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REBrowning
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MAY 17 1982

MEMORANDUM FOR: Hubert J. Miller, Chief
High-Level Waste Technical Development Branch
Division of Waste Management

THRU: John T. Greeves, Section Leader
High-Level Waste Technical Development Branch
Division of Waste Management

FROM: Dr. Lawrence Chase
High-Level Waste Technical Development Branch
Division of Waste Management

SUBJECT: MEETING REPORT, "SITE CHARACTERIZATION TESTS AND INFORMATION NEEDS FOR LICENSE APPLICATION"

In NRC Headquarters, Washington, DC on April 13, 14 and 15, 1982, a meeting was convened by WMHT and chaired by John Greeves, Section Leader, Design Section, High-Level Waste Technical Development Branch, Division of Waste Management. The subject referenced meeting was called to explore technical positions on repository in-situ characterization testing needs in four areas of interest: Hydrogeology, Geomechanics, Geochemistry and Thermomechanics.

The agenda (Appendix A-1), was provided to participants in advance, and contained questions which were intended to focus discussions for the meeting (the answers to these questions are found in Appendix A-2). The key questions were: (1) what information is needed (2) why is it needed and (3) when is it needed.

On April 14 and 15, the group functioning as a workshop, developed prioritized charts of issues that need to be examined in the in-situ environment, (Appendix A-3). Independent views were formulated by individual members of the group and these are contained in Appendix A-4.

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The following is a summary of the key issues, recommendations and conclusions identified during the workshop:

KEY ISSUES

- Hydrological Response: What are the large scale vertical, horizontal and 3 dimensional permeabilities?
- Geomechanical Response: What is the in-situ stress state? What are the repository rock mass deformational characteristics? What is the geological structure and variability of the rock mass at the repository horizon?
- Geochemical Response: What are the retardation characteristics of the host rock and engineered barriers? What is the chemical composition of the pore fluid and composition of the fracture filling material.
- Thermomechanical Response: What are the thermal properties of the repository host rock (conductivity, specific heat, expansion, etc)? What are the effects of thermally induced hydraulic gradients?

RECOMMENDED SCOPE OF TESTING

- Minimum of 500 feet of tunnel; tunnel to be developed in two orthogonal directions; in-situ boreholes (multi-directional) at least 1000 feet long.
- Hydrological: Water balance computations; geologic mapping; multidirectional borehole experiments; chamber test (coupled thermal flow-stress-structure effects).
- Geomechanical: Geologic Mapping; stress measurements; full scale mine-by experiments.
- Geochemical: Laboratory analysis of uncontamined ground-water and joint filling material.
- Thermomechanical: Small and large scale heater tests; temperature logging.

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CONCLUSIONS

- o Time is running out for completing the needed testing prior to License Application. The time required to conduct the needed test work ranges between 2 and 7 years; some of the recommended room size Chamber Tests cannot be completed before License Application. The time factor looms even larger because the in-situ test work cannot be started before completion of the shaft/bell and the associated tunneling.

- o There was unanimous agreement that the range of geologic information needed to characterize the repository rock mass could not be satisfactorily obtained by "working from the bell."

Attached to this memorandum, is the draft report of the meeting which was prepared by Dr. Jaak Daemen prior to adjournment. To the extent possible, comments received from the group have been incorporated into this draft. It should be noted, however, that due to the complexity of the subject and the diversity of opinions expressed, the draft report may not reflect the precise opinion of every participant.

ORIGINAL SIGNED BY

Lawrence Chase, Ph.D.
High-Level Waste Technical
Development Branch
Division of Waste Management

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End to 5-17-82
memo to Miller

WMHT: 3003.1

MEMORANDUM FOR: Dr. Lawrence Chase, Mining Engineer

FROM: Dr. J. Daemen, Consultant to Golder Associates

SUBJECT: REPOSITORY SITE INVESTIGATIONS, PANEL REVIEW MEETING, WASHINGTON, DC, April 13, 14, 15, 1982

Purpose:

Establishment of a technical support basis for the development of a position on repository site characterization testing.

Attendees:

D.L. Pentz (Golder Associates); R. Gates (Golder Associates); H. Wollenberg (LBL); C.O. Babcock (U.S. Bureau of Mines); D.F. Hambley (Engineers International, Inc.); J. Daemen (University of Arizona); H. Miller, J. Greeves, L. Chase, L. Hartung, P. Prestholt, D. Tiktinsky (NRC).

Introduction:

This report provides a summary of the discussions at the subject meeting. The discussions centered on the testing requirements in four key areas: Hydrology, Geomechanics, Thermomechanics, and Geochemistry. Some important related aspects were discussed and are included in section five of this report, entitled, "Common aspects of repository site investigations". The title was selected to emphasize the fact that common prerequisites exist for all key issues of the site investigations, and that there is considerable overlap and interaction between them.

Key Conclusions:

- There is general and strong agreement among all panel members that 500 ft. of horizontal tunneling at the repository horizon is the absolute minimum necessary to have a reasonable chance of providing the information required for a license application (There was strong reluctance on the part of some of the panel members to accept the

500 ft. because they felt a thousand foot long drift is more desirable). Agreement was accepted only because the extremely late starting date of the shafts will make it extremely difficult to follow prudent engineering practice, which would require considerably more tunneling.

- There is general agreement that 2000' of horizontal bore holes at the repository horizon from the tunnels is required (preferably 4-500 ft. multidirectional holes).

- There is general and strong agreement about the need for extensive in-situ testing in order to resolve key uncertainties (e.g., response of rock mass to high temperature, rock stability during tunneling) in the areas of Geochemistry Hydrology, Geomechanics and Thermomechanics. There is general agreement on the key parameters (e.g., permeability of rock mass, stress field in repository host rock, deformation response of rock) that need to be determined, but there is no complete agreement as to what specific tests should be performed to reduce the uncertainty in the knowledge of these parameters.

- A common feeling is expressed that shaft sinking, tunneling and in-situ testing should be started as soon as possible (should have been started already).

- A general unease has been expressed about making the entire in-situ testing up to the license application stage dependant upon a single very small very deep shaft (and, for BWIP, to be constructed by a method not used before in this very hard abrasive rock, moreover, a method which absolutely minimizes any possibilities for obtaining site information).

- It was generally agreed upon that a 12'-15' shaft was the minimum size required to allow efficient muck handling, ventilation, and transportation of men and materials. The shaft sinking method to be used by DOE (blind boring), makes it impossible to get undistured rock samples, difficult to measure water inflow, and impossible to obtain joint and beding plane geometry.

- There is agreement that the funding needed for a satisfactory site characterization for a project of the size and complexity of a repository would be of the order of $50 million.

1. Hydrological aspects of repository site characterization.

There is uniform agreement among the panel members that hydrological characterization is the most important topic of the site investigations. There is general agreement that the needed information can not be obtained from surface holes only, nor from a shaft-bell combination with short holes.

Key Parameters

- ° Permeability
- ° Water Pressure
- ° Water Composition
- ° Excavation & Damage
- ° Storage Coefficients

Key issues identified:

- Determination of vertical and horizontal permeability (general agreement among all panel members) of at least a representative sample of the repository rock.

- Determine variability in permeabilities within repository horizon (general but less strong agreement).

- Determine permeability of disturbed rock (disturbed either by stress changes - excavation or heating - or by excavation damage).

- A representative volume; (i.e., A volume is considered representative when small increases in the test volume have no significant effect on the averaged value of the material property being measured) must be tested.

Key methods:

- Water balance monitoring during construction (general agreement). This is needed to determine approximately the large scale permeability of the horizon, by measuring water inflow and outflow which allows the amount of water flowing into the tunnels to be calculated.

- Multi-directional multi-hole experiments are needed (general agreement). All rock mass parameters (e.g. stress, discontinuites, strength, moduli) are different in different directions. Values can only be determined by measurement in preferably three perpendicular directions.

- Coupled thermal-flow experiments (agreement, but less strong). These are needed to determine permeability and deformational response of the rock mass to temperature and stress changes.

- Chamber tests (agreement, but wide divergences in needed test size, comprehensiveness and urgency). These are needed to determine the rock mass response on a scale approaching the actual, proposed, waste repository.

2. Geomechanical aspects of repository site characterization.

Most but not all panel members agreed this is second priority key topical area. As for the Hydrology, knowledge of the general geological context is an essential prerequisite. There is total agreement that sufficient investigations can not be performed from vertical boreholes because they are likely to miss major structural features. A representative volume will require at least some multidirectional drilling. This is necessary because in a rock mass, to determine directional characteristics (e.g. joint spacing and permeability) measurements must be made in at least two significantly different directions becuase all characteristics can be strongly directional dependant.

Key parameters:

- Geological structure (i.e., lithology, (rock types, presence or absence of faults, joint systems, etc.)

- In-situ (three-dimensional) stress state

- Rock mass deformational characteristics

- Rock mass strength characteristics

- Creep (time dependent behavior)

Key issue:

- Identifying variability of all parameters.

Key testing procedures:

- Field mapping to determine the geological environment (i.e. rock types, faults, joint systems, etc.)
- Monitoring of displacements during construction (might be prevented by some shaft sinking methods as previously noted).
- In-situ plate bearing tests to measure mechanical behavior of the rock mass.
- Overcoring stress measurement (in multidirectional boreholes-in at least three differently orientated directions) to measure in-situ stress.
- Standard laboratory tests on core to assess variability (e.g., uniaxial, brazilian disc, wave velocity).
- Mine by experiments at full scale repository dimensions (there was complete strong agreement on all previously listed tests).

  Agreement is far less strong on this and subsequently listed tests):

- Drill vertical holes at corners of repository to prove presence of proposed repository basalt flow.
- Drill holes in advance of tunnels: predict tunnel rock behavior and assess validity of the model.

3. Thermomechanical aspects of site characterization. A knowledge of the thermomechanical response of the rock mass to the heating induced by the waste is essential to predict the containment and isolation provided by the heated rock mass. This requires specifically determining the dependence of (water)flow paths on heat and the flow-driving mechanism induced by heating.

   Parameters

   o Thermal conductivity
   o Coefficient of thermal expansion
   o Strength and moduli as a function of temperature
   o Heat content
   o Thermal effects on engineered barriers

Key issues:

- There is general agreement that these tests must be done on a rather large scale to assure adequate results.
- General agreement exists that there is a fundamental lack of understanding of the complex factors involved in thermomechanical response, probably requiring further basic (generic) research.

Key tests:

- There is agreement that relatively large scale in-situ heater experiments are necessary, but the agreement is tempered by the knowledge that the interpretation, and hence predictive value, of such experiments remains uncertain at best. The reason for the uncertainty is that the tests involve very complex interactions of rock behavior aspects that have not been studied in much detail previously.
- There is general and strong agreement for the need to determine thermomechanical variability by performing laboratory determinations of standard properties (conductivity, specific heat, expansion, as a function of temperature) from representative samples obtained throughout a rock volume sufficiently large to allow variability to be assessed.
- Experiments must be in-situ because of the coupled heat-flow-stress-structure effects.

4. Geochemical aspects of site characterization

There was disagreement about the importance of geochemical in-situ testing. There was total agreement about the need for obtaining representative uncontaminated samples of groundwater and fracture and joint filling. There was (incomplete) agreement that this would be difficult to do without in-horizon excavation and extensive drilling.

<u>Parameters</u>

o Retardation capacity
o Pore-fluid composition
o Adsorption
o Dispersivity

Key Issue

There was general agreement as to the need to determine retardation capacity of the mechanical enigineered barriers.

Key Tests

No need for in-situ geochemistry testing was experienced; however extensive laboratory testing may be required.

5. Common aspects of repository site characterization

It is essential to recognize that the key objective of the repository is to contain and isolate high level radioactive waste. The overall performance of the rock mass includes various aspects discussed in the separate sections summarized before, but they can not be totally isolated, because of interaction between them.

Deficiencies in one area can be compensated by superior performance in another area, and many aspects of the site characterization are closely related and overlapping.

There is total agreement among the panel members about the absolute need for extensive access to the repository horizon. Providing access is the major cost of site characterization. There is general agreement that it seems very unfortunate to invest a considerable expenditure to promote access to the repository and then not commit the relatively minor additional funds to outline the access to the fullest possible extent.

A more serious concern was expressed, and uniformly agreed with, about the extremely limited information gathering effort that is being planned, and that tests will be severely contained by the extremely small access facilíties. Although the expressions of concern were muted by the recognition that full site characterization would be extremely difficult within the existing time frame, there is no doubt that all participants believed that the proposed in-situ work has been started too late and proposed in too small a scale to be truly satisfactory. If only one shaft is sunk, it should at least be of a sufficient size to allow safe, efficient and large-scale site investigations. A large diameter shaft would permit a drastic speeding up of all underground work by allowing the use of larger equipment, more efficient mucking and better ventilation capabilities.

WMHT: 3103

APPENDIX A-1

MEETING NOTICE

Date: April 13-15, 1982

Location: Willste Building
Conference Room 106
7915 Eastern Avenue
Silver Spring, MD 20555

Subject: Site Characterization Tests and Information Needs for License Applications

Purpose: To evaluate current DOE strategy for in-situ testing and formulate an NRC response to this strategy. This will include evaluation of three media (BWIP, NTS, and SALT) with the emphasis on BWIP.

Chairman: John T. Greeves, Section Leader
Design Section
High-Level Waste Technical Development Branch
Division of Waste Management
Nuclear Regulatory Commission

Agenda

- Introductory Remarks: Hubert Miller — 1 hour
  Branch Chief, High-Level Waste Technical Development Branch
  Division of Waste Management
  Nuclear Regulatory Commission

  a) Overview of High-Level Licensing Schedule (Greeves)

  b) NRC Decisions at the Construction Authorization Stage (Greeves)

  c) Status of 10 CFR 60 Revisions (Greeves)

  d) NWTS Program Strategy (Greeves)

  e) Current Issues at BWIP (Wright)

- What are the information needs specifically required for a License Application in the following technical areas of interest?

  Geomechanical
  Geochemical
  Thermomechanical
  Hydrogeology

  a) Presentation of LBL Report (Wallenberg) — 1 hour

  b) Presentation of Golder Report (Pentz, Gates) — 1 hour

- Group Discussion of Questions — 1 day

- Prepare Meeting Report — 1 day

Invited Attendees

✓Jaak Daemen - University of Arizona
David Pentz - Golder Associates
Richard Gates - Golder Associates
✓Harold Wallenberg - Lawrence Berkeley Lab.
✓Doug Hambley - Engineers International, Inc.
✓Clarence Babcock - Bureau of Mines

NRC

Hubert Miller
John Greeves
Lawrence Chase
Ludwick Hartung
Paul Prestholt
David Tiktinsky
Tom Schmitt

Background Information

10 CFR 60 - Procedural Requirements
10 CFR 60 - Proposed Technical Criteria
10 CFR 60.31
Standard Format & Content for HLW Repositories
NWTS Strategy Document
BWIP Documents on In-Situ Testing Report
Golder Associates's In-Situ Testing Report
Lawrence Berkeley Lab's In-Situ Testing Report
International Engineers, Inc. Report
Hubert Miller's Memo of 3/24/82
John Greeves Program Plan - Dated 3/26/82

INTRODUCTION

The attached agenda and questions are intended to focus discussions for the upcoming April 13-15, 1982 meetings of NRC staff and contractors in preparation for an April 22 meeting with DOE on In-Situ testing plans. The DOE meeting will focus on what investigations are required to support Construction Authorization decisions. The three basis questions are:

1) What are the information needs for a license application?

2) Why are they needed?

3) When does this information have to be submitted?

