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NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

GEOLOGIC AND HYDROLOGIC INVESTIGATION OF YUCCA MOUNTAIN PEER REVIEW DOCUMENTATION

APRIL 1981

UNITED STATES
DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE
LAS VEGAS, NEVADA

HYDROLOGY DOCUMENT NUMBER 213

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INTRODUCTION

This document is a compilation of review comments on the geologic and hydrologic investigation of Yucca Mountain. This investigation is being managed by the Nevada Nuclear Waste Storage Investigations (NNWSI). The principal NNWSI participant organizations conducting the investigation are the U.S. Geological Survey and the Los Alamos National Laboratory (formerly the Los Alamos Scientific Laboratory). The objective of this investigation is to determine whether Yucca Mountain is a technically acceptable location to site an underground, high-level nuclear waste repository.

The NNWSI are a part of the National Waste Terminal Storage (NWTS) Program of the U.S. Department of Energy (DOE). The NNWSI were formally organized in 1977 and are being managed by the Waste Management Project Office of the DOE's Nevada Operations Office. The NNWSI are in the process of developing or improving the technology for high-level nuclear waste handling, containment, and isolation, and determining whether potentially suitable rock units on or adjoining the Nevada Test Site (NTS) are technically acceptable for a licensed, permanent nuclear waste repository.

The review comments compiled in this document are the result of a peer review meeting and tour conducted on September 23-25, 1980, in Las Vegas and at the NTS. The list of peer reviewers and agendas for the three days of the review precede the review comments. The correspondence transmitting the reviews are presented in chronological order. The later review commentaries are those of the NNWSI Technical Project Officers representing the U.S. Geological Survey and the Los Alamos National Laboratory. The final summary review commentary is that of the NNWSI Technical Overview Contractor, Sandia National Laboratories.

The NNWSI FY 1980 Project Plan and FY 1981 Forecast (NVO-196-13) describes the accomplishment plan and objectives of the tasks and subtasks that comprise the geologic and hydrologic investigation of Yucca Mountain. The task and subtask activities are subject to internal technical reviews and quality assurance

programs. The geologic and hydrologic peer review meeting was held to obtain an external assessment of the sufficiency and quality of the program of activities involved in the geologic and hydrologic investigation of Yucca Mountain and to obtain expert recommendations for the continuance or redirection of activities. This assessment provides Project Management with external feedback on the adequacy of the scope and activities being performed to accomplish this major investigative task of the NNWSI. Programmatic decisions with regard to the review comments and recommendations as well as the NNWSI responses are embodied in current Project activities as outlined in the FY 1981 NNWSI Project Plan and FY 1982 Forecast and in internal work plans.

Peer reviewers representing appropriate fields of expertise were invited to attend the review sessions. Nationally known as well as prominent state and local scientists were selected to participate in the peer review process. Prior to the meeting, the peer reviewers were provided with Project information to familiarize them with the geologic and hydrologic investigation and how this task relates to other tasks being conducted by the NNWSI. At the meeting, the NNWSI Technical Project Officers, Principal Investigators, and technical staff members involved made detailed presentations and answered questions about their investigative activities and findings. The presentations were concluded with question and answer sessions. The peer reviewers were given a guided tour of the USGS Core Library to see representative core from the major stratigraphic drill hole at Yucca Mountain (USW-G1), samples of material collected by volcanologists and a paleohydrologist, and detailed geologic maps of the area of interest, a fault in the vicinity of Drillhole Wash at Yucca Mountain, and the major hydrologic drillhole (USW-H1) site and other Yucca Mountain drillhole sites. The peer reviewers were also given a guided overflight of the NTS and contiguous area to observe firsthand the geohydrologic topography. Immediately after the peer review meeting, the peer review panel met and summarized their overall assessment and recommendations which they orally presented to NNWSI Project Management.

GEOLOGIC INVESTIGATIONS PEER REVIEWERS

Dr. Larry Larson
University of Nevada-Reno
Mackay School of Mines
Reno, NV 89557

Dr. Richard Parizele
Penn State
340 Deike Blvd.
University Park, PA 16802

Dr. Patrick Domenico
Department of Geosciences
University of Illinois
Urbana, IL 61801

Dr. John B. Farr
Western Geophysical Company
Post Office Box 2469
Houston, TX 77001

Dr. Rudy Epis
Department of Geology
Colorado School of Mines
Golden, CO 80401

Dr. George Thompson
Stanford University
Palo Alto, CA 94305

Dr. Allan Ryall
Mackay School of Mines
University of Nevada-Reno
Reno, NV 89557

Dr. Paul R. Fenske
Desert Research Institute
Post Office Box 60220
Reno, NV 89506

Dr. Richard Wyman
University of Nevada-Las Vegas
4505 Maryland Parkway
Las Vegas, NV 89154

Dr. H. Frank Morrison
Department of Geophysical
Engineering
University of California, Berkeley
Berkeley, CA 94720

NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

GEOLOGIC INVESTIGATIONS PEER REVIEW

AGENDA

SEPTEMBER 23, 1980

8:00 a.m.	Welcome	M. Gates Manager, DOE/NV
8:15 a.m.	Program Introduction	R. Nelson Project Manager
8:45 a.m.	Introduction	G. Dixon USGS
9:00 a.m.	Geologic Investigations	F. Byers USGS
9:30 a.m.	Break	
9:45 a.m.	Hydrologic Investigations	W. Wilson USGS
10:30 a.m.	Geophysical Investigations	D. Hoover/H. Oliver USGS
11:30 a.m.	Lunch	
1:00 p.m.	Tectonics, Seismicity, Volcanism, Geochronology	W. Carr/A. Rogers/ J. Rosholt - USGS B. Crowe - LASL
2:00 p.m.	Geology of Yucca Mountain	R. Spengler USGS
2:30 p.m.	Break	
2:45 p.m.	Geophysics of Yucca Mountain	D. Hoover USGS
3:15 p.m.	Borehole Geophysics, Yucca Mountain	J. Daniels USGS
3:45 p.m.	Hydrology of Yucca Mountain	G. Doty USGS
4:15 p.m.	Summary	W. Twenhofel USGS

NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

NEVADA TEST SITE TOUR

FOR

GEOLOGIC INVESTIGATIONS PEER REVIEW

FIELD TRIP

SEPTEMBER 24, 1980

8:00 a.m.	Overflight of NTS and contiguous area
	NOTE: Plane will accommodate members of the peer review panel and selected DOE and USGS personnel. Others will be provided bus transportation to the NTS.
11:00 a.m.	Lunch at Mercury Cafeteria (bus will meet plane at Desert Rock)
12:00 a.m.	USGS Core Library
1:00 p.m.	Depart for Rock Valley by bus
1:30 p.m.	View fault trenching
2:00 p.m.	Depart for Yucca Mountain
2:30 p.m.	Arrive Yucca Mountain
4:00 p.m.	Depart for Las Vegas

NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

GEOLOGIC INVESTIGATIONS PEER REVIEW

WORKSHOPS

SEPTEMBER 25, 1980

GEOLOGY/GEOPHYSICS

8:00 a.m.	Introduction	G. Dixon/H. Oliver
8:15 a.m.	Topical Presentations	
10:15 a.m.	Break	
10:30 a.m.	Open Discussion	
12:00	Lunch	

HYDROLOGY

8:00 a.m.	Introduction	W. Wilson/G. Rush
8:15 a.m.	Topical Presentation	
10:15 a.m.	Break	
10:30 a.m.	Open Discussion	
12:00	Lunch	

1:00 p.m.	Peer Panel meets
3:00 p.m.	Break
3:15 p.m.	Summary by Peer Panel
4:15 p.m.	Adjourn

Thursday, Sept. 25, 8-12 AM

Tentative Schedule

GEOLOGY/GEOPHYSICS WORKSHOP ON YUCCA MOUNTAIN

Introduction -- Dixon/Oliver

A) Problems in resolving the Geologic setting, deep structure (2-5 km) and volcanic hazards

1) Geologic characterization -- (Need for determining configuration of Pre-Tertiary basement ----------Carr

2) Volcanic risk assessment for Yucca Mountain -------Crowe

3) Depths to magnetic basement (7200 depth) ----------Bath

4) Gravity ----------Snyder

5) Seismic Refraction ----------Healy

B) Internal structure of Yucca Mountain

1) Local Electrical Conductors ----------Hoover

2) Magnetic methods ----------Bath

3) Seis refraction/reflection ----------Pankratz

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DEPARTMENT OF MATERIALS
SCIENCE AND MINERAL ENGINEERING
ENGINEERING GEOSCIENCE

HEARST MINING BUILDING
BERKELEY, CALIFORNIA 94720
(415) 642-3804

September 29, 1980

Mr. Robert M. Nelson
Project Manager
Nevada Nuclear Waste
Storage Investigations
Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

Dear Bob,

Enclosed is my report on the review panel meeting of last week. I hope some of my comments and observations will be useful to you. My greatest criticism is contained in a section I have labelled "Overall Scientific Direction". I'm not sure that these comments are part of the charge to the committee, namely to review the technical program, but several of us had such strong feelings that the work was fragmented and lacking in a central objective that I felt obliged to report my own opinions.

Thank you very much for giving me the opportunity to review this fascinating study. You are fortunate to have such a uniformly excellent group of scientists involved in the project. It was a pleasure to see so many subprojects being carried our in such a competent manner.

Yours very truly,

HF Morrison

Professor H.F. Morrison
Engineering Geoscience

HFM/mm

enc.

EAD

Report on Review of the Nevada Nuclear Waste Storage Investigations, September 23, 24 and 25

H.F. Morrison
Univ. of Calif., Berkeley

I have broken my report into three sections: some brief comments on the review meeting itself, a lengthier section of detailed comments on the technical aspects of the investigations, and a final section on overall scientific direction.

PEER REVIEW MEETING

The schedule was very well organized and the sequence of general presentations, field trip, workshop and review panel meeting worked very well. I was disappointed in some of the presentations because of an apparent lack of focus and some inattention to the integration with other work. The overflight was extremely worthwhile, pulling together all the details of the previous day's presentation and providing a picutre of the whole setting that could not have been obtained more efficiently. While the flight was very useful, it took too much of the day and the whole meeting desperately needed another 3-4 hours of workshop interaction. In retrospect, I think the visit to the core library and drill site probably should have been dropped in favor of more meeting time.

The division of the workshops, although probably required under the time restraints, should not be made in future reviews. The hydrology and geology are much too interrelated to be discussed separately.

TECHNICAL INVESTIGATIONS

I have broken this section into Regional and Site Specific studies in the fields of Geology, Geophysics and Hydrology.

Regional

GEOLOGY: The tectonic framework for the NTS area has been well worked out. I am a little concerned that one view (USGS) may not include some interesting alternate theories for the regional fault structure. It is satisfying that the site seems to be within a stable crustal block.

I think the study of the volcanics and basalt intrusives has been very well done. How much more of this regional geology-age dating needs to be done depends very much on what sort of data base is required for the stastical predictive work.

I would strongly support further work on these statistics. It eventually will be crucial to any licensing policy to have some sort of number on the changes of local volcanism or intrusion at a repository. Since we do not really understand the detailed mechanism of such activity, the statistics can probably only be based on accurate spatial and temporal mapping of past activities.

Finally, it may be desireable to continue the search for holocene faults within the region. We did not have a chance to discuss all the work in this area but I wonder if any low sun angle photography has been used to find recent scarps. Mapping and age dating these features is crucial to the statistical evaluation of risk as is the volcanic status mentioned above.

HYDROLOGY: I was very impressed with the hydrologic studies on a regional scale, especially the paleohydrology which must be one of the best studies I have seen anywhere. I think the hydrology could benefit from more studies of the quaternary geology (again emphasizing the need to keep the geology and hydrology well coordinated) and there is much more to learn about ground water

flow regimes and travel times from isotope studies and age dating various waters.

GEOPHYSICS: In regional geophysics I detected an interest in pursuing deep crustal-upper mantle tectonism which I think is too esoteric for the goals of this program. Such things as deep crustal refraction and regional seismic networks are not germane to the issue.

There are important studies to be done when regional is interpreted to be on the scale of NTS itself. The determination of the depth and nature of the basement rocks under the tuffs is very important. Excellent gravity and magnetics have been acquired on this scale but I do not think they have been fully interpreted. I would strongly recommend some detailed 2 and 3 dimensional modelling of this data.

Seismic refraction on this scale would be *very* useful as would a permanent samll scale seismic network (along the lines of the microearthquake nets used in geothermal surveying). This network could probably be used for the refraction studies as well as for determining the existence of microearthquake activity within NTS. In my experience it is amazing how many areas deemed to be aseismic from a regional retwork point of view turn out to have strong, patterned, microearthquake activity. This sort of evidence is crucial for this study; detection of such zones can reveal current fault activity that might not have been mapped.

Finally, I would strongly recommend more heat flow work on this same NTS scale. The USGS has established an enviable track record in interpreting all sorts of important geological information from heat flow measurements. I think these measurements would be very useful in sorting out basement lithologies and could also prove useful in studying the major intrusives that seem to be detected in the gravity and magnetics.

Site Specific

GEOLOGY: The presentation of the geology of Yucca Mountain and its environs was, for me, one of the highlights of the review meeting. I was very impressed by the competence of the geologists and the thoroughness of their studies. My only strong recommendation about the mapping is that there is now a need to do some rigorous detail mapping (with plane table) to understand some of the local stratigraphy and faulting. This may also require more trenching and under good geologic direction this activity seems to be very cost effective.

In the short time available, I did not form a very clear idea of the state of knowledge on the clay mineralogy, zeolites and detailed petrology of the tuff sequences. In view of the cost of coring G-1, it seems to me that insufficient manpower has been directed to the analysis of the results. Certainly before a particular formation is identified as a potential repository, a very thorough understanding of the mineralogy and the effects of water and temperature will be needed. In some situations, for example, faults could actually be good if they allowed passage of water which allowed zeoltization which in turn would seal off the fracture. I strongly recommend that a small workshop be convened for all those working in this area including those making the physical property measurements and the well logging experts.

HYDROLOGY: I was very disappointed in the local hydrologic testing. It appears that nothing was learned from G-1 although it clearly had the potential to answer some basic questions about porosity and permeability in the tuffs. The impression that I received was that a hole was contracted and then simply not properly managed during drilling and testing. I am sure that some previous experience somewhere would have ruled out the polymer mud for a hole that could clearly have been a joint purpose hole. I was astounded to learn that testing

equipment for small bore holes was available and in routine use (at Hanford for example) but not considered for this very expensive study.

GEOPHYSICS: Inasmuch as this is in my area of specialization, I will subdivide my comments according to technique.

1) Magnetics and gravity

An excellent detail gravity map and good low level aeromag survey have been made. The low level mag survey reveals a pronounced change in magnetic character roughly over an east-west line toward the north end of Yucca Mountain. More modelling interpretation of this feature is in order and in cerain area ground mapping would be desireable. In the study of structure local stratigraphy the ground mapping could be used for quantitative estimates of location and throw of faults.

2) Electrical and Electromagnetic

A tremendous amount of dipole-dipole, Schlumberger and Slingram e.m. work has been done in the vicinity of the drill holes at Yucca mountain. The maximum depth of investigation has been about 1500 ft. The data quality appears to be good.

In my opinion, considerable interpretation of this data is required. Certainly no more studies on this scale should be undertaken until the existing data are understood. The raw data strongly suggests a basic layering but the block models confuse this picture with a bewildering array of inferred vertical contacts which could lead to an erroneous view of the area being shot through with faults. The Slingram data does show the existence of conductive zones, probably vertical, that suggest fault or fracture zones. These anomalies should be carefully interpreted and related to the dipole-dipole pseudo sections to aid in the interpretation of the latter. For that matter, ground magnetics could be very useful in the matter of

locating faults for this purpose. This electrical data could be very important in assessing this site: at the present time the interpretation and synthesis of results from different techniques needs a lot of work. The bore hole electrical studies are fascinating, especially the hole to surface methods. These need further quantitative interpretation but the picture they present of departures of the conductivity from uniform layering is very useful for determining electrical structure at depth. These studies must continue in future holes and cross hole techniques should be used when appropriate holes become available. Here again I saw no synthesis of the down hole work with the surface work.. Certainly the former would greatly aid in the interpretation of the latter.

I was puzzled by the intense concentration of electrical studies around the drill holes. If one was trying to use these techniques to assess the site why were they not more extensive spatially? I would not, however, recommend more surveys on this scale until the existing ones are interpreted.

Since the maximum depth of these surveys was probably no more than 1500 ft. I would recommend one, or probably two, long dipole-dipole lines across strike with a depth of instigation of at least 5000 ft. It would be very useful to get some idea of the electrical uniformity of a large mass of rock at the depth of the intended repository. Such a survey would require one kilometer dipoles with n spacings up to 7 or 8. I would recommend two parallel lines so that some idea of the two dimensionality of lines perpendicular to strike could be obtained.

Two further techniques might be tried. I am personally very intrigued with recent results of Self Potential (SP) surveys over faults. Since the basic mechanism involves water content and hydraulic gradients SP is often

revealing about the effects of faults on hydrology. I realize that the groundwater table is very deep at this site, but the overlying rocks are not dry; they are simply unsaturated. Strong SP anomalies are observed from faults in unconsolidated alluvium that is also unsaturated. The method is cheap to use and could lead to useful information. Finally, and again with a view to detecting faults, particularly those in which alteration has increased the conductivity, it might be useful to try a few VLF lines. This method is also cheap and in the highly resistive tuffs the depth of detection for conductive zones could be as great as 150 meters (based on 1000 meter resistivity and 10 kHz fields).

SEISMIC: The status of the seismic investigations was very well summed up by Dr. John Farr. His suggestions for some up hole shooting to determine whether detection of reflections is even possible seems a key element in further seismic studies.

I would very strongly recommend further work on the seismic P delay method. We have used the technique very successfully in studying local seismic structure in geothermal areas. In fact, some recent work by Professor T.V. McEvilly at Berkeley, in which he analyzed the spectral content of the arrivals, led directly to conclusions about a change in Q, interpreted as a change in fracture density, across the Geysers geothermal field. The importance of such a method in assessing the fracture density in a potential repository cannot be underestimated. I should reiterate that I think spectral analysis of the arrivals is essential: the delay times themselves may be difficult to pick with an accuracy sufficient to resolve features in the upper few thousands of feet. The attenuation (spectral) properties, however, are very sensitive to the near surface layers.

HEAT FLOW: I was surprised not to find heat flow studies on a local scale. There is an extensive literature on the relationship of shallow heat flow

studies and groundwater hydrology. In fact, there are groundwater exploration groups that use the technique successfully. An integration of electrical, hydrologic and heat flow studies would be *very* useful. I would strongly recommend some detailed heat flow measurements in the vicinity of the proposed repository.

OVERALL SCIENTIFIC DIRECTION

I perceive a very strong need for tighter overall scientific direction for all the investigations. Specifically I would like to list some major comments on this problem:

a) There is no definition of a target. I realize that detailed licensing criteria have not been issued but good scientific practice demands an hypothesis or model against which observations are matched. It is inconceivable to me that such an outstanding group of scientists could not arrive at a common model for a suitable repository. Without this central objective the various studies are bound to be fragmented and the overall assessment will be very inefficient.

I cannot agree with the philosophy that since some regulatory agency has not issued criteria then the only approach is to go out and measure *everything* and see what turns up. In the particular area of electrical studies, this process would take years. Obviously some objective led to the particular concentration of electrical work around the drill sites but it was neither the measure everything approach nor was it an attempt to define the bulk properties at the depth of a potential repository.

b) There is no apparent structure for synthesizing the results of different surveys. I had the distinct feeling that the occasion of the peer review meeting was the first time in a year that the various investigators had gathered to discuss results. I later learned that the USGS had had a

one day workshop. How this could possibly be sufficient since to even get an overview of what has been done required three days is not clear to me.

c) Without this strong scientific direction I can not see how criteria are ever adopted for stopping work. When, and with what evidence in hand, are certain studies terminated? What criteria are to be used for dropping the whole site or at least suspending work until the specific requirements of a repository are better defined? If the electrical methods clearly showed that the area was shot through with major electrical conductors would that kill the site? These sorts of questions must be studied quickly before very expensive surveys are continued that might later on turn out to have been foolish and wasteful.

It is possible that some guidance was expected on these matters from the peer review panel. This was not the stated charge to the panel nor could it have even been possible since some of us had no previous connection with the project and we certainly could not review all the data with broader objective of scientific direction.

