmade components of a disposal system designed to prevent the release of radionuclides from the underground facility or into the geohydrologic setting....." The NRC defines the engineered barrier system as "the waste packages and the underground facility."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 10 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 1.3.2
7. Page 1-26
8. Paragraph (Fig. 1-7)

9. Comment

(major)

Figure 1-7 shows the siting of the "Finished Tuff Pile" upslope from the "Central Surface Facilities Area." The vulnerability of the tuff pile to seismically-induced instability and rapid downslope movement during the preclosure period is an important issue for consideration. But I can't find the issue explicitly addressed anywhere in the ESSE Report. My reading of section 3.3.3.4.4 under "Issue #3: Seismic-induced Surface Failure" (p. 3.3.3-48) suggests to me that the stability of the tuff pile wasn't included among the considerations.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The locations of the surface facilities, ramps, and tuff pile(s) have not been finalized. Fig. 1-7 represents an early design for the waste and tuff portals, surface facilities, and the tuff pile(s) that result from excavation of the underground facility. Current design concepts being examined involve two ramps: one located at the waste portal on Fig. 1-7 and the other to the south of the area included in this figure. Both of the ramps would be used to remove mine tailings. Discussions with engineers working to define the final design indicate that they are aware of the potential for seismically induced slope failures on the tuff piles and that they are mitigating this possible hazard by locating the tuff pile(s) sufficiently far from the surface facilities. These designs are not yet mature enough to modify Fig. 1-7. Note that the new design plans have an additional benefit. The use of multiple tuff piles would reduce the height of each pile and reduce the slope-failure hazard to the surface facilities from the tuff pile(s).

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 10 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

Text will be added to Section 3.3.3.4.4, page 3.3.3-48, at the end of the first paragraph under Issue #3 as follows: "Proper location and design is also expected to mitigate the hazard from seismically induced slope failure on the tuff piles that result from excavation of the underground facility."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 11 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.1.3.1
7. Page 2-14
8. Paragraph first full paragraph

9. Comment

(editorial)

The text states: "The EA acknowledges that stratigraphic and structural relationships appear complex, with rocks ranging in age from Precambrian through Holocene that have undergone many periods of structural deformation." Syntax incorrectly implies that rocks of Holocene age have undergone many periods of structural deformation. Suggested wording: "The EA acknowledges that stratigraphic and structural relationships appear complex. Rocks range in age from Precambrian through Holocene, and many periods of structural deformation have affected the older rocks."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised as suggested by the reviewer.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 12 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.1.3.1
7. Page 2-14
8. Paragraph first full paragraph

9. Comment

(minor)

The use of the term "major" to specify faults here and elsewhere in the report (e.g., section 2.3.7.3.3, p. 2-103, paragraph 6) raises confusion because a definition isn't provided. The sentence structure associates the descriptor, "with vertical displacements exceeding 70 meters," to "faults that occur elsewhere in the Great Basin." If this is to be the definition of "major" faults for the Yucca Mountain area, the wording needs to be revised.

Careful thought should be given here. Labeling some of the faults in the Yucca Mountain area as "major" and inviting comparison to "major" basin-range faults elsewhere in the Great Basin introduces many implications about subsurface structure, seismic potential, and so on.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with the reviewer's point. The adjective "major" comes directly from Bath and Jahren (1984), whose usage merely described faults that produced clearly defined magnetic anomalies as measured from aircraft 120 meters above the land surface. For the magnetic stratigraphy and structural setting of Yucca Mountain, a 70-meter fault displacement was the approximate lower limit of detectability. We propose replacing the last sentence of the referenced paragraph with the following:

"North-striking, high-angle extensional faults displace the eastward-dipping Tertiary volcanic rocks both east and west of the potential site, and smaller faults intersect the site itself (Bath and Jahren, 1984; Scott and Bonk, 1984)."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 13 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.7.1.1
7. Page 2-78, -79
8. Paragraph last para. on p. 2-78

9. Comment

(editorial)

The text first states: "The disqualifying condition is somewhat narrower than the qualifying condition in its considerations." The paragraph then proceeds in an incisive way to analyze key wording in the disqualifying condition [10 CFR 960.4-2-7 (d)]. For cogency, I urge the authors to end this important paragraph after the words: "...would be unlikely to result in a loss of isolation."

The ensuing text, beginning with the statement, "A resolution that the site is not disqualified under this condition can, therefore, be reached by a negative answer to either of the following two questions...," can be better worded, I believe, to alert the reader that a crucial stage of argument is about to follow, rather than specious logic. The authors are about to address the first part of proposition 2(a) of 10 CFR 960, Appendix III--namely, "The evidence supports a finding that the site is <u>not</u> disqualified on the basis of

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team believes this comment is helpful in proposing a more easily understood pathway through the logic of resolving the disqualifying condition. Note, however, that the second question is predicated on the basis of an affirmative answer to the first--a point which, upon rereading, is not sufficiently clear in the report. We propose ending the paragraph as recommended and adding the following paragraph:

"Critical judgment about whether or not the site is disqualified can be guided by sequential consideration of the following two questions: (1) Based on the Quaternary record, is it expected that fault movement will occur within the repository or that ground motion within the repository from outside seismogenic sources will be so severe as to cause a loss of containment with the engineered barrier system (EBS)? (2) If fault movement or ground motion causes a loss of containment, is it likely to result in a loss of waste isolation,

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

that evidence and is not likely to be disqualified." Affirmation will lead to a higher-level suitability finding.

Suggestion: Begin a new paragraph with wording such as, "Critical judgment about whether or not the site is disqualified can be guided by the following two questions: [insert questions (1) and (2) from paragraph 1 on p. 2-79]." Then end the paragraph with wording such as, "A negative answer to either (but preferably both) of the two preceding questions would provide a solid basis for resolving that the site is not disqualified under the technical guideline."

END OF TEXT

10 Proposed Resolution (continued)

i.e., releases of radionuclides to the accessible environment exceeding those allowed by the regulations? A negative answer to the first question would provide the basis for a determination that the site is not disqualified under this condition. However, an affirmative answer to the first question would cause deferral of the determination until the effect on waste isolation, which is addressed in the second question, can be evaluated by system performance calculations."

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 14 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.7.2.2
7. Page 2-83
8. Paragraph (ground-motion model)

9. Comment

(major) (See also Comment XX.)

I understand and strongly endorse the stated need for "a probabilistic assessment of ground motion at the repository depth"--particularly to address the regulatory concept of "likely," specified in the qualifying condition for postclosure tectonics [10 CFR 960.4-2-7(a)]. Within the context of "information required to resolve issues," I believe a well-founded deterministic assessment of ground motion is also required, as a practical matter, and should be specifically mentioned here. Admittedly, regulatory policy has not yet been fully developed regarding the site characterization of seismic ground motion and fault displacement at a geologic repository. Nevertheless, experience, together with preliminary indications of the thinking of NRC staff (Blackford and McConnell, 1991), suggest that the need for companion guidance from a deterministic analysis is inescapable.

Let me be clear. I do not suggest that a deterministic

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The reviewer makes a compelling case, including recent and authoritative references, for explicitly considering deterministic assessment of ground motion as a companion guide to a probabilistic assessment. Relevant perspectives on ground-motion assessment are also given in the responses to this reviewer's Comments #23, #25, #26 and #27, all of which relate to the preclosure time frame. We propose the following revisions to this section:

a. The paragraph labeled "(2) Probabilistic ground-motion model" will be labeled "(2) ground-motion model" and the first paragraph will be replaced by the following text:

"To estimate the postclosure effects of earthquakes, the hazard from ground shaking at the proposed repository depth must be assessed. Models for expected ground motion during the postclosure period are available, but additional calculations will be needed as data, viable

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 14 of 31

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9 Comment (continued)

analysis of seismic ground motion should govern the issue of site suitability--under technical guidelines for either postclosure or preclosure tectonics. What I'm suggesting is the following: (1) Regulators will likely require, for their own understanding and confidence, at least the availability of a rigorous, well-founded deterministic analysis before acceding to the conclusions of a probabilistic analysis. (2) A deterministic seismic hazard analysis has great practical value, either as a companion guide to, or integrated with, a probabilistic analysis; the joint information facilitates critical decision-making among scientists and engineers and provides important information for public scrutiny (see, for example, Reiter, 1990, p. 227-230).

END OF TEXT

10 Proposed Resolution (continued)

tectonic models, and/or analysis techniques change (see Section 3.3.3.4.4, Issue #1: Maximum Ground Motion). Instrumental measurements of subsurface ground motion at Yucca Mountain are sparse, as are reported observations of the effects of ground motion on underground openings. Thus additional data will be needed to improve the reliability of characterizing ground motion at the repository depth compared to predicted ground motion at the surface. Because of various uncertainties relating to future tectonic activity, probabilistic estimates of ground motion (see Section 3.3.3.4.4, for example) are inherently difficult to validate for the long postclosure period of concern. Deterministic analyses will be required to provide companion guidance in evaluating the exposure of the repository to future ground motions associated with the earthquake-generating framework of the Yucca Mountain region."

b. The second sentence of the second paragraph will be revised to read:

"The instrumental record is limited, however, and must be extended by estimates of paleoseismicity from field studies of faults in the vicinity of Yucca Mountain and at sites that are possible analogs for future tectonism at Yucca Mountain region."

c. We propose no changes to third paragraph of this section.

d. A fourth paragraph will be added as follows:

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10 Proposed Resolution (continued)

"Deterministic calculations, probabilistically predicted ground motion guided in part by information from tectonically analogous settings, and observations of subsurface effects must be considered together to reach defensible judgments of the hazard to waste containment and isolation. If the hazard is shown to be of credible consequence, system performance assessments can appropriately be expressed probabilistically, accounting for associated uncertainties."

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 15 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2 (general comment)
7. Page 2-90 ff.
8. Paragraph

9. Comment

(minor)

The scope and objectivity of this "Review of Information Obtained since the EA," relevant to postclosure tectonics, warrant comment. One of the principal charges for this Peer Review is to confirm the adequacy of information presented in the ESSE. I have carefully read: the EA (DOE, 1986); those parts of the SCP (DOE, 1988a) relevant to the site geology, tectonics, and seismic hazards; and dozens of supporting references cited in the ESSE Report that bear on critical issues of tectonic models, potential fault displacement, and seismic ground motion. The text of this section provides an excellent summary, and it reflects well the extraordinary degree of expert examination and devil's advocacy that I find being applied to evaluating geoscience aspects of the suitability of the Yucca Mountain site as a potential repository.

Obviously, site-characterization is still at an early stage. Nevertheless, the approaches taken to date to evaluate geoscience aspects of site suitability

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The authors of the ESSE report appreciate comments by Dr. Arabasz regarding the quality and adequacy of the information presented in the Postclosure Tectonics section. We are encouraged that he found the report to represent a balanced view of the uncertainties related to his area of expertise.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

have been on the right track, in my opinion, and I come away with great confidence in the objectivity of the ongoing process. Put another way, a number of tough questions occurred to me as I read the EA and the SCP, but when I came to the ESSE Report, I was pleasantly surprised to find the authors had explored the same tough questions--and the report candidly discusses problems, alternative interpretations, and basic uncertainties.

END OF TEXT

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2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.1
7. Page 2-93
8. Paragraph last paragraph

9. Comment

(minor)

The text refers to a suggestion of dePolo and others (1990) "that the MBE [maximum background earthquake] for the Basin and Range Province is at least magnitude 6.3 and may be as high as magnitude 6.8...." The upper-bound size of 6.8, suggested by dePolo and others (1990), comes from the 1925 Clarkston Valley, Montana, earthquake, for which no surface rupture was observed. For the record, Doser (1989) has determined an instrumental moment magnitude (M_w) of 6.6 for the 1925 Clarkston Valley earthquake; Gutenberg and Richter (1954) assigned a magnitude [inferred to be a surface-wave magnitude] of 6 3/4.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment, the following changes will be made to the last paragraph on page 2-93. The latter part of the second sentence will be replaced: add a third sentence, and remove ", however," from the former third sentence, so as to read: "...basing their conclusion on analysis of 38 historical earthquakes in the Basin and Range Province." A sentence will be added reading "The upper bound for the MBE, a local (M_1) or surface-wave (M_s) magnitude 6.8, is based on the 1925 Clarkston, Montana earthquake; Doser (1989) has determined an instrumental moment magnitude (M_w) of 6.6 for that earthquake." The word "however" will be removed from the former third sentence.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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(Reviewer completes items 1 - 9.)

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2. Date November 12, 1991
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5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.1
7. Page 2-94
8. Paragraph 1

9. Comment

(minor)

The text incorrectly gives a surface-wave magnitude (M_s) of 7.6 to the 1932 Cedar Mountain, Nevada, earthquake. An authoritative study and catalog made by Abe (1981) assigns that earthquake a surface-wave magnitude of 7.2; dePolo and others (1990, Table 3) also list M_s=7.2 for the earthquake.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The comment is correct and probably identifies a typographical error. The text will be changed to specify M_s=7.2 for the Cedar Mountain earthquake.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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(Reviewer completes items 1 - 9.)

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2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3
7. Page 2-103
8. Paragraph 4

9. Comment

(major)

I agree with the conclusion that a lower-level suitability finding is supported for the qualifying condition under the postclosure guidelines for tectonics [10 CFR 960.4-2-7(a)]. In my judgment, the logic of proposition 3(a) of 10 CFR Part 960, Appendix A applies: "The evidence does <u>not</u> support a finding that the site is <u>not</u> likely to meet the qualifying condition."

In my opinion, the authors of the ESSE Report follow well-reasoned logic in applying the relevant technical guidelines for postclosure tectonics. Their presentation and analysis of available geoscience information is thorough and notably objective. Appropriately, given the preliminary nature of available site-characterization information, the authors are conservative in their evaluation, use carefully-measured arguments, and stay within defensible bounds. The following statement (p. 2-102, para. 4) typifies their careful approach: "Although damaging fault movement or ground motion are not expected,

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The authors of the ESSE Report appreciate explicit statements by Dr. Arabasz in this comment regarding his support for the lower-level finding for the qualifying condition for the Postclosure Tectonics Guideline. We also are pleased that he found the evaluation of this guideline to be objective and appropriately conservative.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

as discussed in Section 2.3.7.3.3.1, neither have they been demonstrated to be so unlikely as to be considered inconsequential."

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 19 of 31
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3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3
7. Page 2-103
8. Paragraph (disqualifying condition)

9. Comment

(major)

Regarding the disqualifying condition for postclosure tectonics, the authors state: "It is the consensus of the team conducting this evaluation that the evidence supports a conclusion that (1) the site is not disqualified and (2) information to be collected in the future is unlikely to result in disqualification under this condition (Level 2)." Hence, the authors assert support for a higher-level suitability finding under this technical guideline. I have come to agree with this position--but only after a great deal of wrestling with the logic and issues involved.

When I first encountered this position in the Executive Summary, I was highly skeptical about being able to agree. There seemed to be evident dilemmas in advocating a higher-level suitability finding for this disqualifying condition while at the same time advocating (1) a lower-level suitability finding for the disqualifying condition for postclosure

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team believes that the necessity for the reviewer's reconstruction of the logic for the recommended finding on this disqualifying condition indicates that clarification is appropriate. We propose the following revision of the disqualifying condition discussion on pages 2-103 and 2-104:

"The consensus of the Core Team is that the evidence supports a conclusion that (1) the site is not disqualified and (2) information to be collected in the future is unlikely to result in disqualification under this condition (Level 2). The conclusion results from the lack of expectation that fault movement or ground motion will cause a loss of containment within the EBS, i.e., a negative answer to the first of the two questions posed in Section 2.3.7.1.1.

Yucca Mountain and the surrounding vicinity have been intensely

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

geohydrology and (2) a lower-level suitability finding for the qualifying condition for postclosure tectonics.

My quandry about linkage to hydrology raised the following questions: What's the scope of site suitability being considered under this guideline for tectonics? Was this guideline intended to isolate direct effects of faulting and vibratory ground motion on the EBS from indirect effects that might be linked to changes in the hydrologic system? Does it deal only with possible damage to the EBS by faulting or ground motion--or does the phrase "such that" require concern too for indirect effects like changes to the hydrologic system that might threaten waste isolation? I finally reasoned, after interactions with members of the core team, that the primary intent of the guideline was to address tectonic events--separate from tectonic-hydrologic-coupled events. And if the latter indeed had to be considered as entangled, such events were possible only as short-duration events and not as a serious disqualifying factor.

The apparent inconsistency of different level findings for the disqualifying and qualifying conditions for postclosure tectonics was easier to reconcile, thanks to the careful analysis presented in section 2.3.7.1.1. The text points out convincingly, I believe, that there are different considerations involved in the qualifying and disqualifying conditions. Importantly, the disqualifying condition focuses on the geologic record rather than on the geologic setting, it restricts consideration to "fault movement or other ground motion," and it uses the key word "expected."

In sum, I'm persuaded by the evidence and arguments for a higher-level suitability finding under guidelines for the disqualifying condition for postclosure tectonics. A screening process can't be inherently open-ended. There's a strong case for resolving the disqualifying condition for postclosure tectonics--but my own experience suggests that others may similarly face some initial mental roadblocks before agreeing.

END OF TEXT

10 Proposed Resolution (continued)

studied by means of geologic mapping, geophysical surveys, remote sensing, and geomorphic analysis. Evaluations of the resulting geologic record, though preliminary, provide a reasonable expectation that Quaternary fault movement has occurred only on the principal north-striking faults, which formed in Miocene time and which have had continued or renewed activity in the Quaternary, but with small slip

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10 Proposed Resolution (continued)

rates. The current state of stress in the shallow crust at Yucca Mountain is consistent with continued movement on these faults rather than initiation of new faults. Although distributive or secondary faulting is probably responsible for the closely spaced small-displacement faults west of the principal faults, such subsidiary faults have not been identified within the boundaries of the potential repository. Furthermore, there is no evidence to suggest that the small Tertiary faults, such as the Ghost Dance fault, within the repository boundaries have Quaternary displacement. The combined evidence argues against an expectation that fault movement will disrupt the EBS directly or cause new infiltration pathways that might lead to accelerated degradation of the EBS.

The geologic record, in terms of observed displacements on presently identified faults, provides a basis for inferring potential ground motion. The Paintbrush Canyon fault is expected to govern both the maximum earthquake and ground motion near Yucca Mountain. Large individual fault displacements during the Quaternary have not been identified in the trenches that have been excavated and examined on the Paintbrush Canyon and other faults, providing paleoseismic evidence against large-magnitude ($M \geq 7$) earthquakes. However, the exposures in these trenches do indicate surface rupture, implying associated earthquakes in the magnitude 6 range, perhaps arguably exceeding the maximum background earthquake of local or surface-wave magnitude 6.8 proposed by dePolo et al. (1990). The stability of steep slopes at Yucca Mountain and the unrotated orientations of heavily varnished colluvial boulders on these slopes provide empirical, though nonquantitative, evidence against severe ground motion from nearby, large-magnitude earthquakes. Peak horizontal acceleration in the repository area is expected to be less than 1g, probably less at the repository depth, and of long wavelength relative to the dimensions of the EBS. Consequently, it is not expected that subsurface ground motion will damage the EBS sufficiently to precipitate a loss of containment.

In summary, based on the available geologic record of the Quaternary Period, the consensus of the Core Team is that the nature and rates of fault movement or other ground motion are not expected to be such that a loss of waste containment is likely to occur. The team therefore conclude that a higher-level suitability finding can be supported for this disqualifying condition. Site characterization

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10 Proposed Resolution (continued)

activities should focus on reducing the existing uncertainties to the levels required for resolving the broader and more stringent requirements of the qualifying condition."

END OF TEXT

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2. Date November 12, 1991	6. Section 2.3.7.3.3
3. Reviewer Walter J. Arabasz	7. Page 2-104
4. Organization University of Utah	8. Paragraph 2

9. Comment

(minor)

In characterizing aspects of the Quaternary geologic record, the text states: "...and the stability of steep slopes at Yucca Mountain, including the mantles of heavily varnished colluvial boulders, argue strongly against the occurrence of strong ground motion within at least the last million years."

I do not agree that "the stability of steep slopes at Yucca Mountain, including the mantles of heavily varnished colluvial boulders, argue [sic] strongly against the occurrence of strong ground motion within at least the last million years." Evidence for the long-term stability of hillslopes in the Yucca Mountain area is described in the SCP (DOE, 1988a, p. 1-31) and is acknowledged. Apart from the fact that the dating of desert varnish is controversial (e.g., Gibson and others, 1991, p. 34-36), no information is presented in the ESSE Report to suggest that heavily varnished clasts have been objectively studied to investigate exposure (or non-exposure) to seismic

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team concurs that the importance placed on the suitability of slopes and varnished colluvial boulders was probably stronger than is justified, and that the argument, if presented here, should be supported in the earlier text. We propose the following changes:

(1) p. 2-97, Section 2.3.7.3.2.2, insert paragraph between existing first and second paragraphs (following "...concern for the postclosure period."):

"Yucca Mountain is characterized by very steep slopes, mantled in places by colluvial boulders that are coated by well developed desert varnish. These features and methods for estimating their antiquity are discussed in Section 2.3.5.3.2.1 relative to their use in demonstrating low rates of erosion (Whitney and Harrington, 1988 and in preparation). Although slope failures and rockfalls occur commonly near epicentral zones of major earthquakes, the inverse problem--that

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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9 Comment (continued)

shaking. I suggest deleting the subjective arguments. Introducing them in a concluding statement, without prior discussion and substantiation, weakens the conclusions.

END OF TEXT

10 Proposed Resolution (continued)

of estimating peak ground motion experienced by still-stable slopes--has apparently not been addressed. Varnished colluvial boulders, including many in apparently precarious positions, have remained unrotated for apparently hundreds of thousands of years suggests that severe ground acceleration approaching 1g has not occurred during this period. However, this observation has not been calibrated by systematic correlations of rockfalls or boulder rotation with measured ground motion."

(2) p. 2-103 and 2-104: See the revised text under the "Disqualifying Condition" paragraph added in response to Dr. Arabasz's Comment #19.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 21 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.0 (general comment)
7. Page 3-1 ff.
8. Paragraph NA

9. Comment

(minor)

Within the realm of seismic-hazard considerations (ground motion and fault displacement), there is fundamental overlap between analyses for postclosure and preclosure tectonics, despite different issues applying. Accordingly, comments about site vulnerability to fault displacement and seismic ground motion are generally relevant to both time frames. Postclosure concerns relate chiefly to whether faulting or ground motion will damage the EBS, and perhaps induce tectonic-hydrologic-coupled changes that could jeopardize waste isolation. The major issues for the preclosure time frame are the potential effects of fault displacement and strong ground motion relating to the location and seismic design of the surface facilities.

Under 10 CFR Part 960, preclosure guidelines are given secondary significance to the postclosure guidelines, and "Ease and Cost" guidelines are ranked lower in importance than guidelines for preclosure radiology safety.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment correctly points out that 10 CFR Part 960 places primary significance on the Postclosure Guidelines. However, as indicated, site data collected to resolve technical issues in tectonics must be used to address both preclosure seismic hazards and postclosure tectonic effects. The need for a unified approach to the general topics of ground motion and fault displacement is recognized by the ESSE Core Team, and close coordination has occurred between the authors of the pre- and postclosure tectonics sections. If the Yucca Mountain Site is found suitable and enters the licensing process with the U.S. Nuclear Regulatory Commission (NRC), the NRC's responsibility for protection of public health and safety ensures that seismic hazard issues will receive further attention. If the NRC technical staff and consultants are not convinced that seismic-hazard issues are properly addressed, it is unlikely they would recommend that licensing proceed.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 21 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz
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4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

This hierarchy shouldn't lead to confusion about the relative importance of information on fault displacement or ground motion. Reliable, unified modeling is needed to address all the seismic-hazard issues, in whatever time frame.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 22 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.4.1(new 3.3.1.4.5.1)
7. Page 3.3.1-17
8. Paragraph 2

9. Comment

(minor)

The text states: "Test areas for UNEs [underground nuclear explosions] are 24 to 33 miles north and east of the Yucca Mountain site. If a repository were to be constructed at the site, it would be built to withstand ground motion from both UNE and natural sources. The maximum ground motion (99 percent confidence) from UNEs was predicted to be 0.32g." The distance range given for the UNEs is confusing.

The report by URS/Blume (1986, p. 73) indicates that the location of the UNE event that has the maximum potential of inducing ground motion at the Yucca Mountain site is "a 700-kt event located in the Buckboard Mesa area at its closest approach, a distance of 21.3 km, to the reference conceptual site for repository surface facilities." Walck and Phillips (1990) similarly refer to "the Design Basis underground nuclear explosion for the Yucca Mountain Project, which is a 700 kt blast in the Buckboard Mesa area, about 23 km from Yucca

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The reviewer points out inconsistencies in the text and supporting references regarding the locations and sizes of underground nuclear explosions (UNE) at the Nevada Test Site (NTS). The text being reviewed in this section is from the Environmental Assessment (DOE, 1986) and thus, is somewhat dated, although it correctly describes the locations of the ongoing UNE program at the NTS. The newer URS/Blume (1986) and Walck and Phillips (1990) references explain that a 700-kt event at Buckboard Mesa is used as the "design basis UNE" for the repository, rather than smaller events that are currently conducted at locations 24 to 33 miles north and east of Yucca Mountain. This is because Buckboard Mesa could become a future UNE testing area under certain scenarios, and the 700-kt event is a size that could not be exceeded due to offsite damage restrictions. Note that the UNE that generates the 0.32g (99 percent confidence) is predicted only if the current limits (The Threshold Test Ban Treaty--TTBT--limits the size of UNEs to 150 kt) on the size of UNEs were no longer in effect. The current U.S. testing program complies with

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 22 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz
(Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

Mountain."

END OF TEXT

10 Proposed Resolution (continued)

the TTBT and is conducted in geographic locations that are further removed from the Yucca Mountain Site than the Buckboard Mesa area.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 23 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.2.1
7. Page 3.3.3-25 f.
8. Paragraph 2 of 3.3.3.4.2.1

9. Comment

(minor)

In describing the four issues for Preclosure Tectonics, the authors propose to analyze "the expected maximum ground motion" in Issue 1 and "the expected surface displacement" in Issue 2. The choice to specify maximum for ground motion but not surface displacement raises confusion about whether the authors are intentionally distinguishing deterministic versus probabilistic considerations for the two issues.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Both Issues #1 and #2 should be cast in a probabilistic framework. The ESSE Core Team agrees, however, with the reviewer's Comment #14 that both probabilistic and deterministic analyses will be expected by the NRC prior to licensing. For site-suitability evaluations under the Preclosure Tectonics Guideline in 10 CFR Part 960, however, we consider the probabilistic approach described here to be adequate to determine if the site should be further characterized and evaluated as a potential repository site. For this evaluation and with a limited data base, a comprehensive probabilistic-deterministic analysis is not warranted at this time; however, we believe that a comprehensive analysis should be performed as data become available.

Wording throughout the text under Issue #1 will be changed from "expected maximum ground motion" to "expected ground motion" to be consistent with the wording for Issue #2 and with the probabilistic approach.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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(Reviewer completes Items 1 - 9.)

1. Comment 24 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.3.1
7. Page 3.3.3-29
8. Paragraph (Table 3.3.3-4)

9. Comment

(editorial)

In the description of DOE findings for Potentially Adverse Condition (2) the text states: "...historical earthquakes and past man-induced seismicity are not expected to cause ground motion at the site that would exceed reasonable design limits." Suggested revision: "...a repeat of historical earthquakes or past man-induced seismicity is not expected to cause ground motion..."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text of the conclusions for the potentially adverse conditions cannot be changed since these were quoted from the Environmental Assessment (DOE, 1986) and therefore are not open to revision. However, the phrase will be corrected as suggested by Dr. Arabasz if it is used again.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 25 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.3.2
7. Page 3.3.3-34
8. Paragraph 3

9. Comment

(major)

The text states: "In general, most north-trending faults at Yucca Mountain are active and have experienced multiple displacements during the Quaternary period. The timing and rate of this seismic activity is important to understanding the seismic threat to the surface facilities and the degree to which RAT can accommodate this activity. Additional paleoseismic studies are needed to reduce current uncertainties with respect to likely seismic activity near and at the site."

The above assessment is part of an excellent summary of information obtained since the EA (DOE, 1986) relevant to Quaternary geology in the Yucca Mountain area. However, both the assessment and the summary are incomplete, in my opinion, in neglecting to point out some fundamental uncertainties.

Alternative tectonic models allow the possibility that Quaternary faulting

10. Proposed Resolution *(To be completed by ESSE Core Team)*

New text will be added to the document discussing the uncertainty in tectonic models and the impact of this uncertainty on expected ground motion. Also, discussion will be added on uncertainties inherent in paleoseismic measurements.

The following text will be added at the end of the discussion on Quaternary Geology within Section 3.3.3.4.3.2, page 3.3.3-34: "It should be noted that multiple tectonic models exist for Yucca Mountain. Some of these models involve strain partitioning or decoupling of the upper and lower crust. Strain rates in the lower crust may be different than those in the upper crust; seismogenic sources at depths not yet accounted for could conceivably result in a higher seismic hazard from ground motion than would be obtained from paleoseismic and historical seismicity studies [see Section 2.3.7.3.2]. These uncertainties should be accounted for in future seismic hazard analyses. In addition, other crustal models have been postulated that suggest regional

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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1. Comment 25 of 31
2. Page 2 of 2
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4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

in the vicinity of the Yucca Mountain site may represent accommodation of deformation above deeper (and perhaps different) seismogenic structures, due to some type of strain partitioning (e.g., Lettis and Hanson, 1991) or decoupling of deformation between upper crustal and underlying levels. The latter issue is raised explicitly in section 2.3.7.3.2 (p. 2-91) in connection with Postclosure Tectonics, where the statement is made: "If at least partial decoupling of an upper plate from the underlying seismogenic zone is demonstrated, paleoseismic investigations in the immediate vicinity of the Yucca Mountain site may have limited application in forecasting ground-motion characteristics; however, local paleoseismic data would still be needed in predicting the probability of primary and secondary faulting within the repository." The idea that upper-crustal faults might represent "accommodation structures" above deeper seismogenic structures does not require validation of a detachment model. For example, extensional faulting in the upper crust can be easily related conceptually to en echelon strike-slip faulting at depth (e.g., Sylvester, 1988).

Another area of uncertainty regarding observed slip rates described in the subject paragraph relates to unknown amounts of strike slip. The SCP (DOE, 1988a, p. 1-208) raises the appropriate caveat, "Considering that Yucca Mountain is in the Walker Lane, a belt of right-lateral shear, vertical displacement rates may be deceiving, because strike slip may well have exceeded dip slip on many of the faults near Yucca Mountain."

END OF TEXT

10 Proposed Resolution (continued)

stresses may be oriented such that strike-slip movement on faults may be the dominant slip component. Paleoseismic data and historical earthquake studies will be needed to evaluate the likelihood of strike-slip faulting as the dominant slip component and to evaluate the probability of distributed faulting within the repository and at the surface facilities."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 26 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.3.2(3) (general comm.)
7. Page 3.3.3-36 ff.
8. Paragraph

9. Comment

(minor)

The subsection dealing with the "Seismic Design of the Repository" summarizes results of a remarkable engineering analysis by Subramanian et al. (1989). I emphasize "remarkable" because seldom does an engineering analysis strike such a hammer-blow for decisive closure to earth-science deliberations.

Unless more site-specific seismic-hazard data change the assumptions of the analysis, a good blueprint has been set for choosing a design level--and accommodation by "reasonably available technology" isn't a serious concern, in my opinion.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team recognizes the need to review the Subramanian et al. (1989) study as new site-specific seismic hazard data become available and appreciates your positive statements about the importance of this study.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 27 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.4
7. Page 3.3.3-37 ff.
8. Paragraph (Issue #1: Ground Motion)

9. Comment

(major)

I offer some general comments regarding Issue #1: Maximum Ground Motion. As in Comment 14, I reiterate my strong belief that the need for both probabilistic and deterministic seismic hazard analyses is inescapable. Work done to date on both types of analyses (briefly summarized on p. 3.3.3-35) is acknowledged. The rigor of the methodology applied by URS/Blume (1987) gives me substantial confidence in the quantitative, probabilistic assessments of both ground motion and surface-rupture hazards--based on existing information. Gibson (1991) forthrightly comments on the numerous deterministic and probabilistic seismic hazard studies performed to date for the Yucca Mountain site and cautions that, "All of these hazard analyses contain large uncertainties, owing to the limited site-specific data." Similarly, the authors of the ESSE Report (p. 3.3.3-52) acknowledge that "additional site-specific data is needed to confirm that estimates of the seismic hazard potential are valid."

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Additional text will be added in response to Dr. Arabasz's Comment #25 describing the uncertainty in tectonic models and the implications of this uncertainty to seismic hazard analysis. Wording at the top of page 3.3.3-40 will be changed to read: "Additional calculations of expected ground motion are likely to be needed as data, viable tectonic models, and/or analysis techniques change."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 27 of 31
2. Page 2 of 2
3. Name Walter J. Arabasz (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

My chief concern regarding seismic hazard (ground-motion) analyses done to date lies with the seismic-source scenarios and maximum magnitudes so far considered. In particular, if the Quaternary faulting in the immediate vicinity of Yucca Mountain reflects deformation that is an accommodation of strain above deeper and different seismogenic structures (see Comment 25), then the hazard hasn't yet been reliably modeled. The "wild card," in my view, would be the nucleation of infrequent sizable earthquakes on buried strike-slip faults beneath or near the site, rather than seismogenesis on a subsurface detachment. The common and not-understood occurrence of background earthquakes with strike-slip focal mechanisms in the general region of Yucca Mountain (DOE, 1988a, p. 1-171 ff.) signals a lack of a fundamental understanding of the earthquake-generating framework in the southern Great Basin.

That said, my familiarity with seismic hazard analysis suggests to me that revised probabilistic seismic hazard analyses--for the exposure period of the surface facilities--will probably not lead to results that invalidate the levels of ground motion already being considered for the repository design. The frequency of sizable earthquakes on buried faults somehow would have to be reflected in the (already known) surface displacement field, and distance to deeper nucleation points would probably result in peak ground-motion parameters comparable to those already being considered. Rigorous analysis should still be pursued though.

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 28 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.4
7. Page 3.3.3-40
8. Paragraph 2

9. Comment

(minor)

The text states: "In summary, during the next 10,000 years, we should expect a maximum PGA of approximately 0.5g, based on the assumptions presented in URS/Blume." Reference is made in the following sentence to "Lee et al., in press" [Lee et al., 1991], who give a design-basis ground motion, for waste canister design, as 0.6g--the peak horizontal ground acceleration with an exceedance probability of less than 10% in 1,000 years. This ground-motion level is also described for the reader in section 2.3.7.3.2.2 (p. 2-97). For consistency, I suggest the results of Lee et al. (1991) should be explicitly mentioned in this paragraph.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text in Section 3.3.3.4.4, page 3.3.3-40, paragraph 2, beginning in the third sentence, will be modified to state: "For a recurrence expectancy of 10,000 years in Fig. 3-6 (previously Fig. 3.3.3-5), the largest expected PGA is about 0.6g, a value where a "light damage" level has a very small probability. Virtually no damage, "light damage," in the worst case, is expected during the next 100 years for a WHB facility (see also Lee et al., 1991), because of its inherent robustness."

The following text will be added to page 3.3.3-40, after the second complete paragraph: "URS/Blume (1987) focuses on the sensitivity of seismic hazard to various earthquake magnitude recurrence and fault behavior parameters. The authors differentiate the contribution by certain faults and families of faults to the total seismic hazard. The calculated ground motion is dominated by the behavior of the Paintbrush Canyon fault and associated nearby faults and by background seismicity. Of the various input parameters

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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1. Comment 28 of 31

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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

considered in the study, the seismic hazard is most sensitive to an assumed slip-rate; however, few Quaternary slip-rates were available at the time of these calculations.

Alternative seismotectonic interpretations were parameterized by considering only normal faulting in one case and oblique-slip in the other. Recent work, including that by Whitney and Muhs (1991), supports oblique-slip on at least the Paintbrush Canyon-Stagecoach fault system. Preliminary evaluation of three alternative tectonic models--oblique-slip, detachment, and shear--was also made by URS/Blume (1987). Of these simple tectonic models, the shear model produced the greatest hazard while the detachment presented the least hazard. These models will presumably be refined as study continues."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes Items 1 - 9.)

1. Comment 29 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.4 (general comment)
7. Page 3.3.3-40 ff.
8. Paragraph (Issue #2)

9. Comment

(minor)

The discussion relating to "Issue #2: Expected Surface Displacement" focuses, appropriately, on the results of rigorous analyses made by Subramanian et al. (1989) and URS/Blume (1987). These results, together with the consistency of the order of magnitude of slip-rate observations for Quaternary faulting in the Yucca Mountain area, allowance for secondary rupture resulting from coseismic slip on nearby faults (Coppersmith and Youngs, 1990), and results of preliminary trenching and geophysical studies in the site area (Gibson et al., 1991), all give me confidence that a good provisional assessment of surface-displacement hazard is in hand.

A tangential issue relating to surface displacement is that of the expected length and pattern of surface faulting which might be inferred from paleoseismic and empirical data. My remarks in Comment 25 about the possibility that upper-crustal faults may reflect accommodation structures above

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team recognizes that the current assessment of surface-displacement hazard is provisional and that further field data on Quaternary fault activity, as well as further investigation of the model that surface faults represent distributed faulting above deeper seismogenic structures, could lead to revisions in the hazard estimates. New text is proposed to explicitly address these uncertainties in the response to Dr. Arabasz's Comment #25.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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1. Comment 29 of 31
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

deeper seismogenic structures lead me to be sympathetic to arguments about the possibility of distributed faulting, analogous to the case of the 1932 Cedar Mountain earthquake (see SCP, DOE, 1988a, p. 111 f.).

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes Items 1 - 9.)

1. Comment 30 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.4
7. Page 3.3.3-48
8. Paragraph para. 1 of Issue #3

9. Comment

(major)

Regarding the discussion of "Issue #3: Seismic-induced Surface Failure," cross-reference is made to Comment 10. It appears to me that the vulnerability of the "Finished Tuff Pile" to seismically-induced instability and rapid downslope movement during the preclosure period was not included among considerations here.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Text will be added to page 3.3.3-48 in response to Dr. Arabasz's Comment #10 regarding the potential for seismically induced slope failures of the tuff pile(s).

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 31 of 31
2. Date November 12, 1991
3. Reviewer Walter J. Arabasz
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.5
7. Page 3.3.3-50
8. Paragraph para. 2 & 3 of 3.3.3.4.5

9. Comment

(major)

Under the guidelines of 10 CFR Part 960 for preclosure tectonics, I agree with the ESSE Report's conclusion that evidence continues to support a lower-level suitability finding for the qualifying condition. I also agree that a higher-level suitability finding is supported for the disqualifying condition. The logic is succinctly stated on p. 3.3.3-52: "Although current evidence indicates that seismic and volcanic hazards at the Yucca Mountain site can be accommodated by RAT, additional site-specific data are needed to confirm that estimates of the seismic hazard potential are valid."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team appreciates Dr. Arabasz's agreement with its conclusions.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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Dr. John H. Bell

HEALTH PHYSICS &
RADIOLOGICAL SAFETY

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EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	✓	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	✓	

Comments 1 through 29 are attached.

Peer Reviewer John N. Bell Date Dec. 11, 1991

Comment Resolution Record

Yes ✓ The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ______ The following comments have not been adequately addressed:

Peer Reviewer John N. Bell Date Dec. 11, 1991

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-11-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.1
7. Page 3.3.1-2
8. Paragraph para. 1 of 3.3.1.1.1

9. Comment

Geographically, what is the closest population for exposure to "any incorporated place" (e.g., unincorporated NTS, Beatty, Amargosa)? Applicable census data re 1990? Is the target population in Las Vegas? If so, how calculate/determine to meet 960.5-1 (a) (1)?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

To better explain population density and distribution in the Yucca mountain area and to resolve concerns regarding the availability of 1990 census data, the following paragraph will be inserted into Section 3.3.1.1.3 in the review of information obtained since the Environmental Assessment (page 3.3.1-4):

"While the complete 1990 census data are not yet available and analyzed, the initial information indicates that the closest 'highly populated area' will be the unincorporated town of Pahrump, approximately 40 miles from the Yucca Mountain site, and the closest 1 mile by 1 mile area with a population of 1,000 or more persons will be in the unincorporated town of Beatty, approximately 20 miles from the site, or in the unincorporated town of Pahrump. The 1980 and 1990 census data do not provide exact information concerning the closest residents to the site. However, information from the radiological monitoring program indicates that the closest resident population is

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 29
2. Page 2 of 2
3. Name John H. Bell (Print Name)
4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

in the Lathrop Wells/Amargosa Valley area, approximately 10 to 14 miles from the Yucca Mountain site, but this population does not meet the population density definitions in the guidelines."

To address the question regarding Las Vegas, the first paragraph of Section 3.3.1.1.3 (page 3.3.1-3) will be modified to indicate that, based on the 1980 census, the Las Vegas urban area is both the closest highly populated area and the closest 1 mile by 1 mile area with a population of 1,000 or more individuals.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.1
7. Page 3.3.1-2
8. Paragraph para. 2 of 3.3.1.1.1

9. Comment

What is the population density in the 1 mile x 1 mile areas adjacent to the "surface facility of the repository? How determined? Daytime population of NTS? (How can third disqualifying condition exist if don't have 1 square mile population data?)

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Information from the radiological monitoring program indicates that the population density in the 1 mile by 1 mile areas adjacent to the "surface facility of a repository" (or the Yucca Mountain site) is zero if the term "adjacent to" is interpreted to mean adjoining or contiguous. In response to Dr. Bell's Comment #1, an additional paragraph will be inserted in Section 3.3.1.1.3 to explain population density and distribution in the Yucca Mountain area. That paragraph also addresses this comment.

A discussion of the daytime population of the Nevada Test Site has not been included in this section because the test site workers are not enumerated by the census as residents of the area.

The third disqualifying condition involves development of an emergency preparedness program, which would be required whether or not a highly populated area is adjacent to the site. The emergency preparedness program is a separate

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 29
2. Page 2 of 2
3. Name John H. Bell (Print Name)
4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

consideration from the population density and distribution factors.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.3
7. Page 3.3.1-3
8. Paragraph para. 1 of 3.3.1.1.3

9. Comment

If the Qualifying Condition #2 can "take into account the possibility of releases" such that a LLS-3 is subjectively (?) determined, why couldn't it just as well be an unsuitable?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The Level 3 finding for the second qualifying condition that was documented in the Environmental Assessment was based on a conservative interpretation of the information available at that time. The information that was assessed did not indicate that the site would be unsuitable, but was not judged to be sufficient to reach the Level 4 finding at that time. To address the concern regarding subjective determination of suitability, the last two sentences of the first paragraph of Section 3.3.1.1.3 will be modified to reiterate the findings of the Environmental Assessment:

"The information regarding the qualifying condition presented in the EA (p. 6-20 and 6-21) resulted in a finding that 'Preliminary calculations indicate that even the expected worst-case radiological dose will not exceed the limits of 10 CFR 960.5-1(a)(1) (1984) and will be negligible when compared to the background radiation dose.' Based on that evaluation, the EA stated that 'the evidence does not

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 29
2. Page 2 of 2
3. Name John H. Bell
   (Print Name)
4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

support a finding that the site is not likely to meet the qualifying condition for population density and distribution,' which resulted in a Level 3 finding."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.3
7. Page 3.3.1-3
8. Paragraph 4

9. Comment

Is there, anywhere, an emergency plan that is site-specific as evidence that DOE can satisfy requirements of DOE Order 5500.3 and 10 CFR 60?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The Nevada Operations Office currently maintains a site-specific emergency response plan under DOE Order 5500.3 A (DOE, 1991a). This can be activated either at their own action or at the request of the State of Nevada. An example of this response process is covered in "DOE/NV Radiological Assistance Team Notification Procedure Revision 17 (DOE, 1991b)."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 5 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.3
7. Page 3.3.1-4
8. Paragraph 2

9. Comment

With the change of administration of YMP is or is not the MOU with DOE/NV applicable, and how does the answer affect the "condition" of the requirement of an emergency preparedness plan per DOE Order 5500.3 or 10 CFR 60?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The Memorandum of Understanding (State of Nevada, 1984) remains applicable as DOE/NV is the "landlord" of Area 25, where the support facilities for the proposed repository would be located. To clarify this, a sentence will be added at the end of the second paragraph on page 3.3.1-4 stating, "Plans and procedures to be developed would be integrated with overall NTS emergency response plans that are in force at that time."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.3
7. Page 3.3.1-4
8. Paragraph 2

9. Comment

Apparent conflict. Who "directly" administers the YMP? DOE/NV?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

As indicated by the response to Dr. Bell's Comment #5, DOE/NV has "landlord" responsibilities for Area 25, where support facilities for the proposed repository would be located. The DOE Project Office reports to the Associate Director of the Office of Geologic Disposal, who reports to the Manager of the Office of Civilian Radioactive Waste Management for programmatic issues.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.4
7. Page 3.3.1-4
8. Paragraph 3

9. Comment

What are the "factors" that demonstrate that there would be no dose to an individual that would exceed the regulatory limits? What is the "maximum individual?" (maximum dose to an individual?) Individuals on NTS or Beatty or Amargosa? (LLS-3?)

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

To address the question regarding population distribution factors, the second sentence in the first paragraph of Section 3.3.1.1.4 will be modified to state the following: "First, because the Yucca Mountain site is not located in or adjacent to a highly populated area, there is nothing to suggest that the site will not meet the requirements of the qualifying condition."

The references to the "maximum individual" in Sections 3.3.1.1.3 and 3.3.1.1.4 referred to the "maximally exposed individual." Conceptually, the maximally exposed individual is any member of public standing at the boundary of the restricted area.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.4
7. Page 3.3.1-4
8. Paragraph para. 2 of 3.3.1.1.4

9. Comment

If the 1990 census has yet to be analyzed to determine "highly populated area" and one (1) square mile area, why the HLF-2?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The higher-level findings for the first two disqualifying conditions were established in the Environmental Assessment using data from the 1980 census. In response to Dr. Bell's Comment #1 an additional paragraph will be added in Section 3.3.1.1.3 to better explain population density and distribution in the Yucca Mountain area and to resolve concerns regarding the availability of 1990 census data. That paragraph also addresses this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.1.4
7. Page 3.3.1-5
8. Paragraph 1

9. Comment

Won't the site specific emergency preparedness plan written under the DOE Order 5500.3 actually be "approved" when accepted by the NRC when DOE submits license application to NRC?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Under DOE Order 5500.3A (DOE, 1991a), DOE can self-approve site-specific emergency response plans. The reviewer is correct that the NRC will review this plan against standards that exist at that time. This would be in addition to any DOE approvals and would occur after site selection. For this reason, no text changes are proposed.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 10 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.3.2
7. Page 3.3.1-9
8. Paragraph all of 3.3.1.3.2

9. Comment

a. What is the definition of "significant amount"? Quantify. Is it related to "source" term? How?

b. How are the potential release of radionuclides, design factors, release of radionuclides to unrestricted areas, weather, and that amount less than allowable related? What method of analysis to determine "significant amount"?

c. What is the existing information that allows for "reasonable judgments"?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

a. The phrase "significant amounts" is a poor choice of words for the sentence. The amount of radioactive release that should be discussed in this context is that amount that is addressed by the allowable releases in the regulations. The first paragraph in Section 3.3.1.3.2 will be revised to read:

"It is not likely that radioactive material in excess of the amount allowable under the requirements specified in 10 CFR 960.5-1(a)(1) will ever become airborne so that atmospheric dispersion or preferential transport would become an issue. However, the qualifying condition requires that consideration be given to design features that limit routine releases, such as ventilation systems, and to the potential for weather conditions to cause an accident."

b. The potential release of radionuclides, design factors, release of radionuclides to unrestricted areas, weather, that amount less than allowable

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 10 of 29
2. Page 2 of 2
3. Name John H. Bell (Print Name)
4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

under the regulations, and many more parameters are all related through a comprehensive dose assessment model and calculations for the site, yet to be completed. Such an effort will be accomplished and discussed as part of the system guideline for radiological safety. All input will contribute to a systems analysis of normal operations and accident scenarios to include parameters of characteristics of populations in the area, weather, land controls, and association with offsite installations and operations. This technical guideline for meteorology addresses primarily site characteristics with regard to natural weather conditions.

c. The phrase "reasonable judgments" was a poor choice of words in that definitions of "reasonable" could be an issue in many different forums. The phrase in the last sentence of the second paragraph of Section 3.3.1.3.2 has been replaced with "good scientific judgments and some assumptions." Nevertheless, the existing information that allows these judgments to be made is five years of site-specific meteorological data. The references to these data reports are on the following page of the report in Section 3.3.1.3.3, Review of Information Obtained since the Environmental Assessment.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 11 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.3.3
7. Page 3.3.1-9
8. Paragraph para. 1 of 3.3.1.3.3

9. Comment

a. Didn't the EA evaluation reveal more than an "indication" of infrequent severe weather?

b. What quantity of radionuclides is expected to be released? Has a dispersion model for the site been developed? What does it show quantitatively?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

a. The EA did not actually reveal a mere "indication" of infrequent severe weather, it directly stated, using area meteorological information, that severe weather was infrequent in the area. The second sentence of the first paragraph of Section 3.3.1.3.3 will be revised to read as follows: "The EA evaluation concluded that occurrences of severe weather....."

b. Radionuclide releases from the proposed facility are expected to be minimal and within allowable regulatory limits. A site dispersion model has not been developed; however, site-specific data indicate good dispersion characteristics and future information (including dispersion modeling) is unlikely to change the conclusion, hence, one reason for recommending the higher-level finding. Site dispersion modeling, however, will be done to better characterize the dispersion characteristics and provide input for the comprehensive dose assessment calculations planned to address the system

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 11 of 29

2. Page 2 of 2

3. Name John H. Bell
(Print Name)

4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

guideline for preclosure radiological safety.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 12 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.3.3
7. Page 3.3.1-10
8. Paragraph 2

9. Comment

a. Isn't Amargosa at the "end" of drainage winds down Amargosa Valley?

b. What are the "assumed" proper design considerations?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

a. The townsite of Amargosa Valley is in a southerly direction from Yucca Mountain and also "downslope" from the Yucca Mountain area. Given the relatively long distance (approximately 14 miles) from the Yucca Mountain site and the complex terrain in the vicinity, effective dispersion characteristics are apparent. However, continued monitoring of the phenomenon will ensure site conditions have been documented adequately for radiological safety and dose assessment calculations as part of the system guideline analysis.

b. The ESSE Core Team agrees the term "proper" should be replaced with some more definitive terms. The second sentence of the second paragraph under the heading labeled "Review of Information Obtained since the Environmental Assessment" in Section 3.3.1.3.3 has been revised to read:

"While these results require further review, they do not represent

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 12 of 29
2. Page 2 of 2
3. Name John H. Bell (Print Name)
4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

unsuitability concerns given that the technology exists to design facilities such that releases of radioactive material greater than that allowable under the regulations will be controlled. In addition, prevailing winds at the site are such that overall effective dispersion is apparent."

In addition, a sentence will be added to the paragraph in Section 3.3.1.3.3. labeled "Atmospheric dispersion." The sentence will read as follows:

"The above information supports the conclusion that dispersion characteristics are not expected to contribute to a potential dose of radioactive material to any population in the Amargosa Valley area in excess of the amount allowable under the regulations, should a release occur."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 13 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.3. (new 3.3.1.5.3)
7. Page 3.3.1-18
8. Paragraph 3,5

9. Comment

a. Why are statements relative to "radioactive releases" only two sentences? What were the estimates of the EA vs MacDougall (SNL, 1987) study? State release amounts and effect/significance. Define "source term."

b. What does "Accident consequences were found to be generally lower than in the EA" mean? Are overflights allowed or prohibited? If overflights are allowed, what are the consequences of an aircraft accident to the WHBs?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

a. The EA evaluation of radiological safety for accidental conditions was based on a preliminary safety assessment performed by Jackson et al. (1984). These release calculations were updated in the Site Characterization Plan - Conceptual Design Report (SNL, 1987). This evolution of information will be explained in the text of the ESSE report.

Section 3.3.1.4.5.3, "Repository Conceptual Design Studies" will be revised to read as follows: "In the Repository Conceptual Design Report, prepared to support the Site Characterization Plan (DOE, 1988a), Sandia National Laboratory (SNL) (1987) revised estimates of radiological releases from accidents that could occur at the repository. Estimates in this study were made taking less credit for release mitigation systems (for example, filters) than the EA. For this reason, higher doses to the maximally exposed individual (up to 1.1 rem) are estimated. At the same time, updated accident frequencies are lower than those presented in the EA. When frequency and consequences are combined to

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 13 of 29
2. Page 2 of 2

3. Name John H. Bell
(Print Name)

4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

predict risk levels (frequency time consequences), both reports predict risks due to accidents are low for the waste handling building."

b. Predicted doses to the maximally exposed individual are higher in the SCP-CDR than in the EA. However, frequencies are lower. Risks predicted by both studies are comparable and low. The text will be added at the end of the second paragraph in Section 3.3.1.4.4.1 (new 3.3.1.4.5.3).

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 14 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.4.4(new 3.3.1.4.5.4)
7. Page 3.3.1-19
8. Paragraph (Ionizing radiation)

9. Comment

If "estimates of expected releases" from NTS can be 'predicted,'" why is there "no specific estimate of planned releases from the repository"? What about "unplanned"? Why any release from the repository if "Technology exists for the control of repository releases to negligible levels"? For example, K-85, T-3, C-14, and I-129?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

No specific evaluation has been done for a repository at Yucca Mountain for expected releases, since design details are not yet available. However, given experience in similar facilities, filtration technology is adequate to avoid unusual dispersion hazards. No site condition precludes mitigation of impacts from small planned releases to levels in compliance with applicable dose standards. These releases would be primarily particulates from activated corrosion products present on the outside of the fuel rods (crud). Unplanned releases could occur if accidents or fuel rod failures occur. These could involve quantities of the isotopes mentioned in the comment as well as spent fuel particulates. Gaseous products are assumed to be released, and particulates are assumed to be reduced with filters.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 15 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.4.4.(new 3.3.1.4.5.4)
7. Page 3.3.1-21
8. Paragraph (Aircraft mishaps)

9. Comment

Will agreements be established to preclude aircraft overflights of aircraft? If not, why not?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The need to preclude overflights will be decided after a review of the overflight analyses. If needed, this could be accomplished through a Memorandum of Understanding with the U.S. Air Force. The current predicted frequencies of potential crashes are on the order of 1 in 1,000,000 per year.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 16 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.4.5 (new 3.3.1.4.5.5)
7. Page 3.3.1-22
8. Paragraph Ionizing radiation

9. Comment

If releases of radioactive material and radiation from the repository are expected ("to be minor"), why not state that technology will be used to control releases to "negligible levels" rather than that the technology just "exists"?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The details of air treatment to be used have not been decided. It will be based on needs identified in a detailed facility analysis. At a minimum, (high efficiency particulate air (HEPA) filters will be used on all hot cells. Filtration of mine air will be available on a diversion basis. This will be added to the discussion. Air treatment for iodine is available, but may not be necessary due to the long cooling time of the fuel. The last sentence of the paragraph will be revised to reflect the lack of specific estimates of releases at this time and will read as follows:

"Releases of radioactive material and radiation from the potential repository are expected to be minor, and will be less than applicable regulations and standards. However, specific estimates for these releases have not been completed. During future design activities, these releases will be evaluated and mitigation technology applied such that ionizing radiation is not expected to lead to an irreconcilable conflict with atomic energy defense

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 16 of 29
2. Page 2 of 2
3. Name John H. Bell (Print Name)
4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

activities."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 17 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.4.5 (new 3.3.1.4.5.5)
7. Page 3.3.1.1-23
8. Paragraph (Facility Accidents)

9. Comment

What is the meaning of "repository" - the total facility or the storage site? Where are explosives and propellants to be stored? What is the distance from "onsite" activities? It would seem that the greatest potential hazard is from an explosion on the repository or WHFS.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

"Repository" refers to both surface and subsurface preclosure activities at the Yucca Mountain site. To clarify this in the text, the word "site" will be inserted after "repository" in the first sentence. Explosive storage will be remote from the waste handling buildings on the surface and waste emplacement underground. The structures used for shielding of high-level waste preclude significant damage from explosions. See Section 3.3.1.4.5.4 on facility accidents leading to radioactive material releases.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 18 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.4.5.(new 3.3.1.4.5.5)
7. Page 3.3.1.1-23
8. Paragraph (...radioactive material)

9. Comment

Though accidents of this type (releases of large quantities of radioactive material) are expected to be "rare" only one (1) needs to occur. Does this statement mean that releases of "large" quantities of radioactive material are to be expected - inevitable? This is the primary concern of the public.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This paragraph heading will be revised to read "Releases of significant quantities of radioactive material." A release with a fenceline 50-year dose commitment of 500 millirem is not "large." The 500 millirem level is a proposed design basis for the repository facilities. The design would limit releases below this level and seek to minimize the potential for all accidents. The first sentence will be revised to state "Repository design standards require that releases under accident conditions will not allow offsite doses to exceed 500 millirem."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 19 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.4.4.5 (new 3.3.1.4.5.5)
7. Page 3.3.1-24
8. Paragraph (Security)

9. Comment

Will there be outside (non DOE) oversight (NV?) of the YMP operation? Or will "security" preclude "outside" oversight?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Security will not preclude oversight. It is our understanding that the State of Nevada, NRC, and DOE safety organizations will have reasonable access to the facility.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 20 of 29	5. Revision Draft/Date August 1991
2. Date November 1991	6. Section 3.3.1.4.4.6 (new 3.3.1.4.5.6)
3. Reviewer John H. Bell	7. Page 3.3.1-24
4. Organization UNLV	8. Paragraph (Discussion)

9. Comment

Question HLS-4 for part (2) of the Qualifying Condition relative to radionuclide releases to an unrestricted area. Wording of "...no significant (?) releases....are expected.", "planned releases" (versus unplanned), "releases of large quantities...", accidents of this type are expected to be rare..." lead one to question confidence of HLS-4. Perhaps the suitability level should be changed (to LLS-3) or the wording changed given the analysis of the data to support the HLS finding.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This finding is based on a review of current technology, conceptual designs, and needed features of the site for radiological safety. Nothing currently at the site or expected to be discovered during characterization would preclude a radiologically safe facility given a comprehensive approach to design. However, the conclusions and recommendations section will be revised and expanded to reflect that the site is suitable for characterization under this guideline and that additional design evaluations are needed to support the higher-level finding.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 21 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.5.1, 3.3.1.5.3
7. Page 3.3.1.1-25, -27
8. Paragraph

9. Comment

The system guideline addresses projected releases during repository operations. The accidental releases are addressed as a result of "normal operations." What accidental releases were considered in the "newer studies" that provide "better descriptions of accident scenarios and releases from abnormal operations" or "nonnormal accidents"? What abnormal accidents did the newer accident scenarios consider?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The reference to radiological dose limits in Section 3.3.1.5.1 is not explicitly used in Section 3.3.1.5.3. The reference documents identify a number of accident scenarios with various dose consequences that could be compared with the limits. However, that discussion would be lengthy and would not add much to the ideas in Section 3.3.1.5.3. In general, the newer evaluations reexamined the major and minor accident scenarios considered in the earlier studies. These studies were designed to assist in the implementation of quality assurance in the design process, not for the resolution of 10 CFR Part 960 issues. The text of Section 3.3.1.5.3 will be modified to discuss intended usage of the studies and to remove the ambiguity of why these things are in the report.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 22 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.1.5.4
7. Page 3.3.1-28
8. Paragraph 2

9. Comment

Until detailed abnormal accident/release scenarios are considered relative to the system guideline, an LLS-3 rather than a level-4 finding is applicable.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that additional design information is necessary to first describe the facility and its operations and then to justify the higher-level finding for the system guideline. Commentary will be added to Section 3.3.1.5.3 to discuss the data obtained since the EA (e.g., SNL (1987) supporting development of the Site Characterization Plan), reverting to the EA (lower-level) finding, and stating that additional facility design information is necessary before a higher-level finding can be supported.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 23 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.2.3.3.1
7. Page 3.3.2-16
8. Paragraph para. 2 of 3.3.2.3.3.1

9. Comment

If the design of the transportation cask precludes rupture and radiation levels external to unruptured casks is negligible (within DOT levels), why is the route unfeasible due to land use conflicts with wilderness study areas and residential development? Won't any other route(s) impact in a similar fashion on other wilderness or populated areas?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The land-use conflict is not radiological in nature. Land-use restrictions preclude the development of any right of way in these areas until their wilderness attributes can be evaluated. No changes to the text are proposed.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 24 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.2.3.3.1
7. Page 3.3.2-16
8. Paragraph (in-text table)

9. Comment

What does 0.37 Regional and 11.3 National Radiological Fatalities mean? How are they caused? Isn't this an "unacceptable risk" to the public or an "unacceptable public health impact"?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

These estimates are based on a linear dose effects model for miniscule radiation doses that would be received by population along the route. Accidental releases of material, weighted by their low expected frequency, are included and are less than 10 percent of the total predicted potential impacts. The indicated potential impacts are insignificant when compared with health effects from natural background radium doses using the same model. No changes to the text are proposed.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 25 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.2.3.3.2
7. Page 3.3.2-17
8. Paragraph 3

9. Comment

What are the different states' "designated routes" For Nevada?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Currently the State of Nevada has not designated alternative routes to I-15 and U.S. 95 to Yucca Mountain. The State is currently evaluating alternatives that include U.S. 93A from Wendover, U.S. 6, and U.S. 95. Past shipments have traveled this general route to the north. Shipments to the south could travel state highways to Baker, California, where they would access I-15.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 26 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.2.3.3.3
7. Page 3.3.2-18
8. Paragraph (Transportation planning)

9. Comment

What specifically is the "planning issue" that remains open at this time relative to cask design?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The Office of Civilian Radioactive Waste Management plans to design, license, and build new cask designs that will carry more fuel than current models. This is possibly due to the long cooling time of fuel available for transport to a repository. Final designs are not available at this time. Thus, final estimates of the numbers of shipments and specific cask design features are not currently available. There is, however, no specific site feature that would need to be considered in the cask design. This makes the cask design activity independent of site suitability evaluations. Thus, no changes to the text are proposed.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 27 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.3
7. Page 3.3.3-2
8. Paragraph 2

9. Comment

How can it be concluded that the site would not require "particularly expensive" mitigation techniques (e.g., for negligible release) if the design requirements and plans for activities are not completely developed?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The intent of the sentence was to convey the fact that no site conditions have been identified to date that would cause difficulties. The last sentence of the second paragraph on p. 3.3.3-2 will be changed as follows: "The Core Team did not identify any characteristics of this particular site that would lead to use of mitigation techniques that are unusually expensive. However, detailed considerations of costs were not made in this evaluation."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 28 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 3.3.3.2.3.1
7. Page 3.3.3-10
8. Paragraph Table 3.3.3-2, 3.3.3.2.3

9. Comment

How can DOE state "no rock characteristics that could cause undue hazards to personnel have been identified..." when compared to the statement "Unacceptable uncertainty remains concerning occupational health risk and environmental impact represented by mordenite"?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The statement "...no rock characteristics that could cause undue hazards to personnel have been identified..." in Section 3.3.3.2.3.1, Summary of Environmental Assessment Findings, was the status at the time of the EA. "Unacceptable uncertainty remains concerning the occupational health risk and environmental impact represented by mordenite" in Section 3.3.3.2.3.2, Information Acquired since the Environmental Assessment, is the current status as a result of the early site suitability evaluation. The subject issue is a post-EA development. The two statements are not inconsistent in that they appear in the proper context for the period of time being discussed, thus no text changes are proposed.

A separate concern with the second phrase discussed above is with the word "unacceptable." Since the lower-level finding has been maintained for this guideline, the uncertainty associated with the subject risk requires additional information through the site characterization program to address the

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 28 of 29

2. Page 2 of 2

3. Name John H. Bell
(Print Name)

4. Date November 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

high-level finding. The term "unacceptable" has been deleted from the sentence (penultimate sentence in last paragraph of Section 3.3.3.2.3, p. 3.3.3-12).

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 29 of 29
2. Date November 1991
3. Reviewer John H. Bell
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section
7. Page 4-7
8. Paragraph 4.3

9. Comment

If "there is some probability that this release limit (EPA limit for gaseous C-14) to the environment" could be exceeded, how can a HLS-4 (Table 4-2) be stated for System Guideline and Offsite Installations and Operations (QC #2)?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that there are areas within the System Guideline and the Offsite Installations and Operations technical guideline, especially regarding surface facility design, that require additional study efforts before higher-level findings can be recommended. For this reason, maintaining lower-level findings for these subject areas is a prudent approach at this time. The conclusion and recommendation sections of the guidelines have been revised to reflect the above approach.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

REFERENCES FOR DR. JOHN H. BELL

DOE (U.S. Department of Energy), 1986. Final Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada, 3 volumes, DOE/RW-0073, Office of Radioactive Waste Management, Washington, DC.

DOE (U.S. Department of Energy), 1991a. Planning and Preparedness for Operational Emergencies, DOE Order 5500.3A, U.S. Department of Energy, Washington, DC.

DOE (U.S. Department of Energy), 1991b. The DOE/NV Radiological Assistance Team Notification Procedure, Rev. 17, U.S. Department of Energy Nevada Field Office, Las Vegas, NV.

Jackson, J. H., H. F. Gram, K. J. Hong, H. S. Ng, and A. M. Pendergrass, 1984. Preliminary Safety Assessment Study for the Conceptual Design of a Repository in Tuff at Yucca Mountain, SAND 83-1504, Sandia National Laboratories, Albuquerque, NM.

SNL (Sandia National Laboratories), 1987. Site Characterization Plan Conceptual Design Report, SAND84-2641. 6 Vol., Sandia National Laboratories Albuquerque, NM.

State of Nevada, 1984. Hazardous Materials, Memorandum of Understanding, to Implement Hazardous Materials Accident Assistance Plan, Nevada Division of Emergency Management.

Younker, J. L., W. B. Andrews, G. A. Fasano, C. C. Herrington, S. R. Mattson, R. C. Murray, L. B. Ballou, M. A. Revelli, A. R. Ducharme, L. E. Shepard, W. W. Dudley, D. T. Hoxie, R. J. Herbst, E. A. Patera, B. R. Judd, J. A. Docka, and L. D. Rickertsen, 1992. Report of Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada, SAIC-91/8000, Las Vegas, NV.

10 CFR Part 60 (Code of Federal Regulation), 1990. Title 10, Energy, Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories, U.S. Government Printing Office, Washington, DC.

10 CFR Part 960 (Code of Federal Regulation). Title 10, Energy, Part 960, General Guidelines for the Recommendation of Site for Nuclear Waste Repositories, U.S. Government Printing Office, Washington, DC., pp 518-551.

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Dr. F. William Cambray

STRUCTURAL GEOLOGY,
TECTONICS

Michigan State University
East Lansing, MI

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	1-4	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	1-4	

Comments 1 through 4 are attached.

Peer Reviewer F. W. Cambray Date 12/16/91
F. W. CAMBRAY

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ______ The following comments have not been adequately addressed:

Peer Reviewer F. W. Cambray Date 12/16/91
F. W. CAMBRAY

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-16-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 4
2. Date November 11, 1991
3. Reviewer F. William Cambray
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3
7. Page 2-104
8. Paragraph 5

9. Comment

Under Recommendations for Future Activities. The need for credible tectonic models is referred to. There seems to be an emphasis on a detachment model for the region but much of the evidence points towards strike-slip being the most important factor in this area in recent times. The observations of Gianella and Callaghan (Bull. Seism. Soc.Am 1934) indicate that there is a marked difference between the strike slip movement associated with the earthquake on the Walker Lane Belt and the proposed low angle normal faulting associated with detachment faults. Wright (ref.#3515) has suggested that detachment faulting was important until 16-14 Ma ago and then strike slip faulting became the dominant tectonic activity in region. This proposed change coincides with the change in igneous activity from predominantly large scale felsic volcanic centers to small basaltic cones and minor intrusions.

The Yucca Mt. Crater Flats region could be modeled as a releasing bend in a strike slip setting on the Walker-Lane Belt. The Yucca Wash Fault extending

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment appropriately points out that earlier revisions, meant to provide a more balanced discussion of alternatives to regional detachment faulting as the basic tectonic model in Section 2.3.7.3.2.1, were not carried over into the discussion on page 2-104. In addition, the comment and subsequent discussions with Dr. Cambray provide a compelling reason to reorganize and supplement Section 2.3.7.3.2.1.

We will revise Section 2.3.7.3.2.1 to read as follows:

"2.3.7.3.2.1 Tectonic models.

The EA considered two basic tectonic models for the Yucca Mountain area. The first was a caldera model, in which the faults near the potential repository block were portrayed as subsidiary features resulting from inferred caldron subsidence in Crater Flat. The second was a Basin-and-Range model, in

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 4
2. Page 2 of 18
3. Name F. William Cambray (Print Name)
4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

NW from the north side of the region could be one branch of the strike slip fault and the proposed buried strike slip fault extending along the south side of Crater Flat and under the Amargosa Valley (Schweickert ref.#3843) the other. The termination of the NS faults against the Yucca Wash Fault and the lack of continuation of this fault to the south east (Scott ref.#3173) makes this a reasonable interpretation. As a first approximation the Paintbrush Fault might represent the eastern termination of the pull-apart basin formed in this releasing bend and the Bare Mountain Fault on the west side of Crater Flats could be the western termination. This would explain why the Bare Mountain normal fault cuts the detachment proposed by Scott (ref.#3173 fig.15). It would place the mafic volcanic rocks in a releasing bend which could help to explain their rise from the mantle without differentiation or contamination (several authors P.2-94 ESSE report) and the clustered arrangement. The thick sequence of volcanic rocks underlying Crater Flats would be the pull-apart basin fill in this model. The detachment referred to by Scott may be a dissected older detachment as he suggests. If so it is now cut by faults associated with the releasing bend. It may however be an accommodation zone that developed in response to the transfer of motion from the underlying strike slip fault in the basement to the package volcanic rocks above (see Manspeizer, W. The Dead Sea Rift, Impact of Climate and Tectonism on Pleistocene and Holocene Sedimentation in Strike-Slip Deformation, Basin Formation and Sedimentation. Soc. Econ. Pal.and Min., Spec.Pub.37, 1985, fig.13). This has important implications for the use of tectonic models in predicting groundwater movement.

In such a setting the NS faults on Yucca Mountain would also be accommodating movements to the underlying strike slip movement and give rise to the decoupling referred to in the report. The clockwise rotation at the southern end of the mountain is consistent with this hypothesis. On page 2-94 the Cedar Mountain earthquake is referred to as 'exceptional' but the author goes on to say that 'the occurrence of the distributed faulting at the smaller Excelsior Mountain earthquake indicates that this model should be considered in the faulting potential at Yucca Mountain'. I endorse this comment and suggest that strike slip faulting be elevated to the most likely source of potentially damaging seismic activity in the area.

END OF TEXT

10 Proposed Resolution (continued)

which crustal extension is accommodated by a combination of N-striking normal faults and NE- and NW-striking strike-slip faults that penetrate to the brittle-ductile transition. More recently, in the Site Characterization Plan

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 4

2. Page 3 of 18

3. Name F. William Cambray (Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

for Yucca Mountain (DOE, 1988a), detachment faulting (low-angle extensional faulting) of various styles and planar-rotational faults (producing a "tilted-domino" block structure), whether deep-seated or terminating on an underlying detachment, have been recognized as possible alternatives to the interpretations in the EA.

Use of Terms

As used in this report without qualifying terms, a detachment fault (or simply detachment) is a low-angle extensional fault within the brittle crust, whether regional or local in areal extent. No implication as to the amount of displacement is intended. The degree of mechanical coupling between the rocks below and above a detachment may vary spatially and temporally, and styles of subsidiary faulting above the detachment are not specified. The subsidiary faults may include additional shallower detachments, planar normal faults that abut downward into an intensely sheared detachment, or listric normal faults, which decrease in dip downward to merge into the detachment surface. Local variations of stress and preexisting geology, particularly near the edges of the upper plate(s), may result in subsidiary strike-slip faults, reverse faults, dip-slip faults that increase in dip with depth, oblique-slip faults, or bending of the upper plate about a steeply plunging axis. Where the special case of essentially lateral dislocation between the brittle crust and underlying ductile deformation is intended, it is specified in the context. The boundaries of such a deep-seated detached plate ideally would be high-angle strike-slip faults and listric faults of such large radius of curvature that, near the land surface, they would be indistinguishable from normal faults that intersect the brittle-ductile transition at high angles. At this scale, there may be a loss of distinction between detachment and deep-seated "Basin-and-Range" styles of faulting in terms of their seismic and hydrologic significance.

Depending on its age, the proposed detachment faulting in the vicinity of Yucca Mountain (see, for example, Scott, 1990) has differing implications for site characterization and performance evaluation. If the detachment structures are very old and overprinted by young tectonic features, they may have little significance for earthquake-hazard or hydrologic studies, but they may laterally displace still older structural and volcanic features. If the detachments are active, paths of upward magma migration might still be offset somewhat along the detachment surface, and the fracturing that may accompany upper-plate movement may dominate the hydrogeologic character of the area. Subsidiary faults in the upper plate, depending on plate thickness, might have

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limited potential for seismic energy release, whereas the greater seismogenic potential may actually be associated with deeper faults that may not be readily identified beneath the detachment. Because of the ranges of the possible significance of different tectonic styles or models, the principal evidence for these models and their significance to this evaluation of postclosure tectonics are discussed in greater detail below.

Regional and Local Evidence for Detachment Faults

The basis for the detachment-fault model in the southern Great Basin has been summarized recently by Scott (1989a, 1990), who cites evidence throughout the region for westward to southwestward migration of gentle doming and multiple levels of west-dipping detachment surfaces. He interprets three levels of low-angle normal faults mapped by Burchfiel (1965) in lowermost Paleozoic and upper Precambrian rocks in the Spring Mountains, 45 km southeast of the Yucca Mountain site, possibly to be part of a relatively deep regional detachment that may now surface at the edge of the Precambrian core complex in the Bullfrog Hills (Maldonado, 1985; 1990b) and in the northern part of Bare Mountain (Monsen et al., 1990), respectively about 40 km and 15 km west of Yucca Mountain. However, Scott (1989a, 1990) also discusses probable shallower, more local detachments identified by seismic investigations in Mid Valley (McArthur and Burkhard, 1986) (25 km east of Yucca Mountain), by mapping of exposures of the Tertiary-Paleozoic contact north of Mercury (Myers, 1987) (40 km east of Yucca Mountain), and by mapping of low-angle faults within the Tertiary and Paleozoic sections of the Calico Hills (Simonds and Scott, 1987) (about 19 km northeast of Yucca Mountain). Common features of the exposed faults are structural discordance with termination of dipping stratigraphic contacts and faults within the upper plate at its base, and structural and textural evidence of shear displacement parallel to the contact of the upper and lower plates.

In addition to the several references cited in the SCP (DOE, 1988a), the following papers discuss the evidence for one or more detachment plates at Yucca Mountain itself: Scott and Rosenbaum (1986); Scott and Whitney (1987); Hamilton (1988); Scott (1989a, 1990); Fox and Carr (1989); and Spengler and Fox (1989). In the composite detachment model of these authors, as recently summarized by Scott (1990), the high-angle north-striking faults that intersect the surface at and near Yucca Mountain decrease in dip listrically with depth, merging with an underlying low-angle extensional fault within the brittle crust. Scott (1989a, 1990) also discusses evidence that the rate of displacement along the detachments decreased markedly before deposition of the

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11-million-years-old Timber Mountain Tuff, but that much less extension continued into the Quaternary along a shallower, secondary fault system. Movement on faults in the upper plate (or uppermost of two or more stacked plates) would be limited in depth of penetration, possibly placing constraints on the depth to which hydraulic pathways would be developed or refreshed. The depth limitation might be expected to limit also the seismic energy released by fault movement in the upper plate, but this may be a moot point if faulting above the detachment is coupled to deep faulting beneath. In fact, detachment of near-surface rocks may be a passive means of accommodating deep strike-slip fault displacement where the shallow section is imperfectly coupled to deeper rocks; this has been proposed by Scott and Rosenbaum (1986) to be the origin of the rotation of the tuffs about a vertical or nearly vertical axis at central and southern Yucca Mountain.

The east-bounding breakaway zone for the detachment with Quaternary movement beneath Yucca Mountain is proposed to occur about 2 km east of the potential repository site, along the Paintbrush Canyon fault. Fox and Carr (1989) suggest that this detachment occurs at the Tertiary-Paleozoic contact beneath Yucca Mountain, though they do not exclude the possibility that it is deeper. A generalized cross section in Scott (1989a, Figure 2) indicates a westward thickening of the upper plate beneath Yucca Mountain, in part because of topographic rise, from about 2.5 km to about 4 km. Young et al. (1991) applied computer techniques in a geometric-kinematic analysis of the geologic observations of Scott and Bonk (1984) and data from a drill hole that penetrates Paleozoic rocks at a depth of about 1.2 km (Carr et al., 1986). They suggest that the cross section cannot be balanced with the representation that the Paintbrush Canyon Fault merges listrically into a detachment at the base of the Tertiary section; rather, they propose that the detachment must occur at a greater depth, in the range of 3.5 to 6 km. The differences between these interpretations probably cannot be resolved, nor can other alternatives be identified, until the structural architecture is explored in greater detail by intensive geologic studies, including mapping, and to greater depths by geophysical techniques and possibly deep drilling.

<u>Alternative Interpretations of the Evidence</u>

Low-angle, even near-horizontal normal faults have been explained in the literature by mechanisms other than detachment faulting, as defined above to occur within the brittle crust. For example, Proffett (1977) proposed that the basic style of faulting in the Yerington district of western Nevada is deep-seated listric faulting, steeply dipping near the surface but decreasing

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in dip with depth until the extension is accommodated by ductile flow. Where segments of faults that were originally deep are now exposed, they dip at very shallow angles, even forming apparent low-angle reverse faults. Proffett (1977) suggests that original dips have further decreased by two mechanisms. First, there is evidence of substantial westward tilting in the Yerington region, such that the east-dipping faults that dominate in the area were rotated to shallower dips. Second, in the Yerington district, the positions of new faults tended to migrate westward or into the footwall blocks of previous faults. The tendency for extensional openings at the shallow, steeply dipping fault segments was accommodated principally by west-dipping sagging of the hanging wall, rather than by antithetic faults, further decreasing the dip of older faults close to their successors (Proffett, 1977).

Wright (1989) accepts the existence of detachment faults in the region within and east of Death Valley, but he argues that, beginning 16 to 14 Mya, this region was divided into structural blocks by major strike-slip and normal faults. He proposes that the detachments, rather than being regional features, are unconnected local features within the individual blocks. The emphasis of Wright's (1989) synthesis of mapped faults and gravity data is the accommodation, beginning in the mid-Miocene, of right-stepping strike-slip fault zones by en echelon, obliquely oriented normal faults, "pull-apart" basins, and associated igneous activity. In his interpretation, the Amargosa Desert and Crater Flat, respectively south and west of Yucca Mountain, are within a zone of pull-apart basins termed the Amargosa Desert Rift Zone (ADRZ). He relates the ADRZ genetically to the Pahrump Valley and Stewart Valley right-lateral strike-slip faults which, if projected to the northwest, coincide approximately with the Walker Lane structural zone. Although Wright (1989) notes that Quaternary faults in Pahrump Valley and western Crater Flat follow those established in mid-Miocene time, he does not address the possible relation of these structures to Pliocene-Quaternary basaltic volcanism in the region. Schweikert (1989), however, suggests that the northwest alignment of basaltic cones in and northwest of Crater Flat may indicate the presence of a major right-lateral strike-slip fault that is not evident at the alluvial surface of Crater Flat.

<u>Controls on Patterns and Characteristics of Volcanics</u>

A series of papers by Crowe and his colleagues (Vaniman and Crowe, 1981; Vaniman et al., 1982; Crowe et al., 1983a; Crowe, 1986) discusses the petrology and geochemistry of the Pliocene-Quaternary basalts of the southern Great Basin, inferring that the magma chambers must be at or below the

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crust-mantle boundary. Crowe et al. (1983b) defined a volcanic zone the Death Valley-Pancake Range Volcanic Zone (DVPRVZ), extending from Death Valley northward to the Pancake Range in Central Nevada, suggesting regional structural control of basalt centers. Carr (1984) suggested that some of the Pliocene-Pleistocene basalt centers occur along northeast-trending rifts within the DVPRVZ. North-northeast-trending structural controls also are components of later models proposed by Fox and Carr (1989), Smith et al. (1990), and Naumann et al. (1991).

In recent reassessments of volcanism patterns and characteristics in the Yucca Mountain area, Crowe and Perry (1989) and Crowe (1990) define the Crater Flat volcanic zone (CFVZ), favoring a northwest alignment of Pliocene-Pleistocene basaltic centers from the Lathrop Wells cone (20 km south of the Yucca Mountain site) to the basalts of Sleeping Butte. This trend is compatible with that of the Walker Lane structural system, suggesting control of paths for ascending magma along northwest-trending, right-lateral strike-slip faults, as was suggested also by Schweikert (1989). Crowe and Perry (1990) consider a secondary northeast alignment of vents in clustered centers to reflect near-surface feeder dikes perpendicular to the direction of regional extension and least principal stress.

Smith et al. (1990) chose to define their area of most recent volcanism (AMRV) based only upon the factor of age, and they did not include magma composition and tectonic setting as criteria. The inclusion of the 2.8 Ma basaltic andesite of Buckboard Mesa allows Smith et al. (1990) to define an elliptical AMRV that encompasses Yucca Mountain. However, it should be noted that all Quaternary (<1.6 Ma) basaltic eruptive centers near Yucca Mountain occur inside the northwest trend of the CFVZ. In the CFVZ model, the geochemically similar basalts erupted since 3.7 Mya within the northwest alignment of the CFVZ are distinct from the basaltic andesite of Buckboard Mesa. The Crowe and Perry (1989) analysis is considered to be more rigorous, but further investigations are planned to examine the structural controls on basaltic volcanism. The structural controls on volcanism are important components of an overall understanding of Quaternary tectonism. A direct linkage of faulting and volcanic activity was proposed by Fox and Carr (1989), who deduced from the common occurrence of volcanic ash within the north-striking fault zones near Yucca Mountain that the Quaternary faulting and nearby basaltic volcanism have been coeval.

Crowe (1991b) has suggested that basaltic volcanism in this extensional setting tend to occur within alluvial basins or along range-front faults, but

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that it is rare in the range interiors. However, there are examples of volcanic centers in uplifted range blocks, such as the Fortification Hill volcanic field south of Lake Mead and basalts in Reveille Range in south-central Nevada (Smith et al., 1990), as well as the intracaldron basalts of the Lunar Crater Field (Crowe et al., 1986). This suggests that gross topography may be related to the occurrence of basaltic centers only where it accurately reflects deep crustal structure, a relationship that is probable but not fully demonstrated near Yucca Mountain.

Evidence from Patterns of Fault Movement

The geochemically indicated ascent of the basalts along northwest-striking, deeply penetrating faults and the temporal coincidence of volcanism with movement on the north-striking faults near Yucca Mountain provide strong grounds for inferring a ginetic linkage between the two directions of faulting. If the north-striking faults represent only shallow, brittle failure within a d tachment plate, the plate must be sufficiently coupled to rocks beneath the detachment to deform in direct response to deeper fault movement. Alternatively, the north-striking faults may be deep-seated structures that accommodate releasing bends resulting from offsets or changes of direction of the strike-slip fault segments (as stated by Cambray in Younker et al., 1992).

The deep-seated accommodation of right-stepping offsets is consistent with Wright's (1989) hypothesis for pull-apart basins, filled by thick volcanic rocks and sediments, beneath the Amargosa Desert and Crater Flat. Irregular boundaries, formed in part by secondary reentrants into the footwalls, probably are part of an evolutionary reestablishment of strike-slip motion through inherently unstable releasing bends (Ellis and Trexler, 1991).

The Las Vegas shear zone, a major right-lateral structure that strikes about N 65 degrees W on average, loses clear expression at its northwest end, about 50 km southeast of Yucca Mountain. If projected to the northwest, it would intersect the projected Walker Lane trend (N 35 - 40 degrees W) in the vicinity of several faults that strike west-northwest in northern Yucca Mountain. The Las Vegas shear zone is aligned in the direction of the current extensional axis and is interpreted to have been inactive since about 11 Ma (Fleck, 1970; Bohannon, 1983). Therefore, it seems unlikely to be temporally related to the Pliocene-Quaternary volcanism or fault displacement, but it may have contributed to the development of the prominent Miocene structural depression beneath Crater Flat.

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O'Neill et al. (1991) describe NW-trending pull-apart structures at Yucca Mountain that are structurally linked to the N-striking faults, which display dominant normal dip slip and auxiliary left-lateral slip. Scott and Rosenbaum (1986) and Scott (1989a, 1990) considered the southward-increasing clockwise rotation of Yucca Mountain about a vertical axis, which is indicated by paleomagnetic data, probably to indicate interaction of an upper detachment plate with right-lateral oroclinal bending and shearing associated with the Walker Lane structural belt beneath the detachment surface. O'Neill et al. (1991) consider this clockwise rotation, the left-lateral oblique slip on the North-striking faults, and the Northwest-trending pull-apart zones to be consistent with "domino style" rotation of rigid fault blocks. These features also are consistent with deformation within a pull-apart structure.

Although considerable progress has been made in understanding the near-surface structural features, extending this understanding to depths of several kilometers in order to infer their seismogenic, volcanic, and hydrologic significance remains elusive. However, modern data on seismicity and ground-water temperatures indicate the importance of gaining an understanding of the deep structures.

Evidence from Seismicity and Heat Flow

Current seismicity in the immediate vicinity of Yucca Mountain is very low, but earthquakes have been recorded in the area at depths as great as 15 kilometers (Rogers et al., 1987b). The deeper historical earthquakes are dominated by strike-slip focal mechanisms. Although the seismicity supports the presence of deeply penetrating faults, it does not preclude interpretations of shallower detachment faulting. The focal mechanisms for the deeper earthquakes may suggest mechanical decoupling from an upper plate in which a normal-faulting stress regime has been interpreted from borehole hydrofracture testing results (Stock et al., 1985) and paleoseismic studies. Historical earthquake locations in the southern Great Basin do not correlate well with major faults at the surface (Rogers et al., 1987b), whereas Coppersmith (1990) notes that inversions of teleseismic data for several Basin-and-Range earthquakes show them to be associated with moderately to steeply dipping faults rather than subhorizontal reflectors seen on seismic-reflection data. dePolo et al. (1990) suggest that partial decoupling within the upper crust may explain the complex surface-rupture patterns (distributed faulting) of several historical Basin-and-Range earthquakes. Partial decoupling is consistent also with the coincident west-northwest direction of the least principal stress for both shallow (hydrofracture) and deep (focal-plane)

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determinations (Rogers et al., 1987b) and with the oblique sense of movement on some of the faults in the vicinity of Yucca Mountain. If at least partial decoupling of an upper plate from the underlying seismogenic zone is demonstrated, paleoseismic investigations in the immediate vicinity of the Yucca Mountain site may have limited application in forecasting ground-motion characteristics; however, local paleoseismic data would still be needed in predicting the probability of primary and secondary faulting within the repository.

Using the data of Sass et al. (1988), Szymanski (1989) constructed a generalized map showing subsurface temperatures at Yucca Mountain at a depth of 350 meters. Fridrich et al. (1991) constructed a similar map but based it on temperatures at the water table. The maps give similar results, showing positive anomalies of several degrees Celsius along the Solitario Canyon Fault and of a few degrees between Yucca Mountain and the Paintbrush Canyon Fault. Szymanski (1989) suggested that the anomalies overlie hydrothermal convection in the fault zones, whereas Fridrich et al. (1991) attribute the anomalies to upward leakage along the faults of water flowing generally southward in the deep (>2 km) Paleozoic rocks, which is within the normal regional flow system and without significant thermal influence on this system. Although the interpretations differ, they both require that the north-striking normal faults both east and west of Yucca Mountain penetrate and provide hydraulic pathways in the Paleozoic rocks.

Most descriptions of the more recent tectonic models have not addressed possible changes in the probability of fault displacement within the potential repository. However, Coppersmith and Youngs (1990) consider secondary faulting potentially to increase the frequency of waste-canister failure by as much as an order of magnitude, relative to the frequency estimated to result from only primary fault movement. Extensive field mapping, remote sensing, and geomorphic studies of the area have not revealed any faults of significance other than those that have been recognized since the mid-1980s (DOE, 1988a). All the faults for which evidence of Quaternary movement is currently available are outside the design repository boundaries, and they all achieved most of their displacement prior to 11 Mya, the age of the Timber Mountain Tuff (Fox and Carr, 1989). The Ghost Dance Fault, which strikes northward through the proposed repository area, is covered by a thin veneer of young alluvium in only a few washes. Although Quaternary movement is unlikely, it has not yet been ruled out because of the very limited evidence. Lee et al. (1991) note that the current waste-emplacement strategy is to avoid known faults and faults or fracture zones identified during excavation of the repository. They

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also present results of probabilistic modeling of exceedance rates for fault ruptures of 5 and 50 cm on the Ghost Dance Fault. Using the most conservative ("high seismicity") of their three models, they conclude that direct or indirect rupture effects that would compromise waste-canister performance are highly unlikely.

dePolo et al. (1990) define the "maximum background earthquake" (MBE) as the largest earthquake that can occur without primary surface rupture. They suggest "that the MBE for the Basin and Range Province is at least magnitude 6.3 and may be as high as magnitude 6.8," basing their conclusion on analysis of 38 historical earthquakes in the Basin and Range Province. The upper bound for the MBE, a local (M_l) or surface-wave (M_s) magnitude 6.8, is based on the 1925 Clarkston, Montana, earthquake. Doser (1989) has determined an instrumental moment magnitude (M_w) of 6.6 for that earthquake. Eight earthquakes of magnitude 6 to 6.6 produced secondary or distributed surface ruptures but no significant primary rupture. One of these, the 1934 Excelsior Mountain, Nevada, earthquake (M_l=6.3) was about 200 kilometers northwest of Yucca Mountain in the Walker Lane, the zone of right-lateral shearing that has been postulated to continue southeastward through the vicinity of Yucca Mountain (Stewart, 1985). The Excelsior Mountain earthquake was preceded by the 1932 Cedar Mountain earthquake, also about 200 kilometers northwest of Yucca Mountain and in the Walker Lane. The Cedar Mountain earthquake, M_s=7.2, produced a 60-kilometer discontinuous surface rupture with a maximum surface displacement of 2 meters and also a zone of secondary faulting 6-15 kilometers wide. Molinari (1984) proposed that right-lateral strike-slip movement on an underlying fault was distributed upward through an upper detachment plate to produce the wide zone of deformation. Hardyman et al. (1975) and Hardyman (1978, 1984) proposed a similar model to explain many of the relationships associated with Tertiary detachments throughout the central Walker Lane. Although the Cedar Mountain earthquake was exceptional, the occurrence of distributed faulting at the smaller Excelsior Mountain earthquake indicates that this model should be considered in the evaluation of faulting potential at Yucca Mountain.

However, the topographic and surficial structural features in the vicinity of Yucca Mountain are not analogous to those of active segments of the Walker Lane, indicating a lack of continuity of this structural zone southeastward across the area into Pahrump Valley. Similarly, there is a lack of observational evidence for extending the Las Vegas shear zone west-northwestward to an intersection with the Walker Lane trend near Yucca Mountain. This may not be merely fortuitous and temporary. Rather, it could

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indicate a fundamental accommodation of deep-seated offsets of the potentially active strike-slip fault zones, which upon further kinematic analysis may be found consistent with the conceptual models of Wright (1989) or Cambray (Younker et al., 1992). The accommodation faults, i.e., the left-lateral oblique-slip north-striking faults at and near Yucca Mountain (O'Neill et al., 1991; Whitney and Muhs, 1991) and the left-lateral northeast-striking faults of the Spotted Range-Mine Mountain zone (Carr, 1984) to the southeast and east of Yucca Mountain, may also be deep-seated structures. In this model, regional displacements might be accommodated locally by coeval smaller displacements on several faults within a moderately large area, consistent with the occurrence of indistinguishable tephra in fault zones both east and west of Yucca Mountain (Fox and Carr, 1989). Implications of this model are (1) the currently mapped faults are probably deep-seated and are the most likely local seismogenic sources, indicating that continued paleoseismic studies are pertinent, and (2) local energy release may be dispersed spatially and perhaps chronologically throughout the set of accommodation structures.

Evidence from Rates of Displacement

Although the paleoseismic data base is far from complete, interpretations of the existing information (Scott, 1990; Gibson et al., 1990) indicate that strain rates have decreased substantially from the Miocene maximum (13 to 11.5 Ma) to the Quaternary. On the basis of the work of Whitney et al., (1986) and Scott and Whitney (1987), Scott (1990) reports estimated slip rates for the period 11.5 Mya to present to be 0.026 mm per year on the Windy Wash fault, 0.010 mm per year on Solitario Canyon and Paintbrush Canyon faults, and 0.029 mm per year on the Stagecoach Road fault. Two of these rates are at least an order of magnitude less than the geologic record indicates for the 13 to 11.5 million year period, and that for the Windy Wash fault is reduced by a factor of 3. The late Quaternary slip rate on the Windy Wash fault, 0.0015 mm per year during the last 270,000, is about half the slip rate during the last 3.4 million years (0.003 mm per year) (J. W. Whitney, oral communication, August 20, 1991) and is more than an order of magnitude less than the slip rate averaged over the last 11.5 million years. In Scott (1990), only maximum ages could be established for Quaternary units that are displaced by the Paintbrush Canyon and Stagecoach Road faults, resulting in calculated minimum slip rates, and dip-slip displacement was assumed. Respectively, these are 740,000 years ago and 0.006 mm per year for the Paintbrush Canyon fault (at Busted Butte) and 1.7 Mya and 0.003 mm per year for the Stagecoach Road fault. More recently, Whitney and Muhs (1991) provide evidence that the Paintbrush Canyon fault at Busted Butte has oblique-slip displacement with a rake of about 45 degrees.

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The deepest soil exposed in a deep arroyo (about 20 m) has a dip-slip displacement of 4.1 m., or about 5.8 m of oblique-slip displacement. The soil is estimated to be 700 years old because it overlies an aeolian unit containing the 738 years old Bishop Ash and underlies a substantial thickness of deposits containing younger soils. The calculated oblique slip rate of 0.008 mm per year is probably close to the actual average rate over the 700,000 year period. The composite results indicate that, relative to the 11.5 million year slip rate, Quaternary slip rates were substantially less on the Windy Wash and Stagecoach Road faults, and somewhat less on the Paintbrush Canyon fault at Busted Butte.

Note, however, that rates of tectonic activity are typically variable, particularly within a small locality. Therefore, average slip rates over long time periods may differ greatly from those during episodes of greater or less activity, requiring that paleoseismic investigations be applied within a broad context of the tectonic history of the specific locale and its geologic setting.

Evidence from Other Tectonic-related Processes

As was stated in Section 2.3.7.2.2.(1), issue resolution requires that considerations of tectonic models address the potential for uplift, subsidence, folding, and natural changes of the hydrothermal regime. Other than the possible minor continuation of detachment rotation, no significant folding, tilting, or vertical movement has been proposed for the Quaternary tectonic environment of Yucca Mountain. However, Fox and Carr (1989) cite geomorphic evidence for late Quaternary uplift of the Skeleton Hills-Mount Sterling area south of the Rock Valley Fault, which is about 25 km southeast of Yucca Mountain.

The possibility of more regional gentle tilting, inferred from a southward decrease in elevation of apparent lake-shore deposits, was discussed by Carr (1984) and in the EA (DOE, 1986). Hay et al. (1986), Huber (1988), and Hoover (1989) conclude that the deposits in question mark isolated marsh and pond locations, for which southward decrease of elevation reflects down-gradient lowering of the discharges from the Pliocene-Pleistocene regional ground-water system. Additionally, Huber's (1988) geomorphic analysis of the Yucca Mountain area suggests relative tectonic stability since about 11 million years ago.

Fox and Carr (1989) and Spengler and Fox (1989) relate their interpretations of tectonic processes to hydrologic effects. The former paper

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proposes that episodic faulting has provided open pathways for the circulation of meteoric water or ground water, as indicated by precipitates of calcium carbonate and silica in the fault zones. The latter paper cites a southward increase of fault displacement and width of broken zones in proposing a corresponding southward increase of transmissivity; it further proposes that the cyclic faulting periodically refreshes the transmissivity of fault zones that might otherwise heal with chemical precipitates.

Szymanski (1989) has proposed the tectonic dominance of deep-seated faulting, driven by viscous flow in the upper mantle, on the geothermal regime and hydrology of the Yucca Mountain region. He relates the tectonic setting of the area to an incipient intracontinental rift zone, which is consistent neither with the geothermal regime (Sass et al., 1988; Dudley et al., 1989) nor with the regional structure. Szymanski (1989) attempts to establish cyclicity of the local tectonism, which is important to transient hydrologic control, from the chronology of secondary calcium carbonate in the region, which he concludes has been deposited by tectonically and hydrothermally driven ascending ground water. A large number of papers, which present incremental results of current investigations, have addressed the origin of the calcite-silica veins in faults near Yucca Mountain with the consistent conclusion that they formed beneath the soil zone as precipitates from infiltrating meteoric water. Among these are Taylor and Huckins (1986), Vaniman et al. (1988), Whelan and Stuckless (1990), Marshall et al. (1990), Quade and Cerling (1990), Cerling and Quade (1991), Kroitoru et al. (1991), Marshall et al. (1991), and Stuckless (1991). Although there is considerable evidence that Szymanski's basis for demonstrating tectonic cyclicity is incorrect, Whitney et al. (1986) and Fox and Carr (1989) propose that extensional episodes (not necessarily cyclic) may have an average period of not greater than 75,000 years, based on the composite slip of the Windy Wash fault during the last 300,000 years.

Summary of tectonic models. The foregoing discussion does not support uniquely any single tectonic model for the Yucca Mountain area. The evidence is at least permissive of the alternatives listed below, and combinations of some features are likely.

(1) Regional detachment model. In this model, regional extension is accommodated above the brittle-ductile transition by detachments along shallower surfaces within the brittle crust. Strike-slip, normal, and even reverse faults may develop to accommodate differential rates or directions of movement within a detachment

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10 Proposed Resolution (continued)

sheet, but these faults are unlikely to cut across detachment surfaces. Structures visible at the surface are limited to the uppermost sheet and provide little if any information about deeper structure. Persistence of cross-cutting pathways for basaltic volcanism would indicate that extension by quasi-horizontal detachments has ended, being replaced by a different mode of extension.

(2) Shallow-detachment model. This model entails at least partial decoupling of the near-surface crust (not more than several kilometers in thickness) from deeper parts of the brittle crust, which is extending by failure along high-angle faults (predominantly strike-slip) that penetrate to ductile crust. The upper sheet (which may be subdivided into more than one sheet) fails complexly in response to both lateral and vertical movements of deeper blocks, and surface structures may bear little apparent relationship to seismogenic structures or deeply penetrating faults that serve as magma pathways. Underlying fault displacement may cause a variety of surface expressions, such as distributed fault zones, sag or collapse structures, vertical-axis bending, or lateral sliding of detachment-sheet segments. In terms of seismogenic capability, this model provides the possibility of undetected and historically inactive faults beneath the detachment surface (possibly as shallow as 2 to 3 km beneath the proposed repository), limiting our capability to place constraints on potential earthquake magnitudes, ground motion, and distributed faulting at the repository site.

(3) Caldera model. Although different in origin, the caldera model presented in the EA (DOE, 1986) is similar in some aspects to the shallow detachment model. The near-surface structures at Yucca Mountain are local and relatively shallow (< 5 km), associated with detachment(s) of (or within) the Tertiary volcanic rocks and slumping or lateral sliding toward the presumed volcanic depression beneath Crater Flat. Structural control of volcanism may be related to the caldera structure or to a later change of tectonic style, such as reestablishment of Walker Lane deformation.