Introductory remarks by NRC will include an explanation of (1) the licensing schedule (2) decisions which must be addressed by the NRC, (3) status of 10CFR60 revisions (4) discussion of the NWTS Program Strategy document and (5) Identification of current issues at the BWIP site.

This will be followed with a brief presentation by GAI and LBL of their recommendations in their recent reports. For NRC to be responsive and sensitive to DOE's schedule and planning needs, positions will have to be taken by the NRC staff in the April 22, 1982 meeting with DOE. Therefore, the April 13-15, 1982 meetings are intended to coordinate all NRC activities in this area, in addition to preparing for the April 22 meeting. Meeting participants should be prepared to address the following questions and prepare a consensus of the technical conclusions.

General Questions

1) What are the information needs for a license application?

2) Why is the information needed?

3) When does the information have to be submitted?

4) How much of this information can be obtained from surface investigations with drill holes?

5) How much of this information requires underground testing?

6) What is an acceptable investigation program to meet these needs?

Specific Questions

1. The DOE schedule calls for sinking a single small diameter (6-7 ft. I.D. at BWIP) shaft at each site before license application. What investigations are feasible and practicable at the bottom of a single small diameter shaft ... away from the bottom?

2. How far out from the shaft can you tunnel without a second shaft? How fast can you go?

3. What is the cost of opening up rooms similiar to the LBL report, at BWIP?

4. What is the cost of large scale tests? What is a reasonable schedule for these tests?

5. What percentage of the repository horizon should be investigated before license application... by surface methods, horizontal borehole or tunnels? Why?

6. Is a mine-by experiment needed prior to license application? If not, when? Why?

7. Is thermomechanical testing in the repository horizon needed prior to license application ? If not, when? Why?

8. Is a large scale chamber test needed prior to license application? If not, when? Why?

9. Does this information satisfy model verification needs at the construction authorization stage?

10. If a license application is to be made in 1988 how much investigation can be done underground?

11. How can the results of these investigations be used to support NRC findings on protection of the public health and safety?

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Licensing Sequence

Based on current thinking 3½ to 4 years will be needed for the Construction Authorization process (see attached figure).

- First the staff must review the L.A. for completeness and adequacy (this will be assured though the SCR review process). Then the staff must develop a position (Safety evaluation report) on all important issues (see 60.31 below).
- The SER is reviewed by the ACRS and a SER supplement is issued if necessary. Only then can the formal hearing process start.
- Even though some prehearing conferences can be started prior to issuing the SER, the formal process takes at least one year
- After the hearing board makes its findings, the commissioners will review the decision.

60.31 Construction Authorization

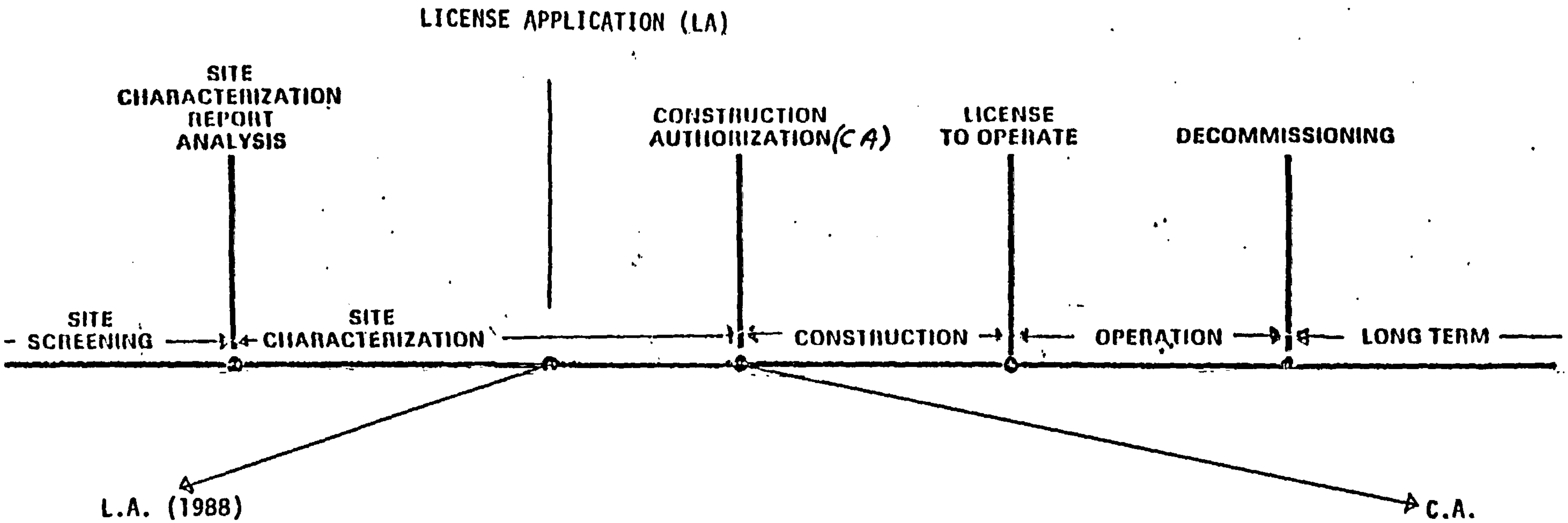
Commission determines:

There is reasonable assurance the design proposed can, without unreasonable risk, protect the public health and safety

The Commission shall consider:

- geologic, geochemical and hydrologic characteristics of the site
- kinds of radioactive waste disposed
- principal engineering criteria for the design and operation
- construction effects
- Whether the site and design comply with technical criteria in 10CFR60
- Quality Assurance requirements
- Environmental issues

LICENSING SEQUENCE



Staff preparation of Safety Evaluation Report	Public Comments ACRS Review	Formal Hearing Process	Commission Review of Hearing Finding
12-15 months	6-9 months	12-15 months	6 months

Appendix A-2

DRAFT
05-17-82
CM

QUESTION 1: The DOE schedule calls for sinking a single, small, diameter (6 ft. I.D. at BWIP) shaft at each site before license application. What investigations are feasible and practicable at the bottom of a 6 ft diameter shaft . . . away from the bottom?

ANSWER: A shaft in principle provides access to the entire rock sequence between (and below) repository level and surface. It appears highly undesirable to restrict access to repository level only.

In bell liner: stress meters-convergence points. Drilling extensometer holes from 6 ft diameter shaft will be very difficult (drilling 50 ft holes) - extensometer installation might be difficult - same holds true for 50 ft overcoring tests.

Need vertical permeability - can (will) holes be used for this purpose?

Measure heat flow, i.e. intake-return air heat content (enthalpy - temperature - moisture)

Maximum drill depth from bell should be at least several hundred ft - should give (vertical fracture patterns, spacings, etc.)

Probably can only drill 2 holes simultaneously

Instrument rock bolts and shaft liner (steel is relatively easy and reliable to instrument)

Use all information gathered during shaft sinking - rate of advance - heat: measure water temperature at various levels, flow?

For BWIP drive at least one tunnel above repository level, parallel to tunnel at repository level - allows vertical testing.

Figure 12* suggests no hydrological testing - seems difficult to believe: a variety of flow tests are possible and desirable: hole pressurization, fracture flow, tracers.

All holes (bolts, stress measurements, etc.) should at least be photographed, preferably cored.

Bell surface should be mapped in detail.

If at all possible install multiple thermocouples in some of the holes (probably needed for stress meter corrections anyway)

Figure 12* states doorstopper tests: 8 @ 20' does this mean or imply multiple measurements up to 20' or point measurements at 20' and 50' only - the former would be preferable.

J. Daemen 04-14-82

*FIGURE 12. Breakout Station Concept.

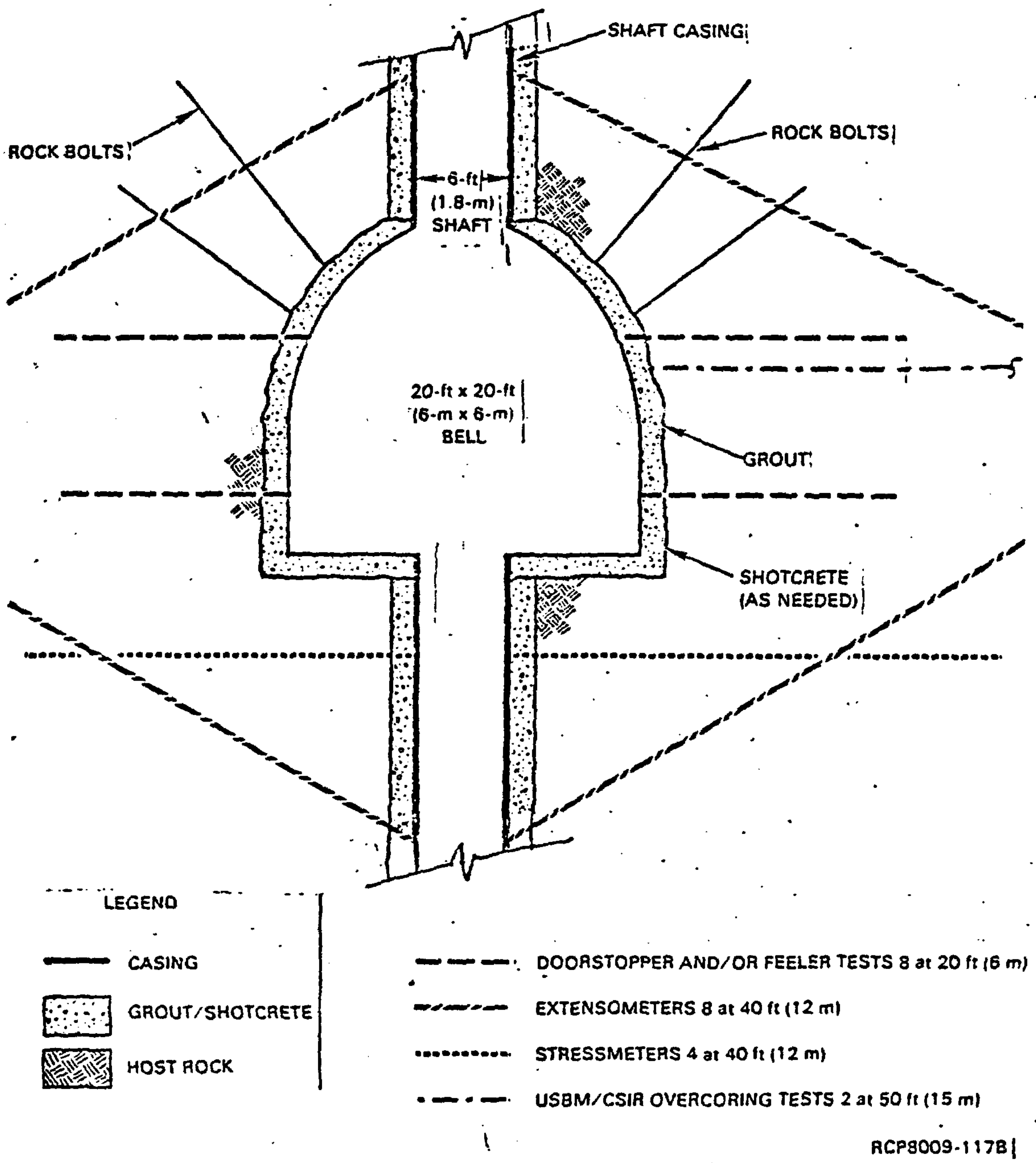


FIGURE 12. Breakout Station Concept.

QUESTION 1: The DOE schedule calls for sinking a single, small, diameter (6 ft. I.D. at BWIP) shaft at each site before license application. What investigations are feasible and practicable at the bottom of a 6 ft diameter shaft . . . away from the bottom?

ANSWER: Tests are very limited for this confined space. Two men will have tight working conditions. Short drill rods will be required. Noise will be a problem from an air drill. Water supply for wet drilling will be a problem especially if water is lost. Tests that should be made are : (1) multiple anchor extensometers, to measure convergence rate of circular hole in rosette form, (2) overcore USBM Deformation gage in at least two perpendicular directions to determine in-situ stress, (3) determine physical properties from core testing in laboratory, (4) determine constitute relationships from convergence measurements, (5) make finite element analyses of convergence vs. stress levels to model closure if non-elastic behavior exists, (6) if shaft is dry enough attempt overcore at bottom of shaft in vertical direction to estimate 3 dimenisonal state of stress after correction from depth difference, (7) place cylindrical pressure cells radially to define in-situ modulus, (8) place borehole pressure cells or (IRAD) gages in horizontal holes to monitor ground pressure changes close to shaft, (9) use USBM borehole shear tester to determine Mohr-Coulomb behavior in-situ in radial directions, (10) packer tests to define permeability along selected length of drill holes, (11) USBM gas detection gages for measuring methane gas if it is present, (12) consider infrared equipment to detect cracks, (13) mirco-seismic noise detectors if rock fracturing is time dependent, (14) study rock cooling behavior of ventilation air or water, (15) measure water inflow rate-does it increase with time, (16) use core recovery as an indication of rock strength in-situ, (17) use RQD index as rock classification method.

All preceeding tests could be made away from shaft. Additional tests away from shaft are: 1) drift convergence behavior with multiple anchor extensometer rosettes; 2) measure stress changes with mine-by simulation with multiple entires (room and pillar); 3) rock bolt behavior for roof support with bolts of the type - (a) conventional with expansion anchor, (b) conventional with grouted anchor, (c) full resin grouted, (d) gypsum grouted, (e) Scotts Split sets; 4) beam, sling, or yielding set support; 5) increase roof width progressively to define stable in-situ roof span and in-situ physical properties; 6) define mining sequence so that air flow requirements can be met during development and later mining; 7) hydrology studies with packers between drill holes; 8) hydrology from blocked drift section (LBL).

C. Babcock 04-14-82

QUESTION 1: The DOE schedule calls for sinking a single, small, diameter (6 ft. I.D. at BWIP) shaft at each site before license application. What investigations are feasible and practicable at the bottom of a 6 ft diameter shaft . . . . away from the bottom?

ANSWER: Without a second shaft, with only 6' diameter ID shaft, and ambient temperature of 135^{o} F (58^{o}), the extent of working at depth must be very limited. The 500' of tunnel, as tentatively proposed at BWIP for ES II, is most likely practicable. More in-situ testing is needed as discussed in other answers. Thus, two shafts may be required prior to License Application if one is only 6' diameter(ID).

At the bell of DOE Phase 1, some rock fracture frequency can be documented, some hydrogeology data collected, possibly some deformation tests (flat jacks) and some in-situ stress measurements can be taken. The shaft structural stability and proof of shaft liner and shaft seals effectiveness can be obtained. Also, horizontal drill holes will alow more rock property and hydrological property determination. With the construction of some small rooms and drifts out of the bell, much more can be learned. More reliable in-situ stress measurements (overcoring) can be taken, some deformation properties can be learned by plate tests and flat jack tests. Hydrogeologic testings to include multiple borehole tracer tests, multiple and borehole permeability tests, and groundwater sampling. Additional testing to include boreholes and logging to check horizontal extent of the horizon, temperature logging, hydraulic fracturing, and geophysical testing could be done to confirm site selection and design criteria.

Dick Gates 04-14-82

QUESTION 1: The DOE schedule calls for sinking a single, small, diameter (6 ft. I.D. at BWIP) shaft at each site before license application. What investigations are feasible and practicable at the bottom of a 6 ft diameter shaft . . . away from the bottom.

ANSWER: In a 20 ft. diameter station, it would be possible to carry out diamond drilling - it is possible to drill holes over 70 ft before deviation becomes severe and with carful stow drilling somewhat longer holes are possible. It will be very difficult to drill 40 ft. long extensometer holes from the shaft above and below the "bell." That is the work that can be done from the "bell" is very limited.