I feel very strongly about the need for this tightening of the scientific management and direction. The huge amount of excellent work to date could very easily be underutilized and some even wasted unless a synthesis of it all, with some objective clearly in mind, is undertaken very soon.

DEPARTMENT OF ENGINEERING

UNIVERSITY OF NEVADA, LAS VEGAS
4505 MARYLAND PARKWAY • LAS VEGAS, NEVADA 89154 • (702) 739-3701

September 30, 1980

Robert M. Nelson, Jr.
Project Manager
Nev. Nuclear Waste Storage Investigation
Department of Energy
Post Office 14100
Las Vegas, NV 89114

RE: Geological Review
September 23, 24, and 25, 1980

Dear Mr. Nelson:

1.0 General Comments

Much excellent geologic work has been completed since last year, particularly in understanding regional and local aspects of the geologic setting of the proposed Yucca Mountain site, the tectonic geomorphology of the area and volcanic history.

However, there still appears to be a tendency of some scientists to lose track of the purpose of the various tests: locating and evaluating a possible repository site.

In order to accelerate the timetable of decision making and eventual construction of the repository, additional budgetary resources should be provided to allow several drill holes to proceed simultaneously for geologic and hydrologic studies.

2.0 Technical Comments

2.1 Geology

Work on assessment of volcanic risk has at last produces a probability (10^{-8}) of maximum risk per year. Two proposed holes, VH-1 and VH-2, may further understanding of this. However, the volcanic risk is not random, and heat flow and seismic studies in the Crater Flat area would support the risk assessment.

Data on depth to the pre-Tertiary basement is ambiguous and needs additional geophysical work. This data is needed at this time for defining the presence of the carbonate aquifer in Yucca Mountains.

The G-1 hole has shown a horizon within the Bullfrog member at a depth of 2,470-2,550' which appears to have good characteristics for a repository. Further drilling of this horizon is necessary to determine its existance throughout the area and lateral continuity of physical properties.

2.2 Geophysics

The geophysics accomplished to date is inconclusive and has also been largely concentrated on the Drill Hole Wash area. I concur with the comments of Dr. Frank Morrison concerning the need for geophysics aimed at evaluating the deeper horizons throughout the proposed repository area. The Slingram and I.P. lines at Yucca Mountain have not been laid out in a systematic pattern for such evaluation, but appear to be bunched in Drill Hole Wash.

2.2 Additional hole-to-surface geophysics holds great promise when used in conjunction with wide spacing dipole-dipole, geologic logs, and downhole geophysics. These should give a good characterization of the repository site.

2.3 Hydrology

The work recommended last year (22 holes, 3 dimensional model of ground water system) has not yet been done, yet this study is of paramount importance in assessing the site.

3.0 Conclusions

3.1 General Plan

A general plan for assessment of the proposed Yucca Mountain site is not apparent. The scientific work being done is concentrated in Drill Hole Wash which is topographically and structurally anomalous as compared to the area south and west. A plan should be prepared for site exploration and correlation of geology, geophysics and hydrology with each other and with necessary engineering aspects and constraints.

For the exploration plan I would suggest completion of good surface geologic mapping on a scale of about 1:5,000. This would be followed by a systematic array of surface geophysical methods. Several multi-purpose drill holes will then be needed to test the general area found to be of interest.

3.3 Engineering Design

In order to evaluate the area three-dimensionally, certain constraints of the ultimate engineering design should be determined. A few of these are as follows:

a) Fracture Density

At the depths under consideration there will be few open standing fractures ("water courses"). However, the plan should allow for sealing any that are discovered during construction. It is unrealistic to expect a 2,000 acre site to be completely lacking in structure.

It is more important to avoid large fracture zones that would provide conduits from major washes such as "Drill Hole Wash."

b) Stratigraphic Media Selection

Physical tests may show the moderately welded portion of the Bullfrog member to the acceptable in regard to conductivity and stability under heat load, low permeability and other physical tests.

However, access to this horizon will be difficult due to the presence of altered tuffs (zeolite and montmorillonite) which will be extremely difficult to support in a wet condition, especially if access is to be required for 30 to 100 years. It can be done, but engineered access through "squeezing ground" is expensive to build and expensive to maintain. For long term physical access there would be no problem in competent rock. In order to preserve this access a mine plan involving two shafts for access and ventilation will be required. Heat production after 30 or 100 years will be much reduced and post-sealing physical effects on rock will be very much less.

Selection of a site in Yucca Mountain should consider these factors, particularly with regard to the Topopah. Fracture premeability is high, but at that depth in the unsaturated zone is it important if other characteristics of the rock are favorable?

c) Backfill and Sealing Studies

Backfill characteristics can be designed to disperse the heat load from the cannisters to a wider area of rock face. At NTS in the weapons area there has been an extensive study of grout design to create particular geophysical characteristics. Hole sealing (stemming) falls within the same general area of study. Both are engineered systems which will be required to stem exploratory holes, seal fractures, and ultimately to backfill around the cannisters.

Early completion of the design of these materials should give confidence to ONWI and to other interested parties that containment can be successful.

I appreciate the opportunity to participate in these studies and hope that my comments will be of value to you in directing further studies in support of this important program.

Yours truly,

Richard V. Wyman

Richard V. Wyman, Ph.D., P.E.
Department of Engineering
University of Nevada, Las Vegas

RVW/t:jd

P.A. DOMENICO
Groundwater Hydrologist
P.O. Box M, Station A
Champaign, Illinois 61820
(217) 398-3861

copy sent to Ziemerhofel & Cutler 10/14/80

October 3, 1980

Robert Nelson
Department of Energy
P.O. Box 14100
Las Vegas, Nevada

Dear Bob:

This letter is intended to convey my comments and impressions of the Nevada Waste Storage Program and ongoing investigations. The presentations of September 23-25 were, for the most part, conducted on a highly professional basis, and the USGS is to be commended for their candid and frank approach in discussing the hydrologic aspects. There were some negative points, however, mostly with regard to the details of presentation. As an example, we did not receive a handout of material from the individual speakers prior to their discussions. Most of us were not that familiar with the geologic formations, their position in the geologic column, or the details that characterize them. In many cases, we had an extensive review of past work unrelated to Yucca Mountain and "one more inch" of new, possibly related material. This was especially true in the geophysical discussions. The details of the new drill hole were not brought out but we did get to see some core and come to our own qualitative conclusions. The future drilling and testing program was not considered important enough for detailed presentation within the agenda. In particular, it was not clear why the drill hole locations appeared to be clustered in one area, and the testing program was discussed only to the extent that it would include "the whole suite of geophysical and hydrological testing". Does this include oriented core samples, downhole televiewers, cameras, acoustic logs, or impression packers to delineate fracture densities, orientations, apertures, roughness, and mineral coating? These would seem to be important if the field testing program is designed specifically for fractured rocks, many of which are of the low permeability variety. Is there any intent of performing laboratory tests on core samples to obtain not only a continuous log of porosity, as has been done, but compressibility, permeability, and distribution coefficients as well? It is certainly recognized by USGS that one of the most important parameters relating to the possibility of contaminant migration is vertical permeability, especially when it is recognized that the hydraulic heads in Yucca Mountain very likely decrease with depth. How is this parameter to be measured? Are those responsible for the design of these tests familiar with single well measurement techniques that have been developed in the last ten years and are these techniques going to be employed in future testing? Answers to these as well as other questions would seem to constitute one of the main reasons for our gathering in Las Vegas.

In short, except for certain efforts discussed in more detail below, it was not clear what has been done in relation to the site specific aspects of Yucca Mountain, what is going to be done in the future, and importantly, how it is to be done. This does not imply that USGS does not have a well formulated plan or the personnel to carry it out, only that the presentations did not include these points or that time was not sufficient to go over them in detail. This prevailing view led the Committee to a unanimous conclusion that some form of geology, geophysics, and hydrology interim integration report or reports would be most beneficial at this time. USGS Open File reports on the variety of topics required for a repository decision and/or siting do not represent a suitable means of getting this information to the public. Indeed, even the scientific community has problems of awareness and accessibility. It appears time to put down between two covers exactly what is known about the Test Site along with all supporting data and methodology of testing and modeling, both current and that planned for the future. The need for supporting data and methodology would seem to preclude the USGS Professional Paper (in its present form) as a suitable medium for these results. Certainly a considerable amount of data and analysis are available on surface geology and structure, geophysics, paleohydrology, far field flow system analysis, and numerical modeling. The main information that is lacking is of the kind that can be obtained only through a comprehensive drilling and testing program, which will take more than a few years to achieve a modest beginning. I refer here specifically to ascertaining a potential target unit for a repository along with the supporting data that suggests such a unit is feasible (i.e., permeability of the various units, hydraulic heads with depth, vertical communication between the units, chemical data and isotopic dating with depth, etc.). I do not think it wise to wait until this testing program is complete prior to integrating and making public the knowledge of the Test Site that pertains to a potential repository site. This would appear to be the only way to invite valid constructive criticism, both from the public and professional groups.

With that in mind, a few of the points I make below may not be valid because I am not completely aware of all the facts. In spite of this, I have cited and discussed my thoughts on five categories of ongoing effort at the Test Site. These categories include paleohydrology, regional flow, numerical modeling, stability analysis for various mineral phases, and the drilling and testing program. This ordering of categories (paleohydrology first, drilling and testing last) is in the direction of increasing priority, at least in my view.

A. Paleohydrology Effort

The paleohydrology effort appears reasonably complete at this time, at least with regard to an assessment of what a return to pluvial conditions means in terms of site suitability. In particular, information has been obtained that bears on Paleo water table "highs". These studies have an impact on the assessment of the thick unsaturated zone as a potential repository unit. If it can be safely stated that a return to pluvial conditions will in no way endanger such a site (or any site at NTS, for that matter), the value of continued studies along these lines has to be viewed within a priority context. In a practical sense, due to conclusions already reached, such a priority is probably not very high. In a scientific sense and for purposes

of completeness, the continued dating of spring deposits (Winograd) and the fascinating rat midden studies (Spaulding) would hopefully be continued. I do not give the paleohydrologic hole a high priority.

B. Regional Flow System

In my letter of June 3, 1979, I encouraged a broadening of the effort to include the regional flow system. At that time I was aware that much work had already been done over the past 10 years or so but it did not appear anywhere in the site assessment studies except for the hydrologic modeling aspect. Over the past year and one half, much of this work has been pulled together. At this stage, I think sufficient information is now available for a reasonable delineation of groundwater discharge areas so that the priority of this continued effort is not exceptionally high. However, there is still room for improvement of a qualitatively reliable pathway analysis through the use of water dating and geochemical analysis. Two reasons may be cited for this. The first is that geochemical knowledge helps in understanding the movement of water, i.e., the geochemical patterns are often indicative of flow paths and relative flow amounts, the latter being obtained from mixing calculations. The second is that a prerequisite to isotopic methods for estimating groundwater age and flow rates is a reliable understanding of the rock-water reactions that give rise to the observed geochemical patterns. Very likely there currently exists insufficient hydrochemical data to provide unambiguous age interpretations from measured Carbon-14 data. In addition, the emphasis thus far seems to be on the use of geochemical data to delineate flow systems (i.e., the so-called Ash Meadows and Pahute Mesa systems). There is a further need for a better understanding of the mineral-water reactions which give rise to the geochemical patterns for the purpose of aiding the study of water age or to specify potential radionuclide--rock reactions which may affect transport. This work should also be extended to water samples collected in boreholes penetrating units other than the alluvium, in particular the tuff. For example, although several test holes are available on the Test Site (two of which were recently drilled, G1 and 25a-1) I am not aware of the extent of the chemical or isotopic work performed to date. Perhaps much work is underway and other work has already been accomplished, but this is impossible to ascertain without some form of synopsis.

C. Numerical Modeling

The most important point to clarify with regard to the hydrologic modeling effort at the Test Site is the basic question of the role of modeling in siting high level waste repositories. With regard to this current effort, I express some skepticism toward model predictions of specific sites. The worth of such predictions clearly rests on the quality of the input data. This data is very difficult to obtain, and at the Test Site has proven to be especially so. The input data base (hydraulic conductivities) is nonexistent and the calibration data base (hydraulic heads) is completely inadequate, something like eleven (?) observations for an area in excess of 900 square miles. The transport algorithms are particularly prone to high uncertainties in predictive values that grow out of the data sparseness. It is not likely that further drilling and testing will appreciably add to this data base, at least insofar as it relates to site specific hydrologic model-

ing. In addition, the theoretical reliability of the current formulations of the transport equations, especially in low permeability fractured rock, is being questioned in certain circles. Thus far no tracer tests have been performed to determine effective porosities, dispersivities, sorption characteristics, and groundwater velocities. Clearly there will have to be some means for determining the manner in which dispersivities in fractured rock vary with the scale of the experiment (as has been done for porous media), and for evaluating the sorptive characteristics of the fractured formation in situ. In spite of this apparent lack of a data base we are informed that a calibrated flow model is already available and that work is progressing on the transport model for fractured media. I assume this last statement (transport model for fractured media) means going beyond the equivalent porous media concept that generally prevails in transport modeling, which implies going beyond the current state of the art. I think this work comes under the heading of research and is better left to the research arm of the USGS or university groups, and not be something that is specifically tailored to the Test Site needs. The obvious reason for this is the time constraints for difficult studies of this type, manpower requirements, the need for other types of modeling, and the worth of the predictions that would be forthcoming from such an effort.

Although the comments above would appear to be negative, hydrologic modeling does have a major role to play in the assessment of sites. It should be used to improve a qualitative understanding of system behavior, to carry out parametric and sensitivity studies, to aid in the design of data collection and monitoring programs, and to aid in the design of near field repository barriers. I would urge the USGS to continue to carry out a major modeling effort, but to eventually switch emphasis from the site specific predictions which currently appear to be the purpose of the exercise to the parametric sensitivity studies discussed here. This switching in emphasis should most likely occur when information is provided on the vertical distribution of hydraulic head and permeability in Yucca Mountain, i.e., after the next two or three test holes are emplaced and adequately tested. With regard to an improved qualitative understanding of system behavior, some of the simulations cited below may be helpful.

(a) To develop hypotheses for an almost assured decrease in head with depth in Yucca Mountain. The most likely route for this downward flow is a high conductivity member (Carbonate aquifer ?) below a potential repository site, but deep enough to be undetected by drilling, or a suspected high permeability zone extending through Forty Mile Canyon. If the heads observed are anomalously low, either of these features may be acting as pirating agents for most of the flow, thereby providing high velocity transport routes to the biosphere that cannot be evaluated with the current one layer model for transport in the horizontal plane. Simulations incorporating these features can be conducted via steady state flow in a vertical two dimensional plane. Each of these simulations will provide head distributions that can be compared with those observed in the field, throwing some light on potential suspected transport routes that may then require actual verification through drilling. Given the existence of either of these permeable features and the potentially short travel times afforded by them, it very well may be that once a contaminant reaches such a zone it has, for all practical purposes,

reached the biosphere. This has at least two implications. First, it renders as secondary the question of whether the flow paths are part of the Ash Meadows or Pahute Mesa system. This could provide some guidance in the location and purpose of future boreholes. Second, it makes clear that the main line of defense against radionuclide transport (other than the engineered repository) lies in the tuff unit itself. That is, the containment will be determined by the degree of vertical hydraulic communication between the repository and the permeable feature itself. This renders the integrity of the repository unit of first rank importance, which will have to be sufficiently demonstrated, again providing guidance to the drilling and testing program.

(b) As discussed above and in the section on drilling and testing, knowledge of the vertical communication between various units in Yucca Mountain is of utmost importance. This communication (permeability) probably exists on two scales: vertical fractures or cooling joints that transect the individual ash beds, and tectonic features of large vertical extent that crisscross the entire structure. An example of the latter may be, for example, Forty Mile Canyon. This vertical permeability has not yet been measured on either of these scales and probably will never be fully ascertained on a scale that is meaningful. As a first step, both of these scales of occurrence can be studied through model calibrations. Such a sensitivity analysis for these fractures is best carried out with a set of steady state regional groundwater flow simulations in vertical two dimensional cross sections. These cross-sections should be true to nature to the extent that hydraulic head data are available and the simulated head distributions should be at least qualitatively similar to those observed in the field. This is one way to study reasonable orders of magnitude for a vertical permeability required to produce these heads. The current modeling effort treating one layer in a horizontal plane does not require this information as it does not take into account the prevailing aquifer-aquitard system.

(c) In support of my statement concerning the need for other types of modeling, near field modeling will require a system of flow that produces horizontal flow in high permeability fracture systems that bound a potential repository unit and vertical flow through the low permeability interior unit in which the repository is placed. In addition, there is a strong need for modeling the deep alluvial system as a potential repository site. In particular a flow model must incorporate the saturated-unsaturated features of the system and the effects of thermal loading. Again, the emphasis here is on sensitivity and parametric studies, and a search for a qualitative understanding of the system, not a site specific prediction. The effects of the reported low thermal conductivity of these sediments should be completely assessed in model studies, thereby providing some order of magnitude of permissible thermal loading. There is clearly some strong support for the unsaturated alluvium as a potential repository site (mine included), and the single drawback of a "low" thermal conductivity should be quantitatively assessed.

D. Stability Analysis of Various Mineral Phases

We are entering a high priority item here because there exists the potential for a site failure mechanism, certainly in the tuff of Yucca Mountain and less likely in the alluvium. I refer specifically to the reported abundance of zeolites and montmorillonite, both in the tuff and in the alluvium. My "data base" for zeolites is meager, except to say they are hydrated silicates that are likely to be unstable under thermal loading. The obvious effect on this is the production of water with a commensurate volume decrease. I will restrict most of my comments to the montmorillonite, which I feel more comfortable with, but I think similar arguments can be made for the zeolites.

Montmorillonite begins to react at about 60 to 70 degrees C, according to several in situ observations in Gulf Coast sediments. The reaction produces a large solid volume decrease due to the release of interlayer water. Under thermal loading, it would appear that fractures containing montmorillonite would be subject to opening, causing an increase in fracture permeability and the conversion of interlayer water to free water. If this permeability increase takes place between the repository and a permeable medium, the integrity of the repository is highly questionable. Even without a throughgoing permeability increase, there is a good chance for a permeability increase in the vicinity of the canisters and a considerable amount of free water developed that can drain toward the canisters. In addition, it is likely that interlayer water will be driven off with heating alone without actually completing the reaction. Most likely, similar arguments can be made for the zeolites, thereby making the effect more pronounced.

From Gulf Coast in situ measurements, the % expandable clays at 60 degrees C is about 75% (that is, at 60 degrees C, the mixed clay layer is initially 75% smectite and 25% illite). At 100 degrees C, the mixed layer is 20% smectite and 80% illite. In the Gulf Coast, this reaction zone coincides with an excess fluid pressure zone (up to 90% of the overburden pressure) which is the result of interlayer water being converted to free water in a low permeability environment, thereby permitting this water to carry a significant part of the overburden load. Such excess pressures are most unlikely in a fractured medium because, unlike a porous medium, the rock is of sufficient strength to support the overburden load. However, permeability increases and the production of free water in the fractures themselves remains a strong possibility. In the cores that I have viewed, much of the montmorillonite (and the zeolites) occur disseminated throughout the rock and are not restricted to fracture fillings. This type of occurrence can indeed produce excess fluid pressures in that the system can be considered as one of constant fluid mass (i.e., no fluid flow in response to the pressures produced), given that the temperature is sufficient to collapse the layers in individual pores and to promote a thermal expansion of the liquids thus produced. The relief of this pressure in isolated pores can come about by the fracturing of the rock, especially brittle rocks such as tuff that have little tensile strength. This, of course, provides a mechanism for the interconnection of individual isolated pores, i.e., the development of a fracture permeability and all of the problems that entails.

Zeolites and montmorillonite in the deep alluvium (if taken as a repository unit) would seem to present a lesser problem. However, the degree of saturation will certainly increase and the opportunity for near field coupled phenomena (flow of fluid in response to temperature gradients) may present some questions.

In my own work, I have had the opportunity to make calculations for the volume of water made available from the conversion of interlayer water to free water under thermal stimulation. Utilizing the Arrhenius equation, known activation energies, a given rate and extent of thermal loading, and an initial volume of expandable structured clay (collapsable), I can perceive some problem, provided activation energies are sufficiently low. This is largely theoretical work, however, which cannot be substituted for hard experimental data. For example, the composition of secondary minerals such as clays and zeolites depends to a great extent on the composition of the host rock. In turn, the amount of volume decrease caused by the release of interlayer water is determined by the composition of the clays (and, of course, the maximum temperatures). Na-rich clays swell to a greater extent than Ca-rich clays. Therefore volume loss potential is greater in the sodic variety, which is probably the variety that dominates the Test Site. The problem is much more complicated than this, however, as Na-rich clays are much more resistant to volume reduction than K-rich clays. Is the groundwater rich in Na and void of K? On the positive side, the heated groundwater will be saturated with respect to silica and clays, which can precipitate in fractures as a result of volume expansion (and consequent decrease in activity). Hence, there is the potential for a self sealing system. In addition, most experiments at atmospheric pressure may be misleading in that an increased water pressure with depth will act opposite the dehydration reaction.