(4) Segmented strike-slip model. Strike-slip faults comprising laterally offset or intersecting segments are the basic mode of extension but are replaced locally by accommodating pull-apart or sag basins, which are bounded by normal or oblique-slip faults. At least

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the principal accommodation faults penetrate to ductile crust. The upper crust may be detached locally in response to vertical dislocations. Displacement on the strike-slip fault is dispersed locally throughout the accommodation structure. Deterministic analyses of paleoseismic data from a single fault may underestimate the energy release and, thus, ground motion in the vicinity of the accommodation structure. As noted above, segment offsets are inherently unstable and over geologic time through-going strike-slip faulting may be reestablished.

(5) Normal-fault model. This model comprises subsets sharing the basic dominance of normal faults that penetrate the brittle crust to a depth (about 15 km) at which extension is accommodated by ductile deformation. Regionally the styles of faulting can include steeply dipping planar faults (horst and graben structure), tilted planar faults and interfault blocks (tilted domino structure), or listric (curving to progressively shallower dip with depth) faults on which the hanging-wall block rotates. On a regional scale, individual domains of normal-fault style may be separated by zones of strike-slip faulting, with associated edge effects such as vertical-axis drag rotation. If this model is appropriate for Yucca Mountain, the tilted fault blocks require either the listric or tilted-domino style. Furthermore, the influence of edge effects would be indicated by the southward increase of displacement and width of north-striking fault zones and by the vertical-axis rotation of the volcanic rocks. Locally, this model may be indistinguishable from the segmented strike-slip model, and the seismogenic implications of the two models are similar.

At this time there is no unambiguous evidence for distinguishing between the shallow-detachment, segmented strike-slip, and normal-fault models. The caldera model represents structures that are inherited from processes that ended locally by mid-Miocene time and, therefore, is an unlikely and nonconservative alternative for understanding Quaternary and future tectonism. Similarly, the regional detachment model does not readily explain the basaltic volcanism in Crater Flat unless the detachment complex reflects an extinct, superseded process. A complicating factor is that shallow or thin-skinned detachments could develop locally within the area as secondary features were superimposed on deep-seated strike-slip and normal-fault styles as proposed by Wright (1989). In view of the rather compelling evidence for both deep-seated faulting and detachment structures in the vicinity of Yucca

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Mountain, the coexistence of these styles currently seems to be likely. Nonetheless, in evaluating the site with respect to the qualifying condition of this guideline, it is prudent to consider the above models, or combinations, to be plausible, but not to the exclusion of considering other alternatives.

In terms of faulting and ground-motion characteristics that are expected based on the currently known Quaternary record, i.e., the basis for evaluating the disqualifying condition, the persistence of tectonic activity on the principal north-striking faults is a significant characteristic. Most of the displacement on these faults occurred before about 11 Mya, the age of the Timber Mountain tuff. Despite intensive study, Quaternary fault displacements have not been found at locations that do not exhibit Tertiary displacement. The persistence of activity on long-established structures suggests the involvement of a substantial thickness of the brittle crust. In turn, this suggests that the segmented strike-slip model, the normal-fault model (with edge effects), or the shallow-detachment model with an upper-plate thickness of at least several kilometers represent the causative processes. Hidden underlying faults, if present, are therefore likely to be quite deep, and the north-striking faults probably penetrate deeply. Predictions made with the assumption that the presently known north-striking faults are the controlling seismogenic structures are unlikely to result in significant underestimates of ground-motion intensity."

In Section 2.3.7.3.3, p. 2-104, para. 5, the following text will be inserted after the first sentence ("... data and observations."):

"Presently, at least three basic models appear to be about equally consistent with the evidence -- (1) a shallow or thin-skinned detachment model, in which surficial structures may not directly reveal the nature of deep extensional faults, probably both strike-slip and normal; (2) a segmented strike-slip model, in which accommodating normal faults may dominate the local deformation and seismicity within a releasing bend; and (3) a normal-fault model, in which a regional domain of deeply penetrating normal faults is interacting with an edge defined by strike-slip faults. Models yet to be identified and those that are currently judged to be less plausible in terms of contemporary tectonics of the area--the caldera and regional-detachment models--should still be considered. The implications of these models as to the potentials for faulting, ground motion, volcanism, and deep ground-water flow differ substantially."

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10 Proposed Resolution (continued)

The second sentence of para. 5 will be deleted (e.g., "Further investigation ... paleoseismic studies."), and a new paragraph will start with the former third sentence ("Continued exploration..."). The former fourth and fifth sentences ("The need to ... and volcanism.") will be deleted and the following text will be inserted:

"Equally important is the deep geometry of principal structures, including possible detachments. The design of subsurface studies should incorporate the need to evaluate the potential importance of secondary or distributed faulting."

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 2 of 4	5. Revision Draft/Date August 1991
2. Date November 11, 1991	6. Section 2.3.7.3.3
3. Reviewer F. William Cambray	7. Page 2-105
4. Organization Michigan State University	8. Paragraph 2

9. Comment

The groundwater gradient north and northwest of the site is of great concern and needs to be understood in more detail. The pattern of the potentiometric surface must be related in detail to the underlying geology in order to construct realistic models for groundwater flow. This involves a better knowledge of the tectonic setting, especially in relation to fracture patterns associated with faulting and the possibility of fast pathways in the system.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees fully with this comment. We propose that the spirit of the comment (and several other comments) can be met by the addition of the following sentence to page 2-105, paragraph 2:

"The results of this exploration should be incorporated into three-dimensional models, simulating both the existing geologic framework and credible modifications of this framework by tectonic processes, in order to predict possible changes to the local flow system and the position of the water table."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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1. Comment 3 of 4
2. Date November 11, 1991
3. Reviewer F. William Cambray
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.1
7. Page 2-94
8. Paragraph 1

9. Comment

Considering the remarks made in Comment #1 I think that more attention should be given to the probability of a Cedar Mountain type earthquake affecting the site. All indications are that there has been a change in tectonic style over the past 12 Ma.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees as to the possible likelihood of a tectonic style similar to that of the releasing-bend model proposed in the reviewer's Comment #1, but also expect that earthquakes within the releasing bend would likely be spatially and perhaps temporally dispersed. However, Dr. Cambray also noted in his Comment #4 that releasing bends are inherently unstable, ultimately allowing the reestablishment of an unsegmented strike-slip fault. We propose to resolve this comment by the wording suggested at the following locations in our response to Dr. Cambray's Comment #1: p. 157, para. 3 under "Evidence from Patterns of Fault Movement"; p. 161, para. 1 under "Evidence from Rates of Displacement"; p. 164, para. (2) - "Shallow detachment model"; and p. 165, para. (5) - "Normal fault model."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 4 of 4
2. Date November 11, 1991
3. Reviewer F. William Cambray
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.1
7. Page 2-95
8. Paragraph 1

9. Comment

If it can be demonstrated that the mafic volcanic rocks are emplaced in a releasing bend on a strike-slip fault would it be useful to investigate the history of other examples of this setting with respect to the frequency and duration of the activity? It appears that releasing bends are an unstable configuration and have a limited lifespan. This has been investigated recently in Death Valley (Ellis, M.A. and Trexler, J.H. Jr., G.S.A. Abstracts with Programs, 1991, p. A82).

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team proposes to resolve this comment partly by the wording suggested in the paragraphs cited in response to Dr. Cambray's Comment #3. We also propose that future studies of volcanism, as recommended on page 2-105, paragraph 4 of the report, are consistent with this recommendation.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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Dr. Steven Carothers

ENVIRONMENTAL QUALITY

SWCA, Inc. Environmental Consultants
Flagstaff, AZ

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	✓	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	✓	

Comments 1 through 14 are attached.

Peer Reviewer Steven W. Carothers Date 23 Dec 1991

Comment Resolution Record

Yes ✓ The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ____ The following comments have not been adequately addressed:

Peer Reviewer Steven W. Carothers Date 23 Dec 1991

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12/23/91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section Executive Summary
7. Page E-7
8. Paragraph 4

9. Comment

After reviewing the 1986 EA materials and 1991 ESSE document and other supporting materials, I agree that the current information supports a finding that NO disqualifying conditions prescribed in the Postclosure Guidelines are present or likely to be present at the Yucca Mountain Site. I also agree that additional information is not likely to change the suitability conclusions for any of the postclosure disqualifying conditions. The comments which follow for Section 2, however, reflect certain areas (primarily geohydrology) where I feel additional information is needed to increase the level of certainty that the accessible environment will be protected from "waste" contamination. Certain comments also call for clarification of issues and intent.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that additional information is necessary to increase confidence in the suitability of the Yucca Mountain site. In the geotechnical areas, the Site Characterization Plan (DOE, 1988a) provides a comprehensive means to improve our overall understanding of site conditions and processes.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 2.3.1.1
7. Page 2-7
8. Paragraph 1

9. Comment

Because of present uncertainties in the Yucca Mountain Geohydrologic setting, I believe a determination of whether or not the site satisfies the Qualifying Condition, that the "Geohydrologic setting (is) compatible with waste containment and isolation," must remain at a low level finding, until data are gathered to demonstrate otherwise. My greatest concern is the apparent lack of an adequately presented research design which has the possibility of eventually producing the data necessary to definitively qualify or disqualify the Yucca Mountain Site. The response I am looking for is a presentation from both the pro and con Yucca Mountain Geohydrologists as to whether or not it is realistic to assume the definitive data can ever be gathered. It seems to me that a "fatal flaw" in the entire site suitability selection process would occur if uncertainties in existing science and technology demand a low level finding on this critical issue.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

It is not the purpose of this report to present details of the research design that is contained in the Site Characterization Plan (DOE, 1988a) and the more specific study plans. However, Dr. Carothers echoes the comments of numerous others in reviews of the project's results and plans, including those of project scientists, who recently ranked the current and possible residual uncertainty regarding aqueous transport as a principal concern (Mattson et al., 1991). Ultimately, the judgment as to the suitability of the geohydrologic setting must be determined by the contribution of aqueous releases to the probabilistic representation of the postclosure system performance calculations, as described in Section 2.4 of this report.

No changes to the text are proposed.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 2.3.1.3.2, 3.3.2.1.3.3
7. Page 2-16, 3.3.2-9
8. Paragraph

9. Comment

Section 3.3.2.1.3.1 Terrestrial Ecosystems, page 3.3.2-5,6
(this comment applies to designated pages in both sections)

The Primary emphasis on groundwater contamination has been, necessarily, on the probability of radionuclide release to the accessible environment. I am concerned with the lack of discussion in the EA and in the ESSE with postclosure groundwater thermal loading. In the EA (Section 5.2.2, Hydrologic Impacts, p 5-36) Potential Impacts to the hydrologic system do not include any discussion of thermal changes, I find this oversight curious. It appears that extensive concern has been given to thermal loading in the surface terrestrial environment (per Ostler, W.K., Biological Resource Concerns, Presentation to the Nuclear Waste Technical Review Board, 8-10 October 1991), however, the importance of understanding potential thermal changes in the saturated zone appears to have been given little consideration.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Carothers has identified a very important inconsistency within the report regarding the source of water in Devils Hole and discharging in Ash Meadows. The cited statement on page 3.3.2-9 is correct. However, the cited statement on page 2-16 requires modification. First, the statement refers to the Ash Meadows ground-water system which, as is explained below, encompasses the eastern half of the Nevada Test Site (NTS), whereas Yucca Mountain is within the Alkali Flat-Furnace Creek Wash ground-water system (referred to in some of the older literature as the Pahute Mesa system). Second, the source cited in the statement suggests that the ground-water travel time from the NTS (presumably from the southern tip south of Mercury and far from the areas of underground nuclear-weapons testing) to Ash Meadows "...is approximately 300 years." This statement is not supported by reference nor by calculations within the document (SAIC/DRI, 1991), although back-calculating results in a represented velocity of 200 to 220 feet per year. This is within the range estimated with considerable uncertainty by various authors over the past three

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 14
2. Page 2 of 5
3. Name Steven W. Carothers (Print Name)
4. Date November 6, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

The Ash Meadows and Devil's Hole aquatic ecosystems could be dramatically influenced by relatively small changes in groundwater temperature if their discharge points are connected to the aquifer underlying Yucca Mountain. Statements in the EA and the ESSE, however, have left me somewhat confused on this issue. On page 2-16 (ESSE) it is stated that the ground-water travel time from the Nevada Test Site to the Ash Meadow discharge area is approximately 300 years. On page 3.3.2-9, however, it is stated that "outflows of springs in the Ash Meadows area would not be affected by water withdrawals for a repository program because the springs in Ash Meadows emerge from a different aquifer than the aquifer underlying Yucca Mountain." For both of the above statements to be true the Yucca Mountain aquifer and the Nevada Test Site aquifers are not within a continuous system. Yet, Figure 2-5 of the EA shows both the Yucca Mountain Area and the Nevada Test Site to be within the "Alkali Flat Furnace Creek Ranch Ground-Water Basin." How could it take 300 years for the water to get from NTS to Ash Meadows if they are in separate ground-water basins? I have not been able to reconcile this in reading the EA. It is clear, however, that the Yucca Mountain aquifer is connected to the Death Valley aquifer, and I assume this to mean there may be some relationship with the Devil's Hole spring. Given that surface temperatures could rise by as much as 5 degrees C, with a terrestrial temperature maximum obtained 2,000-3,000 yrs. after initial emplacement, could there be a waste related change in the Devil's Hole or Ash Meadows discharge temperatures? My personal opinion is that the potential for groundwater temperature change is relatively small, especially over the distances required to negatively influence the endangered species present in the aforementioned aquatic ecosystems, however, this issue demands attention in the overall analysis of site suitability.

END OF TEXT

10 Proposed Resolution (continued)

decades, but toward the higher end of that range. Because the referenced source is an administrative document rather than a properly qualified scientific report, and because it refers to an adjacent ground-water basin with significant geologic differences from the Yucca Mountain area, the proposed resolution for this aspect of the reviewer's comment involves eliminating the citation.

Figure 2-5 of the EA is approximately consistent with current understanding of flow-system boundaries. The eastern boundary of the Alkali Flat-Furnace Creek Wash system should be shifted westward to be consistent with current understanding but would still pass through central Jackass Flats in the southwestern quarter of the NTS, 8 to 10 miles east of the Yucca Mountain site.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 14
2. Page 3 of 5
3. Name Steven W. Carothers (Print Name)
4. Date November 6, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

The paths of ground-water flow from Yucca Mountain are southward through the volcanic rocks and the basin fill of the Amargosa Desert to Alkali Flat, near Eagle Mountain. Approximately the eastern half of the NTS, along with a large area to the east, is tributary to the Ash Meadows ground-water system, in which most flow occurs in the thick sequence of Paleozoic carbonate rocks termed the lower carbonate aquifer. The same carbonate rocks do occur beneath the volcanic rocks at Yucca Mountain, in a narrow segment (along Furnace Creek Wash) of the Funeral Mountains between the Amargosa Desert and Death Valley, and, in fact, throughout much of Utah, most of the eastern half of Nevada, and adjacent parts of Arizona and California. Within this vast area, flowpaths divide as necessary to deliver water most efficiently from areas of recharge to available discharge areas; thus, the regionally extensive aquifer is partitioned hydraulically, though not necessarily geologically, into several flow systems. Locally, the partitioning is in fact assisted by geologic conditions that disrupt the continuity of the aquifer. Additionally, many of the dominant flow paths are controlled by regional structures such as fault zones.

The interaction of hydraulic potential for flow with the availability of flowpaths (provided by aquifers and structural conditions) and discharge areas exists in the third dimension also. Beneath Yucca Mountain, the hydraulic potential (head) in the lower carbonate aquifer is greater than that in the overlying volcanic rocks, providing the potential for upward flow where permeability is sufficient, again due principally to faults or fracture zones because of the low primary permeability of the lower (mainly nonwelded) tuffs. Most of the flow in the deep aquifer, however, is thought to be lateral to the south, beneath but essentially parallel to that in the upper units, gradually leaking upward until most of the head difference is dissipated. The continuity of the lower carbonate aquifer is disrupted by structurally elevated older rocks (the lower clastic aquitard) between Yucca Mountain and Ash Meadows, making it unlikely that deep flow follows a southeasterly path between the two. It should also be noted that, because of the upward hydraulic-potential gradient and the great depth to the carbonate aquifer (>6,000 ft) at Yucca Mountain, there is no credible chance of transporting waste products within that aquifer, regardless of its discharge area.

Although the Ash Meadows area would seem not to be thermally impacted, the question as to whether other areas might be is a legitimate inquiry. The reviewer's intuition that the thermal effect would be small in down-gradient areas is consistent with ours, but calculations to evaluate this postulated effect have not been done. If the entire repository were to be simultaneously

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 14
2. Page 4 of 5
3. Name Steven W. Carothers (Print Name)
4. Date November 6, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

subjected to the nominal thermal load of 57 kilowatts per acre, the total power output would be about 100 million watts, which is significant in the context of the natural geothermal heat flow. During the thermal-pulse period, some of the heat output would be consumed by vaporization of water, but most would be stored temporarily (1000s of years?) in the huge thermal capacitance of the unsaturated rock mass. Ultimately, in a time frame of at least 1000s of years, most of the heat discharge would seek the land surface, which is about 15 degrees C cooler than the present water table.

The question of the magnitude and duration of the average transient temperature rise within the zone of active saturated flow beneath the water table is complex and currently unanswered. Among other requirements, definition of that zone of active flow and its relative contribution to the total ground-water flux at down-gradient locations are lacking. However, some preliminary estimates of the peak temperature beneath the potential repository have been made (Eric Ryder, oral communication), maximizing the thermal effect by neglecting the convective heat sink associated with the flowing ground water. The results indicate the possibility of a temperature increase of about 8 degrees C in the rocks at the water table immediately beneath the repository and declining rapidly with distance from the repository. Because of the much larger volume and thermal mass of water derived from elsewhere but discharging in the same area, and because of the thermal capacitance of the rock itself below the water table, the likelihood of significant effects--even approaching 1 degree C--beyond a very few kilometers from the site appears to be remote. We recommend additional scoping calculations before a fully coupled, transient thermal-hydrologic model is given serious consideration.

A. To address this concern, replace the last sentence ["Ground-water flow velocities...(SAIC/DRI, 1991)."] of paragraph 3, page 2-16 with the following:

"Yucca Mountain and the controlled area for the potential repository are within the Alkali Flat-Furnace Creek Wash ground-water system. Flow within the volcanic rocks underlying the site is southward to the Amargosa Desert, continuing southward and mixing with inflow from other areas in basin-fill deposits to discharge principally at Alkali Flat, about 45 miles south of the site. Some of the discharge in the Furnace Creek Wash area of Death Valley may be derived from water in the Amargosa basin-fill deposits, but other sources probably provide much of the discharge by way of regional flow in the thick Paleozoic carbonate rocks that underlie the region. These carbonate rocks are believed to be present beneath the Yucca Mountain site also, but the hydraulic potential within them is greater than that in

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 14
2. Page 5 of 5
3. Name Steven W. Carothers (Print Name)
4. Date November 6, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

the volcanic rocks (Craig and Robison, 1984). Therefore, if flow occurs vertically, it is from the deep carbonates upward into the volcanics."

B. Dr. Carothers' concerns regarding the long-term (postclosure) thermal impact of the repository do not have an apparent home within the context of 10 CFR 960, which this report addresses. We propose, rather, to submit the comment and the discussion above to the U.S. Department of Energy for further, more thorough consideration.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 2.3.1.3.1
7. Page 2-11
8. Paragraph (Favorable condition 2)

9. Comment

I have one final comment on groundwater thermal loading and its potential impact on site suitability. One of the favorable conditions in the Postclosure Geohydrology Guidelines (DOE, 1986), Favorable condition No. 2, assumes if the hydrologic processes operating in the Quaternary continued to the present, there would still be no significant change in the ability of the repository to isolate the waste. My contention is that any heat generated above ambient rock temperatures is also "waste." Would the favorable condition still be met if transfer of waste heat from the rock to the saturated zone were taken into consideration?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

As noted in Part B of the proposed response to Dr. Carothers' Comment #3, the 10 CFR Part 960 guidelines do not address postclosure, regional thermal impacts. Rather, they specifically address only containment and isolation of the "radioactive materials, including spent fuel, that are received for emplacement in a geologic repository." We propose to submit this comment to the U.S. Department of Energy along with Dr. Carothers' Comment #3 for further consideration.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section
7. Page 2-16
8. Paragraph last paragraph

9. Comment

The following statement reflects a problem I have with the original siting guidelines and DOE's apparent willingness to accept a substantial level of uncertainty in site characteristics and still perhaps find the site suitable. "This work continues to support the lower-level suitability findings presented in the EA that the geohydrologic setting of the site is not incompatible with waste isolation and containment." My problem with the statement is, simply, given the existing constraints on the state-of-the-science in geohydrology and the difficulty in predicting the future, will there ever be a higher-level finding, indeed a lower-level finding that the site is compatible with waste isolation and containment?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that the "state-of-the-science" in the field of unsaturated flow in fractured media is in its infancy and contains large uncertainties that arise from several factors including a limited understanding of the dominant processes and mechanisms influencing flow within unsaturated media. Similarly, predicting the future over any period, much less intervals of thousands of years, is extremely difficult, technically challenging, and also characterized by large uncertainty. We believe that the uncertainty associated with both of these areas can be bounded with reasonable confidence and perhaps reduced, through the implementation of specific activities planned as part of the site characterization program. Sensitivity analyses are planned to evaluate the effects of these uncertainties on the qualifying condition as it relates to waste isolation and containment and on the disqualifying condition related to ground-water travel time. We also recognize (and tried to make clear in Section 2.3.1.1) that our present level of understanding is not adequate to state explicitly that the site is

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 5 of 14
2. Page 2 of 2
3. Name Steven W. Carothers
(Print Name)
4. Date November 6, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

compatible with "waste isolation and containment" on the basis of an evaluation of the existing information pertaining to the Postclosure Geohydrology Guideline. There is a considerable amount of work to be performed before such an assessment can be made (see proposed resolution to Dr. Vogel's Comment #1) and the "burden of proof" clearly rests with the DOE.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 2.3.1.5
7. Page 2-24
8. Paragraph para. 1 of 2.3.1.5

9. Comment

The last two lines of the paragraph read..."substantial testing and analysis are likely to be needed to support a higher-level suitability finding." A more direct and factual sentence would change "are likely to be needed..." to "are necessary."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The wording in the ESSE report that is referred to in this comment reflects a general theme underlying the suitability evaluations. There are very few purely quantitative solutions to questions of suitability, and the level of confidence needed to support a higher-level finding cannot be absolutely specified. Therefore, the ESSE Core Team generally avoided making statements that actions are "necessary" or "required" because we recognize that different overall strategies could dramatically change what is "necessary or required." For example, in this case, if a strategy of placing much greater reliance on the engineered barriers for protecting public health and safety were adopted, then the need for extensive characterization of the natural site features and processes could be reevaluated.

In response to this comment, the "likely to be" will be deleted from the referenced sentence.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 1.2.6
7. Page 1-19
8. Paragraph Table 1-6

9. Comment

Change the organization after Steven W. Carothers from "Southwest Environmental Consultants, Inc" to "SWCA, Inc. Environmental Consultants."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The name of the organization that Dr. Carothers represents will be corrected in the text as requested.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.2.1
7. Page 2-57 to 2-59
8. Paragraph all of section

9. Comment

Hopefully, the authors of this section can forgive some editorial criticisms, but the information on former lake levels seems excessively long and not clearly to the point. The reader and reviewer could be led to the similar conclusions in lots less space. Also, in a number of places the reader is given a definition of ka (thousands of years before present), and some places not, why the inconsistencies? This entire Climatic Change Section with its excessively long paragraphs seems out of synch with the crisp efficiency of earlier and later sections.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The editorial comments are appreciated. The discussion of lake-level data will be revised and, hopefully, condensed. The symbol "ka" needs to be defined and will be defined only when it is first used in the text. The author will revisit the chapter in order to achieve improved "crispness" and "efficiency.

Text in Section 2.3.4.3.2.1 will be revised as follows:

"Past regional and global climatic conditions and variability are inferred primarily from the analysis and interpretation of paleoenvironmental data. Sources of paleoenvironmental data in the western United States include lake-level records from present and former lakes, lake-bottom sediment cores, macrofossil assemblages from pack-rat middens, and stratigraphic pollen sequences. Data and analyses that have become available since the EA indicate that a complex regional pattern of climatic conditions and change developed over the western United States following the last Wisconsin glacial maximum

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 8 of 14

2. Page 2 of 2

3. Name Steven W. Carothers
(Print Name)

4. Date November 6, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

18 to 20 ka. The results of global-scale climate modeling (COHMAP, 1988) support the hypothesis that these climatic conditions and changes occurred in response to the combined effects of increasing summer insolation in the Northern Hemisphere and the initial presence and subsequent retreat of the continental ice sheets in North America. A general trend toward warmer and drier conditions in the Yucca Mountain region during the late Quaternary continues to be supported. Presently available data, however, are not sufficiently well distributed spatially to permit detailed inferences regarding past climatic conditions at the Yucca Mountain site; however, in the discussion that follows, it is assumed the past climatic conditions at the Yucca Mountain were similar to those that prevailed elsewhere in the Great Basin.

Lake-level chronologies for closed-basin late-Pleistocene lakes in the Great Basin have been developed by Benson and Thompson (1987), Benson et al. (1990), Dorn et al. (1990), and Stine (1990). These studies indicate that the period from about 30 to 18 ka prior to and during the last Wisconsin glacial maximum was a time of persistent moderate-to-low lake levels suggesting cool, dry climatic conditions then prevailed in the Great Basin. Lake-level highstands were attained between about 16 and 12 ka, which Dorn et al (1990) attribute to the occurrence of warmer and wetter conditions that developed at the time of and continued following alpine glacial retreat in the region. Evidence indicates that several lakes underwent lake-level oscillations between about 15 and 14 ka, which may have been responses to localized climatic variability during this time. Most of the lakes experienced nearly synchronous recession between about 14 and 13.5 ka, apparently in response to the widespread occurrence of effectively drier conditions. This was followed by a period of lake-level stability until about 11.5 to 10 ka when minor enlargement occurred, apparently in association with a terminal Pleistocene glacial advance in the Great Basin (Dorn et al., 1990). Except for minor oscillations, the lakes have remained at low levels throughout the Holocene. Based on a study of Mono Lake, California, Stine (1990) suggests that the Holocene lake-level oscillations probably occurred in response to hydroclimatic-induced differences in lake inflow and evaporation."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.2.2
7. Page 2-59
8. Paragraph 2, line 17

9. Comment

The sentence beginning..."A trend toward etc..." seems to be leaving out the possibility that spring discharge reduction and abandonment in the upper Las Vegas Valley could be the result of human related over-utilization rather than significant climatic changes in the region.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised as follows: "A trend toward increasing aridity in the region also is supported by evidence cited by Quade (1986) and Quade and Pratt (1989) who interpret widespread fine-grained deposits in the upper Las Vegas Valley, Southern Nevada, to be the sites of former spring-supported marsh environments. Radiocarbon dating of organic materials within these deposits indicate that the springs were active as early as 30 ka and had undergone progressive down-valley dessication and abandonment by about 9 ka." There is no evidence for extensive human habitation, let alone "human-related over-utilization" of water, during this time in the Las Vegas Valley.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 10 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 2.3.6.3.1
7. Page 2-76
8. Paragraph 2, sent. 2 & 3

9. Comment

(Summary of Environmental Assessment Findings)

In sentence 2 "data" is used as singular, in sentence 3 as plural. Throughout the entire ESSE document there is inconsistent use of the tense of the word "data."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be corrected to read "The data that support these evaluations..." and the editors will address this problem throughout the text.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 11 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 3.3.2.1.2
7. Page 3.3.2-3
8. Paragraph 1 and 2 of 3.3.2.1.2

9. Comment

(Approach for Evaluation)

These paragraphs are exact duplicates of paragraphs 3 and 4 Section 3.3.2, page 3.3.2-1.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text referred to in this comment (Section 3.3.2) is a general statement of the approach that was taken in evaluating the Environmental Quality, Socioeconomics, and Transportation Guidelines, as well as for the System Guideline for this group of guidelines. There are minor differences in the text in Section 3.3.2.1.2, which applies only to the Environmental Quality Guideline evaluation. In general, the approach taken was for each guideline evaluation section to be as self-contained as possible because most reviewers read only the material of direct interest to them. We will revise the second paragraph to lessen the duplication.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 12 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 3.3.2.1.3
7. Page 3.3.2-3 & 3.3.2-4
8. Paragraph all

9. Comment

(Status of Current Information)

also: Conclusions and Recommendations, Section 3.3.2.4.4. Page 3.3.2-21

After reviewing Section 3, the EA and additional supporting documents I agree that the evidence does not support a finding that the site is not likely to meet the qualifying condition (level 3) and the evidence does not support a finding that the site is disqualified (level 1) for the disqualifying condition.

I also agree with the team evaluation that there is no reason to believe the Yucca Mountain Site is not suitable with respect to the Environmental Quality, Socioeconomic Impacts, and Transportation Guidelines.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team appreciates Dr. Carothers' support of the evaluation.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 13 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 3.3.2.1.3.1
7. Page 3.3.2-4
8. Paragraph (air quality)

9. Comment

"...air quality impacts remain within acceptable levels (my italics)..." Please reference the air quality standards indicated.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees the indicated air quality regulations should have been cited. The text in question will be modified by adding the following to the last sentence under Air Quality, Section 3.3.2.1.3.1:

"...as required by the standards enumerated in the federal Clean Air Act (CAA, 1977). Radioactive air emissions are addressed by U.S. Environmental Protection Agency regulations and are the subject of preclosure radiological safety requirements of 10 CFR Part 960 presented in Section 3.3.1."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 14 of 14
2. Date November 6, 1991
3. Reviewer Steven W. Carothers
4. Organization SWCA, Inc.
5. Revision Draft/Date August 1991
6. Section 3.3.2.1.3.1
7. Page 3.3.2-7
8. Paragraph 1

9. Comment

(Terrestrial Ecosystems)

The first sentence, "Additional future studies may include evaluating the effects of increased soil temperature on biological resources and monitoring terrestrial resources at Ash Meadows" should be modified to recognize the aquatic ecosystems at Ash Meadows and perhaps be expanded to include consideration for the aquatic ecosystems in Death Valley.

In addition, the presentation by W. Kent Ostler (Presentation to the Nuclear Waste Technical Review Board, 8-10 October, 1991) indicates that a 2.3-3.0 sq. mi. immediately above the repository will undergo an increase in soil temperature and decrease in soil moisture for a period of thousands of years should probably be discussed in the "Soils" Section as an impact.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team partially agrees with the comment. The potential for the Yucca Mountain Project to affect the ecosystem in the Ash Meadows area is low; it is our understanding that the DOE, is committed to studying those biological resources, if warranted. The studies would consist of both terrestrial and aquatic evaluations. The sentence in question will be modified to include "aquatic" studies. We will recommend the DOE consider if the ecosystems in Death Valley should be added to the list of studies; however, given that the potential for impacts on Ash Meadows is marginal, impacts on Death Valley appears even more unlikely.

The "Soils" section referenced by the reviewer addresses information from a preclosure perspective; however, a statement will be added to the discussion that reads as follows:

"During the preclosure time period, soil resources in the area are not

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 14 of 14
2. Page 2 of 2

3. Name Steven W. Carothers
(Print Name)

4. Date November 6, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

expected to be significantly impacted. During the postclosure period, there is the possibility that the area immediately above the proposed repository will undergo an increase in soil temperature and decrease in soil moisture for a period of thousands of years (Ostler, 1991). This potential soil temperature change does not represent a significant impact because the change would be very localized."

A new reference to the bibliography for the report has been added.

END OF TEXT

REFERENCES FOR DR. STEVEN CAROTHERS

CAROTHERS

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Dr. James Drever

GEOCHEMISTRY

University of Wyoming
Laramie, WY

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	Adequate No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	X	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	X	

Comments 1 through 18 are attached.

Peer Reviewer Jan [signature] Date 12-11-91

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments*

No ______ The following comments have not been adequately addressed:

Peer Reviewer Jan [signature] Date 12-11-91.

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager [signature] Date 12-11-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC.5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section General
7. Page
8. Paragraph

9. Comment

The purposes of this review are laid out on p. 1-18 of the ESSE Document: (1) to evaluate the completeness and adequacy of information presented in support of conclusions in the report and (2) to determine if the report presents an objective and technically defensible view of the suitability of the Yucca Mountain site.

The ESSE document is itself a summary of many reports and publications, and cannot be properly reviewed without reference to a very voluminous supporting literature. In several instances where items appeared to be overlooked by the ESSE, other documents showed that the topics were indeed receiving proper consideration. On the other hand, the ESSE does not (to me) give a clear view of the research priorities of the Yucca Mountain Project. It might have been valuable if the Peer Review Panel had had sufficient time to consider questions of focus and direction.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

As pointed out by Dr. Drever, the ESSE Core Team was faced with trade-offs between including summaries of the supporting literature in the ESSE Report, versus creating a document so lengthy that it would be difficult to use efficiently. Clearly, the detailed rationale and justification for most of the conclusions presented in the ESSE Report can only be fully understood in conjunction with the voluminous supporting references. Some of the peer reviewers had familiarity in the region, with respect to their areas of expertise, which provided an advantage given the time limits on the peer review.

Dr. Drever also correctly points out that the ESSE Report does not present the research priorities of the Yucca Mountain Project (see also Dr. Vogel's Comment #7). This was not the responsibility of the ESSE Core Team; our mission was to identify technical guidelines for which information is inadequate to support a higher-level finding. These topics will serve as input

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 18
2. Page 2 of 2
3. Name J. I. Drever (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

The document was received on August 27, 1991. Three members of the Task Group that prepared the report visited me in Laramie on September 24, 1991, and meetings involving reviewers and project personnel were held in San Diego, California on October 23, 1991 and October 24, 1991. Apart from these meetings in San Diego, there have been no opportunities for the Review Panel to meet as a group. These comments thus represent the opinions of one individual, and they have not had the benefit of the interaction that normally takes place with a peer review panel. While I recognize the time constraints involved, I feel the review would have been a more valuable document if we had the opportunity to interact and synthesize our views.

As a summary statement, I believe the ESSE is a well-prepared and technically sound document. I have no serious disagreement with any of the Findings regarding Qualifying or Disqualifying conditions for the site. The task group has taken a conservative approach, and there is no instance where an inappropriate Higher Level Finding has been made.

END OF TEXT

10 Proposed Resolution (continued)

to establishing overall priorities. There are a number of reasons for conducting site characterization activities. These include gathering information needed to (1) design the waste package and repository; (2) evaluate performance of the natural and engineered barriers, both individually and collectively; (3) gain scientific confidence and regulatory assurance; (4) provide support for other testing activities; and, as required by the NRC (10 CFR 60, Subpart F), (5) confirm, to the extent possible, that the natural setting and the engineered components are performing as intended and expected. Some testing activities serve many of these "end uses" while others have a relatively specific objective. Because of these multiple needs and uses for information, prioritization of the research program is a very complicated task.

It is recognized that opportunities for peer reviewers to meet as a panel and exchange ideas were limited. Given the high proportion of academics on the panel and the overlap with the academic-year calendar, it was determined that the peer review panel would not be able to act as a consensus-making body except in a very limited sense. This situation was also exacerbated because the specialities of the panel members had to be sufficiently diverse to cover the complete suite of technical guidelines in 10 CFR Part 960. Unlike most peer review panels, which have a relatively narrow scope, this panel was required to be extremely broad in its coverage.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.3.1
7. Page 2-7 to 2-24
8. Paragraph general

9. Comment

The first key issue is travel-time through the unsaturated zone. There are few (if any) quantitative studies in the literature of actual solute transport over large distances in fractured, porous rock. As a result, there are no data sets against which to calibrate or validate theoretical models. The modeling work appears to be state-of-the-art, but I would have limited confidence in it unless it can be validated against field data. My concern would be, conceptually, that individual discrete features (as discussed or implied on p. 2-18 & 2-19) may significantly affect solute transport, and that such discrete features would not be well represented by continuum models. Will it be technically possible to validate the models adequately, and to "characterize the site" adequately for prediction of unsaturated flow? This is a difficult question,and obviously comes down to one's concept of "adequately". I am skeptical that physical measurements of fractures, porosity etc. in the ESF will be sufficient. Plot-scale irrigation experiments will certainly help, but the vertical and temporal scale that can be studied is limited, and there is a

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The authors share the concerns about model validation and site characterization expressed by the reviewer. Developing the capabilities to quantify the conditions at Yucca Mountain in models that correctly approximate the geohydrologic system is a technically challenging and complex problem that requires a systematic, interdisciplinary approach coupling laboratory and site-scale investigations with theoretical studies and hypothesis testing. Glass and Tidwell (1991) present an approach toward developing and validating conceptual models for flow and transport through unsaturated fractured rock that is being pursued as part of the Yucca Mountain Project. This approach is predicated on the development of a firm understanding of the basic physics governing flow through fractured media, specifically emphasizing unsaturated flow in fractures and fracture-matrix interactions. Similarly, other approaches are being pursued that emphasize specific aspects of the geohydrologic system (e.g., infiltration processes) or are directed at acquiring specific types of data that are intended to provide

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 18
2. Page 2 of 3
3. Name J. I. Drever (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

hit-or-miss element as to whether they capture the effects of specific "discrete features". In my opinion, the most important validation will come from natural tracers, particularly tritium, 14C and 36Cl. Tritium and 36Cl were mentioned briefly (p. 2-17); I did not see any reference to 14C. Stable isotopes in the water of the unsaturated zone (deuterium and 18O) may also indicate recharge under different climatic regimes, and may constrain models of vapor-phase transport in the unsaturated zone. The Study Plan for Study 8.3.1.2.2.7 (Revision Number R 0, July 1990) addresses most of my concerns on this point, even though I still have questions regarding adequacy of sample volumes and possible contamination during sampling.

In summary, modeling flow in the unsaturated zone is an enormously complicated problem, and a crucial issue in the future will be establishing confidence in the models that are developed. The distribution of isotopic tracers should document more or less adequately the present-day (or historically recent) transport regime and provide some sort of validation of the unsaturated-zone flow models. A further question will be predicting the effect of climate change, specifically increased recharged, on travel times. Here I would be reasonably confident in the use of a low model that had been calibrated (validated is probably too optimistic a word) against both the isotopic tracers and the artificial irrigation experiments.

END OF TEXT

10 Proposed Resolution (continued)

additional insight into the dominant processes and mechanisms controlling flow. Collectively, these data may be useful for calibrating flow models and for developing the requisite confidence that these models correctly approximate the conditions at the site.

We agree that a very important element in developing confidence in the models used to predict ground-water travel times is to use natural and environmental tracers and stable isotopes. Although only limited site-specific data have been acquired over the last 5 years, some of these data (i.e., chlorine-36 and tritium) have clearly demonstrated the utility of using tracers to develop an understanding of the flow processes and mechanisms operational at the site. Carbon-14 data (personal communication, 1991, unpublished results from D.C. Thorstenson) suggest differences in the gas flow system between the Topopah Spring unit and the overlying Tiva Canyon unit, which appears to be operating on a much faster time scale. These results require verification through additional testing planned as part of Study Plan 8.3.1.2.2.7. Contingent upon availability of funds, this work will continue in

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 18

2. Page 3 of 3

3. Name J. I. Drever
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

the future as drilling is reinitiated and as access to the primary subsurface units is gained by underground construction. Additionally, a program is being implemented to identify tracers that will be used and that have utility as a means to develop further understanding of these complex processes.

To address this comment, we will add the following text to Section 2.3.1.5, Recommendations for Future Activities:

"Chemical and environmental tracers and dating techniques should be used as an independent means to estimate travel times and to develop confidence in the models that are used to simulate flow processes and mechanism. Water chemistry data from both the unsaturated and saturated zones should be obtained to better understand and constrain the assumptions associated with chemical processes and gaseous flow in the unsaturated zone and to provide boundary conditions for modeling these processes."

This additional text will be inserted in a longer addition responding to Dr. Vogel's Comment #1. (See the response to that comment for the full text of the changes to Section 2.3.1.5.)

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.3.1 & 2.3.2 general
7. Page NA
8. Paragraph NA

9. Comment

2.3.1 Geohydrology and 2.3.2 Geochemistry

As the Freeze Panel (Freeze et al., 1991 [DOE, 1991g]) and others have pointed out, the division between "Hydrology" (movement of water) and "Geochemistry" (movement of solutes in the water, in part at least) is artificial and to some extent counterproductive. The distinction is perhaps overemphasized by the structure of 10 CFR 960. I would hope that as emphasis shifts more towards performance assessment the fields will become more closely integrated.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Drever correctly identifies an important difficulty in addressing site characteristics in a compartmentalized fashion. Note, however, that although these issues were compartmentalized in the text, the considerations were made in a more coherent manner. Therefore, the evaluation of the geochemistry was made in the context of the particular pathways involved. This does not mean, however, that a detailed, integrated evaluation of the characteristics of the site was made in this effort. Such integration is part of a system performance assessment, as is explained in the following paragraphs, which will replace the first three paragraphs of Section 2.2 on page 2-2:

"The site is evaluated against the Postclosure System and Technical Guidelines by considering first the technical guidelines, followed by the system guideline. The technical guideline evaluations are conducted with two objectives in mind. The first objective is to

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 18

2. Page 2 of 3

3. Name J. I. Drever
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

determine if there are any specific features or conditions of the site, within the scope of those guidelines, that would indicate the site is not suitable. If no such features or conditions can be identified, then lower-level suitability findings on the technical guidelines can be supported. The second objective is to determine whether additional information would be likely to change the conclusion. If not, then a higher-level suitability finding can be supported. If the uncertainties are such that the conclusion could change, then the objective is to identify issues that may provide a focus for testing during site characterization and that must be resolved before a high-level finding can be supported. The technical guidelines are evaluated individually and the results of the evaluation of each guideline are discussed in Section 2.3.

The evaluation of the Postclosure System Guideline determines whether the system performance requirements specified in the guideline can be met. This requires an integrated assessment of the issues identified in the technical guideline evaluations and other issues related to waste isolation and containment identified in the performance assessments, themselves. For example, many of the technical guidelines focus only on specific aspects of site performance, such as hydrology, which addresses the movement of water, or geochemistry, which addresses the movement of solutes in the water. Such distinctions are eliminated when these issues are considered together in the system guideline evaluation.

The evaluation of the system guideline involves system and subsystem performance assessments. These assignments are generally accomplished through the following types of analyses:

1. Identification of system performance measures

2. Development of models needed to evaluate the performance measures

3. Evaluation of the performance measures

4. Conduct of sensitivity and uncertainty analyses to identify critical model parameters and to evaluate the importance and role of uncertainties in site information.

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10 Proposed Resolution (continued)

These analyses are explained in the following paragraphs."

END OF TEXT

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6. Section 2.3.1.1.1
7. Page 2-7
8. Paragraph (discussion)

9. Comment

2.3.1.1.1 Discussion, p. 2-7:

This discussion brings up a whole range of unresolved issues, including rigorous definitions of travel time and words such as "likely" and "significant." Rather than these issues individually, it would seem sensible to resolve the critical ones in the context of performance assessment under the Postclosure System Guideline.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Drever has identified an important issue for the site evaluations. The terms "likely" and "significant" should be defined in the context of the overall postclosure performance objectives. Because the evaluations of system performance cannot be definitive at this time, the ESSE Core Team believed it inappropriate to define those terms precisely for this evaluation. However, precise definitions in the context of the postclosure performance objectives will be important in future evaluations.

There is a particular problem with the Geohydrology Guideline, in that the requirements on ground-water travel time are different in the Siting Guidelines and in NRC's regulations. The NRC regulations place limits on travel time along the "fastest path of likely radionuclide travel," while the DOE Siting Guidelines limit travel time along paths of "likely and significant radionuclide travel." In the ESSE report, we tried to define a basis for the evaluation that would hopefully not depend strongly on subtle

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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10 Proposed Resolution (continued)

interpretations. The definitions on page 2-8 read as follows:

> "For purposes of this site suitability evaluation, ground-water travel time is defined as the cumulative displacement of a tracer particle divided by the ground-water velocity along a specified path of likely flow. 'Paths of likely and significant radionuclide travel' are defined to be those identifiable flow paths along which water bearing radionuclides released from the EBS could travel from the disturbed zone to the accessible environment."

We believe this is still the appropriate approach and prefer to maintain the text as it is. However, as stated above, the point is an important one to be addressed in future evaluations that depend more heavily on integrated performance assessments.

END OF TEXT

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6. Section 2.3.1.5
7. Page 2-24
8. Paragraph para. 2 of 2.3.1.5

9. Comment

2.3.1.5 Conclusions and Recommendations for Future Activities

I have no disagreement with the conclusion. I do have questions concerning the discussion. "These conditions can be best identified and characterized through in situ exploration of the potential repository host rock and surrounding units." Exactly what sort of characterization is envisioned? Have experiments been designed that will specifically evaluate the hydrologic models? How much in situ exploration will there be of the region below the repository? I would stress again that a key issue in the future is the extent to which hydrologic models can be validated, and this will not be straightforward even when the ESF is constructed.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In direct response to Dr. Vogel's Comment #1 and other comments raised by the Peer Review Panelists, the Discussion (Section 2.3.1.5) will be replaced with the proposed resolution for Dr. Vogel's comment (see that comment for the complete text).

The testing program planned for the ESF is continuing to evolve as the design matures and as decisions on the phased construction approach are made. The most recent description of the ESF testing program is contained in the ESF Requirements Document, Appendix B (DOE, 1991), which shows the layout of the underground testing program currently planned for the new ESF configuration, augmented by the descriptions contained in the Site Characterization Plan. Although some new experiments are being considered, the current plans call for the tests described in the Site Characterization Plan. Note that a caisson experiment is being planned this spring that will acquire data designed to begin to calibrate flow and transport models for later use at Yucca Mountain.

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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10 Proposed Resolution (continued)

The present configuration (modified option 30 from Dennis, 1991) consists of two ramps entering the repository block from the east, a primary testing area in the northeast, and two northeast-southwest trending drifts located in the Calico Hills and Topopah Spring units. This configuration is expected to provide sufficient access to the Calico Hills and the major structural features located within and proximal to the block to provide for adequate characterization.

END OF TEXT

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7. Page 2-26
8. Paragraph (Issue 1)

9. Comment

2.3.2 Geochemistry Technical Guideline

General comment and Issue 1 (p. 2-26):

The Qualifying Condition for the Postclosure Geochemistry Technical Guideline is much more vague than the corresponding conditions for the Geohydrology Technical Guideline. There are no absolute numbers such as a travel time of 1,000 years. In fact, if the Geohydrology guideline is met, much of the geochemistry becomes irrelevant. If the travel time for water is sufficiently long, the presence of absence of adsorption becomes unimportant. The main importance of the geochemical work this seems to be:

1. As a part of the geohydrological work (for example analysis of ^{36}Cl). As I mentioned in Comment Number 3, the separation between geohydrology and geochemistry seems at times arbitrary.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Drever makes a good point in this comment. Radionuclide retardation by geochemical conditions and processes, however, is viewed as one component of a system of multiple barriers to migration. Its role may indeed be primary or secondary depending on the ground-water travel time. It may be possible, for the purposes of site suitability, to assign no performance criterion to retardation by these conditions and processes and to justify a higher-level finding on this guideline by arguing that there are no known or expected conditions and processes that are <u>in</u>compatible with waste isolation and containment. The ESSE Core Team explored this possibility, but the prevailing sentiment was that the current uncertainty in ground-water travel time estimates prohibits reaching this conclusion now; scenarios exist wherein minimum sorption of some radionuclides may be necessary to meet regulatory release limits.

The three points raised by Dr. Drever are addressed in the following

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

2. Adsorption and retardation may serve as a "redundant barrier." Even if the groundwater travel time is shorter than anticipated, adsorption may prevent the release of radionuclides to the accessible environment.

3. Adsorption and chemical reactions in the "disturbed zone" will have an important influence on the source term that defines the availability of soluble radionuclides for transport by groundwater.

As an editorial point, it would be useful to have a summary table (perhaps an updated summary of Tables 6-24 to 6-26 of the EA, or of Kerrisk, 1985) that shows: 1. A list of nuclides of concern in the waste and their half-lives, 2. the estimated solubility of each element, 3. A qualitative distribution coefficient/adsorption ratio (e.g. "strong", "medium", "weak", "not adsorbed") for each element (2. and 3. might include a range of values if speciation is unclear). Such a table would allow us to focus in immediately on the nuclides most likely to present a problem. The information is implied by the second paragraph on p. 2-30; it could be more explicit.

END OF TEXT

10 Proposed Resolution (continued)

paragraphs:

1. The information and discussion in this guideline evaluation is based upon the narrow and specific definition of "geochemistry" suggested by the guideline statement, i.e., geochemical characteristics of the site...compatible with waste containment and isolation. Geochemical techniques, e.g., isotopic analyses for dating and tracing, are being widely used in support of geohydrology and tectonic investigations. The purpose and organization of this document detracts from an integrated presentation of all these initiatives. We regret that this exacerbates this frequent concern of reviewers and critics, i.e., the seeming inadequacy of horizontal integration between the various SCP investigations.

2. Redundant or multiple barrier (as we prefer) arguments have been the justification for continued investment in study of these processes as they may operate at the Yucca Mountain site.

3. We believe the source term is more influenced by chemical reactions than absorption. Mechanical, chemical, and thermal disturbances

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10 Proposed Resolution (continued)

complicate study and understanding of these phenomenon in the near-field. The source term issue, however, is a Postclosure Rock Characteristics issue as the division of effort has been defined for the purposes of the this early site suitability evaluation.

Table 2-4 (previously Table 2.3.2-2) will be added to the text in Section 2.3.2 to address Dr. Drever's editorial point. A copy of that table is attached to this response.

END OF TEXT

Table 2-4. Important Radionuclides in High-Level Nuclear Waste[a,b]

Radionuclide	Half-life, years	Inventory Percent	Inventory Limit[c]	(Dissolution Rate/ Limit)[d]/year	Probable Sorption Behavior
Ni-59	8.0×10^{4}	0.3	5.2	1.7×10^{-4}	Strong
Zr-93	1.5×10^{6}	0.1	(e)	(e)	
TC-99	2.1×10^{5}	0.7	1.3	1.3×10^{-4}	Weak
Cs-135	3.0×10^{6}	(e)	(e)	3.5×10^{-4}	Strong
U-234	2.4×10^{5}	0.1	2.0×10^{1}	(e)	Weak
Np-237	2.1×10^{6}	0.05	1.0×10^{1}	1.0×10^{-3}	Weak
Pu-238	8.8×10^{1}	0.02	9.7	(e)	Moderate
U-238	4.5×10^{9}	(e)	3.2	(e)	Weak
Pu-239	2.4×10^{4}	17	3.1×10^{3}	6.9×10^{-4}	Moderate
Pu-240	6.6×10^{3}	27	4.8×10^{3}	1.1×10^{-3}	Moderate
Am-241	4.3×10^{2}	51	9.0×10^{3}	4.5×10^{-3}	Moderate
Pu-242	3.8×10^{5}	0.1	1.8×10^{1}	(e)	
Am-243	7.8×10^{3}	0.9	1.6×10^{2}	7.8×10^{-5}	Moderate

[a]Data from Kerrisk (1985).
[b]Based upon pressurized water reactor (PWR) spent fuel 1,000 years after discharge, dissolution by Well J-13-type water, and sorption by Yucca Mountain tuffs.
[c]Radionuclide activity/Environmental Protection Agency (EPA) release limit.
[d]Estimated rate of dissolution of the nuclide in the waste form/EPA release limit.
[e]Unimportant per this ranking criterion.

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7. Page 2-27 to 2-28
8. Paragraph Table 2-2

9. Comment

Table 2-2 (previously Table 2.3.2-1) Favorable Conditions:

1. "Sorptive minerals (zeolites) were present..." A key question is whether zeolites will adsorb all of the nuclides of concern. I am disturbed by possible over-generalizations.

Table 2-2 (previously Table 2.3.2-1) Potentially Adverse Conditions:

3. "Pre-waste-emplacement groundwater conditions in the host rock that are chemically oxidizing." I presume oxidizing conditions would be adverse from the point of view of corrosion of the canisters. From a geochemical point of view, oxidizing conditions may be favorable, as iron and manganese oxyhydroxides (which would not be present under reducing conditions) are an important substrate for adsorption (e.g. Means, J.L., D.A. Crerar, M.P. Borcsik, and J.O. Duguid: Adsorption of Co and selected actinides by Mn and Fe

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team understands Dr. Drever's concern; these statements, however, are not original prose by the ESSE authors but are verbatim quotations from the earlier EA and, therefore, text revisions are not possible.

We believe the ESSE report does not overgeneralize the importance or role of sorptive zeolites present at Yucca Mountain. In fact, this discussion tries to focus attention on real or potential exceptions to these generalizations, i.e., radionuclides and species that may not be sorbed or otherwise so retarded by geochemical conditions and processes. The mention in the ESSE report of occurrence at Yucca Mountain of sorptive minerals other than zeolites including iron and manganese oxides and hydroxides (see p 2-30) is an example. We will add the reference suggested to make it clearer which minerals and radionuclides are of interest. See attached text revision for page 2-34 to this effect.

11. Resolution *(To be completed by original Reviewer)*

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9 Comment (continued)

oxides in soils and sediments. Geochim. Cosmochim, Acta 42, 1763-1774, 1978).

END OF TEXT

10 Proposed Resolution (continued)

Dr. Drever's presumption regarding oxidizing, pre-waste-emplacement ground water is consistent with that of the Core Team. The Core Team decided to address the near-field effects of ground-water chemistry as a part of the Postclosure Rock Characteristics Guideline evaluation. We agree that oxidizing ground water may be a favorable condition in the far-field for the reason you state. This advantage may have to be balanced against the greater solubility of many radionuclides in oxidizing waters. In any case, the presence of oxidizing water in the far-field is not a disqualifying condition under the Postclosure Geochemistry Guideline.

The text on page 2-34, second paragraph, will be revised to read as follows:

"Several types of batch sorption experiments were carried out on pure mineral separates to identify which mineral phases present in tuffs at Yucca Mountain were most effective in sorption of each of the key radionuclides and to investigate the details of the sorption reactions for the most important radionuclide/mineral pairs. The sorption of anionic species of Tc (TcO_4^-) and Np ($NpO_2CO_3^-$) in J-13 water was studied on oxides, carbonates, clays, and zeolites. Of the phases studied, only the iron oxides, geothite and hematite, had any affinity for Tc and then only a small affinity. Iron and manganese oxides had large affinities for Np while clays, zeolites, and carbonates had relatively small affinities for Np (Meijer et al., 1989). These results for iron and manganese oxides corroborate earlier findings regarding the adsorption of actinides by iron and manganese oxyhydroxides (Means et al., 1978). The nature of the Np complex sorbed to the geothite surface was investigated with the Extended X-ray Absorption Fine-Structure (EXAFS) technique (Combes et al., 1990) and the results of this investigation were used in the development of a surface complexation model to explain retardation of the nuclide on geothite (Kohler et al., 1990). Evidence is accumulating that anionic species of key radionuclides released by the engineered barrier system are retarded somewhat by minerals other than zeolites present along potential flow paths."

END OF TEXT

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6. Section 2.3.2.4.2 (new 2.3.2.3.2)
7. Page 2-29
8. Paragraph 2

9. Comment

2.3.2.4.2, p. 2-29

"Dispersion and molecular diffusion also will slow the rate of travel of all species..." Dispersion (as the term is standardly used) will <u>not</u> slow the rate of travel. It will cause a spread in travel times about the mean, with some material arriving earlier and some later. It will in fact accelerate the "first arrival" (defined as some fraction of the peak concentration). Did the ESSE authors imply a different meaning for the term "dispersion" (perhaps involving matrix diffusion)?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised to omit reference to dispersion and to clarify the role of molecular diffusion. The text will be revised to read as follows:

"Two processes figure centrally in retardation by the geochemical barrier: (1) precipitation and (2) sorption by minerals along transport pathways. Sorption may occur as a result of several mechanisms, including ion exchange and surface complexation. Knowledge of mineral distributions along likely flow paths of water to the boundary with the accessible environment will allow a determination of the extent to which precipitation and sorption may occur. Molecular diffusion from fast transport pathways into the surrounding rock matrix also will slow the rate of travel of all species, i.e., ions and complexes. Species that do not..."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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6. Section 2.3.4.2.3 & 2.3.4.2.4
7. Page 2-32 to 2-33
8. Paragraph

9. Comment

2.3.4.2.3 Radionuclide Solubility; 2.3.2.4.2.4 Radionuclide Speciation

The speciation and hence solubility of the actinides is enormously complex (e.g., Nitsche, 1991), and the two cannot be considered in isolation; measured solubility will depend on speciation in solution, and there is no guarantee that speciation in solution will reflect equilibrium with ambient redox conditions or ligand concentrations. The problem can be approached empirically--see how total concentrations of an element behave in J-13 water with minor modifications--or mechanistically, in which all relevant species are studied by the traditional approaches of inorganic chemistry. In my opinion, the more-or-less empirical approach should be adequate for the Yucca Mountain Project at this time. However, sensitivity analyses as part of the performance assessment should provide an indication as to whether further specific studies are needed.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that speciation and solubility are closely interrelated. Sensitivity analyses by Kerrisk preceeded the Nitsche work cited by Dr. Drever, and, in fact, were used to focus and prioritize his work which, incidentally, is being done with direction and funding from Los Alamos National Laboratory as part of DOE's SCP geochemistry investigations. Dr. Nitsche plans continued sensitivity analyses as part of his solubility modeling activity. System and subsystem models for performance assessment are and will probably remain too gross to be useful for speciation sensitivity analyses. Detailed solubility, sorption, molecular diffusion, and coupled process transport/retardation models under development will be used for this purpose. Models are currently data starved or too immature to permit sensitivity analyses.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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7. Page 2-33
8. Paragraph para. 3&4 of S.2.3.2.4.2.4

9. Comment

2.3.2.4.2.4

(p. 2-33, second paragraph)

"Present-day groundwaters collected from the vicinity of Yucca Mountain do not contain a significant concentration of particulate matter." There was no specific reference given for this statement. My questions are: 1) How much does it have to be to be "significant"? 2) Have there been any systematic studies of the abundance of natural colloids, as, for example, at the Grimsel test site in Switzerland (Degueldre, C. et al.: Colloids in water from a subsurface fracture in granitic rock, Grimsel Test Site, Switzerland. Geochim. Cosmochim, Acta 53, 603-610, 1989)? It is not particularly likely that natural colloids are important, but consideration should be given to natural colloids during the water sampling program.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The reference to this statement should have been Kerrisk (1987) it was misplaced at the end of the previous sentence. The text will be revised to correct this error.

"Significant" was an inappropriate choice of words. No systematic studies of the abundance of natural colloids have been done. However, as a result of this and other concerns regarding ground-water composition, ground-water samples will be analyzed for natural colloids. These data should provide the basis for a systematic study of natural colloid occurrence and abundance.

The text in the first full paragraph on page 2-33 will be revised to read as follows:

"Soluble radionuclide species can also sorb on natural or anthropogenically produced colloidal-sized particles forming a pseudocolloid, which may then

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

(p. 2-33, third paragraph)

"Radionuclide transport as colloidal species remains an area of uncertainty." I agree that surrogate experiments with spherical particles are likely to be misleading. Is work underway to resolve the uncertainty? Filtration experiments with actual Pu colloids?

END OF TEXT

10 Proposed Resolution (continued)

move with the impunity of natural colloids. Particulate concentrations in ground waters of the Yucca Mountain region are believed to be low based upon the results of a few preliminary filtration experiments with samples from pumped wells. The best documented of these experiments measured ~0.3µg/1 of particulate material in the size range 0.005 µm to 0.4 µm in water from well J-13. At this concentration, a sorption ratio of ~4 x 10^8 µl/g would have to be demonstrated for this material to contribute to more than 10 percent of the total waste element flux. Such ratios have been seldom approached in sorption experiments using Yucca Mountain tuffs (Kerrisk, 1987). Repository construction and waste emplacement effects may alter this situation unfavorably, however."

END OF TEXT

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7. Page 2-33 to 2-35
8. Paragraph

9. Comment

2.3.2.4.2.5 Radionuclide Sorption

There are two major problems associated with adsorption work, and neither has an easy answer:

1. Adsorption is a function of the species in solution (e.g., Am^{3+}, Am^{4+}, AmO_2^{+}, AmO_2^{2+}, not to mention the effect of ligands) and not of the element Am. When adsorption is discussed simply in terms of elements, it is implicitly assumed either that the appropriate species is present in the experiment, or that equilibration among species is rapid on the time-scale of the experiment. To "do it right" by working out speciation in detail for all elements in all solutions of interest would be prohibitively expensive, and the usefulness of the results would be limited for other reasons (see 2. below). The "minimum K_d strategy" (Radionuclide Adsorption Workshop, Los Alamos National Laboratory, Sept. 11-12, 1990) seems a reasonable and conservative approach. I suspect it

10. Proposed Resolution *(To be completed by ESSE Core Team)*

1. The text in paragraph 1 of Section 2.3.2.4.2.5 (now Section 2.3.2.3.2.5) will be revised to reflect the comment. As described in the text, it is difficult to envision the chemical mechanisms that would result in such a slow interconversion among species present in solution that the distribution coefficient determined by batch experiments is not conservative. However, if the kinetics of attaining equilibrium among species in solution phase are slow, we will be able to measure the elution of the different species in column experiments. The column experiments will allow us to calculate distribution coefficients for each chemical species. We utilize column experiments to assess the applicability of batch sorption experiments under dynamic conditions. Any discrepancies among the two types of experiments are resolved before distribution coefficients are utilized in performance assessment. Whether the speciation in the solutions utilized is the same as the speciation of the solutions that will be present at the proposed repository is a difficult point to address. We use ground waters from the

11. Resolution *(To be completed by original Reviewer)*

Comment resolutions accepted as proposed.

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9 Comment (continued)

is over-conservative; it could be reviewed if performance assessment studies indicate. It appears at present that only a few elements (U, Np, Tc, I, and C) warrant significant effort at this time.

2. Transfer of laboratory-derived adsorption data to the field is an extremely complex problem. If solutions are percolating through a uniform permeable tuff, the problem is relatively straightforward. However if transport occurs through fractures (the likely situation for fast flow-paths) there is a large uncertainty in the mass/surface area of minerals that will contact the flowing solution. Presumably both fracture linings and matrix minerals (through matrix diffusion) will be involved. Here again is an area where hydrology and geochemistry overlap. If hydrologic field studies on fracture flow are instigated, I recommend that sorbing and non-sorbing tracers be included in the tests to provide some validation of related solute transport codes.

END OF TEXT

10 Proposed Resolution (continued)

site, and many of the experiments reported by Thomas (1988) were performed under controlled atmosphere to simulate the amount of carbon dioxide present in the ground water at Yucca Mountain. All we can do is report the method of solution preparation and the chemistry of ground water utilized (as Thomas did in the 1988 sorption summary report) and evaluate those experimental parameters as more speciation data are obtained by Nitsche and as the field sampling plan to obtain ground-water samples and ground-water chemistry is carried out by the USGS and LANL.

The minimum K_d strategy is perceived as both "reasonable and conservative" by its advocates. It is seen as deterministic, bounding, and inconsistent with regulations, policy, and common sense by its detractors who believe a stochastic approach to be reasonable, conservative, and practical. The minimum K_d strategy capitalizes upon empirical sorption data and mineralogy and petrology information accumulated to date on rock units expected to occur along likely flow paths to the accessible environment. It is an admitted attempt to focus resources on key radionuclides and species in the limited time remaining before a decision on site suitability with the (perhaps, too obvious) objective of minimizing the uncertainty in this decision. Performance assessments are indeed expected to determine the conservatism of this position. Contention persists over these assessments because of (a) the dearth of data upon which they are currently based and (b) the idea that the expected value and range for many of the variables involved can be decided by "expert" opinion (this idea is

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10 Proposed Resolution (continued)

an anathema to experimentalists).

2. A saturated-zone pump test at three drill holes at the C-well complex is planned. Both conservative and reactive tracers will be used; however, tracers will not be radioactive because the use of radioactive material is prohibited. The tests will be modeled using multidimensional transport code, and the test results will be used to validate or suggest refinement of the code. In anticipation, detailed laboratory characterization of potential tracers and relevant rock has been done. Fracture network and reactive transport codes are also in place. Other tests of a similar nature are planned for the saturated and unsaturated systems.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 12 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.3.2.4.2.5 (new 2.3.2.3.2.5)
7. Page 2-34 & 2-36
8. Paragraph

9. Comment

2.3.2.4.2.5 Radionuclide Sorption

(p. 2-34)

"Evidence is accumulating that anionic species are retarded somewhat by minerals other than zeolites present along flow paths." When I first read this statement I was unclear as to which anionic species were meant. R.J. Herbst (pers. comm. September 24, 1991) clarified the meaning by explaining the sentence was simply a summary of the preceding paragraph. It is still potentially confusing for a reader.

Along the same lines, 2.3.2.4.3 Issue 1 (p. 2-36) could be more explicit. I would prefer to see a specific list of the radionuclides expected to be retarded (or rather a list of any <u>not</u> expected to be retarded.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Drever's comment.

The revision to the second paragraph on p. 2-34 proposed in the response to Dr. Drever's Comment #7 addresses the first part of this comment.

The text under Issue 1 will be revised as follows:

"Improved knowledge of mineral abundances and distribution, particularly in fractures, strengthens the case for effective sorption of the radionuclides of concern at Yucca Mountain. The effectiveness is least for anionic species of Tc and Np. In general, known and expected geochemical characteristics and processes are expected to retard the rate of transport of radionuclides released to this setting relative to ground-water travel."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 13 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.1
7. Page 2-56
8. Paragraph 1

9. Comment

2.3.4.3.1

(p. 2-56)

"Increased precipitation, however, also could lead to higher rates of erosion within the region resulting in overall base-level lowering that, ultimately, could lead to water-table declines and longer ground-water travel times." While the statement is true in principle, I find it implausible when applied to Yucca Mountain. Where is the base-level lowering going to occur? Certainly not at Furnace Creek, and significantly lowering at Ash Meadows seems unlikely.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The statement cited by Dr. Drever was intended to be general, that is, to identify possible effects and consequences of climatic change without specific reference necessarily to the Yucca Mountain site. The sentence will be removed from the text. It is interesting to note, however, that Winograd and Szabo (1988) consider that base-level lowering could have been a major component of the water-table decline inferred to have occurred at Ash Meadows during the past 750,000 years.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 14 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.4
7. Page 2-98 & 2-99
8. Paragraph

9. Comment

2.3.7.3.2.4 Strain-Response Models

Given the existing panels, I do not propose to spend time evaluating Szymanski's hypothesis. I would simply say that an inordinate amount of effort seems to have been expended on the origin of the deposits in Trench 14. I am convinced that they are pedogenic rather than hydrothermal.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Although the ESSE Core Team agrees that additional review effort on the Szymanski hypothesis appears to be redundant, every additional expert opinion is welcome. The effort expended in evaluating the Trench 14 deposits has served as a training exercise to develop methods and criteria upon which to base judgments as to the origin of various deposits in the region.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 15 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.7
7. Page 2-120
8. Paragraph

9. Comment

2.3.8.3.2.7 Permanent Markers

In designing earthworks or markers, care should be taken to avoid configurations that might increase infiltration. Given the low rates of weathering in the area, natural rock should be perfectly adequate for permanent markers.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following will be inserted as the last sentence in the first paragraph on page 2-121:

"Whichever type of surface marker or earthworks are used, care should be taken to avoid configurations that could increase infiltration."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 16 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.4 general
7. Page 2-129ff
8. Paragraph na

9. Comment

2.4 Evaluation of the Postclosure System Guideline

Performance analysis is the key to provide focus to the site characterization effort. An apparent weakness of past work is that it has not necessarily been prioritized in the context of its contribution to the total system performance. I would advocate this approach, both for making the most effective use of research funds and for advancing the site characterization process as rapidly as possible.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Drever emphasizes the importance of prioritizing site-characterization activities both in this comment and in his opening summary. Other reviewers have also made this point (see Dr. Vogel's Comment #7). As mentioned in our response to Dr. Drever's Comment #1, explicit prioritization was not the responsibility of the ESSE Core Team; rather, the mission was to identify technical guidelines for which information is inadequate to support a higher-level finding. These topics will serve as input to establishing overall priorities.

The report by Mattson et al. (1991) evaluated priorities for tests designed to detect potentially unsuitable site conditions early during site characterization. Prioritization in that report was based on detection of features and conditions that affect postclosure performance. However, there are a number of reasons for conducting site characterization activities. These include gathering information needed to (1) design the waste package and

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 16 of 18

2. Page 2 of 3

3. Name J. I. Drever
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

repository; (2) evaluate performance of the natural and engineered barriers, both individually and collectively; (3) gain scientific confidence and regulatory assurance; (4) provide support for other testing activities; and, as required by the NRC (10 CFR 60, Subpart F), (5) to confirm, to the extent possible, that the natural setting and the engineered components are performing as intended and expected. Some testing activities serve many of these "end uses" while others have a relatively specific objective. Because of these multiple needs and uses for information, prioritization of the research program is a very complicated task. (This point was also made in our response to Dr. Drever's Comment #1.)

The DOE's Test and Evaluation Plan (DOE, 1990) explicitly describes the steps the Project intends to take to ensure that the testing program focuses on those aspects of the site that are most important to system performance. The plan describes the role that performance assessments will play in helping to evaluate the results of the testing program and in providing essential input to those responsible for directing that program.

However, performance assessments that require detailed conceptual and numerical models can only be used to a limited extent early in the site characterization program when those models are not very well developed. Therefore, although the performance aspects have been considered in the evaluations and in developing the general testing plan described in the SCP (DOE, 1988a), it is too early to use them exclusively. The early site suitability evaluation was conducted with that same philosophy. The following paragraph will be added to page 2-5 in Section 2.2 to explain this limitation:

"Although quantitative assessments were considered, they did not provide the principal focus of this early site suitability evaluation. Ultimately, the evaluation of the suitability of the site will involve detailed, quantitative performance analyses to assess compliance with numerical criteria. These analyses will be based on conceptual models that are consistent with the information gathered during site characterization. Because it is too early in the site characterization program to have such information and models fully developed, the Core Team did not rely heavily on quantitative performance models. (A good example is in the area of geohydrologic processes. The models in this area are at a relatively early stage of development, and the Core Team did not consider it appropriate to rely heavily on them at this time.) Nevertheless, the Core Team did review the status of the quantitative assessments in their

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 16 of 18
2. Page 3 of 3
3. Name J. I. Drever (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

evaluation of the system guideline. The results of this review and the evaluation of the system guideline are presented in Section 2.4."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 17 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.4.2
7. Page 2-138 & 2-139
8. Paragraph

9. Comment

2.4.2 Review of information obtained since...

Carbon-14 Studies

The question of C-14 migration seems to be falling through the cracks. It is mentioned in the Geochemistry and Hydrology sections, but I did not see any discussion of attenuation through gas-liquid partition in the vadose zone or consumption by silicate weathering reactions in the vadose zone. I do not know if either would be significant, but it would seem appropriate to conduct some preliminary modeling as fallback position in case the strategy of changing EPA release rates (Van Konyenburg, 1991) does not work out.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Information reviewed by the ESSE Core Team strongly suggests that attenuation due to mechanisms listed by Dr. Drever is not well understood. Ross (1987) estimates the bounds of the retardation factor for C-14 to be between 2 and 2,000. Other calculations place the retardation factor between 30 and 70 with an approximately median at 50 (Ross et al., 1991). An important assumption in these calculations is that of thermodynamic equilibrium between the gas and liquid. Evidence from pore fluids and pore gases (Yang, 1991) suggests the possibility of a very low retardation, especially if the liquid is held in the smallest pores while the gas flows through the paths of least resistance.

Another important uncertainty regarding gaseous release--and the one most amenable to testing--is in the source term, or the rate at which the gas could be released from the engineered barriers. The third sentence of paragraph 2 on page 2-144 will be changed to reflect this point: "Current evidence also

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 17 of 18

2. Page 2 of 2

3. Name J. I. Drever
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

suggests that the probability of meeting the EPA release limits for carbon-14 does not depend strongly on uncertainties in site information. Rather, the major source of uncertainty appears to be the gaseous carbon-14 source term."

Although the performance of the site may be approaching the EPA 10,000 year release limit for carbon-14, the consequence of the gaseous releases (i.e., dose or health effects) is believed to be negligible. This reflects an inconsistency in the regulations, of which the regulatory agencies are aware. It is not clear at the present time if the regulations will be changed to correct this inconsistency, but it is clear that the margin needed to demonstrate compliance with the current regulation will be less than for other radionuclides where the consequences could be much greater. The text will be rewritten to reflect this broader view of the regulatory approach (replacing last three sentences of paragraph 3 on page 2-145):

"The EPA has recognized that this limit may not be consistent with the minimal public health and safety hazards associated with release of gaseous carbon-14 (Clark and Galpin, 1991; Van Konynenburg, 1991). Thus, the release limits for carbon-14 may change, or it is possible that additional information about releases could change the conclusion that the system guideline is met. Therefore, the Core Team feels that a lower-level suitability finding can be supported for the Postclosure System Guideline."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 18 of 18
2. Date November 12, 1991
3. Reviewer J. I. Drever
4. Organization University of Wyoming
5. Revision Draft/Date August 1991
6. Section 2.2.4
7. Page 2-145 to 2-150
8. Paragraph Table 2-14

9. Comment

Table 2-14 (previously Table 2.4-2): Site characterization studies

Again, I see very little prominence given to isotopic tracers. I think ^{14}C and tritium should be there along with ^{36}Cl. Deuterium and ^{18}O should be included.

This lets me conclude with what I think is a fundamental point: the most critical issue for establishing confidence in the suitability of the site will be convincing the scientific community and the public that the hydrologic models for the unsaturated zone actually work--that they are capable of predicting realistically the future movement of fluids. This confidence will not come from increasing the sophistication of the models (desirable as this may be), but from devising tests to validate the models. I have mentioned isotopic tracers as one approach. I am sure there are others, and my final recommendation would be to elevate the whole question of model validation to a

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Drever's concern regarding model validation. Transport model validation is a crucial concern of the geochemistry investigations. (Recognize that program parlance equates geochemistry to radionuclide transport.) Our approach to model validation begins with iterative laboratory studies and model revisions of separate processes and builds to full-scale field experiments in the Exploratory Studies Facility through a series of larger and increasingly complex laboratory and pseudo-field (caisson) experiments. This approach is embodied in current plans and, therefore, no revisions to the ESSE report text are proposed in response to this comment. The approach was also hinted at in our response to part 2 of Dr. Drever's Comment #11, and the concern as it relates to hydrologic models was addressed in our response to Dr. Drever's Comment #2. We propose no further amplification here except to call your attention to recommendation (2) of Section 2.3.2.4 (previously 2.3.2.5) of the report where

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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1. Comment 18 of 18

2. Page 2 of 2

3. Name J. I. Drever
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

high priority.

END OF TEXT

10 Proposed Resolution (continued)

we tried to make this same point as a recommendation for future activities.

END OF TEXT

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Dr. Marco T. Einaudi

ECONOMIC GEOLOGY

Stanford University
Stanford, CA

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	yes, with resolution of my comments	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	yes, with resolution of my comments.	

Comments 1 through 29 are attached.

Peer Reviewer [signature] Date 12/12/91

Comment Resolution Record

Yes yes The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ______ The following comments have not been adequately addressed:

Peer Reviewer [signature] Date 12/12/91

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-12-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment ______ of ______
2. Date November 12, 1991
3. Reviewer Marco T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section 2.3.8
7. Page general
8. Paragraph ______

9. Comment

Summary

Based on my reading of the ESSE and many of the supporting documents, I judge that it is appropriate to extend the effort to characterize the Yucca Mountain site. Assessment of the suitability of the site with regard to the two disqualifying conditions appears to be well in hand, although some clarification and amplification is necessary in the ESSE to support a Level 2 finding with regard to Issue 2 (see below). I concur with the assessment that available evidence continues to support a lower level suitability finding for the qualifying condition. Considerable work remains to be done with regard to the qualifying condition (Issue 3), and these future tasks are reasonably laid out in the ESSE. Discussion of approaches and conceptualizations regarding these future tasks is a key focus of my detailed commentary, and I hope that these can be outlined in the ESSE. An important point that must be stressed in any discussion of resource assessment is the increased difficulty of predicting

10. Proposed Resolution *(To be completed by ESSE Core Team)*

No resolution required to Dr. Einaudi's summary and general commentary.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Not applicable.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment _______ of _______
2. Page 2 of 7
3. Name Marco T. Einaudi (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

the occurrence of mineral resources at depths greater than a few hundred meters below the surface. This difficulty is especially great in an area such as Yucca Mountain which contains no known mineral deposits and little or no sign of past hydrothermal activity at the surface. Judgemental knowledge becomes critical in such cases, pointing to the eventual need for review of data and approaches by a team of experts in mineral exploration.

General Commentary

In this section, I focus on what I consider to be the outstanding issues associated with the Human Interference technical guideline related to non-fuel natural resources. In the sections that follow this general commentary, I submit detailed comments on the ESSE and on several of the supporting documents cited in the ESSE (Castor et al., 1989; Site Characterization Plan).

Assessment of natural resources has a large uncertainty and the probability of false alarms can be high; testing of hypotheses related to potentially economic resources takes the form of exhaustive and expensive drilling campaigns. For these reasons, expert opinion (i.e., judgement) has to be relied on to a large extent. Numerical data involving probabilities of occurrence of certain types of mineral deposits as a function of geological environment can be useful. However, the ultimate assessment of potential loss of waste isolation due to exploration for, or mining of, mineral resources has to rely more on site-specific assessment than on regional probabilities of occurrence (which are not site-specific).

In spite of the above caveats, prioritization of tasks related to the technical guidelines on "Human Interference, Natural Resources" can be achieved. These tasks, in order of importance, include: establishment of specific methods to be used in the projection of resource value and technology into the future; assessment of the indirect effects on the repository of mining outside the controlled area; and establishment of occurrence models for mineral deposits and ore-forming systems that may occur at and near the site.

A major recommendation resulting from my review of the Natural Resources section is that separate panels of experts be convened to review the judgemental issues related to (1) assessment of future value, and (2) mineral deposit occurrence models. The former should involve an interdisciplinary team consisting of (for example) mineral economists, geostatisticians, economic geologists, and geochemists; the latter could be composed dominantly of

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

economic (exploration) geologists, but should coordinate closely with research teams of the Yucca Mountain Project, particularly in the areas of geochemistry, rock characteristics, and tectonics.

The outstanding problems that will require further study include (1) projections of future values of resources and future technologies; (2) indirect affects on the repository of potential future mining outside the controlled area; and (3) assessment of future resource potential based on concepts of ore-forming systems (or ore deposit models).

1. Future Mining Cut-offs, Values, and Technology.

The qualifying condition regarding human interference (natural resources) requires an assessment of future value of commodities, future scarcity of commodities, and future technology related to mining and beneficiation (ESSE, p. 2-107). Issue 3, which relates to this qualifying condition, states that this projection should extend into the "foreseeable future" (ESSE, p. 2-109). The ESSE further interprets "foreseeable future" as referring to "the next few years to 10 years, and occasionally as long as 30 years" (p. 2-108).

There are various approaches that can be used to assess the future economic viability of a metal concentration in the earth's crust.

(a) The simplest is to assume present value and technology, with reassessment taking place periodically until closure. This would establish a baseline, but fully confront the issue.

(b) An approach that would confront the issue more closely would be to conduct assessments for each of a series of declining mining cut-off grades down to a selected lower limit, as suggested by Mattson (1988). The lower limit selected, dependent on the commodity, could be based on the concept of "mineralogical barrier" (Skinner, 1986) or on the concept of "conservative cut-off" (Mattson, 1988). A comparison of these two approaches to setting lower limits to grade for the foreseeable future can be made for copper: Skinner's mineralogical barrier yields a lowest grade of 0.1 percent Cu. whereas Mattson's conservative cut-off yields a lowest grade of 0.03 percent Cu. Skinner's approach may be preferable, because it is based on a physical model for the distribution

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9 Comment (continued)

of elements between minerals, and is linked to the cost of extraction. However, the mineralogical barrier is not well-known for many metals of interest. Neither approach specifically takes into account the question of future demand and future technology.

The issues raised above should be addressed and reviewed by a group of experts in the area of commodity forecasting and future technology. Such a group would have to interface closely with geochemists (crustal distribution of elements unconventional ores) and exploration geologists (mineral deposit characteristics, unconventional ores). Without such advice and guidance, it will be difficult to assess and obtain closure in the evaluation of issues related to this qualifying condition.

2. Indirect Effects of Future Mining.

The indirect effects on the repository of future exploration for, and mining of, mineral resources outside the controlled area will have to be assessed and is particularly important for resolution of the qualifying condition. Studies will have to develop knowledge of the effects of:

(a) introducing drilling fluids,

(b) infiltration of leach fluids from
  (1) surface leach pads,
  (2) underground (in-situ) leaching operations,

(c) withdrawal of groundwater due to mine dewatering activities or water production for mine and mill use,

(d) man-made underground pathways (fractures, openings) created by:
  (1) conventional open pit blasting
  (2) conventional underground blasting,
  (3) surface and underground drilling,
  (4) underground mine tunnels and stopes,
  (5) large-scale underground block caving with attendant rupture to the surface,
  (6) non-conventional underground mining involving large-scale fracturing by conventional or nuclear explosives for in-situ leaching.

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Screening, assessment, and, perhaps, performance assessment calculations of the above factors (and there may be others that I, not being a mining engineer, have not thought of) is required before Issue 3 (qualifying condition) can be resolved. This process also could lead to a substantial reduction of the size of the area that needs to be considered in terms of potential for undiscovered deposits. Therefore, this study of indirect effects on the repository of future exploration and mining outside the controlled area preferably should take place before substantial investment of time on the assessment of mineral resources outside the controlled area. Expert judgement will likely play a large role in this analysis.

3. Ore Deposit Models.

A starting point for resource assessment is knowledge of the location of all past and current mining operations near the site. This knowledge presumably is in hand, although a detailed map showing such sites is absent from the ESSE or SCP. Such a map should become an integral part of Human Interference assessment package.

In assessing the mineral potential of an area, knowledge of location of past and present producers and commodities is insufficient; knowledge has to extend to include key geological and geochemical features of the known mineral deposits that can be used in a predictive manner in other, nearby areas. This type of knowledge commonly is cast in terms of geological "models" of mineral deposits. Ideally, such models deal not only with the immediate ore zone, but also with the broader issue of ore-forming "systems" that can include both numerous different ore zones of the same type or same commodity, and numerous different types of ores or commodities.

In general, the ESSE and SCP did not provide a conceptualization of the links between deposit types and between different commodities in the context of a hydrothermal system that is larger than any individual ore deposit or prospect that it might contain. Such an approach should be listed in the ESSE as a future goal. In the sections that follow this general commentary, specific comments are offered on the SCP which discuss this approach in some detail. Such conceptualization needs to be developed before Issue 3 (qualifying condition) can be resolved, and is a top priority item for future tasks.

Four future tasks related to assessment of resource potential are listed below in approximate order of accomplishment (although iteration between the

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four efforts needs to take place):

(a) RANKED LIST OF TYPES OF MINERAL DEPOSITS. Based on (1) known geological environment of the site and of its surroundings (tectonic setting, rock types, and ages), and (2) presently known ore deposits (past and present producers) and prospects of the surroundings, <u>a list should be established of all types of mineral deposits</u> (as opposed to commodities, and as opposed to ore-forming systems [see below]) that do or could occur in the area. Such a list should include deposits that are presently economic as well as those that have been economic in the past. The list should be <u>ranked in an order reflecting both likelihood of occurrence in the area and potential value</u>. This task requires a knowledge of the geological environment and does not require the definition of a specific area. <u>The ranked list must be made by economic geologists familiar with the Great Basin and ultimately should be reviewed by an expert panel</u>.

(b) OCCURRENCE (DESCRIPTIVE) MODELS OF MINERAL DEPOSITS. For each of the types of deposits identified in (1), key geological, geochemical, and geophysical features need to be compiled. In developing the occurrence models, special weight should be given to characteristic features of ores in the SW Nevada Volcanic Field and in its basement rocks. Priority should be given to the development of models for the deposits ranked at the top of the list generated in Step 1 (above). Such descriptions should include, but not be restricted to, the following:

(1) age distribution,

(2) key rock associations (igneous rock types and textures, favorable sedimentary lithologies, etc.),

(3) alteration styles and their zoning (especially peripheral styles) and the size of alteration halos,

(4) structural controls and vein styles and their zoning,

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9 Comment (continued)

(5) morphology and dimensions of ore zones,

(6) geochemical signatures (e.g., metal associations or correlations and ratios) and their zoning,

(7) typical tonnage and grade data, including co- and by-products.

(c) CONCEPTUAL BASE OF ORE SYSTEMS. The next step is to identify the known observational links (not speculative links) between deposit types, i.e., to establish a conceptual base of "ore systems," larger than individual ore deposits (ore bodies). Examples are the links between mercury deposits and gold deposits of both the Carlin and epithermal (volcanic-hosted) type; link between barite veins and Carlin-type Au; link between porphyry Cu deposits, Cu-skarn deposits, and base-metal vein deposits; link between fluorite deposits and porphyry-type deposits of lithophile elements (W, Sn, Mo, etc.). Links that at present are speculative (e.g., between Carlin-type Au and porphyry systems, or between detachment faults and base- and precious-metal deposits) should be considered, but will be difficult to assess. The choice of conceptual systems to be assessed and the importance of "speculative links" ultimately should be reviewed by an expert panel.

(d) REGIONAL RESOURCE ASSESSMENT (EXPLORATION) MAP. Following the integration of data collected in steps 1-3 above, and as a result of that integration, an exploration map can be constructed. Such a map would display, as a series of overlays on a geologic map base, the distribution of key mineral occurrences, prospects, past and present mines, hydrothermal wall-rock alteration, and structural trends. Such a series of overlays could then be used to construct summary maps indicating the location of highly prospective, moderately prospective, weakly prospective, and non-prospective areas for each of the deposit-types identified in task 1. Again, a panel of experts should be involved in the review and finalization of this work.

END OF TEXT

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8. Paragraph 1

9. Comment

(see comment (5)).

Qualifying condition (Issue 3) - "Reasonable projections of value, scarcity, and technology" are required in order to assess this qualifying condition and it would be useful if some elaboration of this point were made in the ESSE. For example, these projections are to be made over an unspecified period of time that commences on closure of the facility--are there plans to establish guidelines for such projections? Or, could this qualifying condition be assessed in the context of present value and technology, to be reassessed periodically until closure?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Much of this concern and discussion is covered in the Discussion Section (2.3.8.1.1). The last paragraph of this section states "For natural resources without current markets, but which could be marketable given credible projected changes in economic or technological, the resources shall be described by physical factors such as tonnage or other amount, grade, and quantity."

Additional discussion will be added to this section under the subheader of "Reasonable projections of value, scarcity, and technology." The following will be added to the text: "Reasonable projections will need to be made at several points during site characterization and, likely, during any period under which a license application may be pending in the future. The basis for these projections is likely to rely on the expert opinion of individuals in the field of natural resources and perhaps other technical fields.

In addition, the natural resource potential of the site may need to be

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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10 Proposed Resolution (continued)

reassessed at the time a closure decision is considered. This is because closure of any facility could be as far in the future as 150 years, a period much longer than current estimates of natural resource potential (foreseeable future) should be extended and considered credible. Definitions, terms, and assumptions will all need to be reviewed by qualified experts to aid in directing the program toward realistic goals and credible natural resource assessments and to establish that regulatory criteria have been defensibly evaluated."

END OF TEXT

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9. Comment

(see comment (5)).

The disqualifying condition (Issue 2) is that presently valuable natural resources outside the controlled area would be expected to give rise to interference activities now or in the future that would lead to an inadvertant loss of waste isolation. Thus, the disqualifying condition takes into account present value, whereas the qualifying condition takes into account projections of value into the future. Because future interference activities may involve natural resources that are not presently valuable but may be valuable in the future, the reasoning behind the different bases used to assess qualifying and disqualifying conditions should be clarified.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Further clarification of the differences between the disqualifying and qualifying conditions will be added to the text (Section 2.3.8.2.1) for the Postclosure Guidelines concerning human interference. The following will be added to the text: "The disqualifying condition (Issue 2) is concerned with present day activities (e.g., mining, drilling, and blasting) conducted outside the controlled area that could affect the waste isolation capabilities of the site. This includes activities we expect to occur in the near future as a result of identified and presently known economic resources located outside the controlled area. Because these potential activities would be conducted outside the controlled area, a loss in waste isolation could only occur as result of indirect affects (See Section 2.3.8.1.2). In contrast, the qualifying condition is concerned with assessing the natural resource potential for both those resources that are presently valuable and those that are not presently valuable, but which may be valuable in the foreseeable future. The affects of inadvertent human interference could be direct or indirect affects (See section

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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10 Proposed Resolution (continued)
2.3.8.1.2)."

In addition, the following will be added to Section 2.3.8.2.2 under the heading "Resolution of Issue 2." "Indirect effects on long-term waste isolation could result from exploration activities, mining, or drilling. The possible effects include (1) creation of new hydrologic pathways along which waste could travel, (2) loss in the effectiveness of the natural barriers or the engineered barrier system, (3) introduction of fluids that could lead to faster dissolution and transport of waste. Specifically, indirect effects to be considered include (1) introduction of drilling fluids that increase the hydrologic flux or increase rates of dissolution of waste, (2) infiltration of fluids from surface or underground leaching, (3) withdrawal of ground water due to mine dewatering or water production for mine and mill use, and (4) affects related to man-made underground openings (fractures and other openings) created by, for example, open-pit blasting, underground blasting, surface and underground drilling, and large underground block caving."

END OF TEXT

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7. Page 2-108
8. Paragraph 0

9. Comment

(see comment (5)).

I agree with this interpretation of "foreseeable future" as far as the mining industry is concerned. However, this term is not used in the qualifying and disqualifying conditions. Terms that are used include: "reasonablé projections" (Qualifying Condition), and "likely future activities" (Disqualifying Condition). The term "foreseeable future" is used on p. 2-109 as part of the identification of issues (issue 3) related to the guideline and involves only the Qualifying Condition (it comes from 10 CFR 960.4-2-8-1(b)). Further discussion is needed here regarding the interpretation of "reasonable projections" and "likely future activities," with the goal of establishing specific criteria upon which the site is to be evaluated.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment centers around the use of the term "foreseeable future." The term is not specifically used in the qualifying or disqualifying conditions, but is used in the favorable conditions and the potentially adverse conditions, which support and aid in the interpretation of the qualifying and disqualifying evaluations. Further, the term is used in the siting criteria of 10 CFR Part 60. Therefore the use of the term and its associated definition in evaluating the issues is considered to be germane and appropriate.

The evaluation and definition of the terms, such as, "reasonable projections" and "likely future activities" will receive considerable attention in the future and is likely to utilize the review of a panel of experts to establish that the assessments are reasonable and defensible. The spirit of this comment has been included in the text in Section 2.3.8.1.1 as a result of Dr. Einaudi's Comment #1 and as a result of Mr. French's Comment #10 in Section

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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10 Proposed Resolution (continued)

2.3.8.4.

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9. Comment

Some clarification is needed of terminology from 10 CFR 60.21(c)(13): this states that the evaluation of natural resources shall be conducted (1) for the site and (2) for areas of similar size that are representative of and are within the geologic setting.

(1) The "site" presumably is the same as the "controlled area," which has specific boundaries. The point of clarification needed here is that in terms of natural resources, we are really considering a volume. This point is related to the fact that in the assessment of natural resources, the question of depth has to be taken into account because depth is important in deciding whether or not a mineral occurrence is economic. In the SCP (p. 1-258, para 1), it is stated that "it is standard practice to exclude evaluation of mineral resources below 1 km..." Yet, there are numerous mines around the world operating at depths greater than 1 km; there are several mines in the U.S. that hold marginal reserves at depths greater than 1 km (e.g., Bingham mining

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Einaudi discusses several points that could be further addressed in the ESSE. First, the natural resource assessment needs to assess a volume of material. It is inappropriate to evaluate potential economic resources that lie at depths of, say, 5 km and have no surface indications of their presence, because assessment techniques and technologies are not available to evaluate such resources. In contrast, the Site Characterization Plan (DOE, 1988a) called for an evaluation to a depth of 1 km because of established precedent in the geologic literature. It is perhaps wise to reconsider such boundaries in light of the current worldwide depletion of resources, scarcity of resources, and the recognition that resources will need to evaluated to deeper depths in the near future. As an example, Brian J. Skinner was a keynote speaker at the annual Geologic Society of America conference in 1991 where he presented a talk entitled "A Kilometer and Deeper: Will Geologists Be Ready for the Tough Prospecting Challenges Ahead?"

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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9 Comment (continued)

district), and there are some exploration groups in the U.S. that presently are drilling ore targets at depths of 1 km. This question of depth needs to be discussed in the statements of issues and their resolution in order to underscore its importance so that it is dealt with systematically in the presentation and discussion of current understanding.

(2) 10 CFR 60.21(c)(13) states that natural resources shall be evaluated in the site and in "areas of similar size that are representative of and are within the geologic setting." Clarification of the intent of this statement is needed, and such clarification should lead to the establishment of actual (and conceptual) boundaries to the areas (and types of deposits) that need to be assessed. The need is to assess the natural resources in and near Yucca Mountain and compare them with those same resources potentially available outside the area. Given this requirement, determination has to be made of the specific physical boundaries (larger than those of the controlled area) within which the assessment of resources needs to be made. The boundary chosen will be dependent on the use to which the assessment will be put: 1) to establish the character and value of resources outside the area in order to contrast these in economic terms with resources within the controlled area (in this case the "area" would have no physical boundaries); 2) to define geological models of mineral deposits that could occur at Yucca Mountain (in this case the "area" could be the size of the Basin and Range province); or 3) to define areas where potential human incursion would result in release of radionuclides (in this case an "area" could be defined within "X" km of Yucca Mountain, with "X" partly dependent on resolution of my Comment #7 below).

END OF TEXT

10 Proposed Resolution (continued)

Second, the ESSE Core Team agrees with Dr. Einaudi that some definition needs to be added to the text in relation to the types of deposits that should be compared to the Yucca Mountain site. This definition needs to include the size of the areas that need to be compared with the site, as well. The scope of these considerations are too detailed and involved to be include within the ESSE in their entirety, but the following statements are offered to clarify the intent to consider, evaluate, and better define assumptions.

The following text will be added to Section 2.3.8.2.2 under the header of "Resolution of Issue 3," paragraph 2:

"Resolution of Issue 3 will also involve providing additional information before the assessment can be considered complete. First, the volume of

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10 Proposed Resolution (continued)

material to be assessed for natural resources needs to be explicitly defined. The Site Characterization Plan (DOE, 1988a) called for an evaluation to a depth of 1 km for mineral resources because of established precedent in the geologic literature. Given current economic conditions and projections of natural resource demand in the near future, deeper depths will likely need to be considered. Natural resource assessments will, out of necessity, become less detailed with depth, but projections can be accomplished for progressively deeper depths; for example, assessments for potential resources that may occur at depths shallower than 1, 2, and 3 km for mineral resources. Second, further definition of the area that is to serve as a basis for comparison (e.g., the Great Basin, the region surrounding Yucca Mountain) is needed before a detailed comparison with the site can be accomplished. The area in which direct or indirect interference activities could affect the proposed repository needs to be more clearly constrained. Third, geologic models of mineral deposits that should be compared to the proposed Yucca Mountain site need to be prioritized and ranked before a detailed comparison is conducted. Consideration of the above factors as related to the oil or gas potential of the site will strongly depend on the likely presence or absence of potential source rocks in the region (See Section 2.3.8.4 for further information)."

END OF TEXT

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9. Comment

(related to my comments (1), (2) & (3)).

10 CFR 60.21(c)(13) requires that "credible projected changes in economic or technological factors" be addressed. In order that the assessment of suitability (with regard to human incursion) can proceed beyond the compilation of a data base and arrive at a "finding," these projections need to be addressed and resolved. THIS ISSUE OF PROJECTED CHANGES IN ECONOMIC AND TECHNOLOGICAL FACTORS IS THE MOST DIFFICULT AND MOST PRESSING UNRESOLVED ISSUE RELATED TO THE "HUMAN INTERFERENCE TECHNICAL GUIDELINE." It is likely that "credible" projections made by "credible" people will extend no further than 5 or 10 years into the future.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Einaudi that this is an important issue that the regulators, public, and others should be aware. This comment has been addressed in the response to Dr. Einaudi's Comment #1.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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6. Section 2.3.8.2.1
7. Page 2-109
8. Paragraph 2

9. Comment

Issue 2 is an interpretation of Disqualifying Condition 2. Because of the problems I have with the wording of Disqualifying Condition 2 (see my point (2) above), I also have problems with the statement of Issue 2. The text should make it clear that "likely future mining" is not intended to include the mining in the future of undiscovered mineral deposits.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following will be added to the text under Issue 2 in Section 2.3.8.2.1: "Issue 2 is concerned with present day activities (e.g., mining, drilling, and blasting) conducted outside the controlled area that could affect the waste isolation capabilities of the site. This includes activities we expect to occur in the near future as a result of identified and presently known economic resources located outside the controlled area, but does not include future mining of resources that are presently unknown."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9. Comment

It would be useful to have various high-level scenarios for the indirect effects on waste isolation of mining outside the controlled area, because these could be used to place limits on the volume that needs to be considered. For example, if it can reasonably be shown that underground mining (at any depth) of ore by traditional means will have no adverse impact on waste isolation as long as the mining is located more than "X" km from the control perimeter, then presently known mineral resources beyond that limit need not be considered in terms of adverse effects.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment has been addressed in developing responses to Dr. Einaudi's Comments #2 and #4.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9. Comment

Because Issue 3 related to the qualifying condition requires projections into the future, ultimately there will be a need to consider and screen non-traditional extraction methods for resources located near Yucca Mountain. The ESSE should contain a discussion or progress report on the possible effects of traditional (and non-traditional) mining outside the controlled area.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment has been partially addressed in the response developed for Einaudi's Comment #2. In addition, the following changes are recommended for Section 2.3.8.4 and provide the mechanism for documentation and evaluation of indirect human interference activities and their likely effects on the waste isolation capabilities of the site:

"Documentation Needed to Finalize Issue 2: It is recommended that priority be placed on documenting the direct and indirect human interference activities that could potentially affect the waste isolation capabilities of the site. This report should contain (1) information on the kinds of activities, including nontraditional exploration or mining activities, that could occur, (2) in qualitative terms, a ranking of the affects of such activities including the probablility of such activities affecting the waste isolation capabilities of the site, (3) and definitions, assumptions, and direction to any future work to assess the affects of direct or indirect human interferences. Peer review

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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10 Proposed Resolution (continued)

or review of this report by a qualified team of experts may be valuable for enhancing its credibility."

END OF TEXT

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2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.1
7. Page 2-113 to 2-116
8. Paragraph

9. Comment

The section on Review of Information on Precious and Other Metals (2.3.8.3.2.1) should be expanded to include a summary and critique of information gathered since the EA and SCP and of the recent literature on mineral deposits in the SWNVF. A conceptualization of the factors that might control the occurrence of mineral deposits in the area is a future goal. The summary in the SCP on precious and base-metal deposits in the Yucca Mountain area, although more thorough, also lacks a conceptual framework and is out-of-date.

Major gaps in the ESSE presentation include the following:

(a) The ESSE (2.3.8.3.2.1) summary of the study by Castor et al. (1989) is not specific enough in stating that this study was conducted only on surface exposures and that, therefore, it has limited application to the assessment of subsurface potential for mineral resources in the Yucca Mountain Addition.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

(a) Three sentences have been added to Section 2.3.8.3.2.1 as a result of the comments on the Castor et al. (1989) report. "Because the Castor et al. (1989) study was conducted for purposes of land withdrawal, the study did not provide a detailed basis on which to assess resources at depths greater than several hundred meters. In addition, Castor et al. (1989) focused the main detail of their report on the evaluation of precious metals. Studies are planned that will provide more detailed information and further assessments and evaluation of all the mineral resources of the site (see Section 2.3.8.4)."