There are, however, more fundamental questions. First, a 6 ft diameter shaft will require blind shaft boring which is not proven technology in hard rock for depths of 3700 to 4200 ft. Second, if it is intended to monitor the shaft walls as a prediction of performance at larger shafts, expected inflow and so on, this will not occur since boring disturbs the surrounding rock much less that drilling-and-blasting. Third, there is the question of the temperature and ventilation (135°F at 3700 ft). This by itself imposes very real constraints on the amount of dead heading that can be performed, since the shaft and any workings are a dead heading. As far as carrying tunnels away from the shaft, the extent will be severely limited likely to about 1000ft. or so. Thus, one can safety assume that a second shaft would be necessary before drifting is carried very far, with a second shaft more extensive exploration headings could be excavated, so that a more exhaustive suite of tests could be performed. This would better enable one to confirm site selection and design criteria than would the very limited amount of data which one could obtain from the "bell."

D. F. Hambley 04-14-82

QUESTION 1: The DOE schedule calls for sinking a single, small, diameter (6 ft. I.D. at BWIP) shaft at each site before license application. What investigations are feasible and practicable at the bottom of a 6 ft diameter shaft . . . away from the bottom?

ANSWER:

A. WHAT INVESTIGATIONS ARE FEASIBLE IN A 6' I.D. SHAFT?

1. Deformation evaluations (quasi modulus determination).
2. Water pressure (head) evaluations, borehole vertical permeability evaluations of a limited zone surrounding the shaft.
3. 3D Stress determinations in boreholes (3).
4. Hydrological evaluation of shaft grouting.
5. Limited geological framework exploration (40 ft. beyond limits of shaft.)

B. WHAT INVESTIGATIONS ARE FEASIBLE AWAY FROM THE SHAFT?

Assuming the environmental conditions are satisfactory there is no limit to the number and type of investigations that can be made provided there is suitable space to allow decoupling each test.

C. WHAT INVESTIGATIONS ARE PRACTICAL IN A 6' I.D. SHAFT

All methods outlined in (A) above are practical however I doubt if deformation evaluations at this stage are appropriate or cost effective. Hydrological tests carried out in a series of boreholes packed off at different levels are practical but time consuming primarily due to limitations in space. It should noted that all investigations could use the same boreholes if sequenced appropriately.

D. WHAT INVESTIGATIONS ARE PRACTICAL BEYOND THE SHAFT (I.E. IN ACCESS DRIFTS DRIVEN FROM THE SHAFT AT THE REPOSITORY HORIZON

A variety of investigations are practical if there is both a demonstrated need, available time and budget. These investigations should address in part of all the following issues.

Thermal Response
Mechanical Response
Hydrological Response
Geochemical Response
Constructibility

The latter issue addresses only those perturtations induced by construction which can be demonstrated to have long term response in disturbed zone around the openings and design and construction of engineered barriers.

D. Pentz 04-14-82

QUESTION 1: The DOE schedule calls for sinking a single, small, diameter (6 ft. I.D. at BWIP) shaft at each site before and license applicat. What investigations are feasible and practicable at the bottom of a 6 ft diameter shaft . . . away from the bottom?

ANSWER: Directly from Bell

The principal benefit will be investigation of the hydrologic regime (a) in the entablature, (b) the flow top zone and (c) the colonnade zone below the entablature. The investigations can be accomplished primarily by horizontal, inclined holes drilled from the bell. One set, at least 2 bell diameters in length (and 40 to 50 long if inclined) would cover the zone in the vicinity of the bell. Longer holes (500 m) would cover areas in possible directions of test locations and, ultimately a portion of the repository area. All holes would be continuously cored with core oriented and fracture orientation and frequency recorded. Based on information from the cores and borehole TV Survey, intervals in the holes would be packed off and pressures measured. Samples would be obtained of essentially uncontaminated formation fluid for determination of Eh, pH, and major and trace element contents.

The azimuths of the long inclined and declined holes will match those of the long horizontal holes to examine hydraulic gradients between the flow top and colonnade and the repository horizon.

Following establishment of the hydrologic setting, selected packed off intervals could be pressurized for determination of in-situ stress by hydraulic fracturing and compared with results of overcoring tests at similar depths.

If shaft access permits, horizontal holes in interbeds above and below the Untanum should be drilled and instrumented for hydraulic gradient determinations.

H. Wollenberg 04-14-82

NOTE: IMPORTANT CONSIDERATION

It should be assured that as much of the rock shall be exposed as practicable to permit observation of lithology and measurement of fracture orientation and spacing. Stations should be excavated at the corners of the "racetrack" to accomodate long (300 to 500m) horizontal and inclined holes.

H. Wollenberg 04-14-82

QUESTION 2: How far out from the shaft can you tunnel without a second shaft? How fast can you go?

ANSWER: This decision may be determined by MSHA requirements especially since methane gas may be present. The USBM bored shaft in oil shale blind-bored to 2352 in 1977. They were allowed a working distance from the shaft of 200 feet because of gassy conditions. Because the temperatures will be about 135°F 3450 feet in Basalt the miner can work 20 minutes per hour and this will restrict its output and the rate of mining advance. By conventional drill and blast at most one 12 x 12 x 10' round can be driven each 8 hr. shift. A realistic estimate may be 3 rounds for 5 shifts assuming the drifts are naked but bolted. MSHA can make special provisions for experimental or test purposes. 500 to 1,500 ft-long "racetrack" appears feasible.

C. Babcock 04-15-82

QUESTION 2: How far out from the shaft can you tunnel without a second shaft? How fast can you go?

ANSWER: Because of the high ambient temperature (135°F), and the limited hoisting capacity in 6 ft borehole, it is unlikey that tunneling can go more than 500 to 1000' without second shaft. The speed which work will progress will depend on the equipment used.

To have men work under such conditions it will be necessary to have cool ventilating air. This can be accomplished using compressed air or chilled water. The latter has greater cooling capacity but, either way, it will be expensive. The ventilation capacity in cfm will also limit the equipment which can be used for 12 ft by 13 ft tunnels or larger would normally require L-H-D equipment of 4 yd^3; however, in this case 2yd^3 equipment must be used since this will fit in the 6' dia shaft if properly dismantled while larger equipment will not. Dismantling and reconstructing the equipment will add about 1-2 weeks time to this schedule. L-H-D equipment is normally diesel powered: a 2 yd^3 machine has 78HP engine which will require a minimum of about 10,000 cfm of air. However, if one is talking only of 500 - 1000 ft then electric powered L-H-D's could be used - these units normally have 500 ft long trailing cables. Advance rates will likely vary from 3 to 10ft/day.

D. F. Hambley 04-14-82

QUESTION 2: How far out from the shaft can you tunnel without a second shaft? How fast can you go?

ANSWER: The distance that can be expected are up to 500 ft with costs of $1000-$1500/ft 3 to 10 ft average of advance.

We believe this can be done assuming chilled water for cooling and 6 ft. shaft and 12 x 12 ft or 18 x 18 ft. exploratory tunnels. These can be excavated using diesel equipment which will be disassembled at the repository horizon.

D. Pentz 04-15-82

QUESTION 2: How far out from the shaft can you tunnel without a second shaft? How fast can you go?

ANSWER: 500 to 1,000 ft
(Depends mainly on MSHA approval and on safety considerations e.g. what happens if power (hoisting; ventilating; pumping) goes out. 5 to 10 ft/day advance

JUSTIFICATION

Small Tunnel - Full Face
Larger Tunnel - Top Heading/Bench
Drill 10'Rounds in Both Cases
24 Hour Cycle

- o 16 Hour Operations

- o 8 hour ventilation, cooling with chilled water, cooled air can reduce temperature to below 90°F; can handle diesel exhaust; can handle mucking (spoil hoisting) within time limit

This is a conservative estimate - with necessary equipment (underground coolers compressors), might go faster.

J. Daemen 04-15-82

QUESTION 2: How far out from the shaft can you tunnel without a second shaft? How fast can you go?

ANSWER: 500' no problem
1000 at reasonable cost; if MSHA says OK
1,500 if MSHA says OK

Requires compressed air cooled at surface, cold water best extraction, keep temperatures below 90°F 12' x 13' to 17' x 18' tunnel sizes are assumed will cost $1000-$1500/foot of advance average rates of 3'/24 hours - reasonable (16 hour work shift and 8 hour cooling period), thus about 6-12 months.

Assume rock bolt support - No Shot-Crete to allow for mapping of joints.

Dick Gates 04-15-82

QUESTION 3: What is the cost of opening up rooms similar to the LBL report, at BWIP?

ANSWER:

1) *Hydro/Thermomechanical Experiment

Drilling gallery 30 x 30 x 15":	260K
Chamber 125" x 6" diameter:	213K
Liner and bulkhead:	371K
TOTAL	844K

2) Excavation Damage/Sealing Experiment

Excavation Damage Drift, 100' long, 12' x sect:	239K
Center Drift, Liner and Bulkhead:	544K
Cross cut and Bulkheads:	221K
TOTAL	$1004K

(*These costs do not include overhead)

H. Wollenberg 04-14-82

QUESTION 3: What is the cost of opening up rooms similar to the LBL report, at BWIP?

ANSWER: The costs for rooms ranging from 12 ft. by 12 ft. to 17 ft. by 18 ft. would be:

a) A 12' x 12' opening or 12 x 13' would cost at least $1350/ft.

b) A 17 x 18' opening would, assuming the same cost/ft^3 as a 12 x 13', would cost at least $2600/ft.

D. F. Hambley 04-14-82

QUESTION 3: What is the cost of opening up rooms similar to the LBL report, at BWIP?

ANSWER: Probably a minimum of $\$10/ft^3$. Almost certainly will be affected (hampered) severely by small size of access shaft.

J. Daemen 04-15-82

TABLE 1

COST ESTIMATE OF IN SITU TEST FACILITY CONSTRUCTION

(Access tunnels assumed to be part of repository design and not costed)

OPTION 1

Exploratory shaft	$ 13,090,000
Exploratory shaft equipment	1,500,000
Exploratory shaft access tunnel	18,275
Block test room	33,990
Pressure chamber test	116,440
Full-scale heater test room	16,995
Mine-by test observation tunnel	130,500
	$ 14,906,200

OPTION 2 - (Cost of Option 1 and one access tunnel)

Option 1	$ 14,906,200
Access tunnel	527,510
	$ 15,433,710

Golder Associates

Subject to Change

TABLE 2
COST ESTIMATE OF IN SITU TESTING

	Exploratory Shaft		Underground Test Facility	
	# of Tests	Total Test Cost	# of Tests	Total Test Cost
Plate Test	-	-	6	261,600
Block Test	-	-	2	1,116,300
Pressure Chamber Test	-	-	1	621,700
Mine-By Test	-	-	1	948,300
Heater Test (Large Scale)	-	-	1	593,800
Heater Test (Small Scale)	2	568,900	6	1,016,700
Tracer Test (Multiple borehole)	2	289,200	3	385,200
Permeability Test (Multiple borehole)	2	768,600	3	1,006,200
Overcoring	30	114,800	27	72,900
Flatjack Test	6	31,300	9	17,200
Coreholes	40	102,000	9	1,494,000
Groundwater Sampling	40	-	20	-
Temperature Logging	40	-	20	-

	Permeability Test (Single borehole)	100	-	450	-
	Hydraulic Fracturing	10	-	30	-
	Geophysics (Exposure, x-hole)	40	-	40	-
	Gas Detection	c	-	c	-
	Acoustic Monitoring	c	-	c	-
	Exposure Mapping	c	-	c	-
	Displacement Monitoring	c	-	c	-
	Pore Pressure Monitoring	c	-	c	-
	Mine Drainage Monitoring	c	-	c	-
	Construction Monitoring	c	-	c	-
	Operation Monitoring	c	-	c	-
	Exploratory Shaft Testing		$1,874,800		
	Underground Test Facility Testing				$7,533,900

Note: C = Continuous monitoring

$7,533,900
1,874,800
5,659,100

Golder Associates

The following major tests have been used in the cost estimate. Some minor tests have been examined and the minimum required number of tests indicated. These minor test and monitoring activities have not been used in the cost estimate:

- Small scale heater test (2 locations)
- Multiple borehole tracer test (2 locations)
- Multiple borehole permeability test (2 locations)
- Overcoring (30 tests, 3 tests/hole, 10 holes)
- Flatjack test (2 locations, 3 directions/location)
- Coreholes and logging (40 holes, 50 ft min., 2 holes/drill station
- Groundwater sampling (40 samples)
- Temperature logging (40 tests)
- Single borehole permeability test (100 tests)
- Hydraulic fracturing (10 tests)
- Geophysical testing (40 tests)

Underground test facility testing is as follows:

- Plate test (2 locations, 3 directions)
- Block test (1 location, 3 directions)
- Pressure chamber test (1 location)
- Mine-by test (1 location)
- Large scale heater test (1 location)
- Small scale heter test (2 locations, 3 direction)
- Multiple borehole tracer test (1 location, 3 directions)
- Multiple borehole permeability test (1 location, 3 directions)
- Overcoring (3 tests/hole, 9 holes, 3 direction/hole)
- Flatjack test (3 locations, 3 directions)
- Coreholes and logging (9 holes, 1000 ft/hole, 3 stations, 3 directions)
- Groundwater Sampling (20 samples)
- Temperature logging (20 tests)
- Single borehole permeability tests (450 tests, 20/test, 9-1000 ft. long holes)
- Hydraulic fracturing (30 tests, concentrated in long holes)
- Geophysical testing (40 tests, concentrated in short holes)

- In situ testing includes testing in the exploratory shaft and the underground test facility. Emphasis in the testing program is on

  - Permeability
  - Radionuclide migration
  - In situ stress state

- Exploratory shaft testing program is detailed in Table 2. Testing will be conducted in the repository horizon and the overlying strata. The suggested number of tests are the minimum which should be conducted. Cost and practicality have been considered.