I have no idea on the extent of your program, but it is clear that the possibility of phase transformations and/or the release of interlayer water and waters of dehydration must be investigated completely on the laboratory scale. Later, the results of such tests must be verified by in situ tests in any exploratory shafts and tunnels that this project may lead to. Considerable information is required in terms the types of smectite in these rocks and sediments (x-ray patterns for dioctahedral clays look quite simlar to each other and the clays do occur as mixtures, making their identification a difficult proposition), their composition, a laboratory confirmation of reacting temperatures or temperatures sufficient to drive off interlayer water under both atmospheric and simulated overburden pressures, volume changes, interlayer waters made available, and the propensity for self sealing mechanisms in heated waters saturated with silica and clays. A corresponding set of questions can be formulated for the zeolites. In view of the potential consequences, I consider this to be a high priority item.

E. Drilling and Testing Program

Priority item #1 must be a comprehensive drilling and testing program. The testing program should be tailored to low permeability rocks in general and to fractured rocks in particular. It should include tests to measure the fracture parameters discussed in the opening comments of this letter.

In addition, hydraulic head distributions in the horizontal and vertical across Yucca Mountain and the surrounding environment must be carefully and reliably ascertained. In order to be sure that the measurements represent heads at equilibrium between the measuring instrument and the formation, time must be allowed for such equilibrium to be established. This implies head measurements in permanent installations or in packed off intervals which stay undisturbed for a sufficient period of time. Horizontal and vertical permeabilities must be investigated on a local and regional scale. As mentioned previously, there are at least two scales of vertical permeability that must be recognized. The tectonic features, as a first step, can be studied through model calibrations. The smaller scale features in the ash beds themselves will require pumping tests of long duration. Due to the susceptibility of packer tests to large errors due to leakage, some form of quality control may be required. This means going back to the boreholes and retesting previously tested intervals utilizing, perhaps, a different contractor. This is especially important if the data from various boreholes proves anomalous or confusing. Other types of borehole data that are important and can be considered in a supplemental capacity includes water dating and hydrochemical measurements with depth. For example, it would be comforting to know that the waters in a potential low permeability repository unit are rather "old" or of a chemical character that is suggestive of poor communication with the higher permeability units. Other than these borehole tests, other testing will be required to determine effective porosities, dispersivities in the horizontal and vertical direction and on various scales, and sorption coefficients.

Clearly, this is an expensive and time consuming operation, but the costworthiness warrants it. There is no question that it requires a considerable amount of money for drilling but also a good supply of money has to be allocated for testing, otherwise the holes are not worth drilling. The utility of the test results can be viewed on three levels. First, the normal progression toward a repository excavation would in any area include a literature survey, surface exploration and mapping, a drilling and testing program, exploratory shafts, exploratory tunnels and drifts, in situ testing, and, if conditions warrant, repository excavation. It is unlikely that the scientific community or the public will be persuaded as to site suitability without a deep test facility, i.e., exploratory shafts, tunnels, in situ tests, etc. It is equally unlikely that you could support a recommendation for a deep test facility unless positive data are first obtained from a comprehensive drilling and testing program. For all practical purposes the program at NTS has not yet progressed beyond the surface exploration and mapping phase. Of the few holes already drilled, essentially no information of the kind discussed above was obtained. In view of the data needs and the cost of obtaining such data, it seems reasonable to consider going back to these holes (in particular G-1 and 25a-1) in an attempt to obtain such information. In addition, after G-2 is completed and tested, perhaps some thought should be given to well testing techniques that require no reaming, as gathering core and then reaming to 8 inches or so seems one way to spend money that could better be used for testing. Such testing of small diameter boreholes is well within the state of the art technology. I know of one organization that produces an air bladder submersible capable of small pumping rates with

a dynamic head lift of about 2000 feet, and capable of fitting inside a 2 inch tubing.

A second reason for obtaining the kind of borehole data discussed above is that it will remove much of the speculation concerning the site. In general, there is too much speculation and too few hard facts. The thoughts that Forty Mile Canyon is a major conduit is, whether correct or not, pure speculation. There are no hard data. The head distribution and hydraulic properties in Yucca Mountain are not known, and to assume they are favorable for a repository is speculation. Indeed, it is still speculation that a sufficiently low permeability unit of suitable areal extent and thickness (a potential repository) exists in Yucca Mountain. This kind of speculation is no substitue for hard data that can be obtained only through a comprehensive drilling and testing program.

A third reason for obtaining the kind of data discussed above is to provide some facts for which it is possible to calibrate the numerical models, both near and far field.

F. Concluding Statement

It is often said that "nothing is impossible for the man who does not have to do it himself". However, the positions discussed in this letter are, I think, sound and well within the state of the art. Certainly, the drilling and testing program envisioned will require almost constant on-site vigilance and progress. Even given this, it still requires a methodology and technology that incorporates all the advances of the past few years in borehole testing. The numerical model aspects appear to be much more than a one-man effort. The mineral stability questions would appear to require a coordinated effort by a group of specialists who are aware of what it is they wish to determine and how to determine it.

I hope this letter is useful to you and I look forward to providing any additional input that you may require.

Sincerely,

Patrick Domenico

Patrick Domenico

PAD:jr

10/21/80 copy to Pen Lake

WESTERN GEOPHYSICAL
Litton
10001 Richmond Avenue P.O. Box 2469, Houston, Texas 77001
Telephone 713 789-9600 Cable WESGECO Telex 762406

copy sent to Executive & Dir. 12/14/80

October 3, 1980

ACTION WMPO
INFO
R. F.
AMA
AM & C ✓
AND

Mr. Robert M. Nelson
Project Manager N.N.W.S.I.
Department of Energy
P.O. Box 14100
Las Vegas, Nevada 89114

Dear Mr. Nelson:

The following are my general and technical comments on the N.N.W.S.I. peer review meetings held September 23 - 25, 1980 in Las Vegas, Nevada. I enjoyed meeting the U.S.G.S., S.L. and D.O.E. scientists involved in the program and appreciated the opportunity to review a small portion of an investigation I consider to be of utmost national importance.

A. General Comments

1. The Panel

I must admit I felt somewhat alone as the only industry representative among nine university peer reviewers. This presented no problem except when I criticized certain program aspects as being too academic and less result oriented than would be considered acceptable in industry.

The university-industry difference in approach to applied research investigations is well known. Except for what I see as an urgent national requirement, along with the limited personnel, time and funding presently available, I would strongly support a meticulous, thorough and exhaustive (e.g., unlimited) academic research program into all aspects of the disposal of nuclear wastes.

In view of the urgency of the problem, I feel that a more focused, goal oriented (industrial) approach to depository siting should be considered. This is not a criticism of any of technological work done to date nor of the scientists involved, but rather of the organization and management approach to the siting program. As one of ten peer reviewers, I may be oversensitive to what I perceive as lack of focus and would strongly urge you to include more industry representatives on future peer review panels.

The lack of "governmental" peer reviews was also somewhat surprising. It would seem that qualifed peer reviewers could be obtained from "nonconflicting" federal or state agencies. Although nuclear waste disposal is a national problem, I'm sure there are research program administrators in other federal branches who could objectively contribute to the review process. Having firsthand knowledge of government funding and administrative procedures, such "governmental" peer representatives would greatly enhance the review process especially where research effectiveness is to be evaluated.

Coming from university and industrial environments, the present peer reviewers can only evaluate results without full appreciation of the problems encountered in achieving those results.

2. The Presentations

In my opinion, the oral and visual presentations made by all meeting participants were very well done. The speakers were knowledgeable and easily understood. The visuals were easily seen and properly labeled. The format and quality of the presentation is no small matter when it is almost the only avenue of communication between the scientists involved and the peer review group.

More advanced information regarding project objectives, past and proposed work, personnel and funding limitation might help if it could be made available to the peer reviewers in a timely fashion. While the N.V.O.-196-13 and N.V.O.-196-16 reports were most helpful, two weeks prior to the meeting date is too short a lead time. In addition, I found the N.V.O. reports of limited scope. A broad overview of the waste disposal problem and corresponding D.O.E. policies in addressing this problem were conspicuously missing.

I found the formal presentation format somewhat restricting in that due to time limitations, questions and discussions were curtailed. Also, when questions were raised, the answers could not be explained in depth. In a three day meeting, I don't know how this could be improved except by scheduling more informal time for discussion after each presentation or group of presentations.

One possibility for improving meeting effectiveness while retaining the short formal presentation period would be to arrange informal visits by the individual peer reviewers to the work locations where the data and results pertinent to their specialty could be reviewed prior to the meeting. Examination of this data and informal discussions with the scientists involved in the particular research program would give the peer reviewer much more insight than is obtainable in the formal meeting. Such one-day, individual reviews could occur periodically at the convenience of the reviewer and scientists involved. These reviews would provide an "in-depth" look at the project, which could then be passed along to other peer reviewers at the formal meeting.

3. Target Definition

While the geological, geophysical and hydrological investigations are being carried out in a most meticulous and thorough manner on an individual basis, there appears to be definite lack of a common perceived objective among

the scientists involved. I feel this is attributable to unclear target definition. Repeated questions to all scientists present at the meeting failed to bring out any consistent definition of what they were looking for.

No one seems to know the required waste depository dimensions (thickness and areal extent), depth of burial (minimum and maximum economic and geological limits), host rock characteristics (porosity, permeability, fracture frequency, thermal conductivity, etc.), regional location criteria (how close to capable earthquake faults, centers of historical volcanism, etc., is acceptable) or hydrological requirements (is water flow required for cooling, can depository be safely located above water table, etc.).

In my opinion, until some "target definition" can be agreed upon for a working hypothesis, a wide variety of academic research experiments will continue to go in all directions at once. This is to be expected since each scientific investigator perceives the waste depository target differently and generally as it uniquely relates to his particular field of interest. Even though each U.S.G.S. scientist is doing a meticulous, conscienous job in his particular field of research, it seems doubtful that a viable site can be localized unless these individual efforts can be more effectively focused.

4. Program Order

One additional general comment concerns the ordering of research activities. This problem could be a corollary of the above lack of target definition, but deserves separate mention.

It seems the search for a suitable waste depository target should in most ways be similar to the search for a mineral deposit or an oil reservior. Certainly the exploration methodology developed over many years by the oil and mining companies should be applicable to the exploration for a nuclear waste depository.

The commercial approach to exploration goes from regional to site specific and from least to most expensive in utilization of time, personnel and monetary assets. No commercial company drills an exploratory corehole or an exploratory wildcat well before the regional and site specific geology and geophysics are completed. In the Yucca Mountain area (in the vicinity of the G-1 well), it appears geophysical data was being acquired and interpreted after the well was drilled. Either the hole was drilled prematurely or the geophysical program was understaffed or under funded to a degree where results were not available in the proper time frame.

Detailed regional and site specific geology is clearly first in the time sequence of exploratory activities and should be completed prior to most geophysical work and certainly before any drilling is contemplated. Again, in

the Yucca Mountain area, geological investigations on both regional and site specific scales were going full tilt contemporaneously with the drilling activities.

The danger of too early commitments to large drilling expenditures before all geological and geophysical work is completely evaluated can not be overemphasized. Often one finds in the data what one wants to find, particularly when it justifies a previous expensive and irrevocable decision based on inadequate information.

Clearly, drilling is absolutely essential to site characterization. However, drilling should be used most sparingly as a final, not preliminary, check of the proposed target. It should be done only after all other types of data have been acquired and analysed. This has not been done in the Yucca Mountain area, and in the author's opinion, a more carefully ordered approach may produce a more viable end result particularly within the limited time frame available.

B. Technical Comments

1. Integration

The critical technological problems for any N.T.S. nuclear waste depository involve the hydrogeological and tectonic integrity of the target host formation. Although no definitive target parameters are available, an area of at least 2000 acres was casually mentioned as a minimum acceptable depository size. Clearly, to insure integrity of the target formation over such an extensive area will require the careful integration of regional and site specific geological, geophysical and hydrological investigations.

While it is too early to expect such an integrated data analysis at the proposed Yucca Mountain depository area, it is not premature to begin the all important integration process itself. Rather than geologists, geophysicists and hydrologists all doing their own thing, it may be worthwhile establishing interdisciplinary teams or groups. Perhaps if such a team has been active, the unfortunate duplication of 6000 foot geological hole G-1 by a second 6000 foot hydrological hole H-1 only 1500 feet away could have been avoided.

2. Borehole Considerations

While not yet defined, the number of host formation perforations by the drill should obviously be kept as small as possible. Further drilling should be stopped until a drilling technique is jointly developed to obtain good geological and hydrological information from the same hole. Hydrologists should be included when future drilling programs are outlined.

Poor target definition may be responsible for what turns out to be a fatal error. If a 2000 acre depository site is to be perforated by three or more sets of three drill holes (as scheduled in the fiscal year 1980 and 1981

forecasts) how close together they can be drilled and leave any site integrity or how far apart can they be drilled and provide reliable areal information as to host formation characteristics?

As an exercise, consider H-1 which is approximately 1300' from G-1. In locating this hole, the hydrologists anticipate communication between the holes over this distance. It would be reasonable to assume (without better target definition) that no respository boundary could be located closer than 1300 feet to any potential avenue for leakage (such as a fault or borehole). By simple geometrical construction of a 1300 foot radius around both holes it can be seen that approximately 200 acres is condemned for depository use by the presence of these two holes. Even discounting the one shaft location hole, a 200 acre non-access zone for each pair of holes rapidly depletes a 2000 acre depository site. In addition, the closer positioning of investigation holes to acquire more detailed information forces the depository further and further away into areas where no information is available.

If the 2000 or 20,000 acre depository site is to be perforated by nine or x drill holes, how close together can they safely be placed? Is the 1500 feet between G-1 and H-1 too close or too far for adequate formation characterization. Until these most important questions are adequately answered, it seems strange to continue drilling away on H-1. While not a hydrologist, I find it difficult to believe that G-1 could not be reentered, cleaned out and reamed to whatever size is required for hydrological measurements. The problems of the polymer base drilling mud just can't be so difficult to solve as to make it worth jeopardizing what may be the only suitable depository site on the N.T.S. Even if costs were much higher (which I doubt would be the case), host formation integrity would seem the overriding consideration. Modern cementing technology still leaves something to be desired especially when viewed over the 250,000 to 1,000,000 year time frame required for nuclear waste disposal.

I would urge very, very careful consideration of present and future drilling locations especially until clear guidelines are available concerning spacing, cementing, etc., of boreholes through the host formation. Since hydrogeological and tectonic formation integrity are <u>the</u> critical technological problems, it would be most unfortunate to destroy this very integrity in the process of proving site suitability.

3. Excessive Work On "No-Go" Areas

Prior to data integration, the various separate investigations can be individually evaluated for "go" or "no-go" site criteria. Precisely, this approach was successfully applied to the data acquired in the Wahmonie and Calico Hills sites which have now been relegated to a much lower status than

Yucca Mountain. Enough drawbacks in these two sites were found to make further consideration unnecessary. This "no-go" condemnation approach is to be encouraged, thereby focusing efforts on the better remaining candidate areas.

While documentation of research work is most desirable, I would suggest that too much time has been devoted to Wahmonie and Calico Hills, if the percentage of meeting time devoted to these areas is indicative. Even though academically difficult, it is sometimes necessary to walk away from unproductive efforts so that more energy can be focused on the most promising sites.

4. Geology - Extend Regional Studies

In the geological area I believe the studies are being carried out in a highly competent manner. Both regional and site specific surface geology appears to progressing well and my principle recommendation would more of the same.

I do feel that regional studies should be extended to include more areas outside the N.T.S. area (i.e. task 2.7 expanded). Despite the excellent statistical work on volcanic activity, I feel other areas further from cinder cones, etc., should be more extensively investigated. A question can be posed whether an annual 10^{-8} or 10^{-9} chance of the target horizon being cut by an active volcanic dike or sill is reasonable over the proposed 10^{6} year time frame?

The existence of obvious volcanic cinder cones only 11 miles from the proposed Yucca Mountain depository site could well create a psychological barrier to site acceptance. Memories of Mt. St. Helens is and will remain fresh in the public's mind for some years. It is well known that formations are often highly faulted and that stratigraphy is typically extremely variable in volcanic areas. This may produce so great a doubt in the public's and even in the scientific communities mind, that it could result in a "no-go" decision despite statistical rates of volcanism which are seemingly acceptable. Given this situation, I would recommend geological efforts be even more strongly directed toward unraveling the regional volcanic problem. Somehow I feel there are potentially other off N.T.S. sites more favorably situated outside the volcanic belts in the southern Great Basin. However, until a thorough geological study is completed this must remain only an assumption.

In the same way as a depository above the water table is to be preferred to one below (all other factors being equal), a depository site located far away from obvious evidences of recent volcanism is preferred to one only 11 miles removed. What disturbs me is the feeling that everyone is trying to defend a predetermined site location (possibly because it is the last one

within the confines of the S.E. quarter of the N.T.S.) rather than looking for a better site situated beyond the N.T.S. boundaries. A regional study is scheduled under Task 2.7 and I would urge it be given high priority.

5. Deepen G-1 To Basement

The core studies from G-1 are in progress and seem very encouraging to date. I would recommend G-1 (or H-1) be deepened to insure penetration of basement rocks. Knowledge of the type and depth of basement is badly needed as a parameter in the geophysical studies and certainly no hydrological investigation can be considered complete if highly permeable carbonates or other rocks remain untested between 6000 feet and basement material. (7200 feet if the gravity and magnetic studies are reasonably correct.)

6. More Geological Trenching And Shallow Drilling

I found the trenches most interesting and potentially the source of much additional geological information. The use of near surface trenches should be extended when site specific geological programs are undertaken. Bulldozers and shallow boreholes can be effectively used without damage to host formation integrity and should be encouraged. Surface geological investigations over the immediate Yucca Mountain depository area should be completed using shallow boreholes and trenches <u>before</u> any further deep drilling is started.

7. Too Much Drilling Too Early

I view the proposed drilling forecasts for fiscal years 1981 and 1982 as premature. Until regional and site specific geology and geophysics is completely evaluated, it is simply not possible to correctly locate proposed holes G-2, H-2, H-2a, G-3, H-3, H-3a and even H-1a. If money is provided and rigs on location need to be shifted to continue drilling activities, there will be a great tendency to pick a location without benefit of reasonably integrated geological and geophysical data acquired at the surface (the forked stick may be prophetic). It could be that through too many improperly located test holes the depository site would be rendered unusable.

8. Geophysics

The quality and breadth of the geophysical investigations were quite good in most cases. Nearly all geophysical methods were given a try and many were quite successful. I was particularly impressed by the open and critical discussions of the unsuccessful attempts to acquire reflection seismic data. This frank and detailed examination of a failed attempt is to be commended since it is often much easier to gloss over such problems and spend the limited presentation time available on the good looking results.

Insofar as geophysical data acquisition and interpretation is concerned, the meticulous and thorough work by individual U.S.G.S. scientists is to be commended, but I was somewhat disturbed by the lack of integration and focus on a specific target. For example, if the Bullfrog member of the Crater Flat tuff is taken as the hypothetical depository formation, it would seem reasonable to focus the geophysical techniques at the depth of that horizon. Instead, what was presented was very deep "basement" type data and very shallow near surface data neither of which focused on the target itself.

Some lessions in depository siting might be learned from the Nuclear Regulatory Commission where the analysis of geophysical data has been refined over the past five to ten years. If it could be established that a respository site at a depth of, say, 5000 feet would have to meet criteria equivalent to those required for a nuclear power plant located on the surface immediately above the site, a great deal of time could be saved by focusing on the geophysical techniques required for that situation.

9. Reflection Seismic

The reflection seismic data presented was disappointing in that no coherent reflections were seen. This can be the result of a disturbed near surface zone which may be associated with the unusually deep water table in the Yucca Mountain area.

Regardless of the cause, the inability to acquire adequate reflection seismic information must seriously degrade the potential depository site. Drilling alone will not adequately detect small faults which could destroy host formation integrity. Short of actual tunneling, reflection seismic is the only geophysical technique which is capable of delineating local faulting at the depository level.