(b) Paragraph 2 on page 2-114 described the new information available about ore deposits and general geology of the region of Yucca Mountain. This paragraph will be modified to reflect that these deposits can have an effect on the perceived potential of the site. In addition, each of the "zones" (i.e., ore zones for precious metals) described by Greybeck and Wallace (1991) and Castor et al. (1989) will be mentioned in the text. The following will be

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

Furthermore, the summary does not state that the study by Castor et al., (1989) largely is limited to assessing the potential for precious metals.

(b) The ESSE (2.3.8.3.2.1) summary does not state that significant exploration activity since the SCP (DOE, 1988a) has resulted in the discovery of new deposits in the area, and that such discoveries can have an effect on the perception of the exploration potential of the region in and near Yucca Mountain. These new deposits include: Mother Lode, South Zone, West Zone, and Secret Pass Zone (Castor et al., 1989; Greybeck and Wallace, 1991).

(c) Fig. 2-2 (previously Table 2.3-2). This figure is fine as far as it goes, but it doesn't go far enough. As background data for the ESSE, there should be an up-to-date map showing the location of all key mineral occurrences, prospects, past mining operations, present mining operations, and present drilling areas, catalogued by deposit-type, commodity, size, and dates.

END OF TEXT

10 Proposed Resolution (continued)

added to the text: "Thus, significant exploration activity has been conducted and has resulted in new discoveries in the region of Yucca Mountain since publication of the SCP (DOE, 1988a). These discoveries influence the perceived resource potential of the region, including the Yucca Mountain area."

(c) Regarding the comment on the use of maps of the location of all key mineral occurrences, prospects, past mining operations, present mining operations, and present drilling areas that are cataloged by deposit-type, commodity, size, and dates, the work described has been accomplished to various degrees of detail and is described in the ESSE report. The work includes Bonham (1989a), Jones (1989), Bonham and Hess (1990), Raney (1990), and Mattson and Matthusen (1992). The most detailed report including maps can be found in a new reference by Bergquist and McKee (1991). Specific reference to the information contained in these reports will be added to the ESSE.

END OF TEXT

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2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.3
7. Page 2-121
8. Paragraph bottom

9. Comment

It is stated that the current status of findings with regard to Issue 2 (ongoing or future mining activities outside the site) indicates a higher level finding and that no further work is needed. This conclusion is repeated in the section on Conclusions and Recommendations for Future Assessments (p. 2-123, top of page). I am fundamentally in agreement with this conclusion, but believe that discussion of present understanding of indirect effects of mining activities on the site would strengthen the argument.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The last sentence of this paragraph will be modified to read: "No further work is needed to assess the suitability of the site with regard to this issue; however, the team believes that a DOE position on this issue should be developed and defended." In addition, appropriate changes will be made to the paragraph at the top of p. 2-123.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section 2.3.8.4
7. Page 2-122 to 2-123
8. Paragraph

9. Comment

It is stated that further work is needed to resolve Issue 3 (potential resources within the site). This further work with regard to non-fuel resources is stated to include:

1. downhole geochem data
2. soil geochem
3. geochem/petrology on anomalous rocks
4. comparison with surroundings and with similar geologic settings.

The reader is referred to SCP for further discussion. In the SCP, the following activities are planned in order to assess the natural resources of Yucca Mountain:

1. geochemical assessment (all done in conjunction with knowledge of known ore occurrences outside area): selection of elements, systematic and

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following text will replace the material that discussed future work for mineral resources in Section 2.3.8.4:

"Mineral Resources Observational Data Base and Other Data Needs: The most important future work includes (1) the analysis of hydrothermal flow paths based on the detailed consideration of structure, lithology, wall-rock alteration features, and the occurrence of fractures/veinlets/veins, (2) surface and down-hole geochemistry, and (3) an identification, ranking, and comparison of ore-forming systems with the site-specific observational data base collected for the Yucca Mountain site. The term ore-forming systems is emphasized and used here in the context of conceptual ore-deposit types that are attributed to various ore-forming systems in contrast to an approach based on specific commodity types.

New observational data should enable the construction of map views,

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

biased sampling of surface and core samples, evaluation of analytical data in conjunction with geological and geophysical data obtained in other activities, evaluation of potential.

2. geophysical/geologic appraisal: evaluate available geophysical data (no procedures). "Possible hydrothermal alteration zones may be identified through the use of remote sensing (thematic myopia [sic]) and field mapping (reference to SCP section B.3.1.17.4.4). (but this section relates to Quaternary NE-trending fault study??)"

3. integration: mineral assessment of the site, comparison to known mineralized areas, potential for future exploration and undiscovered resources.

I concur that all the activities listed above are important. However, there are some key activities and products missing from this listing. The emphasis is placed (incorrectly, I think) on geochemical sampling, presumably because such an activity yields numbers that can be dealt with in terms of "quantitative" comparisons, statistical analysis, etc.; i.e., geochemical data are "hard" data. It suggests the view that if the analysis does not come back with values in the "ore" category, the potential for resources can be practically ruled out. However, this assessment will fail if it is not combined with other traditional approaches used in mineral exploration.

(a) Observational Data Base. The most important of these traditional approaches, probably as critical as geochemical sampling, is the analysis of hydrothermal fluid flow paths based on detailed mapping of structure, lithologies, fractures/veinlets/veins, and wall-rock alteration. The mapping should include both natural surface exposures, existing trenches, and drill core, and should be conducted as a single exercise by one experienced individual (or a well-coordinated team). Structure and lithology have been (or are planned to be) mapped in addressing other issues, but in my experience one cannot assume that a geologist whose expertise (and mental focus in the field) is igneous petrology or structure will map the evidence for hydrothermal flow paths. A data base on hydrothermal flow paths serves as the context within which the geochemical assays can be interpreted: without such a base, the geochemical assays could be compared out of context with assays from known deposits. One has to know (or be able to reasonably infer) where in a potential hydrothermal system (high-level fringe, central zone, or deep) a particular assay comes

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9 Comment (continued)

from. To compare a Yucca Mountain assay, which may come from a high-level fringe, with a Rhyolite district sample that comes from the core of a deposit makes sense neither in terms of absolute values nor in terms of ratios or metal correlations. In sum, the local data base for mineral assessment of Yucca Mountain needs to include a set of map views and cross sections that display lithology and structure, with overlays for the following features:

1. wall-rock alteration
2. vein and veinlet attitudes
3. vein and veinlet mineralogies
4. sulfide and oxide mineral distribution
5. ore and pathfinder element maps (key ratios should be considered)

(b) Ore-forming Systems. The observational and analytical data base on Yucca Mountain then serves for comparison with (1) deposits known to occur in the area, and (2) deposits not known to occur in the area, but that are known to occur in similar geologic environments. I emphasize that the comparison needs to be made on the basis of deposit-types built on a conceptualization of ore-forming systems, rather than on the basis of commodities. Both the ESSE and the SCP overemphasize the use of commodities as the basis of comparison. Such an approach, involving, for example, comparisons between known mercury deposits and potential mercury deposits in the area of Yucca Mountain, misses the importance of potential genetic and spatial relationships between deposits of <u>different</u> commodities. For example, mercury anomalies cannot simply be assessed as potential mercury deposits; they also must be assessed as indicators of potential gold deposits. Numerous other examples of genetic links between deposits of different commodities exist for the Yucca Mountain area and will need to be assessed. This very important point is elaborated on below in the review of the SCP.

END OF TEXT

10 Proposed Resolution (continued)

overlays, and cross sections that display information on (1) wall-rock alteration, (2) vein and veinlet attitudes, (3) vein and veinlet mineralogies, (4) sulfide and oxide mineral distribution, and (5) primary and pathfinder element and element ratio maps. In the SCP (Section 1.7.1.2.3), it was stated that rock alterations observed at the Yucca Mountain site are not the same mineral assemblages commonly found in epithermal mineral deposits. Some minerals do occur at Yucca Mountain that also occur in precious metal deposits, although the array of different types of wall-rock alteration styles commonly

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10 Proposed Resolution (continued)

found in such deposits are not known to occur at Yucca Mountain. Collection of the observational data base will allow for more detailed and thorough assessments of rock alterations at the Yucca Mountain site.

Additional geochemical sampling will need to be conducted to fully evaluate the potential for natural resources. This includes sampling, with appropriate geochemical detection limits, for such elements as gold, silver, uranium, and mercury. Further discussions of the geochemical elements to be sampled and rock samples to be collected and analyzed have been presented in the SCP, Section 8.3.1.9 (DOE, 1988a). Geochemical soil survey and rock sample information will be important in assessing the potential for undiscovered deposits and help provide a basis on which to fully assess the mineral resource potential of the site. To date, no soil geochemical surveys are available for the proposed site. A large amount of information is currently available from surface outcrops (e.g., DOE, 1988a; Castor et al., 1989). However, few geochemical analyses are available from rock samples that come from areas of "anomalous" rock. In this case, "anomalous" rock refers to rock samples that could be obtained from fault zones, gouge zones, breccia zones, altered areas, or other rocks whose occurrence is limited in the area. Preparation of maps and overlays of chemical data can yield important information on structural trends. Such maps can also assist in definition of prospects by highlighting geochemical anomalies or anomalies in pathfinder elements (i.e., a mercury anomaly could be indicative of a gold deposit), or by identifying areas of alteration that could represent an ore deposit.

No significant gravity or magnetic anomalies have been identified, but for areas that are identified as having minor geophysical anomalies (e.g., induced polarizations anomalies) detailed petrological or geochemical sampling may be required (See Section 1.7 (DOE, 1988a) for additional discussion). Rock alteration maps may prove valuable when used in conjunction with the geological, geochemical, and geophysical surveys.

Very few of the cored drill holes at or near Yucca Mountain have been sampled geochemically for the express purpose of assessing natural resource potential. Available information on geochemistry and petrology has been reviewed by DOE (1988a) and Mattson (1991). Additional downhole information (geochemical and petrological) will be needed on new cored holes at the proposed site, and previously drilled holes may need to be sampled as well. However, much of the core from these holes has been used for other purposes and coverage would be of variable quality and quantity. All of the cored holes have been petrologically examined, and reports on their petrology published.

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10 Proposed Resolution (continued)

Future cored holes should be used to produce rock alteration maps and can serve to identify areas that may require further detailed work. Areas that have been identified as containing alteration that occurs in some ore deposit types in the Basin-and-Range Province should be carefully examined. These areas have been partially identified in the Site Characterization Plan (DOE, 1988a) and in Castor et al. (1989). Downhole petrological and geochemical data will help provide a basis on which to fully assess the mineral resource potential of the proposed site.

Comparisons of the Proposed Site with Known Deposits in Similar Settings: Utilizing the above geologic, geochemical, and petrological information, systematic comparisons of the proposed site with known deposits in the region that occur in similar geologic settings will be necessary. This also includes a consideration of models for ore genesis, structural features of the proposed site, and the general geologic setting of the site. The identification, ranking, and comparison of ore-forming systems in comparison to the site-specific observational data base will be important in assessing undiscovered deposits.

The data that remain to be collected (described above) will be important in contrasting different areas of the site and in comparisons to conceptual ore-deposit types. This information will be used, in part, in assessing the potential for undiscovered deposits in the area of the site and should help provide a basis on which to fully assess the mineral or other resource potential of the proposed site."

END OF TEXT

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8. Paragraph

9. Comment

The following are comments on the paper by Castor et al. (1989), which may be important to consider during the completion of the ESSE.

In Castor et al., 1989, p. 9, para 3: "...because access to subsurface samples was not granted by the DOE due to quality assurance concerns, determinations of economic potential to depths greater than a few hundred meters were not possible."

This statement is critical to understanding the scope of the Castor et al., (1989) report. The ESSE does not adequately stress the fact that assessment was limited to surface manifestations of potential mineralization in the Yucca Mountain Addition.

Further, I question whether or not a reconnaissance study limited to the surface is capable of detecting hidden deposits located within a few

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The main proposed resolution to this comment can be found in the response to a similar comment by Dr. Einaudi (Comment #9). In addition, the following text will be added to the ESSE report as three final paragraphs in Section 2.3.8.3.2.1.

"New information on structural models in the Yucca Mountain region are also available and, in general, these have been reviewed in Sections 2.3.7 and 3.3.4 of this report. These sections describe classical Basin and Range style faulting (i.e., steep normal faults bounded by range front faults), pull-apart basin models, high-angle faults which have been rotated to low angles, and various detachment style faulting models. The SCP may have over-emphasized the importance of detachment models in ore genesis. For example, Einaudi (Comment #19 in Younker et al., 1992) states that, with regard to epithermal precious metal deposits, "In contrast, "detachment type"

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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9 Comment (continued)

hundred meters of the surface, unless the structural/lithological controls on mineralization are dominantly steep and/or the alteration/geochemical halos related to potential mineralization are dominantly steep. Certainly, structural controls in volcanic-hosted epithermal deposits tend to be steep, but there are numerous examples of vein systems with relative shallow dips, especially in extended terranes where early steep normal faults that have served as ore-fluid conduits have been rotated to shallower dips during continued rotation on younger faults (e.g., as low as 30 degrees at Goldfield (Ruetz, 1987) and as low as 15 degrees at Tonopah (T.B. Nolan, in Dreier, 1984)). Discussion of this question should be presented in the ESSE.

END OF TEXT

10 Proposed Resolution (continued)

precious metal deposits have neither proved to be important (in relative terms) nor proved to be easily documented as fundamentally different types of deposit......It can be pointed out that, although the literature on recent discoveries in the area of Bullfrog Hills and Fluorspar Canyon have emphasized the "detachment model" (e.g., Jorgensen et al., 1989), the discoveries of gold deposits near Yucca Mountain probably were made using standard observational and analytical approaches developed for the general class of epithermal precious metal deposits in volcanic rocks." Einaudi further states in Younker et al. (1992) that "Structural controls in volcanic-hosted epithermal deposits tend to be steep, but there are numerous examples of vein systems with relatively shallow dips, especially in extended terrains where early steep normal faults that have served as the ore-fluid conduits have been rotated on younger faults (e.g., as low as 30 degrees at Goldfield (Ruetz, 1987) and as low as 15 degrees at Tonopah (T.B. Nolan, in Dreier, 1984)." All of these models will need to be carefully evaluated in light of their significance to possible ore-forming flow conduits and the potential for hidden mineral deposits at the Yucca Mountain site.

Furthermore, the SCP emphasized new types of deposits discovered and mined in the last two decades. It will be necessary to establish a preliminary ranking or relative importance of these new types of deposits. New types of deposits include disseminated gold deposits in calcerous sedimentary rocks (e.g., Carlin-type gold deposits) that have been the focus of recent gold exploration activities in the Basin and Range because they are the most numerous and economically

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10 Proposed Resolution (continued)

important. The discovery and exploration history of the Carlin deposit has been reviewed by Coope (1991). These deposits may not be very important in the area of Yucca Mountain because of the depth to the basement (greater than 3-4 km) according to Einaudi (in Younker et al., 1992). Other important types of deposits are epithermal disseminated gold-silver deposits in volcanic rocks (e.g., Round Mountain, Rawhide, and Paradise Peak deposits). The identification, ranking, and comparisons of ore-forming systems to site-specific data will be very important in assessing the potential for undiscovered deposits at the site.

The Site Characterization Plan (DOE, 1988a) stated that "Exploration and production of precious metals has recently centered around disseminated deposits that are not produced for base metals." While this statement is still generally true, it should also be pointed out that numerous gold discoveries have been made in districts that historically have been base metal producers and that copper-gold deposits have received considerable attention as a result of these discoveries. Discoveries in the Basin and Range include (1) the Fortitude gold skarn in the Battle Mountain porphyry copper district (Myers and Meinert, 1991); (2) the McCoy (Au) and Cove (Ag) deposits south of Battle Mountain (Brooks et al., 1991); (3) the disseminated gold deposits in sedimentary rocks (e.g., Star Pointer) on the immediate fringe of the Ely porphyry copper stocks (Einaudi in Younker et al., 1992); and (4) the Parnell gold shoot in Cu(Au) skarns of the Bingham district (Einaudi in Younker et al., 1992). This information makes it clear that a careful evaluation will be needed before final conclusions about the resource potential of the proposed site are made."

END OF TEXT

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9. Comment

In Castor et al., 1989, p. 97 para 4: "...methods used were mainly directed toward determination of precious metal potential." Other commodities were considered solely on the basis of the geologic setting. This may not be a severe limitation, given that precious metals may be the only prospective metal resources in these ash flow tuffs. However, this limitation should be mentioned in the ESSE.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment has been previously addressed in the response to Dr. Einaudi's Comment #9.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9. Comment

In Castor et al., 1989, p. 26-29: The summary of past work on subsurface core samples from drill holes in the area of Yucca Mountain indicates the presence of alteration and mineralization characteristic of some types of base- and precious-metal deposits. Such areas should be the focus of future studies and identified in the ESSE.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The intent of this comment has been addressed in the proposed response to Dr. Einaudi's Comment #9.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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9. Comment

In Castor et al., 1989, p.33, para 3: The authors combine (1) a detachment fault hypothesis for Au-Ag ores in the Bullfrog district with (2) the suggestion that a detachment fault exists under Yucca Mountain to (3) conclude that "precious metal mineralization (sic) could occur there (at Yucca Mountain) at depth." I concur with the authors in the necessity to investigate interrelations of this type; my comment deals with the absence of critical review of alternate interpretations regarding hypotheses (1) & (2) and the effect that such alternate interpretations have on the resulting hypothesis (3).

Regarding hypothesis (1), it is true that many of the producing Au-Ag deposits near Yucca Mountain are located near flat faults (potential detachments), and it is true that some publications on these deposits stress the detachment model for these deposits (e.g., Jorgenson et al., 1989, p. 1). However, the genetic relation between the exposed flat faults

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The intent of this comment has been addressed in the proposed response to Dr. Einaudi's Comment #9. The Core Team agrees with the comment, and text has been added to the ESSE, but the Core Team does not believe that the ESSE is the appropriate place for a lengthy critique of the Castor et al. (1989) report. However, the text of this comment will be available to staff conducting research on the Yucca Mountain area for natural resources.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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and the mineral deposits located nearby is far from clear; indeed there is evidence to suggest that mineralization postdated detachment faulting and was controlled by younger steep faults that cut the detachment. Such evidence is found in the relation between the timing of extension, magmatism, and hydrothermal activity. For example, at Fluorspar Canyon, Greybeck and Wallace (1991) suggest that "post-detachment Tertiary extension has resulted in high-angle, northerly striking faults that are important in the localization of gold........ the detachment surface is clearly offset along some younger, northerly-striking faults" (p. 941). At the north end of Bare Mountain, 10.5 Ma old volcanics lie unconformably across the detachment fault (Hamilton, 1988, p. 55). Noble et al., (1991) conclude that the Tuffs and Lavas of the Bullfrog Hills (late Timber Mountain magmatic stage), dated at 10 Ma, and subsequent Au-Ag mineralization in the Bullfrog Hills, dated at about 9 Ma, may have postdated movement on the Bullfrog Detachment which occurred prior to 10 Ma (the age of the detachment fault, based on 11.2 to 10.5 Ma K-Ar dates in Precambrian gneiss (McKee, 1983), is 11.2 to 10.5 Ma if the dates represent cooling on uplift of the footwall (Hamilton, 1988; Jorgenson et al., 1989), or may be older than 11.2 to 10.5 Ma if the dates represent a heating event related to the Timber Mountain magmatic stage (Noble et al., 1991. p. 931). These authors stress that likely pathways for magmas (and hydrothermal fluids?) that formed the Tuffs and Lavas of the Bullfrog Hills are steeply dipping faults that cut (and therefore postdate) the detachment surface. This interpretation is in sharp contrast with the interpretation of Jorgenson et al., (1989, p. 7) that mineralization and detachment faulting were synchronous at the Bullfrog and Montgomery-Shoshone deposits. In sum, the genetic link between detachment faults and ore deposits in the Yucca Mountain area remains controversial and unresolved.

Regarding hypothesis (2), the presence of a flat fault (possible detachment) under Yucca Mountain, as suggested by Hamilton (1988) and Scott (1990), is speculative. These latter authors conclude that the Bare Mountain-Fluorspar Canyon detachment is a domal structure that extends eastward under Crater Flat and Yucca Mountain. The dip and depth of this inferred detachment under Yucca Mountain depends on the interpreted projection eastwards past the eastern range front of Bare Mountain: Hamilton (1988, p. 55) prefers an uninterrupted eastward projection at 30 degrees, whereas Scott (1990, p. 276, Fig. 15) accepts the evidence for Quaternary movement on east-facing range-front faults as presented by Reheis (1988) and this leads him to a model in which a west-dipping detachment surface at depths of 4 km below Yucca Mountain projects to the surface in the Calico Hills. In contrast with these structural

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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

interpretations, Carr (1990) concludes that the Fluorspar Canyon detachment is one of a series of down-to-the west, scallop-shaped faults that dip moderately to steeply west at their eastern termination. Where last exposed, the Fluorspar Canyon fault strikes NE and dips 57 to 70 degrees to the NW, apparently precluding both a sharp right-angle bend to the south (Carr, 1990, p. 296, Fig. 9) and a reversal of dip, as required by the interpretations of Hamilton (1988) and Scott (1990). Both Carr (1990) and Jorgenson et al., (1989, Fig. 1) terminate the Original Bullfrog-Fluorspar Canyon detachment in a breakaway zone located north of Bare Mountain and west of the Timber Mountain caldera. In sum, the presence or absence of a detachment fault under Yucca Mountain remains controversial and unresolved. The high degree of uncertainty regarding both hypothesis (1) (genetic links between detachments and Au-Ag deposits in the Bullfrog-Fluorspar Canyon area) and hypothesis (2) (presence of detachments under Yucca Mountain), results in a higher level of uncertainty for a third hypothesis (presence of detachment-related gold deposits under Yucca Mountain) that is dependent on the first two. Likely alternative hypotheses should be considered in the evaluation of Yucca Mountain.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 16 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section
7. Page
8. Paragraph

9. Comment

In Castor et al., 1989, p. 33-34: "Direct surface observations indicate that no areas of hydrothermal alteration similar to those in the Wahmonie and Bullfrog districts, or at the Mother Lode deposit, occur within the Yucca Mountain Addition." This may be true, but it is based only on surface observations. Also in Castor et al., 1989, p. 34, para 2 & 3, comparison is made between the surface samples at Yucca Mountain Addition and those collected in known areas of mineralization in the vicinity. This comparison is misleading because the implication is that the lack of similarity rules out mineralization at Yucca Mountain, whereas it only rules out mineralization at the surface at Yucca Mountain. The key comparison that needs to be made might be between Yucca Mountain samples and samples collected on the fringe of the producing districts. Finally, the conclusion by these authors that "no significant areas of strongly bleached, limonitized ... rock are present in the Yucca Mountain Addition" is true only for surface. Such sweeping conclusions should be prefaced by

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The intent of this comment has been addressed in response to Dr. Einaudi's Comment #9. The ESSE Core Team agrees with the comment, and text has been added to the ESSE, but we do not believe that the ESSE is the appropriate place for a critique of the Castor et al. (1989) report. However, the text of this comment will be available to staff conducting research on the Yucca Mountain area for natural resources.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 16 of 29
2. Page 2 of 2
3. Name M.T. Einaudi
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4. Date Sept. - Nov. 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

their associated assumptions and limitations. As in Comment #13, mention of these factors should be made in the ESSE.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 17 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7
7. Page 1-261
8. Paragraph 2

9. Comment

"Detailed knowledge of a particular site (e.g., Yucca Mountain) or regional geologic information on a particular site is probably more important than the large scale characteristics and localization of ore deposits discussed previously." I heartily concur with this statement.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with this comment. No text changes were necessary as a result of this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 18 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP 1.7.1.1
7. Page 1-266
8. Paragraph 1

9. Comment

This paragraph contrasts Yucca Mountain with the area of Calico Hills and Wahmonie. The wording is overly biased in favor of the conclusion that there is no potential mineralization at Yucca Mountain. For example, it is stated that Yucca Mountain does not have "alteration characteristic of mineralization at the surface or at depth (Sec 1.7.1.2.3)." Because different styles of alteration accompany different types of mineralization, such a blanket statement is unsupported. It may well be true that Yucca Mountain does not display, at the surface, alteration characteristic of the Calico Hills or Wahmonie area. But the evidence is not yet in whether or not Yucca Mountain (1) displays alteration at the surface that is characteristic of mineralization that is of a different type and style than Calico Hills and Wahmonie, and (2) contains altered areas at depth.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The intent of this comment has been addressed in response to Dr. Einaudi's Comment #11. The ESSE Core Team agrees with the comment, and some text has been added to the ESSE, but the Core Team does not believe that the ESSE is the appropriate place for detailed responses to comments directed at the SCP. However, the text of this comment will be available to staff conducting research on the Yucca Mountain area for natural resources.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 19 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP 1.7.1.1
7. Page 1-268
8. Paragraph 1

9. Comment

This paragraph summarizes new types of deposits discovered and mined in the past two decades, but it fails to place the relative importance of these new deposits (or "models") in perspective. The first example and main emphasis should be on disseminated gold deposits in calcareous sedimentary rocks (Carlin-type gold deposits), because these have been the most numerous and most economically important, although it could be pointed out that these types of deposits may not be important for Yucca Mountain itself because of the depth to basement. The Carlin-types should be followed by disseminated gold-silver deposits in volcanic rocks (e.g., Round Mountain, Rawhide, Paradise Peak). In contrast, the "detachment-type" precious metal deposits, although mentioned first in this paragraph, have neither proved to be important (in relative terms) nor proved easily documented as fundamentally different types of deposit. Although these deposits should be discussed here, especially because of present speculation regarding the presence of detachments in the area of Yucca

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment has been addressed in the proposed response to Dr. Einaudi's Comment #12.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 19 of 29
2. Page 2 of 2
3. Name M.T. Einaudi (Print Name)
4. Date Sept. - Nov. 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

Mountain, the discussion should place this deposit-type in a secondary position with respect to importance. It can be pointed out that, although the literature on recent discoveries in the area of Bullfrog Hills and Fluorspar Canyon have emphasized the "detachment model" (e.g., Jorgensen et al., 1989), the discoveries of gold deposits near Yucca Mountain probably were made using standard observational and analytical approaches developed for the general class of "epithermal precious metal deposits in volcanic rocks."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 20 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP 1.7.1.1
7. Page 1-268
8. Paragraph 2

9. Comment

"However, 93 percent of all major metal-mining districts in Nevada are in lithologies other than silicic tuff." Implicit in this statement is that Yucca Mountain, being made up of silicic tuff, may be less prospective than surrounding areas. This statement is an over-simplification, or appears biased toward supporting a favorable conclusion for the site, for several reasons.

(1) Rather than using numbers of major districts, it might be more instructive to examine production from major districts.

(2) Given the present emphasis on precious metals exploration, perhaps a more relevant statistic would be to compare host rock lithology for precious metal deposits, including separate comparisons for both historical production and present production. Present-day perceptions of prospectiveness are colored largely by present-day producers and recent discoveries.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following will be added to the text of the ESSE on page 2-114, second full paragraph, as the second to the last sentence: "In addition, Einaudi (Comment #20) suggests in Younker et al. (1992) that in comparing precious metal occurrences as a function of host rock lithologies, it would be more germane to compare production statistics from major mining districts than to compare the number of districts." This added text should fulfill the intent of this comment. The ESSE Core Team agrees with the comment, but we do not believe that the ESSE is the appropriate place to respond to detailed comments on the SCP. However, the text of this comment will be available to staff conducting research on the Yucca Mountain area for natural resources.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 20 of 29
2. Page 2 of 2
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

(3) Also hidden in this statement is the long-standing view that intermediate volcanics are more productive than silicic volcanics (e.g., Silberman et al., 1976). I wonder if this remains true for the Great Basin, given the new discoveries in silicic volcanics (has the balance between silicic and intermediate tuffs changed?) More importantly, this long-standing view of the link between intermediate volcanics and epithermal deposits can be questioned on the basis of increased knowledge of the link between extension, magmatism, and ore deposits (e.g., Seedorff, 1991). . .

(4) Given that the SWNVF is composed of a range of rock types, including dominant silic ash flow tuffs but also some tuffs and lavas of intermediate composition and local basalt, there is no reason to presume that the SWNVF (including Yucca Mountain) is less prospective for precious metals than any of the other extension-related volcanic fields in the Great Basin. Specifically, the presence of intermediate (and local basaltic) and silicic volcanism related to the Timber Mountain caldera (11-12 Ma) and the tuffs and lavas of the Bullfrog Hills (10 Ma), which are the "classic" types of volcanics associated with epithermal precious metals in the Basin and Range, and which are younger than the silicic tuffs exposed at Yucca Mountain, would support the idea that the latter could be mineralized by younger events.

A brief synopsis of these ideas should be presented in the ESSE.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 21 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.1
7. Page 1-268
8. Paragraph 3 & 4

9. Comment

These paragraphs on the relation between precious metal deposits and ash-flow tuffs have been taken to task elsewhere, with the conclusion that such deposits can occur outside, on the margins, and within calderas (Raney, 1988; Price, 1988). I agree in general with the assessment by these authors, but there are additional points that need to be made with respect to these paragraphs.

One, the use of percentages ("only 2 of Nevada's 31 recognized calderas (6 percent) have produced..." and "only 5 percent of 98 total districts...") may be valid in attempting to assess probabilities of undiscovered resources, but is not a valid argument in the context of the perception, by a given exploration group, of the exploration potential of the Yucca Mountain setting. The reason is that these percentages are based, by necessity, on historical data, rather than on present views or new exploration models. Explorationists do not examine only historical

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following will be added to the text of the ESSE on page 2-114, second full paragraph, as the second to the last sentence (and prior to the text inserted as result of Dr. Einaudi's Comment #20: "These reviewers agreed that the statistical percentages cited in McKee were problematical." This added text should satisfy the intent of this comment. Thus, the ESSE Core Team agrees with the comment, but we do not believe that the ESSE is the appropriate place for detailed responses to comments on the SCP. However, the text of this comment will be available to staff conducting research on the Yucca Mountain area for natural resources.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 21 of 29

2. Page 2 of 2

3. Name M.T. Einaudi (Print Name)

4. Date Sept. - Nov. 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

production statistics; given one new discovery in a new setting, and the exploration community is off and running. New ideas yield new exploration activities that do not fit statistical molds.

Two, the statement that "strongly altered and metamorphosed" rocks in a caldera setting are the most likely environments for mineralization is slightly misleading, in that ore-bearing volcanic rock need not be (or appear to be) "strongly" altered. For example, the majority of ore at Round Mountain, Nevada, is in weakly altered ash-flow tuff, whereas the large areas of strongly altered tuff contain only a small percentage of the total ore reserve (Sander and Einaudi, 1989). (A final, nit-picking, point, is that the term "metamorphosed" strikes a discordant note; "metasomatized" would be more appropriate in this context.)

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 22 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.2.1
7. Page 1-269
8. Paragraph 1

9. Comment

"Exploration and production of precious metals has recently centered around disseminated deposits that are not produced for base metals." This may be generally true, but the statement is misleading if left without the additional statement that numerous gold discoveries have been made in districts that historically have been base-metal producers and that the Cu-Au associated has received considerable new attention as a consequence of these discoveries. In the Basin and Range, these recent discoveries include: (1) the Fortitude gold skarn in the Battle Mountain porphyry copper district (Myers and Meinert, 1991); (2) the McCoy (Au) and Cove (Ag) deposits south of Battle Mountain (Brooks et al., 1991) that are pluton-related skarn and replacement deposits with locally significant base-metals; (3) the disseminated gold deposits in sedimentary rocks (e.g., Star Pointer) on the immediate fringe of the Ely porphyry copper stocks; and (4) the Parnell gold shoot in Cu(Au) skarns of the Bingham district.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment has been addressed in the proposed response to Dr. Einaudi's Comment #12.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 23 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.2.1
7. Page 1-269
8. Paragraph 2 & 3

9. Comment

These paragraphs summarizing elemental abundances in tuff at Yucca Mountain are overly biased toward supporting a conclusion that Yucca Mountain does not contain undiscovered mineral deposits. It must be pointed out that the samples that were analyzed most likely were the freshest tuff available, given that these analyses were "collected to evaluate petrogenetic models of magma evolution." The fact that such samples would yield values at or near crustal abundance is not surprising, and this fact has limited application in the assessment of resource potential. The ESSE should emphasize that appropriate rock and core samples will be taken during site characterization.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The paragraphs written in the Site Characterization Plan (SCP) concerning elemental abundances serve several purposes. First, the elemental abundances for tuffs at and near Yucca Mountain serve as a elemental baseline for ash-flow tuffs of the region. Second, the SCP was written to a nontechnical, as well as a technical audience, where it was important to establish expectations of elemental abundances. Third, at the time of the SCP, this was the only data available and we would have been remiss not to have reported the data. Some samples were collected for purposes of studying the classical petrology of the rocks, and others where sampled at intervals regardless of their petrologic characteristics. Nonetheless, the SCP clearly identifies these samples as not being adequate for resource assessment. It is emphasized in the SCP, in Sections 1.7 and 8.3.1.9, as well as in the ESSE (Section 2.3.8.4) that appropriate rock samples should be taken for mineral resource assessment. Bias sampling (sampling of fault zones, breccias, rock alterations, and veins) has been strongly encouraged in the SCP and the ESSE. Thus, the ESSE Core Team

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 23 of 29
2. Page 2 of 2

3. Name M.T. Einaudi
(Print Name)

4. Date Sept. - Nov. 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

believes this comment has been adequately addressed, and no text change is proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 24 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.2.1
7. Page 1-269
8. Paragraph 4

9. Comment

"Because Yucca Mountain is composed of tuff, the Au and Ag resource potential in volcanic-hosted deposits will be the main focus..." True, this needs to be the main focus, but the Paleozoic basement at 1.2 km depth also needs to be confronted and discussed in the ESSE.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment has been addressed in the proposed response to Dr. Einaudi's Comment #4.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 25 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.2.1
7. Page 1-276
8. Paragraph 1

9. Comment

"Generally, the mineralization (in epithermal precious metal deposits) is thought to be the result of hydrothermal solutions from epizonal plutons..." This is an oversimplification. This question, which bears on the source of metals and other components in the ore fluid, is best approached by considering two broad categories of epithermal Au-Ag deposits: the "silica-alunite type" and the "sericite-adularia type" (the features of these two types have recently been summarized by Heald et al., 1987).

The silica-alunite type, with examples including Pyramid, Paradise Peak, and Goldfield, Nevada, are thought to be linked genetically to porphyry systems; i.e., a magmatic source may be important for at least a significant portion of the metals. The case for this link is made in general for the Great Basin by Wallace (1979) and specifically for Goldfield by Ashley (1979) and Vikre (1989) and for Paradise Peak by John

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team recognizes that the SCP text represented a "snapshot" in time and thus will be viewed as outdated, or simplistic, as new information becomes available. However, we do not believe that the ESSE is the appropriate place for responding to comments on the SCP. The text of this comment will be available to staff conducting research on the Yucca Mountain resource potential. Future studies will benefit from these comments on epithermal Au-Ag deposits.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
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1. Comment 25 of 29
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

et al. (1991). Host rocks tend to be dacitic to rhyodacitic (quartz latite), are commonly porphyritic, and are part of flow-domes complexes, some containing epizonal plutons. More silicic or more mafic precursors can also be mineralized.

The vast majority of epithermal precious metal deposits in the Great Basin, however, are of the sericite-adularia type, and the majority opinion to date remains that these are not genetically linked to magmatic or hydrothermal fluids, but, rather, to convecting meteoric water driven by magmatic heat input. If this is correct, it would indicate that host lithology is not a critical factor (e.g., andesite versus rhyolite) in the formation of sericite-adularia type deposits (e.g., Heald et al. 1987). Such deposits are found most commonly within the intermediate volcanics of the high-K calc-alkaline suite of andesite-dacite, but they also occur within the silicic endmembers of such suites. Epizonal plutons, if required as heat engines, are unrecognized in most districts.

In sum, a magmatic source of components and an epizonal pluton may not be a critical factor in the genesis of many epithermal precious metal deposits. Many of these deposits are not known to be associated with epizonal plutons, so that the absence of epizonal plutons (say at Yucca Mountain) cannot be taken as evidence that this style of mineralization is not present. This information should be considered in future assessments of Yucca Mountain.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 26 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.2.2
7. Page 1-278
8. Paragraph 2, last sentence

9. Comment

Because the age of ore-forming events in the area of Yucca Mountain is an important factor in evaluating potential ore-forming environments, a table listing the available age dates would be very useful. The wording of this sentence results in non-specific information and lacks a follow-up; although it may be possible to separate pre-13.9 Ma dates from post-13.9 Ma dates, one wonders why such a division is important. More recent information cited in Noble et al. (1991) suggests division of volcanic and ore-forming events into:

(1) a "Main Magmatic Stage (e.g., Crater Flat and Paintbrush tuffs), 15.2 to 12.8 Ma, in which ores of Au-F association are related (genetically?) to stocks and dikes of silicic to intermediate composition that are emplaced and altered late in the volcanic cycle, at 13-11 Ma. Bare Mountain, Wahmonie, and possibly Calico Hills are the main sites of hydrothermal activity.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This report is cited in the text of the ESSE in the first paragraph of page 2-114. This report has not been strongly referenced because it is unclear what the authors are dating (magmatic events or hydrothermal events). Some dates do not correspond with what is known about the regional geology. Nonetheless, the ESSE Core Team agrees with the suggestion that this type of information should be compiled and reported. The text of this comment will be available to staff conducting research on the resource potential of the Yucca Mountain area.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
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(Instructions on back of form)

1. Comment 26 of 29
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4. Date Sept. - Nov. 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

(2) a "Timber Mountain Magmatic Stage" (e.g., Timber Mountain Tuff and tuffs and lavas of Bullfrog Hills), 11.7 to 10.1 Ma, in which sericite-adularia Au-Ag epithermal ores generally post-date emplacement of silicic to intermediate volcanics, at 10-9 Ma. Bullfrog (Rhyolite), Calico Hills, Mine Mountain, and northern Yucca Mountain are the main sites of hydrothermal activity.

A discussion of this new work should be included in the ESSE, and an effort should be made to compile new work as it becomes available.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 27 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.2.3
7. Page 1-282
8. Paragraph 2

9. Comment

Some emphasis is placed in this paragraph on the apparent difference between alteration minerals observed at Yucca Mountain and those that are found in epithermal mineral deposits. This difference probably is real but as stated, the implication is that alteration minerals found at Yucca Mountain are not characteristic of any portion of epithermal precious metal deposits. Because there is some resemblance between the minerals known to occur at Yucca Mountain and some portions of known precious metals deposits, a point of clarification would be to state that the array of different types of wall-rock alteration styles commonly found in known deposits is absent at Yucca Mountain.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following text will be added to Section 2.3.8.4: "In the SCP (Section 1.7.1.2.3), it was stated that rock alteration observed at the Yucca Mountain site is not the same mineral assemblages commonly found in epithermal mineral deposits. Some minerals do occur at Yucca Mountain that also occur in precious mineral deposits, although the array of different types of wall-rock alteration styles commonly found in such deposits are not known to occur at the Yucca Mountain site. Collection of the observational data base will allow for more detailed and thorough assessments of rock alterations at the Yucca Mountain site."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 28 of 29
2. Date Sept. - Nov. 1991
3. Reviewer M.T. Einaudi
4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP, 1.7.1.3
7. Page 1-284
8. Paragraph 3

9. Comment

The discussion regarding presence or absence of mercury mineralization in and near Yucca Mountain is restricted to the assessment of the potential for undiscovered mercury deposits. However, because mercury is linked to other types of deposits mined for other metals, the discussion should be broadened to include these links and to explore their meaning in terms of resource assessment. In general, the SCP lacks a conceptualization of the links between deposit types and between different commodities, in the context of a "hydrothermal system" larger than any individual ore deposits that it might contain.

The presence of mercury mines near Yucca Mountain, at the Harvey and Tip Top, can be taken as suggestive of the presence of precious metal deposits in the same area(s). In fact, the Harvey (Telluride) mine, in Paleozoic sediments, is reported to contain some gold (Cornwall, 1972, p. 36) and two new gold discoveries (the Mother Lode and an unnamed prospect

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The intent of this comment has been addressed in response to Dr. Einaudi's Comment #11. The ESSE Core Team agrees with the comment and text has been added to the ESSE, but we do not believe that the ESSE is the appropriate place for detailed responses to comments on the SCP. However, the text of this comment will be available to staff conducting research on the resource potentialof the Yucca Mountain area.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 28 of 29

2. Page 2 of 2

3. Name M.T. Einaudi
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1 km SE of Mother Lode) were outlined nearby in 1988 (Castor et al., 1989, p. 4, 30). The gold mineralization at Mother Lode occurs in both Paleozoic sediments and in Tertiary silicic tuffs. The Daisy (Crowell) fluorite mine also displays a mercury-gold association (Cornwall, 1972, p. 35).

Thus, the presence of mercury near Yucca Mountain is important from the point of view of "perceptions" of resource potential in the area by the exploration community. Beyond the local Yucca Mountain scene, there are numerous examples of the use of mercury as a pathfinder element in the search for gold deposits (e.g., the McLaughlin gold deposit in California was discovered by assaying for gold in an abandoned mercury mine), and there are numerous examples of gold deposits in Nevada in which mercury is present in relatively high concentrations, in both volcanic-hosted deposits (e.g., Paradise Peak; John et al., 1991) and sediment-hosted deposits (e.g., Carlin mine).

The question of the link between mercury and gold needs to be addressed not only because it affects perceptions of resource potential by the exploration community, but also because it has a direct bearing on the ultimate conclusion by DOE regarding the likelihood of potential gold deposits at and near Yucca Mountain (presumably, this likelihood is higher in a region with known mercury mineralization than in a region lacking mercury mineralization, other factors being equal).

As a data base for assessing the resource potential of Yucca Mountain and the surrounding area, it would be very useful to compile a map overlay that displays all of the reported occurrences of mercury, catalogued by type, amount, etc. Such an overlay, in conjunction with similar overlays for other mineralogical features (e.g., silicified tuffs, silica-filled fractures, quartz veins, fluorite, etc.) represents part of the process of recognizing trends and associations, that (if combined with some knowledge of structural and lithologic controls, the factor of time, and the links between deposit types) are clues to hydrothermal fluid flow and location of potential mineral resources.

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(Reviewer completes items 1 - 9.)

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4. Organization Stanford University
5. Revision Draft/Date August 1991
6. Section SCP
7. Page Various
8. Paragraph Various

9. Comment

The comments that follow are on different sections of the SCP. They should be considered in developing future efforts that assess the potential for natural resources at Yucca Mountain and may be appropriate in considering minor changes to the ESSE. No specific responses to these comments are expected as a result of the ESSE process.

(A) SCP, 1.7.1.1, p. 1-266, 3rd para. Division of Nevada into a western precious metal and eastern base-metal belt may be overly simplistic in terms of exploration tendancies. Although not stated, the implication of this paragraph is that because Yucca Mountain falls in the "eastern base-metal province," the potential for precious metals may be lower than that for base-metals. In fact, numerous precious-metal deposits have been discovered in the eastern belt, including porphyry-related (PRD), volcanic-hosted epithermal (VHED) and Carlin-type deposits (CTD), including: (Bullfrog Hills (VHED), near Yucca Mountain; Fluorspar Canyon

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team appreciates Dr. Einaudi's comments on the SCP text on mineral resources, and will recommend that staff conducting research on the resource potential of the Yucca Mountain area utilize this input to improve future studies.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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(VHED, CTD), near Yucca Mountain; Star Pointer (PRD), Ely district; Tecoma (CTD), Utah-Nev border; Melco and Barney's Canyon (PRD), Bingham district, Utah); furthermore, there are several important past producers of silver, including Park City, Utah; Taylor, Nevada.; Horn Silver, Utah.

(B) SCP, 1.7.1.2.1, p. 1-272, para 1. "The compositional range of erupted tuffs (at Yucca Mountain) are different than the volcanic suites associated with vein deposits in the Great Basin." I disagree on two points. First, there is a misplaced emphasis on "vein deposits," because the most important epithermal precious metal deposits in the Great Basin today are disseminated deposits (associated with historical vein deposits). Second, and more important, this statement vastly oversimplifies a very complex and poorly understood aspect of the origin of epithermal Au-Ag deposits: the link between volcanic suites and epithermal systems. The volcanic suite at and near Yucca Mountain is not fundamentally different than other volcanic suites erupted during extension at other times and places in the Great Basin (Gans et al., 1989; Seedorff, 1991; Noble et al., 1991). Such suites typically include: (1) large volumes of silicic ash-flow tuffs and lesser volumes of intermediate to silicic lavas, predating extension or very early in the history of extension at any given place (in the SWNVF, these would include the Crater Flat-Paintbrush stage at 15-13 Ma); (2) a high-K, calc-alkaline "bimodal" suite of andesite-dacite and rhyolite lavas and small volume silicic tuffs, during the main period of rapid extension (in the SWNVF, these would include the Timber Mountain tuff and tuffs and lavas of Bullfrog Hills, 12-10 Ma); and (3) a strongly bimodal basalt-rhyolite suite, including basalt flows and peralkaline caldera complexes, topaz rhyolites, etc., during the waning stages of extension (in the SWNVF, these would include Black Mountain and Stonewall Mountain volcanic centers, 9-7 Ma). Precious metal deposits have been found with all 3 types of volcanic suites, and in association with either silicic or less-silicic endmembers of any of the suites. A partial list of these associations is: Rhyolites of suite 1 - Round Mountain. Andesites of suite 1 Virginia City. Andesite, dacite and rhyolite of suite 2-Paradise Peak, Rawhide. Trachyandesite/rhyodacite of suite 2 - Tonopah, Goldfield, Divide. Rhyolite of suite 2 - Wah-Wah (Stateline). Basalt of suite 3 - Hog Ranch, Buckhorn, Sulfur.

(C) SCP, 1.7.1.2.1, p. 1-273, Fig. 1-77. It is unclear from the figure caption whether this map is restricted to epithermal deposits only (the inclusion of Battle Mountain suggests that it includes other types). In any event, this map would be more useful if keyed to the suite of

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volcanics associated with mineralization (rather than keyed to the individual rock type in which the deposit is located), according to a system such as that outlined in later comments. Alternately, given that such information is not available for a significant proportion of deposits, the full list of rock types that are mineralized in a given district should by included. For example, although Fig. 1-77 indicates that Tonopah is hosted by andesite, some mineralization also occurs in rhyolite. A wide variety of volcanic rock types are mineralized in sericite-adularia type epithermal systems; this observation supports the current favored hypothesis that sericite-adularia deposits are not linked genetically to magmatic-hydrothermal fluids. Also, the map would display relative importance to a greater degree if keyed to total contained gold (rather than keyed to production). A similar map could be included for sediment-hosted gold deposits to set the context for a discussion of Paleozoic basement potential at Yucca Mountain. All of the above discussion should be considered during the assessment of Yucca Mountain.

(D) SCP, 1.7.1.2.2, p. 1-277, para 1. "At Round Mountain... mineralization is in intracaldera tuff." More recent work (Tingley and Berger, 1985; Boden, 1986; Sander and Einaudi, 1987) suggests that Round Mountain is located in the outflow region of the Jeffarson Caldera and is not "intracaldera." However, it may be located above an older buried caldera located under valley fill to the southwest.

(E) SCP, 1.7.1.2.2, p. 1-277, para 2. Important mineralized areas near Yucca Mountain (e.g., Tonopah, Goldfield, and Bullfrog) are stated as being in volcanic rocks " related to andesitic volcanic rocks." This statement is not accurate and suggests that andesitic volcanics are more prospective than rhyolitic, which is not true (see my Comments S-10, S-12).

(F) SCP, 1.7.1.2.2, p. 1-277, para 3. "The associated bimodal and intermediate composition volcanic rocks of (Tonopah, Goldfield, and Bullfrog) ... are not typical of the volcanic rocks at Yucca Mountain." This statement is somewhat misleading and appears to be biased toward a positive outcome for the assessment because the emphasis is placed on the contrast between "bimodal and intermediate volcanics" (productive) and silicic tuffs such as exposed at Yucca Mountain (unproductive). The use of the term "bimodal" in reference to these districts, without qualification, is misleading; all of these districts are related to trachyandesitic and rhyolitic volcanism (suite 2 of earlier comment) which is characteristic of the middle stages of active extension in the Basin and Range (Gans et al.,

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1989; Seedorff, 1991), rather than to the bimodal basalt-rhyolite (suite 3 of earlier comment) which is characteristic of the waning stages of extension in any given place and time. Further, some very large epithermal systems appear to be located in volcanics of suite 1 (dominantly silicic ash-flow tuffs), as exposed at Yucca Mountain.

(G) SCP , 1.7.1.2.2, p. 1-278, para 1. "The (Round Mountain) district is associated with... tungsten and copper mineralization..." It is accurate to say that tungsten and copper mineralization occurs in the district, but this mineralization is significantly older (Shawe et al., 1986) and therefore unrelated to the Round Mountain gold-silver deposit. The shallow plutons also are older and unrelated to the genesis of the Round Mountain gold-silver deposit. Therefore, the absence of copper and tungsten mineralization and of shallow plutons at Yucca Mountain cannot be taken as evidence for the absence of a Round Mountain-type (or sericite-adularia) gold-silver deposit.

(H) SCP, 1.7.1.2.2, p. 1-280, para 0. "Exploration for precious metals in a deeply buried Paleozoic terrain, such as at Yucca Mountain, cannot be dismissed." I agree, and this statement should be followed up. It appears to contradict earlier statements (SCP, p. 1-269, para 4).

(I) SCR, 1.7.1.2.3, p. 1-281, Fig. 1-80. This figure requires some critical discussion of the methods used, and the uncertainties associated with the different methods. For example, reference to Bish (1987) indicates that fluid inclusion temperatures are based on fluid inclusions in calcite. Yet, neither Bish, nor the SCP points out that calcite is notorious for poor quality microthermometric data because of its tendency to leak (well-developed cleavage).

(J) SCP, 1.7.1.2.3, p. 1-282, para 1. It is stated that paleo-isotherms shift to higher elevations from south to north at Yucca Mountain (based on holes G-1, G-2 and G-3), yet, in the sentences that follow, the top of "more intense" hydrothermal alteration shifts to higher elevations from north to south (based on two drill holes, G-1 & G-2). There is no discussion of this apparent contradiction. Is the interpretation of paleotemperature data incorrect?

(K) SCP, 1.7.1.2.3, p. 1-282, para 1. The hydrothermal alteration in G-1 and G-2 is interpreted to be "regional in extent" on the basis of the 2 km distance between these two holes. The implication of this conclusion is

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not stated. However, because the term "regional alteration" commonly is used in the economic geology literature in contradistinction to local alteration genetically related to an ore-forming system, the use of the term here should be specified. It should be noted that hydrothermal alteration associated with mineral deposits commonly extends over distances considerably greater than 2 km (see summary of physical dimensions of epithermal systems in Heald et al., 1987, Table 6, p. 12).

(L) SCP, 1.7.1.2.3, p. 1-282, para 4. These gold analyses may be meaningless with regard to resource assessment, because they appear to come from fresh tuff (the analyses are reported to have been made for the purpose of modeling magma genesis, but there is no discussion regarding their degree of hydrothermal alteration). The single sample cited as coming from hole G-2, containing 0.06 ppm Au, was collected at 515 m depth, yet alteration increases abruptly below 914 m. Sampling and assaying should be focused on these deeper, altered intervals.

(M) SCP, 1.7.1.2.3, p. 1-283, para 1, no. 1. "Carlin-type gold deposits have the most potential for exploitation in the future." This may be true if the future is five years from now, but probably not true if 10 years is considered. The reason is simply that, given present technology, only oxidized portions of these deposits are economic. The majority of Carlin-type deposits that are economic are those that are located at or near the surface, and therefore oxidized. The majority of these surface deposits will probably have been found within the next few years to 5 years. Thus, their potential for exploitation in the future is limited. Attention is likely to focus once again on exploring for higher-grade epithermal vein deposits (bonanza types).

(N) SCP, 1.7.1.2.3, p. 1-283, para 1, no. 1. It is stated that Carlin-type deposits may be present in the Paleozoic basement under Yucca Mountain, but that the depth involved rules out mining because these deposits require open-pit methods. I concur with the first part of the sentence, but take issue with the second part. The assessment with regard to Carlin-type deposits cannot be based solely on the fact that Paleozoic rocks cannot be reached by open pit methods. Given the experience at Deep Post (Carlin Trend), some Carlin-type deposits are underlain by vein deposits of higher grade that, in spite of being sulfide ores, may be amenable to flotation extraction in the near future. Whether or not a similar deposit under Yucca Mountain would be economic or not obviously depends on the grade and size, given that depths of greater than 1 km

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are involved. Also, we have limited ability to assess the presence of mineral deposits at these depths. In any event, future studies of Yucca Mountain should take into consideration that Carlin-type deposits, or at least higher grade portions of such deposits, may ultimately be mined by underground methods.

(O) SCP, 1.7.1.2.3, p. 1-283, para 1, no 3. See my comments regarding alteration minerals associated with epthermal precious metal ores. The conclusion in this paragraph is overstated.

(P) SCP, 1.7.1.2.3, p. 1-283, para 1, no. 4. See my comment regarding gold analyses. The conclusion in this paragraph is not supported by the data.

(Q) SCP, 1.7.1.3, p. 1-284, para 4. This paragraph contains a listing of "eight different types of (mercury) deposits..." Actually, this list is not a classification of types of deposits, because the "types" listed are not mutually exclusive, and, in terms of genetic concepts, many of the different "types" listed reflect the same hydrothermal environment and can occur within one deposit (e.g., opalite blankets, altered volcanic rocks, and altered interbedded sediment all occur together in the Cordero mine (McDermitt district). This point is important in terms of establishing the scientific credibility of the project's assessment, and in terms of the application of this classification to resource assessment at Yucca Mountain.

(R) SCP, 1.7.1.3, p. 1-286, para 2. This paragraph states that "only two of the eight potential mercury host rock environments are present at Yucca Mountain," including opalite blankets and altered volcanic rocks (Types 2 and 3 from p. 1-284). Considering the genetic tie between these two "types," there actually is only one mercury deposit type to be considered: volcanic hot-spring deposits. In this setting, many "opalite blankets" interpreted to be surface hot-spring deposits are simply opalized tuffs and volcaniclastic sediments.

(S) SCP, 1.7.1.3, p. 1-287, para 1. In addition to mercury occurrences at the Tip Top, Harvey (Telluride), Thompson, and Silicon mines mentioned in the text, mercury also has been reported from: Curly Wright prospect (near the Thompson mine; Holmes, 1965); Daisy (Crowell) fluorite mine (Cornwall, 1972, p. 35); and in quartz-barite-sulfide (Pb-Zn-Ag) veins in Pz seds of the Mine Mountain district (Cornwall, 1972, p. 39; Quade and

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Tingley, 1983, p. 6-7). The possibility of some mercury production from the Mine Mountain district is suggested by Quade and Tingley (1983).

(T) SCP, 1.7.1.3, p. 1-287, para 2. The conclusion that pyrite-bearing tuffs associated with alteration at depths of about 1000 m in drill holes at Yucca Mountain (in Crater Flat Tuff?) are too deep to be potential mercury-bearing zones is based on the observation that most mercury ores around the world are thought to have formed at shallower depths. However, the conclusion arrived at does not consider the possibility that sufficient time existed to form mercury deposit in these altered tuffs (Bullfrog and lower members of Crater Flat Tuff) before they were covered by subsequent tuffs (Paintbrush Tuff). The latter possibility might be discounted on the basis of K-Ar dates of illite-smectite clays (dates cited on p. 1-232, but not discussed in the present context) that arc "greater (sic) than 10 Ma old and equivalent to the timing of the Timber Mountain Tuff" (p. 1-282). (It is unclear why the actual dates reported by Bish (1987) are not cited here: these are 10.9 to 11.0 +/-0.5 Ma) However, use of these dates to discount potential mercury mineralization at depths greater than 1000 m at Yucca Mountain is dependent on the interpretation given to the K-Ar dates derived from illite-smectite. My gut feeling is that illite and clays are susceptible to low-temperature Ar loss. In fact, Bish (1987) suggests that one interpretation of the dates is that older alteration was reset to 11 Ma by Timber Mountain magmatism. Older dates for mercury occurrences in the vicinity of Yucca Mountain do exist and support the possibility of mercury mineralization occurring before emplacement of the upper units of the Paintbrush Tuff: K-Ar dates on alunite associated with mercury mineralization in silicified Paintbrush Tuff at the Thompson mine (Jackson et al., 1988) indicate that mercury mineralization at this locality occurred at about 13 Ma, within the range of dates for the lower members of the Paintbrush Tuff (i.e., broadly within the Main Magmatic Stage of Noble et al., (1991)).

(U) SCP, 1.7.1.3, p. 1-287, para 2 & 3. The conclusion that "there is very little potential for economic deposits of mercury at Yucca Mountain" is not well-supported by the data and discussion presented. (1) The "lack of alteration typically associated with mercury deposits" (e.g., opaline silica) is not supported by earlier statements (e.g., "Deposits of ... opaline silica are found locally along fault zones near Yucca Mountain" (p. 1-282)). (2) "The low alteration temperatures found in tuffs shallower than 1,148 m" does not rule out mercury at greater depth. (3) "The shallow depth of occurrence (rather, ' of formation') of mercury deposits" is not a

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factor if mercury deposits formed during Crater Flat time. (4) The claim that there is a "lack of mercury mineralization in drill holes and at the surface" of Yucca Mountain can only be taken at face value, but shouldn't have to be; this claim needs to be supported by mercury analyses from altered tuff at depth or from opalized fissures.

(V) SCP, Section 1.7.1.4.1. I agree that the evidence to date discounts a high (or even moderate) likelihood of the presence of an undiscovered barite deposit at Yucca Mountain. However, the presence of barite veins in and near Yucca Mountain raises the question of linkage to other deposit types (see my Comment S-29)--e.g., does the presence of barite-quartz-calcite veins in drill hole G-2 at a depth of 1736 m (in an area of more intense alteration, see p. 1-282, para 1) suggest the presence of gold nearby? Barite is a common mineral in both sediment-hosted (Carlin-type) and volcanic-hosted precious metal deposits. The presence of barite at Yucca Mountain could be taken by some exploration geologists as mildly suggestive of precious metals, especially in the presence of wall-rock alteration styles not dissimilar to those found in epithermal systems. The question of the link between barite and precious-metals needs to be addressed not only because it affects perceptions of resource potential by the exploration community, but also because it has a direct bearing on the ultimate decision by DOE regarding the potential for precious metal deposits at and near Yucca Mountain. The likelihood of precious metals is higher in a region with known mercury mineralization, barite veins, and altered silicic tuff, than in a region lacking these occurrences, other factors being equal. As a data base for assessing the resource potential of Yucca Mountain and the surrounding area, it would be very useful to compile a map overlay that displays all the reported occurrences of barite, catalogued by type, amount, etc. Such an overlay, in conjunction with similar overlays Tor other mineralogical features (e.g., silicified tuffs, silica-filled fractures, quartz veins, fluorite, etc.), represents part of the process of recognizing trends and associations, that (if combined with some knowledge of structural and lithological controls, the factor of time, and links between deposit-types) are clues to hydrothermal fluid flow and location of potential mineral resources.

(W) SCP, 1.7.1.4.2, p. 1-293, para 1. Although the potential for economic fluorite deposits at Yucca Mountain may be very low, there is a well-known link between fluorite and gold (especially in this part of Nevada); therefore, the presence of fluorite, in conjunction with other

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favorable factors, can lead to certain conclusions about the potential for gold mineralization. For example, traces of gold were known to occur in clay-bearing envelopes on fluorite veins in dolomite at the Daisy fluorite mine (Smith and Tingley, 1983, p. BMD-4) and this knowledge, combined with Tingley's (1984) report on trace element associations in carbonate rocks at Bare Mountain, led to gold exploration activity. Recent assays from the lower levels of the Daisy mine yielded up to 6.7 m of 0.224 opt gold, and drilling south of the mine led to the discovery of a prospect (South Zone) containing 785,000 tons of 0.097 opt Au, some of it associated with weak fluorite mineralization (Greybeck and Wallace, 1991, p. 944). Drilling west of the Daisy mine led to the delineation of 670,000 tons of 0.027 opt Au (West Zone) associated with silicified shale and dolomite; here, "fluorite is commonly associated with higher gold values" (Greybeck and Wallace, 1991, p. 943). Other fluorite-gold associations also are known in the vicinity of Yucca Mountain. The Goldspar (Diamond Queen) fluorite mine in dolomite actually was first opened as a gold mine (Cornwall, 1972, p. 36) and may be continuous with the Stirling (Panama) gold mine (Bell and Larson, 1982, p. 26). At the latter mine, gold occurs in silicified, fluorite-cemented breccias (Smith and Tingley, 1983, p. BMD-5). The question of the link between fluorite and gold needs to be addressed not only because it affects perceptions of resource potential by the exploration community, but also because it has a direct bearing on the ultimate conclusion by DOE regarding the likelihood of potential gold deposits at and near Yucca Mountain. Presumably, this likelihood is higher in a region with known fluorite mineralization associated with silicified carbonate rocks and volcanic rocks than in a region lacking such features, other factors being equal. As a data base for assessing the resource potential of Yucca Mountain and the surrounding area, it would be very useful to compile a map overlay that displays all the reported occurrences of fluorite. See my similar remarks above, regarding mercury and barite.

(X) SCP, 1.7.1.4.2, p. 1-293, para 2 & 3. The occurrence of fluorite-bearing veinlets in altered tuff can be taken as suggestive of the presence of gold mineralization in tuff, based on the regional association of fluorite and gold. Further, the occurrence of fluorite veins in tuff might suggest a fluorite target in underlying Paleozoic carbonate rocks, given the likelihood that hydrothermal fluids were upwelling from the basement into the tuff and given the tendency for fluorite grades to be higher in carbonate sediments than in silicic tuffs.

(Y) SCP, Section 1.7.1.4.4. This section dealing with construction

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materials supports the conclusion that such materials are not prospective at or near Yucca Mountain. I concur with this view. However, the occurrences of materials such as silica and clay need to be assessed in terms of their potential relation to metalliferous deposits known to be associated with such materials, particularly mercury, fluorite, and precious metals. Again, a useful data base for assessment of resource potential of Yucca Mountain and the surrounding area, could include a map overlay displaying all the known occurrences of hydrothermal silica and hydrothermal clay.

(Z) SCP, 1.8.1.7.1, p. 1-341, para 2. This paragraph states that commodities classed as "other resources," including barite, fluorite, silica, and clays "will not receive further attention." I agree that these commodities probably should not receive further attention in the context of potential economic deposits of these commodities, but they should receive further attention in the context of their use as guides to other types of resources, particularly the precious metals.

END OF TEXT

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Mr. Don E. French

PETROLEUM GEOLOGY

Petroleum Geologist
Billings, MT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	✓	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	✓	

Comments 1 through 13 are attached.

Peer Reviewer Don French Date Dec. 7, 1991

Comment Resolution Record

Yes ✓ The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ______ The following comments have not been adequately addressed:

Peer Reviewer Don French Date Dec 7, 1991

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean K Younker Date 12-7-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 12
2. Date November 2, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section general
7. Page
8. Paragraph

9. Comment

Habitat of Oil, Great Basin Region,
and Implications for Exploration

This summary is a broad generalization of the possible conditions of generation and accumulation of hydrocarbons in the Great Basin part of the Basin-Range Province. It is not comprehensive, and conclusions expressed here should not be accepted as universal.

A key aspect to exploration in the Great Basin is the identification of generation sites in time and space. After generation sites have been located, it is possible to delineate the type of play that is appropriate. For example if a post-Miocene generation site is identified, exploration should focus on nearby fault-block traps; whereas the existence of a Mesozoic-age site implies that accumulations are in anticlinal traps or have remigrated to fault-block traps. The possibility of post-Miocene age generation charging a large

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This comment is a general discussion and does not require resolution.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Not applicable.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 12

2. Page 2 of 3

3. Name Don E. French
(Print Name)

4. Date November 2, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

Mesozoic-age anticline without influence by Basin-Range structure is remote because of the time-and-space relationship of these structures to the generation site. The following comments outline the geologic elements that impart a lower probability of success to exploration in the ranges as compared to the basins of the Basin-Range Province.

Basins of the Basin-Range Province are distinguished from the ranges by the presence of a sequence of valley fill sediments of Miocene to Holocene age with an unconformity at the base of the sequence. The presence of a permeability barrier at this unconformity modifies local heat flow. Above the unconformity heat flow is reduced by the circulation of meteoric water. This influence is mitigated below the unconformity, and the permeability barrier acts as a thermal blanket. The existence of this blanket has an important effect on exploration strategy.

Within the ranges, where the barrier is not present, a potential source rock must be adequately buried by pre-Miocene age strata. Because of the depositional history of the region, in most ranges the bulk of pre-Miocene age overburden is comprised of Triassic and older strata. Therefore, those source rocks present at generating conditions within the ranges today reached those conditions no later than Oligocene time and possible much earlier. Consequently, accumulations of oil generated by source rocks present within the ranges of the region have persisted through the Basin-Range Orogeny and perhaps the Sevier Orogeny.

Within the basins, where the unconformity is an effective permeability barrier, it delineates the position of a change in thermal regime. Above the unconformity, heat flow is affected by circulating meteoric water in the valley fill, and the thermal gradient is similar to that observed in the ranges. Below the unconformity, heat flow is commensurate with the thin crust of the region, and the thermal gradient is steeper. The effect of the barrier is to create a thermal blanket that reduces the amount of overburden required to bury source rocks to generating conditions. Consequently, the thickness of Miocene-Pliocene age valley fill is less important to the thermal conditions in the bottom of a Basin-Range graben than the effectiveness of the permeability barrier at the base of the sequence. Generation conditions will exist under a wide variety of combinations of burial beneath pre-Miocene and post-Oligocene age strata. An important implication is that the source rocks within the basin must have had some generation potential prior to the onset of the Basin-Range Orogeny.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 12
2. Page 3 of 3
3. Name Don E. French (Print Name)
4. Date November 2, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

Because of the conditions described above, accumulations in the ranges of the province must be the result of one of the following circumstances:

1) The product of a generation and migration episode that predates the Basin-Range event and has not been disturbed by subsequent deformation.

2) The product of remigration from an accumulation that formed prior to the Basin-Range Orogeny.

3) The product of migration from a generation site that presently exists in a basin in the vicinity.

Because of the complexity of structure produced by the Basin-Range Orogeny, traps with the greatest probability of containing accumulations are those that are close in time and space to a generation site. Items 1-3 above indicate that prospects located in the ranges of the province will be less likely to contain hydrocarbons than those located in the basins.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 12
2. Date November 10, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.1
7. Page 2-95
8. Paragraph 2

9. Comment

"In the western United States, basaltic volcanism tends to occur either within alluvial basins, such as Crater Flat, or along their margins near range fronts..." This is not an obvious tendency. In addition to the exceptions cited for the Reveille Range and Lake Mead area, Quaternary basalts have been mapped in parts of the Pancake and Grant Ranges; I am confident that other exceptions exist. A statement that links basaltic volcanism to deep-penetrating faults using this location relationship is working up slippery turf.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The second full paragraph in Section 2.3.7.3.2, p 2-95, will be revised to read:

"Crowe (1991b) has suggested that basaltic volcanism in this extensional setting tends to occur within alluvial basins or along range-front faults, but that it is rare in the range interiors. However, there are examples of volcanic centers in uplifted range blocks, such as the Fortification Hill volcanic field south of Lake Mead and basalts in Reveille Range in south-central Nevada (Smith et al., 1990), as well as the intracaldron basalts of the Lunar Crater Field (Crowe et al., 1986). This suggests that gross topography may be related to the occurrence of basaltic centers only where it accurately reflects deep crustal structure, a relationship that is probable but not fully demonstrated near Yucca Mountain."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 12
2. Date November 9, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-116
8. Paragraph 3

9. Comment

Some explorers familiar with the region believe that there is an important relationship between the oil fields and nearby intrusives. The hypothesis is that thermal input from the intrusive has caused local generation of oil. Therefore, migration distances are very short and each field is the product of a limited generation-migration-accumulation system. Intrusives have been found in close proximity to Eagle Springs, Grant Canyon/Bacon Flat, and Blackburn fields. The intrusive near Grant Canyon is 70.2 ma, Rb/Sr (Fryxell, 1988), so that the accumulation first began forming in Late Cretaceous time according to this hypothesis. The present structure of the field postdates deposition of Oligocene-age volcanics. A statement more consistent with what is known is that all commercial fields in the region are located in basins of Miocene-Pliocene age that formed as the result of block faulting during the Basin-Range Orogeny. The implications of this relationship have not been discussed in print but are alluded to in French (1989) and Duey (1983). See my

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following text will be inserted into Section 2.3.8.3.2.2 on p 2-116, P3:

"All fields in the region are situated in Neogene basins, beneath a sequence of Miocene-Recent valley fill. Some of the oil fields in Nevada are in close proximity to intrusives (Hulen et al., 1990), which may contribute to reservoir quality and generation of hydrocarbons. However, all commercial fields in the region are located in basins of Miocene-Pliocene age that formed as the result of block faulting during the Basin-and-Range Orogeny (French in Younker et al., 1992)."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 12
2. Page 2 of 2
3. Name Don E. French (Print Name)
4. Date November 9, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

summary of 11/2/91 for more. (Mr. French's Comment #1.)

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 12
2. Date November 9, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-117
8. Paragraph top (partial) para.

9. Comment

Oil production in Nevada is associated with a tectonic feature which might not exist. It is more accurate to say that oil is in the area of the Antler Belt foredeep and in the vicinity of early Tertiary oil-shale basins. It also coincides with "Eureka Branch of Mesozoic foreland fold and thrust belt" (Saleeby, 1986, p. 47).

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following text will be inserted into Section 2.3.8.3.2.2 on p 2-117, top paragraph:

"In addition, it has been suggested that the significant production in Nevada is closely related to a Mesozoic thrust fault system in the east-central part of the state (Scott and Chamberlain, 1988). However, the importance of the thrust belt is difficult to establish; it is possible that the location of the fields is more directly influenced by the distribution of source rocks deposited in the Antler foredeep and lacustrine basins of Cretaceous and early Tertiary age (Poole and Claypool, 1984)."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 12
2. Date November 9, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-117
8. Paragraph 1

9. Comment

The interpretation of the Diamond Range given in Chamberlain (1991) is incorrect, therefore the analogy with the Eleana Range cannot be made; Aymard does not indicate that older-overmature over younger-submature situation exists (p. 28), rather that subthrust rocks are overmature (p. 29). There is no conclusive evidence that any production in the Great Basin is from overthrust structures. Existing fields are located near Mio-Pliocene age basins and generation sites.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In Section 2.3.8.3.2.2, p 2-117, 1st full paragraph the following changes will be made:

Delete: "...older thermally mature Paleozoic rocks (typically Devonian age Carbonates) are overthrust on younger thermally immature rocks (typically Mississippian age source rocks)."

Add: "...areas with high potential for oil and gas are characterized by Devonian carbonates overthrust on Mississippian source rocks. Similar models have been suggested for the Nevada Test Site (NTS) area (Aymard, 1989)."

Delete: "...Chamberlain, 1991) although no overthrust plays have been discovered in Nevada. There is no conclusive evidence that any production in the Great Basin is from overthrust structures (Allcott, 1991)."

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 5 of 12
2. Page 2 of 2
3. Name Don E. French (Print Name)
4. Date November 9, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

Add: "...A variation of the overthrust model has been proposed for the Eleana Range and the Yucca Mountain area by Chamberlain (1991). In this hypothesis, overmature Mississippian strata are overthrust on submature Mississippian source rocks. The model is based on a specious interpretation of the Diamond Range near Eureka, Nevada. There is no conclusive evidence that any production in the Great Basin is from overthrust structures (Allcott, 1991), and the comments of Flanigan (1986) indicate that there is not a consensus about the validity of the overthrust model. The fault-block model apparently best describes the accumulations found to date in the province. Field limits are controlled by normal faults and fault-block geometry, and accumulations are confined to basins that are defined by Basin-and-Range normal faults."

Delete: "...These models need to be evaluated for the Yucca Mountain area with respect to (1) thermal maturity of the Paleozoic rocks, (2) possible structural models, (3) paleogeothermal history, (4) presence of possible source and reservoir rocks, and (5) comparisons with known occurrences of oil in Nevada."

Add: "...The various models need to be tested for applicability to the Yucca Mountain area by examining model compatibility with known geologic conditions at Yucca Mountain and with known occurrences of oil in Nevada."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 12
2. Date November 9, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-117
8. Paragraph 3

9. Comment

The comment about maturity at outcrop vs. maturity at depth is unsupported by data in Foster et al., 1989. The data base is too sparse to make this statement.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text in section 2.3.8.3.2.2, p 2-117, first full paragraph will be revised as follows:

Add: "...and determining the most appropriate generation-migration-accumulation model for the area."

Delete: "Elsewhere in Nevada, maturity values for source rocks found at the surface are essentially the same as maturity values for source rocks at depth because of the relatively small amount of time since the formation of the Basin and Range (Foster et al., 1989)."

Add: "Additional thermal-maturation data may need to be collected to verify the data presented in Aymard (1989)."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 12
2. Date November 9, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-117
8. Paragraph 3

9. Comment

In addition to maturation data, source rocks of the area need to be tested for remaining generation potential; a CAI value is meaningless unless it can be related to a specific generation potential. In other words, how much energy is required to bring the Eleana to full maturity?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In Section 2.3.8.3.2.2, p. 2-117, insert the following at the end of the third paragraph:

Add: "In addition, generation potential of the various source rocks at different states of maturity needs to be determined so that meaningful conclusions can be drawn about the quantity of hydrocarbons that has been rendered for given levels of maturity.

Delete just before this sentence: "this unpublished source."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 12
2. Date November 9, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-118
8. Paragraph 1

9. Comment

Exploration for oil and gas in the Basin-Range Province may be categorized into 2 district plays. The more important one has been referred to as the Railroad Valley model, wherein the primary objective is an accumulation of oil that has been generated since the onset of the Basin-Range-Orogeny. The fields found to date probably belong in the category. The second play is one that targets oil that was generated and accumulated prior to Basin-Range faulting. In this category are various overthrust exploration models and efforts directed at surface anticlines. Numerous wells have been drilled in the region implicitly based on the premise of an early generation episode but without success. [It may be possible to tabulate these.]

The chances of a Railroad Valley-type accumulation near Yucca Mountain are remote because of the apparent lack of a Neogene generation site, although this merits some more investigation. The likelihood of finding some early-

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In Section 2.3.8.3.2.2, p. 2-118 the following will be inserted at the top of the first full paragraph:

"Exploration plays in the Basin-and-Range Province may be organized into Post-Miocene and Pre-Miocene based on the time of accumulation. Post-Miocene plays are those directed toward finding accumulations that have developed since the onset of the Basin-Range Orogeny. There is no connotation of source or reservoir rock objectives. This category includes the unconformity play as described by Peterson (1988). The exploration targets of pre-Miocene plays are accumulations that predate the beginning of the Basin-Range Orogeny and thus have remained intact through the deformation of that event. Exploration focuses on Paleozoic strata that have been deformed by Mesozoic-age fold and thrust fault structures, although post-Miocene changes to these structures is conceivable. Most exploration targets of the Upper Paleozoic and pre-Devonian plays of Peterson (1988) are in this category. Of the oil found to date in

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 8 of 12
2. Page 2 of 2
3. Name Don E. French (Print Name)
4. Date November 9, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

generation oil is no greater here than in any other part of the region.

END OF TEXT

10 Proposed Resolution (continued)

Nevada, all fields except Currant Field in Railroad Valley and some minor production in Pine Valley clearly belong in the post-Miocene category. There is no production from a pre-Miocene accumulation that can be identified.

The petroleum potential of Yucca Mountain is considered low at this time. The possibility of the presence of a Railroad Valley-type fault-block accumulation near Yucca Mountain is small because of the apparent lack of a Neogene generation site. The possibility exists that a post-Miocene accumulation resulting from remigration from a pre-Miocene trap is present in the vicinity. Although improbable, this possibility merits additional investigation."

The following will be deleted from the same paragraph:

"Pre-Devonian plays, such as those which potentially could occur beneath Yucca Mountain, have been rated to have low potential and have been referred to as highly speculative (Peterson, 1988)." Text continues with "Pre-Miocene targets in the form of overthrust play models have been proposed for the area..."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 12
2. Date November 9, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-123
8. Paragraph 2

9. Comment

Greater detail is justified. [Note: in the early 1980's the University of Wyoming initiated an industry-supported effort to obtain useful seismic data in areas underlain by volcanic rocks. I do not know the results of this work.]

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In section 2.3.8.4, p. 2-123, second full paragraph (Evaluation of Oil and Gas Potential) the text will be revised as follows:

"The potential for oil and gas resources at the Yucca Mountain site requires more investigation. A draft outline for this work has been proposed by the U.S. Geological Survey. That outline is comprehensive but should be reviewed and reorganized so that studies are conducted in a manner to maximize information benefits and cost effectiveness. Recommended investigations are organized below into a stepwise sequence so that work completed is evaluated and the justification established for conducting the next study. Consequently, investigation steps are presented in order of decreasing importance as follows:

1. Test for the presence of a viable source rock that has generated and expelled, or is generating and expelling, significant amounts of hydrocarbons. If it can be established that a viable source rock is not

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 9 of 12
2. Page 2 of 3
3. Name Don E. French (Print Name)
4. Date November 9, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

present, further evaluation is unnecessary. To do this:

- Investigate the stratigraphic section for potential source rocks other than to the Eleana Formation, for example the Bird Spring equivalent and Horse Spring Formation.

- Develop a generation index of potential source rocks by conducting pyrolysis on samples that are at various stages of maturity.

- If viable source rocks are present in the section, determine their areal distribution.

2. If a viable source rock is present, determine its thermal history to identify generation sites in time and space. Much of the data needed for this will be obtained during the investigations of Step 1, above.

3. Evaluate existing production in the Basin-and-Range Province to determine the applicability of various exploration concepts. In particular, it would be valuable to know if remigration from older fold-thrust structures to present accumulations has occurred. These findings can then be used to determine a hierarchy of exploration concepts and estimate the probability of potential within those concepts for the Yucca Mountain area.

4. Prepare a structure map contoured on the base of the volcanic section to identify possible generation sites and to help assess the likelihood of future exploration activity. This mapping should incorporate interpretations of appropriate paleogeologic and geophysical data. The usefulness of existing geophysical data, especially seismic data, should be reviewed, and new surveys using recent technology considered as appropriate.

In addition to the investigations listed above, it is important to establish the means of monitoring and regulating drilling activity. Drilling executed for the purpose of site characterization should utilize gas detection devices, and dipmeter logs should be run where Paleozoic strata are penetrated. It is also important to establish a policy designed to take advantage of industry exploration and government-sponsored drilling in the area. For example, subsidizing source-rock analysis or dipmeter logs at appropriate drill sites could contribute to evaluation of the qualifying condition."

Delete previous paragraph, which started with "Evaluation of Oil and Gas

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 9 of 12
2. Page 3 of 3
3. Name Don E. French (Print Name)
4. Date November 9, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

Potential" in reviewed text.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 10 of 12
2. Date November 11, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.4
7. Page 2-124
8. Paragraph 2

9. Comment

The following is offered as a substitute of the paragraph under Expert Panel of Peer Review Reports in Section 2.3.8.4, p. 124:

As site characterization continues, the judgments of expert panels or peer reviews may need to be considered in reviewing the results of the work collected. They may recommend new studies to be initiated, that studies be continued as planned, or that enough information has been collected to be able to evaluate the regulatory guidelines. In addition, because there is a diversity of opinion and information about the occurrence of and the potential for natural resources in the Great Basin, expert panels or peer reviews will be necessary to fully evaluate and reach conclusions concerning the regulatory guidelines.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

With minor changes, Mr. French's text will be substituted for the last paragraph in Section 2.3.8.4, p. 124.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 11 of 12
2. Date November 15, 1991
3. Reviewer Don E. French
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 2.3.8.3.2.2
7. Page 2-116
8. Paragraph after para. 2

9. Comment

In Section 2.3.8.3.2.2, p. 2-116, after 2nd full paragraph, insert:

"Successful exploration for oil and gas in the Great Basin region is strongly influenced by the location of generation sites in time and space (Poole et al., 1983; and Poole and Claypool, 1984). This contrasts with mature levels of exploration in most productive basins in the U.S., where the position of generation sites is well established and exploration is focused in the location of favorable reservoir rock and trapping conditions. For this reason, the assessment of the potential for oil and gas resources for the Yucca Mountain area should be made initially by developing models of generation rather than models of entrapment. Models of generation are of two basic categories: (1) generation prior to the onset of Basin-Range Orogeny, and (2) generation since the onset of the Basin-Range Orogeny."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

With very minor revision, Mr. French's paragraph will be inserted after the second full paragraph on p. 2-116, in Section 2.3.8.3.2.2.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 12 of 12
2. Date November 2, 1991
3. Reviewer Don E. French
4. Organization Consultant
5. Revision Draft/Date August 1991
6. Section General
7. Page
8. Paragraph

9. Comment

It is important that information concerning the natural resource potential of the site be widely available to the geologic community.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The following text will be added in a new subsection called "Dissemination of Information" in Section 2.3.8.4, p. 2-124, after the Section on Peer Review:

"The postclosure performance of the site with regard to natural resources will be based in part on the perception of the resource potential by the resource industries. Consequently, it is important for the public to be well informed about this aspect of the Yucca Mountain area. Public awareness can be accomplished by disseminating the findings of site studies through technical and nontechnical publications that have wide circulation."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

REFERENCES FOR MR. DON E. FRENCH

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Dr. Kip V. Hodges

TECTONICS, GENERAL

Massachusetts Institute of Technology
Cambridge, MA

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	✓	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	✓	

Comments 1 through 31 are attached.

Peer Reviewer [signature] Date 12/16/91

Comment Resolution Record

Yes ✓ The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ____ The following comments have not been adequately addressed:

Peer Reviewer [signature] Date 12/16/91

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-16-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section no section number
7. Page E-11
8. Paragraph 4

9. Comment

In the last paragraph before Preclosure Guideline Results, one sentence reads: "These issues include uncertainties in the source term for ^{14}C, as well as questions about whether the EPA release limit for ^{14}C should be reviewed." Although the topic is treated well later in the ESSE, this sentence seems unnecessarily vague for an Executive Summary. Given that the summary may be the only part of the ESSE read by an important (but busy) audience, I think that a casual reader may find phrases like "source term for ^{14}C" more confusing than helpful. This paragraph should be simplified and expanded slightly to include an explanation of the source of ^{14}C (for the reader with less geochemical awareness), a statement about the potential hazard of ^{14}C release, and a brief rationale for why you question the current EPA release limit.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised to provide the elaborations suggested. The last sentence of the discussion under the Qualifying Conditions section on p. E-11 will be revised to read as follows:

"These issues include uncertainties in the amount of carbon-14 available to be released as carbon dioxide gas from the waste package and in the ability of the unsaturated zone to retard gaseous-phase carbon-14 transport to the accessible environment above the repository. The potential health hazards in terms of doses to members of the public from releases of gaseous carbon-14 are expected to be negligible, however, which possibly reflects an inconsistency between the regulatory limits and the actual hazards."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 2 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August, 1991
6. Section 1.2.4
7. Page 1-12
8. Paragraph Figure 1-2

9. Comment

I think it likely that a casual reader will be confused by your stated distinction between higher-level and lower-level suitability. I understand and agree with your criteria, but many readers may not. You state in the caption for Figure 1-2 that "the primary distinction between higher-level and lower-level findings is the likelihood that further information will change conclusions about the suitability of the site...". (The italics are mine). Consider the faulty line of reasoning that could arise from this statement. If a lower-level suitability finding for a disqualifying condition means that it is unlikely that the disqualifying condition is present in light of existing data but that it is likely that "further information will change conclusions about the suitability of the site", then doesn't this mean that you fully expect future data to establish the disqualifying condition for the site? The confused reader may reasonably ask why you are reluctant to say simply that you expect the disqualifying condition to be met? What are you trying to hide?

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Hodges makes a good point, which was also made in Dr. Albrecht's Comment #1. The figure and its caption will be changed as shown on the attached figure (will be Figure 1-3).

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

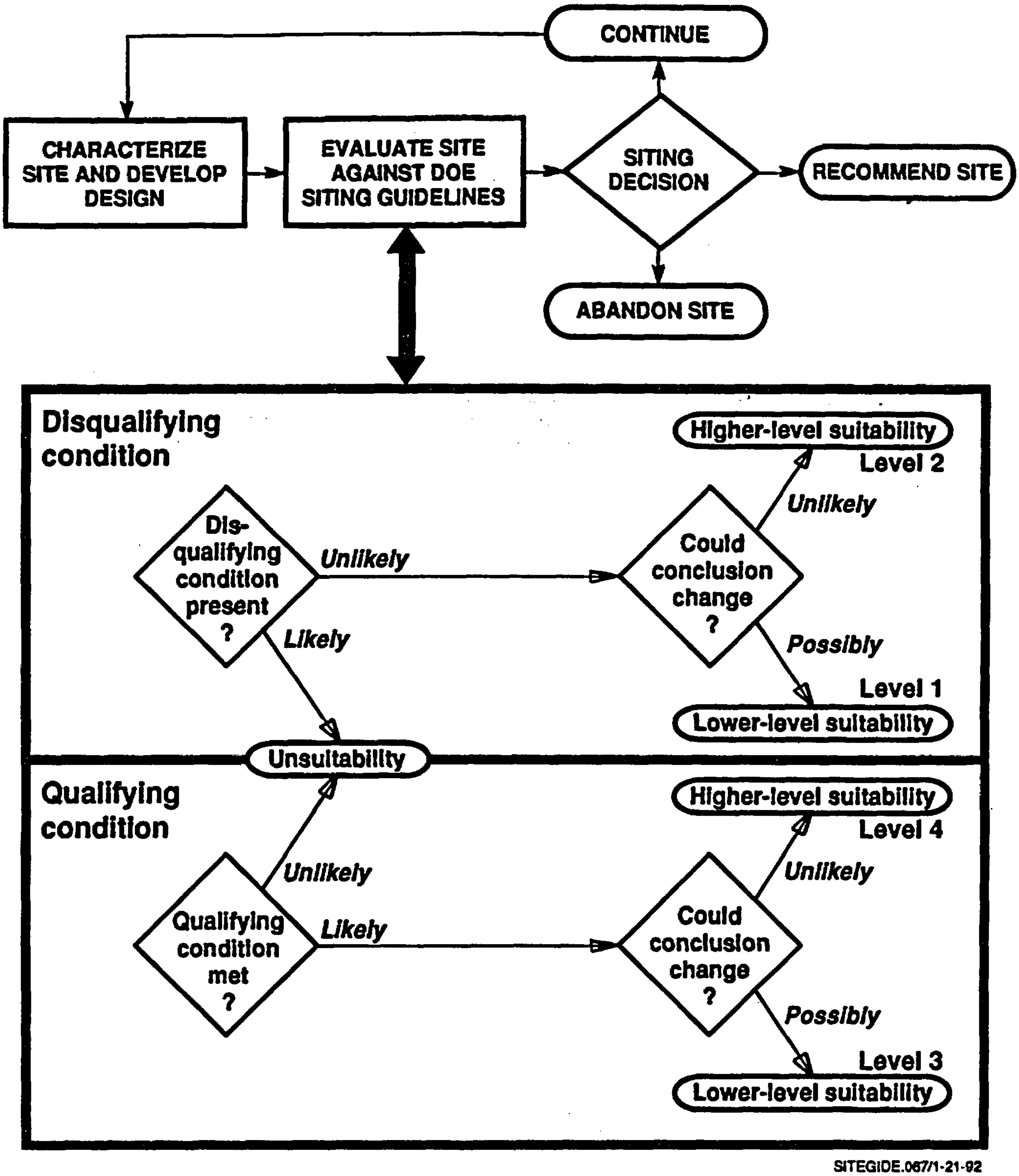

Figure 1-3. Decision logic for suitability and unsuitability findings, based on DOE Siting Guidelines. The primary distinction between lower- and higher-level suitability findings is the likelihood that further information will change conclusions about the suitability of the site for repository development. A higher-level suitability finding is supported when it is unlikely that additional data will change current conclusions; a lower-level suitability finding is supported when additional information could possibly change current conclusions.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 31

2. Page 2 of 2

3. Name K. V. Hodges (Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

It seems to me that it would be clearer to say that a lower-level suitability finding for a disqualifying condition means that you presently see no evidence of the disqualifying condition but you can't reasonably discount the possibility that more data could change the situation. Similarly, a lower-level suitability finding for a qualifying condition means that existing data support the presence of the qualifying condition but you can't reasonably discount the possibility that more data could change the situation. This subtle change in wording would make it much clearer that the team has been extremely circumspect in reaching its findings, and has tried to err on the side of caution wherever possible.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 1.2.4
7. Page 1-14
8. Paragraph 3,4

9. Comment

The transition from the third paragraph to the fourth paragraph on this page is abrupt. One way to improve it might be to begin the fourth paragraph as follows:

The following hypothetical example illustrates that it is possible to support higher-level suitability findings on some technical guidelines while supporting only a lower-level suitability finding on the system guideline. Suppose that current information supports at least...

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This is a good suggestion. The text in Section 1 will be revised substantially to improve the flow and to clarify the example.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 1.2.6
7. Page 1-19
8. Paragraph Table 1-6

9. Comment

My middle initial in Table 1-6 should be "V" not "B".

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Correction will be made in Dr. Hodges's middle initial in Table 1-6.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 1.3.1
7. Page 1-19
8. Paragraph para. 1 of 1.3.1

9. Comment

The first sentence of Section 1.3.1 would be smoother if it read: "The Yucca Mountain site is in Nye County, southern Nevada, about...".

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised as suggested.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 1.3.1
7. Page 1-21
8. Paragraph 3

9. Comment

It might be more informative to say in the third paragraph that the silicic tuff sequence ranges in age from about 15 to 11 Ma rather than to just say that the sequence is older than 11 Ma. Moreover, I would state more clearly that several eruptive episodes of basaltic volcanism occurred over the Late Miocene to Quaternary interval, and that some of the volcanism is at least as young as about 140,000 years.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment and Dr. Arabasz's Comment #7, the third and fourth paragraphs have been replaced by text clarifying the tectonic history of the Yucca Mountain area. See the response to Dr. Arabasz's Comment #7 for the replacement text.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 1.3.1
7. Page 1-23
8. Paragraph Figure 1-5

9. Comment

On Figure 1-5, the faults and boreholes are hard to distinguish. I suggest using an even thicker (perhaps grayed) line for the boreholes.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Distinction between faults and boreholes will be improved on the graphic in Figure 1-6 (previously Figure 1-5) as suggested by Dr. Hodges.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.1
7. Page 2-7ff
8. Paragraph all

9. Comment

Although I am not a hydrologist, my reading of Section 2.3.1 prompts me to make some comments pertaining to the relationships between the structural setting of the proposed repository and its hydrologic characteristics. It has long been recognized that the "effective" permeabilities of real rocks on the outcrop scale is often orders of magnitude greater than the measured permeabilities of intact rocks in the laboratory. The most likely explanation for this in upper crustal rocks is that interconnected fracture networks control effective permeabilities by providing fast flow paths. As a consequence, any hydrologic model applicable to the real world must include some inferences about the number, size, distribution, tortuosity, and interconnectivity of fractures in the area under scrutiny. A number of studies referenced in the ESSE have been predicted on such inferences, but all of them, in my opinion, suffer from an insufficient basic knowledge of the fracture field in this part of the Basin and Range Province.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team concurs with Dr. Hodges' position that "it is imperative that the hydrologic models of Yucca Mountain be based on data rather than theory" and that the results published to date "suffer from an insufficient basic knowledge of the fracture field" and other significant hydrologic characteristics of the site. This comment is similar to that posed by Dr. Vogel (see response to that comment), which identified the need for improving the recommendations for future activities discussion. This discussion emphasizes the need for site-specific data to address several geohydrologic issues including the need for establishing the spatial and temporal variations in the fracture characteristics associated with stratigraphic units located at Yucca Mountain. No additional response is proposed at this time.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 8 of 31

2. Page 2 of 2

3. Name K. V. Hodges
(Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

I have spent very little time at Yucca Mountain, but I have worked extensively in many parts of the Basin and Range and I am satisfied that open fractures are ubiquitous at all scales throughout the province. When I consider the seemingly insurmountable task of quantifying the distribution of these structures, I am reminded of the tongue-in-cheek hypothesis (apocryphally attributed to James Gilluly) that the Basin and Range was shattered when God took the entire province up to 50,000 feet in late Tertiary time and dropped it. If we hope to develop a robust hydrologic model of the proposed repository site, it is imperative that DOE make characterization of the fracture field in an around Yucca Mountain a high priority in the next stage of suitability analysis. Without adequate, site-specific, field data that could establish realistic bounds on in situ permeabilities in the saturated and unsaturated zones <u>at the scale of the facility</u>, I would be skeptical about any hydrologic models of Yucca Mountain.

I believe that the evaluation team has succeeded in presenting a balanced view of the current state of knowledge about the hydrologic characteristics of the Yucca Mountain site, but I would urge that the recommendations for further field work (presented in Section 2.3.1.5) be strengthened. It is imperative, not simply desirable, that hydrologic models of Yucca Mountain be based on data rather than theory.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.5.3.2.1
7. Page 2-69
8. Paragraph 3

9. Comment

The third paragraph of this page uses the age and pristine nature of the Lathrop Wells volcanic cone to illustrate that there has been little, large-scale erosional modification of the Yucca Mountain area for a very long time. Clearly, the significance of this observation is greatly enhanced if the age of the Lathrop Wells cone is about 135-140 ka, as determined by Turrin et al. (1991), rather than < 20 ka, as determined by Wells et al. (1990). Although I was asked to review the ESSE based on my background in the tectonics of the Yucca Mountain area, much of my recent research has been in the field of $^{40}Ar/^{39}Ar$ geochronology and I have the following comments regarding the controversy over the age of the Lathrop Wells cone.

I think it is safe to say that most volcanologists and igneous petrologists feel that radiometric techniques are generically much more robust than comparative geomorphic studies for estimating the age of an eruptive sequence. There are two complications in the case of the Lathrop Wells cone, however,

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team appreciates Dr. Hodges' comment. However, we considered it premature at this time to support either side of the ongoing debate regarding the age of the Lathrop Wells cone without additional information. Additional studies are being considered to further refine the age of the cone (DePaolo, 1991). At this time, we felt it was more appropriate for the purposes of evaluating the erosion guideline to discuss the current evidence, reference the relevant articles, and allow interested readers to review the published material and judge for themselves.

We recognize that if the cone is more than >100,000 years old, then the erosion rates in the area are extremely minor. Should this age determination be verified, such a conclusion will be made. Currently, the important point for the purpose of evaluating the erosion guideline is that even the 20,000-year age assigned to the cone by Wells et al. (1990) and the minor amount of incision of the cone help provide assurance that the erosion rates at Yucca

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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9 Comment (continued)

such that the data of Turrin et al. (1991) bear special scrutiny. First, the half-life of ^{40}K is sufficiently long that very young (< 200 ka) volcanic samples contain very little radiogenic ^{40}Ar and are thus very difficult to date precisely using the conventional K-Ar or $^{40}Ar/^{39}Ar$ techniques. Second, most successful $^{40}Ar/^{39}Ar$ geochronologic studies of very young volcanic rocks have focused on high-purity separates of potassic phases, such as sanidine, that naturally have high $^{40}Ar/^{36}Ar$ ratios and therefore yield more precise ages. The Lathrop Wells volcanic rocks are both very young and devoid of potassic phases, making them not particularly well suited for $^{40}Ar/^{39}Ar$ geochronology.

These difficulties are mitigated by the fact that the analyses in Turrin et al. (1991) were done at the IHO Geochronology Center in Berkeley. In my opinion, this facility is one of the two best $^{40}Ar/^{39}Ar$ geochronology facilities in the world for the dating of very young rocks. They have an impressive track record of dating early hominid sites in Africa, and attempts to calibrate the upper end of the ^{14}C age scale has been an important component of recent research at the center. In short, if anyone can date the Lathrop Wells cone using $^{40}Ar/^{39}Ar$ then the people working at IHO can.

The data in Turrin et al. (1991) are reasonably robust considering the very young age of the Lathrop Wells cone. Because there is so little radiogenic ^{40}Ar in these samples, the analytical uncertainties for individual samples are enormous; for many individual analyses, the 1σ error is so large that it is statistically feasible that the date could be consistent with the < 20 Ma age estimate of Wells et al. (1990). Fortunately, the uncertainties can be beaten back by replication, and the resulting weighted mean ages of forth $^{40}Ar/^{39}Ar$ ages are roughly 183±21 ka and 144±35 ka for the two eruptive sequences (Ql_3 and Ql_5/Qs_5) identified by Turrin et al. (1991). Considering additional conventional K-Ar data (which are currently unpublished) Turrin et al. (1991) cite a "best-estimate" age of 141±9 ka for Ql_3 and 136±8 ka for Ql_5/Qs_5. Without being able to review the K-Ar data, I can't comment on these highly precise estimates except to say that field relationships indicating that Ql_5/Qs_5 is older than Ql_3 suggest that these uncertainties may be a bit overly optimistic. A moderate pessimist (like me) might suggest instead that the age of the Lathrop Wells eruptive sequence was somewhere between 100 ka and 200 ka, but even the worst pessimist wouldn't argue that these data are consistent with a < 20 ka age for the sequence.

My sense is that the flaw in the arguments of Wells et al. (1990) lies in the very point that the authors of Section 2.3.5 are trying to make: the very low rates of erosion in the Mojave Desert region make it such that a 100-200 ka

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9 Comment (continued)

volcanic cone (Lathrop Wells) looks as pristine as a < 20 ka cone in the Cima volcanic field. I would strengthen the comment in the third paragraph of p. 2-69 to include an argument of this kind.

END OF TEXT

10 Proposed Resolution (continued)

Mountain do not indicate that the potential repository horizon could be uncovered by erosional processes during the next 10,000 years. Thus no changes to the text are proposed at this time.

END OF TEXT

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5. Revision Draft/Date August 1991
6. Section 2.3.7.2.2
7. Page 2-82
8. Paragraph

9. Comment

Section 2.3.7.2.2 of the draft ESSE consists of a description of the sequence of actions used to obtain the necessary information to resolve the technical issues raised in Section 2.3.7.2.1. These actions, in effect, are the development of predictive tectonic models that are based on the relatively recent geologic record. The Congressional mandate behind the ESSE requires the construction of such models. Given this fact, I think that the Evaluation Team has responded well. However, it seems to me that the ESSE should include an explicit statement that geology is traditionally an explanatory science and not a predictive science.

As we all know, most earth scientists are concerned with observing ancient geologic phenomena and trying to postulate the processes that led to their creation. We are aided in our quest for understanding by principles like uniformitarianism; by looking at cause and effect today, we can reasonably infer cause and effect in the geologic record. "Predictive geology" is predicated on

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team understands Dr. Hodges' concerns about overstating the confidence that should be placed in "predictive geology." Nonetheless, predictive geology is practiced by a great many earth scientists in fields such as engineering geology, flood prediction, and natural-resource assessment, in addition to earthquake and ground-motion prediction. In each of these fields, and depending upon the hazard to life and property addressed in the specific application, the uncertainties are factors of safety (in design) or estimates of error (where design is not involved).

As Dr. Hodges has noted, the NRC and EPA regulations that apply to the high-level waste program, require probabilistic analyses to identify processes and events that might affect the disposal system; evaluate the effects of these processes and events; and estimate probabilistically the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events. A "high degree of accuracy" in predicting

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.
END OF TEXT

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9 Comment (continued)

the assumption of a sort of inverse uniformitarianism: the past geologic record is the key to future geologic activity. This is a fascinating field with tremendous societal importance, but it is presently an inexact science. Earthquake prediction is one of the most visible examples of predictive geology. This endeavor absorbs millions of dollars of funding and commands the full-time attention of many excellent scientists, but it remains a hit-or-miss proposition.