COST ESTIMATE OF IN SITU TEST FACILITY IN BASALT

o Cost estimate includes:

- Exploratory shaft construction
- Access tunnel and test room construction
- In situ testing

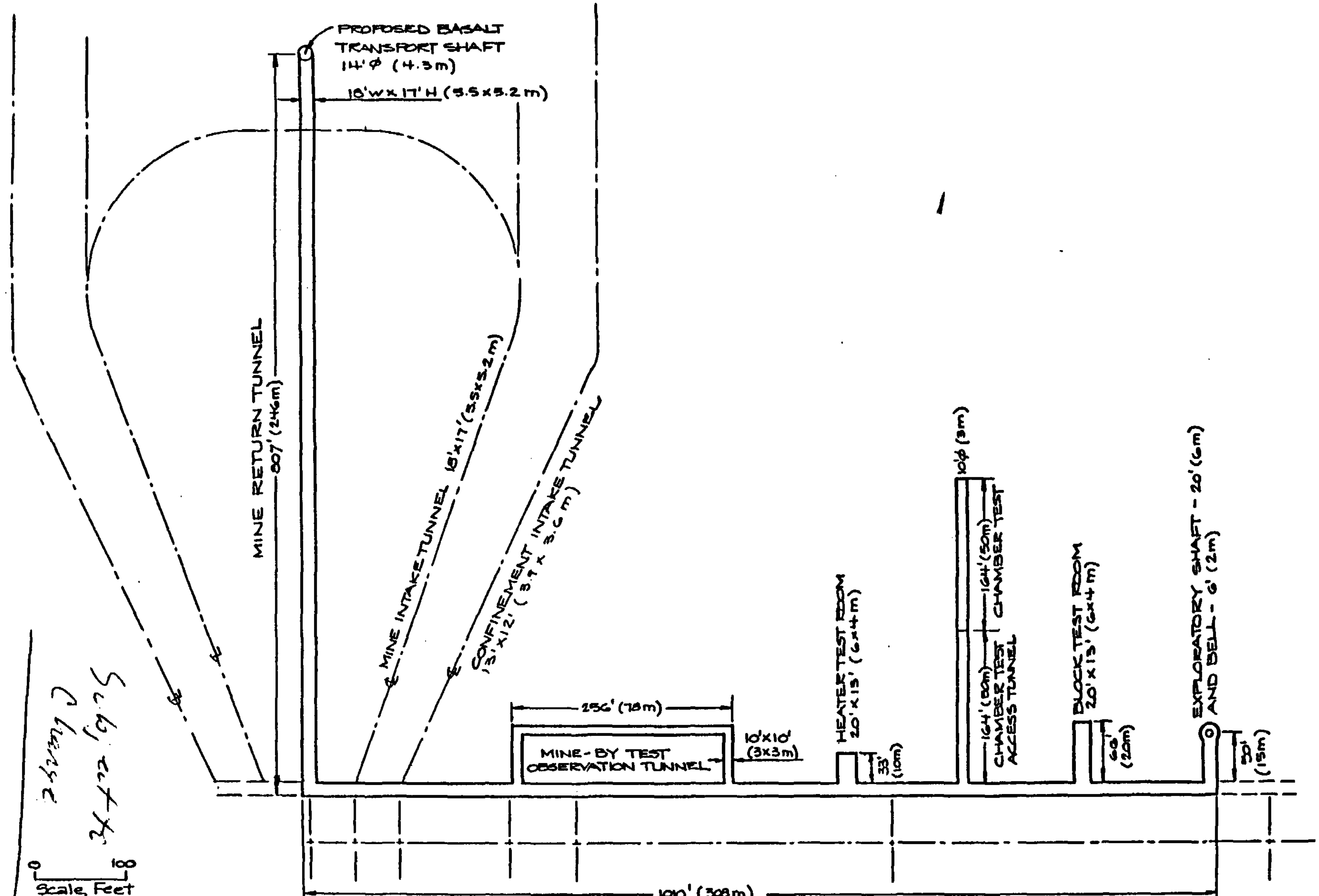
15,000,000
1,500,000
9,408,700

o Exploratory Shaft Construction (Table 1 and Fig. 1)

- Drilled shaft, 8 ft O.D./6 ft I.D.
- 3740 ft deep
- Steel lined
- $3,500/ft of finished shaft
- $1.5 million for shaft equipage
- Cost estimate not based on Task 3 results
- BWIP using $6,400/ft (10' O.D. Liner w/portholes)
- $55 million for everything (surface facilities, escalation, contingency)

o Access tunnel and test room construction (Table 1 and Figure 1)

- Excavation and support cost varied with cross-sectional area of the opening and ranged from $355/ft to $555/ft of advance
- Cost included: exploratory shaft access tunnel,
  block test room,
  pressure chamber test,
  heater test room,
  mine-by test observation tunnel
- Cost not included (repository construction)
  mine return tunnel
  experimental panel entry (includes mine-by test section)
  basalt transport shaft



UNDERGROUND TEST FACILITY ACCESS TUNNEL
PROPOSED EXPERIMENTAL PANEL ENTRY

QUESTION 4: What is the cost of large scale tests? What is a reasonable schedule for these tests?

ANSWER: Costs provided with answer (3) above, 3-4 years will allow for all recommended tests.

R. Gates 04-15-82

QUESTION 4: What is the cost of large scale tests? What is a reasonable schedule for these tests?

ANSWER: No idea

Comments: Will be severely hindered by lack of access (single small shaft)

J. Daemen 04-15-82

QUESTION 4: What is the cost of larger scale tests? What is a reasonable schedule for these tests?

ANSWER: No recent experience in which to base estimates.

C. Babcock 04-14-82

QUESTION 5: What percentage of the repository horizon should be investigated before license application . . . by surface methods, horizontal boreholes or tunnels? Why?

ANSWER: The lateral extent of the basalt should be established by vertical surface drill holes at least at the four corners along the perimeter one mile outside the repository area. Physical tests should be made to establish basalt variability from one boundary to the next. The thickness of the repository horizon should be established to verify that the required basalt volume for containment is present. A minimum of 1000 foot of drift 12' x 12' from a vertical shaft is desirable for both Golder Assoc. and LBL tests. In-situ tests from either drifts mine-by, or drill hole instruments should be made to establish constituate relationships to relate stress to strain or displacment for computer or closed form mathematical analysis. In situ stresses should be obtained from over core tests (USBM). Rock stress change during mining or development by convergence or gages (BPC, CPC, IRSD, SXIRO, deformation gage).

C. Babcock 4-14-82

QUESTION 5: What percentage of the repository horizon should be investigated before license applicaiton . . . by surface methods, horizontal boreholes or tunnels? Why?

ANSWER: The exploration of the horizon prior to submittal of the L.A. should be such to meet the following objectives:

1. To assess the variability of the geological framework, mechanical, thermal, hydrological, geochemical, and construction induced responses can be satisfactorily predicted.

2. There is sufficient excavation to allow needed space for experiments to perform such that the interpretation of each test can be discovered from adjacent test. The types and number of these tests should be sufficient to characterize the response listed above so that their requirements of the SER can be met.

To amplify these comments a 6' shaft at BWIP + bell + limited horizontal holes, and surface borehole is insufficient. A 500' orthogonal drift with minimum 12' x 12' cross section should be regarded as an appropriate lower bound. An upper bound 100' x 800' would be the maximum defined by a 6 ft shaft with an additional smaller driller ventilation shaft. Excavation of the entire perimeter should not be necessary if this appeared to be a need, the overall site would in all probability be unacceptable.

Boreholes drilled from the surface through the center line of all shafts and possible deflected or inclined holes in large pillar areas should be encouraged to determine lateral variability. The above would be very unlikely to be sufficient on its own.

Horizontal boreholes drilled from the subsurface excavation drift should be compared with excavated characteristics. Boreholes should also be drilled beyond the test area to further establish continuing predictability.

QUESTION 5: What percentage of the repository horizon should be investigated before license application . . . by surface methods, horizontal boreholes tunnels? Why?

ANSWER: Drill holes and shaft + bell are not sufficient for safety evaluation report (SER) to contain reasonable assurance of lateral extent of the basalt flow an variability.

A shaft + 500' of tunnel plus most of the test proposed in task 2 report would be enough to prevent me from testifying against DOE/NRC et. a public hearing presenting their SER for a repository.

For me to sign, as a professional, the SER, I would need a system of orthogonal tunnels with at least one shaft (preferably 2) with enough room to conduct appropriate tests as outlined in other questions to confirm lateral extent, constructability, and variability.

A preliminary concept for Hanford with an L (800' + 1000') appears to be an upper bound of need. A minimum would be about 500' x 500' with a target of 600' x 800'. Tunnel size could be 12' x12' to 18' x 17', with 18' x 17' matching the Kaiser design for repository development.

The cost of inclined holes or deflected holes to the horizontal appear to be less effective and more costly than tunnels to learn the required information at repository depths.

Additional drifts in line with future repository development with possible additonal ventilation shafts are prudent and should be done as much as is possible with funds and time available. The 10's of million of dollars may sound expensive until you consider the billions of dollars for surface and underground facilities that could be wasted if siting problems are encountered.

R. Gates 4-15-82

QUESTION 5: What percentage of the repository horizon should be investigated before license application . . . by surface methods, horizontal boreholes or tunnels? Why?

ANSWER: Surface methods are not sufficient to characterize or establish the lateral variability/homogeneity of the candiate horizon. Rather, maximum effort should be applied to subsurface investigations.

Excavation of up to 1000 ft. of drift from the shaft is necessary. Drifts should be oriented in 2 orthogonal directions to intersect all fracture orientations. Drifts should be laid out to accomodate stations for long (300 to 500m) continuously cored horizontal and inclined drill holes, and drift section should be long enough to allow 200 to 300 ft. between locations of tests.

Though the lateral homogenity of the candidate horizon would be not proved, a significant-sized block of ground would be sampled so that the range of variability of critical properties of the candiate repository rock mass would be encountered.

H. Wollenberg 04-14-82

QUESTION 5: What percentage of the repository horizon should be investigated before license application . . . by surface methods, horizontal boreholes or tunnels? Why?

ANSWER: Surface methods: 100% or nearly so should be investigated by means of surface methods: remote sensing, field mapping, geophysical surveys: Why? to avoid or minmize the chance of major surprises.

Underground methods:

- a minimum of two horizontal tunnels, advanced at an angle of at least 60° between them, each direction driven to a distance of at least several hundred feet. From these tunnels are to be driven testing rooms needed for testing as determined in later questions.

- a minimum of two horizontal core holes, each extending for a minimum of 1,000 ft or several shorter holes. For a total horizontal core length of not less that 2,000 ft.

Why?
- identify presence of desirable host formation
- variability of all essential rock properties
- demonstrate constructability in two (preferably orthogonal) directions

More detailed why:

- need variability in joint patterns; to establish this need information in (at least) two directions; map orientation, frequency spacing, aperture, continuity, length, in-filling etc.
- measure deformation/stress in tunnel walls
- need access for horizontal and vertical permeability/flow determinations: presure tests; tracer tests
- need cross hole measurements: flow, permeability, geophysics

J. Daemen 04-14-82

QUESTION 5: What percentage of the repository horizon should be investigated before license application . . . by surface methods, horozontal boreholes or tunnels? Why?

ANSWER: Surface methods i.e. vertical or inclined boreholes from surface will provide only limited information on lithology.
Because of the basic drilling process, it would furthermore, be very expensive to keep the holes sufficiently on line to be useful.

From the 'bell' limited horizontal holes could be drilled - on the order of about 200' per hole. This test would not provide sufficient information to adequately characterize site.

The "racetrack": (ES-II) containing 500 ft of drifting is an improvement for several reasons:

- it allows flow-through ventilation i.e. a loop - this allows better characterization of the rock mass - it allows horizontal boreholes to be driven in which test work can be carried out.

It does not however provide sufficient room to carry out chamber tests free of outside influence: one needs 200-300 ft between tests.

Ideally, one should have the full perimeter of the repository site excavated, or at least one quadrant. The full perimeter would be about 36,000 ft. for the BWIP site - this would take 9 years @ 10 ft/day. Obviously we haven't got that much time available. A quadrant would have 18,000 ft. and, by the same token, this would take 4½ years to drive. This presupposes that satisfactory accesses are available including sufficient shafts of sufficient size to provide for the ventilation.

The minimum satifactory amount of work lies somewhere between ES-II and excavating a full quadrant. From a single shaft of 6 ft. I.D., one can reasonably excavate about 1000 to 1500 ft. of tunnels. To provide for chamber, heater, mine-by and block tests; to provide a reasonable spacing between them requires at least 700 ft. of tunnel in one direction. If two chamber tests were run orthogonal to the main tunnel the requirements for having fracture mapping surfaces in two dimensions will be met. Thus at least 1000' at tunnel will be required.

QUESTION 5: What percentage of the repository horizon should be investigated before license application . . . by surface methods, horizontal boreholes or tunnels? Why?

ANSWER: Surface methods: 100% or nearly so by remote sensing and by seismic surveys: avoid major s rprises (faults especially.)

Underground methods:

- a minimum to two horizontal tunnels, at an angle of a least 60° to each other, for a length of at least one hundred ft. each

Purpose:

- establish a solid data basis to identify and describe adequately the major joints systems (i.e. frequency, spacing, aperture, variability
- provide access for horizontal permeability determinations
- a minimum of several thousands of ft. of horizontal boreholes

Purpose:

- establish lateral continuity of repository horizon
- determine joint patterns
- allow cross-hole measurements (geophysics, flow permeability)
- allow in-hole measurements: stress-state: permeability; jacking tests (?)

J. Daemen 04-15-82

QUESTION 6: Is a mine-by experiment needed prior to license application? If not, when? Why?

ANSWER: Yes, the response of the rock to various tunneling techniques anticipated in repository development can effect the design and effectiveness of engineered barriers and thus ultimate performance of the repository. The SER must show reasonable assurance that performance will meet EPA standards, and thus we must know rock response.

See Golder Task 2 Report.

R. Gates 04-15-82

QUESTION 6: Is a mine-by experiment needed prior to license application? If not, when? Why?

ANSWER: Yes, to model the long time behavior of the rock mass; finite element methods of structural analysis to predict repository behavior will almost certainly be used. If realistic assumptions based on actual observed experimental relationships between deformations or strain and stress in-situ are not used, serious mistakes in design will result. To observe the relationships some method (s) of experimentally measuring them is needed. A mine-by approach of some kind not necessarily the one proposed by Golder Associates should be used. If the work proposed by Golder Associates is accepted it should be carefully reviewed for technical competence. It presently is very weak in many respects.

C. Babcock 04-14-82

QUESTION 6: Is a mine-by experiment needed prior to license application? If not, when? Why?

ANSWER: Yes, The information that it would provide would be the in-situ deformation of rock in response to excavation. This allows estimate to be made of the following:

- in-situ modulus of deformation - in-situ poisson's ratio - degree of fracturing surrounding an excavation

This information is required in order to verify assumptions in model studies at stress distribution as well as for determining the ground support requirements.

D. F. Hambley 04-14-82

QUESTION 7: Is thermomechanical testing in the repository horizon needed prior to license application? If not, when? Why?

ANSWER: Yes, the physical properties of the rock and of the rock instrumentation used to measure them are greatly modified by elevated temperatures. Since the mine must be stable for 50 to 100 years at least with respect to the main haulagaways the long term behavior under these, conditions must be known. The chemical reation rate increases rapidly with temperature and the physical properities are designed for ambient temperature use. There are serious problems in using rock mechanics instruments at elevated temperature. They need to be adapted for elevated temperature use and tested in the environment of their intended use underground.

C. Babcock 04-14-82

QUESTION 7: Is thermomechanical testing in the repository horizon needed prior to license application? If not, when? Why?

ANSWER: Yes, (See Golder Task 2 Report), the coupling of thermal and mechanical response to tunneling and waste package heat is the most unique design feature of a repository. There is no known comparable "experience" to apply "judgement" of experts without in-situ data. Murphy's law will apply to a repository if the new environments being developed in a repository are not tested in-situ. The evaluation associated with license application (SER) appears to be the most critical evaluation by NRC in the life of a repository. Using NRC's words, "all points (CA, License to emplace decommissioning) will be of the nature of confirmatory."

R. Gates 04-15-82

QUESTION 7: Is thermomechanical testing in the repository horizon needed prior to license appliaiton? If not, when? Why?

ANSWER: Yes. The thermomechanical response of the rock is one of the fundamental assumptions in the design of a repository. The physical properities are fundamental to assuring that the geological setting is satisfactory. The thermal properties of the rock must be adequately known if one is to be confident that a site is satisfactory. The thermal properties are of critical importance in ensuring that environmental requirements are met. It there is a possablity that environment requirements cannot be met, then the siting of a repository is seriously in question. Thus, this information is required if a license application is to have any meaning.

D. F. Hambley 04-14-82

QUESTION 8: Is a large scale chamber test needed prior to license application? If not, when? Why?

ANSWER: Yes. the behavior or a multiple hole system close together is a different problem than a single entry drift. The effect must be known before a multiple opening entry system is developed at high cost. These tests allows a determination of rock support problems. Should rock bolts be used? If so, what kind-conventional (expansion anchor or grouted end), resin grouted (full or partial), gypsum grouted or Scotts Split. Set? Is angle bolting necessary because of vertical cracks? Is room and pillar mining method ok with mining geomestry proposed? Should other types of support be used such as steel sets with caps, is logging or grouting ever necessary? What about water inflow problems? Are ground control problems easy to live with or require and unusual work effort?