I am not satisfied that all seismic techniques have been adequately evaluated, at least to the point where it can be categorically stated that reflection seismic profiles can not be obtained in the proposed Yucca Mountain depository area.

Vertical seismic profiles should be attempted using existing boreholes for shot locations and very large array VIBROSEIS should be tried in the immediate Yucca Mountain area. Large (660') source and receiver arrays (up to 144 separate receivers and 96 source positions) have produced good reflection data in similar areas (i.e. Mesquite, Nevada) and should be evaluated.

In my opinion, the inability to acquire reflection seismic data is the single most pressing geophysical problem. Its resolution should be given first priority.

VIBROSEIS reflection surveys are expensive and difficult to obtain since there is a shortage of seismic crews and the petroleum exploration demand are crews is at an all time high. Nonetheless, I cannot envision a suitable site being selected without reflection seismic information if it were at all obtainable. In my opinion, this would foreclose any chance of selecting a first area if it could not be obtained in that area, while being available in a second potential site area.

10. Refraction Seismic

The refraction studies proposed by the U.S.G.S. should be supported and given a priority second only to the reflection work outlined above. Both regional (deep basement) and local (near surface) refraction surveys are needed. The proposed forty mile wash refraction line is excellent.

Since interest has centered on the Yucca Mountain area, I would urge a much denser network of refraction lines such that areal maps can be prepared covering the entire possible depository area. A grid of lines is much more meaningful than an isolated line placed down a convenient road or other easy access route.

11. Heat Flow Measurements

A more formal program to measure regional and local Yucca Mountain heat flows should be instituted. Since heat is a major consideration in site placement, it seems obvious that heat flow, temperature, rock conductivity and other heat associated measurements would be very important.

A downhole heat measurement program using near surface (not penetrating any potential target layer) boreholes should be coordinated with the geologists and other geophysicists who could use these same holes for other useful determinations. An integrated drilling program, using light weight (shot hole type) drilling rigs should be set up to cover the Yucca Mountain depository area with a grid of shallow holes on 2000 to 4000 foot centers. Samples, shallow logs and heat flow measurements should be acquired in these holes. Following this, they should be used for areal borehole to surface geophysical measurements and finally as deep shot holes for seismic recordings.

12. Electrical Surveys

Both deep and shallow electrical soundings should be continued but more highly concentrated in the immediate Yucca Mountain area. The very shallow slingram surveys should be applied in a close spaced dense network over the Yucca Mountain target area to identify shallow conductive zones.

The existing resistivity - I.P. work seems to miss the target somewhat in that it doesn't reach down to potential target horizon depths and is ineffective for deep basement determinations. For this reason, I would give

it a lower priority than either the extremely shallow or much deeper techniques.

In my opinion, the electrical surveys conducted to date are adequate for regional characterization and further work should be restricted to the Yucca Mountain site or to some other more favorable off N.T.S. site. Work on Calico Hills and Wahmonie should be discontinued.

Electrical work on the Yucca Mountain site should be directed toward more complete areal coverage and to long dipole-dipole surveys which can reach at least 4000 feet. Grids of lines are to be preferred, and the use of three rather than two dimensional modeling should accompany such data acquisition procedures.

The M.T. data is of questionable value and I would suggest further M.T. work be done only after very careful consideration of the severe averaging effects involved.

The V.E.S. data is most interesting and seems to provide an excellent approach, if the grid of shallow holes suggested above were systematically located over the entire Yucca Mountain area.

13. Seismicity Determinations

The proposed "local" monitoring network should be established and locations integrated with the refraction profiles recommended above. By coordinating these activities both will benefit. "Local" should in this case be expanded though to cover a typical area. Measurements of local seismicity on Yucca Mountain will mean little if referenced to no other baseline area. The ground transfer function may be a problem in the local Yucca Mountain area, if the poor reflection seismic results are any indication.

In such a "volcanic" area, the seismicity measurements assume great importance in my view. Localized alignments of epicenters (magnitude zero and less) should be clearly defined before any further drilling is contemplated.

14. Borehole Geophysics

The entire borehole geophysics program should be given high priority and expanded if at all possible. Results to date are encouraging but not definitive. My enthusiasm for this program is based on the fact that few boreholes will be available and every possible advantage should be taken of those that are drilled.

Deep, target penetrating boreholes should be logged in every way possible especially with "long range" techniques such as very wide spacing electrical tools, borehole gravity meters, long spacing sonic loggers, etc. With these tools, it may be possible to characterize large volumes of prospective depository formation.

At the opposite end of the spectrum, the shallow boreholes grid suggested above would be ideal for near surface delineation of conductive zones using the inhole to surface technique tried in the immediate drill hole wash area. This technique combined with shallow electrical measurements between the drill hole locations would provide the optimum electrical survey. At the same time, seismic observations, using the drilled holes as source points and seismic detectors at the same surface locations, could provide near surface velocities and corrections for the VIBROSEIS reflection and big refraction surveys.

15. Gravity

The regional gravity work appears very well done and is essentially complete. A very local survey would not add much to the existing data except to show the Yucca Mountain area is free of local anomalies. This alone may be worth a small survey, but I would give this a relatively low priority.

The basement density information which could be obtained from deepening G-1 or H-1 would help refine the gravity picture. And certainly with a control point on site the entire survey could be improved.

16. Magnetics

As with gravity, the regional magnetic data already available could be enhanced with measurements of basement materials depths, etc. from an extension of boreholes G-1 or H-1. The question of magnite charged sediments could also be examined by coring down to basement at one "near depository" location. False basement errors uncovered at Calico would justify some research in this area.

17. Conclusions

From the data presented, Yucca mountain seems to be the only viable nuclear depository site within the permissible N.T.S. quadrant. More geology and geophysics should be done in that area before further drilling is authorized.

The data presented by individual U.S.G.S. scientists showed thorough and careful interpretation. I do question the planning or ordering of site investigation procedures and feel target definition should be given the highest priority.

Both Topopoh Springs and Bullfrog members should be considered potential targets until definitive studies show storage above the water table is not possible. As potential targets, they should be avoided by all deep boreholes until geological and geophysical work is completed. Shallow "near surface" boreholes (well above the Topopoh Springs) should be drilled in a grid covering the entire potential depository area. These holes should be put to multiple uses, such as for geological mapping, geophysical electrical seismic, temperature and other surveys.

Offsite studies should continue and if a more suitable site is located outside the Great Basin Volcanic belt, it should immediately become the prime focus of site specific activities and work at Yucca Mountain immediately discontinued.

A standard high multiplicity, VIBROSEIS survey should be attempted in the Yucca Mountain area. Vertical seismic profiles should also be obtained using the G-1 or H-1 holes to show conclusively whether the reflection seismic method will or will not provide information at the target horizons.

I hope you will find the above comments of value to the development of the nuclear waste depository problem.

Yours truly,

John B. Farr

John B. Farr
Chief Geophysicist
Western Geophysical Company
of America

JBF:dsp

George A. Thompson
421 Adobe Place
Palo Alto, California 94306

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R. F.
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AM & C
AMD

October 3, 1980

Copy sent to Twenhofel & Dixon 10/14/80

Mr. Robert M. Nelson
Department of Energy
P.O. Box 14100
Las Vegas, Nevada 89114

Dear Mr. Nelson:

The Geologic Investigations Peer Review of NTS studies was challenging and interesting. The overflight was particularly valuable in putting regional and local problems into proper perspective. I also appreciated the opportunity to learn more about the hydrological problems, which are inseparable from the geological/geophysical problems.

Along with other members of the panel, I believe the Scientific Management and strategy of the investigations should be improved. This has two facets. First, the definition of objectives needs to be sharpened. What is required of a site, how large an area, range of possible heat loads, etc.? Second, scientific management is needed in the sense of catalyzing communications among investigators, who need guidance especially if their experience on this project is short-term or limited in scope. The manager must be scientifically knowledgable and highly respected and should also have some clout where needed.

The quality, depth and direction of the Geology Program under Bill Twenhofel and his colleagues are simply superb. However, there is a danger that the long-range scientific results of this work will be lost in preliminary, open-file reports. As joint custodians of the geologic products, DOE and USGS share a responsibility to see that time and incentives are provided to the more creative scientists to synthesize and publish the work in journal articles or other professional publications. The intensive peer review and critical thinking required for such publications will benefit the project and also make a major contribution to science in the long run.

Although most of the regional geologic background is adequate, study of key areas such as the Bullfrog (tuffs) and Greenwater (basalts) should be encouraged. Intensive local study of Crater Flats is essential. Local variability of rocks within the potential storage site is critically important and seems poorly known so far.

Some of the Geophysical Studies suffer from a lack of coordination, not having fully utilized geologic data and adequate physical property measurements to arrive at the best and most complete geologic interpretation (granting the difficulties and uncertainties!). Possibly the specialists in various methodologies should get together for informal symposia more often and attempt to focus on critical questions that can be decided by geophysical measurements.

In the area of regional geophysics, depth to basement (gravity, magnetics, refraction) is clearly an important objective. A seismic network on the scale of the Test Site is also important. Observations of microearthquakes, Pg, Pn, and teleseismic times can yield useful data. Regional heat flow and heat flow on the scale of hydrological problems are highly relevant.

On a more local scale, reflection seismology has been disappointing but is so important that it needs further evaluation. What are the specific causes of the failure? The borehole geophysics and hole-to-surface measurements seem excellent and will become more so as the studies narrow down to a specific site. What are the electrical properties of altered rock and can electrical measurements detect altered volumes? Can fracturing be detected seismically as Healy suggested?

Measurements of Hydrologic Parameters on several scales are central and will surely be elaborated by others.

The three-day review was stimulating and informative. I remain optimistic about the site despite its great complexity. Thank-you for the opportunity to participate.

Sincerely,

G. A. Thompson

George A. Thompson
Department of Geophysics
Stanford University
Stanford, CA 94305

WM PO
EAD

October 6, 1980

340 Sparrow Way
Carson City, NV 89701

Mr. Robert M. Nelson
U. S. Department of Energy
P. O. Box 14100
Las Vegas, NV 89114

Dear Mr. Nelson:

The following discussion is addressed to those aspects of TASK 2 of the Nevada Nuclear Waste Storage Investigation presented to the Peer Review Panel on September 23, 24 and 25, 1980. General panel concensus opinions were verbally expressed on the 25th and only a selected few of these will be, for reasons of emphasis, repeated herein. Although most of my observations and opinions will be on Yucca Mountain geologic/geophysics subjects I would also like to breifly comment on a couple organizational aspects of the meeting which I believe were either particularly helpful or troublesome.

ORGANIZATIONAL:

From a reviewers point-of-view with a week to ten days per year involvement in the complex multi-disciplinary program encompassed in TASK 2, the overflight given the panel on Sept. 24 was extremely useful. I believe it helped all of us by allowing an integrated view of the geologic setting, obvious structure, areas of recent volcanism and areas of groundwater discharge such as Amargosa Springs and Death Valley. I know this reviewer can now better inter-relate potential storage sites with groundwater flow paths and times, structural boundaries such as 40-mile wash, zones of recent volcanism and seismicity even if off NTS, and so on. I believe, if the same panel members are to continue to participate in TASK 2, that Sept. 24 was well spent.

I also find (somewhat to my surprise because I didn't like it on the 25th) that time was well spent the afternoon of Sept. 25 when panel members caucused and them provided their consensus comments. It provided an opportunity for me to see the thought processes and immediate responses of my fellow panel members and gave me a chance for either clarification or support of some of my both plus and minus conclusions on TASK 2. I believe it provided you and Sandia Overview Personnel with some "first-run" rather unrefined and certainly unedited comments that may have both more immediacy and more un-hedged truth than those (like this) provide subsequently in writing.

Aspects of the organization I did not like and found either time wasteful, confusing, or in some way negative were several and follow in no particular order. I believe if the panel is to best do its job and if DOE is to receive its greatest return/$ spent on panel meetings and members, that the panel members should be provided before-hand (and more than 1 or 2 days before) such open file reports published since the last meeting, copies of viewgraphs to be presented, lists of what the USGS sees as its principal accomplishments and problems, etc. I know in this recent meeting that I kept busy trying to make notes on data shown in viewgraphs which, unknown to me at the time, were given to us later. I could have better served by listening more intently with the viewgraphs in order in front of me. Also, look as I may, I can't find any copies of what were possibly the most significant presented - e.g. Twenhofel's list if positive, negative and nebulous aspects of Yucca Mountain as a repository based on data now available. In essence

then I guess I'm saying that the USGS presentation could have been somewhat more smoothly organized.

The idea of splitting the panel up on the morning of the 25th into hydro and geologic/geophysical segments was not very satisfactory for several reasons. The main reason is that, in my opinion, geologic, hydrologic, volcanic, tectonic, seismic, geochronologic, etc. aspects are all critical parts of the total problem and geologists need to know the hydrologic evidence as do hydrologists require the geologic etc. evidence to make sound and reasonable recommendations. Perhaps from a time and efficiency standpoint the idea was organizationally desireable but it just didn't work -- at least for me.

Finally, the non-site specific overview of TASK 2 work provided on the morning of the 23rd was, I suppose, necessary for new panel members, but certain aspects were misdirected in what I was led to believe was a Yucca Mountain orientation. For particular example the large part of the geophysics hour (H. Oliver, D. Hoover) appeared to address work done on Wahomie and/or Calico Hills both of which, as sites for waste storage, have been largely discredited and were recommended by both the USGS and the Peer Panel in May, 1979, for dropping. Why the lengthy discussion?

All of the above are small things, very small, and all can be corrected merely by tighter organization and better pre-meeting planning. I realize all investigators are very busy on NTS and other projects, overworked and most likely "over-papered" in bureaucratic requirements but if DOE is to maximize panel effectiveness, tighter focus and pre-meeting information to the panelist will help.

OVERVIEW COMMENTS:

The TASK 2 objective as defined by Dixon appears clear, e.g. "... the most technically suitable rock mass... on NTS." With this as a directive and a limit, the USGS, LASL, etc. have applied almost every existing geologic, geophysical, geochronological etc. tool and tactic at what appears to me usually a state-of-the-art level. I perceive, however, a certain lack of strategy -- or perhaps more accurately lack of "ground rules" upon which to base strategy and tactics. How can one effectively and efficiently search for a waste repository site if firm and distinct specifications on ranges in size, thermal loading, seismic risk, retrievability, length of residence, etc. do not exist? Perhaps if such were, if not etched in stone, at least scratched on soap, certain of the tactics applied on NTS could either be better focused or possibly discontinued. How can one intelligently look for something without guidance parameters? This criticism should not, I believe, be directed at the USGS at all -- they are soldiers in this battle, but rather at DOE or above to "get off the dime" and make some hard decisions so that search guidelines and the subsequent tactics can be intelligently chosen.

A final suggestion on the overview aspect is that I believe sufficient and varied knowledge has now been gathered on argillite, alluvium, granite, tuff, etc. possibilities and limitations that a synthesis or integration report would be most useful. It would, foremost, allow the USGS and DOE to see where they stand in terms of all media, approaches and tools. A lot of science has been applied -- now lets get it interpreted and focussed and out to the scientific public for review and commentary in depth. I doubt if either USGS open-file or USGS Professional Paper outlets of publication would be terribly suitable. Open file reports, as I understand them, receive limited circulation and are smaller progress type offerings and I envisage this report to be substantial and the need for it to be read, wide. Professional Papers take 'forever' in review and publication and I, for one, don't want to wait 3 to 5 years to see the integrated picture. I have no useful positive suggestion other than the question does DOE have a suitable publication outlet?

YUCCA MOUNTAIN SITE AND ENVIRONS:

Geophysics: Since my background is not geophysics it is likely that I have either missed certain significant items or have not interpreted them correctly. My comments, therefore, should be read in this context and I defer to and accept the more geophysically sophisticated commentary of panel members Ryall, Morrison and Farr.

It does not appear to me that a regional passive seismic network will be particularly relevant to any hazard concern for a given repository area on NTS. Rather, concentration of a network to ascertain seismicity immediately about NTS and more specifically the SW part of NTS, seems more appropriate. I am sure that Dr. Ryall will provide more specifics on this observation.

Also, and this may illustrate my confusion on geophysics, it would appear desireable and necessary to the interpretation of Yucca Mountain gravity data and that for Crater Flats as well for the geophysicists and geologists to reach a consensus as to the density of the tuff sequence. As I recall we heard somewhat contradictory modelling versus measurement figures ranging from what would appear to me an unrealistic 1.67 to as much as 2.3. Data from G-1 and to come from subsequent holes should provide some appropriate numbers.

With respect to the problem of determining fracture density in the tuff units at depth in Yucca Mountain it appears that to date no method employed has been particularly successful. Although not my speciality I was impressed by the presentation of the results of down-hole to surface geophysics and believe such measurements are useful and should be encouraged. Dr. Morrison's opinion on this should be quite valuable. This, along with what R. Epis and Farr suggested in terms of large dipole-dipole spacing S.P. and possibly I.P. may, on the basis of a relatively few lines across Yucca Mountain, provide some insight as to at depth fracturing -- particularly if proposed hole G-2 provides more hard base-line data. I doubt, however, that S.P. would be able to provide much useable data at depths greater than perhaps a couple hundred meters -- far above potential repository levels. Although seismic reflection attempts to date have not been notably successful the impression I received from discussion with Mr. Farr is that good data may be obtainable by either or both a redesign of the network and the use of small explosives downhole. Both appear to this non-geophysicst to offer promise and should be considered. Also, additional efforts using the Nimbus-type engineering seismograph and horizontal impact for shear wave generation should be made since they may provide data in support of S.P. etc. for determining fracture density in the upper 200± meters of the sequence. By these means it may be possible to delineate at least larger fractures systems which are the ones most likely to project to depth.

Hydrology: For hydrologic commentary I defer to the opinions of Fenske, Domenico and Parizek. Clearly down-hole site and interval specific hydrologic testing is essential and I submit that it may be possible to do packer and other tests in NX size holes -- thus hopefully (if the polymer can be cleared) making use of G-1 as well as the VH1 and 2 holes. If use can be made of G-1 I wish to emphasize its desireability for hydrologic testing since it, contrary to VH1 and 2 is within the potential repository area. Certainly G-2 when and where-ever within the potential site it is to be drilled should be designed to allow complete hydrologic data to be obtained.

Geology: In my opinion, W. Carr, F. Byars, Jr., R. Spengler and the many other U.S.G.S. geologists as well as D. Crowe (LASL) involved in the mapping, tectonics, volcanism, etc. aspects of TASK 2 are, overall, doing excellent work. There is much that can be singled out as positive and I found particularly interesting some of the work done by Crowe on volcanism, Spengler on the drill core of G-1, and work on the mineralogic behavior of zeolites when heated. I must admit, however, to a lack of understanding of the worse case probability on volcanic risk assessment of 10^{-8} to $10^{-9}/km^2/yr$ given by Crowe and since my understanding is slight my skepticism is the reciprocal of my ignorance.

To me, the mineralogic work done on zeolites which indicates major transformations at 125°C or less suggests that heavily zeolitized tuff units may be quite undesireable as direct repository units and that they may much better serve as hydrologic 'buffer' zones, removed from direct heat sources and encompassing a rock unit with more suitable thermal properties such as a welded tuff -- even if the fracture density is greater in a given welded unit. While fracture densities in several units as shown by G-1 core appear favorable it is clear to me that considerably more drilling must be done within the projected repository area in order to adequately assess lateral continuity of stratigraphic intervals as well as to determine the fracture density of these intervals. I am familiar with and respect the repository integrity argument vis-a-vis drilling but I see no other way (outside of excavation) of obtaining the needed hard data.

Some recommendations that I shall phase as questions with commentary are:

1. Could a detailed geologic map of the repository site -- perhaps at 1"=200' or so -- be useful? I believe it could provide better surface control of drilling, trenching (see 2 below), and site related geophysics. It would help the location and study of larger fracture zones in the Tiva Canyon which might project to repository depths and might allow a distinction between asimuth and attitude of the larger fracture zones which may continue at depth from that of jointing and smaller scale fractures which, it appears to me, may not continue or may be healed by confining pressures at depth. Such mapping would also provide a surface datum and 'base-line' data for comparison with detail mapping which will undoubtedly be required should an at depth repository ever be excavated.

2. Is additional trenching called for? Trenching will surely improve exposures and thus expedite and improve any detailed surface mapping. It may provide precise information on location and extent of fracture zones in the Tiva Canyon member and thus assist the interpretation of bore-hole and other relatively site specific geophysics which will be employed. Relatively speaking I suspect trenching (as mapping in 1 above) is cheap for the information it may provide.