Perhaps predictive geology will improve in the future (I certainly hope so!), but DOE, the Congress, and the American people need to confront the fact that the earth science community does not have the tools necessary to generate models that will permit the prediction of future tectonic activity <u>with a high degree of accuracy</u>. The very best predictive geologists may quote the probability of an event of a certain magnitude happening within a certain time frame, but this probability estimate is inevitably based on a set of largely untestable hypotheses and is therefore subject to uncertainties that are difficult or impossible to quantify. I don't mean to imply that predictive geology is a worthless endeavor or that this ESSE should not rely heavily on probabilistic forecasting, but I think it is imperative that the ESSE contain a frank statement that tectonic predictions, when stripped of statistical sound and fury, are not much better than educated guesses.

END OF TEXT

10 Proposed Resolution (continued)

radionuclide releases is quite realistically not required by the regulations. What is required is reasonable assurance that the uncertainty is adequately incorporated.

The last sentence ("The sequence...as follows:") of the first paragraph in Section 2.3.7.2.2 will be deleted and replaced with the following:

"It must be recognized that predictions resulting from the sequential consideration of these models incorporate the uncertainties that are inherent in geologic prediction. There is uncertainty not only as to the effects of given tectonic processes, but also as to what processes will be acting, and at what rates, in the future. Therefore, reasoned judgment plays an important role in evaluating this guideline, as it does in all aspects of site evaluation."

END OF TEXT

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6. Section 2.3.7.2.2
7. Page 2-83
8. Paragraph 2

9. Comment

In paragraph 2, the ESSE includes a comment that "The last four million years of this chronology...are most directly relevant, but in the southern Great Basin the last 15 million years or more provides an essential context for understanding both the nature and rates of tectonic processes during the Quaternary Period". I agree that one must have a perception of the Cenozoic extensional history of the region in order to understand the Quaternary tectonics, but this comment might be taken as indicating a belief that the rates of various tectonic processes integrated over the last 15 million years is an adequate indicator of the expected rates of these processes over the Quaternary Period (or the next 10 ka, for that matter). If this is the position of the authors of this section, then I disagree strongly. The rates of Neogene extension in the Death Valley region (including Yucca Mountain) are highly dependent on the time slice over which we choose to integrate deformation. If we look carefully at one small area of the region (central Death Valley itself), we find that a minimum estimate of the average extension

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Hodges that the main point of the quoted statement is that the studies will focus on investigating the late Pliocene and Quaternary while gaining enough evidence regarding the earlier Cenozoic Period to understand the tectonic context.

Proposed resolution: Revise the next to the last sentence in the second paragraph on page 83 to read:

"The last four million years of this chronology, i.e., the late Pliocene and Quaternary, are the most directly relevant to understanding the nature and rates of tectonic processes that may affect the site. However, the geologic record of Cenozoic extension, principally mid-Miocene (about 15 Ma) and later, provides an essential context for interpreting the evolutionary nature of tectonism in this area of the southern Great Basin."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

rate over the past 9 million years is 6.4 - 2.7 mm/a while a maximum estimate for average extension rate between 15 Ma and 9 Ma is 10.5 - 5.8 mm/a (McKenna and Hodges, 1990). This implies to me that Neogene extension in the region was episodic, not periodic, over time scales of less than 5 million years. This observation means that we can't use strain rates established for the Yucca Mountain area over the past several million years to predict strain rates in the future at a time scale of 10^4 a. Clearly, the most robust estimates of future deformational activity at the proposed repository will be derived through detailed neotectonic studies aimed at establishing the deformation history over the last 10^4 to 10^5 a. If DOE wishes to prioritize its efforts, then I believe that future studies of the pre-Quaternary tectonic evolution of the site must have a low priority.

I would urge that paragraph 2 contain a clarifying statement that signifies that neotectonic studies have a far greater importance in site evaluation than investigations of pre-Quaternary structures.

END OF TEXT

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4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.7.2.2
7. Page 2-83
8. Paragraph 2

9. Comment

At the bottom of the second paragraph, the word "geothermometry" is used in an unusual and confusing way. A better term here would be "geothermal gradient" or "thermal structure".

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with the more appropriate terminology, "thermal structure," and will make the change in paragraph 2, page 2-83.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.1
7. Page 2-91
8. Paragraph 2

9. Comment

The sentence beginning "In the detachment model, however..." in the second paragraph is very confusing to me. Detachments are simply low-angle omissional faults with major displacement that help to accommodate extension in regions such as the Basin and Range. Subsidiary faults in the hanging walls of detachments can have a variety of geometries ranging from listric to planar-rotational. In the realm of curved faults, there are documented examples of "normally" listric faults (steep at high structural levels, curving to shallow dips at low structural levels), "inversely" listric faults (shallowly dipping at high structural levels, curving to steeper dips at lower structural levels). In the Panamint Mountains, west of Death Valley, I have seen several examples of extensional faults that change from steep to shallow dips along strike rather than down dip, as is the case for a classical "listric normal fault". My point is simply that the existence of one or more detachments in a tectonic model does not automatically imply the geometry of

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Hodges' points that the existence of a detachment does not automatically dictate the geometry of subsidiary faults and that the shape of faults commonly changes along strike. A more general definition of detachment faults, as used in this report, would clarify the intent of this section, as well as the context of later references to listric faulting.

The first two paragraphs on page 2-91 will be replaced with the first three paragraphs of the response to Dr. Cambray's Comment #1, a composite rewrite of Section 2.3.7.3.2.1.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

subsidiary faults.

END OF TEXT

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6. Section 2.3.7.3.2.1
7. Page 2-91 & 2-92
8. Paragraph

9. Comment

There is an implication on this and the following page that the basic justification for the existence of detachments in this area is the case that can be made for a single, master detachment that has a breakaway zone in the Spring Mountains and continues beneath Bare Mountain, the Bullfrog Hills, and perhaps the Grapevine Mountains (Scott, 1990). This argument is highly controversial and largely conjectural. As far as I know, there is no evidence that the normal faults mapped in the Spring Mountains are kinematically linked to a major, regional detachment, and there is no reason to believe that the basal detachments exposed at Bare Mountain, in the Bullfrog Hills, and in the northern Funeral Mountains are the same structure.

Regardless of whether or not the interpretation of Scott (1990) is correct, I think it highly unlikely that detachments do not occur beneath the Yucca Mountain area because such structures are ubiquitous in this part of the Basin and Range. I am concerned, therefore, in the apparent linkage on page 2-92

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Together with Dr. Hodges' previous comment (#13), Dr. Cambray's Comment #1 precipitated a major revision involving both reorganization and additions, of Section 2.3.7.3.2.1. The ESSE Core Team proposes that the revision, provided in response to Dr. Cambray's Comment #1, allows for consideration of detachments of less than regional scale (including the attribution to Scott, 1990), active or inactive, while preserving discussion of the considerable evidence for detachments in the structure of Yucca Mountain and environs.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

between uncritically agreeing with Scott and believing in a detachment model. I suspect that this linkage arises from the use of a definition of "detachment" that includes the presumption of regional extent. In other words, some people reserve the word "detachment" for low-angle normal faults that are exposed over a large region. I think this is a terrible presumption that is not made by most structural geologists working in the Basin and Range. The working definition of a detachment is a low-angle normal fault that appears to have had large throw and has served as the basal decollement for second-order normal fault sets. There are plenty of examples of major detachments that are exposed in only one range in the Basin and Range. The common working definition of detachment seems to be that used by Wright (1989), and I daresay that most structural geologists working in the Death Valley region would be more comfortable with his less conjectural view of the structural architecture of the Spring Mountains - Death Valley corridor.

END OF TEXT

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5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.1
7. Page 2-92
8. Paragraph 3

9. Comment

The term "tensional separation" in the third paragraph is inappropriate; "tension" and "extension" are not the same things. Why not just say that high-angle, normal faults at the surface flatten downward to become low-angle, ductile shear zones in the middle crust?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Proffett (1977) represented, as one mechanism for changing the dip of earlier faults in the hanging wall, sagging or folding of the hanging wall into the opening that otherwise would exist from the pulling away of the hanging wall from the footwall along a listric fault. Therefore, the sense of the near-surface effect needs preservation.

In the first occurrence (the second sentence of the paragraph on page 2-93), change to read, "...listric faulting, steeply dipping near the surface but decreasing in dip with depth until the extension is accommodated by ductile flow." Change the last sentence of the paragraph to begin, "The tendency for extensional openings at the shallow, steeply dipping fault segments was accommodated principally by ..."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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6. Section 2.3.7.3.2.1
7. Page 2-93
8. Paragraph 1

9. Comment

The first paragraph on this page reviews estimates of the depth of a major detachment beneath Yucca Mountain presuming that such a structure occurs. I think that it is important to say that any cross-section constructed from surface data and limited drilling information is an interpretation. Many structural geologists are enamored with computer balancing of cross-sections to the extent of believing the results as gospel. While it is true that a balanced cross-section has a much better chance of being correct than an unbalanced cross-section, a balanced cross-section is invariably non-unique. If a major detachment occurs beneath Yucca Mountain, its depth is clearly very important because it could serve as a fast pathway for radionuclide transport if it was not far below the repository. This makes it extremely important, I think, to make establishment of the structural architecture beneath Yucca Mountain a high priority in DOE's future plans. Based on the experiences of the oil industry, it is safe to say that the most cost-effective way of improving our understanding of the subsurface is through seismic imaging

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with most aspects of this comment. However, it is important to recall that the hydraulic potential increases at depth beneath Yucca Mountain (except to the north and west of the site, where the potentiometric surface rises above 800 meters), providing the potential for upward flow. Therefore, neither the underlying carbonate aquifer nor a postulated detachment within or below the lower part of the saturated tuff section would provide fast pathways for the transport of radionuclides that might escape the repository. Also, it is not readily apparent that even problem-oriented shallow drilling will shed much direct light on the presence or geometry of a detachment at depths of kilometers.

The following sentence will be added to the revised Section 2.3.7.3.2:

"The differences between these interpretations probably cannot be resolved, nor can other alternatives be identified, until the structural architecture

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

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9 Comment (continued)

techniques augmented by problem-oriented shallow drilling of critical areas. It is particularly important to wait until after the seismic work to select sites for drilling, because it will then be possible to limit the number and depth of necessary drill holes and thereby keep costs to a minimum.

END OF TEXT

10 Proposed Resolution (continued)

is explored in greater detail by intensive geologic studies, including mapping, and to greater depths by geophysical techniques and possibly deep drilling."

END OF TEXT

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6. Section 2.3.7.3.2.1
7. Page 2-95
8. Paragraph 2

9. Comment

Differences of opinion between those who argue for a northwesterly alignment of the Crater Flat volcanic zone (e.g., Crowe, 1990) and those who prefer no clear alignment or a northeasterly trend (e.g., Smith et al., 1990) are highlighted in the second paragraph. I think it is extremely important to note that all latest Pliocene to Quaternary eruptive centers lie along a northwesterly trend and only the relatively old (2.8 Ma) Buckboard Mesa center lies off the trend. Coupled with differences in chemical variation trends between the Buckboard Mesa rocks and rocks from the Crater Flat volcanic zone, this observation makes it reasonably safe to concur with the assessment that there is no indication from the surficial migration of latest Pliocene - Quaternary eruptive centers that there is an unusually high risk of a volcanic eruption at Yucca Mountain.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with the comment, but we do have an obligation to report published scientific opinions that are pertinent to site characterization.

The comparable paragraph in the revision will be changed to read:

"Smith et al. (1990) chose to define their area of most recent volcanism ("AMRV") based only upon the factor of age, and they did not include magma composition and tectonic setting as criteria. The inclusion of the 2.8 Ma basaltic andesite of Buckboard Mesa allows Smith et al. (1990) to define an elliptical AMRV that encompasses Yucca Mountain. However, it should be noted that all Quaternary (< 1.6 Ma) basaltic eruptive centers near Yucca Mountain occur inside the northwest trend of the CFVZ. In the CFVZ model, the geochemically similar basalts erupted since 3.7 Ma ago within the northwest alignment of the CFVZ are distinct

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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10 Proposed Resolution (continued)

from the basaltic andesite of Buckboard Mesa. The Crowe and Perry (1989) analysis is considered to be more rigorous, but further investigations are planned to examine the structural controls on basaltic volcanism. The structural controls on volcanism are important components of an overall understanding of Quaternary tectonism. A direct linkage of faulting and volcanic activity was proposed by Fox and Carr (1989), who deduced from the common occurrence of volcanic ash within the north-striking fault zones near Yucca Mountain that the Quaternary faulting and nearby basaltic volcanism have been coeval."

END OF TEXT

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7. Page 2-96
8. Paragraph 3

9. Comment

The third paragraph of this page is an excellent example of the problems reviewed in my comments concerning p. 2-83. A strain rate of $1X10^{-2}$ to $3X10^{-2}$ mm/a averaged over the past 11.5 Ma on faults at Yucca Mountain (Scott, 1990) does not preclude brief periods of rapid strains during that time period. It is impossible to make meaningful comparisons between the averaged strain rates over a 1.5 million year period (13-11.5 Ma) and the averaged strain rates over an 11.5 million year period (11.5 Ma to the present). It is simply not a convincing argument that geologic evidence for a large amount of extension at 13-11.5 Ma compared with evidence of less extension over the past 11.5 Ma predicts a further drop in the amount of extension for the foreseeable future. Consider the deformational history of the Death Valley region from the perspective of a paleogeologist at 13 Ma. At that time, the area had been relatively quiescent for the past 10 Ma. The last previous pulse of activity had been associated with strike-slip faulting along the Furnace Creek fault zone and (perhaps) other structures in Late Oligocene time. If our

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team certainly agrees that short-term episodic rates, which are averaged with perhaps longer periods of lesser activity or no activity, must exceed the average.

Following the paragraph beginning on page 2-96 and ending on 2-97, the following paragraph will be added:

"Note, however, that rates of tectonic activity are typically variable, particularly within a small locality. Therefore, average slip rates over long time periods may differ greatly from those during episodes of greater or less activity, requiring that paleoseismic investigations be applied within a broad context of the tectonic history of the specific locale and its geologic setting."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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9 Comment (continued)

paleogeologist had observed that a brief period of extreme deformation at 25-23 Ma had given way to a ~10 million year interval of little deformation, he might reasonably have predicted a continued waning of deformational activity. Little would he have known that the next big pulse of deformation was right around the bend.

I think that the best we can hope for from the predictive point of view is that the rate of deformation averaged over the last n years at Yucca Mountain will hold for the next n years. If neotectonic studies can only provide us with rates averaged over 10^5 years, then are predictions of future activity are only good averaged over 10^5 years. Clearly, a low strain rate averaged over the next 10^5 years does not necessarily mean that there will be a low strain rate over the next 10^4 years.

END OF TEXT

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6. Section 2.3.7.3.2.5
7. Page 2-100
8. Paragraph 4

9. Comment

The large potentionmetric gradient in the site area is a fascinating phenomenon. As pointed out by the authors, the collapse of this gradient could have a profound effect on containment of radionuclides. Thus, establishing the cause and potential for destruction of this gradient must be one of the major research initiatives during the next stage of site evaluation, and I would urge the authors to make a strong statement to that effect here. I think the first logical step will be to map this gradient in better detail and to compare variations in the gradient with the subsurface geology to see if simple explanations can be found (e.g., alteration fronts in the tuffs or fault zones). It seems inappropriate to let first-order studies of this phenomenon be driven by more convoluted models such as that of Szymanski until simpler explanations can be ruled out. It also seems important to me to build large-scale, three-dimensional, numerical models of ground-water flow near the repository in order to ascertain whether or not the basic structural architecture exerts a major influence on flow paths through and around Yucca

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that the large potentionmetric gradient is a fascinating phenomenon, that it merits intensive investigation, and that the effort should first focus on simple geologic explanations. We believe that earlier responses to Drs. Cambray and Vogel will provide a satisfactory resolution. These responses are as follows:

Response to Dr. Cambray's Comment #2:

The ESSE Core Team agrees fully with this comment. We propose that the spirit of the comment (and several other comments) can be met by the addition of the following sentence to page 2-105, paragraph 2:

"The results of this exploration should be incorporated into three-dimensional models, simulating both the existing geologic framework and credible modifications of this framework by tectonic

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
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1. Comment 19 of 31
2. Page 2 of 2

3. Name K. V. Hodges
(Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

Mountain. If so, we may find that relatively recent tectonic activity is part of the reason that Yucca Mountain seems, at this point, to be a suitable waste repository.

END OF TEXT

10 Proposed Resolution (continued)

processes, in order to predict possible changes to the local flow system and the position of the water table."

Response to Dr. Vogel's Comment #6 (pp. 2-81 and 2-100 also affects p. 2-105):

The ESSE Core Team agrees that there is a need to understand the large gradient and the effects of modifying the causative geologic conditions by tectonic or igneous processes. We believe that the more broadly framed specific concerns stated in the middle paragraph of page 2-81 indeed encompass the effects of tectonism on the gradient and the water table beneath the potential Yucca Mountain site. Similarly, we believe that the third and fourth paragraphs on page 2-100 (continuing onto page 2-101) quite explicitly discuss studies that have been done or are underway to understand the causative geologic conditions and, for at least one such condition, to examine the effects of disruption. Finally, in response to Dr. Cambray's Comment #2, we have proposed adding the sentence quoted previously in this response.

No additional changes to the text are proposed at this time.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 20 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.6
7. Page 2-101 & 2-102
8. Paragraph all

9. Comment

Section 2.3.7.3.2.6 reviews estimates made in a series of papers by Bruce Crowe and co-workers of the probability of volcanic activity and consequent repository disruption over the next 10,000 years. I have read these papers in some detail and was impressed by the careful approach taken toward risk assessment. However, I am worried that Section 2.3.7.3.2.6 paints an overly optimistic picture of our understanding of the volcanic hazard at Yucca Mountain.

It is apparent to me that Crowe and co-workers have an excellent grasp of the uncertainties inherent in this problem. Many of these are reviewed in Crowe et al. (1982) and Crowe and Perry (1989). Two quotes from Crowe et al. (1982) are particularly germane:

"The natural processes involved in the generation, ascent and eventual eruption of basaltic magma are extremely complex. There are numerous areas of uncertainty in current geologic

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Although Crowe and his colleagues indeed have an excellent grasp of the uncertainties inherent in the volcanism studies, their understanding has advanced considerably since the 1982 report quoted by Dr. Hodges. The ESSE text, in the last sentence of page 2-101, does note that these investigators took their more recent grasp of the uncertainties into account in arriving at the latest probability estimates. We refer also to our responses to Dr. Hodges' Comments #10 and #18, regarding the uncertainties that, by design, are incorporated into the probabilistic estimates. The discussion of future plans on page 2-105, paragraph 4, is directed principally at increasing confidence, i.e., reducing uncertainty. The activities specified there directly address the assumptions that underlie the analyses, including that of steady-state. Although the current hypothesis is that volcanism is waning, it is not reflected in current calculations. Planned work could (a) show that this is not the case; (b) show that it is, but at too low a level of confidence to merit complicating the analysis; or (c) show that it is

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 20 of 31

2. Page 2 of 3

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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

understanding that limit the ability to predict these processes." (p. 169)

"The critical point (regarding probability assessment) is whether rates of activity as determined from the geologic record are representative and can be projected into the future with confidence." (p. 171)

The probabilities established by Crowe and co-workers are based on a large number of assumptions. Chief among these, in my opinion, is the assumption that the rate of volcanic activity in the future can be predicted by extrapolating the curve of cumulative magma volume of Quaternary eruptive events vs. time into the near future. The implication is that volcanic activity has reached some steady-state. This assumption may or may not be correct, but it seems fundamental to all of the calculations of Crowe and co-workers. As I understand their results, the range of probabilities given in the first complete sentence of page 2-102 reflects uncertainty in the age of the Lathrop Wells cone and uncertainties in whether or not we believe that future activity will follow the northwesterly trend of the Crater Flat volcanic zone. The range does not reflect the importance of the steady-state assumption; in essence, if the system has not approached steady-state, then it seems to me that we have no really robust way of predicting future activity over short time periods.

I believe that Crowe and co-workers have been very careful in past papers not to "over-sell" their probability calculations, but Section 2.3.7.3.2.6 is not as circumspect as these papers. The casual reader who has not taken the time to read the papers will come away from this section believing that we can reliably predict the probability of volcanic disruption of the repository at 6 x 10^{-5} to within a half an order of magnitude. This section needs careful rewording to reflect the assumptions behind the probability assessment and to reveal the fact that these assumptions will be difficult or impossible to fully evaluate before a siting decision is made.

END OF TEXT

10 Proposed Resolution (continued)

actually increasing.

At the end of the first paragraph on page 2-102 the following sentence will be added:

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(Instructions on back of form)

1. Comment 20 of 31

2. Page 3 of 3

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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

"Numerous assumptions that are believed to be conservative underlie the probability estimates; evaluating the validity of these assumptions and their importance to the analysis is the focus of the future activities that are described in Section 2.3.7.3.3."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 21 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3
7. Page 2-103
8. Paragraph 2

9. Comment

The sentence that begins "Definition of these concerns..." contains too many substantials.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Hodges' observation. The second sentence of the second paragraph on page 2-103 will be revised to read, "Definition of these concerns has progressed since preparation of the EA, and recent data and analyses indicate that eventual resolution of the concerns is probable." In the following sentence, we propose to replace the word, "probabilistically" with "in detail."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 22 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3
7. Page 2-103
8. Paragraph 3

9. Comment

I would strongly disagree that "resolution of (the fourth) technical issue is nearly complete". I find the presumption behind the pertinent technical guideline condition that we can ever demonstrate a probably of 10^{-4} that volcanism will disrupt the repository in 10,000 years to be patently absurd. Even if volcanism in the area is truly periodic (an open question), we simply do not have the tools to establish with a high degree of confidence the numerical probability of volcanic disruption. The work of Bruce Crowe and co-workers demonstrates that this condition might be met if we are willing to make a number preliminary assumptions that are next to impossible to evaluate. The third paragraph of p. 2-103 perpetuates the misconception that geology is a quantitatively predictive science. Someone must tell DOE and the Congress that they are asking the impossible if they want highly precise assurances that the probability of tectonic disruption is negligible. Ultimately, I believe that the prediction of volcanic hazard will come down to the following qualitative (but educated) assessment. There have been only a handful of volcanic

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Again we refer Dr. Hodges to previous responses--in this instance to his Comments #10, #18, and #20. The reviewer's qualitative but educated assessment is precisely what the regulations require, except that the experts must be calibrated as to what is meant by "highly unlikely" and "integrity of the repository." Ultimately, quantitative assessments are nothing but tools to organize thinking, calibrate the experts, and support educated, qualitative assessments. Nonetheless, neither the first nor the last sentence of this paragraph has been well received, and both seem superfluous and therefore will be revised as follows:

(a) The first sentence of the paragraph and the beginning of the second will be revised to read: "With respect to the fourth technical issue, release by volcanism, recent analyses indicate..."

(b) The last sentence of the paragraph will be deleted ("Resolution...

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 22 of 31
2. Page 2 of 2

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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

eruptions near Yucca Mountain since Late Pliocene time and the last one occurred over 100,000 years ago. None of these eruptions clearly would have disrupted the repository, and the space-time trend of volcanic centers suggests that future eruptions, if they happen at all, won't occur on Yucca Mountain itself. It therefore seems highly unlikely that a catastrophic event that threatens the integrity of the repository will happen to occur in the next 10,000 years.

END OF TEXT

10 Proposed Resolution (continued)

nearly complete.")

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 23 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3
7. Page 2-104
8. Paragraph 5

9. Comment

I like the first paragraph under Recommendations for Future Activities but I think it should include a comment about the relative importance of some of these activities. I think it is much more important to know the current structural architecture of the site than to arrive at a unified tectonic model of the last 13 Ma of geologic history. For example, the issue of whether or not there is a detachment beneath Yucca Mountain is clearly germane to detailed modeling of groundwater flow and is therefore a critical problem. On the other hand, establishing why that detachment formed in Miocene time is not particularly critical to assessing the suitability of Yucca Mountain for a waste repository.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team certainly agrees with Dr. Hodges that an understanding of the structural architecture is an important first step and that a knowledge of its historical evolution is important to site characterization only to the extent that it contributes to understanding that architecture and the tectonic processes that may act during the postclosure period. We also agree that prioritization of future work is necessary and desirable, but that task (or opportunity) was not assigned to the ESSE Core Team. Mattson et al. (1991) document the initiation of a test prioritization task, but it was focused on a ranking of activities that could give an early indication of site suitability against conditions that could potentially disqualify the site from a postclosure perspective. The ESSE Core Team has recommended that a broader version of this task should be initiated (See Section 4.4).

No change to the text is proposed at this time.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 24 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.2.1
7. Page 3.3.3-26
8. Paragraph 4

9. Comment

The first sentence of the first paragraph after the list of issues should read: "The wordings for the qualifying and disqualifying conditions are quite similar."

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be revised as suggested in this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 25 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.2.2
7. Page 3.3.3-27
8. Paragraph (Issue 4)

9. Comment

In the same vein as my comments on p. 2-101 and 2-103, I recommend that a caveat be placed in the discussion of volcanic hazards on this page. This could be achieved by rewording the last sentence of paragraph 4 on page 3.3.3-27 as follows:

Given the assumption that the rate of volcanism in the area over the preclosure time frame can be simply extrapolated from the eruptive history of the area over the last 4 million years, the work of Crowe et al. (1982, 1983a) and Crowe and Perry (1989) can be used to estimate the probability of a volcanic eruption that would disrupt the site prior to closure.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be modified in the last sentence of paragraph 4, page 3.3.3-27, as follows: "Given the assumption that the rate of volcanism in the area over the preclosure time frame can be simply extrapolated from the eruptive history of the area over the last 4 million years, the work of Crowe et al. (1982; 1983a) and Perry and Crowe (1990) can be used to estimate the probability of a volcanic eruption that would disrupt the site prior to closure."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

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(Reviewer completes Items 1 - 9.)

1. Comment 26 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.3.2
7. Page 3.3.3-34
8. Paragraph (Nature and age...)

9. Comment

Trying to be extremely even-handed, the authors have presented the positions of both Turrin et al. (1991) and Wells et al. (1990) regarding the age of the Lathrop Wells cone. I think it is important to emphasize the fact that the dating of volcanic rocks using K-Ar and $^{40}Ar/^{39}Ar$ is far more robust than less well calibrated techniques such as thermoluminescence, cosmogenic ^{36}Cl chronometry, and comparative geomorphology. This section seems to imply that it's anybody's guess whether the Lathrop Wells cone has an age of 20 Ma or 130 Ma. It is very difficult to dismiss the Ar data as erroneous, and I think that the authors should express the likelihood that the cone has an age of > 130 Ma. See my comments regarding p. 2-69 for further discussion.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The age(s) of the Lathrop Wells Volcanic Center has been a topic of debate (e.g., DePaolo, 1991). Basically, two contrasting data sets are available that yield very different results in the age of the volcanic center. The ESSE Core Team feels that the text reliably reflects the uncertainties in the age(s) of the volcanic center and do not wish to over endorse the K-Ar and ^{40}Ar-^{39}Ar data sets. As presently represented in the text, no bias toward either data set is suggested. Additional analysis will be carried out to aid in the resolution of this issue. In either case, the hazard from basaltic volcanism remains small.

Minor text changes will be made in Section 2.3.7 to clarify this topic.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 27 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section
7. Page 3.3.3-35
8. Paragraph

9. Comment

Once again, I want to emphasize my comments on pages 2-83, 2-96, and 2-101 regarding the use of past rates of volcanic or tectonic activity to predict the short-term future. The low frequency of volcanism in the Crater Flat volcanic zone over the past 4 million years makes it impossible to say much about short-term changes in the rate of eruptive activity in the recent past. Without robust constraints on the variations in eruptive rate over the time scale of 100 years during the Quaternary or the Holocene, how can we hope to predict the probability of eruptive activity over any 100 year interval in the future? I presume that Crowe's estimate of the probability of site disruption by volcanism over the next 100 years is based on the assumption that it is safe to extrapolate the curve of cumulative magma volume of Quaternary eruptive events vs. time established by Crowe and Perry (1989) into the near future. Since the morphology of the Quaternary curve was established using a few points separated in time by intervals much greater than 100 years (by necessity), this estimate doesn't seem very robust to me. I think it is unfair to the casual

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Although this comment focuses on the preclosure volcanic hazard, it is very similar to Dr. Hodges' Comment #20 where he questions the assumptions underlying the probabilistic hazard calculations by Crowe and coworkers. The reader should refer to the response to that comment and to the text revisions proposed in that response.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 27 of 31
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9 Comment (continued)

reader to present this estimate without further discussion of the assumptions that go into it.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 28 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.3.2
7. Page 3.3.3-35
8. Paragraph (methodologies)

9. Comment

The methodologies behind seismic hazard analysis for the area provide an interesting example of what I would consider "correct" scaling in hazard assessment. The data on which probabilistic models of seismic hazard are based include historical seismicity records and paleoseismic information deduced from neotectonic studies. The time scales over which seismic periodicities are established thus range from 10^6 to 10^2 years. This range includes both the preclosure time scale (10^2 years) and the postclosure time scale (10^4 years), and it seems at least theoretically possible to establish robust estimates of the probability of significant seismic activity over the next 10,000 years. This contrasts, in my opinion, with the situation regarding volcanic hazard assessment, where the established time scales for eruptive periodicity (if the eruptions are periodic) range only from 10^6 to 10^5 years. It thus seems much less likely to me that we can establish the probability of volcanic disruption with high precision.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Hodges implies that the sparsity of data for estimating the probability for volcanic disruption of the proposed repository site results in a high uncertainty in this estimate. Information provided by Crowe (1991, personal communication) indicates that the approach for assessing the magnitude of volcanic hazard at Yucca Mountain rests on use of analogues from Nevada and southern California, e.g., the Lunar Crater and Cima volcanic fields, to constrain possible volcanic activity at Yucca Mountain. Because both of these fields are more active than the Yucca Mountain area, more data from Quaternary volcanic events are available at those sites. Preliminary calculations suggest that even at distances of only a few kilometers to ten kilometers from the center of each volcanic field, consequences would not exceed EPA release limits (40 CFR Part 191). The support for this position will be determined through prelicensing interactions with the regulatory agencies, and later during licensing interactions if the Yucca Mountain site enters the formal licensing process with the NRC.

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
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1. Comment 28 of 31
2. Page 2 of 2

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(Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

No text changes are proposed in response to this comment.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 29 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.4
7. Page 3.3.3-37 and 3.3.3-45
8. Paragraph (Issue #1, Issue #2)

9. Comment

For both Technical Issue #1 and Technical Issue #2, the authors state that they rely heavily on the results of Subramanian et al. (1989) rather than synthesize the myriad studies pertaining to seismic response of the facility. I can understand why they would have done something like this, but I think that they should briefly explain their rationale for choosing Subramanian et al. (1989) as the authoritative work. Did it synthesize other works? Was it more thorough than other treatments? How did its conclusions compare to those of other papers?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Subramanian et al. (1989) considered the work of various investigations and case histories that are applicable to the seismic vulnerability of the potential surface facilities. Text will be added at the end of the first paragraph on the top of page 3.3.3-45 to further explain the use of the Subramanian reference: "The work by Subramanian et al. (1989) is the most recent comprehensive study directly addressing the response of the proposed repository surface facilities to seismic hazard."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 30 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section 3.3.3.4.4
7. Page 3.3.3-50
8. Paragraph last para. of 3.3.3.4.4

9. Comment

I am not familiar with the methodology used by Perry and Crowe to predict the likely volume of silicic ash that might fall on Yucca Mountain as a consequence of eruption of the Coso or Long Valley fields over the next 100 years, but I presume that it involves the same kinds of future projections of rates of volcanism that characterizes their work on the basaltic activity near Yucca Mountain. Once again, it should be emphasized that such predictions are subject to extreme uncertainties; in the case of ash falls from distant eruptive centers, additional uncertainties involving possible changes in climactic conditions and prevailing winds complicate the models. Given these uncertainties, and my concerns expressed in other comments about the "robustness" of the probability estimates for basaltic volcanism, I find the last sentence of the first paragraph on p. 3.3.3-50 just a bit too complacent.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text in the referenced paragraph reflects and is representative of the conclusions found in Perry and Crowe (1990). Their arguments are considered to be robust and are based on several considerations of qualitative evidence. In reaching their conclusions, the dispersal axes of eruptions around vent areas is discussed, but was not considered in their conservative approach. For instance, Miller (1985 and Miller et al., 1982) estimated that an eruption of 1 cubic kilometer of pyroclastic material could potentially deposit 20 cm of ash at a distance of 35 km, 5 cm of ash at a distance of 85 km, and 1 cm of ash at a distance of 300 km. Perry and Crowe discuss all likely locations of future eruptions and the volumes of erupted materials that would likely be associated with renewed activity. Large eruptions are considered to be extremely unlikely with smaller eruptions becoming more probable, but still are considered an unlikely event. Hence, one conservative approach would be to assume the most likely event (eruption of 1 cubic kilometer), with a dispersal axis in line with the proposed site, and determine the amount of ash that would be expected

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 30 of 31

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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

to cover the site (1 cm). This amount of ash would have no significant affect on the preclosure operation of the site.

The last sentence in this paragraph does not conclude that the location or volumes of eruption are certain, only that, in the preclosure time frame, little probability is attributed to the following sequence of events: eruption occurs, eruption is associated with an ash component, prevailing winds distribute the ash to the proposed site, and resulting layer of ash significantly affects preclosure operations, which results in a failure of the site to meet the regulatory guidelines.

The last phrase of the last sentence will be changed from "..., this issue is considered resolved," to "..., this hazard is considered to be properly bound."

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 31 of 31
2. Date November 11, 1991
3. Reviewer K. V. Hodges
4. Organization MIT
5. Revision Draft/Date August 1991
6. Section References
7. Page R-40
8. Paragraph

9. Comment

The reference for Smith et al., 1990 appears twice.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The reference list will be corrected as suggested in this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

REFERENCES FOR DR. KIP V. HODGES

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Mr. Robert H. Jones

TRANSPORTATION IMPACTS

Hazardous Material Systems, Inc.
Los Gatos, CA

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	X	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	X	

Comments 1 through 6 are attached.

Peer Reviewer Robert H. Jones Date 12-19-91

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ______ The following comments have not been adequately addressed:

Peer Reviewer Robert H. Jones Date 12-19091

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-19-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 5
2. Date October 30, 1991
3. Reviewer Robert H. Jones
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 3.3.2.3
7. Page 3.3.2-15
8. Paragraph 1

9. Comment

Qualifying Condition #1

It is understood that the term "local" in this Qualifying Condition is interpreted by the DOE to mean within the State of Nevada. This is an acceptable interpretation but it should be explicitly stated to avoid confusion over at least one of the rail access route options that is about 400 miles in length.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The Qualifying Condition in 10 CFR 960.5-2-7(a) states, "The site shall be located such that the access routes constructed from existing local highways and railroads to the site ..." which leaves the interpretation of "local" open. The discussion in the ESSE Report only talks about rail and highway access to the site from existing rail lines and highways in Nevada. The following will be added to Section 3.3.2.3.2 to clarify what is meant by local: "...the term "local" is interpreted to mean within the State of Nevada."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 5
2. Date October 30, 1991
3. Reviewer Robert H. Jones
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 3.3.2.3.1
7. Page 3.3.2-15
8. Paragraph (para. 1 of discussion)

9. Comment

Qualifying Condition #1

The first subcondition prohibits any route that crosses any Federally protected lands such as National Parks, National Wildlife Refugees, etc. A rail access route that was included in the EA was later withdrawn due to encroachment, however, it is clear from the post-EA work on rail routes that the avoidance of protected areas is possible and this subcondition can be met.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Mr. Jones finds it clear that the present rail spur studies identify rail alignments that do not traverse federally protected lands. However, to make this clear to the reader, the following will be added to Section 3.3.2.3.3.3 in the discussion of "Access Route Characteristics."

"The routing study (DeLeuw, Cather and Company, 1991) provides a conceptual design for an alignment that does not traverse federally protected lands. Alternatives to the current Caliente route need to be developed that have similar characteristics..."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 5
2. Date October 30, 1991
3. Reviewer Robert H. Jones
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 3.3.2.3
7. Page 3.3.2-15
8. Paragraph 1

9. Comment

Qualifying Condition #1

The second subcondition requires that the access routes can be designed and constructed using reasonably available technology. The EA and the post-EA highway and railroad access studies discuss design and construction in civil engineering jargon. The implication is that conventional highway and railroad construction methods are adequate. However, the ESSE Report does not contain any text that specifically states that reasonably available technology is sufficient to implement the recommended routes and alternatives. It is recommended that such text be included.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

We propose to delete the third sentence in the second paragraph of Section 3.3.2.3.3.2 and add in its place "The rail access route for the Caliente route (DeLeuw, Cather and Company, 1991) indicates that for the conceptual design of that alignment, including several options, the railroad can be constructed within the limitations of present railroad engineering practices and normal operating standards. Additional studies will be needed to identify other alignments that have similar characteristics. The highway access route can also be constructed within present highway engineering practices and does not traverse federally protected lands."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 5
2. Date October 30, 1991
3. Reviewer Robert H. Jones
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 3.3.2.3
7. Page 3.3.2-15
8. Paragraph 1

9. Comment

Qualifying Condition #1

The third subcondition is that transportation system components need only to comply with NRC and DOT performance standards: more stringent standards will not be required. Transportation system components should be defined. I envision them as: 1) the transporter components, truck or train, and 2) the packaging components, cask and ancillary equipment.

There should be text, or reference to text, in the ESSE Report that specifically addresses the current performance standards, DOT and NRC, and in general terms indicates how these are sufficient for transportation to the Yucca Mountain site. One particular item that bears consideration is the ambient temperature specified in NRC regulations for cask analysis purposes.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The third subcondition specifies that the site shall be located such that it will not require transportation system components to meet performance standards more stringent than those specified in the applicable DOT and NRC regulations, nor require the development of new packaging containment technology. For clarification, the following will be added as a new paragraph after the present third paragraph in Section 3.3.2.3.3.2: "Transportation of spent fuel in Nevada will not require transportation system components to meet performance standards more stringent than those specified in the applicable Department of Transportation (DOT) and NRC regulations. Transportation system components consist of the transporter components (truck or train) and the packaging components (cask, impact limiters, and personnel shield). The DOT performance standards that apply to the shipment of spent fuel and high-level waste are in 49 CFR 173.401-476, 49 CFR 174, and 49 CFR 177. These regulations apply throughout the United States. The NRC performance standards that apply to the packaging components are in 10 CFR 71 and 10 CFR 73. These regulations

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 4 of 5
2. Page 2 of 2
3. Name Robert H. Jones (Print Name)
4. Date October 30, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

also apply to shipments of spent fuel and high-level waste throughout the United States. Therefore, siting the repository in Nevada would not require more stringent performance standards for the transportation system components."

With regard to the ambient temperature requirement, NRC Regulatory Guide 7.8 presents a range of ambient temperatures from -20 degrees F (-29 degrees C) to 100 degrees F (38 degrees C) as part of the initial conditions. The guide states that "In the contiguous United States, there is a 99.7 percent probability that any hourly temperature reading will fall within this range." The guide also states that "The load conditions given here are considered acceptable to the NRC staff for use in the analytical structural evaluation of shipping casks used to transport Type B quantities of radioactive materials." Table 1 in the guide gives load combinations that should be used in combination with specified initial conditions, which includes the above ambient temperature range.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 5
2. Date October 30, 1991
3. Reviewer Robert H. Jones
4. Organization consultant
5. Revision Draft/Date August 1991
6. Section 3.3.2.3
7. Page 3.3.2-15
8. Paragraph 1

9. Comment

Qualifying Condition #1

The fourth subcondition deals with unacceptable public risk or unacceptable environmental impacts due to transportation operations. This is actually a subset of the second Qualifying Condition and will be addressed below.

Qualifying Condition #2

This is a very broad Qualifying Condition that requires public protection from the hazards of waste disposal from siting through decommissioning. Included in this is transportation.

The ESSE Report borrows from the EA in examining both radiological and non-radiological risk to the public. The EA risk assessments were based on route assumptions, highway and rail. However, as the Report indicates, there

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Mr. Jones is correct that the routes have and/or are likely to change from those described in the EA (DOE, 1986). Overall risk of transportation in the radiological or nonradiological categories is sensitive to primarily total transit distance, population along the route, and transit time given that cask characteristics and transit models would not change.

Potential impacts reported in the EA were based on routes that cross the entire country. Thus, changes in routes for a single state like Nevada will not significantly affect either transit time or distance. Potential rail routes under consideration by the DOE and highway routes under consideration by the State of Nevada all pass through more rural areas than routes described in the EA. Thus, the population potentially affected by waste transportation would also be less. Since all the primary factors for risk related to routing would be unaffected or reduced, overall risk would not be significantly affected by the route change. This issue will be revisited with final route

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 5 of 5
2. Page 2 of 2
3. Name Robert H. Jones (Print Name)
4. Date October 30, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

have been route assumption changes since the EA. It is stated in the Report that the final risk evaluations will be contained in the EIS, and it is further stated that the actual routes are yet to be selected. All of this not withstanding, I recommend augmenting the Report to provide some justification for the continued validity of the EA risk results, pending the EIS.

Since this Qualifying Condition does not specify "local," the issue of nationwide transport cannot be dismissed. I believe that you should reference a source or indicate in some way that the national risk of spent fuel and HLW transportation is essentially independent of the selection of the Yucca Mountain site.

Conclusion

The transportation of spent nuclear fuel and high level radioactive waste is a challenging task. However, we have been doing it safely for over 30 years and have a very good idea of what is required to protect the public and at the same time operate an efficient, dependable, cost-effective operation. In my review of the ESSE Report and its referenced documentation, I have concluded that repository site selection is largely independent of fuel and waste transportation issues.

My comments on the ESSE Report address the inclusion of additional information to better support the findings. I concur with the conclusion that the Yucca Mountain site satisfies the Qualifying Conditions to the levels indicated.

END OF TEXT

10 Proposed Resolution (continued)

preferences during the development of an EIS for the repository.

END OF TEXT

REFERENCES FOR MR. ROBERT H. JONES

JONES

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10 CFR Part 71 (Code of Federal Regulation), 1988. Title 10, Energy, Part 71, Packaging and Transportation of Radioactive Material, U.S. Government Printing Office, Washington, DC.

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10 CFR 960 (Code of Federal Regulation), 1984. Title 10, Energy, Part 960, General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, U.S. Government Printing Office, Washington, DC.

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Dr. David K. Kreamer

HYDROLOGY

University of Nevada
Las Vegas, NV

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	Yes - with incorporation of my comments	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	Yes - with incorporation of my comments	

Comments 1 through 22 are attached.

Peer Reviewer David K. Kreamer Date 12-19-91

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ______ The following comments have not been adequately addressed:

Peer Reviewer David K. Kreamer Date 12-19-91

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-19-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 22
2. Date November 12, 1991
3. Reviewer David K. Kreamer
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 2.4.2
7. Page 130
8. Paragraph

9. Comment

Total System Release

In Section 2.4.2 of the ESSE document, there is a review of information (regarding total system releases) which has been obtained since the 1986 Environmental Assessment (EA). Through preliminary performance assessments, the 1986 Environmental Assessment concluded that, for both the total system and the engineered-barrier system, the regulatory criteria for release would be met. Specifically, performance analyses indicated that the expected 10,000-year release of radionuclides was likely to be less than the release limits specified in EPA standards. The EA analysis identified many sources of uncertainty, including fracture flow, and oxidizing conditions in the unsaturated zone.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Kreamer points out an apparent inconsistency between the results of the Calico Hills Risk/Benefit Analysis (CHRBA) (DOE, 1991d), summarized in Section 2.4.2 of the ESSE report, and the judgment of the unsaturated-zone hydrology peer review panel conducted by Freeze et al. (Freeze et al., 1991 [DOE, 1991g]). This observation illustrates an important aspect of the performance evaluations for the Yucca Mountain site. Calculations of releases under the range of expected values for hyrologic properties give results that are several orders of magnitude below the EPA release limits. [The ESSE Core Team recognizes that these calculations are, to some extent, model dependent.] In the case of the CHRBA, a structured approach was taken to determine the value of gaining new information about Calico Hills unit versus the potential for extensive excavation into the unit to adversely affect repository performance. Sensitivity studies were conducted to determine how "wrong" the hydrologic experts on the CHRBA would have to be about properties of the Calico Hills unit for current predictions to be completely wrong; i.e., for

11. Resolution *(To be completed by original Reviewer)*

The respondent explains the inconsistency between the Calico Hills Risk/Benefit Analysis (CHRBA) Team and the conclusions of the Unsaturated-Zone Hydrology Peer Review Team concerning the value of gaining new information on the Calico Hills unit. Performance evaluations such as CHRBA are often based on models, in which confidence must be developed. Data collections from the Calico Hills unit, as suggested by the Unsaturated-Zone Hydrology Peer Review

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 22
2. Page 2 of 3

3. Name David K. Kreamer
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

Calico Hills Characterization Risk/Benefit Analysis

Section 2.4.2 of the ESSE document reports on the study by DOE (1991) which was conducted to evaluate the potential impacts of testing in the Calico Hills Unit. The results of this study reflected, in part, a judgment that, according to the ESSE, "...little likelihood that information obtained by testing the Calico Hills unit would change the conclusions that EPA release limits would be met." Conversely, Freeze et al., 1991 [DOE, 1991g] state

> One of the most critical features of the conceptual hydrologic model for Yucca Mountain is the postulated ability of nonwelded tuffs to attenuate and retard transient moisture pulses. We encourage early field experimentation in the Paintbrush nonwelded tuff and the nonwelded tuffs of Calico Hills unit to investigate the validity of this mechanism.

This reviewer strongly supports the recommendation of Freeze et al. and believes that early characterization of the Calico Hills unit and Paintbrush nonwelded tuffs is of critical importance. Investigation should not be limited to surface studies and should be carried out within the next few years.

END OF TEXT

10 Proposed Resolution (continued)

calculations to produce releases at or above the EPA release limits. Under this set of assumptions, the CHRBA team reached the conclusion that new data from the Calico Hills unit was unlikely to cause release predictions to change from their current values that are well below the release limits, to values at, or exceeding the limits. This does not mean that collection of in situ or borehole data in the Calico Hills has no value. In fact, when a multiattribute approach was taken in the second phase of the CHRBA, it was concluded that testing in the Calico Hills would be likely to improve confidence in the hydrologic models that serve as part of the basis for predicting performance.

In the case of the Freeze et al. review (Freeze et al., 1991 [DOE, 1991g]), the panel was asked to review the current hydrologic conceptual models and plans for further hydrologic investigations without a specific focus on whether obtaining new information would change conclusions with regard to compliance with regulatory criteria. In this case, the recommendation that early field investigations of the Paintbrush nonwelded tuff and the Calico Hills unit would provide important tests of the validity of the conceptual hydrologic model is consistent with the conclusion of the CHRBA when confidence in hydrologic

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 22

2. Page 3 of 3

3. Name David K. Kreamer
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

models was considered in the analysis. An insert will be added to the text on p. 2-137 in the discussion of the Calico Hills Risk/Benefit Analysis referencing the conclusions of the Peer Review Panel, chaired by Dr. Freeze, with regard to the need for testing in the Calico Hills unit to establish if it attenuates and retards transient moisture pulses.

The current plans for site characterization include collection of extensive data on hydrologic properties of the Calico Hills unit, both from surface boreholes, and from as much as 19,000 feet of drifts trending northeast-southwest as shown on the attached diagram. This drifting is intended to provide access to the major structural features in and near the primary repository area, including the imbricate fault zone on the east, Ghost Dance Fault in the central area, and Solitario Canyon Fault on the west side.

See also the response to Dr. Drever's Comment #1 for a discussion of the diversity of reasons for gathering data about the Yucca Mountain site.

END OF TEXT

11 Resolution (continued)

Team and this reviewer would serve to calibrate and develop confidence in models used by the CHRBA Team. In the current ESSE document, the CHRBA initial findings are presented more fully than the suggestions of the Unsaturated-Zone Peer Review Team, leaving the impression that it is not important to proceed with data collection in the Calico Hills unit. This unequal presentation is probably due to the fact that the Unsaturated-Zone Hydrology Peer Review Team report was only recently available, (finalized in the summer of 1991). As noted by the respondent to this peer review comment, current plans call for extensive data collection in the Calico Hills unit, which seems less in line with the findings of the CHRBA Team as reported upon in the ESSE. Added knowledge of the nature and the properties of the Calico Hills unit will be important to the project, if higher-level suitability with respect to hydrology is ever to be considered.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 22
2. Date November 12, 1991
3. Reviewer David K. Kreamer
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section 2.4.3.3
7. Page 2-134 & 2-135
8. Paragraph (performance assessment)

9. Comment

Gaseous Movement, Part One - Radionuclide Movement to Ground Surface

Section 2.4.2 of the ESSE includes description of modeling approaches which were used to describe aqueous and gaseous releases (Performance Assessment Calculational Exercise, or PACE). The vapor modeling efforts predicted the expected releases for gaseous carbon-14 would be approximately 15% of the EPA release limit. However, the same studies indicated many potentially significant uncertainties existed and the probability of some gaseous releases exceeding the EPA limit was more than 10%, which is important because the EPA regulation specifies that the probability of exceeding the limits should not be greater than 10%.

The gaseous and semivolatile radionuclides which could undergo gaseous transport at repository temperatures include tritium, C-14, Kr-85, I-129, Rn-22, Se-79, Tc-99, Cs-135, and Cs-137. The nuclides which have a

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Kreamer that the performance of the site with respect to release limits for carbon-14 represents a potential problem, unless the waste package design concepts were changed dramatically to guarantee 10,000-year integrity or the EPA release limits are modified. This situation is believed to result, in part, from the unsaturated-zone disposal concept. The text in Sections 2.4.3.2 and 2.4.3.3 has been revised to state that current quantitative estimates of system performance (e.g., Shuman et al., 1991) approach the carbon-14 release limit. Current evidence also suggests (e.g., from Van Konynenburg) that the public health hazard associated with releases at the EPA limit would be insignificant, especially in comparison to natural sources of carbon-14. Since additional information may change the current conclusion, or EPA may revise the release limit for carbon-14, the ESSE Core Team believes that a lower-level suitability finding can be supported at this point. The last paragraph of Section 2.4.3.3 was changed to read:

11. Resolution *(To be completed by original Reviewer)*

The stringency of the EPA limit on gaseous carbon-14 release is said by some to border on the absurd. Yet, with the present regulatory structure, it is tenuous for the ESSE Team to support suitability of any kind for the Post-closure Guideline, unless the release limits are modified.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 22
2. Page 2 of 3
3. Name David K. Kreamer (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

sufficiently long half-life to be present in significant amounts after the 300 to 1000 year containment period are: C-14, I-129 and the semivolatiles Se-79, Tc-99, and Cs-135. Based on work presented by Dr. U-Sun Park, potential gaseous release of $^{14}CO_2$ from the reference conceptual design waste packages would likely exceed NRC and EPA limits. I-129 would likely undergo some gaseous release from waste packages, but the inventory will be less than EPA 10,000 year cumulative release limit. Tc-99 and Se-79 would probably be less important than C-14 or I-129 because of lower vapor pressures and dilution in spent fuel, and Cs-135 would likely be relatively absent in the vapor phase. It is estimated that some C-14 would be released from the waste container (spent-fuel matrix) and zircalloy cladding, and further release would continue with fuel oxidation.

The work of Weeks, Thorstenson, Trautz, LeCain and others indicates that there is potential for gaseous movement from the repository depth in the Topopah Springs Member to ground surface in the order of decades. Post-bomb gases have been found in the shallow unsaturated zone (<110m), and rapid flow is indicated. In deeper members (Topopah Springs) pre-bomb gaseous constituents are indicated and gaseous migration is thought to be dominated by diffusion processes. The Paintbrush non-welded tuffs seem to constitute a significant barrier to gas flow, although the influence of the thermal regime imposed by the repository is unknown. Van Konynenburg (1991) concluded that: gases could be rapidly transported through the unsaturated zone, that there was a potential for exceeding EPA release limits, and that the EPA limits were too stringent with regard to protecting human health and safety.

A discussion of nuclide migration in gaseous form is presented in balanced form in the ESSE document. The problem and its associated uncertainties are recognized by the ESSE authors, and better source term definition with perhaps control (more robust waste containers) is suggested in the ESSE. The stringency of EPA regulations with regard to gaseous movement is referred to in the ESSE, but no strong advocacy toward reevaluation of standards is promoted. This reviewer suggests that a clear, strong position on the relevance of existing gaseous standards be made by the technical team. The conclusions of the 1986 Environmental Assessment, which indicated that the expected 10,000-year release of radionuclides was likely to be less than the release limits specified in EPA standards, should be reexamined to account for the new appreciation of potential C-14 gaseous release. Little confidence can be associated with a finding of even low level site acceptability under current, strict regulatory constraints, and the present understanding of gaseous migration.

END OF TEXT

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10 Proposed Resolution (continued)

INSERT FOR PAGE 2-145

"The EPA has recognized that this limit represents a negligible public health and safety risk and may not be consistent with the public health and safety risks established in other standards (Clark and Galpin, 1991; Van Konynenburg, 1991). Thus, the release limits for carbon-14 may change, or it is possible that additional information about the source term could change the conclusion that the system guideline is met. Therefore, the Core Team feels that a lower-level suitability finding can be supported for the Postclosure System Guideline."

END OF TEXT

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9. Comment

Gaseous Movement, Part Two - Vapor Movement

The flux of water vapor in the vadose zone is a crucially important factor in understanding liquid water migration in the unsaturated zone at Yucca Mountain. Arguably the most important factor in the characterization of the site involves subsurface water movement and its sustainable flow to a repository location. Vapor flux has an important impact on subsurface water movement in two major ways: the near field impacts of water vaporization and recondensation, and the flux of water away from the site with associated drying of the vadose zone.

The volatilization of water due to the burial of heat generating waste and its subsequent recondensation will likely form zones of higher than normal moisture content at some distance from the waste packages. This process of creating moisture "umbrellas" or "envelopes" around waste drifts may be

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Kreamer notes that near-field redistribution of moisture due to the repository-induced thermal perturbation was not discussed in the geohydrology section and notes that additional clarification is needed. We agree, and a text insert has been prepared for Section 2.3.3, the Postclosure Rock Characteristics section, because this is where 10 CFR Part 960 focuses these types of concerns. The insert includes a discussion of important insights gained from recent modeling studies relating to fluid (both liquid and vapor) movement. The effects that are specific to features of the conceptual repository design, such as preferential flow in the region around the central access drifts or between panels, have not been addressed because the current conceptual design has not been accepted for further development, nor do we believe it is necessary to assume a specific design geometry in order to evaluate the postclosure guidelines. On p. 2-45, the first paragraph of the section titled "Hydrologic and Geochemical Characteristics" will be replaced with the following six paragraphs:

11. Resolution *(To be completed by original Reviewer)*

The near-field redistribution of moisture is important to consider both during and after the anticipated thermal pulse. The proposed addition to the ESSE document in response to several peer reviewers' comments is a good one. As is stated in the proposed addition to p. 2-45 of the ESSE, "the flow of water vapor and condensate driven by the heat of decay may dominate the ambient hydrological system," and "because of the low matrix permeability of the host

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9 Comment (continued)

augmented by disturbance and fracturing of the host rock up to several meters by the drilling of drifts to house and transport waste material. The accumulation of water at distance around drifts is potentially important, because of the recondensation process in cooler regions away from the waste packages, and redistribution of moisture which could cause positive water movement downward. Zones of liquid water near the repository could serve as a location for accumulation of radionuclides potentially escaping the engineered barrier system. Recent models of temperature distribution (Eric Ryder, Sandia) under several heating scenarios, including the current repository design 57 kilowatts/acre, indicate that spatially, heat will build up unevenly. Therefore, one can assume that the surrounding moisture "umbrella" will also be formed preferentially in spatially distinct, cooler regions. In Ryder's temperature simulations, the central drift, which in the current reference conceptual design is located between the major heat sources of the lateral drifts, could potentially be a zone of recondensation and liquid water flow. The creation or augmentation of vertically downward flow in and around the repository should be examined to anticipate "weeping" similar to that which occurs in G-tunnel and other tunnels at NTS. Near-field redistribution of moisture due to waste package temperature effects is not extensively discussed in the geohydrology section of the ESSE, perhaps because it is thought to be quantitatively nonsignificant, or perhaps because field measurements have not progressed far enough to reasonably quantify flow. This reviewer believes that some additional clarification of near-field moisture redistribution, particularly with regard to the central drift is appropriate.

Advective movement of water vapor through the unsaturated zone could also be a mechanism for drying, and hence reduction of the potential for downward, or lateral water flow in the vadose environment. The flux of water vapor out of the unsaturated zone directly addresses the issue of sustainability of water to a potential contaminant source, and travel time of water in unsaturated fractured material. Measurement of appreciable quantities of water vapor exiting subsurface at UZ6S indicates that this drying mechanism may be significant. Tracer techniques and infrared methods, such as those demonstrated by C. Johnson, may be useful in characterizing gaseous exudation from Yucca Mountain. Quantification of water vapor migration warrants additional attention in future site characterization efforts.

END OF TEXT

10 Proposed Resolution (continued)

"Much has been learned since the EA about the thermohydrological effects

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10 Proposed Resolution (continued)

that are anticipated from the dissipation of radioactive decay heat in the unsaturated fractured host rock. Numerical models have predicted the time-dependent temperature distribution within the host rock and surrounding hydrostratigraphic units for various repository design concepts, thermal loading densities, and waste receipt and operating scenarios (Ryder, 1990 and 1991; Ballou et al., 1990). Most of these models involve spatial and temporal superposition of heat conduction calculations to account for the emplacement of individual heat sources over the operational life of the repository and the radioactive decay. Areal power densities (APDs) ranging from less than 20 to greater than 100 kW/acre and average waste ages from 10 to 90 years have been modeled. These models do not account for fluid phase changes or heat transfer mechanisms other than heat conduction.

A field experiment to investigate the physical processes that should be incorporated into the models describing thermohydrologic and geochemical processes in fractured, porous, densely welded tuff was conducted at G-Tunnel on the Nevada Test Site (Buscheck et al., 1991b). The experiment used a heater placed in a horizontal orientation, and results show that predominant heat flow mechanism was heat conduction (Buscheck and Nitao, 1991b). Fractures appeared to serve as the predominant flow paths for gases and liquids, and fracture permeability to air increased somewhat due to the heating-cooling cycle. This experiment did not show any mechanisms or phenomena that would indicate that tuffaceous rock is unsuitable for siting of the repository.

Hydrothermal model calculations have been performed for a wide range of fracture and matrix properties in the unsaturated zone using simplified repository geometries. These models include boiling and condensation effects, convection of latent and sensible heat, and thermal radiation. In general, these models predict a drying-out of the near-field rock by boiling of the vadose water in the rock matrix and the flow of water vapor through fractures to cooler regions where it condenses. Because of the very low matrix permeability of the host rock, this condensate will drain considerable distances along fractures before it is totally imbibed by the matrix. The combination of vapor flow away from the heat source and gravity-driven condensate flow down fractures tends to promote shedding of condensate off the sides and away from the boiling zone. This condensate shedding effect was observed during the G-Tunnel heater experiment (Buscheck et al., 1991b; Buscheck and Nitao, 1991b).

Recent hydrothermal model calculations over a range of fuel ages and APDs (Buscheck, 1991) have shown the potential for significant boiling and rock

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10 Proposed Resolution (continued)

dry-out benefits for high APDs (i.e., APD > 80 kW/acre). For 60-year old pressurized water reacters (PWR) fuel and an APD of 114 kW/acre, these calculations show near-field temperatures remaining above boiling for 5,000 to 10,000 years, with the rewetting of the dry-out zone to ambient saturation requiring 100,000 to 200,000 years. The probability of fracture flow reaching a waste package is greatly reduced by near-field boiling conditions. While the dry-out zone is rewetting to ambient saturation, matrix flow will be directed back towards the repository. Buscheck (1991) found that much of the rewetting of the dry-out zone occurs from below the repository horizon. The resulting upward matrix flux below the repository will retard matrix-dominated radionuclide transport towards the water table.

For a range in expected repository fracture and matrix properties, hydrothermal calculations of the repository show the predominant heat flow mechanism to be heat conduction (Buscheck, 1991). The volume of rock dry-out and the duration of near-field boiling conditions was found to be dependent primarily on (1) the thermal properties of the unsaturated zone and (2) thermal loading conditions. Moreover, mass flux rates generated by condensate drainage for high APDs are much greater than current estimates of infiltration flux. The modeling study by Buscheck (1991) showed the duration of near-field dry-steam boiling conditions is insensitive to a wide range in infiltration flux and initial saturation distribution.

Buscheck (1991) found that, for APDs as low as 20 kW/acre, the flow of water vapor and condensate driven by the heat of radioactive decay may dominate the ambient hydrological system. Elevated temperatures and condensate drainage have the potential of driving geochemical changes that may significantly alter the flow and transport properties of the natural barriers underlying the repository horizon. Key concerns include whether hydrothermally induced zeolitization of the vitric nonwelded Calico Hills unit may significantly reduce its capacity to retard fracture-dominated flow. Because of the potential for substantial boiling and rock dry-out benefits at high APDs, the impact of these uncertainties may be significantly reduced.

END OF TEXT

11 Resolution (continued)

rock, this condensate will drain considerable distances along fractures before it is totally imbibed by the matrix." The drilling and emplacement of tunnels and drifts is projected to create fractures in the host rock surrounding the repository in addition to any naturally occurring fractures. The vaporization/ recondensation process has the potential to move water along these fractures

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11 Resolution (continued)

and concentrate this moisture, thus raising its fluid pressure and promoting gravity-driven flow. Cooling regions and associated condensation would surround the repository, and water movement would not only include "shedding... off the sides" and "rewetting of the dry-out zone... from below the repository" as stated in the proposed addition to p. 2-24, but also downward movement from water above the repository. Because of the distance separating the rows of drifts from either side of the central tunnel in the present conceptual design, heating will likely be spatially nonuniform, and overlying condensate will likely also be nonuniform; perhaps more concentrated in the region of the central drift. The response of the ESSE Team to the comment of this peer reviewer expresses some optimism on potentially beneficial near-field properties associated with heating/drying, based on hydrothermal modeling studies. Confidence must be built in these cited modeling studies, and their simplifying assumptions must be scrutinized and tested. Nonuniform heating of the repository environment remains a challenge and is certainly not well enough understood at present to warrant higher-level suitability findings.

END OF TEXT

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9. Comment

Flow of Water Through the Vadose Zone (Unsaturated Zone)*

The primary questions of time of travel and sustainability of flow through the vadose zone are central issues of importance to Yucca Mountain site characterization. This reviewer has several associated concerns, which are documented in the following list.

1. Modeling of flow in the vadose zone at Yucca Mountain has been to a large extent based on simplifying assumptions which have not been fully verified by field observations. There has certainly been a keen interest in the development of theoretical modeling approaches; these predictive approximations must be grounded in appropriate, defendable assumptions. It is this reviewer's observation that many assumptions used in Yucca Mountain vadose zone modeling need to be properly verified. Freeze et al. [DOE, 1991g], in their recent unsaturated zone peer review, specify that there needs to be continued

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team fully agrees with Dr. Kreamer that the predictive approximations associated with theoretical models must be well-founded on the basis of a systematic investigation that couples an integrated field and laboratory experimental program with a model development effort and that examines the underlying assumptions used to approximate the complex interactions controlling flow in the unsaturated zone.

To address this comment and Dr. Vogel's Comment #1, we have added the following to a new subsection in Section 2.3.1.5 called "Recommendations for Future Activities:"

"These data should be augmented with a coupled field and laboratory program that investigates the basic assumptions underlying the models used for the unsaturated zone and that evaluates plausible mechanisms for rapid flow through the unsaturated zone." (See paragraph 2, sentence 4 of proposed

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution by modification of Section 2.3.1.5 is acceptable, although the word "must" should replace the word "should." To achieve a credible scientific program, data generated MUST be coupled with field data and laboratory calibration and verification. Anything less would be offensive to all scientists involved with the project. It is good to hear the ESSE team's

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9 Comment (continued)

evaluation of the assumptions of pressure equivalency across the matrix/fracture interface and the acceptance of the concept of overlapping continua. On page 2-20, the ESSE document echoes this concern, stating that:

> To date, studies conducted to better understand fracture-matrix interactions have focused primarily on the development of conceptual models based solely on theoretical arguments. The resulting conceptual models generally incorporate a single-composite continuum approach, a dual porosity approach, or a discrete-fracture approach. These approaches are all predicated on simplifying assumptions that require continued evaluation.

The proliferation of computer code usage without complete field calibration, can serve some useful heuristic purposes, but future field evaluations may show many modeling assumptions to be inappropriate. In order to encourage cost effective modeling, field and laboratory evaluations of modeling assumptions should receive more attention.

* Point of clarification: this reviewer believes that the standard use of the term "unsaturated zone" is somewhat misleading and not optimal, particularly with regard to Yucca Mountain which has zones of high moisture content within the vadose zone. For this review the terms "unsaturated zone" and vadose zone are used interchangeably.

END OF TEXT

10 Proposed Resolution (continued)

resolution to Dr. Vogel's Comment #1.)

For several reasons, the ESSE Core Team did not consider it appropriate to change the word "should" to "must" in the previous text insert, as requested by Dr. Kreamer in his resolution statement. Because postclosure performance of a repository involves reliance on both natural and engineered barriers, the extent to which hydrologic conditions "must" be fully understood and modeled is, in part, controlled by the extent to which the natural setting is expected to contribute to safe performance of the repository. Therefore, we are hesitant to state that all models "must" be calibrated by field and/or laboratory evaluations, because there may be cases where reliance on bounding calculations, without extensive validation, is appropriate. In addition, gaining confidence in the reliability of 10,000-year predictions may require innovative approaches to validation (e.g., natural analogs), and we do not want to imply that only traditional methods are acceptable. A final reason for our reluctance to use the word "must" is that it might suggest the Core Team is in

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10 Proposed Resolution (continued)

a position to make committtments for the DOE, rather than our appropriate role, which is to make recommendations to the DOE for their consideration.

END OF TEXT

11 Resolution (continued)

enthusiastic agreement.

END OF TEXT

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9. Comment

2. One focus of the Yucca Mountain unsaturated zone site characterization is the area of fracture/matrix interactions, which is well documented in the ESSE and given a balanced presentation. The ability of a fracture to sustain flow has been demonstrated to be inversely related to imbibition of water into the rock matrix, as controlled by matrix wetting diffusivity. Field evidence suggests that water pulses can be transmitted to significant depths at Yucca Mountain (Flint, 1989; Norris, 1989). The possible attenuation of these water pulses, if downward moving water is intercepted and redistributed, is extremely important to quantify.

This reviewer commends ongoing efforts to more adequately characterize imbibition of water into the host rock matrix, particularly with consideration for chemical alteration which may occur inside fractures. The ESSE comment on p.2-21, where it is stated that the validity of applying the Richards' equation to fracture-matrix interactions needs to be determined, is quite suitable if

10. Proposed Resolution *(To be completed by ESSE Core Team)*

We endorse Dr. Kreamer's comment that future emphasis should be placed on fracture dominated flow and dual porosity flow. The various elements contained within the discussion of Issue 1 is intended to convey the need for emphasizing flow in "fast paths." Additionally, we recognize the need to be able to quantify the attenuation and redistribution of transient water pulses occurring through these fast paths.

To address this and other comments, we will add the following to a new subsection in Section 2.3.1.5 called Recommendations for Future Activities:

"Spatial and temporal variations in the hydraulic characteristics and in the fracture characteristics associated with the welded, nonwelded, and bedded tuffs located above and below the repository horizon should be quantified." (See paragraph 2, sentence 4 of the proposed resolution to Dr. Vogel's Comment #1.)

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution by modification of Section 2.3.1.5 is acceptable.

END OF TEXT

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9 Comment (continued)

any confidence is to be placed in the modeling results. This reviewer also suggests that modeling and field efforts center on "fast" flow paths, specifically fracture flow mechanisms which could result in short travel times. At Yucca Mountain, anomalously high values of chlorine-36 and tritium have been encountered at hundreds of meters depth. Many tunnels in the area have fractures which transmit water, particularly in Rainier Mesa at NTS (including G-tunnel). This indicates the possibility of quick and sustainable flow. Fractures which transfer water into the tunnels may be encountered at Yucca Mountain, and therefore modeling efforts should rightfully, as the ESSE suggests, focus on those mechanisms which provide or inhibit fast, sustainable flow. Due to small matrix permeability at Yucca Mountain, matrix-dominated flow should not result in significant vertical movement of radionuclides, hence future studies should concentrate on fracture dominated flow and dual porosity flow.

END OF TEXT

10 Proposed Resolution (continued)

Additionally, paragraph 2, sentence 2 of the new section will state the following:

"Site-specific data are required to understand and quantify, where possible, the mechanisms controlling the spatial and temporal distribution and magnitude of infiltration and the processes controlling the attenuation and redistribution of transient pulses of water."

END OF TEXT

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9. Comment

3. Little discussion is given in the ESSE geohydrology section on the possible changes in fracture permeabilities which could occur with time. Fracture coatings, which affect fracture aperture size and ability of the matrix to imbibe water, may accrete or be removed with time, particularly under the influence of vapor flux and drying. Spatial variation of fracture coatings is mentioned in the ESSE in the context of a discussion on the validity of Richard's equation, but temporal variation is not emphasized. This reviewer suggests that temporal variation of fracture properties be carefully considered.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Kreamer has appropriately identified an omission in the discussion on the effects of fracture coatings on fracture permeability and on fracture-matrix interactions. We agree that temporal changes to fracture permeabilities are an important aspect that must be considered as part of the discussion on fracture-matrix interactions.

To resolve this comment, we will revise the sentence beginning on line 6, page 2-21, paragraph 3 as follows:

"Wetting and drying transients in unsaturated fractures and temporal changes in fracture coatings may greatly complicate the process."

In addition, we will add the following to a new subsection in Section 2.3.1.5 called "Recommendations for Future Activities:"

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution of the omission, by modification of Section 2.3.1.5, is satisfactory.

END OF TEXT

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10 Proposed Resolution (continued)

"Spatial and temporal variations in the hydraulic characteristics and in the fracture characteristics associated with the welded, nonwelded, and bedded tuffs located above and below the repository horizon should be quantified." (See paragraph 2, sentence 4 of proposed resolution to Dr. Vogel's Comment #1.)

END OF TEXT

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9. Comment

4. Studies of preferential flow are crucial to an understanding of vadose flow at Yucca Mountain. Variation in fracture aperture width and spatial distribution of fractures can promote accelerated migration of water due to preferential flow. Possible factors affecting liquid flow along preferential pathways include: the degree of continuity in fracture networks, dispersion or concentration of flow in fracture networks, and the degree of fracture-matrix interaction. This has been well recognized and reported in the ESSE document. Preferential flow is one of the most decisive issues in developing a credible conceptualization of flow. The inherent heterogeneities in the natural Yucca Mountain system will contribute to the development of preferential flow paths, but these heterogeneities may be impossible to completely predict. The development of stochastic models which assign probabilities to flow scenarios is an important corollary step which has been undertaken.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Kreamer's comment, which identifies the importance of preferential flow. No modifications to the text are proposed at this time.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

The agreement on the importance of preferential flow is noted.

END OF TEXT

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9. Comment

5. Just as preferential flow paths induced by fracture distribution are important to an understanding of vadose flow at Yucca Mountain, studies of wetting front instability are potentially pivotal. Fingering of water flow can lead to a dramatic effect on flow in unsaturated fractured media. It is encouraging that study of these effects are being pursued in the Yucca Mountain site characterization; it is not encouraging that so few modeling approaches have provisions for this gravity driven fingering of liquid water, which can allow large portions of the vadose zone to be bypassed.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Kreamer's comment that gravity-driven fingering and other mechanisms that may allow significant volumes of water to bypass the unsaturated zone may be extremely important. A systematic laboratory and field program to investigate this phenomenon is underway as part of a model validation program, which is intended to provide the necessary insight into these processes and to develop the conceptual and mathematical models necessary to address these processes.

To address this comment and Dr. Vogel's Comment #1, we will add the following to a new subsection of Section 2.3.1.5 called "Recommendations for Future Activities:"

"These data should be augmented with a coupled field and laboratory program that investigates the basic assumptions underlying the models used for the unsaturated zone and that evaluates plausible mechanisms for rapid flow through

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution by modification of Section 2.3.1.5 is acceptable. As noted in #4 above, the word "should" (which is used freely throughout the modification to Section 2.3.1.5) is particularly inappropriate in this application. Models <u>must</u> be calibrated to field conditions and verified. Replacement of the word "must" with "should" bodes ill, particularly in the

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10 Proposed Resolution (continued)

the unsaturated zone." (See paragraph 2, sentence 4 of proposed resolution to Dr. Vogel's Comment #1.)

As indicated in our response to Dr. Kreamer's resolution statement for Comment #4, the ESSE Core Team did not consider it appropriate to change the word "should" to "must" in the previous text insert, as requested by Dr. Kreamer in his resolution statement. Because postclosure performance of a repository involves reliance on both natural and engineered barriers, the extent to which hydrologic conditions "must" be fully understood and modeled is, in part, controlled by the extent to which the natural setting is expected to contribute to safe performance of the repository. For this reason, we are hesitant to state that all models "must" be calibrated by field and/or laboratory evaluations, because there may be cases where reliance on bounding calculations, without extensive validation, is appropriate.

END OF TEXT

11 Resolution (continued)

face of any future austere federal budgets.

END OF TEXT

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9. Comment

6. Field bacterial studies have centered on the enumeration of rock-bound microbes. These studies, among other benefits, elucidate the consumption of terminal electron acceptors such as oxygen in the rock matrix. The fact that microbially mediated oxidation-reduction reactions are potentially significant has been recognized by many researchers. A lower emphasis has been given to enumeration of non rock-bound microbes at Yucca Mountain, that is, microbes in the moving aqueous phase at depth. In fractured rock contaminant flow, facilitated transport due to attachment of pollutants to small particles in the aqueous phase can strikingly increase the potential for migration. It has been recognized that plutonium and americium can form colloids, and chemical changes in plutonium may be microbially mediated. Studies of colloidal particles, particularly field microbial enumeration in subsurface water (including projected changes in the amount of particles) should, in this reviewer's opinion, be given more emphasis in site characterization planning,

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Microbial transport or retardation of radionuclides have been recognized as potential mechanisms at Yucca Mountain and is the subject of the study plan for Biological Sorption and Transport. However, little has been learned about this potential since the EA, i.e., no new information has been gathered that would alter our recommended position regarding any 10 CFR Part 960 system or technical guideline. As a result, this topic was not addressed in the ESSE report. The text revisions proposed to describe plans to address this topic are given at the end of this response.

In the Biological Sorption and Transport study plan, no distinction is made between attached or rock-bound versus free-living or non-rock-bound microorganisms. Rather, the plan proposes the study of introduced and indigenous organisms regardless of life style and their potential effects on the transport of key radionuclides, principally actinides. Furthermore, this study plan specifically addresses the role of microorganisms in the colloidal

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution of this comment by modificaion of the ESSE text is satisfactory. This reviewer still wishes to express some concern that microbial enumeration efforts at Yucca Mountain have not yet made distinction between an unattached organisms, which might act as colloidal particles for contaminant transport, and attached microbes or microbial consortia (perhaps

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9 Comment (continued)

as opposed to simply studies of microbes attached to the rock matrix.

END OF TEXT

10 Proposed Resolution (continued)

transport of the actinide elements (Section 1.1.4 of the study plan). It should be emphasized that the microbiological transport study addresses chelation, sorption, and colloidal dispersion.

The following text will be added to Section 2.3.2.3.2.5:

"Microorganisms also may affect the transport of actinide elements in one or more of the following ways by:

1. Altering the composition of the ground-water chemistry through changes in pH or Eh and production of metabolites such as CO_2, H_2S, NH_3, and NO_3

2. Producing chelating agents that can solubilize radioactive elements

3. Transporting radioactive elements via biological movement

4. Affecting the colloidal transport of radioactive elements

5. Sorption of the radioactive elements onto a nonmotile solid phase, thereby retarding the transport of the radionuclide

6. Plugging pores in the host matrix, thereby retarding the movement of ground-water

Batch sorption experiments (Hersman, 1986) have demonstrated that bacteria were able to remove actinide elements from solution. In these experiments, the bacteria, on a per-gram-dry-weight basis, sorbed Pu(IV) nearly 10,000 times greater than crushed tuff. It is possible that microorganisms may strongly sorb significant quantities of the actinide elements and transport these elements via microbial motility. In fact, early studies demonstrated that microorganisms were able to penetrate 4.0-mm-thick wafers of tuffaceous rock taken from the Calico Hills unit.

Hersman (1988) demonstrated that in the presence of microorganisms, the formation of colloidal agglomerates was significantly accelerated. This may be an important observation regarding radionuclide transport by colloidal

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10 Proposed Resolution (continued)

particles. Agglomerated particles more readily settle out of suspension or become entrapped in small pore openings in the rock matrix. It is therefore entirely possible that, in the presence of microorganisms, transport by colloidal particles would be retarded by these processes.

Microorganisms can strongly influence the movement of metals through soils. One mechanism is the microbial production of powerful chelating agents, called siderophores, that may solubilize otherwise very insoluble cations, e.g., Fe(III). In the last three decades, over 80 siderophores have been isolated and characterized, and binding constants have been reported to be as high as 10^{52} (Neilands, 1974). Neilands (1981) believes that because Fe(III) and Pu(IV) are similar in their charge/ionic-radius (4.6 and 4.2, respectively), Pu(IV) may possibly serve as an analog to Fe(III) and could therefore be solubilized by siderophores. Results of experiments demonstrate that a siderophore produced by a soil microorganism isolated from Yucca Mountain form complexes with Pu(IV). It is possible that actinide elements could be transported in the environment via the siderophore transport system.

Work continues on the development of a biological transport term, but evidence does not suggest that such a term would alter the current view of geochemical characteristics and processes in the Yucca Mountain region."

END OF TEXT

11 Resolution (continued)

enshrouded in glycocalyses).

END OF TEXT

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9. Comment

7. The ongoing studies of infiltration at Yucca Mountain are an essential component of site characterization. These studies have been hampered by the several years of drought in southern Nevada, but they are vital to a clear definition of temporal and spatial distribution of water flux into the subsurface. The work of Flint (USGS) and others is well documented in the ESSE, and the importance of this area of research is evenly discussed. Elevated tritium and downward hydraulic head gradients (29A-1) near 40 Mile Wash are particularly suggestive of infiltration. Mention is made in the ESSE of the studies by Sass et al. who reported a temperature profile for well UE-25 a#7 in Drillhole Wash which was altered to approximately 150 m depth during a heavy rainfall event. This temperature alteration was attributed to significant lateral infiltration to the fractured, densely welded tuff of the Topopah Springs Member. High intensity, episodic infiltration events are an important concern. Again, to the credit of the authors of the ESSE, the infiltration studies are regarded as an indispensable and integral part of

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The authors appreciate Dr. Kreamer's compliment. No modifications to the text are proposed at this time.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Noted.

END OF TEXT

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9 Comment (continued)
the research plan.

END OF TEXT

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8. Paragraph

9. Comment

8. The calibration and verification of unsaturated and saturated flow models may never be able to be adequately accomplished, because site heterogeneities may cast doubt on the representativeness and universal site applicability of some field measurements (e.g., fracture analysis). In 10 CFR 960.4-2-1, potentially adverse conditions for site suitability include mention of complicating heterogeneities. The use of water quality parameters as environmental tracers may remedy this situation by giving an independent estimate of travel times and flow retention. Chemical tracers for groundwater flow can include isotopes and isotopic ratios, anthropogenic compounds, and many other chemical parameters. Dating tools such as carbon, oxygen, hydrogen, strontium, and lead isotopes and isotopic ratios, fluorocarbons, chloride/bromide ratios, and chlorine-36 can also be effective. For example, age differences in subsurface waters near 40-Mile Wash have raised some interesting questions. A strong effort to identify all potential tracers for Yucca Mountain is warranted.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Kreamer that calibration and verification of saturated and unsaturated flow models are very difficult and technically challenging tasks for many reasons, including those cited. Although only limited site-specific data have been acquired over the last five years, some of these data (i.e., chlorine-36 and tritium) have clearly demonstrated the utility of using tracers to develop an understanding of the flow processes and mechanisms operational at the site. Contingent on the availabilty of funds, this work will continue in the future as drilling is reinitiated and as access to the primary subsurface units is gained by underground construction. Additionally, a program is being implemented to identify tracers that will be used and that have utility as a means to develop further understanding of these complex processes.

Work has also been initiated to develop capabilities to extract and characterize pore water from both nonwelded and welded tuffs. At this time,

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution by modification of Section 2.3.1.5 is acceptable.

END OF TEXT

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9 Comment (continued)

There is a serious problem for modeling chemical processes associated with the aqueous phase in vadose fractured rock at Yucca Mountain in that, to date, most pore water data are from nonwelded tuffs. More water quality information from the vadose zone is needed. Also, the 18 or so water table wells (WT series) should be more rigorously sampled, in spite of problems with drilling fluid, etc. These water table wells constitute a bottom boundary condition on the vadose zone, and the water quality at the water table is much more relevant to issues of water table recharge and vadose zone gaseous concentrations than deeper well water. This reviewer urges project scientists to sample the water table wells thoroughly.

END OF TEXT

10 Proposed Resolution (continued)

only very preliminary results (unpublished) are available using these new capabilities. Plans have been formulated to sample many of the holes for pore water chemistry as part of the DOE's Integrated Drilling Program.

To address this comment and Dr. Vogel's Comment #1, we will add the following to a new subsection in Section 2.3.1.5 called "Recommendations for Future Activities:"

"Water chemistry data from both the unsaturated and saturated zones should be obtained to better understand and constrain the assumptions associated with chemical processes and gaseous flow in the unsaturated zone and to provide boundary conditions for modeling these processes. Additional hydrologic testing within the saturated zone is necessary to characterize the dominant processes controlling flow to the accessible environment. Existing water table holes and those proposed for the future should be used for additional hydrochemical characterization."

(See paragraph 2, line 22 of proposed resolution to Dr. Vogel's Comment #1.)

END OF TEXT

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7. Page 2-25ff
8. Paragraph NA

9. Comment

9. Another vadose zone issue which is presented and discussed in the ESSE includes sorption in the vadose zone. The study of sorption in the zeolitic tuffs is appropriate, as zeolites are adsorptive for cesium and other compounds, and will survive the thermal pulse from the buried waste. Sorption of potentially leaking contaminants will increase projected travel times. ESSE coverage of this issue, in this reviewer's estimate, is balanced and does a commendable job in relating this phenomena to model adequacy.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team appreciates Dr. Kreamer's support.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Noted.

END OF TEXT

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9. Comment

13. The importance of identifying horizontal, or near horizontal layers of moisture (and perhaps perched zones) in the vadose zone cannot be overemphasized. These layers, which could conceivably range from slightly higher than ambient moisture content laminae to perched aquifers, might have important ramifications to fluid movement in the vadose zone. For example, high moisture content could completely occlude pore space and serve as a barrier to gaseous migration. If these high moisture zones are large, positive water pressure could build up and greatly influence vadose zone water flow. If vadose zone water layers are unexpectedly large, discovered perched groundwater zones might reflect: 1) a potential water source and b) perched water tables which might be directly relevant to the language of "Potentially Adverse Conditions" in 10 CFR 960.4-2-1. Unlike attempting to gain an understanding of vertical geologic features (which might be difficult to accomplish due to heterogeneities and the spatial nature of drilling), identification of horizontal or near horizontal layers should be easier. The relevance of this

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The occurrence and potential consequences of perched-water bodies or zones of anomalously high saturation are not explicitly addressed in either the Postclosure or Preclosure Geohydrology Guidelines, although the Favorable Condition 960.4-2-1(b)(5)(i) of the Postclosure Guideline requires "A low and nearly constant degree of saturation in the host rock and in the immediately surrounding geohydrologic units," and other conditions (See (b)(5)(iv)) refer to free drainage. The EA concluded that (b)(5)(i) was <u>not</u> present at the Yucca Mountain site because saturation is expected to be spatially variable in the host rock and in the surrounding geohydrologic units. Spatially variable saturation could include perched-water bodies, of course, whose presence, however, need not necessarily degrade or otherwise disqualify the site. At issue is whether perched water, if present, would pose adverse consequences for waste containment and isolation in the side unsaturated-zone. Perched water is acknowledged in the evaluation of the Preclosure Geohydrology Guideline but only in the context of its possible implications for repository construction

11. Resolution *(To be completed by original Reviewer)*

The reviewer basically agrees with the respondent and further believes that any perched water table, which might be discovered at Yucca Mountain, appears to be at this time highly unlikely to provide a "source of ground water suitable for irrigation or human consumption without treatment along flow paths to the accessible environment" (Federal Register, Vol. 49, No. 236, p. 47733, 47734). According to the respondent, planned site characterization activities

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9 Comment (continued)

projected work to the overall site characterization cannot be overstated in the ESSE; the present limitations of our understanding of horizontal saturated layers represents an important gap in the current hydrogeological assessment.

END OF TEXT

10 Proposed Resolution (continued)

and operation.

With respect to site suitability, the most important consequences of perched water or of zones of high saturation will be their contribution to the formation of sustained ground-water-flow pathways that could preferentially direct water to the repository or could transport radionuclides from the repository to the water table. These possibilities are implicitly subsumed under Technical Issue 1 of the Postclosure Geohydrology Guideline evaluation. The DOE fully recognizes the possible adverse consequences if extensive perched-water bodies could be sustained above, below, or at the repository. If perched water is likely to occur at the repository horizon, however, such occurrences presumably would contravene the Favorable Condition 960.4-2-1(b)(5)(iv) requiring "a host rock that provides for free drainage."

The most likely sites for perched water in the unsaturated zone at Yucca Mountain probably are within the nonwelded tuff units lying between the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff. The planned surface-based drilling program to be conducted as part of the overall site-characterization program will actively seek to determine the presence of horizontally extensive perched-water bodies and of zones of enhanced saturation within the unsaturated zone at the Yucca Mountain site. In addition, the excavations associated with the Exploratory Studies Facility will provide an opportunity to look for occurrences of perched water within the host rock and the underlying Calico Hills unit. A discussion of these planned site-characterization activities is beyond the scope of the ESSE report.

END OF TEXT

11 Resolution (continued)

to assess potential perched zones under Yucca Mountain are beyond the scope of the ESSE document, but those projected activities do serve as one indication of the limits of our present knowledge of the site's vadose zone, of the reliability of past and projected modeling efforts, and of the early site suitability. Certainly the projected site characterization activities and the level of support for those activities could demonstrate the extent of which, in the words of the respondent, "The DOE fully recognizes the possible adverse

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11 Resolution (continued)

consequences if extensive perched aquifers could be sustained above, below or at the repository." Projected engineering alternatives with regard to the vadose zone could also be indicative of the level of early site suitability. For example, the ability of engineered shallow or deeply penetrating wells to control, drain, or modify any discovered perched aquifers, is directly pertinent to suitability. Non-intrusive procedures can be carried out at the site to further the goal of evaluating the occurrence and extent of perched water, and this ability in itself represents a measure of early site suitability. For example, repeating downhole video photography of boreholes at Yucca Mountain (which have not been photographed for several years) is one non-intrusive measure which could identify wetted zones, seeps or cascading water. The proposed addition to Section 2.3.1.5 regarding "Recommendations for Future Activities" addresses the vadose zone aspects of site characterization more completely than in the original ESSE draft, and is acceptable, though nonspecific.

END OF TEXT

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7. Page 2-24
8. Paragraph (Issue 2)

9. Comment

SATURATED ZONE

Technical concerns relating to the zone under the regional water table, that is, the groundwater zone or unconfined regional aquifer include: 1) groundwater travel time to an offsite location, 2) upwelling of the regional water table, and 3) the existence and effect of a large hydraulic gradient to the north of the Yucca Mountain site.

1. Pre-waste emplacement groundwater travel time is directly addressed in 10 CFR 960.4-2-1 as a disqualifying condition, with expected travel times less than 1,000 years constituting a disqualification. In this reviewer's judgment, current estimates of pre-emplacement groundwater travel time are based on models with assumptions which have not been verified by field observation. A variety of models have been proposed with travel time predictions which vary by many orders of magnitude. The ESSE cites modeling studies where estimated

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that a very important aspect of predicting groundwater travel times is the development of models that properly represent the processes controlling flow in both the saturated and unsaturated zones. A significant objective of the site characterization program presently planned is to collect the information needed to build confidence in the models used to make these predictions. Additionally, laboratory studies are being pursued to test basic assumptions that have been incorporated in many of the models presently being applied for this purpose. It is important to recognize that the results that have been completed to date are strongly contingent on the assumptions used to formulate the analyses, a limited understanding of ambient site conditions, and a limited understanding of likely future conditions at the site. Additionally, it is important to recognize that the disqualifying condition for Postclosure Geohydrology in 10 CFR Part 960 contains the phrase "and significant" specifically to preclude disqualifying a site prematurely before adequate site characterization is completed (see Section 2.3.1.1 of ESSE

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution by modification of Section 2.3.1.5 is acceptable.

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9 Comment (continued)

travel times ranged from less than one year to over 6,000,000 years. According to J. Czarnecki (pers. comm.) who cited estimates of Barr and of Kaplan, approximate travel time estimates could reasonably range from 100 years to 20,000 years, or more, depending on factors such as porosity distribution. Many models assume horizontal groundwater flow under the site, which may not be the case. This reviewer agrees with the ESSE authors that "...analyses have been conducted with a limited hydrologic data set using models that may not correctly approximate the dominant conditions at the site" (p.2-24). This reviewer disagrees with the statement on the same page of the ESSE that "matrix flow is likely to dominate"; there is no persuasive and certainly no conclusive evidence at this time to support such a conclusion (which has a tremendous impact on the decision on site suitability). This reviewer agrees with the consensus of the ESSE team that the available evidence does not at this time support a finding of high level suitability or a finding of unsuitability for either the geohydrology qualifying or disqualifying conditions. It is also uncertain at this time, in this reviewer's judgment, that Geohydrology, Favorable Condition 3, (that is, the geohydrologic system will eventually be able to be readily characterized and modeled with reasonable certainty), is a condition that will be able to be achieved. The lack of site specific field data makes such appraisals speculative at this time. Hydrologic testing of the saturated zone is imperative.

END OF TEXT

10 Proposed Resolution (continued)

Report for discussion of this point).

We also agree that the dominant processes controlling flow in the unsaturated zone (fracture-dominated versus matrix-dominated) may have a significant effect on site suitability if other conditions (e.g., sufficient water to sustain flow, interact with the waste package, and transport waste to the accessible environment) are prevalent. The site characterization program is expected to acquire the necessary and appropriate information to assess whether these conditions are likely.

To clarify the intent of the comment pertaining to "matrix flow is likely to dominate," we have added the underlined phrase as a proposed revision to the text on page 2-24 (Issue 2):

"The results of ground-water travel time analyses indicate that for conditions expected at the site, <u>and for the assumption that matrix flow dominates</u>, the travel times are likely to exceed 1,000 years along paths of

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10 Proposed Resolution (continued)

likely and significant radionuclide travel."

We also recognize the need for a comprehensive and systematic site characterization program that considers both the unsaturated and saturated zones to reduce the uncertainty to levels that are acceptable to a regulator responsible for issuing a license for a potential repository. The recommendations for future work (see proposed resolution to Dr. Vogel's Comment #1) is intended to address additional site characterization needs.

END OF TEXT

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2. Estimates of upward water table movement can potentially involve issues of climate change, tectonic movement, earth tides, barometric fluctuations, and geochemical interpretation. Recent measurements of water table movement indicate that the effects of earth tides and barometric fluctuations are small. This reviewer would suggest that it may be not appropriate to draw many conclusions about paleohydrology from a single trench (#14) dug near Yucca Mountain, which might not be hydrogeologically representative of the entire area. This may be particularly true when topographic low points and pertinent strata might cause spring flow for a hypothetical rising water table to issue elsewhere. This reviewer will defer to other members of the peer review team to assess the effect of climate change, tectonic movement, and associated geochemical interpretations on hypothetical rising water table at Yucca Mountain.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The bottom paragraph of page 2-95, which may have been the basis for this comment, referred to the calcite-vein deposits only in the context of their proposed (Szymanski, 1989) role of supporting the cyclicity of tectonic processes in the Yucca Mountain area. Because of its notoriety, Trench 14 has certainly been prominent in the recent literature, but it by no means represents the entire basis of the Szymanski theory (see ESSE Section 2.3.7.3.2.4) nor of the paleohydrology interpretations or plans of the project. Sections 2.3.4.3 and 2.3.4.4 of the ESSE provide a much broader discussion of the information that is pertinent to the paleohydrology of this region.

No changes to the text will be made in response to this comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment accepted. The original peer review comment was made in regard to the recent literature and not directly in reference to the ESSE document.

END OF TEXT

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9. Comment

3. Yucca Mountain is underlain by two aquifers, a water table aquifer in volcanic tuffs and a deeper, more transmissive, semiconfined carbonate aquifer (Fridrich, 1990). While the water table underlying Yucca Mountain has been shown to be of relatively flat gradient (0.0001), north of Yucca Mountain (upgradient hydrologically) the water table has a dramatic rise of 250 to 300 meters with a much steeper gradient of 0.15, trending northeast under north-central Yucca Mountain. North of this steep rise (further upgradient), there is a medium hydraulic gradient of 0.015. The genesis, variability, and stability of this steep hydrologic gradient is poorly understood. There are several troubling aspects to this gradient which, due to the lack of site specific data, can only be speculated upon at this time. One pertinent element is that the flatter water table may indicate a hydraulic conductivity facies change, from lower conductivity upgradient of the site, to higher hydraulic conductivity under the site. Hydraulic conductivity under the site is a key issue, particularly if flow is not entirely matrix dominated (i.e., might have

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Kreamer raises two valid concerns related to the configuration of the potentiometric surface (approximately the water table) in the vicinity of the site.

The first concern is whether the small gradient beneath the site indicates large, fractured-controlled hydraulic conductivity. Fracture-controlled, at least moderate and perhaps rather large, hydraulic conductivity in the <u>saturated</u> zone beneath the site has been acknowledged, as is discussed in the last three paragraphs of Section 2.3.1.3.1 (pages 2-10 and 2-14) and in the middle paragraph of page 2-16. The topic receives little discussion because the saturated zone has long been considered to be only a secondary barrier to waste migration, and therefore little new work has been directed at saturated-flow characteristics since the EA was completed. Recently, interest that has yet to be expressed in the formal, approved planning has redeveloped for several reasons. One of these reasons is the significance of the large

11. Resolution *(To be completed by original Reviewer)*

The proposed resolution by modification of Section 2.3.1.5 is acceptable.

END OF TEXT

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9 Comment (continued)

potential for shorter travel times under an imposed gradient). In the multitude of scenarios which could be formulated related to the steep gradient, some could be interpreted as detrimental to site hydrologic isolation. For example, a small, constrained drain from the steep hydraulic gradient southward into the repository vadose zone could supply localized water and, if small enough, such a lateral drain might have little effect on the maintenance of upgradient hydraulic head and constant supply. Many flow possibilities and interpretations can be devised, but certainly must be considered hypothetical at this time. Probably most important from a project point of view, understanding the steep hydrologic gradient near Yucca Mountain will certainly be a necessary ingredient in maintaining the scientific credibility of site characterization.

END OF TEXT

10 Proposed Resolution (continued)

hydraulic gradient, discussed on pages 2-16 and 2-100 (in both places, paragraphs beginning "Fridrich et al..."). In the second discussion, mention is made of the proposal that the small gradient beneath the site, rather than necessarily indicating large transmissivity, may result--at least in part--from downward diversion of flow from the volcanics into the underlying Paleozoic carbonates along a fault zone that underlies the large gradient north of the site; that is, the small gradient may represent small flux in the volcanics. Unless this can be demonstrated by future hydrogeologic and hydrochemical exploration, for which plans are being proposed, we must assume that fast pathways are likely in the saturated zone. This is not necessarily adverse, however, as the implied large hydraulic conductivity would also protect the site from a water-table rise under credible flux conditions.

The second concern is also addressed briefly by Fridrich et al. (1991), though not in quite the same sense as in this comment--that southward "fingering" from the higher saturated zone in the north into the unsaturated zone at the site could be sustained if the leakage were relatively small but the supply from the higher saturated zone were large in comparison. This is an interesting scenario that merits consideration. We believe that the developing plans for hydrogeologic and hydrochemical characterization of the gradient zone and the drilling precautions to identify and sample perched water will identify such occurrences if they exist.

In the third paragraph of the new recommendations section of Section 2.3.1.5, the following will be added: "With respect to redistribution of water and occurrence of flow paths in the unsaturated zone, the conditions

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3. Name David K. Kreamer (Print Name)
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

under which perched water may occur or develop in the future merit careful attention. With respect to saturated-zone conditions, the large hydraulic gradient north and west of the potential repository site and the very small gradient beneath it require understanding and evaluation."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 17 of 22
2. Date November 12, 1991
3. Reviewer David K. Kreamer
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section Preclosure - general
7. Page 3.3.3-14ff
8. Paragraph

9. Comment

PRECLOSURE

This reviewer agrees with the ESSE team evaluation that preclosure considerations of surface water, groundwater conditions, water availability and water rights issues are consistent with recommendations of higher level suitability findings. Although Freeze et al. expressed some concern over surface flooding potential being enhanced by construction of several structures on the site, this reviewer believes proper RAT engineering measures can be provided to mitigate the potential for serious flooding. Although RAT can mitigate some subsurface groundwater conditions which are able to be anticipated, the possibility of perched aquifers near the repository location has not been eliminated. As a result, the absence of perched aquifers between the host rock and the land surface, (10 CFR 960.5-2-10, Favorable Condition #1) cannot, in this reviewer's judgment, be assured at this time. The reviewer is pleased to see that site housekeeping issues with regard to drilling, (concerns

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Kreamer that the possibility for perched water bodies cannot at present be eliminated. This is so stated in a discussion presented on page 3.3.3-22 (first paragraph). Although the Environmental Assessment (DOE, 1986) did take credit for presence of favorable condition #1 at the site, this report did not explicitly reevaluate the favorable and potentially adverse conditions of 10 CFR Part 960 (see Section 1.2.3 for explanation). It should be recognized that the Preclosure Hydrology Technical Guideline is principally concerned with whether surface or underground hydrologic conditions could require technology that is not reasonably available. This is the basis for the conclusion presented in the report: "It is not expected that perched water, if encountered, will pose any problems that cannot be accommodated by RAT." However, this conclusion is not intended to declare that no perched water bodies will be detected during underground excavation. No text changes are proposed in response to this

11. Resolution *(To be completed by original Reviewer)*

Response acceptable.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 17 of 22
2. Page 2 of 2
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

expressed by Freeze et al., 1991 [DOE, 1991g]), are being addressed.

END OF TEXT

10 Proposed Resolution (continued)

comment.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 18 of 22
2. Date November 12, 1991
3. Reviewer David K. Kreamer
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section general
7. Page N.A.
8. Paragraph

9. Comment

OTHER ITEMS

1. One cannot be associated with the project for any length of time and not be impressed by the high caliber of the scientists working on the project, and with the open and diligent efforts to identify and answer crucial scientific questions. The scientific staff is to be commended.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team appreciates the comment.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

No response made or needed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 19 of 22
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7. Page
8. Paragraph

9. Comment

2. During the course of this peer review, this reviewer frequently received comments from project scientists indicating that the project efforts might be management top-heavy, as manifested by quality assurance procedures and mandatory training exercises which were often inappropriate and counter-productive to the job at hand. Efforts to carefully characterize Yucca Mountain can be inhibited if quality assurance measures and training exercises are not carefully crafted and implemented.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team recognizes the potential for quality assurance and training to impact productivity. We agree that it is vitally important that training requirements are carefully designed and implemented. However, we also recognize that the majority of scientists and engineers supporting the DOE's Yucca Mountain Project have limited experience in producing the documentation required for administrative law hearings and in demonstrating compliance with quality assurance program requirements for nuclear facilities (ANSI/ASME NQA-1, 1986). The NRC and the DOE have worked together to adapt quality assurance requirements to the unique nature of the repository program. As an example, the 100-plus year lifetime of the repository program places special requirements on documentation and records. Likewise, evaluating compliance with performance criteria that extend over a 10,000-year time period also raises unique questions about requirements for verification and validation of analytical techniques and computer codes used to predict performance.