C. Babcock 4-14-82

QUESTION 8: Is a larger scale chamber test needed prior to license application? If not, when? Why?

ANSWER: Yes. A large-scale chamber test combining thermomechanical and hydrological measurements is needed to determine the response of a large volume of the candidate rock mass to heating. The baseline phase of this test begins with the drilling of short horizontal holes from the bell, and continues with observations of fracture orientations in the drifts and in oriented core. This information is necessary for choosing the optimum direction of the chamber, and with proper instrumentation in the horizontal holes, the hyrological baseline for the test will be established.

The 7-year duration scoped for the entire test (in LBL-13190) exceeds the time frame of application. However, a good portion of information form this test would be available prior to the license application deadline. Results of measurements of initial conditions and the complete heating phase would be available well in advance of 1988 if initial design could begin in 1982-1983.

H. Wollenberg 4-14-82

QUESTION 8: Is a larger scale chamber test needed prior to license appliation? If not, when? Why?

ANSWER: Yes. A chamber test is a practical means of determining the in-situ behavior of the rock mass. The properties which can be determined include (in the case of the LBL test):

- permeability at ambient and elevated temperature.
- deformational response due to in-situ stress and thermal stresses.
- in-situ geochemistry and changes in same due to elevated temperature.

From the information collected the measured response can be compared with the response predicted by hydro/thermomechanical models. Hence the validity of the models can be verified and if necessary, the models can be modified to provide better predictability. The hydrological, geochemical, and thermomehanical properties must be reliably known to be such that EPA requirements can be satisfied and that it can be reasonable assured that the waste packages and any radionuclide emissions are isolated from the accessible environment. If there is any question as to the feasiblity of this at the time of licensing application, then continued effort at such a site should be stopped.

D. F. Hambley

SUBJECT: ENGINEER BARRIERS TESTING PRIOR LICENSE APPLICATION

If DOE is required to take the credit for engineered barrier(s) in the overall performance of the entire system the NRC will require in-situ tests tp support the basis of the values of the parameters of the engineered barriers and or components used in the total performance assessment. These tests should specifically address the uncertainity of the coupling phenomena with the surrounding rock mass. Since time of emplacement and performance of the backfill is a critical issue to retrievability, the testing refered to above may be used in addressing the retrievability standards.

APPENDIX A-3

D. PENTZ

FREQUENCY - A = SEVERAL
B = NUMEROUS
C = CONTINUAL

STAGES - A = SITE CHARACTERIZATION
B = LICENSE APPLICATION
C = CONSTRUCTION AUTHORIZATION
D = EMPLACEMENT AUTHORIZATION

(SEE JOHN GREEVES SCHEDULE) Appendix A-1

GEOMECHANICS

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
DETAILED MAPPING AND CORE LOGGING OF ALL OPENINGS AND ALL CORE.	PRIOR TO L.A.	CHARACTERIZE THE GEOLOGICAL FRAMEWORK OF EXPOSED ROCK AND COMPARE THIS INFORMATION WITH THAT PREDICTED FROM CORE.	A, B	C	DRILL CORE HOLES (PILOT HOLES) PRIOR TO CONSTRUCTION OF ALL MAN SIZED OPENINGS.
DEFORMATION RESPONSE, IN-SITU STRESS DETERMINATIONS		SHORT TERM ENABLES JUSTIFICATION OF REPOSITORY LAYOUT TO BE MADE LONG TERM. ESSENTIAL PARAMETERS TO ESTIMATE DEFORMATION AND HENCE HYDRAULIC CONTAMIMENT		27 TESTS IN 9 HOLES	OVERCOMING OF IN SITU TESTS AT DISTANCE FROM OPENINGS SEE TASK 2 REPORT
PLATE TEST				2 LOCATIONS 3 DIRECTION	SEE TASK 2 REPORT
MINE BY TESTS				1 LOCATION 250' LONG	SEE TASK 2 REPORT
FLAT JACK TESTS				9 LOCATIONS	SEE TASK 2 REPORT

D. PENTZ

GEOMECHANICS

SUMMARY REPORT

	PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) APPENDIX A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
	DETAILED MAPPING AND CORE LOGGING OF ALL OPENINGS AND ALL CORE.	1	PRIOR TO L.A.	THIS TEST WILL BE BASIS FOR EXTRAPOLATING POINT TESTS (GEOMECHANICAL, HYDROLOGICAL, GEOCHEMICAL) SEE ANSWER QUESTION 5.
A	DEFORMATION RESPONSE IN SITU	3	PRIOR TO L.A.	FUNDAMENTAL PARAMETER FOR SHORT AND LONG TERM CONTAIMENT ASSESSMENT.
B	PLATE TESTS	5	PRIOR TO L.A.	ENABLES INDEX ON CORRELATION OF FULL SCALE TESTS WITH REMAINDER OF TEST FACILITY
C	MINE BY TEST	3	PRIOR TO L.A.	IMPORTANT TO ASSESSMENT OF CONSTRUCTION INDUCES ZONE - POTENTIAL IMPORTANT PATHWAY.
D	FLAT JACK TESTS	5	PRIOR TO L.A.	SIMILAR REASON TO PLATE TEST BUT DIFFERENT PARAMETER

H. WOLLENBERG

FREQUENCY - A = SEVERAL
B = NUMEROUS
C = CONTINUAL

STAGES - A = SITE CHARACTERIZATION
B = LICENSE APPLICATION
C = CONSTRUCTION AUTHORIZATION
D = EMPLACEMENT AUTHORIZATION

GEOMECH.

(SEE JOHN GREEVES SCHEDULE) Appendix A-1

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
GEOLOGIC SETTING STRUCTURE & LITHOLOGY	DETAILED MAPPING CORE LOGGING OF ALL OPENINGS & CORES	ASSESS VARIABILITY OF FRACTURE ORIENTATION AND LITHOLOGY OF CANDIDATE ROCK MASS	A, B IN BELL, AND ALONG WITH PROGRESS OF EXCAVATION AND EXAMINATION OF COMPLETED GALLERIES	C	LOGGING ORIENTATIONS OF SIGNIFICANT FRACTURE IN ORIENTED CORES; RECORDING OF LITHOLOGY AND RECORDING AND SAMPLING OF FRACTURE FILLING MATERIAL
IN SITU STRESS	OVERCORING	DETERMINE MAGNITUDES AND ORIENTATIONS OF THE THOSE COMPONENTS OF IN-SITU STRESS	A, B	A	OVERCORING
EXCAVATION DAMAGE	MINE-BY	INVESTIGATE EFFECTS OF EXCAVATING OPENINGS BY ONE OR MORE METHODS ON THE MECHANICAL AND HYDROLOGIC INTEGRITY OF THE ROCK NEAR AND AWAY FROM THE OPENINGS	B	ONE	INSTALL AND MONITOR EXTENSOMETERS IN DRILL HOLES INCLINED OVER THE AREA TO BE MINED. MEASURE PRESSURES IN PACKED OFF INTERVALS IN A SIMILAR SET OF HOLES FOR HYDROLOGIC MONITORING.
DEFORMATION	FLAT JACK TESTS	INVESTIGATE RESPONSE OF ROCK TO MINING	C	A	CONDUCT DEFORMATION TESTS WITH JACKS AND PLATES ORIENTED IN ACCORDANCE WITH CRITICAL FRACTURE ORIENTATIONS, FIRST IN VICINITY OF MINE-BY AREA
	PLATE TESTS		C	A	

MINE-BY AREA.

H. WOLLENBERG

GEOMECH.

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
GEOLOGIC SETTING STRUCTURE AND LITHOLOGY*	(1)	NEEDED FOR LA	1) CHARACTERIZES VARIABILITY TO BE EXPECTED, 2) BASELINE FOR PLANNING AND INTERPRETATION OF GEOMECH., THERMOMECH., HYDROLOGICAL & GEOCHEMICAL TESTS.
IN SITU STRESS	(2)	NEEDED FOR L.A	NEEDED TO EXPLAIN DISKING OBSERVED IN CORES FROM SURFACE DRILL HOLES; CONFIRM PRESENCE OF HIGH HORIZONTAL STRESSES & EVALUATE EFFECTS ON CONSTRUCTION & PERFORMANCE OF REPOSITORY
EXCAVATION DAMAGE	(2)	NEEDED FOR L.A	EVALUATES DEGREE OF SUCCESS OF CANDIDATE MINING METHODS AND MECHANICAL AND HYDROLOGIC RESPONSE OF THE ROCK TO THESE METHODS
DEFORMATION PLATE & FLAT JACK TESTS	(3)	NEEDED FOR ... CONSTRUCTION PLANNING	

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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(SEE JOHN GREEVES SCHEDULE) Appendix A-1

GEOMECHANICS
D. HAMBLEY

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
GEOLOGIC STRUCTURE AND LITHOLOGY	DETAIL MAPPING AND CORE MAPPING OF ALL OPENINGS AND CORES	ASSESS FRACTURE ORIENTATION, SPACING EXTENT	B		THIS CAN BE ACCOMPLSIHED BY DETAIL LINE SURVEYS ALONG WALLS AND FULL CIRCUMFERENTIAL MAPPING OF OPENINGS. USING A SCHMIDT STERONET, PREFERRED JOINT ORIENTATIONS ARE OBTAINED
IN-SITU STATE OF STRESS	A) OVERCORING	TO DETERMINE THE IN-SITU STRESS STRATEGY	B	27	THERE ARE SEVERAL FEASIBLE METHODS. THE BEST ARE THE CSIRO GAGE (PROVIDED THAT IT IS PROPERLY BONDED) AND THE CSIR TRIAXIAL GAGES AS EACH PROVIDES THE ABSOLUTE 3-D STRESS FIELD FROM MEASUREMENTS IN ONE HOLE.
	B) PLATE JACKING TESTS	TO DETERMINE LARGE SCALE DEFORMATIONAL BEHAVIOR	B	6	THESE NEED TO BE CARRIED OUT VERY CAREFULLY TO ASSURE THAT THE LOADING CONDITIONS ARE AS ASSUMED.
DEFORMATIONAL RESPONSE	C) MINE-BY TEST	TO DETERMINE BEHAVIOR OF ROCKS SURROUNDING AN OPENING; TO DETERMINE EXTENT AT DAMAGED ZONE	B	1	THE DAMAGED ZONE SURROUNDING OPENING HAS AN INCREASED PERMEABILITY, THUS ITS EXTENT IS OF GREAT IMPORTANCE.
IN-SITU MODULI	D) FLAT JACKS	CALIBRATE INSTRUMENT		9	THERE IS SOME QUESTION AS TO THE VALUE OF THESE TASKS.
ROCK MASS STRENGTH SHEAR STRENGTH	PRESSURIZED SLOT TESTS (SUCH AS THOSE CARRIED OUT BY BIENIAWSKI IN SOUTH AFRICAN COAL MINES)	TO ASSURE THE INTEGRITY OF THE PILLARS BETWEEN OPENINGS.			THESE ARE AT RELATIVELY MINOR IMPORTANCE IN BASALT BUT LIKELY AT SOME IMPORTANCE IN TUFF.
CREEP	CLOSURE MEASUREMENTS	TO DETERMINE LONG TERM DEFORMATION OF ROCK MASS			THIS IS OF MINOR IMPORTANCE IN BASALT BUT OF GREAT IMPORTANCE IN SALT, AND PERHAPS IN TUFF.

GEOMECHANICS
D. HAMBLEY

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) APPENDIX A	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
GEOLOGIC STRUCTURE AND LITHOLOGY	1) DETAIL MAPPING AND CORE LOGGING	NEEDED FOR LA	THE GEOLOGIC STRUCTURE AND LIGHOLOGY MUST BE KNOWN IN SUFFICIENT DETAIL TO ENSURE THAT GEOLOGICAL ENVIRONMENTAL IS SATISFACTORY FOR A REPOSITORY
IN-SITU STATE OF STRESS DEFORMATIONAL RESPONSE IN-SITU MODULI	2) OVERCORING PLATE JACKING TESTS MINE-BY TEST FLAT JACK TESTS	NEEDED FOR LA	NEEDED TO VERIFY ASSUMPTIONS RE: IN-SITU STRESS STATE MADE ON THE BASIS OF HYDRO-FRACING FROM SURFACE WHICH IS OF QUESTIONABLE VALIDITY.
ROCK MASS STRENGTH SHEAR STRENGTH	5) PRESSURIZED SLOT TASKS PLATE JACKING TESTS	NEEDED FOR EMPLACEMENT AUTHORIZATION IN BASALT. (DESIGN VERIFICATION)	DUE TO THE COMPETENCE OF THE BASALT, ROCK MASS STRENGTH IS UNLIKELY TO BE A PROBLEM.
CREEP	10) CLOSURE MEASUREMENTS	NEEDED FOR DESIGN VERIFICATION	CREEP IS UNLIKELY TO A MAJOR PROBLEM IN BASALT.

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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D = EMPLACEMENT AUTHORIZATION

(SEE JOHN GREEVES SCHEDULE) Appendix A

GEOMECHANICAL

R. GATES

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
GEOLOGIC STRUCTURE AND LITHOLOGY	DETAIL MAPPING AND CORE LOGGING OF ALL OPENINGS AND ALL CORES	VERIABILITY EXTENT OF FLOW	B	CONTINUOUS ALL	SEE TASK 2 REPORT
IN-SITU STRESS	OVERCORING		B	27 9 HOLES 3 TESTS/HOLE	SEE TASK 2 REPORT
DEFORMATION RESPONSE	PLATE TESTS	GEOMECHANICAL RESPONSE INFLUENCES PERFORMANCE	B	6 (2 LOCATIONS, 3 DIRECTION	SEE TASK 2 REPORT
DEFORMATION RESPONSE	MINE BY		B	1	SEE TASK 2 REPORT
DEFORMATION RESPONSE	FLAT JACKS		B	9 (3 LOCATIONS 3 DIRECTIONS	SEE TASK 2 REPORT

GEOMECHANICAL

R. GATES

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) APPENDIX A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
GEOLOGIC STRUCTURE	1	B	TO AVOID LARGE EXPENSE FOR BAD SITE AS EARLY AS POSSIBLE IN THE PROGRAM AND TO REDUCE UNCERTAINTY TO THE POINT OF "REASONABLE ASSURANCE"
IN-SITU STRESS	2	B	TO AVOID LARGE EXPENSE FOR BAD SITE AS EARLY AS IN THE PROGRAM AND TO REDUCE UNCERTAINTY TO THE POINT OF "REASONABLE ASSURANCE"
DEFORMATION RESPONSE	2 PLATE TEST 2B MINE BY 2A FLAT JACKS 2C	B	TO AVOID LARGE EXPENSE FOR BAD SITE AS EARLY AS POSSIBLE IN THE PROGRAM AND TO REDUCE UNCERTAINTY TO THE POINT OF "REASONABLE ASSURANCE"

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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D = EMPLACEMENT AUTHORIZATION