3. Can more information be reasonably gleaned from the core and holes of G-1 and others than is presently being obtained? I am sure that Fenske, Domenico and Parizek will have hydrologic suggestions in this regard and I believe that Farr has suggested that such holes may be suitable for small seismic explosives which may provide better seismic net resolution. Certainly considering the substantial expense of obtaining core and hole, expenditures to study the rock obtained are relatively small and in this regard I am sure that this and next years plans call for complete petrographic and chemical analysis. I would suggest, however, that consideration be given to keeping a complete and detailed color photographic record of the core (and possibly the cuttings from VH1 and 2 and subsequent holes). My reasons for this are several and are based on the experience of such firms as St. Joe Minerals, New Jersey Zinc and others who have conducted extensive diamond core drilling mineral exploration programs. The approach is cheap and

can be easily set-up on a production line basis while initial core logging is being done. It provides a permanent, easily storeable and readily retrievable record. It can be extremely handy in core-to-core comparison of stratigraphic intervals, fracturing, etc. -- certainly much more readily than the laying out of 10's and/or 100's of boxes of core side-to-side. In this regard, the photo record can help select stratigraphic intervals from several holes for detailed re-logging and other study and save a lot of time in core box retrieval which can get to be a hell of a problem -- especially if your hefting the boxes.

In summary and conclusion, I noted nothing at this past meeting which would prohibit the continued consideration of Yucca Mountain as a potential repository site. I encourage the continuation of the evaluation programs presently under way by the USGS, LASL, etc. and hope that additional favorable hard data will be forthcoming. Should the decision be made that an integration report be prepared I look forward to reading it.

Respectfully submitted,

Lawrence T. Larson
Registered Professional Geologist #418
State of Georgia

LTL:jb

copy sent to Lincoln, Dixon, Lawrence 10/24/80

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APPROVED			
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2630 Trentham Way
Reno, Nevada 89509
October 14, 1980

Mr. Robert M. Nelson, Jr.
Project Manager
Nevada Nuclear Waste Storage Investigations
Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, Nevada 89114

Subject: Peer Review of Hydrology, Geology, and Geophysics

Dear Mr. Nelson:

As you know, because of my physical condition, I attended only the meetings at DOE NV in Las Vegas and did not go on the field trip to the NTS. Although I am familiar with the NTS because of prior trips, presentations during the field trip may have contained information that would modify my letter. Since I concur with the general statements made by the peer reviewers as a group on Thursday afternoon, I will not repeat those comments here. Following are my comments on the general organization of the peer review meetings and the hydrology-geology programs.

Organization of Peer Review Meetings

It would be helpful if the peer review panel members were selected as early as possible during the year and provided with current information, such as open file reports, on an ongoing basis, so that they would not come to the meeting "cold". In particular, I believe this would be helpful to new panel members. Overlooking the fact that it was a small inconvenience to me, scheduling the field trip in the middle of the meeting seems to break up the continuity. I do not think that splitting the panel into two groups on the final day was useful. It had the effect of depriving all of us of background material that might have helped in our evaluations. I felt that the presentations were rushed. For a peer review, ample time should be allowed for a comprehensive review. In particular, more time for consideration would be of value to new panel members.

Hydrology-Geology Programs

To repeat the group conclusion, the work done in the areas of hydrology and geology is excellent. The ^{14}C and stable isotope studies as well as the age dating of rocks should continue. These data will probably provide the best information available on which to base conclusions regarding sources of groundwater, rate of movement of groundwater and paleohydrology for the NTS and vicinity. Caution, of course, must be exercised in the interpretation of the isotopic data. For example, (my recollection may be in error here since I don't find this in my notes) two wells on the test site one southeast of Pahute Mesa and one in Jackass Flat were assumed to be on the same

flow path. The isotopic data was then used to reach conclusions regarding recharge to the groundwater flow system between those two points. More than likely, the two wells are not even approximately on the same flow path as discussed below. As an alternate explanation of the isotopic data, one might suggest that each well is about the same distance from its respective recharge region.

Adequate well testing requires time (money). Yet, to evaluate a potential repository site, the regional and near field hydrology must be well characterized, and the basic data is obtained from well testing. I do not understand and have little sympathy with the philosophy of spending large sums of money in drilling holes into the ground only to have a tight budget for the necessary collection of hydrologic data. For example, in my view, valid head measurements are ultimately more useful than precise determinations of transmissivity. Unfortunately, valid head measurements do take time, and the required time is often not available.

I continue to have philosophical problems with the segregation of the hydrologic system beneath NTS into the Ash Meadows Flow System and the Pahute Mesa Flow System. The problems are with the designation of a "Pahute Mesa" Flow System and with the location of the eastern boundary of that system (western boundary of the Ash Meadows Flow System) beneath the NTS. Conceptually there is no problem with the Ash Meadows Flow System. It is the three dimensional region from which all the water is derived that discharges through the many springs in Ash Meadows. All of the boundaries of this region except the free surface are no flow boundaries. The lower boundary of the region is somewhere in the saturated zone because some of the deeper water from the same geographical region may discharge from some of the springs in Death Valley and, therefore, may comprise a different flow system. I do have a problem with the designation of a "Pahute Mesa" Flow System and the location of the boundary separating that system from the Ash Meadows Flow System.

Pahute Mesa is a recharge area. Recharge water probably discharges at Oasis Valley, Ash Meadows via the Paleozoic carbonates beneath Yucca Flat, and beneath the Armagosa Desert as underflow down regions of higher transmissivity such as Forty Mile Canyon. Pahute Mesa groundwater discharges in a variety of areas and a "Pahute Mesa" Flow System cannot exist. It is more appropriate to name groundwater flow systems after their discharge areas. For example, there is an Oasis Valley Flow System.

The boundaries of a groundwater flow system are no flow boundaries with the exception of the free surface. The movement of groundwater to the East and South from Pahute Mesa is well illustrated by the numerical model developed for the NTS by the U.S.G.S. The western boundary of the Ash Meadows flow system has arbitrarily and tentatively been placed along structural features believed to be impermeable and along aquitards such as the Eleana Formation.

However, the potential distribution calculated with the numerical model indicates components of flow across the Eleana west of Yucca Flat as well as south from Pahute Mesa towards Ash Meadows and the Armagosa Desert. Also, water table elevations in wells on Yucca Flat rise to the west and the U.S.G.S. Yucca Flat water table map indicates water moving into Yucca Flat from the west. The tentative boundary is then not a no flow boundary and not consistent with the numerical model or the Yucca Flat water table map. Since the numerical model will probably be used for certifying a repository, the above discussion of flow system boundaries may be largely academic. However, considering the significance of the numerical model, more review time should have been allocated for in-depth consideration.

I appreciate the opportunity of serving on this peer review panel and regret that I was unable to participate fully.

Sincerely yours,

Paul R. Fenske
Hydrogeologist

PRF:sp

cc: William S. Twenhofel
William E. Wilson

Cc: Jerry Fricano, Joe Levine, Jim Weight, Virgil 10/29/80

Alan S. Ryall, Jr.
3475 Lodestar Lane
Reno, NV 89503

24 October 1980

ACTION WMPO
INFO
R. F.
AMA
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Mr. Robert M. Nelson, Jr.
Project Manager, NNWSI
Department of Energy
P. O. Box 14100
Las Vegas, NV 89114

Dear Mr. Nelson:

The following comments are submitted relative to technical presentations on 23-25 September 1980 concerning USGS efforts on Nevada Nuclear Waste Storage Investigations (NNWSI). The comments represent my own opinions, and primarily concern the USGS seismological investigations. However, the first section of this report summarizes general topics on which the review panel had a concensus.

1. General. I concur with other panel members on the following:

- Some additional regional-scale seismic refraction is needed to define "basement" in the NTS area and determine its configuration.

  - Results of seismic exploration conducted to date are discouraging, but a definitive experiment, using state-of-the-art techniques, should be conducted before such techniques are determined not to be useful. The experiment should utilize long profiles, Pg delay times, and small charges in existing boreholes to determine velocity structure. Experienced industry personnel should be called in as consultants.

- Additional heat-flow data is needed to define local patterns and areas of anomalous heat generation.

- The regional geology work by Carr and others is excellent, and involves many years of experience. Work should begin on synthesizing results of these studies.

- There appears to be a need for better technology transfer in regard to studies of the physical properties of rocks at depths of a few thousand feet. Where fracture density measurements and stress tests have been made in deep boreholes on Pahute Mesa and in Hot Creek Valley, an attempt should be made to apply these results to define probable conditions within the Yucca Mountain complex. There has also been a lack of correlation of hydrologic with geological investigations and better integration should be effected in this area.

- Electrical measurements to date have concentrated on very shallow structures. Additional work should be undertaken to search for homogenous structures at the target depth for the waste disposal facility.

- Self-potential studies might identify hydraulic gradients associated with fault zones.

- The borehole geophysics work is excellent and should be expanded.

- If 4-inch boreholes can be used for hydrologic testing at NTS, this should be done. Vertical permeability needs to be tested by 2-hole pumping tests.

- Studies should be undertaken to determine whether old faults act as barriers to ground-water flow.

- Additional trenching should be carried out to determine recurrence times and single-event displacements on known active faults in the region around NTS.

- Studies aimed at determining gross structure of the crust and upper mantle on a regional basis should be dropped, but detailed structural studies of the area in and around NTS should be expanded.

2. Regional Seismic Hazard Investigation. The quality of the regional seismic investigation, presented by Carr and Rogers, is quite good. The study has identified seismicity associated with specific faults. Results to date have confirmed previous conclusions by Rogers et al. (BSSA, 1977, p. 1587) relative to areas of high and low current seismicity. The observation of very low seismicity in some rupture zones with recurrent Holocene offsets (i.e., Death Valley) supports the idea that network studies will not be sufficient to identify seismic hazards over the lifetime (hundreds of thousands of years) of a permanent waste isolation facility, and that supplementary geologic investigations of active faults are required for such an evaluation. However, the network study is useful in determining seismic hazards that exist now and could persist for several decades in the southern Nevada region.

   - In my opinion, stated in last year's evaluation, the justification for continued regional seismic hazard investigations is questionable, if Yucca Mountain is now the primary focus of the NNWSI. I believe that the southern Nevada network could be reconfigured to provide dense coverage of the NTS area, and that such reconfiguration would be more useful to the current NNWSI program without increasing the scope or cost of the seismological investigations (see section 3, below).

   - The magnitude-fault length relationships used in the 1977 paper by Rogers et al., should bemodified for consistency with Great Basin observations, since attenuation and other factors apparently affect magnitude determinations for this region. A relationship given by Ryall and VanWormer (USGS Open File Rept. 80-801, 1980, p. 181; BSSA, 1980, p. 1573) yields magnitudes as a function of fault length that are 0.3-0.4 unit smaller than the values given by Rogers et al., for NTS faults capable of generating high accelerations at Yucca Mountain (Mine Mountain, Cane Spring and Rock Valley faults). This would yield slightly lower "mean value peak accelerations," but would not significantly change the results of the 1977 study.

- Estimation of maximum credible accelerations at the site should be supplemented by a study of signal frequency and duration for a more realistic assessment of risk to the facility. In such a study an attempt should be made to differentiate between the type of motion recorded at San Fernando and motion that might be more appropriate for Great Basin earthquakes, if differences can be shown to exist. Results to date have produced strong-motion estimates that are extremely conservative, and perhaps appropriate for a high-level nuclear waste storage facility. The upper bound of 3 g acceleration given by Rogers et al. (1977) is an example. However, for a rational consideration of design requirements for surface components of the facility that may or may not pose a serious problem to the environment if damaged, a more reasonable model of probable ground motion should be constructed.

  - High accelerations may be associated with only a single pulse or with a few high-frequency pulses for moderate-sized local earthquakes, and may not result in extensive damage, even to structures of standard design. For example, Rogers et al., cite recorded accelerations up to 0.7 g for aftershocks of the 1975 Oroville earthquake. According to T. R. Toppozada (personal communication), these measurements were made in structures located within 2 km of the mainshock epicenter, that were extensively damaged (windows broken, collapse of chimney, fireplace, brick veneer, etc.) by that event; however, further damage was not associated with the high-acceleration aftershocks. Similarly, an earthquake with M_L 6.0 at Mammoth Lakes, California, on 25 May 1980 recorded accelerations of 0.33 and 0.98 g, respectively at the ground level and roof of a high school gymnasium (California Geology, 1980, p. 194) which had no structural damage (John Ragsdale, personal communication). The gymnasium was well constructed and designed for heavy snow loads, and the earthquake occurred after the winter snow had melted.

  - USGS analysis to date has relied heavily on data from San Fernando and and other California earthquakes -- generally earthquakes with strike-slip or reverse-slip motion. In the source mechanism of such events the axis of maximum compressive stress would be close to horizontal and greater than lithostatic stress. On the other hand, faulting in the Nevada region appears to be primarily due to regional extension, with the axis of maximum compressive stress being vertical and equal to lithostatic stress. Major fault segments along mountain ranges in the Nevada region are characterized by normal- or oblique-slip motion, and moderate sized strike-slip earthquakes such as those at Mammoth Lakes last Spring may reflect secondary rather than primary processes. If this picture is correct, surface motions in large Great Basin earthquakes may be more similar to the 1959 Hebgen Lake, Montana, earthquake than to the 1971 San Fernando event. The former, with magnitude 7.1, had maximum vibratory intensities of VII to VIII at points only a few meters from the causative fault; this is far less than the intensity of X predicted from acceleration/intensity relationships of Trifunac and Brady (BSSA, 1975, p. 139), for accelerations of 0.7 g or larger (from magnitude/acceleration relationships of Schnabel and seed, BSSA, 1973, p. 501). In my opinion the USGS effort should be expanded to include modeling

studies aimed at explaining both low- and high-intensity earthquakes as functions of tectonic regime, source mechanism, regional attenuation characteristics, stress drop, etc.

3. Seismic Investigations at NTS. Both the current and planned seismological investigations at NTS are of very high quality, and should be continued and expanded.

   - Results of current investigations have confirmed previous studies of focal mechanisms related to faulting on NTS (BSSA, 1969, p. 2271), and have provided new information on earthquake distribution along NTS faults, and clustering at the ends of those faults. Work by Carr and others to explain the seismicity patterns in the context of a regional tectonic framework is very good.

   - The distribution of current seismicity may not be particularly useful in trying to assess volcanic hazard at NTS, since areas of high heat flow -- and presumably relatively high volcanic hazard -- can be associated with anomalously low seismicity (JGR, 1976, p. 840). However, 3-dimensional velocity inversion of teleseismic and Pn data from a very dense network could define velocity anomalies related either to partially melted rocks in the crust or to zones that have been depleted of partial melt by eruption through the various volcanic centers on and around NTS. This could be extremely important for assessing volcanic hazard, and should be given high priority.

     - As stated above, I believe that the southern Nevada USGS network could be reconfigured to provide very dense coverage of NTS. This would permit detailed studies of seismicity, velocity inversion, v_p/v_s ratios, etc., at minimum additional cost and without much effect on seismic hazard studies related to fault distribution and historic seismicity of the southern Nevada-eastern California region.

4. Project Management. While not ordinarily a topic for technical review, scientific management of the NNWSI program was discussed at some length by the panel. It was difficult for me and for other panel members to identify specific targets for some of the research presented by USGS personnel, and there was no clear definition of problems or factors that could lead to disapproval of Yucca Mountain or potential waste storage sites elsewhere. At this point in the program I strongly recommend that scientific management of the program be improved by (1) better definition of factors that are critical to approval of the facility; (2) definition of a program that will converge at some specified time in the future; (3) designation of key people to begin synthesizing results for the various projects and integrating these for various interdisciplinary areas; and (4) assignment of high priority to compilation and wide distribution within the scientific community of reports on the NNWSI.

   - Peer review should be an ongoing process. Peer reviewers should be appointed with enough lead time to permit better preparation for panel meetings, and they should be supplied with copies of project reports,

reprints, and view graphs BEFORE the meetings take place. Past practice of keeping peer reviewers in the dark until after USGS presentations have been made at a review meeting does not permit a well-informed review and should be stopped.

Respectfully submitted,

Alan S. Ryall, Jr.
Registered Geophysicist No. GP-20
State of California

ASR,Jr.:hm

Colorado School of Mines
golden, colorado 80401 • (303) 279-0300

geology department

January 16, 1981

Mr. Robert M. Nelson, Jr., Project Manager
Nevada Nuclear Waste Storage Investigations
U.S. Department of Energy
P.O. Box 14100
Las Vegas, Nevada 89114

Dear Mr. Nelson:

This constitutes the letter-report you requested of individual members of the peer review committee who attended the meeting on Nevada Nuclear Waste Storage Investigations (NNWSI) in Las Vegas, Nevada, September 23, 24, and 25, 1980. Before I present my personal observations and recommendations and summarize those of the peer review committee, I want to make the following comments. First, I thank you and other members of the project for the invitation to participate in the peer review process; I found it most interesting and informative. Second, in general, I was very positively impressed by the broad spectrum and high quality of the geological, geophysical, and hydrological studies that are being conducted at the test site. It appears to me that essentially every applicable state-of-the-art method of analysis in these disciplines is being considered in order to evaluate the site, Moreover, the thoroughness, up-to-date knowledge, and enthusiasm of the researchers were quite apparent and reassuring.

Please do not hesitate to contact me if you have any questions regarding the personal observations and recommendations which I have made or the abbreviated summary of the entire peer review committee comments which I have included. The latter was assembled from notes I made during the final meeting of the committee.

Sincerely yours,

Rudy C. Epis

Rudy C. Epis, Ph.D.
Professor of Geology

the university of mineral resources

Nevada Nuclear Waste Storage Investigation
Department of Energy
Peer Review Committee Meeting
September 23, 24, and 25, 1980

Observations and Recommendations

by

Rudy C. Epis

1. A thorough and detailed petrographic and petrologic characterization of selected drill core and cuttings should be undertaken. This should include description and evaluation of primary and post-depositional textures, structures and mineralogies of the tuffs and associated rocks. Important aspects to be assessed include the degree of compaction and welding, sorting characteristics of the clasts, ratios of vitric, crystal and lithic constituents, type and amount of devitrification and vapor-phase crystallization, and type and amount of non-volcanic alteration. Characterization of features such as these in the subsurface will lead to a better understanding of the geomechanical properties of the rocks at depth and to a better understanding of the highly variable bore hole geophysical data already obtained. It was clear to me that the bore hole data indicated many more variations in the petrologic features of the rocks than were noted in existing lithologic logs. I do not intend to be critical of the geological logging done to date. I know that what I am suggesting is tedious and time consuming and that there has been neither sufficient time nor staff to do this work. However, I strongly recommend that it be done as soon as possible.

2. The work being done on the zeolitization and argilliz-

ation should be continued and expanded. Detailed petrographic analysis of zeolite and clay mineral paragenesis is essential to interpreting the vertical and lateral characteristics of these secondary, overprint facies. Clearly, the geomechanical properties of the rocks will be significantly affected by the type, amount, and distribution of zeolite and clay minerals, or any other secondary minerals.

3. If not already accomplished, attention should be focused on characterizing the ash-flow tuff formations, many of which are several hundreds of feet thick, in terms of single or multiple eruptive and cooling units. There may be significant vertical and lateral chemical, mineralogical and fabric variations because of the presence of multiple lithogenetic units in a given ash-flow formation.

4. Laboratory experiments to evaluate the effects of proposed temperature changes upon the rocks in and adjacent to a repository should be continued and expanded. These changes could produce sufficient shrinkage and fracturing resulting from temperature responsive processes such as dehydration and recrystallization so as to seriously impair the stability of a disposal site. The experiments should be conducted using all appropriate rock types, including welded, moderately welded, and unwelded tuffs; tuffs with varying degrees of devitrification, vapor-phase crystallization, and alteration; and non-tuff rocks.

5. Investigate and evaluate the nature and extent of paleotopographic variations beneath ash-flow units. These variations influence the orientation of compaction foliation in overlying tuffs as well as local changes in their thickness. In the final, detailed structural analysis of the repository site, consideration must be

given to what extent the dips of the tuffs are tectonic or compactional. In this regard, studies of the remanent megnetic properties of the rocks should be continued and expanded as needed.