11. Resolution *(To be completed by original Reviewer)*

In the Unsaturated-Zone Peer review it was noted by Freeze et al., 1991 (DOE, 1991g) (Conclusions and Recommendations, #4) "In the opinion of the PRT, the quality-assurance procedures in the Yucca Mountain Project have become so over-formalized that they are creating unacceptable delays in the technical progress and a lowering of staff morale." While the need for documentation as expressed by this respondent is recognized, the need to restrict these

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

The ESSE Core Team shares the reviewer's conclusion that the quality assurance program and training should be "carefully crafted and implemented."

END OF TEXT

11 Resolution (continued)

activities to necessary and supportive functions is incumbent upon the project management. In comments I have received from project scientists and from my own personal experience, I have found some of the imposed requirements to be beyond that which are supportive to project goals or regulatory requirements.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 20 of 22
2. Date November 12, 1991
3. Reviewer David K. Kreamer
4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section general
7. Page
8. Paragraph

9. Comment

3. Also during the course of this review, many scientists "in the trenches" spoke about the need to better integrate and disseminate information. The integration and coordination of this peer review is an example of a process which, due to time constraints, did not fully promote interdisciplinary coordination in spite of the efforts of the peer review team, the managers, and the ESSE team. Items such as the integration of computer codes and data acquisition, and updating project scientists (as to what other work was going on) were frequently listed in discussions with many individuals as important, continuing concerns.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The question of how to improve integration and dissemination of information in a program that involves national laboratories, the U.S. Geological Survey, and a number of private contractors has been a continuing concern of the ESSE Core Team (see also Dr. Webb's Comment #20 regarding integration concerns). Although assistance can and is provided in a number of ways, such as general status reports and information exchanges, some of the responsibility must be accepted by the scientists performing the work. Although this effort reduces the time available for mainstream research, there does not appear to be any other means for information to be made available. There are limitations to free exchange of new information, in part due to the need for internal technical review and approval, prior to formal release of information. In addition, quality assurance requirements dictate that an approved review procedure be followed for any information that will later be used to support the licensing process. All of this leads to a situation where the "real-time" exchange of technical information can only occur if the program scientists find

11. Resolution *(To be completed by original Reviewer)*

The integration of computer codes, and better communication of activities is an important aspect of a healthy scientific program, as recognized by the respondent. In order to promote "real-time" exchange of information, more is needed than just a willingness of program scientists to participate. Opportunities for information exchange must be scheduled (far in advance) and coordinated, more frequently than in the past. Computer codes and data bases

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

it in their best interest to participate. The ESSE Core Team recognizes that informal exchange and review of information is a vital part of a healthy technical program.

END OF TEXT

11 Resolution (continued)

used to analyze Yucca Mountain need to be either available for free exchange and external review, or excluded from use in the project.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

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2. Date November 12, 1991
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4. Organization UNLV
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6. Section 2.3.2 general
7. Page
8. Paragraph

9. Comment

4. The possibility exists that the geohydrology of Yucca Mountain will not be able to be fully characterized. It is appropriate to continue to seek regulatory clarification on acceptable uncertainty and acceptable risk limits, in the event that full characterization cannot be achieved.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Kreamer uses the terms "fully characterized," "acceptable uncertainty," and "acceptable risk limits." In the response to Dr. Carothers' Comment #6, this general theme of "how much is enough" is also addressed. As noted in that response, there are very few purely quantitative solutions to questions of suitability and uncertainty, and the level of confidence needed to support a higher-level finding for a given guideline cannot be absolutely specified. The ESSE Core Team recognized that different overall regulatory strategies could dramatically change what is "necessary or required." For example, if the DOE chose to direct significant research and budget into developing a 10,000-year waste container, then the confidence needed in our understanding of hydrologic mechanisms and processes could be reevaluated. Depending upon the confidence that could be developed in the performance of the waste container, the need for extensive characterization of the natural site features and processes could be reevaluated. It seems likely that much of the discussion during the licensing process for a geologic repository will revolve around exactly the issues raised

11. Resolution *(To be completed by original Reviewer)*

The respondent's comments support the idea that regulatory clarification should be sought. The respondent's comment that "there are very few purely quantitative solutions to questions of suitability and uncertainty, and the level of confidence needed to support a higher-level finding for a given guideline cannot be absolutely specified" is somewhat frightening in view of how lengthy the resolution of technical issues could become if technical end

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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1. Comment 21 of 22
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4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

in this comment.

END OF TEXT

11 Resolution (continued)

points are undefined.

A second comment by the respondent that "The ESSE Core Team recognized that different overall regulatory strategies could dramatically change what is 'necessary or required,'" suggests that the site characterization process should contain a continuing scientific effort to identify the best regulatory framework to "solve" the nuclear waste problem in the United States. While the approaches presented in the ESSE seek to answer technical questions within the current regulatory framework, perhaps as time progresses the original scientific questions prompted by regulation become inappropriate and even misleading. The scientific questions which the ESSE addresses may ultimately be an incomplete list because of the present regulatory constraints, which indicates that the reconceptualization of the regulatory framework is continually needed. For example, the idea that "post-closure monitoring is not considered a key factor in site selection" (Federal Register, Vol. 49, No. 236, p. 46632) may need to be reassessed. The current conceptual plans for eventual site closure, with associated backfilling and sealing of the subsurface tunnels will not promote continued waste canister inspection and retrievability. When considering the vast technological changes that have occurred over the last one hundred years, it seems reasonable that possibilities of waste transmutation or better storage in the next centuries may become feasible. The ability to readjust should be incorporated into regulatory structure and scientific design. Some readjustment in design may come from the past. In olden days, underground mines were sometimes convectively dried out by fires built at the junction of several drifts. Perhaps the regulatory structure could be changed to allow an engineered drying system driven by a nuclear "fire" (heat source). The flexibility to accommodate the optimal design alternatives of the future should be incorporated into current disposal plans and regulatory strategies.

The ESSE presents some reevaluation of the regulatory framework in a limited way in its discussion of the potential release of gaseous Carbon-14 to the atmosphere. A more complete, continuing reevaluation of regulatory approaches needs to be formally incorporated into scientific deliberation as site assessment continues.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 22 of 22
2. Date November 12, 1991
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4. Organization UNLV
5. Revision Draft/Date August 1991
6. Section general 2.3.1
7. Page
8. Paragraph

9. Comment

5. Peer reviewers for the ESSE document were given three choices as to site suitability in their areas of expertise. These choices were: a higher level of suitability, a lower level of suitability, or unsuitability under the regulatory guidelines. In geohydrological considerations there is, in this reviewer's judgment, currently not enough defensible, site-specific information available to warrant acceptance or rejection of this site. Therefore, this reviewer's support of the ESSE team's consensus opinion (that the site meets lower level suitability under the geohydrology qualifying and disqualifying conditions) is meant to indicate that the site is acceptable for continued study. It should not be construed to indicate that the site is likely or unlikely to qualify with respect to geohydrology; it is premature to make that decision.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The DOE General Siting Guidelines (10 CFR Part 960) do not allow a "no decision" finding, as pointed out by this reviewer. Thus, the ESSE Core Team followed the intent of the guidelines in (1) reviewing each guideline to determine if any previous lower-level suitability findings in the Environmental Assessment (EA) (DOE, 1986) should be reversed on the basis of new information available since the EA and (2) determining if new information provided adequate confidence to support a higher-level suitability finding. According to the Guidelines, to reverse a lower-level finding would be to recommend that the site should be disqualified on the basis of current information.

The ESSE Core Team concluded that only a lower-level suitability finding could be supported for the Geohydrology Disqualifying and Qualifying Conditions. As described in Chapter 1, Table 1-3, these findings indicate that for the disqualifying condition, the Core Team concluded the condition is not present but additional information could change this conclusion; and for the

11. Resolution *(To be completed by original Reviewer)*

The change in Figure 1-2 is an improvement, in that it more accurately represents the intent of a lower-level suitability finding as expressed in the text of the ESSE. This reviewer's support of continued, hydrological site characterization efforts at Yucca Mountain is not only based on the limited field information, which indicates possible favorable conditions at the site, but is more rooted in the considerable uncertainty and lack of confidence in

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 22 of 22

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4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

qualifying condition, the site is likely to meet the condition but additional information could change this conclusion. On the basis of comments from other peer reviewers, Figure 1-2 in the draft ESSE Report, which portrays the decision process, has been modified (see response to Dr. Albrecht's Comment #1) so that the answer to the question "Could conclusion change?" now has outcomes of "unlikely," which leads to a higher-level suitability finding; and, "possibly," which leads to a lower-level suitability finding. This wording may be more consistent with the reviewer's comment that it is premature to make a decision at this time.

END OF TEXT

11 Resolution (continued)

that limited information.

END OF TEXT

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Dr. William G. Pariseau

ROCK CHARACTERISTICS,
ENGINEERING GEOLOGY

University of Utah
Salt Lake City, UT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	X	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.		X*

Comments 1 through 1 are attached.

*As per Comment 1, there was an initial disagreement that has since been resolved. We are in agreement with the revised findings.

Peer Reviewer W. G. Pariseau Date 12/11/91

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No ____ The following comments have not been adequately addressed:

Peer Reviewer W. G. Pariseau Date 12/11/91

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-11-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 6
2. Date November 11, 1991
3. Reviewer William G. Pariseau
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.3/2.4/3.3.3.2/4
7. Page 2-38+/2-129+/3.3.37+/4.3+
8. Paragraph Rock Properties

9. Comment

In my opinion, a higher suitability finding for post-closure rock properties is not justified by the evidence available at present. There are several reasons why I believe this to be the case.

(1) Only a lower level suitability finding has been determined with respect to preclosure rock properties. As remarked in the ESSE, if a higher level finding cannot be determined for preclosure suitability, then post-closure suitability is moot. Only a lower level finding for preclosure has been justified at present because of the lack of site data. The few and widely spaced drill holes and outcrop studies simply do not allow for detailed definition of the site. Post-closure rock properties cannot be known with greater certainty than preclosure properties, especially in view of the uncertain rock mass modification that will occur as a consequence of repository excavation and operation.

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to this comment, the ESSE Core Team reevaluated its position as to the level of finding supported by the evidence at this time. We decided, following a thorough discussion, to accept Dr. Pariseau's opinion and recommend that the evidence continues to support a lower-level suitability finding, pending the acquisition of additional in-situ data on the characteristics of the potential host rock mass, including its response to the stresses that will be introduced by excavation and thermal loads. In particular, we agree that the role of the site thermohydrologic response and the coupling between fluid and mechanical effects were not adequately considered in the draft and have the potential for affecting the level of current confidence in complying with the qualifying condition.

Section 2.3.3.5, paragraph 1, will be revised as follows:

"The consensus of the Core Team is that the available evidence continues

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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1. Comment 1 of 6
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

(2) The distinction between rock property values determined from tests in the laboratory and field-scale rock mass properties is not accounted for in a scientific manner. Although recognition of this important difference is occasionally made, it is done by arbitrarily reducing laboratory rock properties by 50% or 60%, by ubiquitous joint analysis, and by relegating consideration of fractures to the discussion of geohydrology where structural discontinuities such as joints and fractures are considered only with respect to unsaturated fraction flow and constant permeability. Laboratory tests can be done with precision and reliable statistical information obtained. However, the same cannot be said of the rock mass response as considered in the EA and ESSE.

(3) Rock properties and rock mass response are intimately linked to fluid, as well as thermal phenomena. However, coupling between fluid and mechanical effects in the porous, fractured, faulted rock mass at the Yucca Mountain site seemingly has been ignored. The well-established principle of effective stress has not been taken into account. In view of the many important questions concerning site geohydrology, there accrues an associated uncertainty coupled to rock properties and rock mass behavior.

(4) Structure geology, such as the Ghost Dance Fault, fault properties, and fault hydrology, are not well-known, but obviously have the potential for adverse impacts on site suitability.

At present, the lack of data, a high potential for adverse discovery during site characterization phase, and uncertainty in rock mass response militate against a higher level finding for post-closure rock properties. More site-specific data, perhaps from more closely spaced drill holes, and more realistic analyses are needed to define the rock mass at the site with the degree of confidence necessary for a higher level finding.

END OF TEXT

10 Proposed Resolution (continued)

to support a lower-level (Level 3) suitability finding that the characteristics of the potential host rock at the Yucca Mountain site will accommodate the thermal, chemical, mechanical, and radiation stresses induced by a repository, as well as the interactions expected among the waste, host rock, ground water, and engineered components. Furthermore, it appears an EBS that will meet applicable release limits can be developed using RAT. Given the previously discussed uncertainties, a higher-level suitability finding is not supported at this time."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 6
2. Date November 11, 1991
3. Reviewer William G. Pariseau
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.3/2.4/3.3.3.2/4.
7. Page 2-38+/2-129+/3.3.3-7+/4-3+
8. Paragraph Rock Properties

9. Comment

Fluid-mechanical coupling has not been considered, although the guidelines (e.g., p. 6-206 of the EA) require interactions to be considered especially as they affect radionuclide releases. This is rather surprising, since it is the interaction that one would consider first in most geotechnical engineering situations. Although thermal effects on the mechanical response of rock matrix material are considered in great detail, its importance to radionuclide release would appear to be much less than possible fluid effects, especially in a fractured, porous rock mass. In my opinion, stress-permeability coupling ought to be addressed as thoroughly as stress-temperature coupling even though the site is in the nominally unsaturated zone.

Excavation and operation of the repository will modify the rock mass; new fractures may appear, existing joints may extend, some fault motion may ensue, cracks will open and close, and so forth. The contribution of structural discontinuities to the permeability field, heterogeneous at the start, will

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with the comment. We will add a discussion on fluid-mechanical coupling to ESSE Issue #2 (Section 2.3.3.4, page 2-49, paragraph 1 of Issue 2) to illustrate how mechanical changes may affect fluid flow and how episodic fluid flow may alter the mechanical characteristics of the rock.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
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1. Comment 2 of 6
2. Page 2 of 2
3. Name William G. Pariseau
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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

change and influence motion of air, water and water vapor within the rock mass. The fluid pressure field and phase changes (vaporization, condensation) will, in turn, influence the deformation of the rock mass. What, for example, would be the result of a rare episode of rapid (saturated) water flow into a hot area of the repository where the dry rock temperature is above the boiling point? Would the enormous build-up of pore and fracture pressures dissipate with sufficient speed to avoid a potentially catastrophic motion of the rock mass? Such questions are as important as, say, the question of thermally induced fracturing of the rock matrix and would seem to merit investigation to the same level of detail.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 6
2. Date November 11, 1991
3. Reviewer William G. Pariseau
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.3/2.4/3.3.3.2/4
7. Page 2-38+/2-129+/3.3.3-7+/4+
8. Paragraph Rock Properties

9. Comment

The evaluation of performance measures using numerical models as outlined in the ESSE, p. 2-2, is suspect because of the primitive state of the geomechanical models used. For example, the much cited report by Johnstone and others relies on a ubiquitous joint concept and arbitrary reduction of rock matrix properties to model the rock mass. The first does not describe any real material and the second is justifiable only after site specific rock mass measurements have been made. The analysis is limited to two-dimensions and assumes vertical joints only. Although the authors make clear their assumptions and intend the analysis to be a relative ranking study of four horizons, it is frequently cited by others as an absolute study of the proposed site in the Topopah Spring member at Yucca Mountain.

Before heavy reliance is placed on any particular model, it should be shown to describe real physical phenomena (verified) and should be validated and calibrated to site-specific data. This is admittedly a catch-22 suggestion

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Although the ESSE does not cite the Johnstone et al. (1983) reference, text has been added to the ESSE Report, Section 2.3.3.3.2, Thermomechanical Properties, second full paragraph on page 45, to indicate that modeling studies to date have been limited to two-dimensional analysis and have used idealized fracture descriptions, and to reflect the need for model validation. Text has also been added to Section 2.3.3.5, Repository-Scale, Underground Excavations, end of first paragraph, recommending that results from tests in a repository scale excavation be used to calibrate and validate models used to predict postclosure rock characteristics.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 6
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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

since the modeling here is necessarily being done prior to any site characterization activity. However, results of forward modeling of other underground excavations would add credibility to the procedure and assist model users in the development of the application art.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 6
2. Date November 11, 1991
3. Reviewer William G. Pariseau
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.3/2.4/3.3.3.2/4
7. Page 2-38+/2-129+/3.3.3-7+/4-1
8. Paragraph Rock Properties

9. Comment

There is an apparent contradiction in the logic of selecting a site in an unsaturated environment that is likely to remain unsaturated for many thousands of years and doing a great amount of study, analysis, calculations, modeling and so forth. As long as the site remains dry, there appears to be no mechanism available for the transport of radioactive contaminants to the accessible environment (with the possible exception of gaseous carbon-14). Thus, the post-closure system guidelines can be met, provided the pre-closure guidelines are met. Sinnock and others arrive at essentially the same conclusion.

If this is not the case and modeling is relied upon to anticipate site behavior far into the future, then development and demonstration of a fully coupled three-dimensional jointed rock mass model that allows for transient, unsaturated flow and phase changes in a time-dependent temperature field (and thus has the potential for describing real phenomena at the site) is needed, an

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Pariseau's implication that if confidence is very high that the site will remain unsaturated for many thousands of years, then it should be possible to place reasonable constraints on the amount of study and analysis necessary to adequately characterize the site. The DOE's current management approach is a phased characterization philosophy, where the need for further studies and analysis is reassessed as new information is obtained and evaluated.

We also agree that the amount of detailed modeling needed requires careful consideration relative to its potential impact on evaluating site suitability. High priority should be placed on investigating phenomena that involve credible contaminant release and transport mechanisms. To the extent that fluid transport of contaminants is important, the coupling between stress and fracture permeability should be considered, especially in view of the concern for possible fast (fracture) flow paths in the porous, fractured, faulted rock

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 4 of 6
2. Page 2 of 2
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

ambitious task, indeed.

END OF TEXT

10 Proposed Resolution (continued)

mass at the site. Other transport mechanisms, such as diffusion through bound water films in the unsaturated zone, may also need to be considered.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 6
2. Date November 11, 1991
3. Reviewer William G. Pariseau
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.3/2.4/3.3.3.2/4.0
7. Page 2-38+/2-129/3.3.2.7+/4-1
8. Paragraph Rock Properties

9. Comment

There are two aspects of repository design and operation that relate to safety and the pre-closure guidelines that should be considered more carefully.

There appears to be a potential for the development of very blocky ground because of the presence of closely spaced vertical fractures (4 to 14 per 10 ft), horizontal fractures, and random fractures (Carr et al., 1983) and the unusually high strength of the Topopah Spring tuff. Excavation, support, large-hole drilling and retrieval may be much more difficult than assumed. They may also be less difficult. Site data are not adequate for resolution of the question, so a cautious approach is prudent.

There is also a potential safety threat in working in the vicinity of rock at 100 degrees C. There is no precedent in the mining industry that indicates reasonably available technology for working in such hot ground on a daily and routine basis at the scale of operations anticipated. Rock temperatures in the

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that a cautious approach to repository design and operation is prudent. Requirements for artificial support to ensure the stability of the underground openings are summarized in the EA (Section: 6.3.3.2.3) evaluation of Favorable Condition #2, but limitations on surface-disturbing work have largely precluded the acquisition of new data (ESSE/Section 3.3.3.2.3.2). Repository operating temperatures were only briefly addressed in the EA (Section 6.3.3.2.5) in terms of ventilation system design, and this consideration was not explicitly mentioned in the ESSE (Section 3.3.3.2).

Accordingly, ESSE Issue #2 (Sections 3.3.3.2.2.1 and 3.3.3.2.4) will be expanded to address rock characteristics that might impact personnel safety in the repository in terms of underground rock support and operating temperatures. Until additional site specific data and a more mature repository design concept become available, the qualifying condition for this guideline remains at a

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 5 of 6

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3. Name William G. Pariseau
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

hot, deep, dry and difficult mines of South Africa and India range between 35 to 50 degrees C, for the most part (personal communication: Prof. M. Salamon, Colorado School of Mines; Prof. R. Bhaskar, Univ. of Utah). Again, caution is in order.

In this regard, the attitude projected in the ESSE on p. 3.3.3-8 about the risks inherent in underground operations appears to be a throw-back to the time when industrial safety was not a concern, for example, when inhaling silica dust by stone masons was considered an occupational hazard that workers accepted upon employment. I am sure the impression created is unintentional, but it should be made clear that site workers will not be employed in an unusually hazardous environment.

END OF TEXT

10 Proposed Resolution (continued)

lower-level (Level 3) suitability finding (ESSE/Section 3.3.3.2.5).

Finally, the discussion of ESSE Issue #3 (Section 3.3.3.2.2.1) will be revised to reflect appropriate concern for risk mitigation.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 6
2. Date November 11, 1991
3. Reviewer William G. Pariseau
4. Organization University of Utah
5. Revision Draft/Date August 1991
6. Section 2.3.3/2.4/3.3.3.2/4.
7. Page 2-38+/2-129+/3.3.3.7+/4-1
8. Paragraph Rock Properties

9. Comment

The hot rock temperatures approaching 100 degrees C during the operating life of the repository may be unacceptable. If a decrease in temperature becomes necessary assuming vertical placement, then an addition to the lateral extent of the repository may be required. A decrease in temperature could be achieved by decreasing canister power or by increasing canister spacing. Both would require greater lateral extent of the proposed repository. However, an enlarged repository poses questions not fully addressed in the ESSE or EA. Changing canister spacing and power also affects the source term calculation. There is the possibility of also decreasing drift spacing while increasing canister spacing or decreasing power density and thus staying within the present bounds. The present layout uses a 20% two-dimensional (area) extraction ratio. I was unable to find how this parameter was selected, but it is subject to control through design.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees with Dr. Pariseau's comment. In addition to the text changes made in response to the previous comment (to address the stability of underground openings and repository operating temperature), we will modify ESSE Issue #1 (Section: 3.3.3.2.2.1) to explicitly note the alternate thermal loadings and waste emplacement layouts under consideration. We agree that the parameters identified in this comment are subject to design control; however, specification of values for these parameters will require future characterization of the site and definition of the design requirements.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

REFERENCES FOR DR. WILLIAM G. PARISEAU

PARISEAU

Carr, M. D. and other. A Summary of Geologic Studies Through 1983 of a Potential High-Level Radioactive Waste Disposal Site, Yucca Mountain, Southern Nye County, Nevada. USGS Open-File Report. Cited in Effect of Variations in the Geologic Data Base on Mining at Yucca Mountain for NNWSI, Dravo Engineers, Inc., SAND84-7125, Albuquerque, NM.

DOE (U.S. Department of Energy), 1986. Final Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada, 3 volumes, DOE/RW-0073, Office of Civilian Waste Management, Washington, DC.

Johnstone, J. K., P. R. Peter, and P. F. Gnirk, 1983. Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation, SAND83-0372, Albuquerque, NM.

Personal communications: Professor M. Salamon, Colorado School of Mines, Professor R. Bhaskar, University of Utah.

Sinnock, S., Y. T. Lin, and J. P. Brannen, 1984. Preliminary Bounds on the Expected Postclosure Performance of the Yucca Mountain Repository Site, Southern Nevada, SAND84-1492, Sandia National Laboratory, Albuquerque, NM.

Younker, J. L., W. B. Andrews, G. A. Fasano, C. C. Herrington, S. R. Mattson, R. C. Murray, L. B. Ballou, M. A. Revelli, A. R. Ducharme, L. E. Shepard, W. W. Dudley, D. T. Hoxie, R. J. Herbst, E. A. Patera, B. R. Judd, J. A. Docka, and L. D. Rickertsen, 1992. Report of Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada, SAIC-91/8000, Las Vegas, NV.

Dr. Thomas A. Vogel

TECTONICS - VOLCANOLOGY

Michigan State University
East Lansing, MI

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement:

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	1 -11	
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	1 - 11	

Comments 1 through 11 are attached.

Thomas A. Vogel

Peer Reviewer Thomas A. Vogel Date 12/16/91

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments

No ____ The following comments have not been adequately addressed:

Thomas A. Vogel

Peer Reviewer Thomas A. Vogel Date 12/16/91

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L. Younker Date 12-16-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3. Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.1.5, 2.3.7.3.3
7. Page 2-24 & 2-102ff
8. Paragraph 3&4

9. Comment

2.3.1.5 Recommendations for future activity in this section are very weak. The conclusions and recommendations among the various sections are very uneven. As an example, compare this section with 2.3.7.3.3.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text in Section 2.3.1.5 on page 2-24 will be revised as follows:

Last sentence of paragraph 1: "...however, substantial testing and analyses are needed to support a higher-level suitability finding."

The discussion paragraph (same section) will be replaced with a subsection called "Recommendations for Future Activities" and will read as follows:

"The results of this evaluation have identified specific activities that should be considered as part of the continuing effort to acquire the information needed to assess site suitability. These activities are related to the technical elements in Issue 1 and address (1) flow path occurrence and characteristics; (2) processes controlling the attenuation and redistribution of water entering the unsaturated zone; and (3) development of confidence in the modelling capabilities describing fracture-matrix interactions in the

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 1 of 11
2. Page 2 of 2
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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

unsaturated zone.

Site-specific data are required to understand and quantify, where possible, the mechanisms controlling the spatial and temporal distribution and magnitude of infiltration and the processes controlling the attenuation and redistribution of transient pulses of water. A representative hydrologic data set should be collected to establish the interdependencies of the hydrologic properties that control flow and transport within both the saturated and unsaturated zones. Spatial and temporal variations in the hydraulic characteristics and in the fracture characteristics associated with the welded, nonwelded, and bedded tuffs located above and below the repository horizon should be quantified. These data should be augmented with a coupled field and laboratory program that investigates the basic assumptions underlying the models used for the unsaturated zone and that evaluates plausible mechanisms for rapid flow through the unsaturated zone. The effects of fracture coatings, material property variations near the fracture surfaces, and the effects of wetting and drying transients should be studied as part of this integrated laboratory and field program. The use of chemical and environmental tracers and dating techniques should be used as an independent means to estimate travel times and to develop confidence in the models that are used to simulate flow processes and mechanism. Water chemistry data from both the unsaturated and saturated zones should be obtained to better understand and constrain the assumptions associated with chemical processes and gaseous flow in the unsaturated zone and to provide boundary conditions for modelling these processes. Additional hydrologic testing within the saturated zone should be considered to characterize the dominant processes controlling flow to the accessible environment. Existing water table holes and those proposed for the future should be used for additional hydrochemical characterization. With respect to redistribution of water and occurrence of flow paths in the unsaturated zone, the conditions under which perched water may occur or develop in the future merit careful attention. With respect to saturated-zone conditions, the large hydraulic gradient north and west of the potential repository site and the very small gradient beneath it require understanding and evaluation. Continued efforts should be expended to develop a position on the appropriate definition and regulatory implications of ground-water travel time requirements."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 2 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.1.5, 2.4
7. Page p 2-129ff
8. Paragraph

9. Comment

2.3.1.5 The geohydrology, geochemistry, tectonics, rock characteristics, and climate sections should have conclusions and recommendations that discuss integration among the geotechnical areas. Section 2.4 would be an excellent place to discuss this integration. See also my comment #9.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE approach to evaluating technical guidelines was to consider specific features or conditions that would indicate the site should be disqualified. The integration across technical guidelines was addressed in the evaluation of the System Guideline, and this is the approach that was used. The text in Section 2.2 will be modified to make this point more clearly (second paragraph in Section 2.2):

"The evaluation of the Postclosure System Guideline determines whether the system performance requirements specified in the guideline can be met. This requires an integrated assessment of the issues identified in the technical guideline evaluations and other issues related to waste isolation and containment identified in the performance assessments, themselves. For example, many of the technical guidelines focus only on specific aspects of site performance, such as hydrology, which addresses the movement of water,

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

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1. Comment 2 of 11
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

or geochemistry, which addresses the movement of solutes in the water. Such distinctions are eliminated when these issues are considered together in the System Guideline evaluation."

The integration of different technical areas will be made in the context of system performance assessments. It is still too early to conduct definitive system performance assessments because the necessary conceptual and numerical models are not well enough developed. Text will be added to explain this limitation to early site suitability evaluations (paragraph added at the top of page 2-5):

"Although quantitative assessments were considered, they did not provide the principal focus of this early site suitability evaluation. Ultimately, the evaluation of the suitability of the site will involve detailed, quantitative performance analyses to assess compliance with numerical criteria. These analyses will be based on conceptual models that are consistent with the information gathered during site characterization. Because it is too early in the site characterization program for such information and for having models that are fully developed, the Core Team did not rely heavily on quantitative performance models. (A good example is in the area of geohydrologic processes. Because the models in this area are at a relatively early stage of development, the Core Team did not consider it appropriate to rely heavily on them at this time.) Nevertheless, the Core Team did review the status of the quantitative assessments during their evaluation of the System Guideline. The results of this review and the evaluation of the System Guideline are presented in Section 2.4."

A better job of integration of the uncertainties and issues at the site can be done. Section 2.4 will be expanded to address more of the issues identified in the technical guideline evaluations from an integrated, system perspective. In addition, issues that go beyond individual guidelines are addressed in the existing system guideline discussion. These include issues that address several different types of characteristics, e.g., geochemistry and geohydrology or geohydrology and tectonics, or issues where the central focus is outside the scope of the technical guidelines, e.g., gaseous release pathways. The following text will be added as a replacement for the second paragraph on page 2-145 (Section 2.4.3.2) to focus more attention on these issues:

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 11
2. Page 3 of 4

3. Name T. A. Vogel (Print Name)
4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

"A possibly important factor that has not yet been evaluated thoroughly is the transport of radionuclides in the saturated zone below the water table. Although conservative analyses in the EA did not indicate a strong effect, evidence is accumulating that transport of radionuclides may be slow in this zone and may provide an important contribution to waste isolation at the site. It will be important to evaluate the magnitude of this contribution in future assessments.

Detailed quantitative analyses of the potential effects of disruptive processes and events have not yet been conducted. The technical guideline evaluations suggest two categories of scenarios that need to be addressed: tectonic processes and human intrusion.

The first category of scenarios involves disruptions to the system induced by tectonic processes (see Section 2.3.7). The evaluation of the Postclosure Tectonics Guideline concluded that there are several important issues relevant to postclosure performance. One issue is the potential effect of tectonic activity on the engineered barrier system. The performance assessments that have been conducted show little difference between analyses involving 1,000-year lifetime waste packages and shorter-lived waste packages. Therefore, it is not likely that tectonic disruptions of the waste package would be very important unless such disruptions also involve other phenomena affecting performance, or there is greater reliance on long-lived (e.g., 10,000-year) waste packages.

A second issue associated with tectonic processes is a potential effect on the ground-water flow system such as an increase in the elevation of the water table or a local concentration of flux due to creation of new fast pathways. The performance assessments that have evaluated these effects have indicated that adverse effects would be unlikely. For example, calculations with a hypothetical permanent water table rise of 20 m show virtually no effect on cumulative releases. Likewise, analyses of flux concentration effects show as much likelihood of decreased releases as increased releases because of decreased flow in one part of the repository compensating for increased flux in another part (to maintain the overall water balance). Therefore, the overall effect is not likely to be significant.

A third tectonic-processes issue is the question of volcanism.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 2 of 11

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(Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

In this case, the probability of volcanism at the site is considered to be very low. Although such effects are not expected, additional information is needed to determine possible impacts on waste isolation and containment."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.1.3.2
7. Page 2-19
8. Paragraph 1

9. Comment

There is a great deal of emphasis put on the ability of the unwelded portions of the Paintbrush Tuff to attenuate and retard transient, large volume, water flow. There should be a more detailed discussion of the data that support this conclusion. In order to evaluate this process, further testing is warranted.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team strongly endorses Dr. Vogel's recommendation that additional testing in the unwelded portions of the Paintbrush tuff, as well as other unwelded units, is a prerequisite to fully understanding the processes controlling attenuation and redistribution of transient pulses of water in the unsaturated zone. At present, a limited amount of site-specific data are available that can be used to support the results of the analyses that have been summarized and that can be used as a basis to evaluate the potential importance of these units on attenuation and redistribution. Peters et al., (1987) coupled laboratory imbibition experiments on samples of Paintbrush tuff with analysis using TOSPAC (a one-dimensional finite-difference program for simulating water flow in partially saturated, fractured layered media). They attribute the difference between observed laboratory measurements and analysis results to a lack of accuracy in the limited hydrologic data available from Yucca Mountain.

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 3 of 11
2. Page 2 of 2
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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

To address this comment and Dr. Vogel's Comment #1, we will add the following text to Section 2.3.1.5, Recommendations for Future Activities:

"Spatial and temporal variations in the hydraulic characteristics and in the fracture characteristics associated with the welded, nonwelded, and bedded tuffs located above and below the repository horizon should be quantified." (See paragraph 2, sentence 3 of proposed resolution to Dr. Vogel's Comment #1).

Additionally, the first sentence of paragraph 2, of the new subsection will state the following:

"Site-specific data are required to understand and quantify, where possible, the mechanisms controlling the spatial and temporal distribution and magnitude of infiltration and the processes controlling the attenuation and redistribution of transient pulses of water."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 4 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.1 General
7. Page 2-7ff
8. Paragraph NA

9. Comment

The most important conceptual issue in the ESSE revolves around the hydrologic processes of fracture and matrix interaction. This issue cannot be compartmentalized into hydrology alone, it must be integrated with geochemistry, rock characteristics and tectonics. Questions that are raised about interactions among the radionuclides, the host rock and ground water are fundamentally related. As stated on page 2-26 "The probability of sustained flow along fast flow paths remains an open issue." The core team recognized the fundamental control of fast pathways on geochemical retardation. Yet there is not a detailed discussion of this integration.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In response to Dr. Vogel's Comment #2, text will be added discussing integration of different technical areas across technical guidelines and of site uncertainties and issues. The response to that comment contains added text.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment response accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 5 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.3 general
7. Page 2-38ff
8. Paragraph NA

9. Comment

2.3.3 Is this the place to discuss the effects of a thermal perturbation by the emplacement of the nuclear waste? There needs to be a detailed discussion of this in the ESSE.

Would there be any significant condensates produced by driving out the moisture near the emplacement area? If so what will the effects of this water be?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Dr. Vogel makes a valid point about a shortcoming of the ESSE document. The effects of the repository-induced thermal perturbation was not adequately discussed in the document. A six-paragraph insert has been prepared for Section 2.3.3, pp. 2-45 and 2-46 and will be added to replace the first paragraph in the section titled "Hydrologic and Geochemical Characteristics." The topic of moisture redistribution and a summary of recent modeling of the effects have been added. The text that will be inserted in response to this comment and to Dr. Kreamer's Comment #3 is as follows:

"Much has been learned since the EA about the thermohydrological effects that are anticipated from the dissipation of radioactive decay heat in the unsaturated fractured host rock. Numerical models have predicted the time-dependent temperature distribution within the host rock and surrounding hydrostratigraphic units for various repository design concepts, thermal loading densities, and waste receipt and operating scenarios (Ballou et al.,

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 5 of 11

2. Page 2 of 3

3. Name T. A. Vogel (Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

1990). Most of these models involve spatial and temporal superposition of heat conduction calculations to account for the emplacement of individual heat sources over the operational life of the repository and the radioactive decay. Areal power densities (APDs) ranging from less than 20 to greater than 100 kW/acre and average waste ages from 10 to 90 years have been modeled. These models do not account for fluid-phase changes or heat transfer mechanisms other than heat conduction.

A field experiment to investigate the physical processes that should be incorporated into models describing thermohydrologic and geochemical processes in fractured, porous, densely welded tuff was conducted at G-Tunnel on the Nevada Test Site (Buschek et al., 1991b). The experiment used a heater placed in a horizontal orientation, and results show that the predominant heat flow mechanism was heat conduction (Buscheck and Nitao, 1991b). Fractures appeared to serve as the predominant flow paths for gases and liquids, and fracture permeability to air increased somewhat due to the heating-cooling cycle. This experiment did not show any mechanisms or phenomena that would indicate that tuffaceous rock is unsuitable for siting of the repository.

Hydrothermal model calculations have been performed for a wide range of fracture and matrix properties in the unsaturated zone using simplified repository geometries. These models include boiling and condensation effects, convection of latent and sensible heat, and thermal radiation. In general, these models predict a drying-out of the near-field rock by boiling of the vadose water in the rock matrix and the flow of water vapor through fractures to cooler regions where it condenses. Because of the very low matrix permeability of the host rock, this condensate will drain considerable distances along fractures before it is totally imbibed by the matrix. The combination of vapor flow away from the heat source and gravity-driven condensate flow-down fractures tends to promote shedding of condensate off the sides and away from the boiling zone. This condensate shedding effect was observed during the G-Tunnel heater experiment (Buschek et al., 1991b; Buscheck and Nitao, 1991b).

Recent hydrothermal model calculations over a range of fuel ages and APDs (Buscheck, 1991) have shown the potential for significant boiling and rock dry-out benefits for high APDs (i.e., APD > 80 kW/acre). For 60-yr-old pressurized water reaction (PWR) fuel and an APD of 114 kW/acre, these calculations show near-field temperatures remaining above boiling for 5,000 to 10,000 years, with the rewetting of the dry-out zone to ambient saturation requiring 100,000 to 200,000 years. The probability of fracture flow reaching

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(CONTINUATION SHEET)

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1. Comment 5 of 11
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

a waste package is greatly reduced by near-field boiling conditions. While the dry-out zone is rewetting to ambient saturation, matrix flow will be directed back towards the repository. Buscheck (1991) found that much of the rewetting of the dry-out zone occurs from below the repository horizon. The resulting upward matrix flux below the repository will retard matrix-dominated radionuclide transport towards the water table.

For a range in expected repository fracture and matrix properties, hydrothermal calculations of the repository show the predominant heat flow mechanism to be heat conduction (Buscheck, 1991). The volume of rock dry-out and the duration of near-field boiling conditions was found to be dependent primarily on (1) the thermal properties of the unsaturated zone and (2) thermal loading conditions. Moreover, mass flux rates generated by condensate drainage for high APDs are much greater than current estimates of infiltration flux. The modeling study by Buscheck (1991) showed the duration of near-field dry-steam boiling conditions is insensitive to a wide range in infiltration flux and initial saturation distribution.

Buscheck (1991) found that even for APDs as low as 20 kW/acre, the flow of water vapor and condensate driven by the heat of radioactive decay may dominate the ambient hydrological system. Elevated temperatures and condensate drainage have the potential of driving geochemical changes that may significantly alter the flow and transport properties of the natural barriers underlying the repository horizon. Key concerns include whether hydrothermally induced zeolitization of the vitric nonwelded Calico Hills unit may significantly reduce its capacity to retard fracture-dominated flow. Because of the potential for substantial boiling and rock dry-out benefits at high APDs, the impact of these uncertainties may be significantly reduced."

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.7.2.1
7. Page 2-81, 2-100
8. Paragraph

9. Comment

There is a need to understand the steep hydrologic gradient, and couple this understanding with the questions: Could igneous or tectonic activity disrupt this gradient? What would be the effects of this disruption?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team agrees that there is a need to understand the large gradient and the effects of modifying the causative geologic conditions by tectonic or igneous processes. We believe that the more broadly framed specific concerns stated in the middle paragraph of page 2-81 indeed encompass the effects of tectonism on the gradient and the water table beneath the potential Yucca Mountain site. Similarly, we believe that the third and fourth paragraphs on page 2-100 (continuing onto page 2-101) quite explicitly discuss studies that have been done or are under way to understand the causative geologic conditions and, for at least one such condition, to examine the effects of disruption. Finally, in response to Dr. Cambray's Comment #2, we have proposed adding the following sentence at the end of the second paragraph on page 2-105:

"The results of this exploration should be incorporated into three-dimensional models, simulating both the existing geologic framework and

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 6 of 11
2. Page 2 of 2
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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

credible modifications of this framework by tectonic processes, in order to predict possible changes to the local flow system and the position of the water table."

No additional changes to the text are proposed at this time.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3 General
7. Page 2-102ff
8. Paragraph all

9. Comment

In comparison to other chapters, this is the most complete "Conclusions and Recommendations for Future Activities" section. The chapters are very uneven in their conclusions and recommendations. This also is one of the few places that testing priorities is mentioned. The Mattson et al. (1991) document on testing priorities is mentioned. The Mattson et al. (1991) document on testing priorities should be referred in almost every chapter.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team was aware that the "Conclusions and Recommendations for Future Activities" section in the Postclosure Tectonics evaluation is the most comprehensive of any presented in the ESSE report. The need for investigating tectonic processes and events received significant attention during preparation of the Environmental Assessment (DOE, 1986) and reviews of the SCP. About 30 percent of the studies planned for comprehensive site characterization (DOE, 1988a) addresses either preclosure or postclosure tectonics concerns. In addition, it has long been recognized that, because of the potential catastrophic consequences of certain tectonic processes (i.e., volcanic events or major earthquakes), it will be necessary to place bounds on the effects that such events may have on repository performance. The length and level of detail for each of the conclusions sections also varied in proportion to the numbers of specific conditions enumerated in each guideline and the current level of confidence in each evaluation.

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 7 of 11
2. Page 2 of 2
3. Name T. A. Vogel (Print Name)
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5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

Mattson et al. (1991) addressed priorities with an assumption that the principal reason for conducting the site characterization program was to evaluate the compliance of the repository system with the 10,000-year cumulative radionuclide release limits specified in 40 CFR Part 191. Although the report provided important insights, the need to expand the basis to include other reasons for gathering site information is recognized. The Postclosure Guideline evaluations in the ESSE report will be reviewed to determine if citing the prioritization results in Mattson et al. (1991) would be helpful.

In part, the ESSE report is the next step in evaluating the need for site characterization testing on a broader basis. However, recommendations for areas where additional information will increase confidence to a higher-level finding, or will assist in determining if such finding can be supported, were not systematically developed during preparation of the ESSE report. Additional considerations for conducting tests include (1) providing correlative data for other testing programs (see also the discussion on the need for technical integration in the response to Dr. Webb's Comment #20) and (2) gathering design information. The variety of testing rationales and the complexities of a fully integrated test prioritization are discussed in detail in the response to Dr. Drever's Comment #1.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.3
7. Page 2-105
8. Paragraph

9. Comment

The ESSE recommends that volcanism studies should continue as currently planned. However, it is not clear to me how any more data will add to any better predictions. The recent work by Perry and Crowe (1990), and by Mattson et al. (1991) would indicate the further work on this area should be given a very low priority. There are conflicting statements on this page with respect to this recommendation.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The report of Mattson et al. (1991) specifically was focused on prioritizing work that is currently planned and believed necessary to meet the postclosure performance requirements for a potential repository. The purpose of this prioritization was to identify (1) those concerns that have the greatest potential for leading to a decision that the site cannot be qualified from a postclosure performance perspective and (2) tests that might address the most critical concerns unambiguously, that is, tests that are directly pertinent but also are unlikely to lead to a false indication that the site is unsuitable. The report was also caveated as being based on the opinions of a small group of project scientists without the support of extensive performance calculations or advice from experts outside of the Yucca Mountain Site Characterization Project. That such opinions vary is evident not only from the literature cited in this report (pp. 2-94, 2-95, 2-101, and 2-102), but also from the comments of this peer review panel.

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 8 of 11
2. Page 2 of 2
3. Name T. A. Vogel (Print Name)
4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

The recent results of Crowe and his colleagues are encouraging in that they relate basaltic volcanism in the area to a tectonic model that has considerable merit also from the standpoint of other structural and tectonic features, and in that they predict a modest decline (relative to earlier predictions) in the probability that volcanism might intersect the repository. However, the probability is not negligible within the framework of the regulations, particularly given the current lack of scientific consensus that will heavily influence eventual site-suitability judgments. Both the calculated probabilities and the perceptions of the scientific public may change, for better or for worse, as progress is made in evaluating alternative tectonic models for the region. In fact, further understanding of the evolution of igneous processes is a vital component of this evaluation, as is suggested also by Dr. Cambray's Comment #4.

Finally, to return to the first point made in this response, we refer to the final paragraph of this section (beginning at the bottom of page 2-105 and continuing on page 2-106), and particularly to the last sentence: "However, the gap between current knowledge of the site and the southern Great Basin and that required for site qualification and licensing is sufficiently large to justify continuation of the currently planned investigations into the effects of tectonism (including igneous activity) on waste isolation at Yucca Mountain."

END OF TEXT

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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.4.4
7. Page 2-147
8. Paragraph Last

9. Comment

Many of the major problems in waste isolation occur at the interface among geotechnical research areas such as geohydrology, geochemistry, rock characteristics, tectonics, and climatic changes. These are discussed in this section. In the ESSE (page 2-147), the plans for future testing are discussed, however, this discussion is essentially limited to referring to the SCP in Table 2-14 (previously Table 2.4-2). This is the place where the ESSE should recommend prioritization of tasks to evaluate the site. The objective would be to unambiguously identify tests designed to determine if the site were unsuitable.

Prioritization should be based on determining which tests have a high probability of answering potential concerns, and a low probability for giving false alarms. This approach would reduce uncertainty by focusing the data collection, suggested in the SCP (Table 2-14, previously Table 2.4-2), toward

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text in Section 2.4 will be expanded to address integration of the issues identified in each of the guidelines. However, a detailed prioritization of the testing program based upon the conclusions of this evaluation is not made here since such a prioritization is outside the scope of this effort. Such a prioritization requires consideration of cost, schedule, and reliability of test methods, which are not considered here. The general set of recommendations made in each section is intended to be a set of considerations that should be taken into account in such prioritization.

Section 4.4 of the ESSE report will be expanded to provide a broader recommendation that a systematic prioritization task should be initiated. See the response to Dr. Vogel's Comment #10.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

1. Comment 9 of 11

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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

9 Comment (continued)

testing hypotheses in a prioritized order of importance.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 10 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 4.4 General
7. Page 4-8
8. Paragraph

9. Comment

This section should be expanded. The Test Prioritization Task should be explained better, including the fact that in some areas, no amount of further testing is likely to result in a higher-level finding. The recommendations here are weak. There needs to be some method of prioritization of tasks to evaluate the site and to determine which issue could have a potential for a higher-level finding. This comment could be considered a continuation of comment #9.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The text will be expanded as shown below to provide a better description of the Test Prioritization Task (TPT) (Mattson et al., 1991) and to recommend an integrated approach to prioritization that builds on work done in the ESSE effort and in the TPT.

In his comment, Dr. Vogel makes the observation that "...in some areas, no amount of further testing is likely to result in a higher-level finding." This was recognized in the ESSE procedure for making higher-level findings, as well as in the TPT project. In instances where only a lower-level finding can be supported in this report, it is always because the site is currently judged suitable, but it is possible that additional information might change that conclusion. What if there were no affordable tests available to provide reliable additional information? For example, assume the site is judged to be suitable now, but marginally so. Perhaps there is a 70-percent chance that appropriate suitability criteria are met. (This number is chosen for

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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1. Comment 10 of 11

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3. Name T. A. Vogel
(Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

illustration only.) And assume that there are no more affordable tests to be run. What should be done?

Here there are two schools of thought. One school says, "This situation is no different from any other suitability finding. The site is currently judged to be suitable, and it is unlikely that additional information will change this conclusion (because there will be no additional information). Then, according to the definitions in 10 CFR Part 960, a higher-level finding can be supported, even though there is only 70-percent chance that the suitability criteria are met."

The other school of thought says, "Because DOE does not have 'high confidence' that criteria can be met (only 70 percent), DOE must make a decision. It must choose between stopping testing and abandoning the site (because high confidence cannot be achieved) or stopping testing and recommending the site for repository development. The latter choice is made if the risk associated with the residual 30-percent chance that suitability criteria cannot be met is small in comparison to the societal costs of abandoning the site." This is the school of thought reflected in paragraph 3 of Section 4.4 on page 4-8.

So the first school of thought says "make the higher-level finding," and the second says "make a decision about the site," taking into account the risks associated with recommending or abandoning the site. These apparently conflicting views are, in fact, entirely consistent within the ESSE framework illustrated in Figures 1-1 and 1-2 of the draft ESSE report. That figure distinguishes between the evaluation according to DOE Siting Guidelines--represented by the center box in the figure--and the siting decision to recommend or abandon the site, which is represented by the diamond. Therefore, the first school of thought that says "make the higher-level finding" is an appropriate action performed inside the site evaluation box. The "make a decision about the site" school of thought is appropriate for decision making represented by the diamond. For example, it is not inconceivable for the site evaluation to make higher-level findings, and yet the DOE siting decision is to abandon the site because there is enough residual uncertainty to inhibit licensing.

Not all of the preceding discussion was added to the text because we believe the distinctions involved are subtle and are relatively unimportant at this early stage of site characterization. Instead, the following sentences will be added to the end of paragraph 3 on page 4-8:

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(Instructions on back of form)

1. Comment 10 of 11

2. Page 3 of 4

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(Print Name)

4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

"This is the type of decision represented by the diamond in Figure 1-1. Such decisions are made based on site-suitability evaluation results, but may be different from the evaluation findings because more factors are taken into account."

We will add the following text regarding test prioritization. The last sentence of paragraph 4 on page 4-8 has been deleted, as has paragraph 5. The following new paragraphs will be inserted after paragraph 4.

"The TPT found that the importance of resolving various postclosure issues varies widely. There are instances where establishing the presence of a potentially unsuitable site condition could lead to predictions of measurable releases of radionuclides, and there are other instances where the establishing presence of a site condition has negligible influence on releases. When the accuracies of proposed tests are considered explicitly, there are several instances where the tests are considered explicitly, there are instances where tests are not sufficiently accurate to detect an unlikely but potentially unsuitable site condition. In fact, in many of these cases, the tests are more likely to produce a false indication (i.e., false alarm) that the condition is present when, in fact, it is not.

An approach similar to that used on the TPT could be used to prioritize testing needed to resolve the open site suitability issues. In instances where a higher-level suitability finding can be supported, it may be appropriate to limit or stop further testing designed to improve understanding of the relevant site conditions. However, there are many reasons for testing, and each of these should be considered when prioritizing site characterization activities. In particular, the approach should (1) address preclosure qualifying and disqualifying conditions, (2) analyze all of the technical issues identified in this report, and (3) consider explicitly other reasons for site characterization activities, such as information needed to build confidence, to prepare a license application, to resolve design issues. Furthermore, the economic and false-alarm costs of proposed tests need to be balanced against their benefits in satisfying the above motivations for testing. The Core Team recommends that a comprehensive prioritization effort be considered to identify and

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4. Date November 11, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

prioritize those site characterization activities whose results will bear directly on resolving open site suitability issues."

END OF TEXT

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(Reviewer completes items 1 - 9.)

1. Comment 11 of 11
2. Date November 11, 1991
3. Reviewer T. A. Vogel
4. Organization Michigan State University
5. Revision Draft/Date August 1991
6. Section 2.3.7.3.2.4
7. Page 2-99
8. Paragraph last para. of Section

9. Comment

Possible water table excursions after an earthquake have been discussed in sections on geohydrology and tectonics. On page 2-99, 3rd paragraph from the bottom, this statement is too strong if this refers to the Carrigan et al. (1991) studies. These models considered the transport medium as a continuum. This model does not consider discrete fracture and water transport along fractures. Another related problem is the linkage of tectonic, hydrologic with climatic effects. The models are sensitive to the partial saturation in the unsaturated zone. Climatic changes can affect the extent of partial saturation. At a minimum there should be a recommendation of further modeling here.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In the third line of paragraph 3, page 2-99, we will delete the word, "very," in the phrase, "...from tectonic strain are [very] unlikely to..." Also, the following sentence will be added to the end of that paragraph:

"It is cautioned, however, that currently available simulations may not test the range of geologic conditions and hydraulic parameters that realistically exist, nor have they examined the effects under higher degrees of saturation that may be associated with future climates."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

REFERENCES FOR DR. THOMAS J. VOGEL

VOGEL

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10 CFR Part 960 (Code of Federal Regulation), 1990. Title 10 Energy, Part 960 General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, U.S. Government Printing Office, Washington, DC, pp. 518-551.

40 CFR, Part 191 (Code of Federal Regulations), 1990. Title 40, Protection of the Environment, Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel High-Level and Transuranic Radioactive Wastes, U.S. Government Printing Office, Washington, DC.

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Dr. Thompson Webb III

CLIMATIC CHANGE

Brown University
Providence, RI

EARLY SITE SUITABILITY EVALUATION
COMMENT RESOLUTION RECORD

Peer Reviewer's Statement.

I have reviewed the ESSE Integrated Evaluation Package in accordance with ESSE Peer Review Plan. My conclusions with respect to the review criteria of the ESSE Peer Review Plan are:

Review Criteria	Adequate Yes: See Comment(s) Nos.*	No: See Comment(s) Nos.
In my areas of expertise:		
A. The content of the ESSE Integrated Evaluation Package provides an unbiased and objective presentation of information relevant to the suitability issues covered by each guideline.	______	______
B. The conclusions about the status of lower and higher-level findings on the siting guidelines are balanced and defensible.	______	______

Comments 1 through _____ are attached.

Peer Reviewer Thompson Webb III Date Nov 12, 1991

Comment Resolution Record

Yes X The revised ESSE Integrated Evaluation Package adequately addresses my comments.

No _____ The following comments have not been adequately addressed:

Peer Reviewer Thompson Webb III Date Dec 6, 1991

Comments not resolved between the Peer Reviewer and the ESSE Core Team have been noted by the T&MSS Task Manager.

T&MSS Task Manager Jean L Younker Date 12-6-91

* Note: May explain adequacy of comment(s) if needed.

ESSEFIG4.MISC/5-21-91

Figure B-3 Early Site Suitability Evaluation (ESSE) Comment Response Record.

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 1 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.1
7. Page 2-51
8. Paragraph 2

9. Comment

What about gas phase radionuclide transport? What does "this guideline" refer to?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The reference to gas-phase radionuclide transport will be removed from the text by simply deleting the second to last sentence in paragraph 2 on page 2-51. Gas-phase radionuclide transport is considered expressly as part of the Total System Guideline in Section 2.4 of the report.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
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(Reviewer completes items 1 - 9.)

1. Comment 2 of 20	5. Revision Draft/Date August 1991
2. Date November 12, 1991	6. Section 2.3.4.1.1
3. Reviewer Thompson Webb III	7. Page 2-51
4. Organization Brown University	8. Paragraph 2

9. Comment

Somewhere some follow up is needed for the last sentence. Any plans.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The last sentence of paragraph 2 will be removed because it is out of place at this point in the guideline evaluation and is a redundant summary of the actions needed to resolve the technical issues discussed in Section 2.3.4.2.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 3 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 1.2.3.4.5.3
7. Page 1-14, 2-64
8. Paragraph 5,2

9. Comment

On p. 1-14, a type of sensitivity analysis is mentioned. Is one planned for climate? What about Thompson et al.'s report [Thompson et al., to be published 1992]? I would like to see mention of this report or at least the types studies that the report describes in section 2.3.4. More later on this point.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

An explicit recommendation for a type of sensitivity analysis to support resolution of the guideline is described in the new text that will replace the last paragraph of Section 2.3.4.5.3. The intent of the ESSE report is to identify what could and should be done to resolve the site-suitability issues and not to describe what is currently planned to be done. One recommendation presented by the ESSE Core Team is that the ESSE report be used to review the Site Characterization (DOE, 1988a) Plan and associated study plans in order to prioritize the testing program to ensure that the planned work will be adequate for resolving site-suitability issues, bearing in mind that there are other reasons for testing besides site suitability. To discuss and evaluate the planned work in detail goes beyond the purview of the ESSE study.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 4 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.1 General & EA
7. Page 2-55 & 2-56
8. Paragraph

9. Comment

I note that statements in the EA need checking to be sure they still hold. Check on pp. 6-230, 233, 234. Any reason for higher estimates of precip at 12 ka? What about the predicted 130 m rise in water table if precip. increases by 100%? It is mentioned on p. 6-238. What is the status of the favorable condition mentioned on p. 6-232? I note that a 185 m rise is required to cause problems (6-239) and that the 130 m rise with a 50% error would qualify. What are the errors of estimate? On p. 6-240, the statement about the rocks never being under the water table is qualified by "not for any substantial period of time." How long is substantial? and how long would cause problems for the repository. If 10 years causes a problem and 100 years is substantial, then this statement requires further study. I note the need for the climate studies described in Thompson et al. to deal with the potentially adverse conditions on pp. 6-239 and 241.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The statements on p. 6-230 of the EA have been refined by more recent data and studies but the conclusions remain the same. A discussion of the work that will be published in Thompson et al. (to be published 1992) will be added to Section 2.3.4.3.2.1, which provides a more recent interpretation of climatic conditions at 12 ka than was presented in the EA. The water-table rise modeled by Czarnecki (1985) probably errs on the conservative side because he neglected transient effects, specifically, storage, and did not account for the enhanced transmissivity associated with water-table rise. Quantitative errors of estimate were not evaluated as part of Czarnecki's study. The EA does not define the meaning of "any substantial length of time" on p. 6-240. Apparently "substantial" implies a time, however long, for inundation by the saturated zone to have left an identifiable imprint. To affect waste isolation, the time probably would have to be of the order of 1,000 years. The ESSE Core Team agrees that climate modeling in conjunction with ground-water flow and transport modeling will be needed to address the referenced

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 4 of 20
2. Page 2 of 2
3. Name Thompson Webb III (Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)
potentially adverse conditions.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 5 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.2.1
7. Page 2-54
8. Paragraph 1

9. Comment

Need of more specificity about exactly what methods besides deterministic ones will be used. What sorts of bounding calculations or sensitivity analyses? Climatic studies with models are needed here to simulate both past and future conditions. The data from the Quaternary can be used to test the models and methods used to predict future climates and to do sensitivity analyses. This research will take time and should be mentioned more explicitly as being necessary to assess the guideline.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Identifying specific details of the testing program is beyond the scope of the ESSE task. However, reference to using paleoclimate information to test and calibrate climate models is made in Section 2.3.4.3.2 of the ESSE report, and the use of probabilistic methods and sensitivity analyses will be revised as described in Section 2.3.4.5.2. These discussions are intentionally generic and general and serve to provide guidance rather than to specify detailed tests, studies, or analyses.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 6 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.1
7. Page 2-52 & 53
8. Paragraph Table 2.3.4-1

9. Comment

Are the guidelines ok at a low level finding? If so, shouldn't they be pushed up to a high-level finding level. What research will lead to high level findings?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Higher-level suitability findings for all of the guidelines will be required in order for the DOE to recommend the site for repository development and proceed with licensing interactions with the Nuclear Regulatory Commission. The purpose of the ESSE Report is not to identify the research needed to reach higher-level findings but to determine if, at the present time, there is any evidence to indicate that the site is unsuitable for a repository and for continued characterization and evaluation.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 7 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.2.2
7. Page 2-54 & 55
8. Paragraph

9. Comment

Actions 2 to 4 seem primarily to be based on using data from the Quaternary, but climate models are critical for this research and for getting the best results. Many of the plans of Thompson et al. fit in here and should be described. The report should say much more than that "Actions 4 and 5 will be based partly on the evidence of ... past climates." What is the other part to partly?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The phrase "based on the analysis and interpretation of paleoenvironmental data and the results from climate models" will be added to action (2) on p. 2-54. The listing of these actions was intended to be independent of any work that is planned; so the ESSE Core Team believes it inappropriate to discuss the specific plans in the Thompson et al. (1991) study plan for future climates. The phrase "will be based partly on the evidence of ..." in the last paragraph of Section 2.3.4.2.2. will be replaced by the phrase "will be based on the initial conditions and model calibrations derived from the evidence for..."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 8 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.1
7. Page 2-55, 2-56
8. Paragraph 6

9. Comment

Here the report says that the EA said that the higher-level findings were not then permitted. What is being done to fill in for the insufficient information? What is planned to show just how extreme future climate changes may be? See the comment on p. 2-56 about future changes however extreme. Why not quantify however extreme with some estimates and their uncertainties? The work done and proposed with climate model and simulation of past climates is not mentioned. More description might be given on p. 2-57.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This section of the ESSE report is intended only to review the EA findings and not to describe planned future work. The last paragraph of this section, which contains the phrase "however extreme," is redundant and will be deleted from the report. The kinds of actions and information needed to complete evaluation of the guidelines are described generally in Section 2.3.4.5.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 9 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.2.1
7. Page 2-58
8. Paragraph 1

9. Comment

The Dorn et al. claim for a rise from 10-11 ka, i.e., for the Younger Dryas raises implications for possible quick response to short-term climate changes.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The ESSE Core Team concurs with Dr. Webb that the enlargement of the late-Pleistocene lakes between 11 and 10 ka constitutes evidence for possible rapid and large magnitude hydrologic response to climatic change. However, the consequences of this apparent climatic change in the Yucca Mountain region, which is located south of the major Great Basin lakes, remain undetermined.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 10 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.2.1
7. Page 2-59
8. Paragraph 1

9. Comment

I like the summary, but what more is needed or planned? What about the Thompson et al. plan? Also how might future predictions be modified if they are not cyclic or as closely tied to orbital forcing as some studies show? All the more reason for bounding studies and focus on future greenhouse-gas-induced climates and on past pluvial extremes like 12 ka.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This section is concerned with reviewing work completed since the EA was issued in 1986 and is not intended to discuss planned or future work. Aspects of needed future work are described in broad terms in Section 2.3.4.5. The task of expanding investigations or filling in information gaps is tacitly relegated to the DOE and the principal investigators responsible for the applicable scientific investigations at the site.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 11 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.2.2
7. Page 2-60
8. Paragraph 1

9. Comment

On what time scale is the trend toward increasing aridity occurring. If over the past million years or more, then this trend may not be too relevant to the next 10,000 years.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

As stated in the text (page 2-60, paragraph 2, sentence 1), water-table altitudes at the springs in Ash Meadows have "declined progressively throughout middle and late Pleistocene time." The reference to the work of Quade (1986) and Quade and Pratt (1989) will be revised as follows: "A trend toward increasing aridity in the region also is supported by evidence cited by Quade (1986) and Quade and Pratt (1989) who interpret the presence of widespread fine-grained deposits in the upper Las Vegas Valley, southern Nevada, to be the sites of former spring-supported marsh environments. Radiocarbon dating of organic material within these deposits indicate that the springs were active as early as 30 ka and had undergone progressive down-valley desiccation and abandonment by 9 ka.". The following sentence also will be added: "Pack-rat midden data analyzed by Spaulding (1991) indicate that maximal aridity relative to present-day conditions in the northern Mojave Desert and, by implication, in the Yucca Mountain region occurred during

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 11 of 20
2. Page 2 of 2

3. Name Thompson Webb III
(Print Name)

4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)
middle-Holocene time, 7.8 to 4 ka."
END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes Items 1 - 9.)

1. Comment 12 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.2.2
7. Page 2-61
8. Paragraph 1

9. Comment

The Levy study is encouraging but greenhouse-gas climates are not part of the Quaternary record, so some climate model studies are required.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The work by Levy (1991) was discussed in the context of paleohydrology and the evidence for past water-table altitudes at the Yucca Mountain site. No reference is made to climate modeling in this context, and we did not intend to indicate that Levy's work in any way obviates the need for modeling past and future climates to resolve the issues associated with this guideline.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 13 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.3.2.3
7. Page 2-61
8. Paragraph 1

9. Comment

How will Long's study or method be tied into the Thompson et al. plans? How did Long estimate future storm frequencies? What about Long's concluding two sentences on p. 2-18 of his report? He introduced a method that could be improved and needs more work.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

There are presently no plans to incorporate Long's method (Long, 1990) into the site characterization program. Long's method is discussed as something that possibly could be done in conjunction with future climate-modeling studies. Long assumed a constant mean annual rate of storm occurrence with exponentially distributed storm-event duration and precipitation rate. The first of Long's two concluding sentences probably is true if one can develop the appropriate probabilistic models for the climate scenarios. The second sentence is either a tautology or sophistry. Long's method certainly requires more work, but it is an example of an approach that may be applicable for evaluating the consequences for climatic changes at the Yucca Mountain site.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 14 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.4
7. Page 2-62
8. Paragraph 2

9. Comment

So the lower-level finding of the EA has been strengthened, but how can it be made a higher level finding? Are there any plans to do so? Again I would mention the Thompson et al. plan and the hydrological models that may use the new climate data.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

This section of the report is concerned with reviewing the current status of the technical issues associated with this guideline and not with planned or future work. Recommendations for future work to address these issues is discussed, albeit broadly, in the subsequent Section 2.3.4.5 of the report.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 15 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.5
7. Page 2-62
8. Paragraph 3

9. Comment

You mention here that a higher level finding is not yet supported. Good. What is being done about getting detailed analyses of future climatic changes? I would mention this lack of a higher level finding earlier and note the need for studies and plans to obtain such a finding.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

In this and previous comments, Dr. Webb has requested that reference be made to the planned and future work needed to reach higher-level findings for this guideline. The guideline evaluations, however, are structured progressively with first a statement of the guideline and its associated technical issues followed by a review of the EA findings, summary of new information obtained since the EA, an assessment of the current status of the guideline evaluation based on the new information, and, finally, recommendations for future action to complete the guideline evaluation if higher-level findings cannot be supported by currently available information. The reviewer's concern seems to deal more with the structure of the report than with its technical content.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 16 of 20	5. Revision Draft/Date August 1991
2. Date November 12, 1991	6. Section 2.3.4.5.1
3. Reviewer Thompson Webb III	7. Page 2-63
4. Organization Brown University	8. Paragraph 3

9. Comment

Say more about what Thompson et al. propose to do. Note need to get things going soon if to have the best results when needed to support the case for the repository. The whole of future climate change prediction could be discussed a little. What about IPCC?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The study plan for future climate by Thompson et al. (1991) is referenced to inform the reader that plans have been made to predict possible future climate in the Yucca Mountain region. However, to describe these plans is beyond the purview of the ESSE report. The following sentence is proposed to be added to the first paragraph of Section 2.3.4.5.1 on p 2-63: "One such approach directed specifically at developing scenarios and examining the consequences for possible global climatic change in response to present and future greenhouse-gas emissions is that being taken by the Intergovernmental Panel on Climate Change (IPCC, 1990)."

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 17 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.5.2
7. Page 2-64
8. Paragraph 1

9. Comment

Can you say more about the hydrologic modeling techniques or give a reference on line 2. At the bottom of the page, a resolving of issues is mentioned. Won't accurate bounding calculations from climate models for future climates be critical here too?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

Because of the large number of computer codes that are now available for modeling hydrologic systems, no single reference can be given. The sentence starting on line 2 at the top of p. 2-64 will be revised to read as follows: "A number of numerical-modeling methods have been developed for simulating hydrologic-system response, and these methods probably are ..." The use of bounding calculations is described in the proposed replacement text for the concluding paragraph of Section 2.3.4.5.3.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 18 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 2.3.4.1.1
7. Page 2-51
8. Paragraph 2

9. Comment

Given need to consider past climate changes, I am concerned that the progress reports for the SC report so little progress in assembling paleoclimate data sets for the West. These are needed for specifying past climates and for use in checking the climate models including MM4 to be used for predicting future climate. What can be added to comment on this problem for removing uncertainties and gaining a higher-level finding.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

A number of studies are planned as part of the site characterization program to conduct paleoenvironmental and paleohydrologic investigations with respect to the Yucca Mountain region. Resources probably are lacking to support additional studies over the western United States in order to test and calibrate models such as MM4. We suggest that, perhaps, the work of Thompson et al. and Kutzbach et al. to be reported in Thompson et al. (to be published 1992) will provide an empirical and model basis sufficient to resolve the paleoclimate issue for this guideline.

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 19 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 4
7. Page 4-7
8. Paragraph Line 5

9. Comment

I would insert some mention that approved study plans exist for certain areas of research that will help resolve issues and lead to establishment of higher-level findings for selected guidelines like climate and that this research should be authorized to begin as soon as possible. I have read the study plan for climate and judge it to address key issues.

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The Site Characterization Plan (DOE, 1988a) provided descriptions of the studies that are planned to characterize the Yucca Mountain site, both to evaluate its suitability and to support eventual licensing, if the site proceeds into the licensing phase. An agreement between the DOE and the NRC further commits the DOE to prepare detailed study plans for each of these studies and provide them to the NRC for review prior to initiation of a new study. This process is under way, and approximately 40 study plans of the planned 107 have been forwarded to the NRC. With the recent acquisition of environmental permits, new studies have been initiated at the Yucca Mountain site, and others will start in the near future. Limited budget is the primary factor limiting the initiation of additional studies. References to approved study plans will be considered on a case-by-case basis in the final section of each technical guideline (Conclusions and Recommendations for Future Activities).

END OF TEXT

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM

(Instructions on back of form)

(Reviewer completes items 1 - 9.)

1. Comment 20 of 20
2. Date November 12, 1991
3. Reviewer Thompson Webb III
4. Organization Brown University
5. Revision Draft/Date August 1991
6. Section 4
7. Page general
8. Paragraph

9. Comment

I see a need to develop interfacing between guidelines and to have researchers in climate and hydrology or in hydrology and tectonics discuss issues of mutual concern. Some issues may be falling between the cracks so to speak. Researchers need to investigate the consequences of changes occurring in two areas, e.g., climate and hydrology, at once and leading to an unexpected result. One example might be a shift in the steep hydrological gradient at the same time that the climate becomes wetter. Who is addressing such a simultaneous change? Is the research on the guidelines set up to deal with such an issue?

END OF TEXT

10. Proposed Resolution *(To be completed by ESSE Core Team)*

The interface issue raised in this comment has been an ongoing concern of the bodies charged with review and overview of the DOE's repository program (see also Dr. Drever's Comment #1, Dr. Kreamer's Comment #20, Dr. Vogel's Comments #2 and #4). Both the need for technical integration and attention to specific interface issues have been raised in comments from the NRC (NRC, 1989) and the Nuclear Waste Technical Review Board (1990a,b; 1991). Although the format of 10 CFR Part 960 compartmentalizes geotechnical topics into discrete technical guidelines, the qualifying conditions for the technical guidelines make statements such as "compatible with waste containment and isolation" or refer to compliance with the broader system guidelines. We have generally interpreted those statements to mean that each technical guideline should be looked at in terms of its contribution, or lack thereof, to performance of the total repository system. Furthermore, the direct physical interactions between distinct natural processes, such as climate and geohydrology, demand interdisciplinary cooperation. The

11. Resolution *(To be completed by original Reviewer)*

Comment resolution accepted as proposed.

END OF TEXT

EARLY SITE SUITABILITY EVALUATION
COMMENT RESPONSE FORM
(CONTINUATION SHEET)

(Instructions on back of form)

1. Comment 20 of 20
2. Page 2 of 2

3. Name Thompson Webb III
(Print Name)
4. Date November 12, 1991

5. Comment or Proposed Resolution or Resolution *(Circle one)*

10 Proposed Resolution (continued)

qualifying condition for the Climate Guideline can only be evaluated by assessing the impact of climatic changes on the hydrologic system.

There are activities within planned studies (DOE, 1988a) aimed at investigating the interfaces that could have a potential to affect repository performance. Also, an increasing number of both formal and informal technical meetings within the Project are being held to discuss the interface issues. As site characterization increases our knowledge of specific processes at the site, this type of issue will continue to arise and become even more important to gaining a fuller understanding of the potential performance of the site for a repository.

END OF TEXT

REFERENCES FOR DR. THOMPSON WEBB III

WEBB

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Spaulding, W. G., 1991. A Middle Holocene Vegetation Record from the Mojave Desert of North America and its Paleoclimatic Significance, Quarternary Research, Vol. 35, pp. 427-437.

Thompson, R. S., C. Whitlock, S. P. Harrison, W. G. Spaulding, and P. J. Bartlein, 1992. Late Quarternary History of Vegetation and Climate in the Western United States, in Global Climates Since the Last Glacial Maximum, H. E. Wright, Jr., J. E. Kutzbach, T. Webb III, W.F. Rudiman, F. A. Street-Perrott, and P. J. Bartlein (eds.), University of Minnesota Press, Minneapolis (in press).

Thompson, S. L., T. J. Crowley, G. J. Kukla, R. P. Sandoval, F. Gelbard, and Y. K. Behl, 1991. Study Plan for SCP Study 8.3.1.5.1.6: Characterization of the Future Regional Climate and Environmental, YMP-SNL-SP 8.3.1.5.1.6, SAND91-0514, Rev. 0, Sandia National Laboratories, Albuquerque, NM.

10 CFR Part 960 (Code of Federal Regulation), 1984. Title 10 Energy, Part 960 General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, U.S. Government Printing Office, Washington, DC, pp. 518-551.

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APPENDIX A

RESUMES/CURRICULA VITAE

STAN L. ALBRECHT

Address

Academic Vice President
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[redacted]

Academic Background

B. S.	Brigham Young University, Sociology, 1966
M. A.	Washington State University, Sociology, 1968
Ph. D.	Washington State University, Sociology, 1970

Professional Positions

1989-	Academic Vice President and Associate Provost, Brigham Young University
1985-89	Dean, College of Family, Home, and Social Sciences, Brigham Young University
1979-	Professor of Sociology, Brigham Young University
1974-79	Associate Professor of Sociology, Brigham Young University
1970-74	Assistant Professor of Sociology, Utah State University

Research Experience

1966	Research Assistant, Brigham Young University. A study of the extent and costs of excessive drinking on the Uintah-Ouray Indian Reservation.
1967	Research Assistant, University of Kentucky. Data analysis of a Southern Appalachia poverty study.

Research Experience (continued)

1967-70	Research Assistant, Washington State University. An analysis of the relationship between verbal attitudes and overt behavior. Funded by the National Science Foundation.
1971	Principal Investigator. A study of attitudes toward power plant construction in the Four Corners area of the Southwest. Funded by the Rockefeller Foundation.
1971-74	Principal Investigator. A study of institutional structures for improving community services in rural areas. Funded by the Utah State University Agricultural Experiment Station.
1973-74	Research Associate. A study of the sociological aspects of land use planning. Funded by the Rockefeller Foundation.
1974-75	Principal Investigator. A study of environmental attitudes and behavior of elected state legislators. Funded by the Research Division, Brigham Young University.
1974-75	Co-Investigator. Three studies of the socioeconomic impacts of alunite and phosphate developments in Utah and Idaho. Funded by Earth Sciences, Inc.
1975	Co-Investigator. Social and economic aspects of coal development in Carbon and Emery Counties, Utah. Funded by the State of Utah Science and Technology Advisory Committee.
1975	Co-Investigator. Socioeconomic impacts of oil shale development in the Uintah Basin. Funded by the Bureau of Land Management.
1975-76	Co-Investigator. Conflict and consensus in marital and family role behavior. Funded by the Research Division, Brigham Young University.
1976	Co-Investigator. Socioeconomic impacts of the Bonneville Unit of the Central Utah Project. Funded by the Bureau of Reclamation.
1976-77	Co-Investigator. Socioeconomic impacts of the Harry Allen Power Plant in southern Nevada. Funded by the Bureau of Land Management.
1976-77	Co-Investigator. Socioeconomic impacts of power plant development on the Coalville Indian Reservation. Funded to Harbridge House by the Bureau of Reclamation.

Research Experience (continued)

1977	Co-Investigator. Sociocultural implications of energy development on the Uintah-Ouray Reservation. Funded by OWRT and Bureau of Reclamation.
1981-83	Co-Investigator. Evaluation of Indian Student Placement Program. Funded by the LDS Church.
1981-83	Principal Investigator. Religious affiliation and disaffiliation. Funded by the LDS Church.
1984	Co-Investigator. Social change in Grenada.
1978-89	Involvement in a number of research projects dealing with the social impacts of energy development in the West.

Research Consulting

1972-73	Texas Water Development Board. Socioeconomic impacts of water resource development.
1973	Northern Cheyenne Tribe. Social impacts of coal development on the Northern Cheyenne Reservation.
1974-75	United States Forest Service. Environmental and social impacts of a forest management plan.
1974-75	Earth Sciences, Inc. Socioeconomic impacts of resource development.
1975	Utah State Advisory Council on Science and Technology.
1975	National Council on Water Quality. Social consequences of Public Law 92-500.
1975	Westinghouse Environmental Systems. Sociocultural impacts of proposed Intermountain Power Project.
1975-76	Messer Associates, Native American research projects.
1975-76	Centaur Management Consultants. Evaluation of technical and training assistance delivered to Indian tribes and urban Indians.

Research Consulting (continued)

1976	Harbridge House. Socioeconomic impacts of Provo River and Diamond Fork Systems of the Central Utah Project.
1976-77	Eyring Research Institute. Studies of social impact of energy resource development.
1976-77	Bureau of Land Management. Socioeconomic impacts of Harry Allan Power Plant in southern Nevada. Training sessions in socioeconomic impact assessment.
1977-78	Centaur Management Consultants. Socioeconomic impacts of grazing and energy development on Western lands.
1977-78	Westinghouse Environmental Systems. Training sessions on environmental impact assessment.
1978-89	Consulting on a variety of projects dealing with the social impacts of energy development for Centaur; Harbridge House; ABT Associates; Adcock and Associates; Vaughn Hansen Associates; Architects-Planners Alliance; Department of Energy; Wyoming Research Corporation; Utah Water Lab; Office of Technology Assessment; Utah State University; Mountain West Research; Science Applications, Inc.; Synfuels Engineering and Development; Department of Energy, Office of Nuclear Waste Isolation; and the Federal Emergency Management Agency.

Publications

A. Books

Social Psychology. Englewood Cliffs, N.J.: Prentice-Hall, 1980. Co-authored by B. Chadwick and D. Thomas.

Divorce and Remarriage. New York: Greenwood Press, 1983.

Social Science Research Methods. Englewood Cliffs, N.J.: Prentice-Hall, 1984. With B. Chadwick and H. Bahr.

Social Psychology (second edition). Englewood Cliffs, N.J.: Prentice-Hall. 1986. Co-authored by B. Chadwick and C. Jacobsen.

B. Articles in Refereed Journals

"Political Activity, Issue Salience, and Political Socialization," The Rocky Mountain Social Science Journal, April 1971 (8:127-136).

"The Impact of Social Constraints on the Relationship Between Attitudes and Behavior," Social Forces, September 1971 (50:102-112).

"Attitude-Behavior Relationships: A Re-examination of the Postulate of Contingent Consistency," Pacific Sociological Review, April 1972 (15:149-169). With M. DeFleur and L. Warner.

"Environmental Social Movements and Counter-Movements: An Overview and an Illustration," Journal of Voluntary Action Research, October 1972 (1:1-11).

"Verbal Attitudes and Significant Other's Expectations as Predictors of Marijuana Use," Sociology and Social Research, January 1973 (57:196-207).

"Prediction of Marijuana-Related Behavior In and Out of the Small Groups Laboratory," Western Sociological Review, Fall 1973 (4:1-12).

"The Interactive Effects of Situational and Personality Factors on Attitudes-Action Consistency," Youth and Society, March 1975 (6:344-364).

"Attitudes as Predictors of Behavior vs. Behavior Intentions: A Convergence of Research Traditions," Sociometry, March 1976 (39:1-10). With K. Carpenter.

"Legacy of the Environmental Movement," Environment and Behavior, June 1976 (8:147-168).

"Attitudes Toward the Police: Implications for Police-Community Relations," Criminology, May 1976 (15:67-86). With M. Green.

"Social Class and Sex-Stereotyping of Occupations," Journal of Vocational Behavior, 1976 (9:321-328).

"Another Roadblock to Meaningful Environmental Reform: Voters Rejection of a State Land Use Act," Humboldt Journal of Social Relations, Spring-Summer 1976 (47-53). With R. Geertsen.

"Marital and Family Role Satisfaction," Journal of Marriage and the Family, August 1976 (431-440). With B. Chadwick and P. Kunz.

"Attitudes Toward Accelerated Urban Development in Low-Population Areas," Growth and Change, 1977 (8:22-28). With C. Lewis.

B. Articles in Refereed Journals (continued)

"Public Stereotyping of Sex Roles, Personality Characteristics, and Occupations," Sociology and Social Research, 1977 (61:223-240). With H. Bahr and B. Chadwick.

"Adolescent Attitude-Behavior Inconsistency: Some Empirical Evidence," Adolescence, Fall 1977 (47:433-442).

"Cognitive Barriers to Equal Justice Before the Law," Journal of Research in Crime and Delinquency, July 1977 (14:206-221). With M. Green.

"Religiosity and Deviance: Application of an Attitude-Behavior Contingent Consistency Model," Journal for the Scientific Study of Religion, September 1977 (16:263-274).

"Religion, Marital Happiness, and Divorce," International Journal of Sociology of the Family, December 1977 (7:227-232). With P. Kunz.

"Sociocultural Factors and Energy Resource Development," Journal of Environmental Management, 1978 (7:73-90).

"Land Use Planning: Attitudes and Behavior of Elected Officials and their Constituents," Social Science Quarterly, 1978 (59:20-36). With R. Geertsen.

"Changing Family and Sex Roles: An Assessment of Generational Differences," Journal of Marriage and the Family, February 1979 (41-50). With H. Bahr and B. Chadwick.

"Correlates of Marital Happiness Among the Remarried," Journal of Marriage and the Family, November 1979 (857-867). Reprinted in Jerrold R. Greenburg, Remarriage, 1982.

"The Decision to Divorce: A Social Exchange Perspective," Journal of Divorce, Summer 1980 (319-337).

"Reactions and Adjustment to Divorce: Differences in the Experiences of Males and Females," Family Relations, January 1980 (29:59-68).

"Some Observations about Rural Sociology from the Perspective of An (Almost) Retired Editor," Rural Sociologist, 1981 (1:346-353).

"Local Disruptions from Energy Development: Real or Fabricated," Pacific Sociological Review, July 1982 (297-306).

"Patterns of Religious Disaffiliation: A Study of Lifelong Mormons, Mormon Converts, and Former Mormons," Journal for the Scientific Study of Religion, December 1983 (366-379). With Howard Bahr.

B. Articles in Refereed Journals (continued)

"Secularization, Higher Education, and Religiosity," Review of Religious Research, September 1984 (43-58). With Tim Heaton.

"Boomtowns and Social Disruption," Rural Sociology, Summer 1984 (230-246).

"Secondary Business Impacts of Energy Development: A Study of Seven Western Counties," Impact Assessment Bulletin, 1984 (3:41-53). With J. Halstead, L. Leistritz, D. Albrecht, and S. Murdock.

"Writing and Publishing in Rural Sociology," The Rural Sociologist, September 1984 (336-341).

"The Timing of Divorce," Journal of Marriage and the Family, August 1985 (631-639). With T. B. Heaton and T. K. Martin.

"Discriminants of Editorial Decision Outcomes," Rural Sociology, December 1985 (614-625). With K. Warner, S. Eberley, and B. Johnson.

"The Dimensions of Religiosity: A Conceptual Model with an Empirical Test," Review of Religious Research, March 1986 (226-244). With M. Cornwall and B. Pitcher.

"An Evaluation of an Indian Student Placement Program," Social Casework, November 1986 (515-524). With Bruce Chadwick and Howard Bahr.

"Contemporary Saints in Historical Perspective," BYU Studies, Vol. 27, No. 2, Spring 1987, pp. 119-135. With Tim Heaton and Randal Johnson.

"The Place of Attitudes and Perceptions in Social Impact Assessment," Society and Natural Resources, 1988. With James Thompson.

"Life Events and Religious Change," Review of Religious Research, Vol. 31, No. 1, Spring 1989, pp. 23-38. With Marie Cornwall.

"The Consequential Dimension of Mormon Religiosity," BYU Studies, Vol. 29, No. 2, Spring 1989, pp. 57-108.

"Educational and Occupational Aspirations of Secondary School Students in Grenada Following the American Intervention," Adolescence, Vol. 24, No. 95, 1989. With Bruce A. Chadwick.

"Strangers Once More: Patterns of Disaffiliation from Mormonism," forthcoming in Journal for the Scientific Study of Religion, 1989.

"Lifeworld and Social Disruption," forthcoming, 1990. With Lynn England.

B. Articles in Refereed Journals (continued)

"Stable Unhappy Marriages," forthcoming in Journal of Marriage and the Family, 1990. With Tim Heaton.

C. Book Chapters, Proceedings, and Related Publications

"The Extent and Costs of Excessive Drinking Among the Uintah-Ouray Indians," in H. Bahr, B. Chadwick and R. Day, Native Americans Today: Sociological Perspectives, Harper and Row, 1972. With A. Slater.

"Rural Development: Its Dimensions and Focus," Utah Science, December 1972 (33:115-121).

"Sociological Implications of Power Plant Development," Proceedings, Associated Intermountain Universities' Conference on Policy Formulation in the Development of Energy Resources, May 1972.

"Environmental Social Movements and Counter-Movements: An Overview and an Illustration," in Robert B. Evans (ed.), Social Movements, Rand McNalley, 1973, pp. 244-262.

"The Provision of Health-Related Services in Rural and Urban Areas," Utah Science, September 1973 (34:78-82).

"Legacy of the Environmental Movement," in Arvin Murch, Environmental Concern: Personal Attitudes and Behavior Toward Environmental Problems, New York: MSS Corporation, 1974, pp. 250-273.

"The Environment as a Social Problem," in Armand Mauss, Social Problems as Social Movements, Lippincott, 1975, pp. 556-605.

"Population Crisis and Controversy," in Armand Mauss, Social Problems as Social Movements, Lippincott, 1975, pp. 606-658.

"The Distribution of Justice: Barriers to Equal Legal Participation Among the Poor," in D. Zimmerman et al. (eds.), Understanding Social Problems, Praeger, 1976, pp. 69-95.

"Intergenerational Contact and Alienation in Elderly Mormon Families," Proceedings, The Annual Family Research Conference, Brigham Young University, 1975, pp. 62-77.

C. Book Chapters, Proceedings, and Related Publications (continued)

"Pollution vs. Paychecks: The Environmental Problem-Movement and Its Opposition," in A. L. Mauss and J. C. Wolfe, This Land of Promises: The Rise and Fall of Social Problems in America, Philadelphia: Lippincott, 1977, pp. 397-414.

"Sociocultural Factors and Energy Resource Development in Rural Areas in the West," in E. Allen and B. Crawford, Socioeconomic Impacts of Western Energy Development, Ann Arbor Press, 1977.

"The Impacts of Energy Development on Native American Lands," in E. Allen and B. Crawford, Socioeconomic Impacts of Western Energy Development, Ann Arbor Press, 1977.

"Energy Development: Prospects and Implications for Native Americans," in State-of-the-Art Survey of Socioeconomic Impacts Associated with the Development of Energy Facilities, Atomic Industrial Forum, 1977.

"Social Impacts in Western Energy Boomtowns," Mountainwest, July 1978, 4.

"An Identification and Evaluation of Strategies for Assessing Social Implications of Alternative Actions on Public Lands," Proceedings of a Workshop on Index Construction for Use in High Mountain Watershed Management, Utah Water Research Laboratory, 1979, pp. 111-124.

"Should Rural Sociology be Expanded: A Reply," Newsline, April 1980, p. 8.

"Sociocultural Factors," in Mohan K. Wali (ed.), Mining Ecology, London: Academic Press, 1980.

"Unique Impacts of Rapid Growth on Minority Groups: The Native American Experience," pp. 171-189 in Bruce A. Weber and Robert Howell, Coping with Rapid Growth: Rural Community Impacts and Management Options, Westview Press, 1982.

"Participant Observation," in Steve Murdock and Don Albrecht, Handbook for Assessing Special and Social Effects on High Level Nuclear Waste Repositories, Corvallis, Ore.: Western Rural Development Center, 1982, pp. 73-103.

"The Environment," in Melvin L. DeFleur, Social Problems in America, Wadsworth Publishing Co., 1983, pp. 536-562.

"Community Response to Large-Scale Federal Projects: The Case of the MX," in Steve Murdock et al. (eds.), Nuclear Waste: Socio-Economic Dimensions of Long-Term Storage, Westview Press, 1983, pp. 233-251.

C. Book Chapters, Proceedings, and Related Publications (continued)

"Rural Sociology: The Profession," in Rural Sociology, The Wisconsin Contribution, Current Status, and Future Directions, Proceedings of the 50th Anniversary Symposium, College of Agriculture and Life Sciences, University of Wisconsin, 1983.

"Paradoxes of Western Energy Development: Sociocultural Factors," in Cyrus McKell (ed.), Paradoxes of Western Energy Development, Westview Press, 1984, pp. 247-262.

"Paradoxes of Western Energy Development: Sociocultural Factors," pp. 23-51 in Jessie L. Embry and Howard A. Christy (eds.), Community Development in the American West: Past and Present Nineteenth and Twentieth Century Frontiers. Salt Lake City: Signature Books, 1985.

"The Impacts of Large-scale Developments on Rural Communities in the Western United States." pp. 109-123 in Frank Fear and Harry Schwartzweller (eds.), Research in Rural Sociology and Development, JAI Press, 1985.

"The Process of Change in the Social Organization of Communities." pp. 91-107 in Frank Fear and Harry Schwartzweller (eds.), Research in Rural Sociology and Development, JAI Press, 1985.

"Alcohol Consumption and Abuse," pp. 245-257 in Thomas K. Martin, Tim B. Heaton, and Stephen J. Bahr (eds.), Utah in Demographic Perspective, Salt Lake City: Signature Books. 1986

"Leaving Mormonism: Disaffection and Disaffiliation," in David Bromley (eds.) Falling From the Faith: The Causes, Course, and Consequences of Religions, Sage Publications, 1988. pp. 62-80.

"Great Basin Kingdom--A Socio-Cultural Case Study," forthcoming in Great Basin Kingdom: Revisited, Utah State University Press, 1990.

D. Technical Reports

Sociocultural Impacts of Coal Development in Carbon and Emery Counties, Utah. Published by the Utah State Science and Technology Advisory Committee, Salt Lake City, Utah. April 1975.

Colorado River Regional Assessment Study. Prepared for the National Commission on Water Quality by the Utah State University Water Quality Lab. October 1975. Stan L. Albrecht and Bruce A. Chadwick wrote the sociological segment of this four-volume report.

D. Technical Reports (continued)

Preliminary Sociocultural Impact Analysis of the Intermountain Power Project. To be included as part of the environmental impact statement prepared by Westinghouse Environmental Systems (with Bruce A. Chadwick).

Socioeconomic Impacts Associated with the Harry Allen Station in Southern Nevada. Eyring Research Institute, Provo, Utah. January 1977.

Annotated Bibliography of Materials Relating to Socio-Cultural Characteristics of the Navajo Nation and McKinley County, New Mexico. Wistisen and Associates, Provo, Utah. 1977.

Socioeconomic Impacts of the Third Power Plant Extension at Grand Coulee Dam. Report prepared for the Bureau of Reclamation, Boise, Idaho. 1977.

Numerous additional technical reports on social impacts of energy development prepared. 1978-1989.

Papers Presented at Professional Meetings

"Attitudes and Behavior," paper presented at the meetings of the American Sociological Association, San Francisco, California, 1969.

"Marijuana: Predicting Behavior from Verbal Attitudes," paper presented at the meetings of the American Sociological Association, Washington, D. C., 1970.

"Environmental Issues: Power Plant Development in the Southwest," paper presented at the meetings of the Pacific Sociological Association, Portland, Oregon, 1972.

"Prediction of Behavior from Attitudes In and Out of the Small Groups Lab," paper presented at the meetings of the Rocky Mountain Social Science Association, Salt Lake City, Utah, 1972.

"Social Movements and Counter-Movements: A Review and an Identification of Research Objectives in the Area of the Environment," paper presented at the meetings of the American Sociological Association, New Orleans, 1972.

Papers Presented at Professional Meetings (continued)

"Situational and Personality Factors and Attitude-Action Consistency," paper presented at the meetings of the Southwest Sociological Association, Dallas, Texas, March 1973.

"Health Service Delivery in Rural Areas: An Assessment of Adequacy Indicators and Their Correlates," presented at the Annual Meetings of the Rural Sociology Society, August 1973.

"Legacy of the Environmental Movement," presented at the Annual Meetings of the Pacific Sociological Association, San Jose, California, March 1974.

"Attitudes Toward the Police and the Larger Attitude Complex: Implications for Police-Community Relations," paper presented at the Fiftieth Annual Meeting of the American Association for the Advancement of Science, Southwest and Rocky Mountain Division, Laramie, Wyoming, April 1974.

"Developing Pressures for Migration Toward Rural Areas," paper presented at the Annual Meetings of the Rural Sociology Society, Montreal, Canada, August 1974.

"Cognitive Barriers to Equal Justice Before the Law," paper presented at the Annual Meetings of the Society for the Study of Social Problems, August 1974.

"Legal Justice and the Poor: Failures of Past Programs and Implications for the Future," paper presented at the Annual Meeting of the Association of Voluntary Action Scholars, Denver, Colorado, September 1974.

"The Socioeconomic Impacts of Energy Development in Utah," invited paper presented at the Meetings of the Utah Academy of Sciences, Arts, and Letters, Logan, Utah, October 1974.

"Problems, Priorities, and Environmental Concern: The Case of State Legislators," presented at the Annual Meetings of the Pacific Sociological Association, Victoria, Canada, April 1975. With A. L. Ryssman.

"Consensus on Role Definitions and Perceived Adequacy of Role Performance as Determinants of Marital Satisfaction," presented at the Annual Meetings of the Pacific Sociological Association, Victoria, Canada, April 1975. With B. Chadwick and P. Kunz.

"Attitudes as Predictors of Behavior vs. Behavior Intentions: A Convergence of Research Traditions," paper presented at the Annual Meetings of the Southwest Social Science Association, San Antonio, Texas, March 1975.

Papers Presented at Professional Meetings (continued)

"Intergenerational Contact and Alienation in Elderly Mormon Families," paper presented at the Annual Family Research Conference, Brigham Young University, February 1975. With B. Chappell.

"The Current Meaning of Community Satisfaction in Rural and Urban Areas," paper presented at the Annual Meetings of the Western Social Science Association, Denver, Colorado, May 1975. With H. R. Geertsen.

"Issue Distortion in the Defeat of a State Land Use Plan," paper presented at the Annual Meetings of the Society for the Study of Social Problems, San Francisco, California, August 1975.

"Religious Attitudes of Teenagers and Their Effect on Behavior," presented at the Annual Meetings of the Pacific Sociological Association, San Diego, California, April 1976. With B. Chadwick and D. Alcorn.

"Social Class and Sex-Role Stereotyping," presented at the Annual Meetings of the Southwest Sociological Association, Dallas, Texas, April 1976. With B. Chadwick.

"Implications of Changing Sex-Roles in the American Family," presented at the Annual Meetings of the Western Social Science Association, Tempe, Arizona, April 1976.

"Religiosity and Divorce," presented at the Annual Meetings of the Southwest Sociological Association, Dallas, Texas, April 1976. With P. Kunz.

"Sociocultural Factors and Energy Resource Development in Rural Areas in the West," presented at the Annual Meetings of the Rural Sociological Society, New York, August 1976.

"The Attitude Concept: Contemporary Problems and Prospects," paper presented at the Annual Meeting of the Pacific Sociological Association, Sacramento, California, April 1977.

"Energy Resource Development and Native Americans," paper presented at Symposium on the State of the Art of Social Impact Assessment, sponsored by the Atomic Industrial Forum and Edison Electric Institute, St. Louis, Missouri, January 1977.

"Energy Development: Prospects and Implications for Native Americans," paper presented at the Annual Meetings of the Society for the Study of Social Problems, Chicago, 1977.

Papers Resented at Professional Meetings (continued)

"Assessing Sociocultural Implications of Energy Development Projects," invited paper presented at the 8th Annual Westinghouse International School on Environmental Management, Fort Collins, Colorado, July 1977.

"Growth-No Growth: What do Alternatives Mean for Cities and Towns?" invited paper presented at the meetings of the Utah League of Cities and Towns, Salt Lake City, Utah, September 1977.

"Energy Development in Utah: Blessing or Curse," invited symposium paper presented at the Meetings of the Utah Academy of Science, Arts and Letters, Salt Lake City, Utah, December 1977.

"The Socioeconomic Impacts of Energy Development," presented at the Annual Meetings of the American Association for the Advancement of Science, Washington, D. C., February 1978.

"Contributions of Empirical Social Psychology and Some Thoughts on Man's Social Nature," presented at the Meetings of the Southwest Social Science Association, Houston, Texas, April 1978.

"Changing Family and Sex Roles: An Assessment of Generational Differences," presented at the Meetings of the American Sociological Association, San Francisco, California, September 1978.

"Social Consequences of Rapid Growth on Small Western Communities," paper presented at the Conference on the Community Consequences of Rapid Growth, Gillette, Wyoming, February 1972.

"Unique Effects of Rapid Economic Growth Upon Different Cultural Groups: The Native American Experience," presented at the Conference on Coping with Rapid Growth, Scottsdale, Arizona, February 25-27, 1980.

"Social Participation, Community Attachment, and Quality of Life in the Rapidly Industrializing Rural Community," paper presented at the Fifth World Congress on Rural Sociology, Mexico City, Mexico, August 1980.

"Assessing the Social Impacts of Rapid Growth," annual invited faculty lecture, University of North Dakota, Grand Forks, North Dakota, 1980.

"Growth Management: Social and Economic Impacts of Rapid Growth," address presented at the Meetings of HEGRIC (Higher Education, Government, Research, and Industry), University of Utah, Salt Lake City, Utah, February 1981.

Papers Presented at Professional Meetings (continued)

"Energy Development and Impacts on Human Services," keynote address presented at the Conference on the Impacts of Energy Development on Human Services, Snow College, Ephriam, Utah, March 1981.

"Rural Sociology: Its Status and Future," invited address presented at the 50th Anniversary Symposium of the Department of Rural Sociology, University of Wisconsin, Madison, April 1981.

"The MX Missile: An Analysis of Community Response," paper presented at the Annual Meetings of the Rural Sociological Society, Guelph, Canada, August 1981.

"The Quality of Community Services in the Rapidly Industrializing Rural Community," paper presented at the Annual Meetings of the American Sociological Association, Toronto, Canada, August 1981.

"MX: Impacts on Human Communities," Annual Honors Program and ASBYU Academic Lecture, Brigham Young University, Provo, Utah, October 1981.

"The Changing Face of the Rural West," Plenary Address presented at the Utah Academy of Arts, Sciences, and Letters, St. George, Utah, November 1981.

"Paradoxes of Western Energy Development: Sociocultural Factors," paper presented at the Annual Meetings of the American Association for the Advancement of Science, Washington, D. C., January 1982.

"The Development of Energy Resources: Problems and Prospects," Annual Charles Redd Center Lecture, Brigham Young University, Provo, Utah, January 1982.

"An Overview of the Processes of Mormon Religious Disaffiliation," paper presented at the Annual Meetings of the Pacific Sociological Association, San Diego, California, April 1982.

"Higher Education and Religion: Impacts on Participation and Believe," paper presented at the Annual Meetings of the Pacific Sociological Association, San Jose, California, April 1983.

"Leadership and Organizational Performance in Mormon Congregations," paper presented at the Annual Meetings of the Pacific Sociological Association, San Jose, California, April 1983.

"Dynamics of Defection from Mormonism," presented at the Meetings of the Association for the Sociology of Religion, San Antonio, Texas, August 1984.

Papers Presented at Professional Meetings (continued)

"Contextual and Institutional Factors in Religious Commitment," presented at the Meetings of the Pacific Sociological Association, Albuquerque, New Mexico, April 1985.

"Evaluation of the Mormon Indian Student Placement Program," presented at the Meetings of the Southwest Social Science Association, Houston, Texas, March 1985.

"The Place of Attitudes and Perceptions in Social Impact Assessment," paper presented at the Annual Meetings of the International Association for Impact Assessment, Barbados, June, 1987. With Jim Thompson.

"Contemporary Saints in Historical Perspective." presented at the Annual Meeting of the Mormon History Association, Oxford, England, July, 1987. With Tim B. Heaton

"The Mormon Village and Its Contribution to Rural Community Studies," paper presented at Rural Villages in the Twenty-First Century Symposium, The Mountain West Center for Regional Studies, Utah State University, July, 1990.

Other Professional Activities

Invited panel member for session on the social role of the sociologist. Rocky Mountain Social Science Association, Salt Lake City, Utah, 1972.

Organizer and chairman of sessions on political sociology, Meetings of the Southwest Sociological Association, Dallas, Texas, 1973.

Discussant, Social Science Section, Meetings of the Utah Academy of Sciences, Arts, and Letters, April 1973.

Chairman, Methodology Session, Conference on Social Well Being--Quality of Life Dimensions in Water Resource Development, Utah State University, July 1973.