(SEE JOHN GREEVES SCHEDULE) APPENDIX A.1

GEOMECHANICS

J. DAEMEN

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
GEOLOGICAL STRUCTURE	-DETAILED MAPPING OF ALL U.G. EXPOSURES -LOGGING OF ALL CORE AND HOLES	-NEEDED TO ESTIMATE PERMEABILITY OF ROCK MASS -NEEDED FOR STABILITY ESTIMATES	A/B/ C/D	C	- LINE MAPPING (MINIMUM) - SURFACE (COMPLETE) MAPPING - LOGGING OF ALL CORE AND HOLES (INCLUSIVE PHOTOGRAPHS OF BOTH)
		-NEEDED FOR THERMO-MECHANICAL RESPONSE	A/B/C		- PILOT HOLE IN ADVANCE OF TUNNELING TO DEMONSTRATE CAPABILITY OR LACK THEREOF IN EXTRAPOLATING FROM HOLE TO TUNNEL SIZE
IN-SITU STRESS STATE	OVERCORING	-INFLUENCE ON OPTIMUM SHAPE OF TUNNELS ROOMS -ESSENTIAL FOR STABILITY ASSESSMENT	A/B	B	- HYDRAULIC FRACTURING IN REPOSITORY LEVEL IS UNDESIRABLE - INDUCES (BY DEFINITION) ROCK DAMAGE - MUST HAVE A MINIMUM OF THREE MEASUREMENTS IN THREE (MORE OR LESS) ORTHOGONAL DIRECTIONS
		-ESSENTIAL FOR MODELING OF STRESS/STABILITY/ PERMEABILITY (FLOW)			
ROCK MASS DEFORMATIONAL RESPONSE		-DETERMINE STIFFNESS OF LARGE SCALE ROCK MASS -BACKCALCULATE STRESS STATE(???)	A/B/C	B	- CONVERGENCE MEASUREMENTS DURING TUNNEL ADVANCE - EXTENSOMETER MONITORING
PLATE TESTS		-DETERMINE MODULUS OF ROCK MASS (STIFFNESS)	B/C	A	- DETERMINATION OF YOUNG'S MODULUS AND POISSON'S RATIO
VARIABILITY OF ROCK MASS	INDIRECT INVESTIGATIONS: SEISMIC, RADAR, ULTRASONIC, ACCOUSTIC	-DETERMINE	A/B/C	C	- COVERS LARGE VOLUMES AT LOW COST AND WITH MINIMUM CONSTRUCTION INTERFERENCE

GEOMECHANICS
J. DAEMEN

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) [illegible]	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
GEOLOGICAL STRUCTURE	1	B	NEEDED FOR LARGE SCALE PERMEABILITY ASSESSMENTS, STABILITY ESTIMATES OR ROOMS AND TUNNELS, THERMOMECHANICAL MODELING, PREDICTIONS
IN SITU STRESS STATE	2	B	NEEDED FOR GEOMECHANICAL AND THERMOMECHANICAL MODELING, FOR HYDROLOGICAL MODELING. NEEDED FOR STABILITY EVALUATIONS, TUNNEL AND ROOM DESIGN
ROCK MASS DEFORMATIONAL RESPONSE	3	B	NEEDED FOR GEOMECHANICAL AND — MODELING

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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(SEE JOHN GREEVES SCHEDULE) Appendix A-1

GEOCHEM.

	PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
	GROUNDWATER COMPOSITION AND FRACTURE FILLING MATERIAL COMPOSITION	ANALYSES FOR: MAJOR TRACE-AND RADIO ELEMENT COMPOSITION; STABLE ISOTOPE RATIOS; WATER AND FRACTURE FILLING AGE DETERMINATIONS.	GEOCHEMICAL BASELINE UPON WHICH EFFECTS OF REPOSITORY WILL BE SUPERIMPOSED AGE AND PATHWAYS OF WATER FROM CANDIDATE HORIZON AND STRATIGRAPHIC UNITS ABOVE AND BELOW THE HORIZON-WILL ENABLE PREDICTION OF REACTIONS OF GROUNDWATER WITH COMPONENTS OF ENGINEERED BARRIER SYSTEM.	A, B	C: AS HORIZON-TO DRILLING PROGRESSES & WATER & CORE SAMPLES OBTAINED. HORIZ. BOREHOLES CAN PROVIDE ESSENTIALLY UNCONTAMINATED WATER SAMPLES. FROM SURFACES BOREHOLES	WATER: IN-SITU MEASUREMENTS OF TEMPERATURE, PH, EH; LAB. ANALYSES FOR MAJOR-TRACE-AND RADIOELEMENTS, OXYGEN & HYDROGEN ISOTOPE RATIOS; OTHER CRITICAL ISOTOPES FOR WATER AGE DETERMINATION. FRACTION FILLING MATERIAL: LAB. ANALYSES FOR MAJOR, TRACE- AND RADIOELEMENTS, SUBSTRATE MATERIAL AND MINERALS UPON WHICH IT IS DEPOSITED
B	RETARDATION	LABORATORY ANALYSIS OF CATION EXCHANGE CAPACITY OF ROCK MATRIX FRACTURE FILLING MATERIAL, USING APPROPRIATE RADIOELEMENTS AND FORMATION WATER COMPOSITIONS. IF A SINGLE FRACTURE CAN BE ISOLATED (DOUBTFUL IN BASALT), IN-SITU RETARDATION TEST SIMILAR TO THOSE AT CLIMAX STOCK AND G TUNNEL AT NTS	WILL ENABLE PREDICTIONS OF (INTERACTION OF) GROUNDWATER CONTAINING RADIOELEMENTS WITH NATURAL BARRIERS THAT OCCUR IN THE HYDROLOGIC SYSTEM.	A	C: AS SAMPLES ARE OBTAINED FROM EXCAVATIONS AND HORIZONTAL DRILL HOLE CORPS	LAB. ANALYSES OF EXCHANGE CAPACITY OF ROCK MATRIX AND FRACTURE FILLING MATERIAL.

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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D = EMPLACEMENT AUTHORIZATION
(SEE JOHN GREEVES SCHEDULE) APPENDIX A-1

H. WOLLENBERG

GEOCHEM.

	PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
C	DISPERSIVITY	TRACER TESTS	EXAMINE DISPERSION CHARACTERISTICS AND INTERCONNECTIVENESS OF REPOSITORY HORIZON'S HYDROLOGIC SYSTEM	A	B: FOLLOWING DETERMINATION OF FLUID COMPOSITION AND FRACTURE SYSTEM GEOMETRY	INJECTION RADIOELEMENT AND /OR ANALOG ELEMENT TRACERS INTO FRACTURE(S) AND MONITOR FIRST ARRIVAL IN ISOLATED INTERVALS OF MONITORING DRILL HOLES.

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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D = EMPLACEMENT AUTHORIZATION

D. HAMBLEY

GEOCHEMICAL

(SEE JOHN GREEVES SCHEDULE) A-1

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
Pore Fluid Composition		To determine ionic composition of pore water entering repository area.			
Fracture Filling Composition		It is the substrates (surface coatings) which react with the water so the reactions at this material must be known			
Retardation	Single Fracture Retardation Test	If DOE is going to take credit for retardation this is required.			Very difficult to measure in practice
Dispersivity					

H. WOLLENBERG

GEOCHEM.

SUMMARY REPORT

	PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
A	PORE FLUID COMPOSITION	(1)	NECESSARY FOR SITE CHARACTERIZATION AND PLANNING OF ENGINEERED BARRIER SYSTEM	NECESSARY TO ESTABLISH AN UNDERSTANDING OF THE GEOCHEMICAL SETTING OF THE CANDIDATE REPOSITORY HORIZON; TO DETERMINE WHETHER THE HYDROLOGIC REGIME OF THE HORIZON IS ISOLATED FROM REGIMES ABOVE AND BELOW 2) TO HELP DETERMINE THE AGE AND FLOW RATE OF THE GROUNDWATERS, 3) TO DETERMINES THE SORPTIVE CHARACTERISTICS OF MATERIAL LINING AND FILING THE FRACTURE.
B	RETARDATION	(2)	NECESSARY FOR SITE CHARACTERIZATION AND PLANNING OF ENGINEERED BARRIER SYSTEM	NECESSARY TO EVALUATE "NATURAL BARRIER" SYSTEM'S ABILITY TO RETARD MIGRATION RADIONUCLIDES. INFORMATION ON A AND B REQUIRED TO PROPERTY SCOPE ENGINEERED BARRIER SYSTEM.
C	DISPERSIVITY	(3)	NOT MANDATORY, BUT DESIRABLE IN SITE CHARACTERIZATION AND PLANNING OF ENGINEERED BARRIER SYSTEM.	

D. HAMBLEY

GEOCHEMICAL

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1		JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
PORE FLUID COMPOSITION	(1)	NEEDED FOR	B	LAB TEST OF ACTUAL REPOSITORY ROCK
FRACTURE FILLING COMPOSITION	(1)	"	B	"
RETARDATION (ADSORPTION)	(2)	"	B	"
DISPERSIVITY	(2)	"	B	"

GEOCHEMISTRY

R. GATES

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)		RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
DISPERSIVITY	2	BLOCK TEST	B	CRITICAL TO PERFORMANCE NEEDED FOR "REASONABLE ASSURANCE"
RETARDATION	2	CHAMBER TESTS HEATER TESTS	B	
PORE FLUID COMPOSITION	1	TRACER TESTS	B	
FRACTURE FILLING MATERIAL (SUBSTRATE)			B	

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
B = LICENSE APPLICATION
C = CONSTRUCTION AUTHORIZATION
D = EMPLACEMENT AUTHORIZATION

(SEE JOHN GREEVES SCHEDULE) Appendix A 1

GEOCHEMISTRY

R. GATES

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
DISPERSIVITY		BLOCK TEST	B	1	SEE TASK 2 REPORT
RETARDATION (INCLUDING ADSORPTION)		CHAMBER TEST HEATER TEST (SMALL AND LARGE) TRACER TESTS	B B B	1 1 3(2 LOCATION, 3 DIRECTIONS)	
PORE FLUID COMPOSITION FRACTURE FILLING MATERIALS (SUBSTRATE) FRACTURE FILLING MATERIALS		ALSO LAB TESTS "SINGLE FRACTURE RETARDATION TEST" FOR RETARDATION			SEE NRC GEOCHEMIST (ALEXANDER) IF DOE IS GOING TO TAKE CREDIT, LOW PRIORITY BECAUSE OF RETARDATION UNCERTAINTY IN TEST PROCEDURES - MAKES ENGINEER BARRIERS ALL THE MORE IMPORTANT

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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D = EMPLACEMENT AUTHORIZATION
(SEE JOHN GREEVES SCHEDULE) Appendix A-1

GEOCHEMISTRY
J. DAEMEN

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
CHEMICAL COMPOSITION OF - PORE FLUID - FRACTURE FILLING MATERIAL - ROCK	LAB TEST, INCLUDING INFLUENCE OF TEMPERATURE	RETARDATION PREDICTIONS LONGEVITY PREDICTIONS	B	B	LAB TESTS ON UNCONTAMINATED SAMPLES
RETARDATION					LAB TESTS

THERMO MECHANICAL RESPONSE

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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D = EMPLACEMENT AUTHORIZATION

(SEE JOHN GREEVES SCHEDULE) Appendix A-1

D. PENTZ

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
UNDERSTANDING OF COUPLED MECHANICAL THERMAL THERMO-MECHANICAL HYDRAULIC AND GEOCHEMICAL RESPONSE	BLOCK TEST	REDUCE UNCERTAINLY	PRIOR TO L.A.		SEE TASK 2 REPORT APPENDIX A2-1 INDEPENDENT CONTROL STRESS AND TEMP.
MECHANICAL RESPONSE OF ROCK MASS AS A RESULT THERMAL LOADS. AS ABOVE	HEATER TEST (LARGE SCALE)	SPACING OF WASTE PACKAGES CHANGES IN GEOCHEMISTRY			
THERMAL CONDUCTIVITY MASS HEAT CAPACITY, SPECIFIC HEAT	HEATER TEST (SMALL SCALE)	THERMAL CONDUCTIVITY DIFFUSIVITY TO TO PREDICT TEMP. FIELDS			

GEOCHEMISTRY

J. DAEMEN

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
CHEMICAL COMPOSITION OF - PORE FLUID - FRACTURE FILLING - ROCK	1	B	INFORMATION ABOUT RETARDATION AND LONGEVITY

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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(SEE JOHN GREEVES SCHEDULE) Appendix A-1

THERMOMECHANICAL

H. WOLLENBERG

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
RESPONSE OF ROCK MASS TO HEATING	CHAMBER TESTS (Combined thermo-mechanical & hydrological)	(1) TO INVESTIGATE THE EFFECTS OF HEATING ON HYDROLOGIC SETTING, GEOCHEMISTRY AND THERMOMECHANICAL BEHAVIOR OF A LARGE REPRESENTATIVE VOLUME OF THE CANDIDATE ROCK MASS. (1) TO HELP VERIFY AND FURNISH INPUT FOR MODELS PREDICTING THE ROCK MASS RESPONSES.	B, C	ONCE	COUPLED HYDRO/THERMOMECHANICAL TEST, INCORPORATING A WATER FILLED CHAMBER, HEATED TO 100°C, AND ITS EFFECTS MONITORED BY THERMOCOUPLES, EXTENSOMETERS AND PRESSURE TRANSDUCERS IN RADIAL AND LONGITUDINAL DRILL HOLES EMANATING FROM, AND ROUGHLY PARALLEL TO THE CHAMBER.
	HEATER TESTS	TO INVESTIGATE THE EFFECTS OF HEATING BY SIMULATED WASTE CANISTERS ON THE ROCK PROPERTIES IN THE NEAR AND MID FIELD.	B, C	ONCE	FULL-SCALE HEATER TESTS WITH HEATERS SIMULATING APPROPRIATE WASTE LOADING AND EFFECTS MONITORED BY THERMOCOUPLES AND EXTENSOMETERS IN VERTICAL AND SUB-HORIZONTAL DRILL HOLES.
	HEATED BLOCK TESTS				

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
RESPONSES OF ROCK MASS TO HEATING	(CHAMBER TEST) (1)	IF STARTED IN A TIMELY FASHION, A GOOD PORTION OF THE RESULTS OF THE TEST WOULD BE AVAILABLE FOR THE LICENSE APPLICATION EVALUATION. THE COST-DOWN PORTION OF THE TEST WOULD CONTINUE INTO THE CONSTRUCTION AUTHORIZATION STAGE.	THE MOST COMPLETE METHOD TO ACHIEVE THE EVALUATION OF THE RESPONSE OF A LARGE VOLUME OF THE ROCK MASS TO HEATING.
	(HEATER TEST) (1)	STARTED IN SITE CHARACTERIZATION STAGE SO THAT A GOOD PORTION OF THE RESULTS WOULD BE AVAILABLE FOR EVALUATION OF THE LICENSE APPRECIATION	THE BEST METHOD TO EVALUATE THE EFFECT OF HEATING BY THE WASTE CANISTERS ON THE MECHANICAL PROPERTIES OF THE ROCK IN THE NEAR-FIELD.