6. Continue studies of the episodicity of the young basaltic volcanism using statistical attempts to predict the timing and style of future eruptions. Concentrate efforts on the temporal, structural, and caldera relations of the young basalts and spend little or no effort on considerations of the deep-seated source of the magmas, eg., the mantle. Although interesting, such considerations do not appear to be important to the task at hand except for possible minor variations in eruptive style of different magma types.

7. More work should be done on the age, stratigraphy and petrology of the Quaternary surficial deposits. Their floral and faunal content, lithologic composition, sedimentary structures, and environments of deposition could reveal important information regarding variations in ancient climatic conditions. This work would have to be regional or semi-regional in scope and should be conducted by scientists well-versed in fluvial, alluvial, and eolian processes and products.

8. There is need for a large scale, detailed surface geologic map of the proposed disposal site or sites. The map should be prepared at a scale of about 1:1200 to 1:4800 with appropriate topographic contour interval. It could be accomplished by using the plane table and alidade method or by mapping on a suitable topographic base prepared by other engineering methods. Detailed geologic mapping at such a scale would permit plotting of densities of fractures of cooling, compaction, tectonic and release origin in various types of units. The different types of fractures should be petro-

fabrically analysed and the analyses used as an independent basis for predicting fracture intensities and symmetries of different types at depth. In addition, a detailed topographic and geologic map at such a scale would be useful in constructing more accurate structural cross-sections and in any further geological or engineering activities within the site. The regional and semi-regional geology has been very well documented and needs no further work.

9. I suggest there should be more personal, one-on-one interplay and exchange of data and ideas among the scientists and engineers working on the project. Again, I don't mean to be overly critical because I understand most of the investigators are engaged in several other projects elsewhere. Simply, it seemed to me that a number of geological interpretations of geophysical data might have been more realistic if there had been mutual input from both groups. I suspect the same situation prevails with respect to the hydrologists although most of us were unable to attend their detailed session.

10. The final personal observation and comment I would make is that I realize in order to complete the studies I have recommended above within a reasonable time frame, additional staff would have to be added to the project. I feel this is such a critical and important matter to the nation that DOE and USGS officials should seriously consider increasing the number of scientists and engineers on the project to accomplish the tasks which I and my co-peer reviewers have recommended to your group.

Summary of Peer Review Committee Comments

Notes by Rudy C. Epis

Hydrology

1. Need for regional and local three dimensional hydrologic models that are integrated with stratigraphy, structure, petrology, and geophysics of host rocks.
2. Test all bore holes hydrologically.
3. Run hydrologic interference tests between adjacent bore holes.
4. Relate heat flow measurements to hydrological framework.
5. Define hydrological gradients and rates and directions of flow in and near Yucca Mountain.
6. Continue to examine and evaluate the unsaturated zone as a potential storage site.
7. Continue isotopic characterization of the subsurface waters, including dating of their times of origin.

Geophysics

1. Deep crust-mantle geophysical studies are not needed for this project.
2. There is a need to locate and define the regional and local basement.
3. Heat flow measurements should be continued and expanded.
4. Attempt seismic reflection analysis of stratigraphy and structure by setting off charges in bore holes.
5. Try large dipole-dipole resistivity measurements to evaluate framework to depths of 4,000 feet.
6. Attempt an SP array to look for shallow perched water tables, structures, hydraulic gradients, and alteration zones.
7. Continue the good work in bore hole geophysics; try some in-hole gravity measurements.

Geology

1. Regional and semi-regional geology appears to be adequately known and presented.
2. Need for local, detailed geological features of proposed site or sites.

3. Drill a hole in Drill Hole Gulch upstream from Drill Hole G-1 to test the graben hypothesis suggested by geophysical studies.
4. Sink a shaft into proposed repository host rocks to map, sample and test them.
5. More trenching in and near proposed sites.

General

1. Need to define geomechanical properties of acceptable repository for waste; enumerate and quantify and compare with properties of proposed host rocks.
2. Consider alternate sites within the Nevada Test Site regardless of socio-economic, military, or political constraints - eg., Silent Canyon caldera, possible caldera under Crater Flat.
3. Need for more and earlier submittal of materials to peer reviewers; perhaps change format to on-going peer review process.
4. Need for better definition of scientific management and specification of roles of DOE, USGS and Sandia Labs.
5. Need for a master plan of the project, including criteria needs and methods to obtain them.
6. Peer review committee should attend all sessions of the review - geological, geophysical, and hydrological - and not be separated according to professional discipline.
7. Need for written interim reports by investigators integrating geological, geophysical, and hydrological results to place current progress in perspective.

Rudy C. Epis

Rudy C. Epis, Ph.D.
Professor of Geology

No written comments were received from Dr. Richard Parizele.

United States Department of the Interior
GEOLOGICAL SURVEY
BOX 25046 M.S. 954
DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY REFER TO:

April 20, 1981

Mr. Robert M. Nelson, Jr., Project Manager
Nevada Nuclear Waste Storage Investigations
Nevada Operations Office
U.S. Department of Energy
P.O. Box 14100
Las Vegas, Nevada 89114

Dear Mr. Nelson:

The U.S. Geological Survey reponse to review comments from the NNWSI Peer Review, September 23-25, 1980, is attached. We have responded in a synthesized manner, addressing the consensus of comments, rather than comments from individual reviewers.

The peer review was stimulating and constructive and we look forward to future review meetings.

Sincerely yours,

G L Dixon

G. L. Dixon
Acting Chief
Special Projects Branch

Attachment

cc: L. D. Tyler
L. W. Scully
B. R. Erdal
L. D. Ramspott

NNWSI PEER REVIEW, SEPTEMBER 23-25, 1980

General Comments

Meeting schedule and format:--As with previous peer reviews, several panel members felt the schedule of presentations should be changed. It will indeed be difficult to satisfy everyone with any given schedule. However, several points appear consistent. Among these are: (1) more information should be provided to peer reviewers prior to the actual review meeting, and (2) more time should be allowed for the review. Item 1 is a NV policy decision as to how much advance information is sent to panel members. We feel that the request for more advance information is very reasonable and justified. If panel members could be given a description of the program and a background document describing objectives and progress to date, these items would not have to be described at the meeting, thus allowing more time for concentration on current activities without adding additional days to the meeting time.

An additional problem is the lack of format for panel members comments. In previous reviews, the panel members submitted comments in letter format that addressed many topics in no specific order. Comments ranged from those addressing specific technical issues or techniques to general statements. This format is cumbersome and makes response to the comments extremely difficult and time consuming. At future meetings, it is recommended than an itemized schedule be established for the meeting and panel members requested to comment on specific items by their schedule number. With this format, comments on a given topic from all reviewers, such as the geology of Yucca Mountain, could be easily discerned and addressed, but would not preclude panel members from presenting general comments in their transmittal letter.

We do not agree with some reviewers that the visit to the site and the core library be eliminated in favor of more meeting time. Aside from the fact that three days of continuous meetings is deadly, it is essential for the reviewers (new ones at least) to see the core and the site area. New access roads, such as the one to G-2, will provide means for a better ground overview of the site than previously possible.

Repository criteria:--Several panel members were also concerned about the lack of specific criteria regarding a repository site, i.e., actual size, depth, etc. Determination of specific criteria is not within the scope of the USGS program. The USGS studies, as well as those of other agencies and contractors working on waste disposal programs, are operated under general criteria. The current general criteria and the fact that final determination does not rest within the USGS program should be made available to panel members prior to the meeting. Again, this would save meeting time by giving panel members a "rule-of-thumb" with which to assess current studies and not waste discussion time on the lack of firm criteria. Experience has shown that too detailed or inflexible exploration plans are always in need of alteration as work progresses. We believe we have a general exploration plan which recognizes the critical factors needed for site approval. Every site will have one or more negative factors, but if sufficient redundancy exists in favorable characteristics site integrity can still be

preserved. Our general plan has been to try and disqualify the site as early as possible, proceeding within the restrictions and guidelines imposed by DOE.

Even though there is some difference of opinion on the suitability of various media and geologic settings, we think that there is general agreement on the type of repository site we are seeking. Furthermore, if guidelines for that target are too rigid, a site will never be found. As we see it, our target is simply a site that is relatively stable tectonically, which possesses several natural barriers to transport of radionuclides, a medium capable of withstanding the waste form, and which is not so complex as to require an unreasonable amount of exploration or risk in development.

Scientific direction and management:--There is some truth in the criticism of lack of scientific direction, but it should be emphasized that the problem of nuclear waste storage is highly complex and probably has more scientific interfaces than any other national problem. Division of the NNWSI work among three national laboratories and the USGS, not to mention various contractors, complicates direction and coordination. Coordination of efforts within the USGS is also difficult as many organizational units are involved. Solving a problem such as nuclear waste storage requires a certain amount of innovation and freedom to pursue various lines of research, even though that work may not obviously focus directly on a specific site. What really is required of management is to insure that the results of the work and the credible witnesses are not lost during the years required for exploration of a site.

Several reviewers commented about the need for better interdisciplinary communication. We agree there is a problem--one that varies in severity with individuals, but much of the apparent lack of communication must be ascribed to differences in opinion or interpretation rather than ignorance of other investigators' work. The important result is that at some point a reasonable and experienced judgment be made of how the interdisciplinary information fits together and what it means. We believe this judgment is being made reasonably well.

Alternate Sites at NTS

Whereas it may appear to the reviewers that we have not considered other potential sites at NTS, this is not the case. Three other sites in southwest NTS and one in northeast NTS (Wahmonie, Calico Hills, Topopah Wash, and Twinridge) have been given not only serious consideration, but some exploration. Several other NTS areas have been identified as having waste storage potential. These include Timber Mountain, Pahute Mesa, Argillite Ridge, and Moorhen Meadow. However, it would be prudent to conduct a parallel low-level exploration effort at one other location, if only to insure that, should Yucca Mountain fail, we would not have to spend 2 or 3 years bringing another site up to the state of knowledge that now exists at Yucca Mountain. The major problems with this approach are the lack of resources available--manpower, equipment, and money--and restriction of exploration to the southwest NTS.

Inadequate Publication Plans

We believe the open-file report, as being used, is a practical method of making available progress and interim results of the NNWSI program. We are uncertain as to what the reviewers mean by higher profile reports. Open-file reports are advertized monthly with other USGS publications. The time frame for

publication of a journal article (as long as 18 months until publication for some journals) precludes rapid dissemination of the information. A more serious problem is the scarcity of time and personnel available for synthesis and preparation of final reports. An adequate solution to this problem does not appear to be forthcoming.

Geologic Investigations

Some panel members felt no further work was necessary on regional geology. Although it is true that a good base of knowledge exists about the regional geology, further data are necessary to provide the best interpretation of local tectonics and hydrology. Thompson and Farr agree with this position.

We agree that an up-to-date detailed site map is needed. However, a scale of 1 inch = 1,000 feet will be adequate to show any feature of geologic significance.

As to the suggestion for more work being needed on the Quaternary, we agree, in general, and plan on such work, but some of the reviewers are apparently unaware of the difficulties in precisely dating events in the Quaternary. While we have done much to "fine tune" the chronology of events in the Quaternary, we have probably reached about the limits of the "state of the art" on Quaternary geochronology. We believe we should continue to work on (1) completing the detailed mapping of Quaternary deposits in the southwest NTS and Amargosa Valley area and (2) trying to relate this mapping to Quaternary hydrologic and tectonic events of this area and the Amargosa River drainage system.

Use of low-sun angle photos to find fault scarps is not required in our opinion. Any scarp visible under low-sun angle conditions will also be visible on high-sun angle photos.

In general, we agree with the comments from Epis regarding petrographic and petrologic work, and feel that current petrographic work will answer many of his comments. The Los Alamos National Laboratory has the major responsibility of mineralogy/petrology in the NNWSI program and should be included in the next peer review.

Geophysical Investigations

Morrison and Wyman thought there was too much emphasis on geophysics around the drill holes and drill-hole wash, and that a better distribution of work over the repository surface should have been made. A better spatial distribution of work would be desirable, but there are several reasons for the concentration of electrical studies in the wash area. First is the need to obtain data in advance of drilling, because the drill-hole casing would significantly perturb electrical work in its vicinity. Second, the drilling information helps correlate the geophysical response to the geologic section. Third, drill-hole wash appears to be the most distinct electrical discontinuity in the repository area. Fourth is the problem of access and suitability of terrain. Practical methods for taking terrain into effect in VES work are not available. Thus, Farr's suggestion of a VES grid over the area is not practical at this time. Slingram work could be done, but in rough terrain the stations should be surveyed in for good results. This is why in the initial stages, this work was confined to areas of little topographic relief.

Many suggested large dipole IP lines in an attempt to look deeper to full repository depths. The purpose would be to get an idea of the electrical uniformity of a large block at repository depths to 5,000 feet. This should be done as it is the most practical means of getting electrical information from those depths in this terrain. However, the importance of that data at this time is questionable because of the very poor resolution obtained with 1-km dipoles. For that matter, any of our surface geophysical methods give poor resolution at those depths.

Self-potential surveys also were suggested for fault identification. Their use at NTS would probably contribute little at this time. The very deep water table and low hydraulic heads in the repository region probably preclude data being obtained relative to the saturated region. For shallow detection of faults other electrical methods appear adequate and do not suffer from questions of source mechanism.

Farr suggests more intensive Slingram and VES work at the site, while Morrison suggests no further work of this type until the data are analyzed and integrated with other work. We believe Morrison is correct except for experimental work to develop better methods.

Farr commented that the inability to obtain reflection data is the most pressing geophysical problem we have. Unfortunately, an easy solution does not appear to be forthcoming.

Tectonics, Seismicity, and Volcanism

The consensus of panel members was that there is no need for deep crust and mantle studies. However, such studies may aid in assessing volcanic hazard problems. The ongoing modest P-wave studies are an easy way to get at one aspect of the problem. Deep electrical surveys of a specified area, such as Crater Flat, might help to ascertain whether potential exists for renewal of volcanism.

Investigations to date that affect final basaltic volcanism hazard assessment show the value of basic basalt geochemistry. Trace-element abundances support a two-fold division of southern Great Basin basalts. Based on field mapping, dating, and geochemistry, the transition in basalt types appears to have occurred about 4 m.y. ago. This provides a more dependable basis for predicting future basalt types. NTS rift basalts have high strontium-87/86, but the younger two basalt cycles of Crater Flat are strontium rich and rubidium poor. Some data point to a Late Cenozoic episode of rubidium depletion, which must be evaluated for hazards, particularly if it is a young event. Young NTS basalts are evolved with no erupted parental rocks, perhaps due to the tectonic setting. If this is uniformly true, it may explain the history of small volume basalt eruptions separate in time and space that have characterized the NTS for the last 3.7 m.y.

In response to comments regarding finding a site away from young volcanism, such an objective is, of course, desirable, but the actual distance has not been determined. The risk of volcanism at Yucca Mountain is very low (Crowe and Carr, 1980[1]). The risk could be lowered a little more by finding a site 100 miles away

[1] Crowe, B. M., and Carr, W. J., 1980, Preliminary assessment of the risk of volcanism at a proposed nuclear waste repository in the southern Great Basin: U.S. Geological Survey Open-File Report 80-357, 15 p.

from any Pliocene or Pleistocene volcanic activity, but chances are some of the more important attributes, such as zeolitized volcanic rocks, might well be lacking, or conversely, carbonate rocks might be the dominant rock type in the site area. We have decided that the total geohydrologic setting is more important than the threat of one element, such as volcanism, as long as certain environments are avoided that we perceive as relatively high risk (such as caldera ring-fracture zones).

Purpose and rationale for operating a regional seismic net remain the same (see memo Rogers and Carr to R. M. Nelson, NV, Oct. 4, 1979): (1) A repository site could be chosen anywhere in southern Nevada; (2) a reasonable degree of understanding of regional seismicity and faulting will be required for repository licensing; and (3) risk and magnitude of potential ground motion must be determined for safe design of surface and transportation facilities. It should be noted that we now have in operation a close-spaced net at Yucca Mountain. Additional stations at NTS would not contribute significantly to accuracy of locations or greatly improve our interpretation of the seismicity.

Drilling and Mining

There was a feeling among some reviewers that too much drilling was being done too early. In our opinion, drilling is the only way to get hard facts concerning the continuity and character of the rocks at depth. Other methods are helpful, but they must be interpreted. Drill holes facilitate and bound such interpretations. In general, we have targeted the drilling to disqualify the site as early as possible, but we are currently beginning only our third deep drill hole (G-2); one of the two deep holes is a hydrology hole. After G-2 and G-3 are drilled and logged, we are fairly certain we will be able to say with confidence whether or not we have a large enough site with the required thickness of suitable tuff units.

One panel member suggested a hole is needed in upper "drill-hole wash" to test the graben hypothesis. There is no evidence, except possibly for the electrical data, that indicates a graben or structure of any consequence is present at or near G-1. The G-1 hole itself argues against the presence of any important structure there.

Another reviewer thought mining in clay and zeolites will be a problem. Experience from mining in tuffs in the tunnels at Rainier Mesa permits a reasonable forecast of mining conditions. Only local problems are encountered and these can be handled relatively easily with modern engineering practice. Zeolitized tuffs cause few, if any, problems and clay is troublesome only in high quantities or along faults.

Hydrology

Multiple-use test holes:--A reevaluation of the approach to the NTS test drilling program has been made as a result of reviewers' comments concerning the desirability of utilizing multipurpose holes to obtain geologic and hydrologic information. Because reviewers compared the NTS program to that of BWIP, a visit to Hanford was made by representatives from USGS, DOE, REECo, F&S, and Sandia to determine if the coring and hydrologic testing program at the Hanford site was applicable to the NTS operations.

It was concluded that in general the approaches being used at Hanford are not applicable to the NTS, because of (1) the substantial differences between the two sites, and (2) the unavailability at this time of appropriate small-hole equipment and instrumentation. The potential availability of small-hole packers is being further explored.

Hydrologic characteristics of Yucca Mountain block:--The concern for excessive "puncturing" of the block with drill holes is shared by all participants in the program. Current policy is to drill only around the periphery of the block and to avoid further penetration of the block center with drill holes.

We agree with the need to determine vertical as well as lateral distribution of hydraulic head. A hydrologic observation well is planned in which a permanent nest of piezometers will be installed. A long-term pumping test is planned at this site in order to assess vertical leakance. As recommended, the application of single-well testing techniques for determining hydraulic properties, including storage coefficient and vertical leakance, is being explored.

Delineation of fractures is being done by several techniques. Measurement of joints and fractures near potential drilling sites for hydrologic holes is now being done prior to choosing the site. Mapping of photo-lineaments also precedes siting. Within boreholes, fractures observed in cores are analyzed. Television and acoustic seisviewer data are collected in the hydrologic holes, which have diameters large enough for the necessary logging tool.

Cores are available for laboratory measurements of compressibility and permeability. Samples will be submitted when analyses of packer and pumping tests are completed.

Two holes near UE25a-1 are being drilled in a manner that tracer experiments can be performed for determination of dispersivity and effective porosity. Hole UE25a-1 will be used in its present state after evaluation indicated that rehabilitation of the hole would be too costly and difficult.

Geochemical investigations:--Reviewers encouraged continuation of age-dating and stable-isotope analysis. Chemical analysis and age-dating of water samples from test holes are being done where practical, although obtaining samples from the low-permeability zones of tuff has not always been feasible.

A geochemical study of ground water in the Amargosa Desert, currently underway, will provide improved understanding of the regional flow systems and rock-water interactions that occur along the flow paths.

Regional flow systems:--As a result of modeling and geochemical analysis, we recognize a flow system in which ground water flows predominantly through carbonate rocks, and one in which ground water flows predominantly through tuff and alluvium. The boundary between these systems is imprecise, and some flow does occur between the systems. The inappropriate term "Pahute Mesa flow system" is no longer used.

Hydrologic modeling is being used to guide selection of sites for test holes to help define regional hydrologic conditions. As a result of this systematic evaluation of needs, the number of regional holes planned has been substantially reduced. The regional test drilling is proceeding concurrently with the detailed site drilling.

Paleohydrology:--Most of the paleohydrologic investigations will be completed in FY81. Results of various investigations will be synthesized to present conclusions pertinent to the waste-disposal problem, principally concerning the hydrologic effects of potential climatic changes.

Hydrologic modeling:--The hydrologic modeling program is progressing through the following steps: (1) Synthesize available hydrologic, geologic, geophysical, and geochemical data and derive a conceptual model of the hydrologic system; (2) develop a mathematical, approximate description (numeric model) of this system; (3) perform sensitivity analyses on this model; and (4) determine types of data that are needed to decrease uncertainty in the model. In addition, the transport modeling will have an additional step to predict the movement of radionuclides from a repository, and estimate the errors in these predictions.