Discussant for session on "Environmental Problems: Social, Political and Policy Aspects," at the Meetings of the Society for the Study of Social Problems, New York City, August 1973.

Panel member for session on "Environmental Problems and the Social Sciences," at the Meetings of the Society for the Study of Social Problems, New York City, August 1973.

Chairman, Political Sociology Session, Meetings of the Pacific Sociological Association, March 1974.

Other Professional activities (continued)

Chairman, session on social problems and environmental issues, Meetings of the Society for the Study of Social Problems, Montreal, Canada, August 1974.

Chairman, session on social movements and social change, Conference of the Association of Voluntary Action Scholars, Denver, Colorado, September 1974.

Member of Program Committee, Rural Sociological Society, 1975.

Member of Program Committee, Environmental Problems Division, Society for the Study of Social Problems, 1975.

Chairman, session on environmental problems, Society for the Study of Social Problems, San Francisco, California, 1975.

Chairman, session on social psychology, Annual Meetings of the American Psychological Association, Chicago, September 1975.

Discussant, Environmental Sociology Session, Annual Meetings of the Western Social Science Association, Tempe, Arizona, April 1976.

President-elect, Environmental Problems Division, Society for the Study of Social Problems, 1976-77. President for a two-year term, 1977-79.

Discussant, Sociology of Rural Sociology, Annual Meetings of the Rural Sociological Society, San Francisco, California, September 1978.

Discussant, Environmental Sociology: Toward a Framework for Analysis, Annual Meetings of the Rural Sociological Society, San Francisco, California, September 1978.

Roundtable Discussion Leader, Attitude-Behavior Relationships: Applications to the Study of Religion and Delinquency, Meetings of the American Sociological Association, San Francisco, California, September 1978.

Member, Congressional Office of Technology Assessment Panel on Alternatives for MX Basing, 1980-81.

Editor, Rural Sociology, 1978-82.

Awards Committee, Pacific Sociological Association, 1982-83.

Chair, Awards Committee, Pacific Sociological Association, 1984.

Council, Rural Sociological Society, 1981-83.

Other Professional activities (continued)

Vice President, Rural Sociological Society, 1984-85.

Book Reviews

Review of Carl Klockar, The Professional Thief, in Social Science Quarterly, December 1975.

Review of Northcentral Regional Center for Rural Development, Communities Left Behind, in Rural Sociology, Fall 1975.

Review of Ron Clark and Peter List, Environmental Spectrum: Social and Economic Views on the Quality of Life, in Urban Life, forthcoming.

Review of Mehrabian, A Theory of Affiliation, in Sociology and Social Research, April 1976.

Review of A Kingdom Transformed: Themes in the Development of Mormonism, in Journal for the Scientific Study of Religion, 1985.

Review of Davis Bitton and Maureen Ursenbach Beecher (eds.), New Views of Mormon History: Essays in Honor of Leonard J. Arrington, BYU Studies, Vol. 28, No. 1, Winter 1988.

Membership in Professional Associations

American Sociological Association
Pacific Sociological Association
Society for the Study of Social Problems
Rural Sociological Society

(revised 9/14/90)

WALTER J. ARABASZ

BIRTHPLACE AND DATE: [redacted]

ACADEMIC POSITION: Research Professor of Geology and Geophysics, University of Utah, Salt Lake City, Utah.

EDUCATION:

B.S. Geology, summa cum laude, Boston College (1964).

M.S. Geology, California Institute of Technology (1966).

Ph.D. Geology, California Institute of Technology (1971). Minor in geophysics with emphasis on seismology. Supervised by Professor Clarence R. Allen.

Thesis: *Geological and geophysical studies of the Atacama fault zone in northern Chile* (submitted July 1970).

SOCIETY AFFILIATIONS:

Seismological Society of America
American Geophysical Union
Geological Society of America
Earthquake Engineering Research Institute
Utah Geological Association

PROFESSIONAL EXPERIENCE:

1963-1964 Scholar of the College, Boston College: Year of independent study in tectonics under J. W. Skehan, photogeology of TIROS satellite photography, field study of joint patterns near Colorado Springs, Colorado.

1964-1970 Research/Teaching Assistant, Division of Geological Sciences, California Inst. of Tech. Field geology of part of the San Juan Mountains, Colorado (1965); gravity study of the San Jacinto fault zone, California (1965); petrologic studies in the San Bernardino Mountains, California (1965-66); microseismicity of the San Jacinto fault zone, California (1967-68); geological and geophysical field studies of the Atacama fault zone, northern Chile, including extensive geological mapping, microearthquake reconnaissance, gravity and magnetic profiling, and off-shore seismic profiling (1966-68).

1970-1973 Post-Doctoral Research Fellow, Seismological Observatory, Geophys. Div., Department of Scientific and Industrial Research, Wellington, New Zealand. Studies of seismicity, tectonics, geologic structure, and extensive micro-earthquake field studies. Chief duty as a post-doctoral fellow was to develop and carry out a microearthquake research program, which included studies of aftershock zones, geothermal areas, and broad regions of active faulting.

1973-1974 Research Scientist, Lamont-Doherty Geological Observatory of Columbia University. Continued studies of New Zealand tectonics and seismicity; field study of microearthquakes at Blue Mountain Lake, New York (1973).

1974-Present University of Utah, Department of Geology and Geophysics.

1974-1975: Research Seismologist
1975-1977: Research Assistant Professor of Geology and Geophysics
1976-1977: Acting Assistant Director, University of Utah Seismograph Stations (UUSS)

1977-1980: Research Associate Professor of Geology and Geophysics, and Assistant Director, UUSS. Short-term expert for International Atomic Energy Agency: Chile 1979.

1980-1983: Research Associate Professor of Geology and Geophysics, and Associate Director, UUSS.

1983- Research Professor of Geology and Geophysics; Director, UUSS (since April 1985). Professional management certificates: Charles R. Hobbs Corporation, 1983; University of Utah Personnel Administration, 1983.

Responsibilities at the University of Utah have included: seismological research; supervision of graduate research; part-time teaching in seismology, seismic geology, and structural geology; and extensive project management (including primary day-to-day responsibility since 1976 for fiscal, administrative, and project management of the University of Utah Seismograph Stations—10 full-time and 10 part-time staff). For academic year 1990-91: Principal or Co-Principal Investigator on research projects totalling ca. $800,000—in regional seismicity and tectonics of the southern Intermountain seismic belt, operation of an 85-station telemetered seismic network, and evaluation of seismicity and earthquake hazards in the Intermountain area.

STATEMENT OF SPECIAL INTERESTS:

Fields of interest include: network seismology and earthquake-hazard evaluation, tectonics and seismicity of the Intermountain area, microearthquake research, and seismic geology. After early training as a structural field geologist, interest in active faulting and seismic hazards led to earthquake research at the Caltech Seismological Laboratory and motivated a degree minor in geophysics. Work at the Seismological Observatory in Wellington, New Zealand, led fully into earthquake seismology. Move to Lamont-Doherty Geological Observatory was to participate in evolving research on earthquake prediction, and subsequent move to Utah was to continue research in seismotectonics and earthquake-hazards assessment—in a seismically active region with the benefit of a modern telemetered seismic network.

AWARDS AND HONORS:

- Full-tuition scholarship from Boston College for four years of undergraduate study.
- Hamilton Award, Boston College (for achievement as undergraduate science major), 1964.
- Knight Commander, Order of the Cross and Crown, senior year at Boston College (in recognition of academic achievement and extracurricular activities).
- Scholar of the College, senior year at Boston College.
- National Science Foundation Summer Fellowships for Graduate Teaching Assistants, 1965 and 1966.
- California State Scholarship, 1968-1969.
- New Zealand National Research Advisory Council Post-Doctoral Fellowship, 1970-1973.
- U.S. National Research Council Postdoctoral Research Associateship, 1974 (declined in preference for position at University of Utah).
- Certificate of Appreciation, from U.S. Geological Survey and Federal Emergency Management Agency for "leadership and recognized accomplishments" toward earthquake loss-reduction in Utah, 1987.
- Distinguished Faculty Research Award, 1987-88, Department of Geology and Geophysics, University of Utah.

SCIENTIFIC COMMITTEES AND WORKING GROUPS

1975	Invited participant, Geological Society of America Penrose Conference on Regional Geophysics and Tectonics of the Intermountain West, Alta, Utah.
1976	Invited participant, Geological Society of America Penrose Conference on Evaluation of Fault Activity, Mammoth Lakes, California.
1978	Invited participant, U. S. Geological Survey Workshop on Seismic Risk, Vail, Colorado.
1979	Invited participant, U. S. Geological Survey Conference on Earthquake Hazards Along the Wasatch Front and in the Reno-Carson City Area, Alta, Utah.
1979	Invited participant, U. S. Geological Survey Workshop on Seismic Zoning in the Basin and Range Region, Golden, Colorado.
1980	Invited participant, U. S. Geological Survey Conference on Tectonics of the Central Region, Golden, Colorado.
1981, 1982	Member, Peer Review Panel, U. S. Geological Survey Earthquake Hazards Reduction Program.
1982	Invited participant, American Geophysical Union Chapman Conference on Fault Behavior and the Earthquake Generation Process, Snowbird, Utah.
1983	Co-Organizer, 1983 Annual Meeting of the Seismological Society of America, Salt Lake City, Utah.
1983	Co-Convener and editor of Proceedings of "Workshop on Guidelines for Instrumentation Design in Support of a Proposed Lithospheric Seismology Program," Salt Lake City, Utah (sponsored by the National Science Foundation).
1983	Chairperson: Working Group on Earthquake Hazard Research Needs and Dissemination of Information, Governor's Conference on Geologic Hazards, Salt Lake City, Utah.
1984	Invited participant, Organizational Meeting for National Lithospheric Seismology Program, Madison, Wisconsin.
1984	Invited participant, U. S. Geological Survey Earthquake Prediction Data Review Meeting, Los Angeles, California.
1984	Co-Organizer and editor of "Proceedings of a Seminar on Defining Tectonic Mechanisms Causing Earthquakes in the Eastern United States," Salt Lake City, Utah (sponsored by the Electric Power Research Institute).
1984	Member of steering committee, co-organizer of scientific technical sessions, and moderator, U. S. Geological Survey Workshop on Evaluation of Regional and Urban Earthquake Hazards and Risk in Utah, Salt Lake City, Utah.
1984-1986	Member, Seismic Hazard Methodology Team, Electric Power Research Institute, for development of state-of-the-art methodologies for evaluating earthquake hazards in the central and eastern United States for siting nuclear facilities.

1985	Member, Peer Review Panel, U. S. Geological Survey Earthquake Hazards Reduction Program.
1985	Co-Organizer and editor of "Proceedings of a Seminar on Maximum Earthquakes in Intraplate Regions," Menlo Park, California (sponsored by the Electric Power Research Institute).
1985	Member, Resource Team, multiple workshops jointly sponsored by the U. S. Geological Survey, the Utah Geological and Mineral Survey, the Federal Emergency Management Agency, and the Utah Division of Comprehensive Emergency Management--"Earthquake and Landslide Hazards in the Wasatch Front Region of Utah."
1985	Regional coordinator for Great Basin-Intermountain-Rocky Mountain region, Symposium and Workshop on Regional Seismographic Networks, Knoxville, Tennessee.
1985	Invited participant, U. S. Nuclear Regulatory Commission/U. S. Geological Survey Workshop on Probabilistic Earthquake Hazards Assessment, San Francisco, California.
1985-1986	Member, ACORN, National "Ad Hoc Committee on Regional Networks."
1986	Member, Peer Review Panel, U. S. Geological Survey Earthquake Hazards Reduction Program.
1986	Technical coordinator for tectonic framework and earthquake potential, U.S. Geological Survey Workshop on Earthquake Hazards Along the Wasatch Front, Utah; Salt Lake City, Utah.
1987	Invited participant, Workshop on Earthquake Ground Motion estimation in Eastern North America; Palo Alto, California; sponsored by the Electric Power Research Institute.
1987	Invited participant, U.S. Geological Survey Workshop on Future Directions for Seismic Networks; Alta, Utah.
1987	Member, working group for formulation of a science plan for a National Seismic System.
1987	Invited participant, U.S. Geological Survey Workshop on Continuing Actions to Reduce Earthquake Hazards Along the Wasatch Front; Salt Lake City, Utah.
1985-1988	Associate Editor, *Bulletin of the Seismological Society of America.*
1988-1989	Member, advisory group to Branch of Global Seismology and Geomagnetism, U.S. Geological Survey.
1988-1989	Member, organizing committee, Fifth Annual Workshop on Earthquake Hazards and Risk Along the Wasatch Front, Utah.
1988-1990	Member, Panel on Regional Networks of the Committee on Seismology, National Research Council.
1989	Co-Organizer, Utah Policy Panel on Earthquake Instrumentation (blue-ribbon panel of nationally prominent seismologists, earthquake engineers, and earthquake policy experts).

1989	Organizer, Earthquake Engineering Colloquium—A Strong-Motion Instrumentation Program for Utah; Salt Lake City, Utah.
1989-1991	Primary Organizer, $3M initiative to Utah State Legislature for multi-part package of earthquake instrumentation.
1989-1991	Member, Committee on Seismology, National Research Council.
1990	Co-Organizer, Meeting the Earthquake Challenge in Utah, a colloquium for public officials and Utah's emergency management and engineering communities; Salt Lake City, Utah.
1990	Invited participant, U.S. Geological Survey Intermountain Regional Workshop on Goals and Priorities for the USGS Earthquake Hazards Reduction Program; Salt Lake City, Utah
1990-1991	Member, State Earthquake Task Force, Utah Advisory Council on Intergovernmental Relations
1991	Member, Working Group on Seismograph Networks, advisory group to Branch of Global Seismology and Geomagnetism, U.S. Geological Survey
1991	Member, Joint Subcommittee on the U.S. Strong-Motion Program, National Research Council

PROFESSIONAL CONSULTING

Consulting in Earthquake-Hazard Evaluation and Earthquake Seismology:

1. Rollins, Brown and Gunnell, Inc., Provo, Utah (1977). Site-response analysis for proposed hospital in Logan, Utah.

2. International Atomic Energy Agency, Vienna, Austria (Short-Term Expert, Chile, 1979). Seismotectonic considerations in northern Chile, 21°-27°S, with respect to the siting of a nuclear power plant.

3. Weidlinger Associates, Menlo Park, California (1980). Geological and geophysical information relevant to site-dependent ground motions at Wing V (Wyoming-Nebraska-Colorado).

4. EG&G Idaho, Inc. (Department of Energy), Idaho Falls, Idaho (1980-81). Preparation and presentation of proposal for seismic risk zone revision in southeast Idaho to International Conference of Building Officials.

5. EG&G Idaho Inc. (Department of Energy), Idaho Falls, Idaho (1982). Document review: "Site Investigation at Idaho National Engineering Laboratory, LMFBR Large Developmental Plant (LDP), Conceptual Design Study—Phase III."

6. Lindvall, Richter and Associates, Los Angeles, California (1981-82). Seismic safety investigation of eight Soil Conservation Service dams in southwestern Utah.

7. U.S. Bureau of Reclamation, Engineering and Research Center, Denver, Colorado (1982-83). Review and analysis of geologic, seismotectonic, and design data for the proposed Jordanelle Dam, Bonneville Unit, Central Utah Project, Utah. (Consultant review by W.J. Arabasz, R. H. Jahns, and R.B. Peck.)

8. EG&G Idaho, Inc. (Department of Energy), Idaho Falls, Idaho (1983). Member, Geotechnical Advisory Panel to assist EG&G Idaho, Inc. and D.O.E. regarding programmatic efforts toward site characterization of the Idaho National Engineering Laboratory for the proposed siting of a NEW Production Reactor Facility.

9. Electric Power Research Institute, Palo Alto, California (1984). Participant, "Data Needs Workshop; regarding data management plan and tectonic evaluation for earthquake hazards in the eastern U.S.; participant in and editor of "Proceedings of a Seminar on Defining Tectonic Mechanisms Causing Earthquakes in the Eastern United States."

10. Dames & Moore, Golden, Colorado/Electric Power Research Institute (EPRI), Palo Alto, California (1984-85). Member of "Seismic Hazard Methodology Team," EPRI Seismic Hazards Research Program, for evaluation of earthquake hazards in the eastern United States for the siting of nuclear generating facilities. (Participation in 7 formal workshops, 2 academic seminars, and 3 series of interactive meetings with 6 teams of tectonic evaluation contractors in the central and eastern U.S.).

11. Electric Power Research Institute, Palo Alto, California (1985-87). Participation in scientific review, technical description, and comparative evaluation of EPRI seismic hazard methodology for the central and eastern United States.

12. U.S. Bureau of Reclamation, Engineering and Research Center, Denver, Colorado (1986-87). Review and analysis of geologic, seismotectonic, and design data for the proposed Jordanelle Dam, Bonneville Unit, Central Utah Project. (Consultant review by R. B. Peck, W. J. Arabasz, G. S. Tarbox, and D. D. Campbell.)

13. U.S. Bureau of Reclamation, Engineering and Research Center, Denver, Colorado (1988). Review and evaluation of seismotectonic conclusions and details of final embankment dam design for Jordanelle Dam, Bonneville Unit, Central Utah Project. (Consultant review by R.B. Peck, W.J. Arabasz, and T.G. McCusker.)

14. Dames & Moore, Los Angeles, California (1989). Member of advisory panel for project on seismic code decisions under risk, sponsored by the National Science Foundation.

15. Lawrence Livermore National Laboratory, Livermore, California (1990-91). Member of Seismicity and Tectonic Expert Group, New Production Reactors Project, Idaho National Engineering Laboratory Site.

16. U.S. Bureau of Reclamation—Engineering and Research Center, Denver, Colorado, and Regional Office, Salt Lake City, Utah (1990). Review and evaluation of foundation conditions, ongoing geologic mapping procedures, and seismic-safety aspects of the Jordanelle Dam, Bonneville Unit, Central Utah Project.

SCHOLARLY JOURNAL REVIEW, PROPOSAL REVIEW, AND EDITORIAL SERVICE

1975-present	Reviewer for Geological Society of America, GSA *Bulletin* and *Geology*
1976-present	Reviewer for the *Bulletin of the Seismological Society of America*
1977-present	Reviewer of proposals for National Science Foundation, Seismology and Deep Earth Structure Program
1978-present	Reviewer for *Journal of Geophysical Research*
1980-1982	Reviewer of proposals for National Science Foundation, Polar Earth Science Program
1981-1982, 1985-present	Reviewer of proposals to U.S. Geological Survey Earthquake Hazards Reduction Program
1983-present	Reviewer of proposals to National Science Foundation, Crustal Structure and Tectonics Program
1985	Reviewer for U.S. Geological Survey, manuscripts submitted to *Open-File Report* series
1985-1988	Associate Editor, *Bulletin of the Seismological Society of America*
1986	Reviewer for *Tectonophysics*
1986-1988	Reviewer of proposals to National Fund for Scientific and Technological Development, Council of Science and Technology, Chile
1988	Reviewer of multiple proposals to National Science Foundation, Science and Technology Research Centers (STC) Program
1988	Reviewer for *PAGEOPH*, special issue on seismicity in mines

Walter J. Arabasz

PUBLICATIONS

Skehan, J. W. and W. J. Arabasz, 1965. Photogeology of the Sahara and the Kalahari from Tiros: *Air Force Cambridge Research Laboratories publ. AFCRL-65-229*, 48 p.

Arabasz, W. J., 1968. Geologic structure of the Taltal area, northern Chile, in relation to the earthquake of December 28, 1966, *Bull. Seism. Soc. Am. 58*, 835-342.

Arabasz, W. J., J. N. Brune, and G. R. Engen, 1970. Locations of small earthquakes near the trifurcation of the San Jacinto fault southeast of Anza, California, *Bull. Seism. Soc. Am. 60*, 617-627.

Evison, R. R., R. Robinson, and W. J. Arabasz, 1974. Late aftershocks, tectonic stress and dilatancy, *Nature 246*, 471-473.

Robinson, R. and W. J. Arabasz, 1975. Microearthquakes in the north-west Nelson region, New Zealand, *N.Z. Jour. Geol. and Geophys. 18*, 83-91.

Robinson, R., W. J. Arabasz, and F. F. Evison, 1975. Long-term behaviour of an aftershock sequence: The Inangahua, New Zealand, earthquake of 1968, *Geophys. J. R. Astr. Soc. 41*, 37-49.

Arabasz, W. J. and R. Robinson, 1976. Microseismicity and geologic structure in the northern South Island, New Zealand, *N.Z. Jour. Geol. and Geophys. 19*, 569-601.

Evison, F. F., R. Robinson, and W. J. Arabasz, 1976. Microearthquakes, geothermal activity, and structure, central North Island, New Zealand, *N.Z. Jour. Geol. and Geophys. 19*, 625-637.

Arabasz, W. J., R. B. Smith, and W. D. Richins, editors, 1979. *Earthquake Studies in Utah, 1950 to 1978*, University of Utah, Salt Lake City, 552 p.

Arabasz, W. J., 1979. Historical review of earthquake-related studies and seismographic recording in Utah, in *Earthquake Studies in Utah 1950 to 1978*, University of Utah, Salt Lake City, p. 33-56.

Arabasz, W.J., R. B. Smith, and W. D. Richins, 1979. Earthquake studies along the Wasatch Front, Utah: Network monitoring, seismicity and seismic hazards, in *Earthquake Studies in Utah, 1850 to 1978:* University of Utah, Salt Lake City, 253-285. (Also in *Proc. of Conf. X, Earthquake Hazards Along the Wasatch and Sierra-Nevada Frontal Fault Zone*, U.S. Geol. Survey Open-File Rept. 880-801, 1-33.).

Arabasz, W. J., W. D. Richins, and C. J. Langer, 1979. The Idaho-Utah Border (Pocatello Valley) earthquake sequence of March-April 1975, in *Earthquake Studies in Utah, 1850-1978:* University of Utah, Salt Lake City, Utah, 339-373.

Smith, R. B. and W. J. Arabasz, 1979. Seismicity, tectonics, and crustal structure in Utah: important aspects from new data in *Earthquake Studies in Utah 1850 to 1978:* University of Utah, Salt Lake City, Utah, 395-408.

Arabasz, W. J. and R. B. Smith, 1979. The November 1971 earthquake swarm near Cedar City, Utah in *Earthquake Studies in Utah 1850 to 1978*, University of Utah, Salt Lake City, Utah, 423-432.

Griscom, M. and W. J. Arabasz, 1979. Local magnitude (M_L) in the Wasatch Front and Utah region: Wood-Anderson calibration, coda-duration estimates of M_L, and M_L versus m_b, in *Earthquake Studies in Utah, 1850 to 1978:* University of Utah, Salt Lake City, 433-443.

Arabasz, W. J. and M. A. Lowry, 1980. Microseismicity in the Tararua-Wairarapa area: Depth-varying stresses and shallow seismicity in the southern North Island, New Zealand, *N.Z. Jour. Geol. and Geophys. 23*, 141-154.

Arabasz, W. J., R. B. Smith, and W. D. Richins, 1980. Earthquake studies along the Wasatch Front, Utah: Network monitoring, seismicity, and seismic hazards, *Bull. Seism. Soc. Am. 70*, 1479-1499.

Arabasz, W. J., W. D. Richins, and C. J. Langer, 1981. The Pocatello Valley (Idaho-Utah border) earthquake sequence of March to April 1975, *Bull. Seism. Soc. Am. 71*, 803-826.

Arabasz, W. J. and R. B. Smith, 1981. Earthquake prediction in the Intermountain seismic belt--An intraplate extensional regime, in *Earthquake Prediction--An International Review*, D. W. Simpson and P. G. Richards, Editors, *American Geophysical Union, Maurice Ewing Series 4*, 238-258.

McKee, M. E. and W. J. Arabasz, 1982. Microearthquake studies across the Basin and Range-Colorado Plateau in central Utah, in *Overthrust Belt of Utah*, D. Nielson, Editor, *Utah Geol. Assoc. Publ. 10*, 137-149.

Arabasz, W. J., 1984. Earthquake behavior in the Wasatch Front area: Association with geologic structure, space-time occurrence, and stress state, in *Proceedings of Conference XXVI, A Workshop on "Evaluation of Regional and Urban Earthquake Hazards and Risk in Utah,"* W. W. Hays and P. L. Gori, Editors, *U.S. Geol. Survey Open-File Rept. 84-763*, 310-339.

Arabasz, W. J. and D. R. Julander, 1986. Geometry of seismically active faults and crustal deformation within the Basin and Range-Colorado Plateau transition in Utah, in *Cenozoic Tectonics of the Basin and Range Province: A Perspective on Processes and Kinematics of an Extension Origin*, L. Mayer, Editor, *Geol. Soc. Am. Special Paper 208*, 43-74.

Arabasz, W.J., J.C. Pechmann, and E.D. Brown, 1987. Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch Front area, Utah, in *Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah*, P.L. Gori and W.W. Hays, Editors: *U.S. Geol. Survey Open-File Rept. 87-585*, D1-D58.

Coppersmith, K.J., A.C. Johnston, and W.J. Arabasz, 1987. Estimating maximum earthquakes in the central and eastern United States: A progress report, in *Proceedings from the Symposium on Seismic Hazards, Ground Motions, Soil-Liquefaction and Engineering Practice in Eastern North America*, K.H. Jacob, Editor, *National Center for Earthquake Engineering Research Tech. Rept. NCEER-87-0025*, 217-232.

Nava, S.J., J.C. Pechmann, and W.J. Arabasz, 1988. The magnitude 5.3 San Rafael swell, Utah, earthquake of August 14, 1988: A preliminary seismological summary, *Survey Notes, 22*, 16-19.

Williams, D.J. and W.J. Arabasz, 1989. Mining-related and tectonic seismicity in the East Mountain area, Wasatch Plateau, Utah, U.S.A., *PAGEOPH*, 129, 345-368.

Heaton, T.H., Anderson, D.L., Arabasz, W.J., Buland, R., Ellsworth, W.L., Hartzell,S.H., Lay, T., and Spudich, P., 1989. National Seismic System science plan, *U.S. Geol. Survey Circular 1031*, 42 p.

McGuire, R.K., and W.J. Arabasz, 1990. An introduction to probabilistic-seismic hazard analysis, in *Geotechnical and Environmental Geophysics, Vol. 1: Review and Tutorial*, S.H. Ward, Editor, Society of Exploration Geophysicists, *Investigations in Geophysics No. 5*, 333-353.

Arabasz, W.J., J.C. Pechmann, and E.D. Brown, 1991. Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch Front area, Utah: *U.S. Geol. Survey Prof. Paper 1500-D* (in press).

Smith, R.B., and W.J. Arabasz, 1991. Seismicity of the Intermountain seismic belt, in *Neotectonics of North America*, D.B. Slemmons, E.R. Engdahl, M.D. Zoback, M.L. Zoback, and D. Blackwell, Editors, *Geological Society of America SMV V-1* (in press).

Walter J. Arabasz

PUBLICATIONS IN PREPARATION

Arabasz, W.J. and D.R. Mabey: *The Earthquake Threat—and Challenge—in Utah* (book in prep. for publication by Utah Geological and Mineral Survey).

Veneziano, D., Y. Shimizu, and W.J. Arabasz: Earthquake clustering in the Wasatch Front region, Utah (in prep. for *Bull. Seism. Soc. America*).

Walter J. Arabasz

ABSTRACTS

Allen, C. R., T. Matsuda, W. J. Arabasz, and A. Okada, 1970. Comparison of features of active faulting in northern Chile, California, and Japan (abstract): Int. Symposium on Recent Crustal Movements and Associated Seismicity, Wellington, New Zealand.

Arabasz, W. J. and C. R. Allen, 1972. Tectonics of northern Chile as reflected by the Atacama fault system (abstract): International Upper Mantle Project, Conference on Solid Earth Problems, v. II, Symposium on the Results of Upper Mantle Investigations with Emphasis on Latin America, Buenos Aires, Argentina, 443-444.

Arabasz, W. J., R. Robinson, and F. F. Evison, 1972. Microearthquake activity at Broadlands geothermal field (abstract): Department of Scientific and Industrial Research—Victoria University of Wellington Vulcanological Conference, Rotorua, New Zealand, 24.

Arabasz, W. J., and R. Robinson, 1973. Microseismicity and geologic structure in the northern South Island, New Zealand (abstract): *EOS, Trans. Am. Geophys. Union 54*, 1137.

Arabasz, W. J. and R. B. Smith, 1974. The 1971 Cedar City, Utah, earthquake swarm: dilatancy-fluid diffusion in a normal fault zone? (abstract): *EOS, Trans. Am. Geophys. Union 56*, 1149.

Arabasz, W. J., W. D. Richins, C. J. Langer, R. B. Smith and A. M. Rogers, 1975. The March 1975 Idaho-Utah border earthquake: A seismological summary (abstract): *Geol. Soc. Am., Abst. With Programs 7*, 979.

Arabasz, W. J., W. D. Richins, and C. J. Langer, 1975. Detailed characteristics of the March 1975 Idaho-Utah border earthquake sequence (abstract): *EOS, Trans. Am. Geophys. Union 56*, 1022.

Smith, R. B., W. J. Arabasz, K. L. Cook, and W. D. Richins, 1976. Detailed seismic monitoring of the Wasatch Front, Utah (abstract): *Earthquake Notes 47*, 20-21.

Arabasz, W. J. and W. D. Richins, 1976. Late aftershocks—a search for premonitory seismic changes (abstract): *EOS, Trans. Am. Geophys. Union 57*, 67.

Richins, W. D. and W. J. Arabasz, 1976. Space-time changes in seismicity in the Idaho-Utah border area (abstract): *EOS, Trans. Am. Geophys. Union 57*, 958-959.

Arabasz, W. J., 1977. Time-varying source properties and use of initial P-wave pulse width for temporal monitoring (abstract): *EOS, Trans. Am. Geophys. Union 58*, 1193.

Arabasz, W. J., R. B. Smith, W. D. Richins, and A. J. Kastrinsky, 1978. Seismicity and seismic network coverage of the Wasatch Front, Utah (abstract): *Geol. Soc. Am., Abst. With Programs 10*, 209-210.

Richins, W. D., W. J. Arabasz, D. G. Bones, and R. B. Smith, 1978. Regional relationship of seismicity of the Utah-Idaho border and Idaho-Wyoming border areas (abstract): *Geol. Soc. Am., Abst. With Programs 10*, 236.

Smith, R. B., W. D. Richins, W. J. Arabasz, and D. J. Wechsler, 1978. An overview of the seismicity and tectonics of the southern Intermountain seismic belt from new array data with detail for southern Utah (abstract): *Geol. Soc. Am., Abst. With Programs 10*, 238.

Bones, D. G. and W. J. Arabasz, 1978. Seismicity of the Intermountain seismic belt in southeastern Idaho and western Wyoming, and tectonic implications (abstract): *Earthquake Notes 49*, 19.

Arabasz, W. J. and M. Griscom, 1978. Precursory seismicity patterns in the Utah region: Can regional variations in the precursor time scale be large? (abstract): *EOS, Trans. Am. Geophys. Union 59*, 1126.

Arabasz, W. J. and M. Griscom, 1979. Attenuation in the eastern Great Basin from intensity and ground-amplitude data (abstract): *EOS, Trans. Am. Geophys. Union 60*, 881.

Griscom, M. and W. J. Arabasz, 1979. Space-time seismicity patterns in the Utah region: A 300-km-long seismicity gap in the Intermountain seismic belt (abstract): *Earthquake Notes 50*, 69.

Arabasz, W. J. and R. B. Smith, 1980. Earthquake prediction in the Intermountain seismic belt—An intraplate extensional regime (abstract): *Proceedings of Third Maurice Ewing Symposium: Earthquake Prediction*, New Paltz, N.Y., May 12-16, 1980.

McKee, M. E. and W. J. Arabasz, 1981. Microearthquake studies across the Basin and Range-Colorado Plateau transition in central Utah (abstract): *Earthquake Notes 52* (1), 62.

Arabasz, W. J., 1981. Seismicity and listric faulting in central and SW Utah (abstract): *EOS, Trans. Am. Geophys. Union 62*, 960.

Richins, W. D., G. Zandt and W. J. Arabasz, 1981. Swarm seismicity along the Hurricane fault zone during 1980-81: A typical example for SW Utah (abstract): *EOS, Trans. Am. Geophys. Union 62*, 966.

Arabasz, W. J., 1982. Correlation of crustal seismicity with geologic structure: Spatial patterns, problems, and evolving insights from observational seismology (abstract): Proc. AGU Chapman Conference on Fault Behavior and the Earthquake Generation Process, Oct. 11-15, 1982, Snowbird, Utah.

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Arabasz, W. J., and D. R. Mabey, 1990. Expert Synthesis and Translation of Earthquake Hazard Results—A Book for Non-Scientists in the Wasatch Front Region (See Summ. Tech. Repts., vol. 30, U.S. Geol. Survey Open-File Rept. 90-334, 558).*

Arabasz, W. J., R. B. Smith, J. C. Pechmann, and S. J. Nava, 1990. Regional Seismic Monitoring Along the Wasatch Front Urban Corridor and Adjacent Intermountain Seismic Belt (See Summ. Tech. Repts., vol. 31, U.S. Geol. Survey Open-File Rept. 90-680, 8-9).*

Smith, R. B., W. J. Arabasz, and J. C. Pechmann, 1990. Seismotectonic Framework and Earthquake Source Characterization (FY90)—Wasatch Front, Utah, and Adjacent Intermountain Seismic Belt (See Summ. Tech. Repts., vol. 31, U.S. Geol. Survey Open-File Rept. 90-680, 105-108).*

Arabasz, W. J., and D. R. Mabey, 1990. Expert Synthesis and Translation of Earthquake Hazard Results—A Book for Non-Scientists in the Wasatch Front Region (See Summ. Tech. Repts., vol. 31, U.S. Geol. Survey Open-File Rept. 90-680, 498).*

Nava, S. J., J. C. Pechmann, W. J. Arabasz, E. D. Brown, L. L. Hall, P. J. Oehmich, E. McPherson, and J. K. Whipp, 1990. Earthquake Data for the Utah Region: January 1, 1986 to December 31, 1988. Special Publication, University of Utah Seismograph Stations, 96 p.

Arabasz, W. J., editor, 1990. A Guide to Reducing Losses from Future Earthquakes in Utah—"Consensus Document", Utah Geol. and Mineral Survey Misc. Publication 91-1, 30 p.

*Summaries of Technical Reports submitted to National Earthquake Hazards Reduction Program, U.S. Geological Survey, Menlo Park, California.

RESEARCH FUNDING

1975-76

Operation of high-gain telemetered seismograph stations for data collection and epicenter determination along the Wasatch Front, Utah: $51,000, U.S. Geological Surv., 10/1/75-9/30/76, Co-I.

Continued study of the detailed seismicity and feasibility of earthquake prediction along the Wasatch Front, Utah: $49,315, U.S. Geological Surv., 10/1/75-9/30/76, Co-I.

Continued study of regional seismicity and tectonics of the southern Intermountain seismic belt, including the Wasatch Front: $100,000 for two years, National Science Foundation, 10/1/75-3/31/78, Co-I.

Publication and dissemination of bicentennial volume: $7,010, State of Utah, 1975-79, Co-I.

1976-77

Studies of seismicity and feasibility of earthquake prediction, and operation of seismic network, along the Wasatch Front, Utah: $98,000, U.S. Geological Surv., 10/1/76-9/30/77, Co-I.

Seismograph Stations Operation: $93,500, State of Utah, 7/1/76-6/30/77, (effective PI).

1977-78

Earthquake research and network operations in the Intermountain seismic belt—Wasatch Front: $250,000, U.S. Geological Surv., 10/1/77-9/30/78, Co-PI.

High-resolution seismicity, the mechanics of active faulting, and crustal deformation across the Basin and Range-Colorado Plateau/Rocky Mountain Transition: $80,000 for two years, National Science Foundation, 3/14/78-5/31/80, PI.

Seismograph Stations Operation: $103,700, State of Utah, 7/1/77-6/30/78, (effective PI).

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph stations: $6,340, U.S. Geological Surv., 10/1/77-9/30/78, Co-PI.

Telemetry and maintenance of seismic station STI (Star Valley, Idaho) for effective seismic monitoring of southeastern Idaho and western Wyoming: $3,910, U.S. Geological Surv., 10/1/77-9/30/78, PI.

1978-79

Earthquake research and network operation in the Intermountain seismic belt—Wasatch Front: $165,000, U.S. Geological Surv., 10/1/78-9/30/79, Co-PI.

Seismograph Stations Operation: $123,300, State of Utah, 7/1/78-6/30/79, (effective PI).

High-resolution seismicity, the mechanics of active faulting, and crustal deformation across the Basin and Range-Colorado Plateau/Rocky Mountain transition (continued): National Science Foundation, 3/15/78-5/31/80, PI.

Telemetry and maintenance of seismic station STI (Star Valley, Idaho) for effective seismic monitoring of southeastern Idaho and western Wyoming: $3,200, U.S. Geological Surv., 10/1/78-9/30/79, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $4,000, U.S. Geological Surv., 10/1/78-9/30/79, PI.

1979-80

Earthquake research and network operations in the Intermountain seismic belt—Wasatch Front: $174,900, U.S. Geological Surv., 10/1/79-9/30/80, Co-PI.

Seismograph Stations Operation: $129,400, State of Utah (effective PI).

High-resolution seismicity, the mechanics of active faulting, and crustal deformation across the Basin and Range-Colorado Plateau/Rocky Mountain transition (continued): National Science Foundation, 3/15/78-5/31/80, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,300, U.S. Geological Surv., 10/1/79-9/30/80, PI.

1980-81

Earthquake hazard and prediction research in the Wasatch Front—southern Intermountain seismic belt: $192,191, U.S. Geological Surv., 10/1/80-9/30/81, Co-PI.

Seismograph Stations Operation: $142,400, State of Utah, Co-PI.

Seismological studies across the Basin and Range-Colorado Plateau transition in central Utah: $75,000 for two years, National Science Foundation, 6/1/80-11/30/82, P.I.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,500, U.S. Geological Surv., 10/1/80-9/30/81, PI.

1981-82

Earthquake hazard and prediction research in the Wasatch Front—southern Intermountain seismic belt: $192,000, U.S. Geological Surv., 10/1/81-9/30/82, Co-PI.

Seismograph Stations Operation: $152,400, State of Utah, Co-PI.

Seismological studies across the Basin and Range—Colorado Plateau transition in central Utah (continued): National Science Foundation, 6/1/80-11/30/82, PI.

Seismic event monitoring and analysis (SEMA), Jordanelle Damsite, Bonneville Unit, Central Utah Project: $12,000, U.S. Bureau of Reclamation, 10/1/81-9/30/82, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,500, U.S. Geological Surv., 11/1/81-9/30/82, PI.

1982-83

Earthquake hazard and prediction research in the Wasatch Front/southern Intermountain seismic belt: $225,595, U.S. Geological Survey, 10/1/82-9/30/83, Co-PI.

Seismograph Stations Operation: $167,600, State of Utah, Co-PI.

Seismological studies across the Basin and Range-Colorado Plateau transition in central Utah (continued): National Science Foundation, 6/1/80-11/30/82, PI.

Seismic event monitoring and analysis (SEMA), Jordanelle Damsite, Bonneville Unit, Central Utah Project: $15,225, U.S. Bureau of Reclamation, 10/1/82-9/30/83, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,500, U.S. Geological Survey, 10/1/82-9/30/83, PI.

Meeting on "Instrumentation for a Continental Lithospheric Seismology Program": $10,000, National Science Foundation, Co-PI.

1983-84

Regional seismic monitoring along the Wasatch Front urban corridor and adjacent Intermountain seismic belt: $186,663, U.S. Geological Survey, 10/1/83-9/30/84, Co-PI.

Integrated studies of earthquake prediction and hazard research in the Wasatch Front urban corridor and adjacent Intermountain seismic belt: $80,015, U.S. Geological Survey, 10/1/83-9/30/84, Co-PI.

Characteristics of coal-mining-induced and tectonic seismicity, Wasatch Plateau Utah: $50,000, National Science Foundation, 4/1/84-3/31/85, PI.

Seismic event monitoring and analysis, Jordanelle Damsite, Bonneville Unit, Central Utah Project: $15,988, U.S. Bureau of Reclamation, 10/1/83-9/30/84, PI.

Development of a field playback computer/Instrument testing in support of lithospheric seismology: $60,000, National Science Foundation, 8/1/84-1/31/86, Co-PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,500, U.S. Geological Survey, 10/1/83-9/30/84, PI.

Seismograph Stations: $168,700, State of Utah, 7/1/83-6/30/84, Associate Director.

1984-85

Integrated studies of earthquake potential, prediction, and hazards in the Wasatch Front urban corridor and adjacent Intermountain seismic belt: $119,000, U.S. Geological Survey, 10/1/84-9/30/85, Co-PI.

Regional seismic monitoring along the Wasatch Front urban corridor and adjacent Intermountain seismic belt: $160,418, U.S. Geological Survey, 10/1/84-9/30/85, Co-PI.

Characteristics of coal-mining induced and tectonic seismicity, Wasatch Plateau, Utah: $50,000, National Science Foundation, 4/1/84-9/30/85, PI.

Seismic event monitoring and analysis (SEMA), Jordanelle Damsite, Bonneville Unit, Central Utah Project: $16,400, U.S. Bureau of Reclamation, 10/1/84-9/30/85, PI.

Analysis and interpretation of seismographic data recorded in vicinity of Joes Valley Dam, Emery County Project, Eastern Wasatch Plateau, Utah: $16,447, U.S. Bureau of Reclamation, 10/1/84-6/30/85, PI.

Development of a field playback computer/Instrument testing in support of lithospheric seismology: $60,000, National Science Foundation, 8/1/84-1/31/86, Co-PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,500, U.S. Geological Survey, 10/1/84-9/30/85, PI.

Seismograph Stations: $184,900, State of Utah, 7/1/84-6/30/85, Associate Director.

1985-86

Seismic network operations and research along the Wasatch Front urban corridor and adjacent Intermountain seismic belt: $173,762, U.S. Geological Survey, 10/1/85-9/30/86, Co-PI.

Seismotectonic framework and earthquake source characterization—Wasatch Front, Utah, and adjacent Intermountain seismic belt: $132,735, U.S. Geological Survey, 11/1/85-10/31/86, Co-PI.

Methods for assessing maximum earthquakes in the eastern United States: $20,828, Geomatrix Consultants/Electric Power Research Institute, 5/13/85-3/31/86, PI.

Characteristics of coal-mining induced and tectonic seismicity, Wasatch Plateau, Utah: $55,000, National Science Foundation, 6/1/85-11/30/85, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,512, U.S. Geological Survey, 10/1/85-9/30/86, PI.

Seismic event monitoring and analysis, Jordanelle Damsite, Bonneville Unit, Central Utah Project: $25,000, U.S. Bureau of Reclamation, 2/13/86-9/30/86, PI.

Seismograph Stations: $202,700, State of Utah, 7/1/85-6/30/86, Director.

<u>1986-87</u>

Regional seismic monitoring along the Wasatch Front urban corridor and adjacent Intermountain seismic belt: $165,074, U.S. Geological Survey, 10/1/86-9/30/87, Co-PI.

Seismotectonic framework and earthquake source characterization (continued)—Wasatch Front, Utah, and adjacent Intermountain seismic belt: $120,000, 11/1/86-10/31/87, Co-PI.

Seismic event monitoring and analysis, Jordanelle Damsite, Bonneville Unit, Central Utah Project: $19,293, 10/1/86-9/30/87, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,512, U.S. Geological Survey, 10/1/86-9/30/87, PI.

Upgrading of portable seismographs for field research: $9,300, University of Utah Research Instrumentation Funds, 7/1/86-6/30/87, Co-PI.

Seismograph Stations: $203,600, State of Utah, 7/1/86-6/30/87, Director.

<u>1987-88</u>

Regional seismic monitoring along the Wasatch Front urban corridor and adjacent Intermountain seismic belt: $165,074, U.S. Geological Survey, 10/1/87-9/30/88, Co-PI.

Seismotectonic framework and earthquake source characterization (FY 88)—Wasatch Front, Utah, and adjacent Intermountain seismic belt: $120,000, U.S. Geological Survey, 11/1/87-10/31/88, Co-PI.

Seismic event monitoring and analysis, Jordanelle Damsite, Bonneville Unit, Central Utah Project: $20,000, U.S. Bureau of Reclamation, 10/1/87-9/30/88, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,512, U.S. Geological Survey, 10/1/87-9/30/88, PI.

Seismograph Stations: $208,100, State of Utah, 7/1/87-6/30/88, Director.

<u>1988-89</u>

Seismic network operations and research along the Wasatch Front urban corridor and adjacent Intermountain seismic belt (FY89): $165,000, U.S. Geological Survey, 10/1/88-9/30/89, Co-PI.

Seismotectonic framework and earthquake source characterization (FY 89)—Wasatch Front, Utah, and adjacent Intermountain seismic belt: $120,000, U.S. Geological Survey, 11/1/88-10/31/89, Co-PI.

Expert synthesis and translation of earthquake hazard results—A book for non-scientists in the Wasatch Front region: $55,550, U.S. Geological Survey, 1/1/89-12/31/89, Co-PI.

Seismic event monitoring and analysis, Jordanelle Damsite, Bonneville Unit, Central Utah Project: $21,000, U.S. Bureau of Reclamation, 10/1/88-9/30/89, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,512, U.S. Geological Survey, 10/1/88-9/30/89, PI.

Seismograph Stations: $211,200, State of Utah, 7/1/88-6/30/89, Director.

1989-90

Seismic network operations and research along the Wasatch Front urban corridor and adjacent Intermountain seismic belt (FY90): $165,000, U.S. Geological Survey, 10/1/89-9/30/90, Co-PI.

Seismotectonic framework and earthquake source characterization (FY 90)—Wasatch Front, Utah, and adjacent Intermountain seismic belt: $136,200, U.S. Geological Survey, 11/1/89-12/31/90, Co-PI.

Expert synthesis and translation of earthquake hazard results—A book for non-scientists in the Wasatch Front region (continued): $55,550, U.S. Geological Survey, 1/1/89-6/30/91, Co-PI.

Seismic event monitoring and analysis, Jordanelle Damsite, Bonneville Unit, Central Utah Project: $22,000, U.S. Bureau of Reclamation, 10/1/89-9/30/90, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,512, U.S. Geological Survey, 10/1/89-9/30/90, PI.

A task-force report specifying and prioritizing instrumentation needs for Utah's earthquake program: $5,000, Utah Geological and Mineral Survey, 6/26/89-12/31/89, PI.

Seismograph Stations: $217,700, State of Utah, 7/1/89-6/30/90, Director.

1990-91

Seismic network operations and research along the Wasatch Front urban corridor and adjacent Intermountain seismic belt (FY90): $165,000, U.S. Geological Survey, 10/1/90-9/30/91, Co-PI.

Seismic network operations and research along the Wasatch Front urban corridor and adjacent Intermountain seismic belt (FY91): $142,775 *Supplementary Award for Instrumentation*, U.S. Geological Survey, 10/1/90-9/30/91, Co-PI.

Seismic network operations and research along the Wasatch Front urban corridor and adjacent Intermountain seismic belt (FY91): $108,595 *Mandatory Matching Funds*, University of Utah, 10/1/90-9/30/91, Co-PI.

Seismotectonic framework and earthquake source characterization (FY91)—Wasatch Front, Utah, and adjacent Intermountain seismic belt: $118,800, U.S. Geological Survey, 1/1/91-12/31/91, Co-PI.

Expert synthesis and translation of earthquake hazard results—A book for non-scientists in the Wasatch Front region (continued): $55,550, U.S. Geological Survey, 1/1/89-6/30/91, Co-PI.

Seismic event monitoring and analysis, Jordanelle Damsite, Bonneville Unit, Central Utah Project: $23,000, U.S. Bureau of Reclamation, 10/1/90-9/30/91, PI.

Cooperative seismic program for support and utilization of Dugway, Utah, seismograph station: $2,512, U.S. Geological Survey, 10/1/90-9/30/91, PI.

Seismograph Stations: $232,000, State of Utah, 7/1/90-6/30/91, Director.

CURRICULUM VITAE of JOHN H. BELL, Ph.D.

May 1, 1989

General Information

Place of Birth: [redacted]

Personal: Excellent health; married with one dependent son

Address: [redacted]

Education

Secondary: Diploma, Chester High School, Chester, Pennsylvania, 1950

College: B.S., Chemistry/Biology, Widener University, Chester, Pennsylvania, 1950–1954

Post Graduate: M.S., Education (Science), University of Pennsylvania, Philadelphia, Pennsylvania, 1959–1961

M.S., Public Health (Health Physics), University of North Carolina, Chapel Hill, North Carolina, 1964–1965

Ph.D., Biophysics, University of Texas, Graduate School of Biomedical Sciences, San Antonio, Texas, 1972–1979

———, Educational Administration (31 graduate credits), University of Alaska Fairbanks, Fairbanks, Alaska, 1987

Professional Development Courses (in part)

1984	Personnel Management for Executives, Department of the Army, Southwest Regional Training Center
1984	Medical Effects of Nuclear Weapons, Armed Forces Radiobiology Research Institute
1982	Planning for Nuclear Emergencies, Harvard University
1981	Faculty Development Course, Academy of Health Sciences
1979	Current Trends in Radiation Protection, US Army Environmental Hygiene Agency
1979	Symposium on Electron Beam Therapy, American Association of Physicists in Medicine
1978	X-Ray System Maintenance and Calibration, American Hospital Association
1978	Radiology Management, American College of Radiology

Professional Development Courses (cont.)

1979	Current Trends in Radiation Protection, US Army Environmental Hygiene Agency
1979	Symposium on Electron Beam Therapy, American Association of Physicists in Medicine
1978	X-Ray System Maintenance and Calibration, American Hospital Association
1978	Radiation Management, American College of Radiology
1972	Accelerator Radiation Protection, US Public Health Service
1971	Radiation Protection Guides and Dose Assessment, US Public Health Service
1970	Laser and Microwave Hazards Course, US Army Environmental Hygiene Agency
1969	Fundamentals of Nonionizing Radiation Protection, US Public Health Service
1969	Radionuclide Analysis by Gamma Spectroscopy, US Public Health Service
1969	Reactor Safety and Hazards Evaluation, US Public Health Service
1968	Occupational Radiation Protection, US Public Health Service
1968	Nuclear Hazards Training Course, US Public Health Service
1967	Medical X-Ray Protection, US Public Health Service

Employment History

1988–Present — Academic Program Director/Associate Professor, University of Nevada, Las Vegas. Director of radiological health program. Teach undergraduate students in radiological science subjects.

1985–1986 — Project Officer and Chief of the Deployable Medical System (DEPMEDS) Training Branch, Directorate of Training and Doctrine, Academy of Health Sciences, US Army. Responsible for developing and implementing the DEPMEDS training strategy for individual and collective training on DEPMEDS medical and non-medical equipment for worldwide fielding of DEPMEDS. Directly managed professional staff of eight educational and technical specialists. Developed and published the Individual and Collective Training Plan, which is the base document for new equipment training in approximately 160 modernized field hospitals. Developed a comprehensive training set to facilitate the training for DEPMEDS equipment.

Employment History (cont.)

1981–1985 <u>Chief/Assistant Chief, Preventive Medicine Division, and Chief, Nuclear, Biological, and Chemical Sciences Branch</u>, Academy of Health Sciences, US Army, Fort Sam Houston, Texas. Managed all administrative, operational, and logistical support for the Division. Managed yearly budget of $90,000, less salaries. Provided and coordinated the use of subject matter expertise in support of 16 courses (11 officer, 5 enlisted) managed by the Division and 19 additional courses conducted at Academy of Health Sciences. Through five branch chiefs, supervised approximately 60 faculty and staff members; professional members included physicians, veterinarians, environmental science officers, sanitary engineers, health physicists, community health nurses, biochemists, entomologists, and chemists. Served as technical expert in nuclear/radiation subject matter. Instructed in nuclear medical science/health physics. Established health physics technician course which included curriculum, facilities, and instrumentation. Was the AHS Radiation Safety Officer.

1978–1981 <u>Medical Physicist and Staff Officer</u> to Department of the Army Material Development and Readiness Command (DARCOM). Provided Command Surgeon with technical advice and judgment on health hazards from ionizing and nonionizing radiation. Evaluated plans, programs, and actions within DARCOM involving the use of radiation-producing devices or materials. Evaluated management of health physics operations within elements of DARCOM and made recommendations to Command. Maintained staff liaison with major Army commands and Federal regulatory agencies. DA representative to the DOD Intrinsic Radiation (INRAD) Working Group sponsored by the Assistant to the Secretary of Defense for Atomic Energy. Recommended that DA conduct health hazard study of INRAD which has been implemented.

1976–1978 <u>Director, Department of Radiology</u>, Dwight David Eisenhower Army Medical Center. Managed the total operation of the Department of Radiology except radiographic procedures and interpretations. Staff included five radiologists and 30 technical and clinical individuals. The Department included Diagnostic, Nuclear Medicine, Radiation Therapy (planned), and Health Physics Services. Responsibilities included management of personnel, budget ($360,000, less salaries), operations, capital equipment, consumables, technical training, and radiation safety. Directly responsible for $1.8 million professional services contracts. The management process included independent decision making regarding policies of the Department and input into hospital policy as regards the radiology service. Equipment included two gamma scan cameras, three R/F units, a mammographic unit, a tomography unit, and three routine units. Workload averaged 250 patients and 350 examinations per duty day. Effected a $28,000 savings per quarter in clinic operation during tenure. Formulated accountability procedures for film use and silver recovery which were adopted by the AMEDD. Was the Radiation Safety Officer; managed two NRC licenses—nuclear medicine and radiation therapy. Formulated course concept for Radiology Management Course which was implemented by the Academy of Health Sciences.

Employment History (cont.)

1976 — Medical Physicist, Radiation Therapy Service, Dwight David Eisenhower Army Medical Center. Established the resource requirements for the Radiation Therapy Service and Health Physics Service.

1970–1972 — Radiation Safety Officer, US Army (Chief, Environmental Health Division, Medical Department Activity), White Sands Missile Range, New Mexico. Formalized and managed the WSMR Radiation Safety Program which included a staff of one health physicist, five technicians, and a secretary. Implemented AEC and DA Regulations governing the use of all types of potentially hazardous radiation-producing devices. Managed a radiation protection program involving four AEC licenses, nine DA authorizations, four health physics technicians, three health physicists, nine radiographers, 23 radioisotope operators, 672 radionuclides, 15 industrial radiographic units, six medical radiographic units, one nuclear reactor, one linear accelerator, one neutron generator, 618 radars, 39 microwave generators, 37 lasers, and a dosimetry program involving 900 film badges.

1969–1970 — Medical Operations Officer, US Army Headquarters, II Field Force, Vietnam. Assisted the Command Surgeon of a corps headquarters in fulfillment of his responsibilities. Managed office administration. Coordinated unit and field Army medical support. Formulated and wrote medical policies for the corps headquarters.

1967–1969 — Chief, Nuclear Branch (Radiation Safety Officer), US Army Medical Field Service School, Fort Sam Houston, Texas. Managed use of minor test sources in training at the USA MFSS. Determined subjects taught to professional medical personnel, scheduled subjects, managed fiscal budget, and supervised four other officer instructors within the Nuclear Branch. Was the MFSS Radiation Safety Officer.

1965–1969 — Instructor, Nuclear Medical Science, US Army Medical Field Service School, Fort Sam Houston, Texas. Instructed US Army Medical Department personnel attending the USA MFSS in military aspects of nuclear weapons effects and radiation phenomena. Taught specific blocks of instruction in nuclear science to physicians, dentists, nurses, and paramedical personnel.

1963–1964 — Medical Equipment Project Officer, US Army, Darnall Army Hospital, Fort Hood, Texas. Programmed all noncontractor-furnished medical equipment needs of facility, determined functional and special requirements, coordinated equipment needs with professional medical staff, and established total cost of programmed equipment.

Publications

M.S.P.H. Thesis — "Effect of Ionizing Radiation on Human Spermatogenesis," University of North Carolina, 1965

Publications (cont.)

Ph.D. Dissertation	"Comparison of Experimental to Theoretical C_E Values for Electrons of 6, 9, 12, 15, and 18 MeV from a Medical Linear Accelerator Using a Tissue-Equivalent Dosimetry System," University of Texas Health Science Center, San Antonio, Texas, 1979
	"A Method for Rapid Determination of the Energy of Electron Beams from Medical Linear Accelerators," *Radiology*, Volume 126, Number 3, March 1978
	Bell, John H. and Waggoner, Robert G., "Equipment List for Medical Physics and Acquisition Priority," *Handbook of Medical Physics*, Volume III, CRC Press, Boca Raton, 1984

Presentations

25–30 July 76	*A Comparison of Central-Axis Depth-Dose Values in Water and Tissue-Equivalent Liquid for Electron Beams from a Medical Linear Accelerator* presented to the Fourth International Conference on Medical Physics, Ottawa, Canada
14–19 Nov 76	*Water to Tissue Conversion Factors for Electron Beams of 6, 9, 12, 15, and 18 MeV from a Medical Linear Accelerator* presented to the Annual Meeting of the Radiological Society of North America, Inc., Chicago, Illinois

Exhibits

14–19 Nov 76	*Water to Tissue Conversion Factors for Electron Beams of 6, 9, 12, 15, and 18 MeV from a Medical Linear Accelerator* presented to the Annual Meeting of the Radiological Society of North America, Inc., Chicago, Illinois

Professional Societies

1978	American Hospital Radiology Administrators
1977	American College of Hospital Administrators
1974	American Association of Physicists in Medicine
1965	Health Physics Society
1965	Delta Omega, Honorary Public Health Society

Fields of Interest

Management of Health Physics Program

Management of Medical Physics Program

Awards

1986	Legion of Merit Medal
1968/1981	[redacted]
1970	Outstanding Instructor Designate, US Army Medical Field Service School
1969/1970	Bronze Star Medal with Two Oak Leaf Clusters
1965	Election to Delta Omega Honor Society, University of North Carolina
1960	National Science Foundation Fellowship for academic year to University of Pennsylvania
1950	Four-year academic scholarship to Pennsylvania Military College

References for RSO Experience:

DARCOM	Robert T. Cutting, M.D. Staff Physician Savannah River Project Medical Department Aiken, South Carolina 29808 803/557-9537
DDEAMC	Marion P. Johnson, M.S. Hospital Administrator McKenna Memorial Hospital New Braunfels, Texas 78130 512/625-9111
	Nicholas F. Conte, M.D. [redacted]
AHS	* Donald G. Ebner, Ph.D. Director of Life Procedures and Testing USAA Life Insurance Company 9800 Fredericksburg Road San Antonio, Texas 78288 512/498-6400
DDEAMC AHS	John M. Sowell, M.D. Staff Physician San Antonio State Hospital 6711 South New Braunfels San Antonio, Texas 78223 512/532-8811, ext. 1460

* Former Dean, Academy of Health Sciences

CURRICULUM VITA

F. WILLIAM CAMBRAY

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East Lansing, Michigan 48824-1115
(517) 355-4600

[redacted]

Birthdate: [redacted]

Nationality: [redacted]

Marital Status: Married with four children, [redacted]

EDUCATION

1964 Ph.D., King's College, University of London

1958 B.Sc. (Special Honors, Geology) King's College, University of London, England.
A.K.C. (Associate of King's College)

PROFESSIONAL EXPERIENCE

1989 Director, Center for Integrative Studies in General Science, Michigan State University

1974-89 Chairman, Department of Geological Sciences, Michigan State University

1974 Professor, Department of Geological Sciences, Michigan State University

1971-74 Chairman, Geology Department, Wayne State University, Detroit, Michigan

1969 Associate Professor Geology Department, Wayne State University, Detroit, Michigan

1967 Lecturer, Geology Department, Wayne State University, Detroit, Michigan

1964	Lecturer (Associate Professor with Tenure), Geology Department, Sir John Cass College, London
1962	Assistant Lecturer (Assistant Professor), Geology Department, Sir John Cass College, London
1961	Research Demonstrator, Geology Department, University of Wales, Swansea
1958-61	Demonstrator (Teaching Assistant), Geology Departments, King's College, London, and Sir John Cass College, London

OTHER PROFESSIONAL ACTIVITIES

1991	Short courses/Structual Geology and Mineral Deposits - Cominco, Alaska.
1989	Assistant Editor, Geological Society of London
1988	Short courses/Kinematic Indicators - Callahan Mining Co., Michigan
1987	Invited Panelist, GLIMPCE Workshop, Washington, D.C.
1987	Invited Panelist, Midcontinent Rift System Workshop, Duluth, Minnesota (DOSSEC)
1983	Visiting Professor, NSF sponsored, Northwestern University, Xian, and College of Geology, Chengdu, China
1979	Visiting Professor, School of Mines, University of Zambia, Africa
1978	Governor's Task Force (Michigan) on low-level nuclear waste disposal
1976	Cooperative research visit, University of Tuzla, Yugoslavia
1970	Cooper Range Mining Company, Michigan, mineral exploration
1957	Buchan's Mining Company, Newfoundland, Canada, mineral exploration

GRADUATE STUDENTS' THESES DIRECTED, MICHIGAN STATE UNIVERSITY

1989	Cunniff, Robert T., The tectonic style of the Keweenawan deformation (MS)
1988	Sack, William, R., Geometric analysis and kinematics of folding associated with overthrusting: Blue Ridge Province, Tennessee (MS)
1985	Raab, James A., A finite strain study of the Baraboo Quartzite: observations from quartz grain shape (MS)

1984	Myers, Gary A., Structural analysis of foliated Proterozoic metadiabase dikes, in the Marquette-Republic region of northern Michigan (MS)
1983	Breithart, Mark S., The significance of the distribution of clastic lenses within the Negaunee Iron Formation at the eastern end ofthe Palmer Basin, Marquette Synclinorium, northern Michigan (MS)
1983	Meyer, Rudi A, A strain study in the Kona Formation, Michigan (MS)
1982	Jank, Mary E., Pressure solution and the development of cleavage in the Baraboo Quartzite (MS)
1981	Fisher, Jeanne A., Fault Patterns in southwestern Michigan (MS)
1979	Fortuna, Mark A., Paleomagmetism and shear history of Precambrian X dikes, (MS)
1978	Shanabrook, David C., A geophysical and geological study of the basement complex along the Peshekee River, Marquette County, Northern Michigan (MS)
1978	Westjohn, David B., Finite strain in the Precambrian Kona Formation, Marquette County, Michigan (MS)

CURRENT PROJECTS

Refolding in shear belts
The tectonics of the Midcontinent Rift System
The role of sills in detachments
The strain history of the Proterozoic Penokean Orogeny

PAPERS PUBLISHED

1990	Tectonics of the Laptev Sea and Moma Rift Systems, Northeastern U.S.S.R. Marine Geology, 93, pp. 95-118. (with Kazuya Fujita)
1984	Proterozoic Geology, Lake Superior South Shore, Field Trip Guidebook: Geol. Assoc. Canada/Mineral. Assoc. Canada, 55 pages.
1983	Pressure solution and cleavage development in the Barabook Quartzite: Geoscience Wisconsin, v. 10, p. 54-65 (with M. E. Jank).
1977	Field Guide to the Marquette District, Michigan: Mich. Basin Geol. Soc.
1972	Provenance of the Richmond Formation, Jamaica, from sole marks: Geonotes, Jour. Geol. Soc. Jamaica, West Indies, v. 11, p. 13-18 (with P. Jung).

1971 Paleomagnetism of cretaceous dykes from Jamaica: Geophys. Jour. Royal Astron. Soc., v. 22, p. 163-174 (with N. D. Watkins).

1971 Physiography of the sea floor east of Jamaica, West Indies: Symposium on Investigations and Resources of the Caribbean Sea and Adjacent Area, Unesco, Paris, p. 285-289 (with E. R. Robinson).

1969 The Kilmacrenan Succession East of Glenties, Co. Donegal, Eire: Proceedings, Royal Irish Academy, v. 67, lect. B, no. 13, p. 291-302.

1969 The Dalradian of Donegal and Northern Ireland: Amer. Assoc. Petrol. Geol., Mem. 12, p. 181-193.

1964 The Lennan Fault: Quart. Jour. Geol. Soc. Lond., v. 120, pt. 2, no. 478, p. 241-273.

ABSTRACTS AT MEETINGS

1991 Detachment faulting and the origin of the asymmetric depositional pattern of the Marquette Trough. Proceedings of the 37th I.L.S.G., Eau Claire, Wisconsin. (with J. Mancuso and W. Slitor)

1991 Collision induced ripoffs, ancient and modern: the midcontinent rift system and the Red Sea-Gulf of Aden compared. Proceedings of the 37th I.L.S.G., Eau Claire, Wisconsin. (with Kazuya Fujita)

1991 A late Keweenawan thrust? Marquette County, Michigan. Proceedings of the 37th I.L.S.G., Eau Claire, Wisconsin. (with Glenn Scott)

1990 Detachment controlled sill emplacement in the Midcontinent Rift System of the Lake Superior Region. Geol. Soc. Amer., Abstract with programs, Vol. 22, No. 7, p. A369. (with Marco Antonelli)

1990 Style of emplacement of the Duluth Complex. Geol. Soc. Amer., Abstract with programs, Vol. 22, No. 7, p. A369. (with James D. Miller, Jr., Va. W. Chandler, and David L. Southwick)

1990 Tectonic relationship between large ash flow eruptions and mid-crustal intrusions: Timber Mountain Tops. EOS, Transactions, American Geophysical Union, Vol. 71, No. 43, p. 1685. (with T. A. Vogel)

1990 Magma flow emplacement direction in the Midcontinent Rift System using shear strain indicators and anisotropy of magnetic and anhysteretic susceptibility. EOS, Transactions, American Geophysical Union, Vol. 71, No. 43, p. 1288. (with Marco Antonelli)

1989 A simple shear model for the Laptev Sea rift system, Arctic, Siberia. 11th Texas A & M Geodynamics Symposium, World Rift Systems, program and abstracts, pp. 60-62. (with M. A. Velbel)

1989 Seismicity and tectonics of the North American plate boundary in Northeast Asia. 28th Int. Geol. Conference, Washington, DC, abstract, Vol. 1, pp. 517-518. (with K. Fujita, D. B. Cook, and C. A. McMullen)

1989 Collision induced ripoffs, modern and ancient. Trans. Amer. Geophys. Union, Vol. 70, p. 371.

1988 Tectonics of the Laptev Sea and Momar Rift Systems. Tran. Amer. Geophys. Union, Vol. 69, p. 1416. (with K. Fujita and D. B. Cook)

1988 The opening and closing of the Midcontinent Rift System: Geol. Soc. Amer., Abstr. w/Programs, v. 20, no. 7, p. A386.

1988 A tectonic model for the Midcontinent Rift System: Geol. Soc. Amer., Abstr. w/Programs, v. 20, no. 5, p. 338.

1987 Precambrian structure beneath the Michigan Basin: Int. Assoc. Great Lakes Res. 30th Ann. Conf., Invited Paper.

1987 The Baraboo Syncline: The shape and refolding explained as a result of superimposition of simple shear on a pre-existing fold: Geol. Soc. Amer., Abstr. w/Programs, v. 19, no. 4, p. 192.

1987 An alternate stratigraphic correlation within the Marquette Range Supergroup, N. Michigan: Geol. Soc. Amer., Abstr. w/Programs, v. 19, no 4, p. 192.

1986 The role of shear in the origin of superimposed structures in thrust belts: Shear Criteria Mtg., Imperial College, London, England, Abstr. w/Programs, p. 3.

1985 The origin of coaxial folding in thrust belts: Tectonic Studies Group, Geol. Soc. London 16th Ann. Mtg., Southhampton, England, Prog. w/Abstr., p. 79.

1985 Structural and stratigraphic fabric of the Ouachita Thrust Belt, Oklahoma and Arkansas: A Paleozoic accretionary complex: Geol. Soc. Amer., Abstr. w/Programs, v. 17, no. 7, p. 746 (with M. J. P. Welland and D. S. Voight)

1984 Southward verging structures and coaxial refolding in the Benton Uplift, Ouachita Mountains, Arkansas: A result of southerly directed thrusting: Geol. Soc. Amer., Abstr. w/Programs, v. 17, no. 7, p. 538 (with M. J. P. Welland).

1984 Ductile shear on early mafic dikes in the Proterozoic Penokean Orogeny, Michigan: A source of strain heterogeneity: Geol. Soc. Amer., Abstr. w/Programs, v. 16, no. 6, p. 461 (with G. A. Meyers).

1984 Basement cover relations in the Marquette and Republic Districts, Michigan: 30th Inst. Lake Superior Geol., Wasau, Wisconsin, p. 6 (with R. O. Meyer and G. A. Myers).

1983 Evolution of the Penokean Orogenic Belt, north-central U.S.A.: Geol. Soc. Zambia, Proterozoic '83 Conf., Lusaka, Zambia, Invited paper.

1983 Pressure solution and the development of cleavage in the Baraboo Quartzite: Geol. Soc. Amer., Abstr. w/Programs, v. 15, no. 4, p. 210 (with M. E. Jank).

1981 Preliminary results of a detailed gravity survey in the eastern half of the Iron River Crystal Falls district, Iron, Michigan, Inst. Lake. Sup. Geol., 27th Annual Meeting, Abstract and Program. (with D. R. Paddock, K. Fujita, and H. F. Beant)

1981 A plate tectonic setting for the Penokean Orogeny: Int. Proterozoic Conf., Univ. of Wisconsin, April, Invited paper.

1979 Finite strain in the Precambrian Kona Formation, Marquette County, Michigan: Geol. Soc. Amer. North-central Section, Abstr. w/Programs, v. 11, no. 5, p. 259 (with D. Westjohn).

1979 Cross folding in the eastern Marquette Trough, Michigan: 25th Inst. Lake Superior Geol., p. 27 (with D. K. Larue).

1978 Plate tectonics as a model for the environment of deposition and deformation of the Early Proterozoic (Precambrian X) of northern Michigan: Geol. Soc. Amer., Abstr. w/Programs, v. 10, no. 7, p. 376.

1978 The origin and timing of cleavage formation in the Siamo Slate of Precambrian X age, Marquette County, Michigan: Geol. Soc. Amer., North-central Section, Abstr. w/Programs, v. 10, no. 6, p. 248.

1978 Finite strain in the Precambrian Kona Formation of the Marquette Synclinorium: 24th Inst. Lake Superior Geol., p. 7 (with D. Westjohn).

1978 Plate tectonics as a model for the environment of sedimentation of the Marquette Range Supergroup and the subsequent deformation and metamorphism associated with the Penokean Orogeny: 24th Inst. Lake Superior Geol., p. 6.

1971 Eocene paleomagnetism from Jamaica: Trans. Amer. Geophys. Union, Abstr. w/Programs, v. 52, no. 4, p. 188 (with S. A. Vincenz and S. N. Dasgupta).

1970 Early Tertiary sedimentation and structure in the Wagwater Trough, Jamaica, West Indies: Geol. Soc. Amer., Abstr. w/Programs, v. 2, no. 7, p. 514.

1970 Paleomagnetism of cretaceous dikes from Jamaica: Trans. Amer. Geophys. Union, Abstr. w/Programs, v. 51, no. 5, p. 270 (with N. D. Watkins).

1968 The Caledonian chronology and structural development of northwestern Donegal, Eire: Geol. Soc. Amer., Special Paper no. 121, p. 22 (with A. R. Berger).

SOCIETY MEMBERSHIPS

Geological Society of London
Engineering Group - Geological Society of London
Geologists Associations, London
British Geotechnical Society (Institute of Civil Engineers, London)
Geological Society of Jamaica (Secretary, 1967-69)
Geological Societey of America
Michigan Basin Geological Society (Vice President, 1976-77; President, 1977-78)
Phi Kappa Phi
British Tectonic Studies Group, North American Representative
Sigma Xi

REFEREES

Dr. Robert B. Furlong, Geology Department, Wayne State University, Detroit, Michigan 48202. Phone: 313-577-2507

Dr. Dennis S. Wood, Robertson Research Institute, Ty'n-y-Coed, Llanrhos, Llandudno, Gwynedd, LL30 1SA, North Wales, U.K. Phone: Deganwy (0492) 81811

Dr. Ian W. Dalziel, Institute for Geophysics, University of Texas, Austin, Texas 78751. Phone: 512-471-5172

Dr. Richard U. Byerrum (Dean Emeritus, College of Natural Science), Department of Biochemistry, 305 Biochemistry Building, Michigan State University, East Lansing, Michigan 48824. Phone: 517-355-9726

Dr. Michael Welland, Manager, Exploration Planning, ARCO International Oil and Gas Company, P.O. Box 260888, Plano, Texas 75026-0888. Phone: 214-754-4262

Dr. Duncan F. Sibley, Professor, Department of Geological Sciences, Michigan State University, East Lansing, Michigan 48824-1115. Phone: 517-355-8307

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SWCA ENVIRONMENTAL CONSULTANTS

STEVEN W. CAROTHERS

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(602) 774-5500

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Tucson, Arizona 85719
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Home Address
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Education

Ph.D.	1974	University of Illinois, Urbana, Zoology. Dissertation I. Time and energy budget of the Vermilion Flycatcher: Dissertation II. The social organization of riparian birds.
M.S.	1969	Northern Arizona University, Flagstaff, Biology. Thesis: Respiratory metabolism in two species of Juncos.
B.S.	1966	Northern Arizona University, Flagstaff, Biology

Expertise

Dr. Carothers is an aquatic and terrestrial biologist with over 20 years of experience in ecological research, environmental planning, and management. His pioneering studies of riparian communities demonstrated the importance of streamside habitats to fish and wildlife. The diversity of Dr. Carothers' academic and professional experience enables him to work effectively in a wide array of natural resource-related disciplines. His specialties include riparian ecology, environmental planning, management of interdisciplinary study teams, and the formulation of environmental mitigation plans. His experience integrates scientific knowledge with the needs and goals of community developers, recreationists, resource managers, and government agencies. Evaluation of long-term impacts of developments, recreation, and resource utilization on biological communities are of particular interest to Dr. Carothers.

Professional Experience

1984-Present	SWCA, Inc. Environmental Consultants, President and Director
1984-Present	Northern Arizona University, Adjunct Professor
1985-Present	University of Arizona, Adjunct Professor
1980-84	SWC Associates, Principal Consultant
1974-80	Museum of Northern Arizona, Head, Department of Biology
1980	Museum of Northern Arizona, Research Associate
1980	Museum of Northern Arizona, Research Ecologist
1979	University of Illinois, Artist in Residence
1978	University of Virginia, Instructor in Department of Environmental Sciences
1971-74	Museum of Northern Arizona, Curator of Zoology
1970-71	University of Illinois, Teaching Assistant
1970	Northern Arizona University, Instructor of Ornithology

Professional Experience (continued)

1969	Museum of Northern Arizona, Assistant Curator of Zoology
1967-68	Northern Arizona University, Teaching Assistant
1966	Museum of Northern Arizona, Assistant Ornithologist

Recent Development, Master Planning, and Environmental Consulting Projects

Science Applications International Corporation

1991 Yucca Mountain Site Characterization Project, Las Vegas, Nevada. Peer Review Committee: review and comment on content and objectivity of current status of the Site with regard to the 10 CFR Part 960 siting guidelines as those guidelines relate to biological and cultural resources. Project entails extensive review of background material and existing data to evaluate the suitability for the Yucca Mountain Site for a geologic repository for the disposal of radioactive waste and spent nuclear fuel.

Alta-West Development

1991 Altamira Project, Palm Desert, California. Principal in Charge. Preparation of Environmental Analysis with particular emphasis on the Threatened Peninsular Desert Bighorn Sheep and the Bighorn Institute in Palm Desert, California.

Hopi Tribe

1991 Glen Canyon Environmental Studies, Flagstaff, Arizona. EIS writing team representing the Hopi Tribe. An Environmental Impact Statement is under preparation that will review alternatives concerning water relese schedules from Glen Canyon Dam.

Washington County

1991 Habitat Conservation Plan, St. George, Utah. Preparation of a habitat Conservation Plan (HCP) including field surveys for federally listed Endangered Species surveys, design and development, public scoping meetings, and NEPA documentation.

High Desert Corporation

1991 High Desert Development, Albuquerque, New Mexico. Principal in Charge. Resource assessment, mitigation planning and management for environmental factors on 1,000 acres of land in the Sandia Foothills, in order to plan future development of the area with minimal environmental impacts to cultural and natural resources.

Recent Development, Master Planning, and Environmental Consulting Projects (continued)

Southwest Travis County Limited

1991 Bohls Ranch Property, Austin, Texas. Principal in Charge to provide services for obtaining regulatory approval for the US Fish and Wildlife Service for the development of property. This project includes a biological assessment, regulatory support, and field surveys for endangered bird species.

Fulbright and Jaworski

1990 Cielo Vista Development, San Antonio, Texas. Principal in Charge. Acted as a liaison between the client and government agencies, including the US Fish and Wildlife Service and the Army Corps of Engineers, overseeing Section 7 processes for threatened and endangered bird species.

Brohm Mining Company

1990 Gilt Edge Expansion Project Principal in Charge. Reviewed the technical feasibility of a proposed open pit reclamation program involving a proposed lake. Researched existing recreational supply and project recreational demand for the Northern Black Hills region to facilitate development of compatible alternative concepts.

Transcontinental Properties, Inc.

1990 Lake at Las Vegas. Principal in Charge. Implementation of requirements as stipulated in Biological Opinion, issued by the US Fish and Wildlife Service, concerning desert tortoises. Implementation of an education program as required as part of Section 7 process. Designed five-acre wetlands as part of Corps Section 404 permit to mitigate for wetlands loss.

Ranpac Engineering

1990 Section 7 Mitigation. Principal in Charge. Acted as a liaison between client and government agencies, including the US Fish and Wildlife Service and the Corps of Engineers concerning desert tortoise mitigation.

Westinghouse Desert Communities

1990 Bighorn Sheep Institute. Principal in Charge regarding environmental impact project development on adjacent Bighorn Institute lands. Coordinated studies to determine impacts on Bighorn Sheep and directed team of scientists to review information.

Recent Development, Master Planning, and Environmental Consulting Projects (continued)

The Estes Company

1988-1990 Half Moon Bay Principal in Charge concerning coordination and assistance in developing a potential mitigation plan for the endangered San Francisco garter snake. Also supervised on-site survey for same.

1987-Present Rocking K Ranch. Senior Consultant in development of solution to environmental issues associated with the planning and development of a 7,000-acre development immediately adjacent to Saguaro National Monument.

1981-1986 La Reserve. Senior Consultant to determine project impacts to sensitive wildlife and wilderness issues. Interfaced with environmental groups, U.S. Fish and Wildlife Service, U.S. Forest Service, Arizona Game and Fish, conservation and academic groups to resolve environmental issues.

1982-1987 Ventana Canyon. Senior Consultant in habitat restoration and mitigation program for 1,100 acre master planned destination resort. Conceptualization of the integration of the resort into the surrounding environments and utilization of this concept as a promotion technique.

1986 James M. Montgomery Consulting Engineers. Senior Consultant for analysis of Harbor Lake aquatic ecological problem. City of Los Angeles.

Grand Canyon Railways

1990 Alternate Spur Line. Principal in Charge for preparation of an Environmental Impact Statement for Grand Canyon Railways proposed spur line from Grand Canyon Airport the South Rim of Grand Canyon National Park. Directed interest groups and agency coordination.

City of Flagstaff

1990 Rio de Flag Floodplain Alternative Public Involvement Program. Principal in Charge. Determined public perception of flood hazards and resulting constraints and opportunities for Rio de Flag Floodplain management. Produced Public Participation Report conforming to NEPA requirements.

1988 Fourth Street Alignment. Principal in Charge. Environmental assessment of alternatives for the proposed 4th Street extension traversing national forest lands involving sensitive species surveys and public involvement program, City of Flagstaff, Arizona.

Recent Development, Master Planning, and Environmental Consulting Projects

Phelps Dodge Development Corporation

1988 — Reclamation of Peck's Lake and Clarkdale Corporation Conceptual alternatives and preliminary cost estimates were prepared for restoration and reclamation of Pecks Lake and Clarkdale Tailings Pond. Alternative shoreline modifications and dredging programs were prepared to provide varying levels of aquatic habitat enhancement as well as a variety of land use and recreation alternatives.

1986-1988 — Strategic Plan. Senior Consultant in federal land exchange programs and appraisal of several non-mineral assets based on ecological values. Development of land trade package.

1986-1988 — Indian School Property. Senior Consultant in land exchange program involving property in the Phoenix metropolitan area and ecologically sensitive areas in New Mexico containing critical habitat for an endangered species. Provided expert testimony to the House Insular Affairs Committee regarding ecological quality of proposed trade property.

Homestake Mining Corporation

1988-89 — Spearfish Canyon Homeowners Association Document Principal in Charge of research and document finalization for Homeowners Association, which obtained land ownership, along with the US Forest Service, from Homestake Mining Company.

1987 — Non-Mining Assets South Dakota/Wyoming: A Preliminary Assessment of Development Potential, Environmental Values, and Management Requirements. Senior Consultant in ecological appraisal of non-mineral assets to be utilized in federal land exchange program. Enhancement concepts for increasing value.

Fairfield Flagstaff

1987-Present — Lake Elaine Water Quality Management. Senior Consultant for the development of secondary treated effluent irrigation reservoir/lake management program addressing water quality, nuisance insect infestation problems and operation and maintenance plan. Served as liaison between homeowners and developer. Water quality is balanced using biological pest controls, especially the introduction of fish and other aquatic organisms to control nuisance insects. Project includes determination of appropriate biological controls and monitoring of bottom sediments.

Recent Development, Master Planning, and Environmental Consulting Projects (Continued)

City of Phoenix

1989 Principal in Charge for the Squaw Peak Summit Trail Master Plan. Development of a trail reconstruction master plan for the Squaw Peak Summit Trail, one of the most popular trails in the nation. Directed public involvement and agency coordination.

1986-1988 South Mountain Park Master Plan. Project Director for the development of a master plan for 16,000 acre municipal park involving ecological enhancement, trail network, picnic and recreation facilities.

Desert Tortoise Project Experience

1990 Project Scientist. SUMMA Corporation. Relocation of the Mohave Desert Tortoise on 3,200 acres in the Las Vegas Valley.

Project Scientist. Peccole Ranch. Relocation of the Mohave Desert Tortoise on 1,000 acres.

Project Scientist. Howard Hughes Properties. Biological Assessment for the Mohave Desert Tortoise. 4875 acres in the Las Vegas Valley.

Project Scientist. Bureau of Land Management. Biological Assessment for Mohave Desert Tortoise in 3 one-square-mile study plots. Field surveys include population density, growth rates, distribution, age class composition, health profiles, and habitat utilization. Sites included Mohave Mountains, East Bajada, and Santan.

Project Scientist. Foothills Corporation. Biological Assessment for Mohave Desert Tortoise on over 3200 acres in the Las Vegas Valley.

Project Scientist. ENSR. Mohave Desert Tortoise surveys.

Project Scientist. Howard Hughes Properties. Mohave Desert Tortoise relocation project, involving moving tortoise according to strict US Fish and Wildlife guidelines.

Project Scientist. Mohave Desert Tortoise Survey on the Moapa Indian Reservation. Sierra Delta Corporation.

1989 Project Scientist. Foothills Corporation. Biological Assessment for Mohave Desert Tortoise on over 700 acres in the Las Vegas Valley.

Project Scientist. Somerset Properties. Mohave Desert Tortoise survey in Las Vegas Valley.

Desert Tortoise Project Experience (continued)

Project Scientist. McCarran International Airport. Biological Assessment for Mohave Desert Tortoise on 3103 acres in the Las Vegas Valley.

Project Scientist. US Bureau of Land Management. Desert Tortoise Surveys on 3 one-square mile study plots. Sites included Sand Hollow, Mormon Mesa, and Piute Valley.

Project Scientist. Mohave Desert Tortoise Survey. Bureau of Land Management, Las Vegas, Nevada.

Other Consultant Services

1991 Spotted Owl Surveys on the Kaibab National Forest. US Forest Service, Williams, Arizona.

Spotted Owl, Mohave Desert Tortoise, and other Threatened and Endangered Species Surveys throughout northern Arizona. Transwestern and El Paso Natural Gas Companies, El Paso, Texas.

Land Exchange concerning six National Forests throughout Arizona. Federal Land Exchange, Phoenix, Arizona.

1990 Spotted Owl Surveys on the Dixie National Forest. US Forest Service, Cedar City, Utah.

Biological Studies for an Environmental Impact Statement. Terra Nova, Ontario, California.

Land Exchange between the City of Williams and the Kaibab National Forest. City of Williams, Arizona.

Environmental Assessment for the Hidden Valley Project. Lowe Development Corporation, Indian Wells, California.

1989 Summary of Analysis for the Flagstaff II Land Exchange. Federal Land Exchange, Inc. Phoenix, Arizona.

Environmental Assessment for Laughlin Bay Lake Management. Sierra Delta Corporation, Las Vegas, Nevada.

Threatened and Endangered Species Study. Apex Land Exchange. Kerr-McGee Corporation. Oklahoma City, Oklahoma.

Spotted Owl Survey. United States Department of Agriculture, Gila National Forest, Silver City, New Mexico.

1988 Baseline Studies of Soils, Vegetation and Wildlife at UPRC's Sage Mine Site. Union Pacific Resources Company, Denver Colorado.

Black Mesa Vegetation Studies. Peabody Coal Company, Flagstaff, Arizona.

Other Consultant Services (continued)

1987 Impacts of Development on Urban Birds. Estes Company, Tucson, Arizona.

Interconnection Facility Electric Fish Barrier, Central Arizona Project/Salt River Project, Phoenix, Arizona. Contract No. 1408-G/22-DG 362/88.

1987-90 Grand Canyon Peregrine Falcon Population Study, U.S. Department of the Interior, Grand Canyon National Park. Grand Canyon, Arizona.

1986 Ecological Overview of Forest Highlands. Baily-Bartlett Development Group, Flagstaff, Arizona.

Glen Canyon Environmental Studies Scientific Editorial Services. Bureau of Reclamation, Salt Lake City, Utah. Contract No. 6-CS-40-04430.

Influence of Wind Energy on Birds of Prey. Zond Systems, Inc., Tohachape, California.

Tuba City Oil Leak. Mangum, Wall, Stoops and Warden. Flagstaff, Arizona.

The Analysis of Development Impacts on Lake Havasu Water Quality and Fisheries. McCullough Oil Company, Lake Havasu City, Arizona.

Environmental Assessment for the City of Hemet, California. McSweeny Farms. Hemet, California.

Saddleback Mountain Vegetation Management Plan. Realty Asset Management, Phoenix, Arizona.

1985 Feral goat removal from San Clemente Island. United States Navy, San Bruno, California.

Harbor Lake storm drain upgrade for the City of Los Angeles. J.M. Montgomery Consulting Engineers, Pasadena, California. Subcontract No. 77.0041.

Mittry Lake Wildlife Area revegetation project for the Bureau of Reclamation, Yuma, Arizona. J.M.Montgomery Consulting Engineers, Pasadena, California.

Lower Colorado River bankline modifications. Bureau of Reclamation, Salt Lake City, Utah.

1984 Aquatic habitat survey of China Lake Springs, Naval Weapons Center, China Lake, California. James M. Montgomery Consulting Engineers, Pasadena, California. Contract No. N62474-84-C-1229.

Aquatic habitat survey of China Lake Springs, Naval Weapons Center, China Lake, California. J.M.Montgomery Consulting Engineers, Pasadena, California.

Other Consultant Services (continued)

1984 Electrofishing of Cataract Canyon for endangered Colorado Squawfish. Bureau of Reclamation, Salt Lake City, Utah.

1983 Human impact on Colorado River beaches in Grand Canyon. Grand Canyon National Park, National Park Service. Grand Canyon, Arizona.

An assessment of biological resources of Airport Wash, Rillito River, and tributaries, Tucson, Arizona. U.S. Army Corps. of Engineers, Los Angeles, California.

1983-85 Wildlife and fisheries studies, upper Gila River water supply project, Arizona and New Mexico. J.M.Montgomery Consulting Engineers, Pasadena, California.

Grazing management plan, Naval Weapons Center, China Lake, California. J.M. Montgomery Consulting Engineers, Pasadena, California.

1982 Interim Wild Horse Management Plan, Naval Weapons Center, China Lake, California. Phillips, Brandt, Reddick. Irvine, California.

Vertebrate survey of selected riparian habitats of the Naval Weapons Center, China Lake, California. Phillips, Brandt, Reddick. Irvine, California.

Impact of feral burros on vegetation and small mammals in the Mohave Desert, California. Phillips, Brandt, Reddick. Irvine, California.

1981 A survey of the fishes, aquatic invertebrates and aquatic plants of the Colorado River and selected tributaries from Lees Ferry (Mile 0) to Separation Rapids (Mile 240). Bureau of Reclamation.

Feral burro reduction program. Department of the Navy, China Lake, California.

Evaluation of the nesting and habitat, requirements of the Black Hawk on the San Francisco River, Arizona/New Mexico. Apache/Sitgreaves National Forest.

Recreational impacts on Colorado River beaches in Glen Canyon. National Park Service.

A survey of potential natural landmarks of the southern Colorado Plateau, Arizona, New Mexico, Colorado, and Utah. Division of Natural Landmarks, Heritage Conservation and Recreation Service, Denver, Colorado.

1980-81 Feral burro management program, Naval Weapons Center, China Lake, California. Phillips, Brandt, Reddick. Irvine, California.

Technical Publications

In Press	Reducing Electrofishing-Induced Injury in Rainbow Trout. North American Journal of Fisheries Management (with N.G. Sharber).
1991	Rocking K's Rincon Institute. Urban Land. 50(6):15 (with Luther Propst).
1990	Abundance of Peregrine Falcons in Grand Canyon National Park has implications for regionwide recovery. Park Science: A Resource Management Bulletin. 10(2):7 (with Brian T. Brown, Stephen W. Hoffman, and Richard Glinski).
1989	Electrofishing-Induced Spinal Injuries in Adult Rainbow Trout Mediated by Pulse Shape. North American Journal of Fisheries Management (with N.G. Sharber).
1987	External Threats: The Dilemma of Resource Management on the Colorado River in Grand Canyon National Park. Environmental Management 11(1):99-107 (with R.R. Johnson).
	A Non-mechanical Live Tank Design for Electric Fishing Boats. North American Journal of Fisheries Management (with N.G. Sharber).
	Demography of Feral Burros in the Mohave Desert. J. Wildl. Manage. 51(4): (with R.A. Johnson and T.J. McGill).
1985	Status of Riparian Ecology and Management. Proceedings of National Wetland Assessment Symposium. Portland, Maine, June 17-20, 1985 (with R.R. Johnson).
	Topographic changes in fluvial terrace deposits used in campsite beaches along the Colorado River in Grand Canyon. Journal of Arizona-Nevada Academy of Science 20(2):111-120 (with S.S. Beus and C.C. Avery).
1984	Birds of the Grand Canyon Region: an annotated checklist. Grand Canyon Natural History Association. Monogr. No. 1, Second Edition (with B.B. Brown, L.T. Haight, R.R. Johnson and M.M. Riffey).
	Recreational Impacts on Colorado River Beaches in Glen Canyon, Arizona. Environmental Management 8(4):353-358 (with R.A. Johnson and R. Dolan).
1982	Age structure, condition and reproduction of two *Equus asinus* (Equidae) populations from Grand Canyon National Park. Southwestern Naturalist 27(4) (with G.A. Ruffner).
1981	Southwestern riparian habitats and recreation: inter-relationships and impacts in the Rocky Mountain Region. (with R.R. Johnson). Contract with Eisenhower Consortium.

Technical Publications (continued)

A Riparian Classification System. Proceedings of California Riparian Systems: A Conference on Their Ecology, Conservation and Productive Management. University of California, Davis. September 17-19, 1981 (with R.R. Johnson and J.M. Simpson).

1980 Infestations of the copepod parasite, *Lernaea cyprinaceae*, in native fishes of Grand Canyon. National Park Service Transactions and Proceedings Series, Washington, D.C. (with C.O. Minckley, J.W. Jordan and H.D. Usher).

Avifauna of habitat islands in the Grand Canyon. Southwestern Naturalist 24(2):563- 576 (with M.F. Willson).

Recent collections of the Colorado River Squawfish and Razorback Sucker from the San Juan and Colorado Rivers in New Mexico and Arizona. Southwestern Naturalist 24(4):686-687 (with C.O. Minckley).

Age and growth rate of the flannelmouth sucker, *Catostomus latipinnis*, and Bluehead mountain sucker, *Pantosteus discobolus* in the Colorado River, Grand Canyon National Park. National Park Service Transactions and Proceedings Series, Washington, D.C. (with H.D. Usher, C.O. Minckley and J.W. Jordan).

Observations on the humpback chub, *Gila cypha*, within the Colorado and Little Colorado Rivers, Grand Canyon National Park. National Park Service Transactions and Proceedings Series, Washington, D.C. (with C.O. Minckley, J.W. Jordan and H.D. Usher).

1979 Natural resources, white water recreation and river management alternatives on the Colorado River, Grand Canyon National Park. Proceedings of the First Conference on Scientific Research in the National Parks, New Orleans, November 9-13, 1976, National Park Service Transactions and Proceedings Series WOC No. 5, pp 253-260.

1978 Birds of the Grand Canyon Region: an annotated checklist. Grand Canyon Natural History Association. Monogr. No. 1 (with B. T. Brown, P. S. Bennett, L. T. Haight, R. R. Johnson and M. M. Riffey).

1978 Distribution and natural history of some mammals from the Inner Gorge of the Grand Canyon, Arizona. Journal Ariz./Nev. Academy of Science 13:85-91 (with G. A. Ruffner and N. J. Czaplewski).

1977 The importance, preservation and management of riparian habitats: an overview. Proceedings of the Symposium on Riparian Habitats, Tucson, July 9, 1977 U.S.D.A. Forest Service General Technical Report WO-2.

1977 Man's impact on the Colorado River in the Grand Canyon. National Parks and Conservation Magazine 51:13-16 (with R. R. Johnson, R. Dolan, B. P. Hayden and A. Howard).

1977 Some ecological considerations associated with river recreation management. Proceedings of River Recreation Management and Research Symposium, January 24-27, Minneapolis, Minnesota (with S. W. Aitchison and R. R. Johnson).

1977 Lead concentration in small mammals not correlated with exposures of tetraethyl lead. American Midland Naturalist 98(1):250-254 (with J. Laerm).

1976 The effects of stream channel modification on birds in the southwestern United States. Proceedings from Symposium on Stream Channel Modification. Harrisburg, Virginia, August 15-17, 1975 (with R. R. Johnson).

1976 Burros threaten parts of Grand Canyon. National Park Service Newsletter 11:1-2 (with P. Shoemaker).

1976 The Mississippi Kite in Arizona: a second record. Condor 78:114-115 (with R. R. Johnson).

1976 Feral asses on public lands: an analysis of biotic impact, legal considerations and management alternatives. Transactions of the North American Wildlife and Natural Resources Conference, Washington, D. C., March 21-25, 1976 (with M. E. Stitt and R. R. Johnson).

1976 An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs. Technical Report No. 10, National Park Service (with S. W. Aitchison).

1975 Water management practices and their effects on nongame birds in range habitats. Proceedings of the Symposium on Management of Forest and Range Habitats for Nongame Birds. U.S.D.A. Forest Service General Technical Report WO-1, July (with R. R. Johnson).

1975 Recent observations on the status and distribution of some birds of the Grand Canyon region. Plateau 48(4):140-158 (with R. R. Johnson).

1975 Recent notes on the distribution of some mammals of the Grand Canyon region. Plateau 48(4):154-160 (with G. A. Ruffner).

1974 Population structure and social organization of southwestern riparian birds. American Zoologist 14:97-108 (with R. R. Johnson and S. W. Aitchison).

1974 History and bibliography of biological research in the Grand Canyon region with emphasis on the riparian zone. United States Department of the Interior National Park Service, Western Region, San Francisco, California (with J. H. Overturf, D. S. Tomko, D. S. Wertheimer, W. Wilson, and R. R. Johnson).

1974 Unusual feeding habits in two species of blackbirds. Wilson Bulletin 86(2):121 (with L. E. Beasley).

1974 Scaly-leg (*Knemidokoptiasis*) in a population of Evening Grosbeaks. Wilson Bulletin 86(2):121-124 (with N. J. Sharber and G. F. Foster).

1973 Ornithological literature of the San Francisco Mountains area: an annotated bibliography. Museum of Northern Arizona Technical Series No. 12 (with J. R. Haldeman and E. Aitchison).

1973 Recent changes in status and distribution of some northern Arizona birds. Museum of Northern Arizona Technical Series No. 12 (with J. R. Haldeman, R. P. Balda, and G. F. Foster).

1973 Habitat selection and density of breeding birds of a coniferous forest in the White Mountains, Arizona. Museum of Northern Arizona Technical Series No. 12 (with R. P. Balda and J. R. Haldeman).

1973 A summary of the Verde Valley breeding bird survey. Arizona Game and Fish Department Land and Water Projects Investigations, Verde River Studies. Project FW-16-13, Job 2, Progress Report 7-1-73 to 6-30-74 (with R. R. Johnson).

1973 Breeding birds of a ponderosa pine forest and a fir, pine, aspen forest in the San Francisco Mountains, Arizona. Museum of Northern Arizona Technical Series No. 12 (with J. R. Haldeman and R. P. Balda).

1972 Steller's Jays prey on Gray-headed Juncos and a Pygmy Nuthatch during periods of heavy snow. Wilson Bulletin 84(2):204-205 (with N. J. Sharber and R. P. Balda).

1972 A summary of the Verde Valley breeding bird survey. Arizona Game and Fish Department Land and Water Projects Investigations, Verde River Studies. Project FW-16-12, Job 2, Progress Report 7-1-72 to 6-30-73 (with R. R. Johnson).

1971 Notes on *Tadarida macrotis* in northwestern Arizona. Southwestern Naturalist 15(3):389-404 (with G. A. Ruffner).

1971 A summary of the Verde Valley breeding bird survey. Arizona Game and Fish Department Land and Water Projects Investigations, Verde River Studies. Project FW-16-10, Job 8, Progress Report 7-1-71 to 6-30-72 (with R. R. Johnson).

1970 Northern Arizona Field Research Expedition II. Interim Report. Atmospheric Science Research Center, S.U.N.Y. ASRC #138, pp 26- 28.

1970 Abnormal bill of a Western Meadowlark, *Sturnella neglecta*. Auk 87:173-174 (with R. P. Balda).

1970 A checklist of the birds of Flagstaff, Arizona. Museum of Northern Arizona (with R. P. Balda and J. E. Hildebrand).

1970 A summary of the Verde Valley breeding bird survey. Arizona Game and Fish Department Land and Water Projects Investigations, Verde River Studies. Project FW-16-10, Job 8, Progress Report 7-1-70 to 6-30-71, pp 43-64 (with R. R. Johnson).

1969 Mammals of Flagstaff, Arizona. Plateau 41:184-188 (with D. F. Hoffmeister).

1968 Fauna of Rio de Flag: I. Birds. Plateau 40:101-111.

1968 Additional records of *Notiosorex crawfordi* in Arizona. Southwestern Naturalist 13:449.

1968 Nest protection by the Brown-headed Cowbird, *Molothrus ater*. Auk 85(2):324-325 (with R. P. Balda).

1967 New records of northern Arizona birds. Plateau 40(1):41-43 (with J. R. Haldeman).

Popular Articles and Books

In Press The Mohave Desert Tortoise: Biology, Politics, and Management. (with C.H. Lowe).

1991 The Colorado River Through Grand Canyon: Natural History and Human Change. University of Arizona Press, Tucson, Arizona (with B. Brown).

1987 Wildlife of the Colorado Plateau. Plateau 57(4) and 58(1), 48 pp.

The Birds of Grand Canyon. University of Arizona Press, Tucson, Arizona (with B. Brown and R.R. Johnson).

1986 Mountain Islands. In: Arizona, Its Land and People. University of Arizona Press.

1985 Too Thick to Drink, Too Thin to Plow. Arizona Wildlife Views, Arizona Game and Fish Publications.

The San Francisco Peaks as a Resource: What Does the Future Hold? (update of 1977 issue) Plateau 56(3):19-23 (with D.A. House).