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
B = LICENSE APPLICATION
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D = EMPLACEMENT AUTHORIZATION

(SEE JOHN GREEVES SCHEDULE) Appendix A-1

THERMOMECHANICAL

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
THERMAL CONDUCTIVITY	HEATER TEST	TO DETERMINE THE IN-SITU RESPONSE OF THE ROCKMASS TO ELEVATED TEMPERATURE	B	LARGE SCALE 6 SMALL SCALE	PERMITS ASSESSMENT OF THERMAL CONDUCTIVITY, THERMAL DIFFUSIVITY, SPECIFIC HEAT AND COEFFICIENT OF THERMAL EXPANSION.
THERMAL DIFFUSIVITY SPECIFIC HEAT	LAB TESTS	TO PROVIDE A FIRST APPROXIMATION TO ROCK THERMAL PROPERTIES	A, B	NUMEROUS	IT IS DIFFICULT TO EXTRAPOLATE RESULTS OF LAB TESTS ON INTACT SPECIMENS TO THE IN-SITU BEHAVIOR OF A ROCK MASS.
THERMAL EXPANSION	TEMPERATURE LOGGING	TO PROVIDE INFORMATION ON THE GEOTHERMAL GRADIENT AND THERMAL DIFFUSIVITY	B	20	
TEMPERATURE EFFECTS ON ROCK PROPERTIES	CHAMBER TEST	TO DETERMINE IN-SITU ROCK MASS PROPERTIES AT ELEVATED AND AMBIENT TEMPERATURE	B	1	A LARGE SCALE CHAMBER TEST SUCH AS PROPOSED BY LBL CAN PROVIDE A LARGE AMOUNT OF DATA ON ROCK BEHAVIOR AT ELEVATED TEMPS. UNDER CONTROLLED CONDUCTIONS.
	BLOCK TEST	TO DETERMINE THE IN-SITU ROCK MASS PROPERTIES AT ELEVATED TEMPERATURES	B	2	BY USING FLAT JACKS IN THE PERIMETER AT THE BLOCK TOGETHER WITH SURROUNDING HEATERS ONE CAN MONITOR THE EFFECT OF ELEVATED TEMPERATURE ON THE DEFORMATION RESPONSE OF THE ROCK USING CONTROL HEATERS AND JOINT PERMEAMETERS, THE EFFECT OF ELEVATED TEMPERATURES ON JOINT PERMEABILITY CAN BE ASSESSED.
TEMPERATURE EFFECT ON ENGINEERED BARRIERS	LAB TESTS	TO PROVIDE A FIRST APPROXIMATION TO BEHAVIOR OF ENGINEERED BARRIERS AT ELEVATED TEMPERATURES.	B		THIS IS IMPORTANT FOR ASSESSING THE ISOLATION OF THE WASTE AS WELL AS THE PRACTICALITY OF RETRIEVAL.

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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D = EMPLACEMENT AUTHORIZATION

(SEE JOHN GREEVES SCHEDULE) Appendix A

THERMOMECHANICAL

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
	CHAMBER TEST	TO DETERMINE IN PLACE PROPERTIES OF ENGINEERED BACKFILL AND BULKHEADS.	C		

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(SEE JOHN GREEVES SCHEDULE)/Appendix A-1

THERMOMECHANICAL

R. GATES

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
THERMAL CONDUCTIVITY		MAJOR IMPACT ON PERFORMANCE			SEE TASK 2 REPORT
SPECIFIC HEAT	BLOCK TEST		B	1	SEE TASK 2 REPORT
THERMAL EXPANSION	LARGE SCALE TEST		B	1	SEE TASK 2 REPORT
HEAT EFFECT ON ROCK PROPERTIES HEAT EFFECT ON ENGR. BARRIERS	SMALL SCALE TEST		B	6	SEE TASK 2 REPORT
	CHAMBER TEST ALSO LAB TESTS; NSTF TEMPERATURE LOGGING	(GOLDER ASSOC.)	B	1 20	SEE TASK 2 REPORT

D. HAMBLEY

THERMOMECHANICAL

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)		RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
THERMAL CONDUCTIVITY THERMAL DIFFUSIVITY SPECIFIC HEAT COEFF. OF THERMAL EXPANSION	HEATER TEST TEMPERATURE LOGGING LAB TESTS	(1) (2) (3)	PRIOR TO B	A HEATER TEST IS THE MOST PRACTICAL MEANS OF DETERMINING IN-SITU ROCK MASS PROPERTIES. TESTS IN THE NEAR SURFACE TEST FACILITY (NSTF) WOULD BE INAPPROPRIATE BECAUSE OF DIFFERENT STRESS LEVELS, DIFFERENT BASALT FLOW AND DIFFERENT HYDROLOGICAL CONDITIONS. IT IS DIFFICULT TO SCALE FROM LAB SPECIMENS TO FULL-SCALE IN-SITU BEHAVIOR
TEMPERATURE EFFECT ON ROCK PROPERTIES	CHAMBER TEST BLOCK TEST	(1) (1)	PRIOR TO B	BOTH US THESE TESTS ARE RELATIVELY UNTRIED. HOWEVER, WITHIN THE LIMITATIONS OF THE TEST PROCEDURES, VALUABLE DATA CAN BE OBTAINED.
TEMPERATURE EFFECTS ON ENGINEERED BARRIERS	LAB TESTS		PRIOR TO B	THE PROPERTIES OF PROPOSED ENGINEERED BARRIERS AT ELEVATED TEMPERATURES ARE CRITICAL TO THE FUNCTION OF THE REPOSITORY. ANY DOUBT AS TO THE VALUE OF THESE BARRIERS CALLS IN QUESTION WHETHER THE REPOSITORY WOULD BE EFFECTIVELY ISOLATED AND HENCE SATIFY LICENSING REQUIREMENTS.

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(SEE JOHN GREEVES SCHEDULE) APPENDIX A-1

THERMOMECHANICAL
J. DAEMEN

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
THERMAL CONDUCTIVITY SPECIFIC HEAT (ETC.--) THERMAL EXPANSION	LABORATORY DETERMINATIONS ON CORE	DATA NEEDED FOR THERMO-MECHANICAL MODELING, HENCE INDIRECTLY FOR HYDROLOGICAL MODELING	B	B	STANDARD LAB TESTS
THERMAL EFFECTS ON GEO-CHEMICAL PROPERTIES	LABORATORY DETERMINATIONS ON SAMPLES OF GROUNDROCK MATERIALS INCLUDED IN WASTE ISOLATION PERFORMANCE	NEEDED TO ASSESS THE INFLUENCE AT TEMPERATURE ON ISOLATION PERFORMANCE	B	B	
RESPONSE OF ROCK MASS TO HEATING			C/D	A	HEATER TESTS 1. LARGE SCALE 2. SMALL SCALE CHAMBER LARGE SCALE
RESPONSE OF ROCK MASS TO COOLING	MONITORING OF TEMPERATURES, STRESSES AND DISPLACEMENTS DURING COOLING DUE TO CONSTRUCTION VENTILATION	MODEL VALIDATION - COMPARE MEASURED WITH PREDICTED RESPONSE	B/C/D	B	CAN BE DONE AT RELATIVELY LOW COST - IF STARTED FROM START OF EXCAVATION WILL PROVIDE A LOW-COST LARGE VOLUME DATA BASE. WILL COVER A FAIRLY LIMITED TEMPERATURE RANGE ONLY.

THERMOMECHANICAL
R. GATES

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
HEAT EFFECT ON ROCK PROPERTIES		B	THERMALLY INDUCED HEAD ON HYDROLOGY IS MAJOR VEHICLE FOR RADIONUCLIDE MOVEMENT, THEREFORE, BEST AVAILABLE TESTING (POSSIBLY BETTER THAN NOW) MUST BE USED TO TRY TO GET BEST AVAILABLE ANSWER

HYDROLOGICAL RESPONSE

FREQUENCY - A = SEVERAL
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STAGES - A = SITE CHARACTERIZATION
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(SEE JOHN GREEVES SCHEDULE) Appendix A-1

D. PENTZ

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
DIRECTIONAL HYDRAULIC PROP. HYDRAULIC CONDUCTIVITY AS FUNCTION OF ANISOTROPY, CHANGE IN EFFECTIVE STRESS, CHANGES IN TEMPERATURE AND SPECIFIC STORAGE IN UNDISTURBED ROCK ZONE.	MULTIPLE BOREHOLE TESTS	DEFINE LONG TERM CONDITIONS IMPOSSIBLE TO DETERMINE FROM VERT. HOLES	PRIOR TO L.A.	3 PUMPS/ HOLES IN 3D	HORIZONTAL HOLES (BWIP) 1 PUMP HOLE, 8 OBSERVATION HOLES NOTE. THIS TEST COULD BE ADOPTED TO MEASURE THE PERMEABILITY OF CONSTRUCTION INDUCED HYDRAULIC PROPERTIES.
POINT HYDRAULIC PERMEABILITY INDEX PERMEABILITY ASSESSMENTS	SINGLE BOREHOLE 8 SHADDLE PACKER TESTS	CONFIRM HYDRAULIC VARIABILITY	PRIOR TO L.A.	SAY 200 IE B	CHEAP SMALL TESTS IN UNDISTURBED AND CONSTRUCTION INDUCED DAMAGED ROCK.
GEOLOGICAL FRAMEWORK GROSS VERTICAL. PERMEABILITY OF TEST FACILITY	MONITOR PRESSURE DISTRIBUTION BEFORE AND AFTER CONSTRUCTION OF OPENINGS IN ROCK MOUNDING. MEASURE GROSS WATER BALANCE AND AIR SEQUENTIALLY AND WITH TIME	CONFIRM GROSS PERFORMANCE OF THE IN SITU CONSTRUCTION WITH DETAILED POINT EVALUATION	PRIOR TO L.A.	CONTINUOUS	NOTE ALL TESTS CAN ONLY TO PERFORMED AT DEPTH.

NOTE

EVERY EFFORT SHOULD BE MADE TO QUANTIFY HYDRAULICAL VARIABILITY THROUGHOUT THE ENTIRE SITE FROM SURFACE BOREHOLES. PARTICULAR EMPHASIS ON VERT. PERMEABILITY.

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
THERMAL CONDUCTIVITY SPECIFIC HEAT (ETC.--) THERMAL EXPANSION	2	B	NEEDED FOR PRELIMINARY MODELING OF THERMO-MECHANICAL ROCK MASS RESPONSE
THERMAL EFFECTS ON GEO-CHEMICAL PROPERTIES OF ROCK AND JOINT FILL MATERIALS	1	B	NEEDED FOR PRELIMINARY LONGEVITY CALCULATIONS AND LONG-TERM ROCK/FILL (JOINT) PREDICTIONS OF THERMOCHEMICAL STABILITY
LARGE SCALE ROCK MASS RESPONSE TO COOLING	3	B/C/D	VALIDATION OF THERMOMECHANICAL AND GEO-MECHANICAL MODELS AT RELATIVELY LOW COST - LARGE SCALE ROCK VOLUME - LOW COST

H. WOLLENBERG

FREQUENCY – A = SEVERAL
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(SEE JOHN GREEVES SCHEDULE) *APPENDIX A-1*

HYDRO.

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
DIRECTIONAL (VERTICAL) PERMEABILITY & STORAGE COEFF. IN HOST ROCK	MULTIPLE BOREHOLE	ESTABLISH PERMEABILITY RECTORS IN CANDIDATE HOST ROCK	A	DEPENDS ON RESULTS OF DETAILED MAPPING OF WORKINGS	PUMP PACKED-OFF INTERVAL OF CENTRAL DRILL HOLE AND MEASURE PRESSURES IN A SET OF MONITORING HOLES.
PERM. & STORAGE COEF. OF OPENING AND/OR THERMALLY INDUCED FRACTURES	VENTILATION TEST (& DETERMINATION OF MINE WATER BALANCE)	ESTABLISH PERMEABILITY OF LARGE VOLUME OF ROCK MASS	A	FOLLOWING DETAILED MAPPING OF WORKINGS	SEAL OFF END OF DRIFT AFTER DRILLING RADIAL HOLES. INTRODUCE DRY AIR INTO DRIFT AND MEASURE WATER CONTENT OF OUTLET AIR, AND CONCURRENT PRESSURE IN PACKED OFF INTERVALS IN RADIAL HOLES.
	CHAMBER TEST	INVESTIGATE EFFECTS OF HEATING ON PERMEABILITY OF A LARGE VOLUME OF ROCK UP TO 10M FROM WALL OF WORKINGS	A	ONCE, FOLLOWING DETAILED MAPPING & CORE LOGGING	COUPLED HYDROLOGIC-THERMOMECH. TEST- (SEE WRITEUP ON THERMOMECH. SHEET)
HYDROLOGICAL PORTION OF GEOLOGICAL FRAMEWORK	ASSUME PARTIALLY ESTABLISHED BY SITE CHARAC. ACTIVITIES INCORPORATING SURFACE DRILLHOLES. THE EXISTING HOLES SHOULD BE UTILIZED FULLY TO ACHIEVE A GOOD UNDERSTANDING OF THE REGIONAL VERTICAL PERMEABILITY.				

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D. PENTZ

HYDROLOGICAL RESPONSE COMBINED

(SEE JOHN GREEVES SCHEDULE) APPENDIX A-1

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
EVALUATION OF CONSTRUCTION INDUCED FRACTURE ZONE IN HYDROLOGICAL TERMS	(1) CHAMBER TEST (2) MODIFICATION OF MINE- BY TEST (3) LBL TYPE (4) POINT SINGLE POINT (5) BLOCK TESTS				THESE TESTS ARE ONLY NECESSARY IF THE CHAMBER TEST IS PERFORMED

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(SEE JOHN GREEVES SCHEDULE) Appendix A-1

HYDROGEOLOGICAL

D. HAMBLEY

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
DIRECTIONAL PERMEABILITY AND STORAGE COEFF. IN HOST ROCKS	SINGLE BOREHOLE TEST MULTIPLE BOREHOLE TEST	TO DETERMINE THE PERMEABILITY OF THE ROCK MASS AND HENCE THE TRAVEL TIME FOR GROUNDWATER	A	SEVERAL 1	LIMITED TESTING COULD BE CARRIED OUT FROM THE "BELL" BUT THERE WOULD BE LITTLE ASSURANCE THAT THE VOLUME SAMPLED IN THAT MANNER WOULD BE REPRESENTATIVE.
PERMEABILITY AND STORAGE COEFFICIENT OF EXCAVATION OR THERMALLY-INDUCED FRACTURES	A) CHAMBER TEST B) SINGLE BOREHOLE TEST C) MULTIPLE BOREHOLE TEST D) BLOCK TEST	TO DETERMINE THE PREMEABILITY OF FRACTURES SURROUNDING OPENINGS AND THE EFFECT THEREON AT ELEVATED TEMPERATURE	PRIOR TO LA	2 1 1	THESE TESTS COULD BE POSTPONED IF AND ONLY IF, WORST CASE MODELING INDICATES THAT EPA STANDARDS VIS-A-VIS THE ACCESSIBLE ENVIRONMENT CAN BE MET - FOR EXAMPLE, MODELING THE ROCK AS GRAVEL. OF TESTS LISTED, CHAMBER TEST IS TOP PRIORITY.
HYDROLOGICAL PORTION OF GEOLOGICAL FRAMEWORK		TO DETERMINE THE RELATIVE IMPORTANCE OF THE HYDROLOGICAL REGIME TO TOTAL GEOLOGICAL ISOLATION AT THE REPOSITORY FROM THE ACCESSIBLE ENVIRONMENT	PRIOR TO LA		HYDROLOGICAL CONDITIONS ARE CRITICAL TO ASSURANCE THAT A SITE COULD FUNCTION AS A REPOSITORY.

H. WOLLENBERG

HYDRO.

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) Appendix A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
DIRECTIONAL (VERTICAL) PERMEABILITY AND STORAGE COEFF. IN HOST ROCK	(1)	A	PERMEABILITY VECTORS IN CANDIDATE HOST ROCK MUST BE DETERMINED
PERM. AND STORAGE COEFF. OF OPENING AND/OR THERMALLY INDUCED FRACTURES	(1)	A	THE EFFECT OF THE CONSTRUCTION AND OPERATION OF THE REPOSITORY ON THE PERMEABILITY OF THE ROCK WITHIN 10M OF THE REPOSITORY GALLERIES (THE ZONE OF POSSIBLE SHORT CIRCUIT TO THE ACCESSIBLE ENVIRONMENT) MUST BE DETERMINED.
HYDROLOGICAL PORTION OF THE GEOLOGICAL FRAMEWORK	(1)	A	REGIONAL VERTICAL PERMEABILITY MUST BE UNDERSTOOD TO PREDICT AND ASSESS EFFECTS OF INTRODUCING A REPOSITORY AND TO DECISION POSSIBLE FLOW PATHWAYS FROM THE REPOSITORY INTO AND THROUGH THE ROCK UNITS ENCOMPASSING THE REPOSITORY.