As more is learned of the system, parts of this sequence must be repeated. This sequence incorporates parametric studies and leaves the predictive task until parametric studies have been completed.

Currently, a two-dimensional regional flow model has been completed, sensitivity analyses (using two different, formalized techniques) have been completed, and recommendations for additional data collection are being developed. Synthesis of the hydrologic, geologic, geophysical, and geochemical data for Jackass Flats, Crater Flat, Yucca Mountain, and the Amargosa Desert is also underway. A numerical technique for modeling transport of sorbing members of decay chains has been developed, and a procedure for performing sensitivity analyses is under development.

The inadequacy of the data base is a valid concern and is the motivation for performing the sensitivity analyses to guide the collection of data and to allow estimates of errors to be made.

The theory for predicting transport in fractured rocks is poorly developed and also is of concern. The approach being used assumes porous media models. On the scale modeled (tens of kilometers), this assumption is probably warranted. Near-field models (scale of tens of meters) are not yet being developed, but the assumption of porous media will probably not be valid. Also of concern is the sensitivity of dispersion to time and distance of transport, and the question of the appropriateness of the convective-dispersive equation for modeling chemical transport. We are performing no research on these questions, but are keeping up with work being done by others.

We agree that it would be desirable to model head changes with depth to develop hypotheses for "almost assured" decrease with depth, and to estimate vertical conductivities. However, data do not yet allow realistic modeling of head changes with depth. For example, the data in USW-G1 suggest decreasing head with depth. Vertical temperature profiles indicate downward movement of water in the upper 5,500 feet but possible upward flow from 5,500 to 6,000 feet. A tentative interpretation is that the distribution of hydraulic conductivity within the drill holes probably controls the vertical distribution. Until more data are available and interpretations are completed, it is not feasible to attempt modeling in the vertical plane. Also, until reliable estimates of vertical flux are available, use of vertical gradients to estimate vertical conductivities is impractical.

Reviewers suggested modeling the deep alluvial system as a potential repository site. The unsaturated alluvium of the test site is being investigated as part of a research project by U.S. Geological Survey personnel under programs outside of NNWSI. While the project is not specifically designed to determine the suitability of the alluvium of the NTS for nuclear waste disposal, data applicable to the waste problem will be collected to determine heat and moisture transport for comparison with numerical models.

Summary

We feel the peer review was worthwhile and provides fresh insight and constructive criticism to technical programs and objectives. However, in the future, it should be structured so as to provide the most expeditious use of time for both the panel members and those being reviewed. Thus, we recommend the following items be considered for future peer review meetings:

1. More advance information to panel members (brief history of program to date, objectives, current criteria).

2. Numbered schedule for meeting topics.

3. Critique by panel members addressed to numbered items on the schedule.

Sandia Laboratories

Albuquerque, New Mexico 87115

April 20, 1981

Mr. R. M. Nelson, Director
Waste Management Project Office
U. S. Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, Nevada 89114

Dear Bob:

Attached is the Technical Overview Summary of and comments about the 1980 Geological Peer Review.

This summary and comment attachment is much longer than the equivalent Technical Overview Radionuclide Migration comment since this response was written without having the TPO comments and response.

Sincerely,

R. C. Lincoln

Richard C. Lincoln
NTS Waste Management Overview
Division 4538

RCL:4538:njw

Attachment:
As stated

Copy to:
1417 F. W. Muller
4530 R. W. Lynch
4531 L. W. Scully
4533 S. G. Bertram
4537 L. D. Tyler
4538 J. A. Fernandez
4538 R. C. Lincoln
4538 R. L. Link
4538 J. T. Neal
4538 S. Sinnock
4538 A. E. Stephenson
G. L. Dixon, USGS, Denver, CO
W. E. Wilson, USGS, Denver, CO
W. S. Twenhofel, Denver, CO
B. R. Erdal, LANL, Los Alamos, NM
L. D. Ramspott, LLNL, Livermore, CA
A. R. Hakl, W-AESD, Mercury, NV

MEETING CONDUCT AND PEER REVIEW PROCESS

Preparation for the Review

A belief expressed by most, if not all, reviewers was that their preparation prior to the intensive three-day meeting was inadequate. While all the reviewers were provided preparatory materials, several said they would have been better prepared had they been provided reports throughout the year. This appears to be a legitimate observation; attempts will be made in the future to initiate early the forwarding of review material once the composition of the review team is known. This should also help reduce the "rush" tone of the meeting that a few of the reviewers felt.

Field Trip

Most all of the reviewers seemed to favor a field trip, and none expressed disapproval of the aerial observation afforded by the F-27 overflight. One reviewer thought the field trip on the second day broke the continuity of the presentations, whereas the lack of comments from the other reviewers seems to imply concurrence with the manner in which it was conducted.

Future field trips held in conjunction with reviews should be tailored to the needs of the review group. Pre-meeting preparations could establish what the group desires are regarding overflights or field visits to drill sites, trenches, outcrops, etc.

Meeting Organization, Panel Discussions

The third day separation of hydrology and geology panel discussions met with disapproval of most of the peer reviewers.

The belief was strongly voiced that the separation of presentations was counter to the integration that is needed in their assessing the overall geohydrologic environment.

Future peer reviews should consider another means of final day discussions. One solution would be to have a brief pre-meeting (perhaps the previous night) wherein important discussion topics could be identified and agenda of the most significant topics could be developed. This would allow the reviewers to prepare for the panel deliberations the following day, and to permit more complete development of positions.

Peer Review Compositions

Dr. Farr noted the conspicuous absence of government and other industrial peer reviewers, and suggested that their presence would be desirable. This comment should be considered for future peer reviews.

Prior Visits by Reviewers to Specialty Locations

Dr. Farr suggested that the reviewer specialists, e.g., geophysicists, etc., visit their counterpart NNWSI specialists at their place of business prior to the formal Peer Review Meeting. This would help reduce the "education gap" which all the reviewers felt to a greater or lesser degree. This is a worthwhile suggestion which the NNWSI project management should consider.

GEOLOGY COMMENTS

General

There was complete agreement by all reviewers that the overall geology program is being accomplished in a thoroughly professional manner by highly competent scientists. There were also comments provided by all reviewers on ways in which the various geology efforts might be enhanced, modified, or diminished. For the most part, the comments involved program balance or priorities, based on individual reviewers' perceptions of the problem. Most comments indicated a need for additional work; thus the need for additional resources to achieve the work was implicit (or stated directly in several cases).

Emphasis

There was concern by two reviewers that excessive effort was being expended on documenting the Wahmonie intrusive and Calico Hills after the decision had already been reached to focus on Yucca Mountain. It is also important to note that discredited locations demand technical substantiation and documentation to enable the transitioning to (and defensibility of) other preferred locations.

Mapping and Trenching

There existed essentially complete agreement by the reviewers that detailed, large-scale surface mapping and trenching of Yucca Mountain should begin, in concert with shallow drilling. Benefits would include better understanding of surface structure (faults and fracturing), and of stratigraphic variations. These detailed

efforts will be needed, it is true, but at a time when Yucca Mountain is formally selected as the favored repository location. Nonetheless, planning and scheduling of these efforts is underway now.

Drilling

One reviewer (Dr. Farr) felt strongly that too much drilling was being done too soon, and that more geophysics should precede borehole studies. However, he also advocated prioritizing the borehole geophysics program, and deepening the G-1 hole to basement (presumably as a means of calibrating other geophysical methods, e.g., gravity, seismic, electric, magnetic). Other reviewers felt that substantially more drilling should be accomplished. The NNWSI approach is between the two extremes, striving for balance between all program elements. The project management is very much aware of the reasons given and is considering these as the focus on Yucca Mountain narrows.

Petrology and Mineralogy

Several reviewers (Drs. Epis, Domenico, Morrison) expressed their concern that insufficient attention was being given to characterizing the various tuff lithologies, and especially the clay mineral and zeolite paragenesis. The effects of thermal loadings on these sorptive minerals also should receive more intensive study, especially as they affect the groundwater flow regime. These views are shared by NNWSI project personnel and are being addressed as the program continues to grow and focus on Yucca Mountain. The next peer review should include scheduled formal presentations on these topics.

Quaternary Studies

Drs. Epis and Morrison suggested more work be done on mapping Quaternary alluvium, and especially on identifying Holocene faults. The suggestion is a good one, because such recent activity could disqualify a site if discovered later on. The NNWSI should reconsider its relative attention to this topic.

Volcanism

Five reviewers recognized and endorsed the significance of volcanism in the safety assessment process, but differed somewhat in their suggested approaches to gain further knowledge. One reviewer believed more regional study was needed, while three reviewers thought more intensive study of the younger basaltic volcanism and structure in the Crater Flat area was needed. There were no objections to the work being done, and no specific recommendations for changes in the program other than shifts in emphasis.

Technical Approach

Dr. Farr advocated a more goal-oriented, phased approach to the investigations, emphasizing geological and geophysical data interpretation prior to confirmatory drilling. The balance between and timing of geological, geophysical, and hydrological studies and drilling activities are complex programmatic issues. The NNWSI program management is aware of these issues and attempts to provide balance in the technical program.

GEOPHYSICS

Most reviewers stated or impled that a comprehensive suite of geophysical techniques was being applied by the NNWSI exploration program. Suggestions were focused on the priorities that should be given to specific geophysical surveys. Each general set of geophysical methods is discussed in order of the priority recommended by the reviewers.

Seismic Reflection and Refraction:

Though many of the reviewers expressed disappointment that seismic reflection surveys to date have not yielded usable results, they also were optimistic that continued pursuit of new survey designs would result in finding successful means to obtain meaningful energy returns from the depths of interest. The reviewers generally recommended that highest geophysical priority be given to resolving the issue of whether seismic reflection will work in the tuff stratigraphy of the NTS, and if it will, to spend the necessary money to conduct a high resolution survey, perhaps VEIBROSEIS, throughout the Yucca Mountain block. This recommendation is consistent with the NNWSI plans and is being pursued. Specific recommendations about how to redesign reflection surveys, including detonation of shots in a series of new shallow and existing deep boreholes, are being considered by USGS geophysicists and seismic consultants.

Drs. Morrison, Farr, and Ryall recommended that seismic refraction work be continued and expanded to investigate deep, large structures (Ryall) and small structures (Morrison and Farr) in the block of interest. Seismic P wave arrival time

analysis was cited by Drs. Morrison and Ryall as a useful technique for these purposes, especially for studying the geometry of the pre-Tertiary basement. Farr suggested that a closely spaced array of seismic refraction grid lines and accompanying shallow drillholes for explosive detonations in the Yucca Mountain area would be highly useful for investigating small structures at the depths of interest. The specific recommendations are being carefully considered by the NNWSI. The usefulness of seismic exploration methods as well as their high priority are recognized by the project and included in its exploration plans.

Electrical Surveys

Though the reviewers expressed confidence in the quality of electrical work performed to date, they generally questioned the relevance of that work to project objectives. In particular, the reviewers felt that too much emphasis had been placed on shallow looking techniques (Slingram) and very deep methods (magneto - telluric, M.T.), and too much effort has been concentrated on "Drill Hole wash". Drs. Morrison, Farr, Ryall, and Epis suggested that studies of the very deep crust should be discontinued as too academic unless unlimited funds are available. On the other hand, dipole-dipole and self potential (SP) surveys were considered a high priority for electrical work because when properly designed they are suited to explore target depths of a few thousand feet, i.e., the depths of interest. Most of the reviewers noted that these surveys should be extended throughout the block of interest, perhaps utilizing the same gridlines as they recommended for seismic work. Dr. Farr mentioned that more VLF surveys might be

considered for investigating shallow (~150 m) fracture systems. He also commented that a gridded array of VES soundings could be useful. Dr. Morrison recommended that existing data be modeled and analyzed before pursuing much additional work, thus helping define the objectives of future geophysical surveys. These recommendations are generally consistent with NNWSI electrical exploration plans, though the array of shallow drill holes may be cost prohibitive at this phase of site screening exploration.

Heat Flow Studies: Drs. Wyman, Morrison, Thompson and Fenske recommended on increase in the study of heat flow, both for general tectonic-volcanic and hydrologic assessments. Again, an extensive array of shallow boreholes was suggested for the heat flow measurements. The NNWSI has recently included heat flow studies in the exploration program and intends to implement the spirit of the recommendations, budget, of course, constraining the extent.

Borehole Geophysics: Most reviewers were very complimentary of the borehole geophysical studies and suggested more of the same in all targets of opportunity. They especially were intrigued with the promise of such techniques to identify small scale anomalies in an extended zone around the boreholes and between the total depth of drilling and the surface. The NNWSI intends to continue such studies.

Groundmotion Studies: Drs. Larsen, Morrison and Ryall questioned the utility of the regional seismic net and joined Thompson in recommending that earthquake monitoring be condensed to a much smaller area centered around Yucca Mountain. The NNWSI is in

the initial phase of developing a micro-seismic monitoring program in the Yucca Mountain area, but believes the regional net should be retained to assist the regional tectonic studies and to better define the earthquake environment of the region in which the NTS is located. Dr. Ryall provided some specific suggestions on how the modeling of acceleration data could be modified to better account for Great Basin attenuation processes. These suggestions will be considered by the NNWSI seismic analysts.

Gravity and Magnetic Surveys: Dr. Farr expressed the opinion that the existing regional gravity and magnetic data were excellent and joined Dr. Morrison in recommending that the data be modeled two and three-dimensionally as a wrap-up of such work. Both reviewers suggested that ground surveys in the Yucca Mountain area could be useful for delineating local structures. Dr. Farr again recommended the use of a gridded array of ground traverses. The modeling of existing data is underway, and the development of ground surveys is under consideration by the NNWSI exploration geophysicists.

HYDROLOGY

Drs. Domenico and Fenske emphasized that more time and money should be allocated to hydrologic testing of the boreholes, especially for investigation of fracture flow conditions. Dr. Fenske pointed out that valid head measurements throughout a system of confined water bearing units take considerable time but such measurements are ultimately very useful. Dr. Domenico mentioned that head distribution as a function of depth and vertical permeability are two important parameters that warrant investigation. He agreed that pumping tests of long duration should be performed. Drs. Fenske, Domenico and Morrison endorsed the continuation of isotopic water dating and geochemistry. The NNWSI is pursuing these studies as opportunities arise from the drilling program.

Dr. Farr suggested that either G-1 or H-1 should be deepened to the pre-Tertiary basement to determine the nature of the underlying Paleozoic aquifer at Yucca Mountain, if one exists. The NNWSI project is currently conducting a review of this issue. If there is in fact an aquifer below the repository horizon, a drillhole connecting the aquifer with the repository horizon will greatly complicate safety assessment and jeopardize the site's containment and isolation capabilities. These considerations must be balanced with the desire for direct information about the nature of aquifers thousands of feet below the target emplacement depths. Dr. Farr suggested that the existence of a pair of boreholes 1300 feet apart might render 200 acres or so of a site unsuitable for use if hydraulic communication occurs

across the distance separating the boreholes. This addresses the issue of the number and location of allowable penetrations into a repository site, an issue the NNWSI is acutely aware of and is addressing through consequence fault tree analysis. A definite conclusion can be reached only after considerable consequence assessment has been performed. Unfortunately, such assessments aren't available during early phases of the exploration program when the issue is most critical.

Drs. Domenico, Larsen, and Ryall commented that it was disturbing that a target of opportunity, G-1, had been missed with respect to hydrologic testing and suggested that attempts should be made to reenter the hole and perform a suite of hydrologic tests. The NNWSI will consider this option. G-1 may be used as an observation well, but NNWSI participants are concerned that the drilling fluid used in G-1 may impact hydrologic test results.

Dr. Morrison commented that regional hydrology and paleohydrology programs were excellent. Dr. Wyman suggested that the regional program get under way as soon as possible. Dr. Domenico observed that the paleohydrology program was essentially complete and recommended low priority be given to the paleohydrology drillhole in Frenchman Flat. He also commented that the regional flow system is sufficiently known and that future work should concentrate on Yucca Mountain and downgradient areas. However, Drs. Morrison and Fenske recommended additional work on defining the regional flow system. Dr. Fenske spent considerable discussion challenging the basis for distinguishing between the so-called

Pahute Mesa and Ash Meadows flow systems, a distinction he feels is artificial.

Dr. Domenico stressed that the regional flow system modeling may not provide realistic portrayal of actual flow conditions in the multi-layered flow environment of the NTS. He pointed out that modeling is a critical high priority task, but cautioned that model results should not be used for predictive purposes but rather as a parametric tool to guide hydrologic drilling and determination of critical parameters and geographic locations.

PROGRAM MANAGEMENT AND INTEGRATION

Most of the peer reviewers offered comments on program management, integration, and synthesis. The overall view reflected a need for tighter management and more sharply focused program objectives. These views appear to originate as a result of the following comments that arose over individual aspects of the program:

(a) Coordination and synthesis of individual investigations, e.g., geology/geophysics/ hydrology (Drs. Thompson, Ryall, Epis, Farr, Domenico)

(b) Perceived need for a technical integration report(s) (Drs. Thompson, Ryall, Larsen, Domenico)

(c) Apparent lack of specific criteria for locating and constructing a high-level waste repository (Drs. Thompson, Ryall, Larsen, Morrison, Farr)

(d) Unified scheduling of above activities, so as to converge at a specific future date (Drs. Ryall, Wyman)

A number of factors require explanation to minimize misunderstandings that appear to have developed. The belief that

Yucca Mountain "has been selected" as the potential repository site is erroneous. While it is favored according to current understanding, the decision to "go" with Yucca Mt. awaits administrative decision following the area screening. This means that the program is deliberately semi-focused at this time so as not to bias the selection of any location for artificially contrived reasons. This is also a primary reason for the step-wise approach that is advocated in DOE's position statement in the Waste Confidence Rulemaking proceedings. Specific decision points and documentation are required to substantiate the transitioning and focusing of the program. The next peer review should include more background on the national program status and plans and NNWSI history and plans.

Regarding (a) above, the need for improved coordination of investigations is apparent. At the same time, the geographical separation of investigations handicaps this process; the peer review meeting actually provides one opportunity for this coordination. More meetings would not necessarily make the coordination better; they might only result in less work being accomplished. Because of the interdisciplinary nature of the program, it is, however, clear that more careful integration of results is needed to insure consistency of interpretation of the natural environment.

Regarding (b) above, there is a definite need for integration reports in both geology and hydrology. Such information is needed not only for the technical community, but it is required to support the focusing process, and if appropriate, eventually

the licensing process. These reports are scheduled for mid-1983, when sufficient technical information is available to report on.

Regarding (c) above, the criteria required for siting are indeed known imperfectly at this time. Both EPA and NRC attempts to develop specific criteria for licensing have been drawn out and frustrating, resulting in general performance criteria (still preliminary), rather than specific numerical values that have strong technical justifications. The reasons for this are several and important to understand.

Almost no siting factors are exclusionary. That is, there are means to handle most problems through avoidance, engineering, or by compensation. The presence of an undesirable element can be overshadowed by a strongly favorable feature. For these reasons, the total repository system will have multi-faceted variations which include the site, the waste form, waste package, backfill, and barriers of several kinds to limit radionuclide migration. The implication of this approach on siting is that site conditions will influence the design of the other elements; the reverse is also true.

At this stage in the NWTS program, it is neither possible nor desirable to have precise "target definition" regarding waste form and packaging, repository design, and site suitability criteria. To be too definitive at this time would foreclose some options that need to be left open for several years. Some of these options rest on technical issues, and some rest on political and/or institutional issues. The resolution of these

issues is an important element in the national program and must proceed in parallel with R&D programs. What is most needed at this time in the overall national program is quality site definition, so that the engineering design can proceed. Indeed this is the approach that DOE is following in the 1981-82 time frame.

Regarding (d) above, the explanations offered in response to (a), (b), and (c) support the overall schedule integration being followed at the time of the peer review, and subsequently modified in early 1981. We believe the approach is realistic and defensible, leading to commencement of an exploratory shaft in late 1983.

NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

INTERNAL PROJECT DISTRIBUTION LIST

C. A. Heath, Director
Office of Waste Isolation
U. S. Department of Energy
Room B-207
Germantown, MD 20767

D. L. Vieth, Director
Repository Development Division
U. S. Department of Energy
Room B-220
Germantown, MD 20767

M. E. Gates, Manager
U. S. Department of Energy
Nevada Operations Office
Post Office Box 14100
Las Vegas, NV 89114

R. W. Taft, Assistant Manager
for Energy & Conservation
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

M. P. Kunich
Waste Management Project Office
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

H. L. Melancon
Waste Management Project Office
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

C. P. Bromley
Waste Management Project Office
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

R. H. Richards
Waste Management Project Office
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

F. C. Hood, Manager
Quality Assurance
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

J. O. Neff, Program Manager
National Waste Terminal
Storage Program Office
U. S. Department of Energy
505 King Avenue
Columbus, OH 43201

L. D. Ramspott
Technical Project Officer
Lawrence Livermore National
Laboratory
University of California
Post Office Box 808
Mail Stop L-204
Livermore, CA 94550

B. R. Erdal
Technical Project Officer
Los Alamos National Laboratory
University of California
Post Office Box 1663
Mail Stop 514
Los Alamos, NM 87545

R. C. Lincoln
Technical Overview Management
Sandia National Laboratories
Post Office Box 5800
Organization 4538
Albuquerque, NM 87185

A. R. Hakl, Site Manager
Westinghouse - AESD
Post Office Box 708
Mail Stop 703
Mercury, NV 89023

G. L. Dixon
Technical Project Officer
U. S. Geological Survey
Post Office Box 25046
Federal Center
Denver, CO 80301

A. E. Stephenson (10)
Technical Overview Management
Sandia National Laboratories
Post Office Box 14100
Organization 4538
Las Vegas, NV 89114

L. D. Tyler
Technical Project Officer
Sandia National Laboratories
Post Office Box 5800
Organization 4537
Albuquerque, NM 87185

L. W. Scully
Technical Project Officer
Sandia National Laboratories
Post Office Box 5800
Organization 4537
Albuquerque, NM 87185

F. W. Muller
Technical Project Officer
Sandia National Laboratories
Post Office Box 5800
Organization 1417
Albuquerque, NM 87185

NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

DISTRIBUTION LIST

R. L. Morgan
Acting Assistant Secretary
for Defense Programs
U. S. Department of Energy
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Washington, D. C. 20545

M. E. Gates
Acting Assistant Secretary
for Nuclear Energy
U. S. Department of Energy
Room A-416
Germantown, MD 20767

D. E. Clark
Brookhaven National Laboratory
Department of Nuclear Energy
Building 701
Upton, NY 11973

L. Lanni
U. S. Department of Energy
San Francisco Operations Office
1333 Broadway, Wells Fargo Bldg.
Oakland, CA 94612

R. Stein
Office of Waste Isolation
U. S. Department of Energy
Room A-269
Germantown, MD 20767

C. R. Cooley, Director
Research & Development Division
U. S. Department of Energy
Room B-214
Germantown, MD 20767

M. W. Frei
Repository Development Division
U. S. Department of Energy
Room B-219
Germantown, MD 20767

G. P. Dix
U. S. Department of Energy
Room G-167
Germantown, MD 20767

C. D. Newton
Repository Development Division
U. S. Department of Energy
Room B-213
Germantown, MD 20767

F. R. Standerfer
U. S. Department of Energy
Richland Operations Office
Post Office Box 550
Richland, WA 99352

D. J. Squires
U. S. Department of Energy
Richland Operations Office
Post Office Box 550
Richland, WA 99352

R. Deju
Rockwell International
Atomics International Division
Rockwell Hanford Operations
Richland, WA 99352

R. W. Newman, Assistant Manager
for Defense
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

J. B. Cotter, Director
Energy Applications Division
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

A. J. Roberts
U. S. Department of Energy
Nevada Operations Office
Post Office Box 14100
Las Vegas, NV 89114

R. M. Nelson, Jr., Director
Waste Management Project Office
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

D. F. Miller, Director
Office of Public Affairs
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

R. H. Marks
U. S. Department of Energy
CP-1, M/S 210
Post Office Box 14100
Las Vegas, NV 89114

B. W. Church, Director
Health Physics Division
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

R. R. Loux
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114 (10)

J. H. Dryden, Director
Nevada Test Site Support Division
U. S. Department of Energy
Post Office Box 435
Mercury, NV 89023

F. R. Huckabee
U. S. Department of Energy
Post Office Box 435
Mercury, NV 89023

L. P. Skousen
U. S. Department of Energy
Post Office Box 435
Mercury, NV 89023

D. J. Cook
Director of External Affairs
U. S. Department of Energy
DOE-IX
333 Market Street, 7th Floor
San Francisco, CA 94105

J. C. Malaro
Nuclear Regulatory Commission
M/S SS-674
Washington, D.C. 20555

R. Boyle
Nuclear Regulatory Commission
Mail Stop P-522
Washington, D.C. 20555

D. H. Alexander
Nuclear Regulatory Commission
M/S 905SS
Washington, D.C. 20555

A. E. Gurrola
Holmes & Narver, Inc.
Post Office Box 14340
Las Vegas, NV 89114

A. Holzer
Lawrence Livermore National Laboratory
University of California
Mail Stop L-209
Post Office Box 808
Livermore, CA 94550

L. B. Ballou
Lawrence Livermore National Laboratory
University of California
Mail Stop L-204
Post Office Box 808
Livermore, CA 94550

R. L. Wagner
Lawrence Livermore National Laboratory
University of California
Mail Stop L-1
Post Office Box 808
Livermore, CA 94550

K. Street, Jr.
Lawrence Livermore National Laboratory
University of California
Mail Stop L-209
Post Office Box 808
Livermore, CA 94550

W. C. Patrick
Lawrence Livermore National Laboratory
University of California
Mail Stop L-204
Post Office Box 808
Livermore, CA 94550

A. B. Miller
Lawrence Livermore National Laboratory
University of California
Mail Stop L-204
Post Office Box 808
Livermore, CA 94550

D. J. Isherwood
Lawrence Livermore National Laboratory
University of California
Mail Stop L-224
Post Office Box 808
Livermore, CA 94550

K. Wolfsberg
Los Alamos National Laboratory
Mail Stop 514
Post Office Box 1663
Los Alamos, NM 87545

L. S. Germain
Los Alamos National Laboratory
Mail Stop 570
Post Office Box 1663
Los Alamos, NM 87545

L. E. Lanham
Los Alamos National Laboratory
Mail Stop 755
Post Office Box 1663
Los Alamos, NM 87545

B. R. Erdal
J. R. Smyth
Los Alamos National Laboratory
Mail Stop 514
Post Office Box 1663
Los Alamos, NM 87545

B. M. Crowe
Los Alamos National Laboratory
Mail Stop 329
Post Office Box 1663
Los Alamos, NM 87545

W. R. Daniels
Los Alamos National Laboratory
Mail Stop 514
Post Office Box 1663
Los Alamos, NM 87545

P. M. Halleck
Los Alamos National Laboratory
Mail Stop 977
Post Office Box 1663
Los Alamos, NM 87545

D. C. Nelson
Los Alamos National Laboratory
Mail Stop 985
Post Office Box 1663
Los Alamos, NM 87545

R. G. Warren
Los Alamos National Laboratory
Mail Stop 586
Post Office Box 1663
Los Alamos, NM 87545

E. N. Vine
Los Alamos National Laboratory
Mail Stop 514
Post Office Box 1663
Los Alamos, NM 87545

D. C. Hoffman
Los Alamos National Laboratory
Mail Stop 760
Post Office Box 1663
Los Alamos, NM 87545

J. T. Whetten
Los Alamos National Laboratory
Mail Stop 570
Post Office Box 1663
Los Alamos, NM 87545

D. T. Oakley
Los Alamos National Laboratory
Mail Stop 671
Post Office Box 1663
Los Alamos, NV 87545

E. H. Beckner
Sandia National Laboratories
Organization 4500
Post Office Box 5800
Albuquerque, NM 87185

R. W. Lynch
Sandia National Laboratories
Organization 4530
Post Office Box 5800
Albuquerque, NM 87185

W. D. Weart
Sandia National Laboratories
Organization 4510
Post Office Box 5800
Albuquerque, NM 87185

M. L. Kramm
Sandia National Laboratories
Organization 4540
Post Office Box 5800
Albuquerque, NM 87185

R. M. Jefferson
Sandia National Laboratories
Organization 4550
Post Office Box 5800
Albuquerque, NM 87185

T. O. Hunter
Sandia National Laboratories
Organization 4512
Post Office Box 5800
Albuquerque, NM 87185

A. E. Stephenson
Sandia National Laboratories
Organization 4538
Post Office Box 14100
Las Vegas, NV 89114 (10)

J. B. Wright
Westinghouse - AESD
Post Office Box 10864
Pittsburgh, PA 15236

W. R. Morris
Westinghouse - AESD
Post Office Box 10864
Pittsburgh, PA 15236

T. E. Cross
Westinghouse - AESD
Post Office Box 10864
Pittsburgh, PA 15236

R. J. Bahorich
Westinghouse - AESD
Post Office Box 10864
Pittsburgh, PA 15236

C. R. Bolmgren
Westinghouse - AESD
Post Office Box 10864
Pittsburgh, PA 15236

W. A. Henninger
Westinghouse - AESD
Post Office Box 10864
Pittsburgh, PA 15236

J. G. McCray
Nuclear Fuel Cycle Research
University of Arizona
Tucson, AZ 85721

G. D. DeBuchananne
U. S. Geological Survey
National Center
Mail Stop 410
Reston, VA 22092

P. R. Stevens
U. S. Geological Survey
National Center
Mail Stop 410
Reston, VA 22092

D. B. Stewart
U. S. Geological Survey
National Center
Mail Stop 959
Reston, VA 22092

J. C. Frye
Geologic Society of America
3300 Penrose Place
Boulder, CO 80301

W. W. Hambleton
Kansas Geological Survey
University of Kansas
Lawrence, KS 66044

N. E. Carter
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

S. C. Matthews
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

W. E. Newcomb
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

W. M. Hewitt
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columubs, OH 43201

R. J. Hall
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

S. J. Basham
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

G. E. Raines
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

N. J. Hubbard
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

J. E. Monsees
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

J. A. Carr
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

ONWI Library
Battelle
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505 King Avenue
Columbus, OH 43201 (5)

R. A. Robinson
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

W. A. Carbiener
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

R. M. Hill
State Planning Coordinator
Governor's Office of Planning
Coordination
State of Nevada
Capitol Complex
Carson City, NV 89710

F. D. Waltman
Fenix & Scisson, Inc.
Post Office Box 498
Mercury, NV 89023

N. A. Clark
Department of Energy
State of Nevada
Capitol Complex
Carson City, NV 89710

Western Region Library
Woodward-Clyde Consultants
No. 3 Embarcardero Center
San Francisco, CA 94111

J. L. Thompson
Department of Chemistry
Idaho State University
Pocatello, ID 83201

G. E. Christensen
Holmes & Narver, Inc.
Post Office Box I
Mercury, NV 89023

P. Yanev
John A. Blume Engineers
Sheraton Palace Hotel
130 Jessie Street
San Francisco, CA 94105

R. Siever
Department of Earth Sciences
Harvard University
Cambridge, MA 02138

J. Lyons
Department of Earth Sciences
Dartmouth College
Hanover, NH 03755

J. P. Colton
International Atomic Energy Agency
Division of Nuclear Power & Reactors
Karntner Ring 11
Post Office Box 590, A-1011
Vienna, Austria

J. A. Cross
Fenix & Scisson, Inc.
Post Office Box 15408
Las Vegas, NV 89114

G. Pinder
Department of Civil Engineering
Princton University
Princeton, NJ 07540

A. Soinski
California Energy Resources
Conservation & Development
Commission
1111 Howe Avenue
Sacramento, CA 95825

P. Witherspoon
Lawrence Berkeley Laboratory
Energy & Environment Division
University of California
Berkeley, CA 94720

D. Cantley
Hanford Engineering Development
Laboratory
Post Office Box 1970
Richland, WA 99352

C. R. Hadlock
Arthur D. Little, Inc.
Acorn Park
Cambridge, MA 02140

B. Giletti
Department of Geological Sciences
Brown University
Providence, RI 02912

J. Handin
Center for Tectonophysics
Texas A&M University
College Station, TX 77840

B. Woodward
Law Engineering Testing Co.
2749 Delk Road, S.E.
Marietta, GA 30067

S. Lanes
Subcommittee on Energy Research
& Production
Room B-374
Rayburn House Office Bldg.
Washington, D.C. 20575

G. W. Allen
Bureau of Radiation Control
Department of Health and Environment
Forbes Field
Topeka, KS 66620

F. N. Brenneman
Energy Research and Policy
State of Connecticut
80 Washington Street
Hartford, CT 06115

W. C. Taylor
Executive Office
Lansing, MI 48909

A. Liberatore
Director for Policy and Planning
Room 300, 325 West Adams Street
Springfield, IL 62706

L. H. Bohlinger
Nuclear Projects Coordinator
Nuclear Energy Division
Post Office Box 14690
Baton Rouge, LA 70808

D. W. Godard
Oregon Department of Energy
Labor & Industries Bldg.
Room 111
Salem, OR 97310

R. L. Craig
Radiation Protection Division
1000 Northeast 10th Street
Post Office Box 53551
Oklahoma City, OK 73152

H. D. Cunningham
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 555
Post Office Box 14400
Las Vegas, NV 89114

W. G. Flangas
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 615
Post Office Box 14400
Las Vegas, NV 89114

G. W. Adair
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 154
Post Office Box 14400
Las Vegas, NV 89114

V. M. Milligan
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 765
Post Office Box 14400
Las Vegas, NV 89114

C. W. Dunnam
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 745
Post Office Box 14400
Las Vegas, NV 89114

R. L. Powell
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 634
Post Office Box 14400
Las Vegas, NV 89114

R. B. Land
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 585
Post Office Box 14400
Las Vegas, NV 89114

E. Walters
Radiation Health Information Project
Environmental Policy Inst.
317 Pennsylvania Ave., S.E.
Washington, D.C. 20003

J. A. Lieberman
Nuclear Safety Associates, Inc.
5101 River Road
Bethesda, MD 20016

O. H. Davis
Federal Agency Relations
1050 17tyh St., N.W.
Washington, D.C. 20036

K. J. Buttleman
Environmental Program Supervisor
903 Ninth Street Office Bldg.
Richmond, VA 23219

P. Massicot
Energy Administration
Department of Natural Resources
Tawes State Office Bldg.
Annapolis, MD 21401

J. F. McAvoy
State of Ohio Environmental
Protection Agency
Box 1049, 361 E. Broad St.
Columubs, OH 43216

J. W. Anderson
State of Connecticut
House of Representatives
One Hundred and Sixth District
24 Rock Ridge Road
Newtown, CT 06470

T. D. Davis
Missouri Department of
Natural Resources
Suite 228, Barefield Complex
455 North Lamar Street
Jackson, MS 39201

G. A. Brown
Council Member
374 South Rock River Drive
Berea, OH 44017

D. Falkenheier
Public Law Utilities Group
One American Place, Suite 1601
Baton Rouge, LA 70825

R. Williams
Associate Dean for Research
Georgia Institute of Technology
Atlanta, GA 30332

D. A. Robins
Fenix & Scisson, Inc.
Post Office Box 498
Mercury, NV 89023

E. H. Weintraub
Reynolds Electrical & Engineering Co., Inc.
Mail Stop 625
Post Office Box 14400
Las Vegas, NV 89114

J. W. Rowen
U. S. Department of Energy
Division of Waste Isolation
Room A-272
Germantown, MD 20767

M. E. Langston
U. S. Department of Energy
Division of Waste Isolation
Room E-459
Germantown, MD 20767

N. D. Lewis
Energy Facility Site Evaluation Council
820 East Fifth Avenue
Olympia, WA 98504

E. G. Wermund
University of Texas at Austin
University Station, Box X
Austin, TX 78712

R. M. Fry
Department for Human Resources
Commonwealth of Kentucky
Frankfort, KY 40601

L. Morgenstern
Office of Energy Resources
73 Tremont Street
Boston, MA 02108

D. S. Kell
Department of Environmental
Regulation
Twin Towers Office Bldg.
2600 Blair Stone Road
Tallahassee, FL 32301

V. L. Angell
Holmes & Narver
Post Office Box I
Mercury, NV 89023

R. L. Malloy
Westinghouse Electric Corp.
Post Office Box 708
Mercury, NV 89023

W. C. Roper
EG&G, Inc.
Post Office Box 295
Mercury, NV 89023

M. J. Golis
Battelle
Office of Nuclear Waste Isolation
505 King Avenue
Columubs, OH 43201

D. L. Garland
Hanford Engineering Development
Laboratory
Post Office Box 1970
Richland, WA 99352

D. A. Turner
Rockwell Hanford Operations
Post Office Box 800
Richland, WA 99352

D. I. Hulbert
Westinghouse Electric Corp.
Post Office Box 40039
Albuquerque, NM 87196

H. C. Claiborne
Oak Ridge National Laboratories
Post Office Box X
Oak Ridge, TN 37830

K. R. Hoopingarner
Rockwell Hanford Operations
Energy Systems Group
Post Office Box 800
Richland, WA 99352

J. L. McElroy
Battelle Pacific Northwest Laboratory
Post Office Box 999
Richland, WA 99352

J. D. Osnes
RE/SPEC, Inc.
Post Office Box 725
Rapid City, SD 57709

L. D. Rickertsen
Science Applications, Inc.
Post Office Box 843
Oak Ridge, TN 37830

N. E. Bibler
E. I. DuPont de Nemours & Company
Savannah River Laboratory
Aiken, SC 29801

R. W. Barber
Nuclear Environmental Application Branch
Mail Station E-201
U. S. Department of Energy
Germantown, MD 20767

K. Kuhn
Gesellschaft fur Strahlen-und
Umweltforschung MBH Munchen
Institut fur Tieflagerung
3392 Clausthal-Zellerfeld
Berliner Strasse 2
Federal Republic of Germany

K. E. Maass
Hahn-Meitner-Institut fur Kernforschung
Glienicker Strasse 100
1000 Berlin 39
Federal Republic of Germany

M. Langer
Bundesanstalt fur Geowissenschaften
und Rohstoffe
Postfach 510 153
3000 Hannover 51
Federal Republic of Germany

R. Kraemer
Kernforschung Karlsruhe
Postfach 3640
7500 Karlsruhe
Federal Republic of Germany

H. Rothemeyer
Physikalisch-Technische Bundesanstalt
Bundesalle 100, 3300 Braunschweig
Federal Republic of Germany

R. Randl
Bundesministerium fur Forschung
und Technologie
Postfach 200 706
5300 Bonn 2
Federal Republic of Germany

M. Carter
Georgia Institute of Technology
School of Nuclear Engineering
Atlanta, GA 30332

J. L. Yow
Lawrence Livermore National Laboratory
University of California
Mail Stop L-366
Post Office Box 808
Livermore, CA 94550

A. M. Friedman
Argonne National Laboratories
9700 S. Cass Avenue
Argonne, IL 60439

N. E. Kaiser
Southern States Energy Board
Information Center
One Exchange Place
2300 Peachford Road, Suite 1230
Atlanta, GA 30338

W. G. Stockdale
Energy Division
Building 4500N, D-33
Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, TN 37830

H. W. Smedes
Geologic Siting Division
U. S. Department of Energy
Room A-254
Germantown, MD 20767

J. L. Meinhardt
Office of International Security Affairs
U. S. Department of Energy
Room 4B-026
Washington, D.C. 20585

D. E. Munson
Office of Waste Isolation
U. S. Department of Energy
Room A-218
Germantown, MD 20767

R. W. Barber
Nuclear Environmental
Application Branch
U. S. Department of Energy
Room G-118
Germantown, MD 20767

B. Dietz
Rockwell International
Atomics International Division
Rockwell Hanford Operations
Richland, WA 99352

P. J. Mudra, Director
Operations Support Division
U. S. Department of Energy
Nevada Operations Office
Post Office Box 14100
Las Vegas, NV 89114

T. H. Blankenship, Director
Safeguards & Security Division
U. S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

S. Meyers, Dep. Asst. Secretary
Office of Nuclear Waste Management
U. S. Department of Energy
Room A-416
Germantown, MD 20767

R. G. Romatowski
Office of Nuclear Waste Management
U. S. Department of Energy
Room A-416
Germantown, MD 20767

A. E. Stephenson
Sandia National Laboratories
Post Office Box 14100
Las Vegas, NV 89114 (15)

P. T. Bankston
Mississippi Department of Natural Resources
Suite 228, Barefield Complex
455 North Lamar Street
Jackson, MS 39201

J. A. Thomas
Tennessee Energy Authority
Suite 708 Capitol Blvd. Bldg.
Nashville, TN 37219

UC-70

☆USGPO: 1981 — 758-983/2040