1982 Dam Changes on the Colorado River. Natural History 91(1):74-83 (with R. Dolan).

1980 The Living Canyon: Plants, Animals and their Inter-relationships with Man. In: The Grand Canyon-Up Close and Personal. Western Montana College Foundation (with N.H. Goldberg).

1979 Dammed Colorado. Arizona Outdoor/Recreation Phoenix Magazine Publishing Co., Arizona.

1979 Enchanted Light. Museum of Northern Arizona Press, Flagstaff, Arizona.

1978 Biology. Plateau 50(4):24-32.

1977 The San Francisco Peaks as a Resource: What Does the Future Hold? Plateau 49(5):18-23.

1977 Let's Carry It All Out. Down River, August.

1977 Man's Use of the Grand Canyon: Is it Time for Change? Plateau 49(4):24-31.

1977 Life After the Rain of Fire: The Biology of the Wupatki and Sunset Crater Region. Plateau 49(2):14-21 (with N. H. Goldberg).

1976 Canyons, Commitments and Experiences: A Naturalist Reflects. Plateau 49(1):16-25.

Awards/Honors

Council Member: National Parks and Conservation Association (1991)
Board of Trustees: Nature Conservancy (1990 to present)
Fellow, Arizona/Nevada Academy of Science (1985)
Governor's Commission on Arizona Environment Award (1984)
Elected to Beta Beta Beta Biological Honorary Society (1969)

Affiliations

American Ornithologists Union
American Society of Mammalogists
Arizona/Nevada Academy of Sciences
Cooper Ornithological Society
Sigma XI Scientific Research Society
Wildlife Society - Arizona/New Mexico Chapter
Wilson Ornithological Society
Bald Eagle Recovery Team, Fish and Wildlife Service
North American Riparian Council
Society of Wetlands Scientists

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CURRICULUM VITAE - JAMES I. DREVER

BORN: [redacted]

CITIZENSHIP: [redacted])

EDUCATION:

B.A. Cambridge University (England), 1964, Chemistry
(M.A. Cambridge University, 1968)

A.M. Princeton University, 1967
Ph.D. Princeton University, 1968, Geochemistry
Dissertation: Electrophoresis and the study of clay minerals in Recent sediments.
Adviser: H.D. Holland.

Fellowships: 1966-68, Harold W. Dodds Fellowship, Princeton University: "among the most distinguished available to students who have completed the General Examination ... without regard to department or field of study."

PROFESSIONAL APPOINTMENTS:

1968-69 Postgraduate Research Oceanographer, Scripps Institution of Oceanography, University of California, San Diego.

1969-71 Assistant Research Oceanographer, Scripps Institution of Oceanography.

1971-74 Assistant Professor, Geology Department, University of Wyoming, Laramie, Wyoming.

1974-77 Associate Professor, Geology Department, University of Wyoming (tenure 1975).

1977- Professor, Dept. of Geology & Geophysics, University of Wyoming.

1979-80 and 1987-88 Visiting Professor, Swiss Federal Institute for Water Resources and Water Pollution Control, Swiss Federal Institute of Technology, Zürich (Sabbatical years).

PUBLICATIONS:

Books

Drever, J. I. (1977) (Editor) Sea Water: Cycles of the Major Elements. Benchmark Papers in Geology, Dowden, Hutchinson & Ross, 344 p.

Drever, J. I. (1982) The Geochemistry of Natural Waters. Prentice-Hall, Englewood Cliffs, N.J., 388 p.

(Russian language edition published by MIR, Moscow, 1985, 440 p.)

Drever, J. I. (1985) (editor) The Chemistry of Weathering. NATO Advanced Science Institute Series, Reidel, 324 p.

Drever, J. I. (1988) The Geochemistry of Natural Waters, Second Edition. Prentice-Hall, Englewood Cliffs, N.J., 437 p.

Articles

Drever, J. I. (1969) The separation of clay minerals by continuous particle electrophoresis. American Mineralogist, v. 54, p. 937-942.

Drever, J. I. and Fitzgerald, R. W. (1970) Fluorescence elimination in X-ray diffractometry with solid-state detectors. Materials Research Bulletin, v. 5, p. 101-108.

Drever, J. I., Fitzgerald, R. W., Liang, S. S., and Arrhenius, G. (1970) Phyllosilicates in Apollo 11 samples. Proc. Apollo 11 Lunar Science Conference, v. 1, p. 341-345.

Arrhenius, G., Asunmaa, S., Drever, J. I., Everson, J., Fitzgerald, R. W., Frazer, J. Z., Fujita, H., Hanor, J. S., Lal, D., Liang, S. S., Macdougall, D., Reid, A. M., Sinkankas, J., and Wilkening, L. (1970) Phase chemistry, structure and radiation effects in lunar samples. Science, v. 167, p. 659-661.

Drever, J. I. (1971) Magnesium-iron replacement in clay minerals in anoxic marine sediments. Science, v. 172, p. 1334-1336.

Drever, J. I. (1971) Chemical weathering in a sub-tropical igneous terrain, Rio Ameca, Mexico. J. Sedimentary Petrology, v. 41, p. 951-961.

Drever, J. I. (1971) Early diagenesis of clay minerals, Rio Ameca Basin, Mexico. J. Sedimentary Petrology, v. 41, p. 982-994.

Drever, J. I. (1971) Chemical and mineralogical studies, Site 66. Initial Reports of the Deep Sea Drilling Project, v. 7, p. 965-975.

Drever, J. I. (1973) The preparation of oriented clay mineral specimens for X-ray diffraction analysis by a filter-membrane peel technique. American Mineralogist, v. 58, p. 553-554.

Drever, J. I. (1973) Relations among pH, alkalinity, carbon dioxide pressure, and calcium concentration in waters saturated with respect to calcite at 25°C and one atmosphere total pressure. Contributions to Geology, v. 11, p. 41-42.

Drever, J. I. (1974) The magnesium problem. *In* The Sea, Ideas and Observations, E.D. Goldberg, editor, v. 5, p. 337-357.

Drever, J. I. (1974) A geochemical model for the origin of Precambrian banded iron formations. Geological Society of America Bulletin, v. 85, p. 1099-1106.

Smith, C. L. and Drever, J. I. (1976) Controls on the chemistry of springs at Teels Marsh, Mineral County, Nevada. Geochimica et Cosmochimica Acta, v. 40, p. 1081-1093.

Drever, J. I. (1976) Chemical and mineralogical studies, Site 323. Initial Reports of the Deep Sea Drilling Project, v. 35, p.741-747.

Anderson, T. F., Donnelly, T. W., Drever, J. I., Eslinger, E., Gieskes, J. M., Kastner, M., Lawrence, J. R., and Perry, E. A. (1976) Geochemistry and diagenesis of deep-sea sediments from Leg 35 of the Deep Sea Drilling Project. Nature, v. 261, p. 473-476.

Miller, W. R. and Drever, J. I. (1977) Water chemistry of a stream following a storm, Absaroka Mountains, Wyoming. Geological Society of America Bulletin, v. 88, p. 286-290.

Drever, J. I., Murphy, J. W., and Surdam, R. C. (1977) The distribution of As, Be, Cd, Cu, Hg, Mo, Pb, and U associated with the Wyodak coal seam, Powder River Basin, Wyoming. Contributions to Geology, v. 15, p. 93-101.

Miller, W. R. and Drever, J. I. (1977) Chemical weathering and related controls on water chemistry in the Absaroka Mountains, Wyoming. Geochimica et Cosmochimica Acta, v. 41, p. 1693-1702.

Drever, J. I. and Smith, C. L. (1977) Repeated wetting and drying of the soil zone as an influence on the chemistry of ground water in arid terrains. Proc. 2nd. International Symposium on Water-Rock Interaction, Strasbourg, France, p. 50-55.

Lawrence, J. R., Drever, J. I., and Kastner, M. (1977) Low temperature alteration of the basalts predominates at Site 395 of the Deep Sea Drilling Project. Proc. 2nd. International Symposium on Water-Rock Interaction, Strasbourg, France, p. 355-362.

Sands, C. D. and Drever, J. I. (1978) Authigenic laumontite in deep-sea sediments. *In* Natural Zeolites, Occurrence, Properties and Use, Sand & Mumpton, editors, Pergamon, p. 269-275.

Drever, J. I. and Smith, C. L. (1978) Cyclic wetting and drying of the soil zone as an influence on the chemistry of groundwater in arid terrains. American Journal of Science, v. 278, p. 1448-1454.

Drever, J. I., Lawrence, J. R., and Antweiler, R. C. (1979) Gypsum and halite from the Mid-Atlantic Ridge, DSDP Site 395. Earth and Planetary Science Letters, v. 42, p. 98-102.

Lawrence, J. R., Drever, J. I., Anderson, T. F., and Brueckner, H. K. (1979) Importance of alteration of volcanic material in the sediments of Site 323 of the DSDP: chemistry, O^{18}/O^{16} and Sr^{87}/Sr^{86}. Geochimica et Cosmochimica Acta, v. 43, p. 573-588.

Drever, J. I. and McKee, C. R. (1979) The push-pull test: a method of evaluating formation adsorption parameters for predicting the environmental effects of in situ coal gasification and uranium recovery. *In* In Situ Uranium Mining and Ground Water Restoration, W. J. Schlitt and D. A. Schock, eds., Society of Mining Engineers of AIME, p. 87-97.

Lawrence, J. R., Drever, J. I., and Kastner, M. (1979) Low temperature alteration of basalts predominates at DSDP Site 395. Initial Reports of the Deep Sea Drilling Project, v. 45, p. 609-612.

Drever, J. I. and McKee, C. R. (1980) The push-pull test: a method of evaluating subsurface adsorption parameters for predicting the environmental effects of in situ coal gasification and uranium recovery. In Situ, v. 4, p. 181-206.

Lawrence, J. R. and Drever, J. I. (1981) Evidence for cold water circulation at DSDP Site 395: isotopes and chemistry of alteration products. J. Geophysical Research, v. 86, p. 5125-5133.

Mott, L. V. and Drever, J. I. (1983) Origin of uraniferous phosphatic beds in Wilkins Peak Member of the Green River Formation, Wyoming. American Association of Petroleum Geologists Bulletin, v. 67, p. 70-82.

Antweiler, R. C. and Drever, J. I. (1983) The weathering of a late Tertiary volcanic ash: importance of organic solutes. Geochimica et Cosmochimica Acta, v. 47, p. 623-629.

Bumb, A., McKee, C. R., Reverand, J., Halepaska, J., Drever, J. I., and Way S. C. (1984) Ammonia and nitrate in groundwater: assessment of containment and restoration options. Environmental Symposium '84, Orlando Florida, p. 81-118.

Fahey, T. J., Yavitt, J. B., Blum, A. B., and Drever, J. I. (1985) Controls of soil solution chemistry in lodgepole pine forest ecosystems, Wyoming. *In* Planetary Ecology, editors D. E. Caldwell, J. A. Brierly and C. L. Brierly, Van Nostrand Reinhold, New York, p. 473-484.

Bumb, A. C., Drever, J. I., and McKee, C. R. (1985) In-situ determination of dispersion coefficients and adsorption parameters for contaminants using a push-pull test. Proc. 2nd. Internat. Conf. on Ground Water Quality Research, Oklahoma State Univ., p. 186-190.

Drever, J. I. and Hurcomb, D. R. (1986) Neutralization of atmospheric acidity by chemical weathering in an alpine drainage basin in the North Cascade Mountains. Geology, v. 14 p. 221-224.

Jenkins, M. D., Drever, J. I., Reider, R. G., and Buchanan, T. (1987) Chemical composition of fresh snow on Mount Everest. Journal of Geophysical Research, v. 92, p. 10999-11002.

Mast, M. A. and Drever, J. I. (1987) The effect of oxalate on the dissolution rates of oligoclase and tremolite. Geochimica et Cosmochimica Acta, v. 51, p. 2559-2568.

Bumb, A. C., McKee, C. R., Way, S. C., Drever, J. I., and Halepaska, J. (1987) Ammonia and nitrate migration from the vadose zone to the ground water system: Containment, recovery, and natural restoration. Proceedings of the First National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, National Water Well Association, Dublin, Ohio, p. 95-123.

Drever, J. I., Li, Y.-H., and Maynard, J. B. (1988) Geochemical cycles: The continental crust and the oceans. *In* Chemical Cycles in the Evolution of the Earth, editors C.B. Gregor, R. M. Garrels, F. T. Mackenzie, and J.B. Maynard. Wiley-Interscience, New York, p. 17-53.

Walker, J. C. G. and Drever, J. I. (1988) Geochemical cycles of atmospheric gases. *In* Chemical Cycles in the Evolution of the Earth, editors C. B. Gregor, R. M. Garrels, F. T. Mackenzie, and J. B. Maynard. Wiley-Interscience, New York, p. 55-76.

Rochette, E. A., Drever, J. I., and Sanders, F. S. (1988) Chemical weathering in the West Glacier Lake Drainage Basin, Snowy Range, Wyoming: Implications for future acid deposition. Contributions to Geology, v. 26, p. 29-44.

Drever, J.I. (1988) Background Paper on Geochemistry. Final Report of the Special Programme on Global Transport Mechanisms in the Geosciences. North Atlantic Treaty Organization, p. 64-69.

Drever, J.I. and Swoboda-Colberg, N. (1989) Application of laboratory-derived mineral dissolution rates to weathering in the field. Water-Rock Interaction, WRI-6, editor D.L. Miles, Balkema, Rotterdam, p. 211-214.

Reddy, K.J., Drever, J.I., Essington, M.E., and Lindsay, W.L. (1989) Strontium supplement to Technical Bulletin 134: Selection of standard free energies of formation for use in soil chemistry. Technical Bulletin LTB89-2, Agricultural

Experiment Station, Colorado State University, 24 p.

Reddy, K.J., Lindsay, W.L., Workman, S.M., and Drever, J.I. (1990) Measurement of calcite ion activity products in soils. Soil Science Society of America Journal, v. 54, p. 67-71.

Zobrist, J. and Drever, J.I. (1990) Weathering processes in alpine watersheds sensitive to acidification. In "Acidification Processes in Remote Mountain Lakes", ed. M. Johannessen, R. Mosello and H. Barth, CEC Brussels (Belgium), p. 149-161.

Mast, M.A., Drever, J.I., and Baron, J. (1990) Chemical weathering in the Loch Vale Watershed, Rocky Mountain National Park, Colorado. Water Resources Research, v. 26, p. 2971-2978.

Accepted for publication

Reddy, K.J., Drever, J.I., and Hasfurther, V.R. The effect of a CO_2 pressure process on the solubilities of major and trace elements in oil shale solid wastes. Environmental Science and Technology.

Submitted

Swoboda-Colberg, N., Clow, D.C., and Drever, J.I. Chemistry of snowmelt and soil-water interaction in a small high-elevation catchment in Wyoming. To Water Resources Research. (Accepted subject to minor revision)

Drever, J.I. and Zobrist, J. Chemical weathering of silicate rocks as a function of elevation in the southern Swiss Alps. To Geochimica et Cosmochimica Acta (Garrels Memorial Volume) (Accepted subject to minor revision)

Mazor, E., Drever, J.I., Finley, J., and Huntoon, P.W. Hydrochemical implications of groundwater mixing and undersaturation, a calibrated example from the southern Laramie Basin, Wyoming. To Water Resources Research.

GRANTS AND CONTRACTS:

NSF (Submarine Geology & Geophysics): Research on diagenetic reactions of silicates in cores taken by the Deep Sea Drilling Project. $36,900 for 1972-74; $30,000 for 1974-76.

NSF (Geochemistry): Controls on the chemical composition of surface waters in the Absaroka Mountains, Wyoming, and Teels Marsh, Nevada. $35,700 for 1973-75.

Wyoming Environmental Institute/ARCO: Impact of proposed strip mining on water quality, Thunder Basin, Wyoming. $22,800 for 1973-74.

EPA: A cooperative project to evaluate surface and ground water problems associated with potential strip mine sites. Wyoming Geochemistry Sub-Project, $147,727 for 1975-78.

EPA: Phase two of above project, $50,000 for 1978-81.

NSF (Submarine Geology & Geophysics): Alteration of igneous rocks sampled on Leg 45 of the DSDP. $17,100 for 1977-78.

NSF (Geochemistry): Research on the chemistry of weathering of volcanic rocks. $44,300 for 1978-80.

NSF (Submarine Geology & Geophysics): Isotopic, chemical and mineralogical studies of sediments, pore waters, and altered igneous rocks sampled by the Deep Sea Drilling Project: III. Chemical and mineralogical studies of sediments and altered basalts. $44,400 for 1978-80.

Collaborating Investigator on EPRI Project "Lake Acidification and Fisheries", PI H.L. Bergman (Zoology Dept). Project has a budget of about $3 million, 1983-88.

Office of Water Policy/USGS: Processes controlling the composition of infiltrating water in forested mountain watersheds. $13,662 for 1983-84.

NSF (Environmental Geosciences): Rock weathering: geochemical and biological controls. $135,615 for 1983-86.

NATO Scientific Affairs Division: Support of advanced research workshop "The Chemistry of Weathering". 1,000,000 Belgian Francs (approx $20,000), 1984.

Co-principal investigator (with D.H. Knight and W.A. Reiners), Eisenhower Consortium/U. S. Forest Service, "Acid neutralization in Rocky Mountain coniferous forest ecosystems". $59,444 for 1985-86.

Co-investigator on U.S. Forest Service project "Characterization of High Elevation Research Sites for Atmospheric Deposition Studies" (P.I. J. H. Gibson, Colorado State Univ.), 1985-87.

Co-investigator on U.S. Nuclear Regulatory Commission project, "Flow of Groundwater and Transport of Contaminants Through Saturated Fractured Geologic Media from High-Level Radioactive Waste". $1,200,000 for 1985-88 (P.I. S.C. Way, In-situ, Inc.)

Co-principal investigator (with F.S. Sanders, WWRC), U.S. Geol. Survey: "Temporal variability and fluxes of acidic materials and selected trace elements in the surface waters of West Glacier Lake, Snowy Range Mountains, WY." $59,930, 1986-88.

EPA, Cation Supply Task Group, Watershed Manipulation Project, Univ. of Wyoming sub-contract, $245,112 for 1986-1989.

DOE (through Western Research Institute): "Geochemical modeling related to the surface disposal of processed oil shale solid waste" $186,000 for 1986-89 (with K.J. Reddy and V. Hasfurther).

Co-principal investigator (with W. A. Reiners and D. H. Knight), U. S. Forest Service: "Acid neutralization in Glacier Lakes Basin, Medicine Bow Mountains" $78,487 for 1987-88.

Wyoming Water Research Center: "Seasonal variability and transport of acidic materials and selected trace elements in surface waters at the West Glacier Lake Watershed, Snowy Range, Wyoming", $29,782, 1987-88 (with F. S. Sanders, WWRC).

Co-principal investigator (with H. L. Bergman, Zoology Dept.): U.S. Geological Survey: "Development of biologically relevant methods for determination of bioavailable Al in surface waters". $173,533 for 1988-1990.

Wyoming Water Research Center: "Importance of chemical weathering, soil-water interaction, and in-lake processing as controls on surface water chemistry at West Glacier Lake, Snowy Range, Wyoming", $15,000 for 1988 (with F.S. Sanders, WWRC).

USDA, Forest Service: "Water from snowpack". $15,000, 1988-89, $15,000 for 1989-90.

Wyoming Water Research Center: "Hydrology and recharge mechanics of alpine carbonate terranes in Wyoming thrust belt mountain ranges". $40,680 for 1989-1990 (P.W. Huntoon & J.I. Drever). Renewal by J.I. Drever and P.W. Huntoon funded for $12,395 for 1990.

Wyoming Water Research Center: "Soil-water interaction as a control on surface-water chemistry, West Glacier Lake Basin, Snowy Range, Wyoming". $22,465 for 1989-90; $23,302 for 1990-91.

EPA: "Watershed Manipulation Project: A field study of processes which regulate surface water acidity". U. Wyoming sub-project, $203,770 for 1990-92.

Co-principal investigator (with K.J. Reddy and S.P. Gloss) Electric Power Research Institute: "Development of a CO_2 pressure technique for chemical stabilization of alkaline CCT wastes." $116,849 for 1990-1992.

U.S. Air Force: $113,183/y, $339,550 total, "A new approach to the determination of bioavailable metals in surface waters", 1991-94 (Co-PI with H. L. Bergman, Zoology Dept..)

SERVICE TO PROFESSIONAL ORGANIZATIONS:

Associate editor, Geochimica et Cosmochimica Acta, 1982-present.

Editorial Board, Chemical Geology, 1977-85.

Editorial Board, Geology, 1984-86.

Councilor, The Geochemical Society, 1985-88.

Fellow, The Mineralogical Society of America, 1989-

Member NSF Panel (Seabed Assessment, IDOE), 1981-83

Director of NATO Advanced Research Workshop "The Chemistry of Weathering", Rodez, France, July 2-6, 1984.

Organizing Committee, for NATO Advanced Study Institute "Physical and Chemical Weathering in Geochemical Cycles", Aussois, France, September, 1985.

Member of Mineralogical Society of America MSA Award Committee, 1985-87.

Member, NADP review panel for Materials Effects, 1986.

Director (with D.F. Grigal, U. Minnesota), EPRI/EPA/NCASI Workshop on weathering processes and acid deposition, May 1986.

Invited observer/reviewer, USGS Retreat on Earth Science Studies for the Yucca Mountain Project, October, 1989.

Proposal reviewer for: NSF (Geochemistry Program, Environmental Geosciences Program, Geology Program, Geologic Record of Global Change Program, Petrology Program, Surficial Processes Program, Stratigraphy & Paleontology Program, Marine Chemistry Program, Submarine Geology & Geophysics Program, Thermodynamics and Mass Transfer Program, International Programs, International Decade of Ocean Exploration (Sea Floor Processes), RANN, EPA, DOE, USGS (various programs), ACS Petroleum Research Fund, National Sciences and Engineering Research Council of Canada, MONTS, Virginia Water Resources Research Center, Hudson River Foundation, Cottrel Foundation, Abandoned Coal Mine Lands Research Program.

Manuscript & book reviewer for: Academic Press, American Chemical Society Symposium Series, American Journal of Science, American Mineralogist, American Scientist, Applied Geochemistry, Arctic and Alpine Research, Canadian/American Conferences on Hydrogeology, Canadian Journal of Earth Sciences, Catena, Chemical Geology, Clays and Clay Minerals, Contributions to Geology, Contributions to Mineralogy & Petrology, DNAG, Earth & Planetary Science Letters, Encyclopedia of Earth System Science, Geochimica et Cosmochimica Acta, Geological Society of America Bulletin, Geology, Harcourt Brace Jovanovich, Initial Reports of the Deep Sea Drilling Project, In Situ, Journal of Geology, Journal of Geophysical Research, Journal of Mathematics Applied in Medicine and Biology, Journal of Sedimentary Petrology, Marine Geology, Minerals and Metallurgical Processing, National Geographic Research, National Research Council Studies in Geophysics, Paleoceanography, Precambrian Research, Prentice-Hall, Princeton University Press, Science, Water, Air & Soil Pollution, Water Resources Research, various symposia.

Society memberships: Geochemical Society, Geological Society of America, International Association for Geochemistry and Cosmochemistry, International Humic Substances Society, Mineralogical Society of America (fellow).

COURSES TAUGHT (University of Wyoming):

Geochemistry of Natural Waters (graduate)

Clay Mineralogy (graduate)

Geochemical Analytical Methods (graduate, shared)

Chemical Aspects of Contaminant Transport Modeling (graduate)

Geochemistry (senior/graduate)

Non-Clastic Sedimentation (senior/graduate)

Introduction to Oceanography (undergraduate)

Physical Geology (freshman, shared)

Various graduate seminars, including

Global Geochemical Cycles

Stable Isotopes in Low-Temperature Processes

Dissolved Organics in Natural Waters

Acid Deposition and Surface Water Chemistry

Environmental Geochemistry of Heavy Metals and Metalloids

FAMILY STATUS:

Married, two children.

MARCO T. EINAUDI

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Stanford University
Stanford, California 94305-2225
(415) 723-0575 phone
(415) 725-0979 fax

home:
[redacted]

Social Security Number: [redacted]...... *Born:* [redacted]

EDUCATION

B.A. Geology 1961 Cornell University
M.A. Geology 1965 Harvard University
Ph.D. Geology 1969 Harvard University

EMPLOYMENT

1961-1963 Lieutenant, U. S. Army, Military Assistance Advisory Command-Vietnam (MAACV), South Vietnam.

1965-1968 Teaching Assistant, Research Assistant, Dept. Geological Sciences, Harvard University.

1968-1971 Geologist, The Anaconda Company.

1971-1975 Project Geologist, The Anaconda Company.

1975-1977 Assistant Professor, Department of Applied Earth Sciences and Department of Geology, Stanford University.

1977-1980 Associate Professor, Departments of Applied Earth Sciences and Geology, Stanford University.

1980-pres Professor, Departments of Applied Earth Sciences and Geology, Stanford University.

1981-1982 Visiting Investigator, Geophysical Laboratory, Carnegie Institution of Washington, Washington, D.C.

HONORS AND AWARDS

1982-1983 Thayer Lindsley Visiting Lecturer, Society of Economic Geologists.

1984-pres Welton Joseph and Maud L'Anphere Crook Professor of Applied Earth Sciences, Stanford Uinversity.

1986 Hugh Exton McKinstry Memorial Lecturer, Harvard University.

1988 Fellow, Geological Society of America

PROFESSIONAL ACTIVITIES

Membership in Professional Societies:

Fellow, Society of Economic Geologists
Fellow, Geological Society of America

Society of Economic Geologists:

1974-1977 Program Policy Committee
1979-1983 Research Committee
1979-1981 Councilor to the Society
1980-1982 S.E.G Medal Committee (Chairman, 1981-82)
1983-1985 International Exchange Lectures Committee
1985 Chairman, Committee on Committees
1988-1989 Distinguished Lecturer Committee

Editorships:

1979-1984 Editorial Board, *Economic Geology*
Editor, Special Issues of *Economic Geology:*
1978 Bingham mining district, Utah
1982 Skarn Deposits
1986 Mineral deposits of northern Alaska
1984-pr Member, Economic Geology Publishing Co.
1984-pr Editorial Advisory Board, *Encyclopedia of Physical Science and Technology:* Academic Press.
1989-pr Executive Advisory Board, *Dictionary of Science and Technology:* Academic Press.

Symposia and Conferences:

1975 Co-Organizer, S.E.G Bingham Mining District Symposium, Geol. Soc. Amer., Salt Lake City, Utah.
1978 Co-Organizer, Symposium on Skarns in Porphyry and Non-porphyry Environments, Cordill. Sect. GSA, Tempe, Arizona.
1981 Co-Chairman, Gordon Research Conference on Inorganic Geochemistry, New Hampshire.
1985 Co-Organizer, Symposium on Shale-hosted Pb-Zn Deposits, Stanford University.
1987 Lecturer, NATO Advanced Study Institute on the Geochemistry of Hydrothermal Ore-Forming Processes, Spain, Jan '87.
1988 Convener, Symposium on Ore-Forming Processes, V. M. Goldschmidt Conference, Hunt Vally, Maryland.
1990-92 Co-convener, Symposium # 44, Magmatic hydrothermal systems, 29th IGC, Kyoto, Japan.

Invited Lectures:

1973
-Gordon Research Conference, Inorganic Geochemistry, Andover, N.H.
1975
-Peninsula Geological Society, Stanford, CA.

1976-77
- Journal Club, University of California, Berkeley, CA.
- Gordon Research Conference, Inorganic Geochemistry, Andover, N.H.
- Geochemistry Seminar, Univ. of California, Berkeley, CA.

1977-78
- Journal Club, Univ. California, Berkeley CA.
- Compania de Cobre de Chile, El Salvador, Chile.

1978-79
- National Association of Geology Teachers, Calif. State College, Stanislaus, CA.
- Peninsula Geological Society, Stanford, CA.
- Geology Club, California Institute of Technology, Pasadena, CA.

1979-80
- Nevada Geological Society, Reno, NV.
- Short Course in Mineral Deposits, U. S. Geological Survey, Menlo Park, CA.

1980-81
- University of Colorado, Boulder, CO.
- University of California, Davis, CA.
- Arizona Geol. Soc., Symp. on Tectonics and Ore Deposits, Tucson, AZ.
- Noranda Exploration, Inc., Lakewood, CO.

1981-82
- Gordon Research Conf., Inorganic Geochemistry, Colby-Sawyer College, NH.
- Geological Society of Washington, D.C.
- Petrologist's Club, Washington, D.C.
- Friends of Ore Deposits, U. S. Geological Survey, Reston, VA.
- University of Utah, Salt Lake City, Utah.

1982-83
- University of Indiana, Bloomington, Ind.
- University of Michigan, Ann Arbor, Mich.
- Colorado School of Mines, Golden, Colo.
- SUNY-Buffalo, N.Y.
- New Mexico Inst. Tech, Socorro, N.M.

1984-85
- Branch of Alaskan Geology, U.S.G.S., Anchorage, Alaska (2 lectures).
- Irish Geol. Soc. and Irish Assoc. Exploration Geologists, Navan, Ireland.

1985-86
- Geology Lecture Series, Univ. California Los Angeles, CA.
- McKinstry Memorial Lecture, Harvard Univ., Cambridge, Mass.
- Annual Exploration Meeting, Freeport Exploration Co., Reno, NV.
- Western Mining Corporation, 12 lectures: Adelaide, Olympic Dam, Kalgoorlie, Kambalda, and Melbourne, Australia.

1986-87
- Geology Colloquium, Univ. Colorado, Boulder.
- Geology Colloquium, Ariz. State Univ., Tempe, AZ.

1987-88
- Missouri Geol. Survey, Rolla, MO.
- University Seminar, Stanford University.

1988-89
- Minery Conference, Stanford Alumni Assoc., Fallen Leaf Lake.

1989-90
- Stanford Alumni Association, Fallen Leaf Lake.

-R.L.Stanton Symposium, 10th Australian Geol. Conf., Hobart, Tasmania.
-Stanford Earth Sciences Centennial Alumni Day speaker.

1990-91
-Geology Club, Washington State Univ., Pullman, WA.
-Geology Seminar, Oregon State Univ., Corvallis, OR.

1991-92
-Key-note Speaker, opening plenary session, 7th Internat. Symp. Water-Rock Interaction, Park City, UT.

Geological Consulting:

1975-76 The Anaconda Co., Salt Lake City, Reno
1977-78 Superior Oil, Chile
1976-79 SRI International, Menlo Park
1978-81 Conoco Minerals, Reno
1980 Noranda Exploration, Inc., Denver
1981 Dames and Moore, San Francisco
1983-84 McGuinn, Hillsman and Palefsky, San Francisco
1983-84 Hunt, Ware, and Proffett, La Jolla
1985 Umont Mining, Salt Lake City
1987-90 Homestake Mining Co., San Francisco
1988-89 U. S. Geol. Survey, Central Mineral Resources
1990-p Kennecott Corporation

Other:

1977 Faculty Lecturer, Stanford Alumni Assoc., Hell's Canyon Expedition, Oregon.
1978-79 Visiting Committee, Geology Department, Univ. of Sonora, Hermosillo, Mexico.
1982 Faculty Lecturer, Stanford Alumni Assoc., Galapagos Islands Expedition, Ecuador.
1986 Joint Visiting Committee to the Geophysical Laboratory/Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D.C.
1987-89 Science Experiments Panel for Creede, DOSECC Inc.
1988-90 Member, Panel on Mineral Resources, Committee on the Solid Earth Sciences, National Research Council.
1989-90 Extramural Review Team, Geological Sciences, Univ. Cal. Riverside.
1991 Faculty Lecturer, Stanford Alumni Assoc., Walking Tour of Tuscany, Italy.

UNIVERSITY ADMINISTRATIVE ACTIVITIES:

1975-1982 Member, faculty search committees in mineral economics, geochemistry, paleomagnetics.
1976-1977 Member, University Search Committee for New Dean of Earth Sciences.
1979-1980 Representative, Senate of the Academic Council.
1982-1986 Chairman, Department of Applied Earth Sciences.
1983-1985 Freshman Advisor.
1986-1987 Member, Faculty Panel for the French Centers, Stanford Overseas Studies.
1986-1987 Chairman, Faculty Search Committee in Hydrogeology, Dept. Applied Ear. Sci.
1976-present Member, Admissions and Awards Committee, Dept. of Applied Earth Sci. (Chairman, 1976-77, 1979-80).
1982-present Member, Dean's Council, School of Earth Sciences.
1986-present Associate Dean for Research, School of Earth Sciences

1990 Member, Task Force on Budget Repositioning, School of Earth Sciences
1990-91 Freshman Advisor
1990-91 Chairman, Ten-Year Planning Committee, School of Ear Sci.
1991-93 Representative, Senate of the Academic Council.

RESEARCH AND EQUIPMENT GRANTS

1980 NSF, EAR 79-19588, 1 Jan 80 to 1 Jan 82, "An integrated study of the genesis of tungsten-, copper-, and zinc-bearing skarns": $120,784.

1982 NSF, EAR 82-06380, 15 Jun 82 to 31 May 83, "Microchemical analysis of synthetic and natural phases by electron microprobe techniques" (w/ Brown): $100,000.

1984 NSF, EAR 84-16936, 1 Jan 85 to 31 Dec 86, "Geological and geochemical environment of gold deposition in unoxidized ore at Carlin, Nevada": $153,667.

1985 NSF, EAR 85-07264, 1 Jul 85 to 30 Jun 87, "Geology and geochemistry of porphyry mineral deposits": $75,000.

1987 NSF, EAR 86-18432, 1 Feb 87 to 31 Jan 89, "An investigation into the Origin of REE-enriched Iron-oxide Rocks at Olympic Dam, South Australia, and Related Deposits": $100,000.

1987 PRF, Amer. Chem. Soc., 1 Mar 87 to 31 Aug 88, "Petroleum in Mercury Deposits of the California Coast Ranges": $27,530.

GRADUATE STUDENT THESES SUPERVISED AND COMPLETED

16 M.S. students: Rainer J. Newberry (1978), Jeanine N. Schmidt (1978), Peter A. Mitchell (1979), Ron A. Sonnevil (1979), Eric Seedorff (1981), Horacio Ferriz D. (1981), Philip B. Gans (1982), Richard P. Menell (1982), Stanley W. Stearns (1982), Jorge Benavides A. (1983), Yehuda A. Diner (1983), Paul A. Bartos (1984), Ian Douglas (1984), Helen M. Nuckolls (1985), John E. Black (1988), Rob Masinter (1990).

26 Ph.D. students: John F. Slack (1976), Peter G. Vikre (1977), Randolph A. Koski (1978), Harvey S. Eastman (1979), Nick B. Harris (1980), Larry D. Meinert (1980), Rainer J. Newberry (1980), Rich B. Carten (1981), Jeanine M. Schmidt (1983), John H. Dilles (1983), David C. Dobson (1983), Timothy S. Hayes (1983), Michael L. Zientek (1983), Steven F. Olson (1983), Murray Hitzman (1983), Ken W. Weissenberger (1984), Steven A. Shaver (1984), Robert J. W. Turner (1986), David A. John (1986), Darby I. Fletcher (1987), Mark V. Sander (1987), Eric Seedorff (1987), Carey Peabody (1989), Barbara M. Bakken (1989), Naomi Oreskes (1989), Scott Manske (1991).

PUBLICATIONS

Journal Articles:

Marvin, U. B., and Einaudi, M. T. (1967) Black magnetic spherules from Pleistocene and Recent beach sands: Geochim. et Cosmochim. Acta, v. 31, p. 1871-1884.

Einaudi, M. T. (1968) Sphalerite-pyrrhotite-pyrite equilibria-- a re-evaluation: Econ. Geol., v. 63, p. 832-834.

Frondel, C., and Einaudi, M. T. (1968) Zinc-rich micas from Sterling Hill, New Jersey: American Mineral., v. 53, p. 1752-1754.

Einaudi, M. T. (1970) An iron-sensitive stain for iron-rich sphalerite: American Mineral., v. 55, p. 1048-1051.

Einaudi, M. T. (1971) The intermediate product of pyrrhotite alteration: American Mineral., v. 56, p. 1297-1302.

Einaudi, M. T. (1977) Petrogenesis of copper-bearing skarn at the Mason Valley mine, Yerington district, Nevada: Econ. Geol., v. 72, p. 769-795.

Einaudi, M. T. (1977) Environment of ore deposition at Cerro de Pasco, Peru: Econ. Geol., v. 72, p. 893-924.

Hart, P. E., Duda, R. O., and Einaudi, M. T. (1978) Prospector--a computer-based consultation system for mineral exploration: Jour. Math. Geol., v. 10, p. 589-610.

Atkinson, W. W., Jr., and Einaudi, M. T. (1978) Skarn formation and mineralization in the contact aureole at Carr Fork, Bingham, Utah: Econ. Geol., v. 73, p. 1326-1365.

East Pacific Rise Study Group (Einaudi and 11 others) (1981) Crustal processes of the Mid-Ocean ridge: Science, v. 213, no. 4503, p. 31-40.

Harris, N. B., and Einaudi, M. T. (1982) Skarn deposits in the Yerington district, Nevada, I. Metasomatic skarn evolution near Ludwig: Econ. Geol., v. 77, p. 877-898.

Yun, Suckew, and Einaudi, M. T. (1982) Zinc-lead skarns of the Yeonhwa-Ulchin district, South Korea: Econ. Geol., v. 77, p. 1013-1032.

Hayes, T. S., and Einaudi, M. T. (1986) Genesis of the Spar Lake strata-bound copper-silver deposit, Montana: Part I. Controls inherited from sedimentation and preore diagenesis: Econ. Geol., v. 81, p. 1899-1931.

Einaudi, M. T. (1987) Phase relations among silicates, copper iron sulfides, and aqueous solutions at magmatic temperatures--a discussion: Econ. Geol., v. 82, p. 497-501.

Einaudi, M. T., and Oreskes, Naomi (1990) Progress towards an occurrence model for Proterozoic iron-oxide deposits -- a comparison between the ore provinces of South Australia and SE Missouri, *in* Pratt, W.P., and Sims, P.K., eds., The Midcontinent of the United States--Permissive terrane for an Olympic Dam-type deposit?: U.S. Geol. Survey Bull. 1932, p. 58-69.

Oreskes, Naomi, and Einaudi, M. T. (1990) Origin of REE-enriched hematite breccias at Olympic Dam, Roxby Downs, South Australia: Econ. Geol., v. 85, p. 1-28.

Sander, M. V., and Einaudi, M.T. (1990) Epithermal deposition of gold during transition from propylitic to potassic alteration at Round Mountain, Nevada: Econ. Geol., v. 85, p. 285-311.

Sander, M.V., and Einaudi, M.T. (1991) Epithermal deposition of gold during transition from propylitic to potassic alteration at Round Mountain, Nevada--Reply to Discussion by Henley: Econ. Geol., v. 86, p.

Newberry, R.J., Einaudi, M.T., and Eastman, H.S. (1991) Mineral and metal zoning and a re-interpretation of thermal and isotopic zoning at the Darwin Pb-Zn-Ag skarn deposit, California: Econ. Geol., v.'86, p.

Seedorff, Eric, and Einaudi, M. T. (in review) Evolutionary paths of hydrothermal fluids, Henderson porphyry molybdenum system, Colorado: Econ. Geol.

Oreskes, Naomi, and Einaudi, M.T. (in review) Origin of hydrothermal fluids at Olympic Dam: Preliminary results from fluid inclusions and stable isotopes: Econ. Geol.

Dilles, J.H., Solomon, G.C., Taylor, H.P., Jr., and Einaudi, M.T. (in review) Oxygen and hydrogen isotope characteristics of hydrothermal alteration at the Ann-Mason porphyry copper deposit, Yerington, Nevada: Econ. Geol.

Hitzman, M.W., Oreskes, N., and Einaudi, M.T. (in review) Geological characteristics and tectonic setting of Proterozoic iron-oxide(Cu-U-Au-REE) deposits: Precambrian Research.

Peabody, C. E., and Einaudi, M. T. (in review) Significance of the cinnabar-petroleum association at the Culver-Baer mercury deposit, Mayacmas district, California: Econ. Geol.

Dilles, J. H., and Einaudi, M. T. (in prep) Sources and flow paths of hydrothermal fluids in the Ann Mason porphyry copper sytem, Nevada--a 7-km vertical reconstruction: Econ. Geol.

Bakken, B., and Einaudi, M.T, (in prep) Volume loss and mass transfer during gold deposition and wall-rock alteration at Carlin, Nevada: Econ. Geol.

Einaudi, M.T. (in prep) Zoning of gold and silver in porphyry copper deposits: Econ. Geol.

Chapters in Books:

Hart, P. E., Duda, R. O., and Einaudi, M. T. (1979) A computer-based consultation system for mineral exploration, *in* David, M., ed., Computer methods for the 80's, Soc. Mining Eng, A.I.M.E., p. 127-140.

Einaudi, M. T., Meinert, L. D., and Newberry, R. J. (1981) Skarn deposits: 75th Anniversary Vol., Econ. Geol., p. 317-391.

Einaudi, M. T. (1982) Description of skarns associated with porphyry copper plutons, southwestern North America, *in* S. R. Titley (ed.), Advances in the Geology of the Porphyry Copper Deposits, Southwestern North America: Univ. Ariz. Press, Tucson, p. 139-184.

Einaudi, M. T. (1982) General features and origin of skarns associated with porphyry copper plutons, southwestern North America, *in* S. R. Titley (ed.), Advances in the Geology of the Porphyry Copper Deposits, Southwestern North America: Univ. Ariz. Press, Tucson, p. 185-210.

Introductions to Special Issues of *Economic Geology*:

Einaudi, M. T., Moore, W. J., and Wilson, J. C. (1978) An issue devoted to the Bingham min-

ing district--Introduction: Econ. Geol., v. 73, p. 1215-1217.

Einaudi, M. T., and Burt, D. M. (1982) A special issue devoted to skarn deposits, Introduction--Terminology, classification, and composition of skarn deposits: Econ. Geol., v. 77, p. 745-754.

Einaudi, M. T., and Hitzman, M. W. (1986) Mineral deposits in northern Alaska--Introduction: Econ. Geol., v. 81, p. 1583-1591.

Guidebook Articles, Symposia Volumes, etc.:

Einaudi, M. T. (1975) Iron metasomatism in sedimentary rocks near the Bingham stock, *in* Bray, R. E., and Wilson, J.C., eds., Guidebook to the Bingahm Mining District: Soc. Econ. Geologists, Bingham Mining Dist. Symp., Oct 23, 1975, Bingham Canyon, Utah, p. 135-139.

Einaudi, M. T., and Atkinson, W. W., Jr. (1976) General geology and zoning of alteration in sedimentary rocks at Carr Fork, Bingham district, Utah: Utah Geol. Assoc., Pub. 6, p. 14-17.

Newberry, R. J., and Einaudi, M. T. (1981) Tectonic and geochemical setting of tungsten skarn mineralization in the Cordillera, *in* Dickinson, W. R., and Payne, W. D. (eds.), Symposium on the Relations of Tectonics to Ore Deposits in the Southern Cordillera, Tucson, AZ, Mar 19-20, 1981: Ariz. Geol. Soc. Digest, v. 14, p. 99-112.

Einaudi, M.T. (1984) Yerington skarns, *in* Johnson, J.L. (ed.), Exploration for Ore Deposits in the North American Cordillera: Field Trip Guidebook, Field Trip 10: Assoc. of Exploration Geochemists, p. 31-39.

Bakken, B. M., and Einaudi, M. T. (1986) Spatial and temporal relations between wall-rock alteration and gold mineralization, Main Pit, Carlin gold mine, Nevada, *in* Macdonald, A.J., ed., Proc. of Gold '86, an Internat. Symp. on the Geology of Gold: Toronto, 1986, p. 388-403.

Turner, R. J. W., and Einaudi, M. T. (1986) The geological setting and genesis of the South Zone stratiform Pb-Zn-barite deposits, Macmillan Pass, Yukon, *in* Turner, R.J.W., and Einaudi, M. T. (eds.) The genesis of stratiform sediment-hosted lead and zinc deposits--conference proceedings: Stanford Univ. Pubs., Geol. Sci., v. XX, Stanford, CA, p. 5-12.

Sander, M. V., and Einaudi, M. T. (1987) The Round Mountain gold-silver mine, Nye County, Nevada, *in* Johnson, J. L. (ed.), Guidebook for Fieldtrips, Symposium on Bulk Mineable Precious Metal Deposits of the Western United States: Geol. Soc. Nevada, p. 130-135.

Reviews of Books:

Einaudi, M. T. (1980) Review of "Geochemistry of hydrothermal ore deposits", H. L. Barnes (ed.): Econ. Geol., v. 75, p. 1245-1248.

Einaudi, M. T. (in press) Review of "W-Sn Skarn Deposits", by T.A.P. Kwak: Amer. Jour. Sci.,

Published Reports:

Meinert, L. D., Newberry, R. J., and Einaudi, M. T. (1981) An overview of tungsten, copper, and zinc-bearing skarns in western North America: U. S. Geol. Survey Open File Report 81-355, p. 303-327.

Einaudi, M. T. (1982) Garnet and pyroxene compositions in skarn deposits: Carnegie Inst, Wash., Ybk. 81, p. 320-324.

Einaudi, M.T. (1983) An approach to regional mineral evaluation based on terrain classification, *in* Reboh, R. et al., eds., A knowledge-based system for regional mineral resource assessment: Report No. 4119, SRI International, p. 55-77.

Adams, S.S., Bailly, P.A., Barton, P.B., Jr., Einaudi, M.T., Graybeal, F.T., and Reed, M.H. (in press) Mineral resource research: Status and Opportunities: Panel on Mineral Resources, National Research Council, Washington, D.C.

Don E. French

[redacted]

CONSULTING PETROLEUM GEOLOGIST

Successful petroleum explorationist with 15 years of experience in developing and evaluating exploration projects in the Rocky Mountain region. Areas of particular expertise include the Basin-Range, Overthrust Belt, and Bighorn Basin. Technical expertise in application of source-rock evaluation to basin analysis, analysis of complex structural geology, delineation of hydrodynamically influenced traps, and computer application to geologic problems.

PROFESSIONAL EXPERIENCE

CONSULTING GEOLOGIST - Billings, Montana — since 1987

Independent Work

Exploratory prospects in eastern Nevada have been developed and placed for evaluation.

Continuing geologic investigations with the purpose of developing drillable exploratory prospects in Nevada, central and northwest Montana, and southwest Utah.

Developed computer programs for dipmeter analysis, map plotting, economic analysis, well log analysis, crude oil analysis.

Client-related Work

Co-authored geological and geophysical study of northern part of Trap Spring Field, Railroad Valley, Nevada.

Geological analysis for purchase of Kate Spring Field, Railroad Valley, Nevada.

MERIDIAN OIL - Billings, Montana — 1980-1987

Senior Staff Geologist

Developed exploratory prospects in eastern Nevada, Bighorn Basin, Idaho-Wyoming Thrust Belt, western Montana, central Utah, Bighorn Basin, Wind River Basin, Green River Basin, and Pacific Northwest.

Supervised study of coal-bed methane resources of central and western Washington.

Selected and supervised well-site personnel for geologic evaluation of wildcat wells.

Reviewed for approval Gulf Coast joint-venture prospects.

NORTHWEST EXPLORATION COMPANY - Denver, Colorado 1977-1980

Staff Geologist

Developed exploration program that delineated prospects in Railroad and White River Valleys, Nevada. Three of these have been developed as Kate Spring, Bacon Flat, and Grant Canyon Fields.

Completed interdisciplinary geologic and reservoir analysis of Trap Spring Field, Nye County, Nevada.

Developed exploratory prospects in eastern Nevada, central and southwest Utah.

Reviewed and approved Canadian joint-venture prospects.

Well-site geologic evaluation, Railroad Valley, Nevada.

Formulated and conducted geologic field work for eastern Nevada, including source-rock investigations, prospect delineation, and reservoir investigations of Trap Spring Field.

TEXACO, INC., Denver, Colorado 1976-1977

Geologist

Formulated and conducted geologic field work for Idaho-Wyoming Thrust Belt, including prospect delineation and source rock analysis.

Developed exploratory prospects in Green River Basin and Idaho-Wyoming Thrust Belt.

Well-site geologic evaluation, Green River Basin, Wyoming.

EDUCATION

B.S., Geology	Kansas State University	1971
M.S., Geology	Utah State University	1975

Master's Thesis: Geology and Mineralization of the Southeastern Part of the Black Pine Mountains, Cassia County, Idaho.

AAPG Short Course	Petroleum Geochemistry	April, 1979
Pet. Eng. Short Course	Reservoir Engineering for Geologists	August, 1981
OGCI Short Course	Structural Geology	June, 1982
AAPG Short Course	Cretaceous Transgressive & Regressive Cycles in Utah	June, 1984

PROFESSIONAL ACTIVITY

PROFESSIONAL AFFILIATIONS

American Association of Petroleum Geologists

Geological Society of America

Rocky Mountain Association of Geologists

Wyoming Geological Association

Montana Geological Society
1983-87, Treasurer, 2nd Vice President, 1st Vice President, President
1984 Field Conference Co-Chairman
1989 Field Conference Guidebook Editor

PROFESSIONAL PRESENTATIONS

Tertiary Volcanic Stratigraphy of Trap Spring Field, Nye County, Nevada. Don E. French and Kevin J. Freeman, 1978. Amer. Assoc. of Petroleum Geologists Bulletin v. 62, p. 884. (Abstract of talks delivered at Amer. Assoc. of Petroleum Geologists Rocky Mountain Section Meeting, March 21, 1978, Salt Lake City, Utah).

Geology and Reservoir Analysis of Trap Spring Field. Don E. French and Dan Stright. January, 1979. Report prepared for Northwest Exploration Company.

Tertiary Volcanic Stratigraphy and Reservoir Characteristics of Trap Spring Field, Nye County, Nevada. Don E. French and Kevin J. Freeman, 1979. Rocky Mountain Assoc. of Geologists, Basin and Range Symposium Guidebook, pp. 469-476.

Origins of Oil in Railroad Valley, Nye County, Nevada. Don E. French, 1983. Amer. Assoc. of Petroleum Geologists Bulletin v. 67, p. 1337. (Abstract of talk delivered at Amer. Assoc. of Petroleum Geologists Rocky Mountain Section Meeting, September 21, 1983, Billings, Montana).

Origin of Oil in Railroad Valley, Nye County, Nevada. Don E. French, 1983. Wyoming Geol. Assoc., Earth Science Bulletin v. 16, pp. 9-21.

Hydrocarbon Potential of the Mississippian Chainman Shale, Railroad Valley, Nevada. Don E. French. 1989. Amer. Assoc. of Petroleum Geologists Bulletin v. 73, p. 356. (Abstract of talk delivered at Amer. Assoc. of Petroleum Geologist Annual Convention, April 24, 1989, San Antonio, Texas).

CURRICULUM VITA

Kip Vernon Hodges

Personal Data

Address: Room 54-1120, Department of Earth, Atmospheric & Planetary Sciences, Massachusetts Institute of Technology, Cambridge,Massachusetts 02139
Telephones: (617) 253-2927 office; (617) 253-6208 fax; [redacted]
Date of Birth: [redacted]
Social Security Number: [redacted]

Research Specialties

Application of the concepts and techniques of structural geology, metamorphic petrology, and isotope geochemistry to tectonic problems.

Educational History

1982 Ph.D. Geology, Massachusetts Institute of Technology, B.C. Burchfiel, advisor. Thesis title: *The Tectonic Evolution of the Aefjord-Sitas Area, Norway - Sweden.*

1978 B.S. Geology with Highest Honors, University of North Carolina at Chapel Hill.

Academic Employment

1987 - present Associate Professor, Massachusetts Institute of Technology. Tenured in 1990.

1983 - 1987 Assistant Professor, Massachusetts Institute of Technology.

1982-1983 Assistant Professor, The University of Wyoming.

Courses Taught

Undergraduate: Freshman Advising Seminars, Introduction to Geology, Structural Geology, Field Methods, Geology Field Camp, Metamorphic Petrology

Graduate: Regional Tectonics Seminar, Megascopic Strain Analysis in Orogenic Belts, Pressure-Temperature-Time Evolution of Orogenic Belts, Advanced Field Geology

Awards, Fellowships, and Honors

Amoco Foundation Scholarship
NAGT Summer Field Camp Scholarship
Phi Beta Kappa
Op White Award for Outstanding Undergraduate in Geology, University of North Carolina, 1978
National Science Foundation Graduate Fellowship
National Science Foundation Grant for Improvement of Doctoral Dissertation Research
Chris Goetze Award for the Outstanding Ph.D. Thesis in the Solid Earth Sciences, Massachusetts Institute of Technology, 1982
MIT Graduate Student Council Award for Teaching Excellence, 1986

National Services

Member, Tectonics Review Panel, National Science Foundation, 1990-present
Member, Peer Review Panel, Department of Energy Early Site Suitability Evaluation for the Potential High-Level Nuclear Waste Repository at Yucca Mountain, Nevada, 1991.
Associate Editor, *Geological Society of America Bulletin.*

University Services

Faculty Committee on the Writing Requirement, 1987-1989
Chairman, Faculty Committee on the Writing Requirement, 1989-1990
Faculty Committee on the Hobby Shop, 1990-present
Freshman and Upperclassman Advisor

Departmental Services

Graduate Admissions Committee, 1984-1989
Student Research Fund Committee, 1986-1987
Coordinator for the Writing Requirement, 1988-present
Graduate Education Committee, 1989-1990
Chairman, Geology and Geochemistry Graduate Education Subcommittee, 1989-1990
Chairman, Graduate Education Committee, 1990-present

Graduate Students Advised

Blevins, D.M., Computer assisted structural analysis of the western termination of the Flat Top anticline, Carbon County, Wyoming. M.S. completed 1984.

Harding, M., Structural evolution of the Wildrose Peak area, Death Valley National Monument, California. M.S. completed 1987.

Saltzer, S., Applications of computers to balanced cross-sections. M.S. completed 1986.

Stock, J., Evolution of the Main Gulf Escarpment and related structures, eastern Baja California Norte and the relationship between Basin and Range extension and the opening of the Gulf of California. Ph.D. completed 1988.

Hubbard, M., Structural and metamorphic evolution of the Main Central Thrust Plate, eastern Nepal. Ph.D. completed 1988.

Knapp, J., Structural development, thermal evolution, and tectonic significance of a Cordilleran basement thrust terrane, Maria Fold and Thrust Belt, west-central Arizona (co-advised with B.C. Burchfiel). Ph.D. completed 1988.

McKenna, L., Igneous controls on pre-extension reconstructions of the Death Valley extensional terrain, southeastern California. Ph.D. completed 1990.

Silverberg, D., The tectonic evolution of the Pioneer metamorphic core complex, south-central Idaho. Ph.D. completed 1990.

Saylor, B., The Titus Canyon Formation: Evidence for Early Oligocene extension in the Death Valley area, California. M.S. completed 1991.

Applegate, D., Evolution of the Funeral Mountains metamorphic core complex, California-Nevada. Ph.D. in progress.

Coleman, M., Polyphase tectonic denudation in the Annapurna-Manaslu region, central Nepal. Ph.D. in progress.

House, M., Mesozoic-Cenozoic thermal evolution of the Bitterroot metamorphic core complex, Idaho. Ph.D. in progress.

Macfarlane, A., Structural and metamorphic evolution of the Langtang area, Nepal. Ph.D. in progress.

Invited Lectures (1986-Present)

Institutional Colloquia: Carelton University; Chengdu Institute of Geology (Chengdu, Szechwan, PRC); University of Chicago; Cornell University; Geological Survey of Canada; Harvard University; Pennsylvania State University; Stanford University; State University of New York - Albany;

University of Kansas; University of North Carolina; University of Rochester; Yale University.

Symposia: Royal Society of London Discussion Meeting: *Himalayan Tectonics*; Geological Society of America Penrose Conference: *Metamorphic Core Complexes Revisited.*

Publications

Papers

Rogers, J.W., Hodges, Kip V. and Ghuma, Mohamed A., 1980, Trace elements in continental margin magmatism: Part II. Trace elements in Ben Ghnema batholith and nature of the Precambrian crust in central North Africa. *Geol. Soc. Amer. Bull.* 91, 445-447, 1742-1788.

Willemin, J.H., Guth, P.L. and Hodges, K.V., 1980, Comment on "High fluid pressure, isothermal surfaces and the initiation of nappe movement". *Geology* 8, 405-406.

Hodges, K.V. and Spear, F.S., 1982, Geothermometry, geobarometry and the Al_2SiO_5 triple point at Mt. Moosilauke, New Hampshire. *Amer Miner.* 67, 1118-1134.

Hodges, K.V., Bartley, J.M. and Burchfiel, B.C., 1982, Structural evolution of an A-type subduction zone, Lofoten-Rombak area, northern Scandinavian Caledonides. *Tectonics* 1, 441-462.

Hodges, K.V. and Fountain, D.M., 1984, The Pogallo Line, South Alps, northern Italy: An intermediate crustal level, low-angle normal fault. *Geology* 12, 151-155.

Hodges, K.V. and Royden, L.H., 1984, Geologic thermobarometry of retrograde metamorphic rocks: An indication of the uplift trajectory of a portion of the northern Scandinavian Caledonides. *J. Geophys. Res.* 89, 7077-7090.

Royden, L.H. and Hodges, K.V., 1984, A technique for analyzing the thermal and uplift histories of eroding orogenic belts: A Norwegian example. *J. Geophys. Res.* 89, 7091-7106.

Spear, F.S., Selverstone, J., Hickmott, D., Crowley, P. and Hodges, K.V., 1984, P-T paths from garnet zoning: a new technique for deciphering tectonic processes in crystalline terrains. *Geology* 12, 87-90.

Hodges, K.V., 1985, Tectonic stratigraphy and structural evolution of the Efjord-Sitasjaure area, northern Scandinavian Caledonides. *Norges Geologiske Undersøkelse Bull.* 399, 41-60.

Hodges, K.V. and Crowley, P., 1985, Error estimation and empirical geothermobarometry for pelitic systems. *Amer. Mineral.* 70, 702-709.

Tull, J., Bartley, J., Hodges, K.V., Andresen, A., Steltenpohl, M. and White, M., 1985, The Caledonides in the Ofoten region (68° - 69°N), north Norway: key aspects of tectonic evolution. In: *Caledonide Orogen - Scandinavia and Related Areas,* D.G. Gee and B.A. Sturt, eds., John Wiley, p. 553-568.

Wernicke, B.P., Hodges, K.V. and Walker, J.D., 1986, Geological setting of the Tucki Mountain area, Death Valley National Monument, California. In: *Mesozoic and Cenozoic Structural Evolution of Selected Areas, East-Central California. Guidebook and Volume,* California State University, Los Angeles, p. 67-80.

Burchfiel, B.C., Hodges, K.V., and Royden, L.H., 1987, Palinspastic controls on the geometry of a Neogene range-bounding fault, northern Panamint Valley, California. *J. Geophys. Res.* 92, 10422-14026.

Hodges, K.V. and McKenna, L.W., 1987, Realistic uncertainties in metamorphic P-T estimates based on experimentally calibrated equilibria. *Am. Mineral.* 72, 673-682.

Hodges, K.V., Walker, J.D. and Wernicke, B.P., 1987, Footwall structural evolution of the Tucki Mountain detachment system, Death Valley, California. In:*Continental Extensional Tectonics*, Coward, M.P., Dewey, J.F., and Hancock, P.L., eds., Geological Society Special Publication 28, 393-408.

Hodges, K.V. and Silverberg, D.S., 1988, Thermal evolution of the Greater Himalaya, Garwhal, India. *Tectonics* 7, 583-600.

Hodges, K.V., Hubbard, M.S., and Silverberg, D.S., 1988, Metamorphic constraints on the thermal evolution of the central Himalayan orogen. *Phil. Trans. Roy. Soc. Lond.* A 326, 257-280.

Hodges, K.V., Hubbard, M.S., and Silverberg, D.S., 1988, Metamorphic constraints on the thermal evolution of the central Himalayan orogen. In: *Tectonic Evolution of the Himalayas and Tibet*. Shackelton, R.M., et al., eds., The Royal Society, London, p. 257-280. (reprinting of previous reference in book form).

Hodges, K.V., Le Fort, P., and Pêcher, A., 1988, Possible thermal buffering by crustal anatexis in collisional orogens: Thermobarometric data from the Nepalese Himalaya. *Geology* 16, 707-710.

McKenna, L.W., and Hodges, K.V., 1988, Accuracy vs. precision in locating reaction boundaries: implications for the garnet - plagioclase - aluminum silicate - quartz geobarometer. *Am. Mineral.* 73, 1205-1208.

Ruppel, C., Royden, L., and Hodges, K.V., 1988, Thermal modelling of extensional tectonics: Application to the pressure-temperature-time histories of metamorphic rocks. *Tectonics* 7, 947-958.

Saltzer S. and Hodges, K.V., 1988, The Middle Mountain Shear Zone, southern Idaho: Kinematic analysis of a Tertiary, high-temperature detachment. *Geol. Soc. Amer. Bull.* 100, 96-103.

Wernicke, B.P., Walker, J.D., and Hodges, K.V., 1988, Field guide to the northern part of the Tucki Mountain fault system, Death Valley region, California. In: *This Extended Land, Geological Journeys in the Southern Basin and Range, Geological Society of America, Cordilleran Section, Field Trip Guidebook,* Weide, D.L., and Faber, M.L., eds., Las Vegas, p. 58-64.

Hodges, K.V., 1989, Reconnaissance in Tibet. *Science* 244, 1202-1203.

Hodges, K.V., LeFort, P., and Pêcher, A., 1989, Reply to comments by M. Brunel on: "Possible thermal buffering by crustal anatexis in collisional orogens. Thermobarometric data from the Nepalese Himalaya". *Geology* 17, 575-576.

Hodges, K., McKenna, L., Stock, J., Knapp, J., Page, L., Sternlof, K., Silverberg, D., Wüst, G., and Walker, J.D., 1989, Evolution of extensional basins and Basin and Range topography west of Death Valley, California.*Tectonics* 8, 453-467.

Stock, J.M., and Hodges, K.V., 1989, Pre-Pliocene extension around the Gulf of California and the transfer of Baja California to the Pacific plate. *Tectonics* 8, 99-115.

Wernicke, B.P., Snow, J.K., Axen, G.J., Burchfiel, B.C., Hodges, K.V., Walker, J.D., and Guth, P.L., 1989, Extensional tectonics in the Basin and Range Province between the southern Sierra Nevada and the Colorado Plateau. *28th International Geological Congress Field Trip Guidebook T138*, American Geophysical Union, Washington, 80pp.

Chen, Z., Liu, Y., Hodges, K.V., Burchfiel, B.C., Royden, L.H., and Deng, C., 1990, Structural evolution of the Kangmar dome: a metamorphic core complex in southern Xizang (Tibet). *Science* 250, 1552-1556.

Hodges, K.V.,1990, Review of "Tectonics of the Western Himalayas" (Malinconico, L.L. and Lillie, R.J., eds.). *Econ. Geology.* 85, 1956-1957.

Hodges, K.V., and Walker, J.D., 1990, Thermobarometric constraints on the unroofing history of the Funeral Mountains, SE California. *J. Geophys. Res.* 95, 8437-8445.

Hodges, K.V., McKenna, L.W., and Harding, M.B., 1990, Structural unroofing of the central Panamint Mountains, Death Valley region, SE California. In: *Basin and Range Extensional Tectonics at the Latitude of Las Vegas, Nevada*. B.P. Wernicke, ed., Geological Society of America Memoir 176, 377-390.

McKenna, L.W., and Hodges, K.V., 1990, Geometry of Late Miocene extensional faulting, Panamint Range, Death Valley, California. In: *Basin and Range Extensional Tectonics at the Latitude of Las Vegas, Nevada.* B.P. Wernicke, ed., Geological Society of America Memoir 176, 363-376.

Stock, J.M., and Hodges, K.V., 1990, Miocene to Recent structural development of an extensional accommodation zone, northeastern Baja California, Mexico. *J. Structural Geology* 12, 315-328.

Copeland, P., Harrison, T. M., Hodges, K. V., Maruéjol, P., LeFort, P.and Pêcher, A., 1991, An Early Pliocene thermal disturbance of the Main Central Thrust, central Nepal: Implications for Himalayan tectonics. *J. Geophys. Res.* 96, 8475-8500.

Hodges, K.V., 1991, Pressure-temperature-time paths. *Ann. Rev. Earth Planet. Sciences* 19, 207-236.

Hubbard, M., Royden, L., and Hodges, K., 1991, Constraints on unroofing rates in the High Himalaya, Eastern Nepal. *Tectonics* 10, 287-298.

Hurlow, H.A., Snoke, A.W., and Hodges, K.V., 1991, Temperature and pressure of mylonitization in a Tertiary extensional shear zone, Ruby Mountains-East Humboldt Range, Nevada: Tectonic implications. *Geology* 19, 82-86.

Burchfiel, B.C., Chen, Z., Deng, C., Hodges, K.V., Liu, Y., Royden, L.H., Xu, J., in press, Extension contemporaneous and parallel to shortening in the Himalaya. *Geol. Soc. Amer. Spec. Pap.*

Hodges, K.V., Snoke, A.W., and Hurlow, H.A., in press, Thermal evolution of a portion of the Sevier hinterland: the northern Ruby Mountains - East Humboldt Range and Wood Hills, northeastern Nevada. *Tectonics.*

Silverberg, D.S., Hodges, K.V., Kunk, M., and Sutter, J., in press, Thermal evolution of the Pioneer metamorphic core complex, south-central Idaho: Diachronous Paleogene extension of the middle crust. *Tectonics.*

Hodges, K.V., and Walker, J.D., in press, Extension in the Cretaceous Sevier Orogen, North American Cordillera. *Geol. Soc. Amer. Bull.*

Applegate, J. D. R., Walker, J. D. and Hodges, K. V., submitted, Late Cretaceous extensional unroofing in the Funeral Mountains metamorphic core complex, California. *Geology.*

Hodges, K.V., Burchfiel, B.C., Lux, D., Royden, L.H., and Chen, Z., submitted, Tectonic denudation and pressure-temperature-time paths in the Himalayas: Nyalam transect, southern Tibet. *Contrib. Mineral. Petrol.*

Macfarlane, A., and Hodges, K.V., submitted, Structural evolution of the Langtang area, central Nepal. *Tectonics.*

McKenna, L.W., Snee, L.W., and Hodges, K.V., submitted, Time-temperature history of extension in the Panamint and Black Mountains, Death Valley, California. *Tectonics.*

Ruppel, C. and K.V. Hodges, submitted, Pressure-Temperature-Time paths from 2D thermal models: Prograde, retrograde, and inverted metamorphism, *Tectonics.*

Abstracts

Willemin, J.H., Guth, P.L. and Hodges, K.V., 1979, Limitations on the role of pore pressure in gravity gliding. *EOS* 60, 955.

Hodges, K.V., Bartley, J.M., Krueger, H.W. and Hodges, L.R., 1980, K/Ar and Rb/Sr mineral ages and the cooling history of part of the northern Scandinavian Caledonides. *Geol. Soc. Amer. Abst. Prog.* 12, 448.

Pegram, William J., Sando, Thomas W. and Hodges, K.V., 1980, Rare earth element geochemistry and Nd isotopic composition of some Egyptian Younger Granites. *Geol. Soc. Amer. Abst. Prog.* 12, 497.

Hodges, K.V. and Spear, F.S., 1981, Geothermometry, geobarometry, garnet closure temperatures, and the Al_2SiO_5 triple point, Mt. Moosilauke N.H.. *EOS* 62, 1060.

Hodges, K.V., 1981, Caledonian metamorphic conditions near Aefjord, Nordland, Norway. *TERRA Cognita* 1, 52.

Hodges, K.V., 1981, Basement-cover relationships in the Aefjord-Skjomenes area, northern Norway (68°15'N; 16°45'E). *Geol. Soc. Amer. Abst. Prog.* 13, 474.

Hodges, K.V. 1982, The use of geothermometry and geobarometry to constrain the uplift history of a portion of the Scandinavian Caledonides. *Geol. Soc. Amer. Abst. Prog.* 14, 516.

Hodges, K.V. and Furlong, K.P., 1982, Argon diffusion in muscovite: constraints from field studies and thermal models. *EOS* 63, 1145-1146.

Royden, L.H. and Hodges, K.V., 1983, A technique for analyzing the thermal and uplift histories of eroding orogenic belts: a Norwegian example. *Geol. Soc. Amer. Abst. Prog.* 15, 675.

Hodges, K.V., and Fountain, D.M., 1983, The Pogallo Line, South Alps, northern Italy: An intermediate crustal level, low-angle normal fault. *EOS* 64, 861.

Hodges, K.V., Walker, J.D., and Wernicke, B.P. 1984, Tertiary folding and extension, Tucki Mountain area, Death Valley region, California. *Geol. Soc. Amer. Abst. Prog.* 16, 540.

Hubbard, M.S. and Hodges, K.V., 1984, Calculating P-T paths: a comparison of two techniques. *Geol. Soc. Amer. Abst. Prog.* 16, 545.

Hodges, K.V. and McKenna, L., 1986, Structural and metamorphic characteristics of the Raft River -Quartzite assemblage juxtaposition, Albion Mountains, southern Idaho. *Geol. Soc. Amer. Abst. Prog.* 18, 117.

Saltzer, S.D. and Hodges, K.V., 1986, Mylonitic fabric analysis at Middle Mountain, southern Idaho. *Geol. Soc. Amer. Abst. Prog.* 18, 180.

Walker, J.D., Hodges, K.V. and Wernicke, B.P., 1986, The relation of tilt geometry to extension direction. *Geol. Soc. Amer. Abst. Prog.* 18, 194-195.

Burchfiel, B.C., Hodges, K.V., and Royden, L.H., 1986, East-west striking Miocene (?) normal faults within the High Himalaya, south-central Tibet. *Geol. Soc. Amer. Abs. w. Prog.* 18, 553.

Hodges, K.V., LeFort, P. and Pêcher, A., 1986, Possible evidence for anatectic buffering of the thermal structure of the Tibetan Slab, central Nepalese Himalaya. *Geol. Soc. Amer. Abs. w. Prog.* 18, 638.

Silverberg, D.S. and Hodges, K.V., 1986, Pressure-temperature constraints on metamorphism and tectonism in the Tibetan Slab, Kumaun Himalayas, north India. *Geol. Soc. Amer. Abs. w. Prog.* 18, 750.

Stock, J.M. and Hodges, K.V., 1986, Miocene to Recent changes in extensional kinematics of southern Valle Chico, Baja California, Mexico. *Geol. Soc. Amer. Abs. w. Prog.* 18, 764.

Wernicke, Brian, Hodges, K.V., and Walker, J.D., 1986, Tucki Mountain fault system, Death Valley, California: Extensional tectonics through the upper 15 km of continental crust. *Geol. Soc. Amer. Abs. w. Prog.* 18, 786.

Burchfiel, B.C., Hodges, K.V., and Royden, L.H., 1987, East-west striking Miocene-Pliocene normal faults within the High Himalaya, south-central Tibet. *Geol. Soc. Amer. Abs. w. Prog.* 19, 605.

Copeland, P., Harrison, T.M., Parrish, R.R., Burchfiel, B.C., Hodges, K.V., and Kidd, W.S.F., 1987, Constraints on the age of normal faulting, north face of Mt Everest: Implications for Oligo-Miocene uplift. *EOS* 68, 1444.

McKenna, L.W., and Hodges, K.V., 1987, Realistic propagation of uncertainties in geologic thermobarometry. *Evolution of Metamorphic Belts Prog Abs*, University College Dublin, Ireland, 35.

Selverstone, J., and Hodges, K., 1987, Unroofing history of the western Tauern Window: evidence for west-directed removal of the Austroalpine nappe sequence. *Terra Cognita* 7, 89.

Burchfiel, B.C., Walker, J.D., and Hodges, K.V., 1988, The Neogene Kingston Range detachment system, SE California. *Geol. Soc. Amer. Abs. w. Prog.* 20, 147.

McKenna, L.W., and Hodges, K.V., 1988, A late Miocene extensional duplex, E. Panamint Range, Death Valley, CA. *Geol. Soc. Amer. Abs. w. Prog.* 20, 214.

Wernicke, Brian, Walker, J. Douglas, and Hodges, K.V., 1988, Hanging wall structural evolution of the Tucki Mountain detachment system, Death Valley region, southeastern California. *Geol. Soc. Amer. Abs. w. Prog.* 20, 242.

Hubbard, Mary, Harrison, T. Mark, and Hodges, Kip, 1988, 40Ar/39Ar timing constraints for deformation along the Main Central Thrust and leucogranite intrusion, eastern Nepal Himalaya. *EOS* 69, 120.

Burchfiel, B.C., Hodges, K.V., Royden, L.H., Chen, Z., Deng, C., and Liu, Y., 1988, Extension parallel to and contemporaneous with compression in the High Himalaya, southern Tibet. *Geol. Soc. Amer. Abs. w. Prog.* 20, A321.

Copeland, Peter, Hodges, Kip V., Harrison, T. Mark, LeFort, P., and Pêcher, A., 1988, Rapid Pliocene uplift associated with the Main Boundary Thrust, central Nepal. *Geol. Soc. Amer. Abs. w. Prog.* 20, A321-A322.

Hodges, K.V., 1988, Metamorphic and geochronologic constraints on the uplift history of Cordilleran metamorphic core complexes. *Geol. Soc. Amer. Abs. w. Prog.* 20, A18.

Ruppel, C., Royden, L., and Hodges, K., 1988, Two-dimensional thermal models of compressional and extensional tectonics: theoretical pressure-temperature-time paths of metamorphic rocks. *EOS* 69, 1513.

Royden, L.H., Burchfiel, B.C., Hodges, K.V., Chen, Z., Liu, Y., Kou, Z., 1989, Basin and Range type extension within the High Himalaya, southern Tibet. *Geol. Soc. Amer. Abs. w. Prog.* 21, 200.

Hodges, K.V., Burchfiel, B.C., Royden, L.H., Chen, Z., Liu, Y., and Kou, Z., 1989, An extensional origin for the North Himalayan gneiss domes: Metamorphic core complexes in southern Tibet. *EOS* 70, 465.

Hodges, K.V., Lux, D., Burchfiel, B.C., Royden, L.H., Chen, Z., Deng, C., Liu, Y., Xu, J., 1989, Tectonic denudation and the unroofing history of the central Himalayas. *Geol. Soc. Amer. Abs. w. Prog.* 21, A182.

McKenna, L.W., and Hodges, K.V., 1989, Constraints on Middle Miocene - Recent extension, Death Valley region, Basin and Range province. *Geol. Soc. Amer. Abs. w. Prog.* 21, A353.

Applegate, J.D.R., and Hodges, K.V., 1990, Solution model effects on the precision of an empirically calibrated geobarometer. *EOS* 71, 1661.

Hodges, K.V., 1990, Tectonic denudation and anatectic melting in compressional settings. *EOS* 71, 1618.

Hodges, K.V., and Walker, J.D., 1990, Widespread evidence for Cretaceous extensional collapse in the hinterland of the Sevier Orogen of western North America. *Geol. Soc. Amer. Abs. w. Prog.* 22, A276.

Wernicke, B., and Hodges, K.V., 1990, Crustal shortening in the Cordilleran core zone. *Geol. Soc. Amer. Abs. w. Prog.* 22, A275.

Applegate, J. D. R., Walker, J. D. and Hodges, K. V., 1991, Structural and geochronologic constraints on Late Cretaceous extensional deformation in the Funeral Mountains metamorphic core complex, southeastern California. *Geol. Soc. Amer. Abs. w. Prog.* 23, A83.

Hodges, K. V., Burchfiel, B. C., Chen, Z., Housh, T., Lux, D., Parrish, R. and Royden, L. H., 1991, Rapid Early Miocene unroofing of the metamorphic core of the Himalaya: Evidence from the Qomolangma (Everest) region, Tibet. *Geol. Soc. Amer. Abs. w. Prog.* 23, A372.

House, M. A., Hodges, K. V., Burchfiel, B. C., Royden, L. H. and Chen, Z., 1991, Structural characteristics of a portion of the South Tibetan detachment system near Dinggyê, Xizang (Tibet). *Geol. Soc. Amer. Abs. w. Prog.* 23, A372.

McKenna, L. W. and Hodges, K. V., 1991, How uncertain are uncertainties in thermobarometry?. *EOS*, 72, 559.

Saylor, B. Z. and Hodges, K. V., 1991, The Titus Canyon Formation: Evidence for Early Oligocene extension in the Death Valley area, CA. *Geol. Soc. Amer. Abs. w. Prog.* 23, A82.

ROBERT H. JONES

PROFESSIONAL BIOGRAPHICAL DATA

DATE AND PLACE OF BIRTH: [redacted]

CITIZENSHIP: [redacted]

EDUCATION:

B.S. Mechanical Engineering, 1966
San Jose State University
San Jose, CA

MBA, 1970
Santa Clara University
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PROFESSIONAL CREDENTIALS:

Registered Professional Engineer - Mechanical
State of California, Reg. No. 14846

Registered Professional Engineer - Nuclear
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State of California Standard Teaching Credential
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SUPLEMENTARY EDUCATION:

Alpha-Emitting Nuclides Course

GE - Vallecitos Engineering Program

THTD Users Course

GE Professional Business Management Course

Transactional Analysis for Interpersonal Effectiveness

Management Practices Course

Kepner-Tregoe Decision Analysis Course

INDUSTRIAL AND TECHNICAL ORGANIZATIONS:

Member, U.S. Council for Energy Awareness

Member, American Nuclear Society

Member, American Society of Mechanical Engineers

Member, California Radioactive Materials Management Forum

HONORS, AWARDS, AND PATENTS:

Co-Inventor: Radioactive Material Shipping Cask
Patent Application No. 850181, 1969

General Electric/NEBG Candidate for 1969-70
White House Fellows Program

General Electric/NEBG Nominee for the 1978 Gerald L. Phillipe Awards for Distinguished Public Service

General Electric Elfun Society - Outstanding Member for 1978

STANDARDS/INDUSTRIAL COMMITTEES:

ANSI	N14.8	Fabrication and Testing of Spent Fuel Shipping Casks
ANSI	N14.9	Packaging of Radioactive Wastes for Transportation
ANSI	N14.12	Evaluation of Type B Containers
ANSI	N552/N14.24	Water Transportation of Radioactive Materials
ASTM	E-10.11.05	Standards Matrix Committee

USCEA Transportation Subcommittee

ASME/NUPACK Main Committee on Cask Containment Design and Construction Rules

TECHNICAL PAPERS AND RELATED ACTIVITIES:

Author, APIO-1073, Summary of the GETR 50 MW Power Ascension Program, September 1967.

Author, A Uranium Shielded Shipping Cask with Specific Neutron Shielding, ANS Winter Meeting, 1969.

Author, IF300 Cask Design Development, 3rd International Symposium on the Packaging and Transportation of Radioactive Materials, Richland, WA, 1971.

Closing remarks at the Heat Transfer Session on Shipping Casks, ASME Winter Meeting, Washington, D.C., 1971.

Author, NRC Requirements for In-Plant Cask Drop Protection, 4th International Symposium on the Packaging and Transportation of Radioactive Materials, Miami Beach, FL, 1974.

Co-author, Some Unique Fabrication Techniques Employed on the General Electric IF300 Shipping Cask, Ibid.

Co-author, 1984 Fact or Fiction? The Transportation Requirements of the Nuclear Reprocessing Industry, Ibid.

Contributing Author, EPRI-310, Denatured Plutonium: A Study of Deterrent Action, July 1975.

Author, Transportation Q&A Section, General Electric Co., Nuclear Power Reference Document, 1976.

Author, NEDO-10084-1 and -2, IF300 Shipping Cask Design and Analysis Report, 1973 and 1979.

Author, NEDO-21796, BWR Basket Internal Shielding SAR, December 1977.

Co-Chairman, Session on Transportation Forcasting and Logistics, 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, NV, 1978.

Advisor, AIF/NESP-014, A Generic Assessment of Barge Transportation of Spent Nuclear Fuel, September 1978.

Developer and Chairman, Session on Application of ASME Code to Radioactive Material Containers, ASME 3rd National Congress on Pressure Vessel and Piping Technology, 1979.

Contributing Author, NEDG-24715, Report on Certain Aspects of the Transportation of Tarapur Spent Fuel from India to the United States, August 1979.

Co-author, NEDE-24821, Thermal Evaluation of the General Electric Model 600 Shipping Package Under Regulatory Conditions, 1980.

Co-author, AGNS-35900-1.4-115, Transportation of Radioactive Material by Water, November 1980.

Co-author, Design Rules for Containment Systems for Nuclear Spent Fuel and High Level Waste Transport Packagings, 6th International Symposium on Packaging and Transportation of Radioactive Materials, Berlin (West), Germany, 1980.

Author, NEDE-24913, Thermal Evaluation of the General Electric Model 100 Shipping Package Under Regulatory Conditions, January 1981.

Co-author, NEDO-24899, GE Model 1500 Shipping Package Heat Test for Thermal Benchmarking, April 1981.

Contributing Author, AGNS-35900-1.4-161, Nuclear Transportation Studies Related to the Use of the Barnwell Nuclear Fuel Plant, Appendix B, November 1981.

Author, NEDE-24914, Thermal Evaluation of the General Electric Model 1500 Shipping Package Under Regulatory Conditions, December 1981.

Co-author, PNL-SA-9872, Transportation Packaging for Processed Transuranic Waste, December 1981. Presented at the 2nd Joint ASME/ANS Nuclear Engineering Conference, Portland, OR, July 25-28, 1982.

Contributing Author, EPRI NP-3365, Review of Proposed Dry Storage Concepts Using Probabilistic Risk Assessment, February 1984.

Contributing Author, SAND85-2072, TTC-0424, A Description of the Reference Transportation System for the Subseabed Disposal of High Level Waste (HLW), October 1985.

Co-author, CWS-001, Private Industry Participation in the Transportation of Spent Fuel and High Level Waste Under the Nuclear Waste Policy Act of 1982, September 1985.

Co-author, ANL/ER-TM-85-2, Preliminary Assessment of Costs and Risks of Transporting Spent Fuel by Barge, December 1985.

Co-author, IAEA-SM-286/59, A Standard for Barge Transport of Type-B Quantities of Radioactive Material, PATRAM '86, June 16-20, 1986, Davos, Switzerland.

Contributing Author, SAND83-0698, TTC-0430, Beneficial Uses Shipping System - Safety Analysis Report for Packaging, Sandia National Laboratories.

Co-author, SAND87-0151, TTC-0713, Feasibility and Incentives for the Consideration of Spent Fuel Operating Histories in the Criticality Analysis of Spent Fuel Shipping Casks, August 1987.

Co-author, ORNL/TM-10811, Transportation Operations Functions of the Federal Waste Management System, Oak Ridge National Laboratory, June 1988.

Author, A Survey of Previous and Current Industry-wide Efforts Regarding Burnup Credit, ANS Tutorial Session, Burnup Credit Issues in Spent Fuel Transportation, Washington, DC, November 2, 1988.

Co-author, ORNL/TM-11232, Transportation Functions of the Federal Waste Management Systems, Oak Ridge National Laboratory, June 1989.

Co-author, EPRI NP-6425, Design Considerations for On-Site Spent Fuel Transfer Systems, June 1989.

Co-author, Design Considerations for an On-Site Spent Fuel Transfer System, PATRAM '89, Washington, DC, June 1989.

Co-author, Final Report on MRS-to-Repository Transportation System Design Characterization and Capacity Study, Roy F. Weston, December 1989.

Contributing Author, Elastic vs. Inelastic Design Criteria for Spent Fuel Shipping Casks, Anatech Research Corp., May 1991.

Co-author, GE-NE-189-34-0691, In-Transit Shock and Vibration Measurement and Analysis of the IF 300 Spent Fuel Shipping Cask, June 14, 1991.

WORK EXPERIENCE:

1961 - 1963

Lenkurt Electric Company
1105 Old County Rd.
San Carlos, CA

Materials planner for electronic components in the Military Products Department.

Production control dispatcher in final assembly area of Military Products Department.

Production scheduler for several departments producing commercial micorwave components.

1966 - 1969

General Electric Company
Vallecitos Nuclear Center
P.O. Box 846
Pleasanton, CA 94566

Manufacturing Engineer:

Developed work-flow plans for machine shop and experiment assembly area.

Nuclear Safety Engineer:

Responsible for the development of analytical models for use in experiment and business hazards evaluation.

Design Engineer:

Task Leader - Coordinated the efforts of three engineers working on the design of sodium-cooled breeder reactor fuel experiments. Responsible for project schedule, cost, and performance.

Experiment Designer - Performed structural, mechanical, and thermohydraulic design on a wide variety of advanced nuclear fuel experiments. This work included supervision of the experiment fabrication as well as the establishment and conduction of in-

reactor test and operating procedures.

1969 - 1979

General Electric Company
Nuclear Energy Business Group
175 Curtner Ave.
San Jose, CA 95125

Product Service and Transportation Engineer:

Conceived, developed, and evaluated new and improved equipment concepts for both light water and breeder reactor fuel shipping.

Provided guidance to vendors and others during detail design and fabrication of equipment. This included QA plan development and vendor auditing.

Worked with reactor plant designers in arriving at site facilities necessary to accommodate fuel shipping equipment.

1969 - 1970

Responsible for the successful execution of spent fuel shipments to the GE Midwest Spent Fuel Storage Facility (MO). This included the preparation of operating procedures, personnel training, and work supervision.

1970 - 1973

Prime contributor to the design, analysis, NRC licensing, pre fabrication planning, and post-fabrication testing of the initial two IF300 shipping packages. This project was valued in excess of two million dollars.

1973 - 1974

Senior Engineer - Product Service and Transportation

Supervised the work of other engineers engaged in MO support activities, primarily in the area of radioactive materials handling and transportation.

Provided technical and regulatory support of IF300 cask fabrication and use.

Responsible for budgeting and planning activities associated with the Company's continuing participation in the fuel storage business.

Provided continuing consulting services to the nuclear industry on all aspects of cask design, handling and transportation.

1974 October 1979

Manager - Transportation Systems

Supervised and assisted two or more engineers or specialists to accomplish the following objectives:

o Develop and implement plans for Spent Fuel Services Operation (SFSO) for transportation systems. Interface with MO, marketing, and utility customers to obtain data for planning.

o Plan and schedule intermediate-range fuel shipping/storage campaigns. Support marketing in resolving contractual, scheduling, and operational problems. Work with customers, other cask owner-operators, and carriers to assure the most efficient use of transportation-related resources.

o Recommend for Department General Manager approval: transportation strategies, business proposals relating to transportation, contractual conditions, and improvement or expansion of the existing business.

o Perform analyses of transportation systems to determine the quantity and mix of casks required to support the shipping/storage business; initiate action (build, buy, or lease) to acquire said equipment.

o Conceive and design transportation systems in accordance with business needs and in conformance with NRC regulations, NRC guides, and industry standards. Analyze and evaluate designs by state-of the-art or advanced techniques to assure safety of the systems and optimization of economics related to fabrication and use. Specify requirements to SFSO Projects, and support Projects during fabrication.

o Document system design and safety analysis, and use documentation to obtain appropriate licenses, certificates, and permits from regulatory agencies. Make decisions during negotiations for these permissions so as to optimize timeliness and cost of system implementation. Provide regulatory services to lessees of systems and customers, as requested.

o Represent the Section on industry committees, task forces, etc., related to the packaging and transportation of radioactive material.

o Represent the Section in negotiations with carriers. In particular, strive for complete acceptance of SFSO transportation systems and commodities as normal, low risk, shipments requiring no special handling.

o Provide consultation on fuel cask applications, design, and operations to functions within GE as well as to outside organizations.

o Perform continuing studies on improving operability of existing equipment through design modifications or changes in procedures.

Specific Consulting as a GE Employee

o 8/76 - Customer: Sandia National Laboratories

Participated in a formal design review of the Aerojet-designed shipping cask for FFTF/CRBR spent fuel.

o 8/78 - Customer: Portland General Electric

Preparation and presentation of testimony on spent fuel transportation before the Oregon Energy Facility Siting Council re: Pebble Springs Nuclear Plant (proposed).

o 9/78 - Customer: DOE/DuPont

Conceptual study and report on the modification of the GE IF300 cask for the transportation of FFTF/CRBR spent fuel assemblies.

o 6/79 - Customer: Duke Power Company

Preparation and presentation of testimony on spent fuel transportation before the ASLB in the matter of fuel transfers between Oconee and McGuire stations.

o 1977/1979 - Customer: Carolina Power & Light Co.

Provided consultation services in the areas of cask engineering and licensing as part of the GE IF300 cask sale to CP&L.

October 1979 to Present

Robert H. Jones, P.E.
Consultant
Hazardous Material Systems
P.O. Box 1510
Los Gatos, CA 95031-1510

Consultant

Application of accumulated work experience to the design, analysis, fabrication, licensing, and utilization of hazardous material packages and related systems, with an emphasis on radioactive commodities. Included are economic, logistical, and safety studies and assessments.

Partial list of clients and activities:

o General Electric Company - Spent fuel cask SARP and QA consulting. Heat transfer work related to certification of spent fuel, waste, and radioisotope casks.

o Battelle/PNL - Contributor to DOE program on solidification, packaging, transportation, and disposal of processed TRU and HL defense wastes. ASME NuPack Committee work sponsorship.

o Teledyne Energy Systems - Reviewer and commentor on DOE/TTC sponsored industry survey on cask fabrication capability.

- Transnuclear, Inc. - General consulting on packaging and regulatory matters.

- Sandia/TTC - Contributor to water carrier workshop, workshop on spent fuel accident scenarios, and other packaging and transportation matters.

- SRI International - Reviewer and commentor on DOE sponsored study of nuclear materials shipping statistics.

- General Atomic Co. - Performed study of the use of LWR spent fuel shipping casks for the movement of HL Defense Wastes.

- Allied General Nuclear Services - Performed study of the logistics and economics of shipping spent fuel by barge. Contributed to ANSI N552 Standard on water transportation of spent fuel.

- Alpha Omega Services - Assisted in the renewal of the Certificate of Compliance for the Model 5979 cask.

- Ridihalgh, Eggers & Associates - Contributor to the NRC sponsored study of extra-severe accidents, and the subsequent definition of bounding physical tests for Type B and fissile packages.

- Applied Science & Technology - Shielded waste package licensing and thermal evaluation. Regulatory strategy and interpretation.

- FMC Corporation - Seminar on shielded package design and regulations.

- General Atomic Company - Member of the Transuranic Package Transporter (TRUPACT) design team.

- S. Levy, Inc. - Operational analysis of dry storage systems in support of an EPRI sponsored risk assessment.

- Brookhaven National Laboratory - Co-authored an assessment of the Brookhaven Waste Shipment Overpack's ability to be recertified under current Federal regulations.

- Quadrex Corporation - Technical support and field survey of reactor waste packaging and transportation activities for Taiwan Power Company's Chin Shan Units 1 and 2.

- General Atomic Company - Transportation logistics support of DOE sponsored Test and Evaluation Facility (TEF) project.

- Carolina Power & Light - Assessment of the IF300 Spent Fuel Shipping Cask for the movement of consolidated PWR assemblies.

- S. Levy, Inc. - Support for EPRI employee participation in the ASME NUPACK Design Task Group. Design rule editing and distribution.

- Kaiser Engineers, Inc. - Provided consulting services on transportation and storage casks for the BWIPP Project.

- C.W.Smith/DOE - Participant in study of industry participation in the implementation of the NWPA.

- Pacific Nuclear - Consulting on IF300 cask technical and regulatory issues.

- Carolina Power & Light - Review of proposal to DOE for a licensed at-reactor, dry storage demonstration program.

- Sandia/TTC - Support for the efforts of the ANSI N14.24 committee on water transportation of radioactive materials.

- JNT Associates, Inc - Contributor to the SARP for the recertification of the Brookhaven Waste Shipment Overpack.

- General Electric Company - Co-authored a DOE sponsored study of spent fuel cask-to-reactor facility interfaces.

- JNT Associates, Inc. - Performed shielding assessments, mechanical design, control/safety system design, and project management in support of a food irradiation plant design effort.

- GA Technologies, Inc. - Member of the Defense High Level Waste Cask design/analysis team. Project was DOE sponsored and administered by Sandia.

- Sandia/TTC - Performed technical reviews and authored several sections of the BUSS cask SARP.

- Radiation Sterilizers, Inc. - Performed fabrication follow up, authored procedures, constructed QA program, and offered operational consulting on the Model 1500 shipping package.

- Roy F. Weston, Inc. - Performed various functions in support of the DOE/Office of Civilian Waste Management. Efforts include environmental assessment support, regulatory issue resolution, and cask acquisition support. Member of the MRS Systems Study Peer Review Group.

- Electric Power Research Institute - Performed studies on various aspects of the storage, transportation and disposal of spent nuclear fuel.

- S. Levy, Inc. - Participated in litigation document review as part of pre-licensing activities for Houston Light and Power's South Texas Project.

- Sandia/TTC - Performed various studies related to radioactive material packaging and transportation in support of the Technical Issues Resolution Project for OCRWM.

- Wildman, Harrold, Allen & Dixon - Litigation support in spent fuel transportation issues.

- Oak Ridge National Laboratory - Support for the development of the Transportation Operations System for OCRWM.

- Burns, Doane, Swecker & Mathis - Litigation support in a RAM packaging patent issue.

- S. Levy, Inc. - Supported EPRI efforts on the ALWR baseline document. Contributed in the area of reactor fueling/defueling.

- Radiation Sterilizers, Inc. - Canister design, construction, testing, and operation. Cask modification, certification and testing. In support of the Decatur, GA Cs-137 capsule leak and facility contamination incident.

- Oak Ridge National Laboratory - Contributing member of the OCRWM Cask Maintenance Facility Peer Review Group.

- Anatech Research Corporation - Participant in the DOE/Sandia sponsored Spent Fuel Source Term Project.

- S-TRON - Technical consulting on irradiation facility design and licensing for the testing of FEMA dosimeters.

- SAIC/Santa Clara - Designed and specified a Type A container for the transportation of a 15 ci cesium source for use in a densitometer.

- S. Levy, Inc. - Co-developer of a set of design considerations for use in the development of a system for transferring spent fuel between a reactor storage pool and a dry, on-site storage cask. Work sponsored by EPRI.

- Electric Power Research Institute - Review and comment on an EPRI sponsored conceptual design effort for an on-site spent fuel transfer system.

- Nuclear Assurance Corporation - Participant in the Near-Site Infrastructure Study.

- General Electric Company - Member of proposal team for the movement of Shoreham fuel to Laguna Verde or Nine Mile Point 2 for reinsertion.

- Roy F. Weston, Inc. - Member of the peer review team examining the PNL/Parsons preconceptual design of an early-receipt MRS facility.

- S. Levy, Inc. - Member of the project team studying the movement of Shoreham fuel to Nine Mile Point 2 for reinsertion.

- Roy F. Weston, Inc. - Member of a core group advising Sandia on the success probabilities and related issues for alternative early-receipt MRS systems.

- Radiation Sterilizers, Inc. - Development and implementation of Model 1500 cask testing procedures. QA audit of cask records and management system.

- General Electric Company - Member of project team for the instrumentation and monitoring of the IF-300 cask to determine the shock and vibration associated with railroad transportation.

- Anatech Research Corporation - Member of the project team investigating the merits of inelastic structural analysis methods as applied to spent fuel shipping casks. Project sponsored by the DOE and Sandia National Laboratories.

- General Electric Nuclear Energy - Staff Consultant on the packaging and transfer of Shoreham Station slightly irradiated nuclear fuel to Nine Mile Point-2 for reinsertion and use.

- SAIC Las Vegas - Member of the Peer Review Group chartered to review the 10 CFR 960 siting guidelines compliance report for the Yucca Mountain Project.

- Roy F. Weston, Inc. - Conducted a study to estimate the amount of corrosion products on LWR fuel and to determine if any incentives exist for at-reactor fuel cleaning prior to shipment to the FWMS.

- ORNL/Martin Marietta - Participated in a workshop on spent fuel shipping cask accident recovery. Produced draft meeting report and edited final report.

- S. Levy, Inc. - Authored performance specification to be used by SMUD in the procurement of transportable storage casks for use at the Rancho Seco power station.

- EPRI - Performed a study of the BWR fuel channel bulging and bowing phenomena. Data will be submitted to the DOE by EPRI to aid in the dimensional assessment of BWR fuel baskets for spent fuel shipping casks.

- Roy F. Weston, Inc. - Participated in the QA peer review of the From-Reactor Cask Proposal Solicitation document.

RESUME - David K. Kreamer

Degrees

Ph.D.	Hydrology, minor Geoscience, 1982, University of Arizona.
M.S.	Hydrology, 1976, University of Arizona.
B.S.	Microbiology, minor Chemistry, 1973, University of Arizona.

Work Experience

1990-	Associate Professor and Director of the Water Resources Management Program, University of Nevada, Las Vegas. Graduate Faculty Member in Geoscience and Civil Engineering Departments.
1985-1990	Assistant Professor, Department of Civil Engineering, Arizona State University.
1984-1985	Visiting Assistant Professor, Department of Civil Engineering, Arizona State University.
1980-1984	Associate in Research, Department of Hydrology and Water Resources, University of Arizona.
1976-1979	Instructor, Department of Hydrology and Water Resources, University of Arizona.
1977	Research Assistant III, Staff Member, Water Resources Research Center, University of Arizona.

Teaching

University of Nevada, Las Vegas

1. Advanced Hydrogeology
2. Hydroscience
3. Site Characterization and Subsurface Contaminant Transport

Arizona State University

1. Groundwater Hydrology
2. Hazardous/Nuclear Waste Disposal and Contaminant Transport
3. Water Resources Engineering
4. Physical/Chemistry Water and Wastewater Treatment
5. Surface Water Hydrology
6. Hydraulics and Hydrology
7. Groundwater Hydrology - Monitoring, Protection and Cleanup
8. Subsurface Contaminant Transport

University of Arizona

1. Water and the Environment
2. Kayaking (Continuing Education)
3. Hydrology Summer Field Camp

Short Courses Given, Invited Lectures

Dr. Kreamer has given over 60 invited lectures, seminars and workshops in recent years including:

1. An August 1989 presentation in Sao Paulo, Brazil, requested by the U.S. Executive branch, on the disposal of hazardous and nuclear waste. Dr. Kreamer was one of three American scientists invited, along with the head of the Department of Earth and Planetary Sciences, Harvard University and the Head of the Joint Oceanographic Institutions, Washington, D.C.

2. National lectures for the U.S. Environmental Protection Agency, U.S. Bureau of Land Management, and for the National Water Well Associations's, Association of Groundwater Scientists and Engineers.

3. Short courses for the Alaska Department of Environmental Conservation, Arizona Department of Transportation, City of Phoenix, Idaho State Health Department, the Hanford Nuclear Site, and the Arizona Hydrological Society.

Research Experience (Summary)

Dr. Kreamer has received approximately $1,200,000 in research funding, awarded on a competitive basis, in the last 5 years.

1983-present	Investigation of volatile contaminants (such as TCE) in, and in the unsaturated zone above polluted groundwater. Arizona field sites include 52nd Street Motorola and Indian Bend Wash in the Phoenix metropolitan area, and the Tucson Superfund site.
1987-1988	Hydrological study of the Arizona Superconducting Super Collider Site.
1985-present	Study of contaminant migration around leaking underground storage tanks.
1985	Assessment of Priority Pollutants in the water supply for the Salt River Project, Arizona.
1981-present	Several research projects concerning gaseous diffusion in unsaturated porus media. The research developed a new in situ tracer method for measuring and modeling characteristics of volatile contaminant transport through the vadose zone at nuclear or hazardous waste sites. This technology is being used to test a new method of mixed-waste, low level nuclear waste disposal at the Nevada Test Site.
1977&1986	Interdisciplinary research project on water quality in the 4,500 square mile San Pedro river basin, Arizona.
1980-1984	Four research grants for evaluation of potential indicators of groundwater source and movement, particularly certain trace gases and stable isotopes.
1978	Research exploring water supply feasibility (quality and quantity) for a ten hectare shrimp aquaculture facility at Puerto Penasco, Mexico. Studied groundwater and estuarian surface water.
1975	Evaluation of the effectiveness of large interdisciplinary water-related research projects.
1973-1975	Water quality studies on the Colorado River and over 50 Arizona Lakes.

Awards and Honors

Recipient of the Arizona Foundation's 1979 Award for Meritorious Performance in Teaching.
Environmentalist of the Year Award, 1979-1981 by the University of Arizona Ramblers.
Recipient of the Koch, Regent's, Educational Encouragement, Graduate Academic, and Blois du Bois Scholarships.
Recipient of the Arizona Society of Professional Engineers 1990 Award for Service in Water Resources.

Community Service

Governor's Commission on Arizona Environment, Member and Advisory Council Member, 1984-1990.
Advisor to the Arizona Water Resources Research Center, 1985-1987
Reviewer for U.S. Department of Energy and U.S. Environmental Protection Agency (Kerr Laboratory, Ada, OK and Environmental Systems Monitoring Laboratory, Las Vegas) technical documents.
Referee for Journal Environmental Science and Technology.
Rockclimbing Instructor for the Arizona School for Deaf and Blind.
Advanced First Aid Instructor, American Red Cross, 1973-1988.
Southern Arizona Rescue Association, volunteer mountain rescue, 1973-1980.
Technical Advisor to Arizona Nature Conservancy, Canelo Hills Cienega, 1986.
City of Phoenix, Water Quality Advisory Committee, Member, 1984-1986.
Nevada Representative, Universities Council on Water Resources, 1990-present.
UNLV Representative, U.S. Geological Survey Liaison Committee for the Nevada Basin and Range National Water-Quality Assessment (NAWQA) study.
Participant, 1991 Nevada Governor's Institute.
Nevada Advisory Council on Water Resources, 1991.

Membership in Scientific and Professional Societies

American Association for the Advancement of Science
American Geophysical Union
American Water Resources Association
Association of Groundwater Scientists and Engineers, NWWA
American Society of Civil Engineers
ASTM - Section D-18.21.02 Vadose Zone Monitoring
Nevada Advisory Council on Water Resources
Universities Council on Water Resources

PUBLISHED PAPERS, REPORTS, ABSTRACTS AND ARTICLES BY DAVID K. KREAMER
(in reverse chronological order)

Kreamer, D.K. and K.J. Oja, 1991. Vapor Adsorption of a Solvent on Quartz Sands of Varying Grain Size. Journal of Environmental Engineering, ASCE. Accepted for Publication.

Oja, K.J. and D.K. Kreamer, 1991. The Effect of Moisture on Adsorption of Trichloroethylene Vapor on Natural Soils. Proceedings of the 1991 U.S. Environmental Protection Agency Symposium on Soil Venting, April 29 - May 1, 1991, Houston, Texas.

Kreamer, D.K., 1991. Waste Disposal in Terrestrial Environments. Proceedings of the 1989 Seminario A Imprensa E O Planeta, Sao Paulo, Brazil, August 13-16, 1989.

Suchomel, K.H., Kreamer, D.K., and A. Long, 1990. Production and Transport of Carbon Dioxide in a Contaminated Vadose Zone: A Stable and Radioactive Carbon Study. Environmental Science and Technology, Vol. 24, No. 12, p.1824-1831.

Kreamer, D.K. and K.J. Stetzenbach, 1990. Development of a Standard, Pure-Compound Base Gasoline Mixture for Use as a Reference in Field and Laboratory Experiments. Ground Water Monitoring Review, Spring 1990, p.135-145.

Kreamer, D.K., Starr, K., Chaganti, S., Johnson, T. and H.A. Phillips, 1990. Gasoline Vapor Compound Ratios as a Tool to Locate Subsurface Fuel Leaks; from Minimizing Risk to the Hydrologic Environment, Selected Papers from the American Institute of Hydrology Conference, Las Vegas, Nevada, March 13-15, 1990, p.243-249.

Houston, S.L., Kreamer, D.K. and R. Marwig, 1989. A Batch-Type Testing Method for Determination of Adsorption of Gaseous Compounds on Partially Saturated Soils. Geotechnical Testing Journal, ASTM, March 1990, p.3-10.

Weaver, J., Enfield, C.G., Yates, S., Kreamer, D.K. and D. White, 1989. Predicting Subsurface Contaminant Transport and Transformation: Considerations for Model Selection and Field Validation. U.S. Environmental Protection Agency Publication EPA/600/2-89/045, (peer-reviewed), 60p.

Kreamer D.K., Pottorf, E.T. and H.A. Phillips, 1988. Interpretation of Gaseous Tracer Tests in Unsaturated Alluvial Material, EOS, Transactions of the American Geophysical Union, Vol.69, No.44, p.1217.

Oja, K.J., Kreamer, D.K. and S.L. Houston, 1988. Adsorption of Gaseous Compounds on Unsaturated Soils. EOS, Transactions of the American Geophysical Union, Vol.69, No.44, p.1188.

Kreamer Publications, continued

Suchomel, K.H., Long, A., Kreamer, D.K., Tull, A.J.T. and L.J. Toolin, 1988. Production and Transport of Carbon Dioxide in a Contaminated Vadose Zone: A Stable and Radioactive Carbon Study. EOS, Transactions of the American Geophysical Union, Vol. 69, No. 44, p.1216.

Kreamer, D.K., Phillips, H.A., Starr, K., and S. Chaganti, 1988. Report on Technical and Safety Procedures for Simulating Leaks with Small Physical Models. Report for the U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, No. 8V-0975-NASA, 40p.

Pottorf, E.T., Phillips, H.A. and D.K. Kreamer, 1988. Analysis of Gaseous Tracer Migration for the Greater Confinement Disposal Test 5. Report to Reynolds Electrical and Engineering Company, Inc., Nevada Test Site, 33p.

Kreamer, D.K., Weeks, E.P. and G.M. Thompson, 1988. A Field Technique to Measure the Tortuosity and Sorption-Affected Porosity for Gaseous Diffusion of Materials in the Unsaturated Zone with Experimental Results from near Barnwell, South Carolina. Water Resources Research, Vol. 24, No. 3, p.331-341.

Kreamer, D.K., 1988. Monitoring Technology for Augered Shaft Waste Disposal - The Shallow Test Plot Experiments. Report to Reynolds Electrical and Engineering Company, Inc., Nevada Test Site, 79p.

Pijawka, D. Omart, R. and D.K. Kreamer, 1988. Issues in Environmental Quality, Chapter 3. 1988 Sedona Forum - Research Report on the Quality of Life in Sedona, Sedona Academy, 28p.

Kreamer, D.K., Golightly, W. and M. Ryniak, 1987. Investigations of Vertical Distribution and Migration of Volatile Organic Compounds. Report to the U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, 122p.

Kreamer, D.K., Houston, S.L. and K.J. Oja, 1987. Laboratory Test Methods for the Measurement of Gaseous Adsorption by Partially Saturated Soils. Report to Reynolds Electrical and Engineering Company, Inc., Nevada Test Site, 39p.

Kreamer, D.K., 1986. Vapor Transport and Its Implications to Underground Storage Tanks. Chapter 3 from Process Affecting Subsurface Transport of Leaking Underground Tank Fluids, S. Tyler et al., Desert Research Institute Publication #41100, (peer reviewed). NTIS publication.

Kreamer, D.K., 1986. TCE - Sources, Migration, and Cleanup. Proceedings of the 1986 Annual Conference of the Arizona Water Pollution Control Association, Phoenix, AZ. 11p.

Self, O. and D.K. Kreamer, 1986. Water Quality Issues. Chapter 3 from Water Resources Issues of the Upper San Pedro Basin, Arizona, Arizona Water Resources Research Center. 82p.

Daughton, D., Kreamer, D.K., Morgan, R., Rich, J. Wolf, V., Lee, R. and J. Derourin, 1986. Phoenix Water Quality Advisory Committee - Final Report. Submitted to the Mayor and Council, November 24, 1986. 86p.

Kreamer, D.K., 1986. Trichloroethylene - Remaining Solvent. (Invited Paper), Proceedings of the Conference on Southwestern Water Issues, October 20-22, 1986, Tempe Arizona. Association of Ground Water Scientists and Engineers, National Water Well Association, Dublin, Ohio. 15p.

Kreamer, D.K., Houston, S.L. and R. Marwig, 1986. Laboratory Methods for Gaseous Tracer Sorption. Report to Reynolds Electrical and Engineering Company, Inc., Nevada Test Site, 79p.

Kreamer Publications, continued

Kreamer, D.K., Manera, P.A. and J.J. Lemon, 1986. Water Quality. Chapter 3 from Groundwater Quality for Real Estate Appraisers and Other Professionals. Arizona Hydrological Society and American Institute of Real Estate Appraisers. 15p.

Kreamer, D.K., Ohler, B. and R. Caldwell, 1985. Assessment of Priority Pollutants in the Salt River Project's Water Supply. Report for the Salt River Project, Phoenix, Arizona. 155 p.

Thurnblad, T.W., Kreamer, D.K. and H.W. Bentley, 1982. An Evaluation of the Effectiveness of Hydrogen and Oxygen Isotopes Used in Concert with Chemical Water Quality Parameters as Indicators of Subsurface Water Movement and Source. Report for the Office of Water Research and Technology, U.S. Department of the Interior, No. 1-103-ARIZ. 130p.

Thompson, G.M. and D.K. Kreamer, 1981. In Situ Measurement of Fluorocarbon Diffusion Rates in Unsaturated Porous Media. Report for the U.S. Geological Survey, No. 14-08-0001. 35p.

DeCook, K.J., Kreamer, D.K. Keith, S., Mack, S.F. and J.P. Hutton, 1977. Surface Water Quality Monitoring, San Pedro River Basin, Arizona. Report to the Arizona Department of Health Services, Bureau of Water Quality Control. 107p.

Ince, S., Kreamer, D.K., Young, D.W., and C.L. Constant, 1976. Water Quality Study of Lake Havasu, Arizona Near the CAP Intake Area. Hydrology and Water Resources in Arizona and the Southwest. Vol. 6, p.81-88.

Kreamer, D.K., 1976. Future Effects of the Central Arizona Project of Lake Havasu's Thermal Regime. Hydrology and Water Resources in Arizona and the Southwest. Vol. 6, p.75-80.

CURRICULUM VITAE

William G. Pariseau

[redacted]

315 WBB
University of Utah
Salt Lake City, Utah 84112
(801) 581-5164

EDUCATION	Doctor of Philosophy University of Minnesota Major: Mineral Engineering Emphasis: Rock Mechanics	June 1966 Minneapolis, Minnesota Minor: Applied Mathematics
	Bachelor of Science University of Washington Major:	March 1960 Seattle, Washington Mining Engineering (Geological Option)
	Magna Cum Laude graduation	
	Registered Professional Engineer Pennsylvania (by examination) Montana (by reciprocity)	

PROFESSIONAL AND RELATED EXPERIENCE

(1) Malcom McKinnon Endowed Chair in Mining Engineering (1986-present)

Professor of Mining Engineering (1973-present), Associate (1971-73), University of Utah.

Adjunct Professor, Geology and Geophysics, University of Utah (1985-present).

Affiliate Professor, Mining and Metallurgy, University of Idaho (1985-present).

(2) Visiting Academic (1978), Imperial College of Science and Technology, (Interdisciplinary Rock Mechanics Group).

(3) Visiting Research Professor (1977-78) Brown University, (Engineering Division).

(4) Associate Professor of Mining Engineering (1970-71), Assistant (1968-70), Montana College of Mineral Science and Technology.

(5) Assistant Professor of Mining Engineering (1966-68), The Pennsylvania State University.

(6) Consultant:

Allied Chemical Corporation	Ingersoll-Rand Research
AMAX Coal Company	Intera Environmental Group
Anaconda Minerals Company	Kansas State Geological Survey
ARCO Coal Company	McIntyre-Porcupine Coal Division

Callahan Mining Company
Call and Nicholas, Inc.
Engineers International, Inc.
Georgia Marble Company
Georgia-Pacific Corporation
Homestake Mining Company
Pittsburgh Mining Research Center
R & M Consultants
Research Specialties, Inc. (RE/SPEC, Inc.)
Sandia Laboratory
Spokane Research Center

(7) Graduate Teaching and Research Assistant, U. of Minnesota; Engineering Department, City of Anchorage; Alaska Department of Highways; Mineral Resources Division; U. S. Bureau of Mines--Spokane; Anaconda Copper Co., Butte, Montana; New York-Alaska Gold Dredging Corp., Nyac, Alaska (1957-1965).

(8) United States Marine Corps (1953-1956).

(9) Short Course Instructor: Beginning and Advanced Rock Mechanics, U. of Minnesota (1966); Stabilizing Mine Excavations, The Pennsylvania State University (1968); Plasticity Theory, Gonzaga University (1971); Plasticity Theory and Slope Stability, USBM Spokane Research Center (1979).

PERSONAL

Born [redacted]

Married [redacted]

REFERENCES

Supplied on request.

MEMBERSHIPS

Professional

American Institute of Mining, Metallurgy and Petroleum Engineers
American Association for the Advancement of Science
American Association of University Professors
International Society for Rock Mechanics
Society of Engineering Science
Utah Academy of Sciences, Arts and Letters

Honorary

Phi Beta Kappa
Tau Beta Pi
The Society of Sigma Xi

HONORS AND AWARDS

University of Utah Distinguished Research Award, 1991
AIME/SME Rock Mechanics Award, 1990
U.S. National Committee for Rock Mechanics (NRC/NAS/NAE)*, Award for Applied Research, 1986.
U.S. National Committee for Rock Mechanics (NRC/NAS/NAE), Award for Case Histories, 1985.
U.S. National committee for Rock Mechanics (NRC/NAS/NAE), Award for outstanding Rock Mechanics Research, 1973.

Society of Mining Engineers Publication Board Commendation, 1984.
University Travel Grant (Australia, 1973)
National Science Foundation Travel Grants
Yugoslavia, 1970, Second ISRM Congress.
Czechoslovakia, 1969, CHISA-II Congress.

NSF Summer Fellowship for Teaching Assistants.
NSF Cooperative Graduate Fellowships.
Reserve Mining Co. Scholarship.

AIME/SME Student Prize Paper Award (Undergraduate, 1960).
Outstanding Senior Award in Mining Engineering.
High Scholarship Award.

Magna Cum Laude graduation.

* NRC - National Research Council
NAS - National Academy of Sciences
NAE - National Academy of Engineering

COMMITTEE ACTIVITY

University of Utah

Departmental:
- Executive Committee
- Curriculum Committee
- Graduate Program Committee
- Library Committee

College:
- Faculty Relations Committee (Chairman, two terms)
- Executive Council
- Ad Hoc Space Committee
- Curriculum Committee
- Loan Committee

University:
- Instrumentation Committee
- Graduate Program Review (Chairman)
- Academic Policy Advising Committee

Montana College of Mineral Science and Technology

Research Control Group
Graduate Program Committee
Policy and Development Committee (Chairman)
Committee on Teaching Effectiveness (Chairman)

Professional

Editorial Advisory Board--International Journal of Numerical and Analytic Methods in Geomechanics
Editorial Board--International Journal of Rock Mechanics and Mining Science and Geomechanics Abstracts

Contributor: NSF Sponsored U.S. - India Seminar/Workshop Thick Seam Extraction, Dhanbad, India, January, 1986.
Contributor: NSF Sponsored U.S. - Italy Workshop on "Characterizing and Modeling Rock Mass for Design and Construction of Underground Cavities," Turin, Italy, September 1982.

Geomechanics Unit Committee--Society of Mining Engineers
Rock Mechanics Award Committee
M & E Division, Program Committee
Peele Award Committee
Committee on Geotechnical and Geophysical Phenomena--Society of Engineering Science

NSF Workshop on Mechanics Problems Associated with Mining and Processing Energy Related Minerals
U. S. National Committee for Rock Mechanics (Member-at-Large)
U. S. National Committee for Rock Mechanics (In situ and Mining Sub-panel)
U. S. National Committee for Rock Mechanics (Award Panel)

Student Affairs Committee (Chairman)--Utah Section AIME
ASTM Committee C-18 Natural Building Stone
Advisor Student AIME Chapters

COURSES TAUGHT

University of Utah

Advanced Rock Mechanics-I (Plasticity Theory)
Advanced Rock Mechanics-II (Field Instrumentation)
Landslides and Slope Stability (Analysis)
Advanced Metal Mining

Rock Mechanics-I (Natural Support)
Rock Mechanics-I Lab (Rock Properties)
Rock Mechanics-II (Artificial Support)
Rock Mechanics-II Lab (Field Instrumentation)
Heat Energy Systems (Thermodynamics)
Hydraulic Systems
Mine Valuation
Principles of Mining

Montana College of Mineral Science and Technology

Unit Operations
Engineering Probability and Statistics
Rock Mechanics-I, -II (with Lab)
Advanced Topics (Finite Element Analysis)

The Pennsylvania State University

Introduction to Mining
Mine Ventilation
Post-yield Mechanics of Rock
Graduate Seminar

TECHNICAL REPORTS

by

William G. Pariseau

1. "Slope Stability Research Study; Analysis Section," Prepared for the Anaconda Co., August 1970 (with K. Stout, et. al.).

2. "Slope Stability Research Study: Descriptive and Data Sections," Prepared for the Anaconda Co., August 1970 (with K. Stout, et. al.).

3. "Evaluation of Teaching Effectiveness," Report of the Committee on Teaching Effectiveness, Montana College of Mineral Science and Technology, 1971 (with M. J. Doman).

4. "Interpretation of Rock Mechanics Data: Single Entry System Sunnyside Mine, Utah," Ann. Rept., USBM Contract H0220077, June 1973).

5. "Analysis and Evaluation of the Rock Mechanics Aspects of the Proposed Salt Mine Repository-II," Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., September 1973 (with P. F. Gnirk et. al.).

6. "Thermoelastic/Plastic Analysis of Waste-Container Sleeve: I. Initial Estimates of Loading on the Sleeve," (RSI-0010), Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., May 1974.

7. "Analysis and Evaluation of the Rock Mechanics Aspects of the Proposed Salt Mine Repository Concepts--III," Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., September 1974 (with P. F. Gnirk, et. al.).

8. "Finite Element Analysis of Preliminary Underground and Open Pit Mine Geometrics for Oil Shale Lease Tract Gas," (RSI-0015), Prepared for Gulf-Standard and submitted to M-K Co., Inc., February 1975 (with J. Ratigan, et. al.).

9. "Thermoelastic/Plastic Analysis of Waste-Container Sleeve: II. Influence of Large Displacements of Sleeve Loading," (RSI-0017), Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., March 1975.

10. "Thermoelastic/Plastic Analysis of Waste-Container Sleeve: III. Influence of Salt Strength of Sleeve Loading, (RSI-0018), Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., March 1975.

11. "Thermoelastic/Plastic Analysis of Waste-Container Sleeve: IV. Air gap Influence of Hole Closure, (RSI-0019), Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., March 1975.

12. "Design Aspects of the Alpha Repository: I. Preliminary Results of Facility Layout, Room Stability and Equipment Selection Efforts, (RSI-0024), Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., April 1975 (with P. F. Gnirk, et. al.).

13. An Approximate Procedure for Estimating Stresses in Three-Dimensional Room and Pillar Mine Configuration from a Two-Dimensional Analysis of Stress," (RSI-0025), Prepared for Gulf-Standard and submitted to M-K Co., Inc., April 29, 1975).

14. "Design Aspects of the Alpha Depository: IV. Structural Analysis of Excavation Geometries," (RSI-0030), Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., June 1975 (with J. Ratigan, et al.).

15. "Analysis and Evaluation of the Rock Mechanics Aspects of the Proposed Salt Mine Repository," (RSI-0030), Prepared for ORNL/UCC and submitted through RE/SPEC, Inc., June 1972.

16. "Description of the Thermoelastic/Plastic Computer Program TEPO," (RSI-0040), Prepared for HNL/UCC and submitted by RE/SPEC, Inc., September 1975.

17. "Gravity Flow Bin Design," Final Report, U.S.B.M., Grant G0133028, September 1975.

18. "Simulated Solution Mining of a Utah Bituminous Coal," Bull. 144, Utah Eng'g Rept Stat., August 1977 (with T. F. Roylance, L. L. Anderson and L. H. Lattman).

19. "Coal Pillar Strength Study," (The Design of Production Pillars in Coal Mines), U.S.B.M. Contract H 0242059, Final Report, July 1977 (with W. Hustrulid, S. Swanson and L. Van Sambeek).

20. "Interpretation of Rock Mechanics Data," (A Two-Dimensional Finite Element Approach to the Evaluation of Underground Coal Mine Stability), Vol. I, U.S.B.M. Contract H0220077, Final Report, June 1978.

21. "Interpretation of Rock Mechanics Data," (A Guide to Using UTAH2), Vol. II, U.S.B.M. Contract H0220077, Final Report, June 1978.

22. "Ground Control in Multi-level Room and Pillar Mines," First Annual Report, U.S.B.M. Mineral Institutes Program, December 1982.

23. "Ground Control in Multi-level Room and Pillar Mines," Final Report, U.S.B.M. Mineral Institutes Program, June 1983.

24. "Guidelines for Open Pit Ore Pass Design," Vol. 1, Final Report, U.S.B.M., Department of Interior, September 1983 (with D. F. Hambley and M. M. Sinh).

25. "Research Study on Pillar Design for Vertical Crater Retreat (VCR) Mining," Final Report, U.S.B.M. Contract J0215043, August 1985.

26. "Rock Mass Modification," W. G. Pariseau, Ed. and Chair, U.S. National Committee for Rock Mechanics, National Research Council, 1990, pp. 62.

PAST AND CURRENT RESEARCH FUNDING

William G. Pariseau

"Gravity Flow of a Granular Material in a Wedge-shaped Hopper," The Pennsylvania State University; Sponsor: Central fund for Research.

"Lower Limits of Continuum Concepts in the Mechanics of Ideal Soils," The Pennsylvania State University; Sponsor: National Science Foundation.

"Experimental Determination of Stress and Velocity Fields During Ore Pass Drawdown," The Pennsylvania State University; Sponsor: National Science Foundation.

"Apparatus for the Demonstration and Teaching of the 'Effective' Pressure Concept in the Mechanics of Geologic Media," Sponsor: Central Fund for the Improvement of Teaching, The Pennsylvania State University.

"Computer Simulation of Mine Subsidence," Sponsor: Mineral Conservation Section, The Pennsylvania State University.

"The Engineering Prediction of Ground Subsidence and Surface Damage over Coal Mines in Pennsylvania," (with B. Voight), Sponsor: Coal Research Section, The Pennsylvania State University.

"Experimental Determination of Stress and Velocity Fields During Ore Pass Drawdown," (continuation), Montana College of Mineral Science and Technology; Sponsor: National Science Foundation.

"An Improvement Plan for Plane and Mine Surveying," Montana College of Mineral Science and Technology; Sponsor: National Science Foundation.

"Slope Stability," (with K. Stout, et al.), Montana College of Mineral Science and Technology; Sponsor: The Anaconda Company.

"Mechanics of Fine Powders," Spokane Mining Research Center (NASA contract).

"Analysis of Risk in the Stability of Open Pit Mine Slopes," (with J. Mutmansky), University of Utah; Sponsor: Uniform School Fund.

"Influence of Temperature Change on the Safety of Mine Pillars," University of Utah; Sponsor: Uniform School Fund.

"Interpretation of Rock Mechanics Data, Single Entry System, Sunnyside Mine," University of Utah; Sponsor: U. S. Bureau of Mines.

"Rock Mechanics Testing Equipment," (with W. Wawersik and J. E. Willson), University of Utah; Sponsor: Research Development Fund.

"Rock Mechanics Data Acquisition Equipment," University of Utah; Sponsor: Research Development Fund.

"Gravity Flow Bin Design," University of Utah; Sponsor: U. S. Bureau of Mines.

"In Situ Coal Pillar Strength Study," (with W. Wawersik, et al.), University of Utah; Sponsor: U. S. Bureau of Mines.

"Optimal Assignment of Different Capacity Trucks to Shovels," University of Utah; Sponsor: Uniform School Fund.

"Solution Mining of Coal," University of Utah; Sponsor: Utah State Oil, Gas and Mining Board.

"The Rock Mechanics of Level and Raise Spacing in Deep Vein Metal Mines," University of Utah; Sponsor: Mining and Minerals Industries Resource Research Institute (U of U).

"Ground Control in Multi-Level Room and Pillar Mining," Sponsor: Office of Surface Mining.

"Coal Pillar Stability in Inclined Seams," Sponsor: Mineral Leasing Fund.

"Pillar Design for Vertical Crater Retreat (VCR) Mining," Sponsor: USBM/Anaconda/Homestake.

"Scale Effects on Rock Deformability in Boreholes," (with M. K. McCarter); Sponsor: Chevron Research Fund (U of U).

"Guidelines for Open Pit Ore Pass Design," (with M. M. Singh, Engineer International, Inc.), Sponsor: U. S. Bureau of Mines.

"Ground Control Stress Measurement in Utah Coal Mines," Sponsor: Mineral Leasing Fund (U of U).

"Numerical Simulation on Comminution Processes in Jointed Geologic Media," (with M. K. McCarter); Sponsor: USBM/Comminution Center (U of U).

"Evaluation of Field Parameters Controlling Explosive Fragmentation," (with M. K. McCarter), Sponsor: USBM/Comminution Center (U of U).

"Ground Control and Cable Bolting in VCR Stopes," Sponsor: Office of Mineral Institutes, Generic Centers (VPI).

"Stability Analysis of Mine Openings in Jointed Rock Masses", Sponsor: Mineral Leasing Fund.

"Seepage in Jointed Rock Masses", Sponsor: Mineral Leasing Fund.

Media Mechanics and Breakage in Tumbling Mills", (with K. Rajamani) Sponsor: USBM/Comminution Center (U. of U.).

"Escarpment Stability Study", Sponsor: Utah Power and Light Company.

"Jointed Rock Mass Modulus", Sponsor: Mineral Leasing Fund.

"Application of PM Theory, Lucky Friday Mine", Sponsor: U.S. Bureau of Mines

LIST OF PUBLICATIONS

William G. Pariseau

(refereed journals, reviewed symposia proceedings, reviewed government publications)

1. "A New View of the Ideal Plasticity of Soils and Unconsolidated Rock Materials," W. G. Pariseau, International Journal of Rock Mechanics and Mining Sciences, 3, Nov. 1966, 307-317.

2. "The Force-Penetration Characteristic of a Wedge Penetrating Rock," W. G. Pariseau and C. Fairhurst, International Journal of Rock Mechanics and Mining Sciences, 4, 1967, 165-180.

3. "The Post-Yield Mechanics of Rock and Soil," W. G. Pariseau, Mineral Industries Bulletin, 36, The Pennsylvania State University, May 1967.

4. "A Contribution to the Discussion Concerning the Brittle Fracture of Rock," W. G. Pariseau, Failure and Breakage of Rock, (C. Fairhurst, editor) Am. Inst. Mng. Met. Pet. Engrs., N.Y., 1967, 145-50.

5. "Soil Plasticity and the Movement of Materials in Ore Passes," W. G. Pariseau and E. P. Pleider, Trans. Quart. Soc. of Mining Eng., 241, March 1968, 42-56.

6. "Plasticity Theory for Anisotropic Rocks and Soils," W. G. Pariseau, Basic and Applied Rock Mechanics (K. E. Gray, editor), Am. Inst. Mng. Met. Petr. Engrs., N.Y., 1972, (Chapter 10), 267-295.

7. "Mine Subsidence and Model Analysis," W. G. Pariseau and D. Dahl, Trans. Quart. Soc. of Mining Eng., 241, December 1968, 488-494.

8. "The Post-Yield Flexure of Geologic Strata," W. G. Pariseau, Trans. Quart. Soc. of Mining Eng., 244, June 1969, 203-209.

9. "Gravity Flows of Ideally Plastic Materials Through Slots," W. G. Pariseau, J. or Eng. for Ind. (Trans. ASME), May 1969, 414-422.

10. "State of the Predictive Art in Subsidence Engineering," W. G. Pariseau and B. Voight, J. of the Soil Mech. and Foundations Div. (Proc. ASCE, 96, SM2, 7210750), March 1970, 721-750.

11. "Discontinuous Velocity Fields in Gravity Flows of Granular Materials," W. G. Pariseau, Power Technology, 3, 1969/70, 218-226.

12. "Finite Element Analyses of Elastic-Plastic Problems in Geologic Media: An Overview," W. G. Pariseau, B. Voight, and D. Dahl, Proc. 2nd Congress of the Int. Soc. for Rock Mechanics, 2, September 1970, 3-45.

13. "Wedge Indentation of Anisotropic Geologic Media," W. G. Pariseau, Dynamic Rock Mechanics (G. G. Clark, editor), Am. Inst. Mng. Met. Petr. Engrs., N.Y., 1971, (Chapter 27), 529-546.

14. "Influence of Topography on the Pre-Mining State of Stress," W. G. Pariseau,

Proc. 4th Canadian Symp. on Research Tectonics and 7th Canadian Symp. on Rock Mechanics, U. of Alberta, Edmonton, March 1971, 191-200.

15. "Gravity Flow of Power in a Lunar Environment," (in two parts) II. Analysis of Flow Initiation," W. G. Pariseau Proc. Int. Powder Technology and Bulk Solids Conf., Powder Advisory Centre, London, 1971, 183-192.

16. "Gravity Flow of Powder in a Lunar Environment," (Par II), U. S. Bureau of Mines Report of Investigation 7577, W. G. Pariseau (1971) 20 pp.

17. "Open Pit Mine Slope Stability: The Berkeley Pit," W. G. Pariseau and K. Stout, Stability of Rock Slopes (R. J. Cording, editor), Am. Soc. Civil Engrs, N.Y., 1972, 367-395.

18. "Elastic-plastic Analysis of Pit Slope Stability," W. G. Pariseau, Application of the Finite Element Method in Geotechnical Engineering (C. S. Desai, editor), U. S. Army Waterways Experiment Station, Vicksburg, 1972, 349-393.

19. "Support Potential of Hydraulic Backfill in Cut-and-Fill Stopes," W. G. Pariseau and C. Daniel Kealy, New Horizons in Rock Mechanics (H. R. Hardy, Jr., and R. Stefanko, editors), Am. Soc. Civil Engrs., N.Y., 1973, 501-526.

20. "Bin Hopper Engineering and Bulk Materials Flow: A State-of-the-Art Report on Empirical and Theoretical Analysis," W. G. Pariseau and R. S. Fowkes, U. S. Bureau of Mines I. C. 9552, 1972, 36 pp.

21. "Rock Mechanics and Risk in Open Pit Mining," W. G. Pariseau, Proc. 11th International Symposium on Computer Applications to the Mineral Industry, (J. R. Sturgul, editor), College of Mines, Univ. of Arizona, 1973, A106-124.

22. "Support Performance Prediction for Hydraulic Fill," W. G. Pariseau, M. M. McDonald, J. R. M. Hill, Proc. Symposium on Mine Filling, The Australasian Inst. of Mining and Metallurgy, 1973.

23. "Materials Handling Research: Penetration of Selected/Granular Materials by Wedge-shaped Tools," R. S. Fowkes, D. E. Frisque, and W. G. Pariseau, U. S. Bureau of Mines Rept. Inv. 7739, 1973, 19 pp.

24. "Influence on Hydraulic Backfill on Closure and Pillar Stress in Narrow Cut-and-Fill Stopes," Applications of Rock Mechanics (E. R. Hoskins, Jr., editor), Am. Soc. Civil Engrs., N.Y., 1975, 23-35.

25. "Influence of Rock Properties Variability on Mine Opening Stability Analysis," W. G. Pariseau, Proc. 9th Canadian Symp. on Rock Mechanics, Mines Branch, Dept. of Energy, Mines and Resources, Ottawa, 1974, 141-165.

26. "Estimation of Support Load Requirements for Underground Mine Openings by Computer Simulation of the Mining Sequence," W. G. Pariseau, Soc. Min. Engrs. Trans., 262, June 1977, 101-109.

27. "Limit Design of Mine Pillars Under Uncertainty," W. G. Pariseau, Design Methods in Rock Mechanics (S. L. Crouch and C. Fairhurst, editors), Am. Soc. Civil Engrs., N.Y., 1977, 287-301.

28. "Optimal Assignment of Trucks to Shovels in Open Pit Mines," B. Daud and W. G. Pariseau, Proc. 13th Internat. Symp. on the Application of Computers in the Mineral Industry, University of Clausthal, Germany, Oct. 6-11, 1975.

29. "Thermoelastic/Plastic Analysis in Rock Mechanics," W. G. Pariseau, Numerical Methods in Geomechanics (C. S. Desi, editor) Am. Soc. Civil Engrs., N. Y., 1976, 1168-1187.

30. "A Support Performance Prediction Method for Hydraulic Backfill," W. G. Pariseau, J. R. M. Hill, M. M. McDonald and L. M. McNay, U. S. B. M. R. I. 8161, 1976, 1168-1187.

31. "Experimental Observations of Velocity Discontinuities in Flowing Sand," W. G. Pariseau, The Effects of Voids on Material Deformation, Am. Soc. Mechanical Engrs., Applied Mech. Div., 16, N. Y., 1976, 47-70.

32. "Post-Elastic Vibrating Wire Stress Measurements in Coal," W. G. Pariseau and I. M. Eitani, Proc. Internat. Symp. on Field Measurements in Rock Mechanics, 1977, 255-273.

33. "Statistical Analysis of Laboratory Compressive Strength and Young's Modulus Data for the Design of Production Pillars in Coal Mines," W. Sorenson and W. G. Pariseau, Proc. 19th Symp. Rock Mech., May 1978.

34. "3D Mine Pillar Design Information from 2D FMB Analysis," W. G. Pariseau and W. Sorenson, Internat. J. Numer. Anal. Methods Geomech., 3, 1979, 145-157.

35. "A Note on Monitoring Stress Changes in Situ," W. G. Pariseau, Intl. J. Rock Mech. Min. Sci & Geomech. Abstr., 15, 1978, 161-166.

36. "Rockslides and Avalanches: An Introduction," B. Voight and W. G. Pariseau, Rockslides and Avalanches (B. Voight, editor) I, (Natural Phenomena) Elsevier Scientific Pub. Co., Amsterdam, 1978, 1-67.

37. "A Simple Mechanical Model for Rockslides and Avalanches," W. G. Pariseau, Engineering Geology, 16, 1980, 111-123.

38. "Elastic-Plastic Finite Element Analysis of Hopper Filling and Flow Initiation," W. G. Pariseau and D. E. Nicholson, Mechanics Applied to the Transport of Bulk Materials, Applied Mech. Div., Am. Soc. Mech. Engrs., 31, 1979 61-77.

39. "Finite Element Approach to Strain Softening and Size Effects in Rock Mechanics," W. G. Pariseau, Numerical Methods in Geomechanics, (W. Wittke, editor), Blakema, 2, 1979, 545-558.

40. "Elastic-plastic and Elastic-brittle Finite Element Analysis of Cave Zone Growth in Response to Longwall Face Advance," W. G. Pariseau, Proc. 20th U. S. Symp. of Rock Mechanics, U. of Texas, 1979, 541-553.

41. "Inexpensive but Technically Sound Mine Pillar Design Analysis," W. G. Pariseau, Internation. J. Numer. Anal. Methods Geomech., 5, 1981, 425-447.

42. "Comparisons between Finite Element Calculations and Field Measurements of Room Closure and Pillar Stress during Retreat Mining," W. G. Pariseau and I. M. Eitani, Internat. J. of Rock Mechanics and Mining Sciences and Geomechanics Abstracts, 18, 1981, 305-319.

43. "Rockslides and Avalanches: Basic Principles and Perspectives in the Realm of Civil and Mining Operations," W. G. Pariseau and B. Voight, Rockslides and Avalanches - 2 (Engineering Sites), (B. Voight, editor), Elsevier, Amsterdam, 1979, 1-92.

44. "Finite Element Method Applied to Cut-and-Fill Mining," W. G. Pariseau, Application of Rock Mechanics to Cut-and-Fill Mining, University of Lulea, Sweden, 1, 1980, 447-481.

45. Shear Stability of Mine Pillars in Dipping Seams," W. G. Pariseau, Proc. 23rd U. S. Symposium on Rock Mechanics, Chap. 105, AIME, N.Y., 1982.

46. "Safety and Stability in Rock Mechanics Design Analysis," W. G. Pariseau, Proc. 24th U. S. Symposium on Rock Mechanics, Association of Engineering Geologists, 1983.

47. "On the Use of the Computer for Ground Control Planning," W. G. Pariseau, Proc. First Conference on the Use of Computers in the Coal Industry, Chap. 55, SME/AIME, N.Y., 1983.

48. "Linearization of In Situ Stress Change Formulas for Gages of Arbitrary Down-Hole Orientation," W. G. Pariseau, International J. for Numerical and Analytical Methods in Geomechanics, 9, No. 3, 1985, 277-283.

49. "Geomechanics of the Carr Fork Mine Test Stope," W. G. Pariseau, M. K. Fowler, J. C. Johnson, M. Poad, E. L. Corp, Geomechanics Applications in Underground Hardrock Mining, SME/AIME, N.Y., 1984.

50. "Numerical Assessment of the Influence of Anisotropy on Steeply Dipping VCR Stopes," W. G. Pariseau, and F. Duan, Geomechanics Applications in Underground Hardrock Mining, SME/AIME, 1984.

51. "Finite Element Approach to Cable Bolting in Steeply Dipping VCR Stopes," K. Donovan and W. G. Pariseau, Geomechanics Applications in Underground Hardrock Mining, SME/AIME, 1984.

52. "Recent Experience in Calibration of Finite Element Models by Back Analysis of Underground Mine Data", W. G. Pariseau, E. L. Corp and M. E. Poad, Proc. International Symposium on Large Scale Underground Mining, November 1985, University of Lulea, Sweden.

53. "Rock Mechanics of a Deep VCR Stope of the Homestake Mine," W. G. Pariseau, M. Poad, E. L. Corp and C. H. Schmuck, Application of Rock Characterization Techniques in Mine Design, SME/AIME, 1986.

54. "Numerical Simulation of Fragmentation During the Throw Stage of Blasting," C.-H. Ryu and W. G. Pariseau, Proc., Society of Explosives Engineers Mini-Symp., Atlanta, February 1986, pp. 103-117.

55. "An Alternative Solution for the In Situ Stress State Inferred from Borehole Stress Relief Data", W. G. Pariseau, Sixth International Congress on Rock Mechanics, August/September 1987, Montreal, Canada.

56. "A Three Dimensional Finite Element Analysis of the VCR Study Stope at the Homestake Mine," W. G. Pariseau and F. Duan, Proc. 5th Annual Workshop, GMTC, Mine Systems and Ground Control, Virginia Polytechnic Institute and State University, Blacksburg, 1987, pp 67-78.

57. "Stability Analysis of the VCR Study Stope at the Homestake Mine," W. G. Pariseau and F. Duan, Gold Mining 87, SME, 1987, pp 199-213.

58. "Elastic Moduli of Well-jointed Rock Masses," W. G. Pariseau and H. Moon, Numerical Method in Geomechanics (Innsbruck), Balkema, 1988, pp 815-822.

59. "Influence of Cable Bolts and Hanging Wall Stability," W. G. Pariseau, Proc., 6th Annual Workshop, GMTC, Mine Systems and Ground Control, Virginia Polytechnic Institute and State University, Blacksburg, 1988, pp 31-40.

60. "On the Concept of Rock Mass Plasticity," W. G. Pariseau, Key Questions in Rock Mechanics,.Balkema, 1988, pp 291-302.

61. "Rock Mechanics", W. G. Pariseau, Geotimes, Vol. 34, No. 2, pp 23-25.

62. "Finite Element Analysis of the Homestake Mine Study Stope: An Update," W. G. Pariseau and F. Duan, Numerical Models in Geomechanics, Elsevier Applied Science, New York, 1989, pp 566-576.

63. "Influence of Joints on the Elastic Response of a LFUFL Stope to FEM Mining," W. G. Pariseau and H. Moon, Proc. 30th U.S. Symp. on Rock Mechanics, Balkema, 1989, pp 931-941.

64. "A Comparison Between Two- and Three-Dimensional Numerical Models of a Coeur D'Alene District Mine," T. J. McMahon and W. G. Pariseau, Proc. 30th U.S. Symp. on Rock Mechanics, Balkema, 1989, pp 963-970.

65. "Ropes Mine Crown Pillar Rock Mechanics," W. G. Pariseau, A. C. Walkup, W. W. Carlson, and K. K. Wu, Proc. 30th U.S. Symp. on Rock Mechanics, Balkema, 1989, pp 909-918.

66. "Extended Three Dimensional Finite Element Analyses of the Homestake Mine Study Stope," W. G. Pariseau, M. Poad, and E. L. Corp., Proc. Int'l Symp. on Rock at Great Depth, Pau, France, 28-31 Aug 1989.

67. "Sandstone Escarpment Stability in Vicinity of Longwall Mining," R. E. Jones, W. G. Pariseau, V. Payne, and G. Takenaka, Proc., 31st U.S. Symposium on Rock Mechanics, Balkema, 1990, pp. 555-562.

68. "Three-dimensional Analysis of a Shaft Pillar at the Homestake Mine," W. G. Pariseau, J. C. Johnson, and S. Orr, Proc., 31st U.S. Symposium on Rock Mechanics, Balkema, 1990, pp. 529-536.

69. "Rock Mechanics," W. G. Pariseau, SME Handbook, Sec. 10.2, to be published.

70. "Finite Element Applications in Mining Engineering," W. G. Pariseau, Vol. 1, Chapter 27, Comprehensive Rock Engineering, Pergamon Press, to be published.

71. "Fast Engineering Analysis of Alternative Cable Bolt Patterns," F. Duan and W. G. Pariseau, Eighth Annual Workshop, GMTC, Mine System and Ground Control, 1990, pp. 3-13.

72. "Equivalent Elastic Moduli of Cable Bolted Finite Elements," F. Duan and W. G. Pariseau, Proc., Int'l. Conf. on Computer Methods and Advances in Geomechanics, 6-10 May, 1991, Cairns, Australia.

73. "Estimation of Permeability in Well-jointed Rock Masses," W. G. Pariseau, Proc., Int'l Conf. on Computer Methods and Advances in Geomechanics, 6-10 May, 1991, Cairns, Australia.

VITA
OF
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CURRENT POSITION:
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EDUCATION:
Ph.D. University of Wisconsin, Madison, 1963

EXPERIENCE:

ACADEMIC:
1974 - present: Professor, Michigan State University, East Lansing
1968 - 1974: Associate Professor, Michigan State University, East Lansing
1963 - 1968: Assistant Professor, Rutgers University, New Brunswick, New Jersey

RESEARCH - GOVERNMENT/INDUSTRIAL:
Consultant: Bear Creek Mining Co., Spokane Wa, 1964-68
Consultant: White Pine Copper Co., 1971-73
National Science Foundation Contract, 1973-75
Visiting Professor, University South Carolina 1974-75
National Science Foundation Contract, 1976-78
Consultant: Various mining, environmental, engineering and petroleum companies (as well as state and federal agencies). 1974-present
National Science Foundation contract 1979-1981
Visisting Scientist, Lawrence Livermore National Laboratory 1981-1982
Summer Fellowship, Lawrence Livermore National Laboratory 1982
Department of Energy contract 1984-87.
Various contracts and consultantships with LLNL 1988 to present
Visiting Scientist, Lawrence Livermore National Laboratory 1988-89
National Science Foundation Contract 1989-92

CURRENT RESEARCH
A. Volatile contents in magmas through infarred studies of glass inclusions.
B. Evolution of high-level silicic magmas bodies.
C. Dynamics of magma emplacement
D. Relationship between tectonics and magma emplacement

GRADUATE STUDENTS PRODUCED 1963-1991
Ph.D. 16
MS. 24

REVIEWED PAPERS

The most recent are:

Dye, J. L. and T. A. Vogel, 1978. Water and Magmas: Application of the Gibbs Duhem Equation. Geochim. Cosmochim. Acta, v. 42, p. 275-276.

Vogel, T. A. and J. T. Wilband, 1978. Coexisting Acidic and Basic Melts: Geochemistry of a Composite Dike. Jour. Geol., v. 86, p. 353-371.

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Widmayer, R. E. and T. A. Vogel, 1979. Feldspar Geothermometry of the Hell Canyon Pluton, Boulder Batholith, Montana. Contr. Mineral. Petrol., v. 71, p. 151-155.

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deGruyter, P. and T. A. Vogel, 1981. A Model for Alkaline Magmatism: Application to the Egyptian Alkaline Province. Nature, v. 291, p. 571-574.

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Noble, D. C., T. A. Vogel, P. S. Peterson, G. P. Landis, N. K. Grant, P. A. Jezek and E. H. McKee, 1984. Rare-element-enriched, S-type Ash-flow Tuffs containing Phenocrysts of Muscovite, Andalusite, and Sillimanite, Southeastern Peru. Geology, v. 12, p. 35-39.

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Mills, J. G. Jr., B. C. Schuraytz, T. P. Flood, T. P. Rose and T. A. Vogel, 1987. Evolution of a Zoned Magma System in the Southwest Nevada Volcanic Field, Geol. Soc. Am. Abst. with Prog., Annual Meet, v. 19, no. 7, p. 773.

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CURRICULUM VITAE

1. Name: Thompson Webb III
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3. Education:

   A. Undergraduate degree:
   B.S. (Honors), Swarthmore College (Botany), 1966

   B. Higher degrees:
   Ph.D., Univ. of Wisconsin-Madison (Meteorology), 1971

   C. Dissertation topic:
   The late and postglacial sequence of climatic events in Wisconsin and east-central Minnesota: quantitative estimates derived from fossil pollen spectra by multivariate statistical analysis. 161 pp.

4. Professional appointments:

I.S.T. Postdoctoral Fellow (Zoology Dept.), University of Michigan, 1970-71.
Assistant Research Paleoecologist, Great Lakes Research Division, University of Michigan, 1971-72.
Assistant Professor (Research), Brown University, 1972-75.
Research Specialist, Center for Climatic Research, University of Wisconsin-Madison, Summer (1973, 1974, 1975).
Associate Professor, Brown University, 1975-84.
Visiting Associate Professor, Department of Meteorology, University of Wisconsin-Madison, Summer 1976.
Visiting Fellow, Clare Hall and Botany School (Subdepartment of Quaternary Studies), University of Cambridge, 1977-78.
Visiting Fellow, Cooperative Institute for Research in Environmental Sciences, University of Colorado, 1988-89.
Professor, Brown University, 1984- .

5. A. Publications:

Edited Books or Issues of a Journal:

1) Webb, T. III and J.-M. Dubois (eds.). 1985. Tendances climatiques à l'Holocène en Amérique du Nord. Géographie physique et Quaternaire 39, no. 2:113-226.

2) Huntley, B. and T. Webb, III (eds.) 1988. Vegetation History. Vol. 7 in Handbook of Vegetation Science. Kluwer Academic Publ., Dordrecht, The Netherlands, (803 p.).

3) Wright, H.E., Jr., T. Webb III, W.F. Ruddiman, F.A. Street-Perrott, J.E. Kutzbach, and P.J. Bartlein (1992). Global Climate Change since the Last Glacial Maximum. Univ. of Minnesota Press, Minneapolis (in press).

B. Journal Articles and Book Chapters

1) Bryson, R. A., B. Hayden, V. Mitchell, and T. Webb III, 1970. Some aspects of ecological climatology of the Jornada Experimental Range, New Mexico. In Wright, R. G., and G. M. Van Dyne (eds.). Science series No. 6, Colorado State University, Fort Collins, p. 1-2 to 1-74.

2) Webb, T. III, 1971. The late- and post-glacial sequence of climatic events in Wisconsin and east-central Minnesota: quantitative estimates derived from fossil pollen spectra by multivariate statistical analysis. Ph.D. Thesis. University of Wisconsin, Madison, Wisconsin. 161 pp.

3) Webb, T. III, and R. A. Bryson, 1972. Late- and post-glacial climatic change in the northern Midwest, U.S.A.: quantitative estimates derived from fossil pollen spectra by multivariate statistical analysis. Quaternary Research 2:70-115.

4) Davis, M. B., L. B. Brubaker, and T. Webb III. 1973. Calibration of absolute pollen influx. pp. 9-25. In Birks, H. J. B. and R. G. West (eds.). Quaternary Plant Ecology. Blackwells Scientific Publ., Oxford.

5) Webb, T., III. 1973. Pre- and post-settlement pollen from a short core, Blackhawk Lake, west-central Iowa. Proceedings of the Iowa Academy of Science 80:41-44.

6) Webb, T., III. 1973. Lake sediments as pollen traps: numbers of pollen reflect the vegetation. pp. 117-128. In Edmonds, R.L. and W.S. Benninghoff (eds.). Proceedings of Workshop Conference II. US/IBP Aerobiology Program Handbook No. 3. University of Michigan, Ann Arbor, Michigan. 186 pp.

7) Webb, T.,III. 1973. Pre- and post-settlement pollen from a short core, Trout Lake, north-central Wisconsin. Wisconsin Academy of Sciences, Arts, and Letters, Transactions 61:141-148.

8) Webb, T., III. 1973. A comparison of modern and pre-settlement pollen in southern Michigan (U.S.A.). Review of Palaeobotany and Palynology 16:137-156.

9) Webb, T., III. 1974. Corresponding distributions of modern pollen and vegetation in lower Michigan. Ecology 55:17-28.

10) Webb, T., III. 1974. A vegetational history from northern Wisconsin: evidence from modern and fossil pollen. American Midland Naturalist 92: 12-34.

11) Webb, T., III. 1974. The pollen-vegetation relationship in southern Michigan: an application of isopolls and principal component analysis. Geoscience and Man 9:7-14.

12) Davis, R. B., and T. Webb III. 1975. The contemporary distribution of pollen from eastern North America: a comparison with the vegetation. Quaternary Research 5:395-434.

13) Birks, H. J. B., T. Webb III, and A. A. Berti. 1975. Numerical analysis of surface pollen samples from central Canada: a comparison of methods. Review of Palaeobotany and Palynology 20: 133-169

14) Webb, T., III, and J. H. McAndrews. 1976. Corresponding patterns of contemporary pollen and vegetation in central North America. Geological Society of America Memoir 145:267-299.

15) Webb, T., III, and D. R. Clark. 1977. Calibrating micropaleontological data in climatic terms: a critical review. Annals of the New York Academy Sciences 288:93-118.

16) Bernabo, J. C., and T. Webb III. 1977. Changing patterns in the Holocene pollen record from northeastern North America: a mapped summary. Quaternary Research 8:64-96.

17) Sachs, H. M., T. Webb III, and D. R. Clark. 1977. Paleoecological transfer functions. Annual Review of Earth and Planetary Sciences 5:159-178.

18) Webb, T., III, and J. C. Bernabo. 1977. The contemporary distribution and Holocene stratigraphy of pollen types in eastern North America. In Elsik, W. C. (ed.). Contributions of Stratigraphic Palynology, Vol. 1, Cenozoic Palynology, The American Association of Stratigraphic Palynologists, Inc., Contribution Series 5A:130-146.

19) Howe, S., and T. Webb III. 1977. Testing the statistical assumptions of paleoclimatic calibration functions. Preprint Volume Fifth Conference on Probability and Statistics in Atmospheric Sciences, American Meteorological Society, Boston, pp. 152-157.

20) Webb, T., III, G. Y. Yeracaris, and P. Richard. 1978. Mapped patterns in sediment samples of modern pollen from southeastern Canada and northeastern United States. Geographie physique et Quaternaire 32:163-176.

21) Webb, T., III, R. A. Laseski, and J. C. Bernabo. 1978. Sensing vegetation with pollen data: control of the signal-to-noise ratio. Ecology 59:1151-1163.

22) Peterson, G. M., T. Webb III, J. E. Kutzbach, T. van der Hammen, T. A. Wijmstra, and F. A. Street. 1979. The continental record of environmental conditions at 18,000 B.P.: an initial evaluation. Quaternary Research 12:47-82.

23) Van Zant, K. L., T. Webb III, G. M. Peterson, and R.G. Baker. 1979. Increased Cannabis/Humulus pollen, an indicator of European settlement in Iowa. Palynology 3:227-233.

24) Barry, R. B., A. D. Hecht, J. E. Kutzbach, W. D. Sellers, T. Webb III, and P. B. Wright. 1979. Climatic change. Reviews of Geophysics and Space Physics 17:1803-1813.

25) Webb, T., III. 1980. Reconstructing climatic sequences from botanical data. Journal of Interdisciplinary History 10:749-772.

26) Webb, T. III, S. E. Howe, R. H. W. Bradshaw, and K.M. Heide. 1981. Estimating plant abundances from pollen data: the use of regression analysis. Review of Palaeobotany and Palynology 34:269-300.

27) Webb, T. III. 1981. 11,000 years of vegetational change in eastern North America. Bioscience 31:501-506.

28) Webb, T. III, and G. Y. Yeracaris. 1981. Comparison of patterns in pollen data from southeastern Canada and northeastern United States. IV International Palynological Conference, Lucknow (1976-77) 3:173-187.

29) Imbrie, J., and T. Webb III. 1981. Transfer functions: calibrating micropaleontological data in climatic terms. In Berger, A. (ed.). Climatic Variations and Variability: Facts and Theories, D. Reidel Publishing Co., pp. 125-134.

30) Imbrie, J., and T. Webb III. 1981. 13. Session 12. Paleoclimate reconstruction: diagnostics and modeling -- II. p. 1017. In Winston, J. S. (ed.). First Conference on Climate Variations A.M.S., 19-23 January 1981, San Diego, Ca. Bulletin of the American Meteorological Society 62:1011-1017.

31) Arigo, R., S. E. Howe, and T. Webb III. 1982. Computer programs for climatic calibration of pollen data: a user's guide. pp. 79-109. In Berglund, B. E. (ed.). Palaeohydrological Changes in the Temperate Zone in the Last 15,000 Years, Sub-project B. Lake and Mire Environments. Project Guide. Vol. 3. Specific Methods, Dept. of Quaternary Geology, Lund, Sweden.

32) Webb, T., III. 1982. Temporal resolution in Holocene pollen data. Third North American Paleontological Convention, Proceedings 2:569-572.

33) Bartlein, P. J., and T. Webb III. 1982. Holocene climatic changes estimated from pollen data from the northern Midwest. pp. 67-82. In Knox, J. C. (ed.). Quaternary History of the Driftless Area, Field Trip Guide Book No. 5, Univ. Wisconsin Extension, Geological and Natural History Survey, Madison.

34) Webb, T. III. 1983. Calibration of Holocene pollen data in climatic terms. Quaternary Studies in Poland 4:107-113.

35) Delcourt, H. R., P. A. Delcourt, and T. Webb III. 1983. Dynamic plant ecology: the spectrum of vegetational change in space and time. Quaternary Science Reviews 1:153-175.

36) Webb, T., III, E. J. Cushing, and H. E. Wright, Jr. 1983. Holocene changes in the vegetation of the Midwest. pp. 142-165. In Wright, H. E., Jr. (ed.). Late-Quaternary Environments of the United States, Vol. 2, The Holocene, University of Minnesota Press, Minneapolis.

37) Webb, T., III, P. J. H. Richard, and R. J. Mott. 1983. A mapped history of Holocene vegetation in southern Quebec. Syllogeus 49:273-336.

38) Howe, S. E. and T. Webb III. 1983. Calibrating pollen data in climatic terms: improving the methods. Quaternary Science Reviews 2:17-51.

39) Bartlein, P. J., T. Webb III, and E. C. Fleri. 1984. Holocene climatic change in the northern Midwest: pollen-derived estimates. Quaternary Research 22: 361-374.

40) Delcourt, P. A., H. R. Delcourt, and T. Webb III. 1984. Atlas of paired isophyte and isopoll maps for important eastern North American tree taxa. The American Association of Stratigraphic Palynologists, Inc., Contribution Series No. 14, 131 pp.

41) Webb, T., III. 1984. Letter to the Editor (on fire history). Bulletin of the Ecological Society of America 65:2.

42) Webb, T. III. 1984. A global paleoclimatic database for 6 and 9 ka B.P. Annals of Glaciology 5:236-237.

43) Webb, T., III. 1984. Discussion of "Late-Quaternary Vegetational Dynamics and Community Stability Reconsidered." Quaternary Research 22:262.

44) Bartlein, P. J. and T. Webb III. 1985. Mean July temperature at 6000 yr B.P. in eastern North America: regression equations for estimates from fossil-pollen data. Syllogeus No. 55:301-342.

45) Webb, T. III. 1985a. A Global Paleoclimatic Data Base for 6000 yr B.P. Final Report for DOE Contract DE-AC02-79EV10097, TR018, Carbon Dioxide Research Division, Office of Basic Energy Sciences, Office of Energy Research, U.S. Dept. of Energy, Washington, D.C. (available from N.T.I.S., Springfield, VA 22161). 155 pp.

46) Webb, T. III, J. E. Kutzbach, and F. A. Street-Perrott. 1985. 20,000 years of global climatic change: paleoclimatic research plan. In T. F. Malone and J. G. Roederer (eds.). Global Change. ICSU Press Symposium Series No. 5. Cambridge University Press, Cambridge, pp. 182-218.

47) Webb, T. III. 1985b. Holocene palynology and climate (Chapter 4). In Hecht, A. D. (ed.). Paleoclimate Analysis and Modeling, J. Wiley and Sons, Inc., New York, pp. 163-195.

48) Bradshaw, R. H. W. and T. Webb III. 1985. Relationships between contemporary pollen and vegetation data from Wisconsin and Michigan, U.S.A. Ecology 66:721-737.

49) Overpeck, J. T., T. Webb III, and I. C. Prentice. 1985. Quantitative interpretation of fossil pollen spectra: dissimilarity coefficients and the method of modern analogs for pollen data. Quaternary Research 23:87-108.

50) Gaudreau, D. C. and T. Webb III. 1985. Late-Quaternary pollen stratigraphy and isochrone maps for the northeastern United States. In Bryant, V.M., Jr. and Holloway, R. G. (eds.). Pollen Records of Late-Quaternary North American Sediments, American Association of Stratigraphic Palynologists, pp. 247-280.

51) Webb, T. III and T. M. L. Wigley. 1985. What past climates can tell about a warmer world. Chapter 7. In MacCracken, M. C. and Luther, F. M. (eds.). DOE State of the Art Report: Projecting the Climatic Effects of Increasing Carbon Dioxide, Department of Energy, Washington, D.C., pp. 235-257.

52) Solomon, A. M. and T. Webb III. 1985. Computer-aided reconstruction of late-Quaternary landscape dynamics. Annual Review of Ecology and Systematics 16:63-84.

53) Webb, T. III and J.-M. Dubois. 1985. Presentation for Special Issue on the Holocene climatic trends in North America. Geographie physique et Quaternaire 39:113.

54) Arigo, R., S. E. Howe, and T. Webb III. 1986. Climatic calibration of pollen data: an example and annotated computing instructions. Chapter 40. In Berglund, B. E. (ed.). Handbook on Palaeoecology

and Palaeohydrology. J. Wiley and Sons Ltd. Publishers, London, pp. 817-849.

55) Bartlein, P. J., I. C. Prentice, and T. Webb III. 1986. Climatic response surfaces based on pollen from some eastern North America taxa. Journal of Biogeography 13:35-57.

56) Clark, J. S., J. T. Overpeck, T. Webb III, and W. A. Patterson III. 1986. Pollen stratigraphic correlation and dating of barrier-beach peat sections. Review of Palaeobotany and Palynology 47:145-168.

57) Webb, T. III. 1986. Is vegetation in equilibrium with climate? How to intrepret Late-Quaternary pollen data. Vegetatio 67: 75-91.

58) Prentice, I. C. and T. Webb III. 1986. Pollen percentages, tree abundances and the Fagerlind effect: a comparison of vegetational calibration methods for pollen spectra. Journal of Quaternary Science 1:35-43.

59) Webb, T. III. 1986. Vegetational change in eastern North America from 18,000 to 500 yr B.P. (C. Rosenzweig and R. Dickinsoneds.), pp. 63-69, Climate-Vegetation Interactions. Office for Interdisciplinary Earth Studies, Report OIES-2, UCAR, Boulder, CO.

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B. Book Reviews:

1) Review of Tree Rings and Climate (H. C. Fritts) in Science. 1977. v. 197, p. 361.

2) Review of British Quaternary Studies: Recent Advances. (R. W. Shotten, ed.) in Nature. 1978. v. 273, p. 411.

3) Review of Quaternary Palaeoecology (H. J. B. Birks and H. H. Birks) in Quaternary Science Reviews. 1982. v. 1, p. i-ii.

4) Review of Geobotany II (R. Romans, ed.) in American Scientist. 1982. v. 70, p. 647.

5) Review of Climate from Tree Rings (M. K. Hughes, P. M. Kelly, J. R. Pilcher, V. C. LaMarche, Jr., eds.) in American Scientist. 1983. v. 71, p. 651-652.

6) Review of Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science (M. J. Muller) in Bulletin of the Torrey Botanical Club. 1983. v. 110, p. 235-236.

7) Review of Paleoecology of Beringia (D. M. Hopkins, J. V. Matthews, Jr., C. E. Schweger, S. B. Young, eds.) in Arctic and Alpine Research. 1984. v. 16, p. 121-122.

8) Review of Catastrophes and Earth History: The New Uniformitarianism (W. A. Berggren and J. A. van Couvering, eds.) in Bulletin of the American Meteorological Society. 1985. v. 66, p. 309.

9) Review of An Atlas of Past and Present Pollen maps for Europe: 0-13000 Years Ago (B. Huntley and H. J. B. Birks) in American Scientist. 1985. v. 73, p. 291.

10) Review of Late Quaternary Environments of the Soviet Union. (A.A. Velicho, ed., and H.E. Wright and C. Barnosky, English Language eds.) in The Quarterly Review of Biology. 1985. v. 60, p. 386.

11) Review of Quaternary Paleoclimatology (R. S. Bradley) in Arctic and Alpine Research. 1985. v. 17, p. 467-468.

12) Review of Numerical Methods in Quaternary Pollen Analysis (H. J. B. Birks and A. D. Gordon) in American Scientist. 1986. v. 74, p. 678.

13) Review of Handbook of Palaeoecology and Paleohydrology (B. E. Berglund, ed.) in Progress in Physical Geography. 1987. v. 11, p. 302-303.

14) Review of Milankovitch and Climate (A. Berger et al., eds.) in Review of Palaeobotany and Palynology. 1987. v. 52, p. 252-254.

15) Review of Global Bio-Events (O.H. Walliser, ed.) in Bulletin of the American Meteorological Society. 1987. v. 68, p. 1280-1281.

16) Review of Climate and Plant Distribution (F. I. Woodward) in Ecology. 1988 v. 69, p. 294-295.

17) Review of Evolution and Environment in Late Silurian and Early Devonian (W.G. Chaloner and J.D. Lawson, eds.) in Ecology. 1988. v. 69: 551.

18) Review of Long-term Forest Dynamics of the Temperate Zone (P.A. Delcourt and H.R. Delcourt) in Trends in Ecology and Evolution. 1988. v. 3, p. 281-282.

19) Review of Plant Migration (J.D. Sauer) in Ecology. 1989. v. 70, p. 519-520.

20) Review of the Past Three Million Years: Evolution of Climatic Variability in the North Atlantic Region. (N.J. Shackleton, R.G. West, and D.Q. Bowen, eds.) in Bulletin of the American Meteorological Society. 1989. v. 70, p. 800-801.

21) Review of A Climate Modelling Primer. (A. Henderson-Sellers and K. McGuffie) in Ecology. 1989. v. 70, p. 1197-98.

22) Review of Plant Community History: Long-term Changes in Plant Distribution and Diversity. Chapman and Hall, New York (J.H. Tallis) in Ecology 1991, v. 72 (in press).

C. Government Panels and Workshops:

1) U.S. Department of Energy, Ecologist/Meteorologist Workshop, 1976, Douglas Lake, Michigan, August 1976.
Caprio, J., S. Barr, H. C. Fritts, D. M. Gates, D. A. James, J. E. Newman, J. S. Olson, W. E. Reifsnyder, B. W. Rust, A. M. Swain, E. G. Walther, T. Webb III, and B. Wunder, 1978. Panel I: Biological indicators of climatic variation, pp. 5-41 in Ecologist/ Meteorologist Workshop 1976, Douglas Lake, Michigan (CONF-7608116) available from N.T.I.S., Springfield, VA.

2) a) National Ocean Atmospheric Administration, Workshop to Inventory Paleoclimatic Data Banks, Harpers Ferry, W. VA, November, 1978.

b) National Climate Program Office and E.D.I.S. of N.O.A.A., Climate Data Management Workshop, Harpers Ferry, W. VA., May, 1979. Hecht, A. D., G. I. Smith, L. D. Delorme, H. Diaz, M. L. Parker, M. Shartran, T. Webb III, and P. Woodbury. 1979. Proxy and non-instrumented data resources (Working Group 5), pp. 115- 126 in Report of the Climate Data Management Workshop. Sponsored by the National Climate Program Office and by E.D.I.S. of N.O.A.A., Washington, D.C., 300 pp.

3) U.S. Department of Energy, Carbon Dioxide Effects Research and Assessment Program, Three Reports:

a) Kutzbach, J. E. and T. Webb III. 1980. The use of paleoclimatic data in understanding climatic change. pp. 163-171. In Schmitt, L. E. (ed.). Carbon Dioxide Effects Research and Assessment Program. Proceedings of the Carbon Dioxide and Climate Research Program Conference. UC-11. CONF-8004110. Office of Health and Environmental Research. U.S. Department of Energy, Washington, D.C., 287 pp.

b) Webb, T. III. 1982. The use of paleoclimatic data in understanding and possibly predicting how CO2-induced climatic change may affect the natural biosphere. Environmental and Societal Consequences of a Possible CO2-Induced Climatic Change, V. 2 (Part 17). Carbon Dioxide Research Division, Office of Basic Energy Sciences, U.S. Dept. of Energy, Washington, D.C., 22 pp.

c) Webb, T. III. 1985. Global paleoclimate data for 6,000 yr B.P. NDP-011. Carbon Dioxide Information Center, Oak Ridge National Laboratory, Oak Ridge, TN, 39 pp.

D. Meetings Attended in 1989 to 1991:

1) Climate Systems Modeling Initiative Meeting, NCAR, Boulder, CO, 1989
2) DOE Workshop on Radioactive Effects of Global Warming, Germantown, MD, 1989
3) Global Change Institute on Records of Past Global Change, Snowmass, CO, (co-director) 1989
4) International Workshop on Circumpolar Climate Dynamics and Vegetation Changes since 18,000 yr B.P., Sigtuma, Sweden, 1990
5) Ecological Society of America Annnual Meeting, Snowbird, UT, 1990
6) Climate Systems on Orbital Time Scales, Providence, RI, 1990
7) USSR/US Working Group VIII on Paleoclimates, New York, 1990
8) NATO Workshop on Paleoclimate Modeling, Paris, 1991
9) Dahlem Workshop on Global Changes in the Perspective of the Past, Berlin, 1991
10) Workshop on Paleoclimate Boundary Conditions for Climate Modeling Experiments, New York, 1991
11) COHMAP Executive Meeting, Madison, WI, 1991

E. Invited Departmental Lectures:

1) 1991: Harvard University, Woods Hole Oceanographic Institution, University of California, Berkeley
2) 1990: Brown University, Woods Hole Research Center, Mt. Holyoke College (5 college lecture)
3) 1989: University of Colorado, University of Wyoming, University of North carolina, Colorado State University, University of Iowa, University of Rhode Island, University of Virginia

Service:

A. To the University:

1) University Screening Committee for Fulbright Applications, 1991
2) University Graduate School Citation Committee, 1990-
3) Environmental Studies, Executive Committee, 1983-
4) Feinstein World Hunger Center, Advisory Committee, 1986-
5) Steering Committee for the Committee on Statistics, 1987-
6) Committee on Advanced Computing, 1989-90
7) Chair, Faculty Advisory Committee on Computing, 1986-88
8) University Research Council, 1987-88
9) Committee on Academic Computing, Ex-officio Member, 1987-88
10) Randall Councelor, 1986-88

B. To the Profession:

1) Chair, Committee on Professional Ethics, Ecological Society of America, 1988-
2) Technical Advisory Panel for EPA Global Change Program, 1988-
3) Advisory Panel for NOAA NGDC Paleoclimate Data Center, 1989-
4) Advisory Panel for North American Pollen Data Base Project, 1990-
5) Member, INQUA (International Union for Quaternary Research) Subcommission on Paleoclimatology, 1982-

6) Bureau Member, INQUA Committee on Global Change, 1987-
7) President, INQUA (International Union for Quaternary Research) Holocene Subcommission for North America and Greenland, 1982-1991
8) Editorial Board, *Review of Palaeobotany and Palynology*, 1979-
9) Editorial Board, *Quaternary Science Reviews*, 1981-
10) Editorial Board, *Journal of Climate*, 1989-
11) Editorial Board, *Journal of Vegetation Science*, 1989-
12) International Advisor, Editorial Board, *Journal of Quaternary Science*, 1986-
13) Editorial Board, *Ecology* and *Ecological Monographs*, 1985-88
14) Editorial Board, *Journal of Paleoclimatology*, 1986-88
15) Member, Academic Advisory Board, Center for the Study of Early Man, University of Maine, Orono, ME, 1985-1990
16) Program Committee American Quaternary Association Meeting, Boulder, CO, 1984 and Amherst, MA, 1988
17) Member, Advisory Committee, Virginia Coastal Reserve, LTER (Long-Term Ecological Resaerch) Site, Univ. of Virginia, 1987-1990
18) Member of Subpanel on Paleoclimatology of US-USSR Bilateral Agreement. Participant at the three meetings and negotiating sessions: November, 1976, in Moscow and Baku; June, 1978, in New York; September, 1988, in Madison, WI
19) Reviewer of 30 papers over the past two years in geological, meteorological and ecological journals
20) Reviewer of 30 N.S.F. and D.O.E. proposals over the past 2 years
21) Member, Committee of Climate Variations, American Meteorological Society, 1977-84, 1991-
22) Member, Cooper Award Committee, Ecological Society of America, 1989-90
23) Co-Director, OIES Global Change Institute, "Records of Past Global Change," Snowmass, CO, July, 1989

A. Academic Honors, Fellowships, Honorary Societies:

1) B.A. with Honors, Swarthmore College, 1966
2) Awarded an NSF Postdoctoral Fellowship for 1970-71
3) Awarded an I.S.T. (Univ. of Michigan) Postdoctoral Fellowship for 1970-71
4) Elected to membership in Sigma Xi, 1966
5) Elected as a Visiting Fellow at Clare Hall, University of Cambridge for 1977-78
6) CIRES Fellowship, Visiting Professor, University of Colorado, Boulder, 1988-89
7) Elected as a Fellow of AAAS, 1991

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APPENDIX B

CONSENSUS POSITION

I. PRIORITIZATION

Tasks to evaluate the site need to be prioritized. The objective would be to unambiguously identify tests designed to determine if the site were unsuitable. Prioritization should be based on determining which tests have a high probability of answering potential concerns, and a low probability for giving false alarms. It should be decided before characterization the potential significance of the result. This approach would reduce uncertainty by focusing the data collection toward testing hypotheses in a prioritized order of importance.

The site characterization project is a very large one with many administrative units involved. In projects as large as this one there is a tendency for many units to continue collecting data forever, regardless of the data's relevance to reducing conceptual uncertainty. For this reason we strongly recommend prioritizing tasks.

II. INTERDISCIPLINARY RECOMMENDATIONS

Many of the major problems that have been identified by this panel occur at the interface among geotechnical research areas. In order to address these interdisciplinary problems there needs to be closer integration of the program on all levels. Three specific topics are of particular concern:

1. A major recommendation of the committee is the need to evaluate fast pathways in the unsaturated zone, and to fully understand the matrix-fracture interaction. In order to assess the importance of fast pathways to waste isolation, the areas of geohydrology, geochemistry, rock characteristics, climatic changes, and tectonics will have to coordinate their efforts.

2. A major recommendation of the committee is the need to determine the origin of the steep hydrologic gradient. Although the panel agrees that there is a low risk of this steep gradient being disrupted by tectonic or volcanic activity, the site characterization program loses credibility if this gradient is not understood. Understanding the origin of this gradient would help build a scientific consensus about the evaluation of site suitability, and for this reason it is an important task. Other important questions to ask in this respect are:

   a. What could destroy the steep gradient?

   b. What would be the effect on containment if the gradient were destroyed?

This issue can only be resolved by an integrative approach.

3. A major recommendation of the committee is the need to understand the effect of the thermal perturbation that would be produced by the radioactive waste.

a. Would there be significant condensates produced by driving the moisture away from the repository?

b. If so, will it have any effect on containment?

This issue depends upon an integrative approach among geohydrology, geochemistry and rock characteristics studies.

III. QUANTIFICATION OF RISKS

It is the opinion of the panel that many aspects of site suitability are not well suited for quantitative risk assessment. In particular are predictions involving future geologic activity, future value of mineral deposits and mineral occurrence models. Any projections of the rates of tectonic activity and volcanism, as well as natural resource occurrence and value, will be fraught with substantial uncertainties that cannot be quantified using standard statistical methods. In most cases, critical issues will have to be decided by expert panels or peer reviews that would serve to synthesize diverse information and make educated inferences based on the available data.

NOTE: The original statements with signatures of the following reviewers are on file:

Dr. Walter J. Arabasz
University of Utah
Salt Lake City, UT

Dr. F. William Cambray
Michigan State University
East Lansing, MI

Dr. James Drever
University of Wyoming
Laramie, WY

Dr. Marco T. Einaudi
Stanford University
Stanford, CA

Mr. Don E. French
Petroleum Geologist
Billings, MT

Dr. Kip V. Hodges
Massachusetts Institute of Technology, Cambridge, MA

Dr. Thomas J. Vogel
Michigan State University
East Lansing, MI

Dr. Thompson Webb III
Brown University
Providence, RI

Kreamer's Addendum to the Consensus Document of the ESSE Peer-Review Team

I am in general agreement with the ESSE Peer-Review Team (PRT) Consensus Document. I fully agree with the group recommendation for prioritization of site characterization tasks, and I support the interdisciplinary recommendations in general. As the hydrology representative of the PRT, I believe that there are some additional issues of strong interdisciplinary concern beyond the points raised in the ESSE PRT Consensus Document. For example, in my opinion it is as important to understand ground-water travel time in the saturated zone underlying the repository site as it is to understand the postulated large hydraulic gradient north of the site. Although I am not personally convinced that the most relevant issues

regarding the steep hydraulic gradient are factors associated with its potential destruction as mentioned in the ESSE PRT Consensus Document (some preliminary models indicate there would be little effect), I strongly support the recommendation for studying the steep gradient, particularly as to the effect that small, constrained, sustainable leakage from this gradient toward the repository site might have. I enthusiastically support the need for quantification of risks mentioned in the consensus document and share in the concern that considerable uncertainties may exist. I doubt that decision-making for Yucca Mountain will ultimately be able to have great reliance on non-quantitative opinion and subjective probabilities.

NOTE: The original signed statement is on file.

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APPENDIX C

GENERAL COMMENTS

BRIGHAM YOUNG
UNIVERSITY

STAN L. ALBRECHT
ACADEMIC VICE PRESIDENT
AND ASSOCIATE PROVOST

THE GLORY OF GOD
IS INTELLIGENCE

November 11, 1991

Jean L. Younker
ESSE Task Manager
Science Applications International Corporation
Valley Bank Center
101 Convention Drive, Suite 407
Las Vegas, Nevada 89109

Dear Jean:

With this letter I am including my ESSE Comment Response Forms for the socioeconomic section of the document. Also enclosed are a couple of responses on other related segments of the report. I hope you will find these to be in the appropriate format for your purposes.

I would like to use this letter to discuss several issues that, for me, are probably at least as important as any of those addressed in the Comment Response Forms. I assure you that I understand that none of this will be new to you or to your colleagues. You have, no doubt, wrestled with these questions numerous times. I bring them up simply in the hope that an outsider's perspective might be of some value in what you are trying to accomplish (and because, I believe, that is part of the charge that is given to peer reviewers). I choose this format because it may not be necessary for some of these observations to become a part of the formal comment resolution process. I leave that decision up to you and your colleagues. Nevertheless, for me these are as critical as any comments I have on specific segments of the ESSE report.

I begin with the observation that you have produced a very fine report. To better inform myself of the whole process, I have reviewed the complete document. My sense is that you have dealt with a very broad range of difficult and complex issues in a competent and effective manner. I compliment you and your team on a job well done. At the same time, this broader review has left me with the distinct impression that the socioeconomic portions of the report are treated in a manner quite different from what is observed in the geohydrology, geochemistry, tectonics, and other sections of the document. Let me outline the understanding I have developed of why this is the case because, if I am badly informed, that lack of understanding will have important consequences for what follows.

It is my understanding that DOE, using legal precedent established in the Three-Mile Island case, is operating with the assumption that strictly social and psychological (particularly perception-based) impacts are not cognizable under NEPA. As a result, the decision has been made not to include them in the Environmental Assessment or the ESSE document. It is also my understanding that site-characterization phase impacts are defined as exempt from NEPA requirements. For these two primary reasons, DOE has concluded that any assessment of social and perception-based impacts can be delayed until a later stage of the project. After site-characterization is completed and the decision is made to continue with the project, NEPA will "kick-in" and an EIS will be undertaken. At that stage social and perception-based impacts will be considered, along with more traditional socioeconomic, demographic, and infrastructure impacts, but with the understanding that impacts must be mitigatable, rather than non-existent.

If my understanding is correct, then what we see in the ESSE is the result of a very conscious set of decisions and is guided, primarily, by DOE's apparent assessment that much of the work in this area will be postponed until the EIS. This decision, I believe, is clearly supportable but results in certain outcomes that I feel deserve some comment.

It is my impression that while most of the other areas of the ESSE document focus on the business of <u>science</u>, the socioeconomic section is more a reflection of <u>process</u>. For this reason, this is quite unlike the typical peer review with which I have been involved. In the more usual case, the attention of the reviewer is directed to questions of the appropriateness of the research methods employed, the various assumptions that have guided the analysis, the analysis itself, and the interpretations that follow from the analysis. Because there is relatively little of that here one has little basis for assessing methods, analysis, or interpretation. Instead, the reader is left with the task of determining the validity of a process--a process that has apparently resulted in the decision to delay fundamental decisions and conclusions until a later stage of the project or until an EIS is required. My most basic observation, then, is that while there may be little reason to disagree with the fundamental conclusions reached by the core team relative to qualifying and disqualifying conditions for socioeconomics, the fact remains that most of the serious and important data collection and analyses, activities are projected into the future and so most of the more difficult decisions will be delayed until then. This sequence seems quite unlike what is occurring in other areas of the report where the really important research and analyses are ongoing and, consequently, affecting the process much earlier.

I have compared the Environmental Assessment with the ESSE document and concur that one can justify at least a lower-level suitability finding on the socioeconomic qualifying condition. I also believe that additional study will not result in the identification of unmitigatable social and/or economic impacts that will occur if a repository is developed at the Yucca Mountain site. The uniqueness of this qualifying condition, of course, is that it doesn't ask if impacts will occur; it is concerned, instead, with the question of whether or

not impacts that will result can be mitigated. There is ample evidence in the literature that those demographically driven impacts typically identified as infrastructure changes in a community--i.e., demands for additional housing, new schools, greater law enforcement capability, and so on--can be mitigated if sufficient resources are provided to that community. This suggests that there really isn't anything here that would be likely to be a "project stopper." However, as I will detail below, this is only part of the problem. There is that other set of possible impacts that the procedure has excluded, impacts that may not be so easily mitigatable and, as a result, may become more problematic as the project develops.

I believe that the lower-level suitability finding for the disqualifying condition can also be supported. In this case, it seems quite appropriate to delay a higher-level suitability finding until the additional water resource information can be assembled and analyzed from both quantity and quality standpoints. I agree with the ESSE team, however, that there is little likelihood that this additional information will result in serious problems for the project.

This leads to my primary concern. Since there is little opportunity in this review to assess the presentation of data and the conclusions that would follow from that data--primarily because most of the data gathering and analysis are projected into the future--there is a significant need to provide further elaboration of the process that has led you to where you are. In other words, the core team has reached a conclusion--that most of the socioeconomic work will be done in the future as part of the projected EIS--and the reader needs more information on the steps followed in reaching that conclusion. That could probably be done in a relatively straight-forward statement somewhat along the lines of the understanding I have outlined above. You could provide whatever detail you define as sufficient to help the reader understand the reasons for the particular approach that has been adopted. As long as it isn't entirely clear exactly what process was followed in reaching the procedural approach used, then I believe the document will be left open to significant criticism from a broader reading audience. Those on the core team who have been involved from the beginning in the politics of this process, and who understand why DOE has reached certain conclusions about what will be done and what will not be done in the socioeconomic sections of the report, can probably feel quite comfortable with what is here. But for those not privy to that whole process, the report will appear to ignore some of the major issues that many will feel need to be addressed. I will say a bit more about this below. The specific request here is that since many important decisions have been deferred to the future, the reader deserves some more detailed explanation of why the decision to do this was reached and why alternative approaches were not adopted.

Let me turn to a related set of issues that, I believe, flow directly from those referred to above. The social science literature generally concludes that the political nature of this kind of assessment and the perceptual issues that flow from it are of central importance

in the nuclear arena. As you are well-aware, this makes the socioeconomic assessment of projects with a nuclear focus quite different from other large-scale development projects. Should any acknowledgement of this be made in the ESSE, even independent of the kind of work that might later be reflected in an Environmental Impact Assessment? It might be helpful to at least acknowledge your awareness of this debate, given its centrality in the literature, rather than just ignore it altogether. Because you have already done a great deal of good work that is relevant to the political nature of the process--i.e., extensive public information efforts, etc.--I would recommend that somewhat more detail be provided in the ESSE on the kinds of interactions that have occurred and that will occur with the various interested political entities and with the general public. Additional reference to the negotiation process might also be considered.

I must admit that I remain concerned that many social science reviewers of the document will object to the fact that virtually no attention is given to perception-based issues. Because many analysts believe that such perception-based impacts are the things that most set nuclear-related projects apart from other large-scale development projects, I believe that some will fault you for not including them. I also believe that questions of this type will come up regularly in the public response phase of the work and will be used by the state and other interested parties to criticize your effort. I personally do not believe, as some apparently do, that there will be <u>substantial</u> impacts associated with perception-based concerns on the tourist industry or on the communities more generally. However, this does not mean that such issues should be ignored. Perhaps the greater detail I am suggesting on the process of decision-making will help alleviate these concerns.

If you decide to include some additional detail on the decision process in the ESSE, I would urge you to maintain the conceptual distinction between socioeconomic assessment activities and public participation in the nuclear waste siting decision. The latter should inform, but be conceptually distinct from, the former. Both are an essential part of the effort, but they are quite different activities. Public participation is important because of the very complex political nature of this whole effort. The procedure, as outlined, requires careful and thoughtful input from the public. On the other hand, socioeconomic assessment is the application of science to the decision-making process. It is done to provide decision-makers with a clear understanding of the socioeconomic impacts that might result from the project and, in this case, with a clear sense of the extent to which anticipated impacts can be appropriately mitigated. Both types of activities are required to comply with regulatory requirements; both can also help protect against the occurrence of undesirable outcomes.

Finally, and this is one area that I will emphasize in my comment response forms, it seems to me that you simply must acknowledge the work on potential social and perception-based impacts that has been done by others since the Environmental Assessment. While DOE may have decided that you are not required to do any of this work yourselves at this stage of the project, it seems to me that a state-of-the-art understanding of the work of

others should be included in the report. This, too, would help alleviate some of the criticisms that you are not doing more of this work yourselves.

I hope these observations are helpful. Again, I am choosing not to include most of them on the response forms because it may not be particularly helpful to get them into the comment-response process. What is more, if I am seriously off-base with any of this, you can simply choose to ignore it.

If you have questions or reactions to any part of what is here, please let me know. I don't see many challenges with resolving the other comments I am making on the report.

Best Regards,

Stan L. Albrecht

Stan L. Albrecht

Enclosures

[redacted]

November 12, 1991

Dr. Jean Younker
Science Applications International Corporation
101 Convention Center Drive, Suite 407
Las Vegas, Nevada 89109

Dear Dr. Younker:

Here are my formalized comments from a careful, in-depth review of the *Report of Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada (Preliminary Draft, August 1991)* (hereafter referred to as the ESSE Report).

For convenience, I've classified my comments into three categories—major, minor, and editorial—described as follows:

- Comment (major)—addresses substantive, important issue(s) or major conclusions
- Comment (minor)—involves observation judged to be worth noting, but of secondary importance
- Comment (editorial)—relates to minor problem(s) of text, such as syntax or composition

For perspective, let me outline some of the thoughts that guided me in my review, given my responsibility to assimilate a great amount of technical information—not only from the report itself, but also from its supporting references and from briefings by members of your core team regarding ongoing investigations.

As plainly spelled out in the *Peer Review Plan*, my foremost responsibility was "to confirm the adequacy of information presented in, and the methodology used in the analysis of, the ESSE Report, taken with its supporting references, as to whether it presents an objective and technically defensible view of the suitability of the Yucca Mountain site with regard to the 10 CFR Part 960 siting guidelines."

My review focuses on seismic hazards, relating primarily to siting guidelines for preclosure and postclosure tectonics. Also, I understood my responsibility was to address not only scientific aspects of the ESSE Report, but also "compliance" of the report with the legal guidelines of 10 CFR Part 960.

During the course of my review, my appreciation increased for the value of "checks and balances" between scientific, engineering, and regulatory aspects of the siting process. In the case of the Yucca Mountain site, there's abundant complexity to be dealt with, and much of the earth science information in hand tends equivocally to support multiple interpretations. My particular view is that engineers—"as problem solvers"—have the ability to bring closure to the seemingly open-ended deliberations and multiple-working hypotheses of earth scientists. By modeling and quantifying in probabilistic terms the diverse performance characteristics of the site—carefully taking into account uncertainties and consequences if wrong—engineers will ultimately define, I believe, the bounds of "relevance" of particular earth-science information to solving the problems at hand. Earth scientists, of course, will provide the necessary "reality check." Regulators, on behalf of society, will use their best judgment to legally define the level of acceptable risk—bringing to closure the decision-making of both the engineers and the earth scientists.

I've intentionally tried to keep in mind that the purpose of my review wasn't to find "truth" amid competing hypotheses, nor to provide a solution for any of the complex problems involved. Rather, the focus of the review was to question whether "the weight of evidence so far indicates that Yucca Mountain is suitable for development of a geologic repository." (Executive Summary, p. E-1, para. 1.) From the viewpoint of seismic hazards as they relate to preclosure and postclosure tectonics guidelines, I agree with the authors of the ESSE Report that "the available evidence supports a conclusion that the site is suitable, although additional information is needed in specific areas to strengthen this conclusion." (Executive Summary, p. E-1, para. 1.)

It's a tribute to you and your team that the majority of my review comments are either minor or editorial. Simply put, your team did a good job of playing its own devil's advocate.

Thank you for the opportunity of being involved in this process.

Sincerely,

Walter J. Arabasz

Walter J. Arabasz

P.S. Attachment 1 lists references cited in my comments that don't appear in Section 5 of the ESSE Report. Attachment 2 lists a few typographic errors in the report.

Don E. French
Petroleum Geologist
[redacted]
[redacted]

November 27, 1991

Peer Review of Early Site Suitability Evaluation,
Yucca Mountain Potential Repository,
Section 2.3.8.3.2.2,
Human Interference Technical Guideline:
Natural Resources: Coal, Oil, and Gas

INTRODUCTION

These documents and comments constitute work done for the Peer Review of the Early Site Suitability Evaluation (ESSE) of the Yucca Mountain Site Characterization Project during August-December, 1991. This work was done under contract to Science Applications International Corporation. My assignment was to review and comment on the statements concerning petroleum and natural gas resources in the ESSE. This topic is discussed in the Human Interference Technical Guideline, Section 2.3.8 of the ESSE. It was also made clear that any comments outside my specific assignment would be welcome.

SUMMARY OF PEER REVIEW

Activity

The following paragraphs summarize the work conducted and include a few observations and recommendations that are general in nature and do not elicit a response from the authors of the ESSE. A short paper following this document concerning the habitat of oil and gas in the Basin-Range Province was written because of a deficiency in technical literature on this subject. Following the habitat paper are 13 comments prepared in review of the ESSE. The first comment is a compilation of editorial suggestions to be used at the discretion of the ESSE authors. The remaining 12 comments address the substance of parts of the ESSE.

This review required reading various support documents, and meetings and discussions with ESSE Core Team personnel. The Environmental Assessment of the Yucca Mountain Site (1986) and the Site Characterization Plan of the Yucca Mountain Site (1988) were provided and read in part. Various published and unpublished reports that are germane to the assignment were also examined. The ESSE arrived for review during the last week of August. I attended meetings of the Peer Review Panel on August 14-15 in Las Vegas, and October 23-24 in San Diego. Meetings were also conducted with Steve Mattson of the Core Team in Billings on September 13-14, and in Las Vegas on November 14-15. A preliminary compilation of the comments by the Peer Review Panel members arrived and was read during the week of November 18.

Results

The results of my review are in the form of the comments and documents provided here. This work was facilitated by numerous discussions with various members of the Core Team and the Peer Review Panel. I found the professionalism and honesty of the Core Team members to be exemplary; this is reflected in the ESSE. On some occasions there was concern expressed about how the document would be received by regulatory agencies and interest groups, but I recognized no prejudicial advocacy for or against the site.

The Peer Review Plan calls for a judgment by the reviewer on the presentation of information and appropriateness of findings, higher or lower level, on the Qualifying and Disqualifying Conditions of the relevant technical guideline in the ESSE. The discussion of oil and gas resources is a subheading under the Human Interference Technical Guideline. This guideline has a single Qualifying Condition and a single, two-part Disqualifying Condition. Because my expertise is limited to petroleum resources, my judgment of the discussion and findings of this guideline is restricted to the relevance to those resources, and does not constitute approval or disapproval of the findings as they relate to water, coal, geothermal, or other mineral resources of the area.

The review information pertaining to oil and gas resources of the Yucca Mountain area given in Section 2.3.8.3.2.2 is unbiased and objective. The paucity of publications relating geologic models for the occurrence of oil and gas in the Basin-Range region resulted in an uneven discussion of those models. This situation is addressed by the comments enclosed herein, and the following document on the habitat of oil and gas in the Basin-Range region.

The findings on the conditions of the Human Interference Technical Guideline are presented in Section 2.3.8.4:

Qualifying Condition	Lower level suitability (Level 3)
Disqualifying Condition	
Part 1	Higher level suitability (Level 2)
Part 2	Higher level suitability (Level 2)

I judge the findings outlined in Section 2.3.8.4 to be acceptable as they pertain to petroleum and natural gas resources. This acceptance is made with a recommendation for the Qualifying Condition as outlined below.

REMARKS

Human Interference Technical Guideline: Future Developments and the Qualifying Condition

The identification of natural resources is affected by perceived value in addition to geologic circumstances. Changes in technology and theory of occurrence can alter the perception of value and accessibility of a resource. It is conceivable that factors of perception, external to geologic conditions, could affect the assessment of natural resources for the Yucca Mountain area. This question is circumvented in the discussion of Issue 3 (p. 2-110) in the ESSE by adhering to the regulatory definition of "foreseeable future" as a period of 30 years or less. This definition was probably adopted because it is impractical to consider all possible eventualities. I concur with this reasoning, but logic also indicates that the Qualifying Condition of the Human Interference Guideline should contain the flexibility to adjust to unforeseen developments.

Various members of the Core Team have indicated the likelihood of reevaluation of the Human Interference Guideline at the time of repository closure. However, there is a connotation of finality when a Qualifying or Disqualifying Condition is given a higher level suitability assessment. Therefore, as part of the deliberation for a higher level-suitability finding, I believe it would be prudent to explicitly acknowledge the desirability of periodic reevaluation of the Qualifying Condition of the Human Interference Guideline. This review should include both the regulatory definition of the Qualifying Conditions and the suitability finding under that condition. The tacit assumption would then be made that the suitability finding could be abandoned and restored as circumstances required.

Implementation of the Peer Review

The evaluation of the Yucca Mountain area as a repository site can be characterized as a iterative process of research, compilation, and review. The Core Team has completed a formidable task in compiling the results of research in widely diverse fields into the ESSE. However, some consideration should be given to the best method of implementing the review

segment of the evaluation process.

Periodic peer review of the site evaluation will provide the opportunity to identify points of oversight and conflict, and to reassess the prioritization of research tasks. Errors of oversight are likely to occur when the impact of research in one discipline is not recognized in another. Review will also highlight areas of disagreement among specialists. Resolution of these conflicts will involve devising appropriate tests and prioritization of future investigations. Thus, the review can be used to focus research and improve the efficiency of the site characterization.

For these reasons the process of review is important to the site evaluation. Because of the competency of the persons involved, the peer review of the ESSE has been well executed in the face of severe time and logistic constraints. But I believe that some modification of the implementation of the peer review plan will maximize the usefulness of the review process. Core Team and review panel members should conduct an initiation meeting for the purpose of introducing the problem and identifying the amount and location of background material that reviewers will have to assimilate to conduct a proper review. It might also be useful for the review panel to convene later in a workshop format so that comments and observations can be exchanged and the expertise of the specialists can be applied across disciplines. Although these activities will cause additional expense at the time of review, this is easily justified by the potential for substantial savings through greater efficiency in ensuing research stage.

ACKNOWLEDGEMENT

This assignment could not have been completed without the cooperation of the members of the Core Team. They were universally helpful and at no time was it indicated that my comments were unwanted or inappropriate. Differences concerning content of the ESSE were openly discussed and usually resolved to our mutual satisfaction. Their work in assembling the material on this complex and controversial subject is commendable.

Don E. French, Consulting Petroleum Geologist
Billings, Montana

Don E. French
Petroleum Geologist
[redacted]

November 10, 1991

Re: Early Site Suitability Evaluation,
Yucca Mountian Potential Repository,
Section 2.3.8.3.2.2,
Human Interference Technical Guideline:
Natural Resources: Coal, Oil, and Gas

The attached document, "Habitat of Oil, Great Basin Region, and Implications for Exploration," is included for the purpose of clarifying some of the points made in my review comments of the Early Site Suitability Evaluation (ESSE) of the Yucca Mountian potential repository, Section 2.3.8.3.2.2, Human Interference Technical Guideline: Natural Resources: Coal, Oil, and Gas. Because of the complexity of the geology of the Basin-Range Province, the conditions of generation and entrapment of oil and gas in this region are ambiguous. Because of this ambiguity there is not a well-developed consensus about the geological model that best explains its occurrence. Recognition of this fact is important when reviewing the literature pertaining to oil and gas in the province. In this paper I have attempted to isolate some aspects about the occurrence of hydrocarbons that I believe are important.

Don E. French, Geologist
Billings, Montana

Habitat of Oil, Great Basin Region, and Implications for Exploration

This summary is a broad generalization of the possible conditions of generation and accumulation of hydrocarbons in the Great Basin part of the Basin-Range Province. It is not comprehensive, and conclusions expressed here should not be accepted as universal.

A key aspect to exploration in the Great Basin is the identification of generation sites in time and space. After generation sites have been located it is possible to delineate the type of play that is appropriate. For example, if a post-Miocene generation site is identified, exploration should focus on nearby fault-block traps; whereas the existence of a Mesozoic-age site implies that accumulations are in anticlinal traps or have remigrated to fault-block traps. The possibility of post-Miocene age generation charging a large Mesozoic-age anticline without influence by Basin-Range structure is remote because of the time-and-space relationship of these structures to the generation site. The following comments outline the geologic elements that impart lower probability of success to exploration in the ranges as compared to the basins of the Basin-Range Province.

Basins of the Basin-Range Province are distinguished from the ranges by the presence of a sequence of valley fill sediments of Miocene to Holocene age with an unconformity at the base of the sequence. The presence of a permeability barrier at this unconformity modifies local heat flow. Above the unconformity heat flow is reduced by the circulation of meteoric water. This influence is mitigated below the unconformity and the permeability barrier acts as a thermal blanket. The existence of this blanket has an important effect on exploration strategy

Within the ranges, where the barrier is not present, a potential source rock must be adequately buried by pre-Miocene age strata. Because of the depositional history of the region, in most ranges the bulk of pre-Miocene age overburden is comprised of Triassic and older strata. Therefore, those source rocks present at generating conditions within the ranges today reached those conditions no later than Oligocene time and possibly much earlier. Consequently, accumulations of oil generated by source rocks present within the ranges of the region have persisted through the Basin-Range Orogeny and perhaps the Sevier Orogeny.

Within the basins, where the unconformity is an effective permeability barrier, it delineates the position of a change in thermal regime. Above the unconformity, heat flow is affected by circulating meteoric water in the valley fill and the thermal gradient is similar to that observed in the ranges. Below the unconformity heat flow is commensurate with the thin crust of the region, and the thermal gradient is steeper. The effect of the barrier is to create a thermal blanket which reduces the amount of overburden required to bury source rocks to generating conditions. Consequently, the thickness of Miocene-Pliocene age valley fill is less important to the thermal conditions in the bottom of a Basin-Range graben than the effectiveness of the permeability barrier at the base of the sequence. Generation conditions will exist under a wide variety of combinations of burial beneath pre-Miocene and post-Oligocene age strata. An important implication is that the source rocks within the basin must have had some generation potential prior to the onset of the Basin-Range Orogeny.

Because of the conditions described above, accumulations in the ranges of the province must be the result of one of the following circumstances:

1) the product of a generation and migration episode that predates the Basin-Range event and has not been disturbed by subsequent deformation.
2) the product of remigration from an accumulation that formed prior to the Basin-Range Orogeny
3) the product of migration from a generation site that presently exists in a basin in the vicinity.

Because of the complexity of structure produced by the Basin-Range Orogeny, traps with the greatest probability of containing accumulations are those that are close in time and space to a generation site. Items 1-3 above indicate that prospects located in the ranges of the province will be less likely to contain hydrocarbons that those located in the basins.

Don E. French
November 2, 1991

THE UNIVERSITY OF UTAH

Professor W. G. Pariseau
The Malcolm N. McKinnon Endowed Chair

November 12, 1991

Dr. Jean L. Younker
SAIC
101 Convention Center Drive
Suite 407
Las Vegas, Nevada 89109

RE: ESSE Comments

Dear Dr. Younker:

Enclosed for your consideration please find six comment response forms concerning rock properties and engineering geology features of the ESSE. The comments are somewhat general in scope. Very detailed questions such as why a Mohr-Coulomb failure criterion was used in some analyses did not seem appropriate to the overall issue of site suitability.

Initially, I was quite skeptical about the argument for locating the site in an unsaturated zone. The main reason was that any transient, saturated flow would be from the surface towards the mined region which is expected to be more permeable than the region beyond. Higher permeability fault zones that are near vertical and transect the repository horizon would assist the process. Flow would continue down through the repository towards the water table below with a potential for contamination. A climate change towards greater precipitation would aggravate the situation. The advantages of the unsaturated zone therefore appeared questionable, and a more costly saturated zone design with impermeable barriers about the waste seemed required anyway.

However, the more I examined the geologic evidence concerning rock types, structure, tectonic history and climate, the more suitable the site appeared to be. The physical evidence obtained from the geologic record and rock properties studies indicate that the site is in dry, competent rock at present and is likely to remain dry indefinitely; the site certainly is worthy of characterization, in my opinion.

At the same time, it also seemed that what was needed for engineering design and what was more a matter of scientific curiosity were quite mixed. If the repository were a purely commercial venture, it would have been done some time ago at considerably less cost. Of course, it is not a commercial

venture, so it is not clear how much should be spent on scientific curiosity for the purpose of persuading others of the feasibility of the project. A decision in this regard is necessarily political as well as scientific and complicated by special interests, scientific and otherwise.

I hasten to add that engineering design cannot be done by geologic study alone; calculations are essential. How much calculation, computer code development, verification, testing and so forth are questions that might be profitably addressed before freezing the site characterization plan. A peer review process similar to the ESSE review is a logical way of proceeding. I would add a stipulation that the reviewers remain in a advisory capacity for an appropriate time period in order to be as objective as possible in such a review.

Sincerely,

William G. Pariseau

William G. Pariseau

P.S. A fax from Tom Vogel just arrived.
I'll have to look at later.

★U.S. GOVERNMENT PRINTING OFFICE: 1992-686-180/79058