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(SEE JOHN GREEVES SCHEDULE) APPENDIX A-1

HYDROGEOLOGY

R. GATES

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
DIRECTIONAL PERMEABILITY AND STORAGE COEFFICIENT IN HOST ROCK; HYDRAULIC CONDUCTIVITY, EFFECTIVE POROSITY, SPECIFIC STORAGE PERMEABILITY AND STORAGE COEFFICIENT OF OPENING OR THERMALLY-INDUCED FRACTURES	MINE DRAINAGE (IN WATER AND AIR) MONITORING	UNCERTAINTY - REDUCE FOR CHEAP EASY IMPORTANT KNOWLEDGE ABOUT FLOW PROPERTIES	B	C	SEE TASK 2 REPORT
	PERMEABILITY TEST (MULTIPLE BOREHOLE) PERMEABILITY TEST (SINGLE BOREHOLE) TESTS WILL GO THROUGH FRACTURE ZONE (DAMAGED ZONE) AND INTO UNDISTURBED HOST ROCK, THEREFORE BOTH	TO GET FIRST RELIABLE INFORMATION ON DIRECTIONAL FLOW FOR LARGE REPRESENTATIVE SAMPLE	B B	3 (3 DIRECTIONS, 1 LOCATION)	SEE TASK 2 REPORT
		SAME AS ABOVE PLUS LEARN ABOUT VARIABILITY WITH MULTIPLE TESTS	B B	C 450	SEE TASK 2 REPORT
IN-SITU HYDRAULIC FIELD (PART OF GEOLOGIC FRAME WORK)	PIEZOMETER READINGS IN BOREHOLE (PORE PRESSURE MONITORING)		A,B	C HUNDREDS	SEE TASK 2 REPORT
	BLOCK TEST	TO LEARN ABOUT COUPLED EFFECT WITH THERMO-MECHANICAL RESPONSE	B	1	SEE TASK 2 REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) APPENDIX A-1	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
DIRECTIONAL PERMEABILITY AND STORAGE COEFFICIENT IN HOST ROCKS (EMPHASIS ON VERTICAL PERMEABILITY)	1	PRIOR TO LICENSE APPLICATION	LOW PERMEABILITY AND, HENCE, LARGE TRAVEL TIMES FROM THE REPOSITORY TO THE ACCESSIBLE ENVIRONMENT (BOTH VERTICALLY AND HORIZONTALLY) ARE THE PRIMARY PREREQUISITES FOR SUITABILITY OF A CANDIDATE SITE.
PERMEABILITY AND STORAGE COEFFICIENT AT EXCAVATION - ON THERMALLY-INDUCED FRACTURES	1	PRIOR TO LICENSE APPLICATION	IF IT CAN BE SHOWN THAT EVEN WITH HIGH PERMEABILITY MODEL STUDIES INDICATE THAT EPA STANDARDS CAN BE SATISFIED, THEN THIS PARAMETER BECOMES REDUCED IN PRIORITY. HOWEVER, IT MUST BE BORNE IN MIND THAT FRACTURE ZONES WILL EXIST SURROUNDING OPENINGS AND THAT THE PERMEABILITY OF THESE ZONES WILL BE SEVERAL ORDERS OF MAGNITUDE GREATER THAN THE INTACT ROCK, I.E., PERMEABILITY WILL BE FRACTURE CONTROLLED.
HYDROLOGICAL PORTIONAL GEOLOGICAL FRAMEWORK	1	PRIOR TO LICENSE APPLICATION	TRANSPORT OF RADIONUCLIDES BY WATER IS THE PRIMARY MEANS, IF ANY, THAT MATERIALS FROM THE STORED WASTES WILL REACH THE ACCESSIBLE ENVIRONMENT. THUS, THE HYDROLOGY OF THE ROCK MASS AT THE REPOSITORY HORIZON (AND ABOVE) IS OF PARAMOUNT IMPORTANCE IF THE REPOSITORY IS TO BE ISOLATED.

HYDROGEOLOGY

R. GATES

SUMMARY REPORT

PARAMETER	TEST NEEDED FOR LICENSE APPLICATION IN PRIORITY ORDER (1 HIGH, 10 LOW)	RECOMMENDED STAGE (SEE J. GREEVES SCHEDULE) [illegible]	JUSTIFICATION FOR PRIORITY COMMENTS, RECOMMENDATIONS, ADVISE
SEE OTHER SHEET	ALL PRIORITY 1	ALL B PRIOR TO LICENSE APPLICATION	THESE TESTS ARE REQUIRED TO REDUCE UNCERTAINTY TO OBTAIN "REASONABLE ASSURANCE" HYDROLOGY IS THE MEANS OF ESCAPE OF RADIONUCLIDES FOR ULTIMATE PERFORMANCE, SO OUR UNCERTAINTY MUST BE SMALL ENOUGH THAT OUTSIDE CRITICS CANNOT DELAY

Hydrology
J. Daemen

SUMMARY REPORT

Parameter	Test needed for license application in priority order (1 high, 10 low)	Recommended stage (see J. Greeves schedule) [illegible] A-1	Justification for priority comments, recommendations, advise
Large scale vertical and horizontal permeability	1 (Highest priority of all isolation aspect parameters) Water balance monitoring	B	Information can be obtained only from large scale testing, i.e. inflow into and losses from shaft and tunnels, during and after construction. Cost is small, only monitoring is needed - data must be kept and interpreted
3-dimensional permeability tensor	2 Multiple hole tests in 3 directions	B	Must be sufficiently large scale to be representative of repository horizon rock flow. It is essential for estimating near field isolation performance. Number of holes needed is debateable difficult to estimate until fracture characteristics (spacing, width, filling, orientation, continuity) are better known, i.e. until several hundreds of ft. of drilling has been completed.
Damaged zone permeability - excavation damage - stress redistribution		B/C/D	Risk analysis must show its importance. Can only be measured in representative excavation, i.e. need "typical" excavation - the "bell" is not representative, it is a complicated shape (for blasting), in a difficult situation (at the bottom of a shaft)
			General comment: the shaft/bell combination does not provide sufficient representative access for during any large scale hydrological work.

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(SEE JOHN GREEVES SCHEDULE) A-1

PARAMETER	TESTS NEEDED FOR LICENSE APPLICATION (WHAT)	PURPOSE (WHY)	STAGE (WHEN)	FREQUENCY	TEST DESCRIPTIONS AND REMARKS (HOW)
LARGE SCALE VERTICAL AND HORIZONTAL PERMEABILITY ESTIMATES	MONITORING OF WATER BALANCE - DURING SHAFT SINKING - DURING TUNNEL EXCAVATION	THE MOST CRITICAL ISOLATION PARAMETER FOR THE FAR FIELD CONTRIBUTION TO WASTE ISOLATION	A/B/C D	C	CONTINUOUSLY MONITOR WATER BALANCE DURING AND AFTER ALL UNDERGROUND CONSTRUCTION AND DRILLING. IS THE LOWEST COST POSSIBLE INDICATOR (MEASUREMENT) OF LARGE SCALE DRAW-DOWN AND DEPRESSURIZATION. WITH ADDITION OF A FEW MONITORING WELLS, WILL PROVIDE ESSENTIAL INFORMATION ABOUT LARGE SCALE RESPONSE. SHOULD BE THE MAJOR OBJECTIVE OF IN-SITU INVESTIGATIONS. WILL PROVIDE LARGE SCALE STORAGE COEFFICIENT, PERMEA-BILITY.
HYDROLOGICAL PART OF GEOLOGICAL FRAMEWORK	PUMPING TESTS, MULTIPLE PACKER TESTS, TRACER TESTS IN ALL AVAILABLE VERTICAL HOLES.	DETERMINE FLOW AND STORAGE CHARACTERISTICS AT, ABOVE AND BELOW REPOSITORY HORIZON	A/B/C	B	HOLES ARE AVAILABLE - MAJOR COST HAS BEEN EXPENDED - SHOULD BE UTILIZED CONTINUOUSLY
DETAILED 3-D PERMEABILITY	IN-SITU MEASUREMENTS				

Appendix A-4

1. <u>Hydrological aspects of site characterization</u>

Key issue: isolation capability of repository horizon; potential driving force that could cause radionuclide migration, potential paths for migration.

Most likely potential driving force is heat induced convection. Convention must be prevented by eliminating significant pathways. Licensing will require reasonable assurance that no such pathways exist or that they can be closed off.

Key information needed: potential pathways-their presence or absence in repository rock mass. This includes as essential parameters the fracture system in the repository rock.

Methods: as no reliable methods exist to determine fracture (discontinuity) characteristics, they have to be obtained from direct observation. This key information can be obtained from holes, tunnels and shafts. Because of the inherent three-dimensional nature of fracture systems in rock, one needs information along at least two significantly different directions. The considerable depth of a typical repository level makes it extremely inefficient to try to obtain such basic information from the surface, and impossible to obtain numerical values for the actual flow parameters from the surface or from boreholes (which cannot sample a representative elementary volume). Underground excavation of minimum representative volume is a prerequisite to valid hydrological assessment. In a typical rock mass this requires access for at least several hundred feet in three (more or less) perpendicular directions. The shaft provides one direction, two horizontal drifts the additional directions needed. The first numerical estimates of in-situ large scale characteristics are obtained by monitoring the water balance during all excavations. These numbers have to be improved by in-situ testing. Because of the well-known influence of stress and temperature on flow parameters, and because of the need to study a "typical" rock sample such tests can be performed only in-situ, and have to be site-characteristic. Testing in boreholes is not feasible because cross-hole testing is essential, in multiple directions, and at great depth.

J. Daemen (4-15-82)

Permeability of the zone directly around the tunnel has been mentioned as a key issue. Damage of this zone could be caused by stress redistribution, by inappropriate excavation methods, and by heating. Stress redistribution damage will depend on the stress field (hence on the orientation of the stress field and of the tunnel), on the size of the tunnel and on its shape, on the stiffness of the support and on the installation time after excavation. It will be extremely difficult to obtain a representative sample of the real repository situation during any experimental tunneling, and impossible for the support method and for excavation damage which depend to a great extent on the contractor. The license application should specify how DOE will write the construction contract such that a very tight stiff support is in place even shortly after opening up around, and how they will make sure that no excessive construction damage is done. A carefully written contract can be prepared without delay in the testing program and is as important as the in-situ conditions.

2. Geomechanical aspects of repositorylicensing information requirements

The key issue to be addressed by the geomechanical investigation of the repository rack is to determine to what extent, if any, the geomechanical response to excavation will affect the isolation capacity of the rock mass. The most likely influence is a change in the hydrological regime of the near field, associated with disturbances around excavations. The most severe case would be a major collapse, propagating (and hence influencing-disturbing) a large distance from the excavation (tunnels-shafts).

Information needs: major discontinuity system and their geomechanical characteristics within the repository horizon; mechanical characteristics of discontinuity systems (particularly strength), stress state.

Methods: the primary information need, the geological structure, requires mapping of a representative sample. Need at least three directions, in each direction for a length of several hundred feet this minimum required (is needed for the license application, in order to determine that the variability does not exceed acceptable limits, and that geomechanical stability is exceedingly difficult to predict until a clear understanding of rock structure is available it must be considered necessary to excavate tunnel, in at least two different directions to determine potential stability problems. Two directions will provide opportunity for assessments of the influence, of anisotropy, both of stress state and of rock characteristics.

Stress measurements at repository level are essential as they provide input needed for any rational predictive method. Standard lab testing of mechanical properties is necessary to determine variability within sampled rock volume, which requires access to sufficient rock volume.

Need data on large scale in-situ strength and deformational characteristics, First (essential) method is monitoring of rock mass response to excavation. This can be performed by convergence and extensometer displacement monitoring, combined with monitoring stress changes. These results can be used to backcalculate the stress state (treating the excavated opening as a large undercoring stress measuremtnt). Although the in-situ stress state is usually considered mainly in the context of geomechanical stability its influence on permeability, especially directly around a tunnel, deserves attention (for example, if the stress ratio in one horizontal direction is 2:1. the permeability of vertical joints parallel to the tunnel located in crown and floor will decrease, due to compressive stress concentration, (assuming excavation damage has been prevented by careful excavation) if the tunnel is normal to this direction.

J. Daemen (4-15-82)

3. <u>Thermomechanical aspects of repository licensing information needs</u>

<u>Key issue:</u> influence of heating on containment-isolation performance of rock mass i.e. consequence of thermal loading on flow-path and on flow-driving mechanism.

<u>Information needs:</u> flow consequence of heating rock mass, in particular displacement response and its influence on closing or opening of discontinuties.

<u>Methods:</u> first necessary prerequisite is establishment of geological framework (lithology, structure) and its variability. Next step is gathering properties (thermomechanical) by lab testing on samples from representative rock volume. Requires horizontal tunneling for sample collection at a number of points sufficient to establish variability.

Large scale in-situ testing of heat influence is necessary because the rock mass response depends on stress state, discontinuity geometry (orientation, spacing, width, etc...) and fill, possible excavation influence, factors which are virtually impossible to duplicate or scale.
The prime objective of in-situ thermomechanical tests is to demonstrate that it will be possible to predict the rock mass response to the heat generated by canisters, and to demonstrate that the rock response will not have an excessively damaging effect on containment.

J. Daemen (4-15-82)

Thermomechanical (continued)

A key problem in the thermomechanical area is that the heat-flow-displacement predictive models have not yet been demonstrated or validated generically, for the very short term. It is clear that the long-term response prediction will have to rely exclusively on theoretical predictions. It should be required therefore, that DOE should demonstrate, in the license application, its research efforts to improve model validation in this area. Because this is fundamental problem it can be studied generically, i.e. without interference with progress at a specific site. In-situ site specific testing can be considered confirmatory, and design fine-tuning. Of particular concern should be the long term behavior at design temperatures. If design temperatures exceed ambient significantly DOE should demonstrate in the license applicaton that is is performing generic long term studies of potential rock damage due to high persistent temperatures.

J. Daemen (4-16-82)

4. Geochemical aspects of repository licensing information requirements

Key issues: longevity (and possibly radionuclude retardation if hydrology considerations require it); past hydrological regime thermodynamic systems equlibrium analysis is the only method available for predicting the longevity of a repository (including its many components and aspects).

Key information needs: present physicochemical environment within repository horizon, as this will be the basic for predicting the far-field as well as the near-field response to waste influence, i.e. long term bahavior of the rock system when heated water age and compositon above and below repository level to estimate past vertical transmissivity.

Key methods: 1) collection of uncontaminated representative samples of rock joint fill material this would be extremely difficult from boreholes, and more reliable from a large size excavation. To determine variability one needs undisturbed samples from a number of points sufficiently far apart to allow sampling a representative volume.
2) lab studies of samples: These two steps, together with long term goechemical stability predictions (and retardation assessments) must be provided for license application. Confirmatory in-situ tests should be initiated for license application, and continue until decommissioning.

3) collect uncontaminated water samples from above,within (if present) and below the repository horizon.

Retardation almost certainty is an area which requires further fundamental research before it can be relied on.

5. Repository site investigation-licensing information needs

Key issues: determine suitability of a rock formation for safe permanent disposal of HLW

Key aspects: 1. Hydrology 2. Geomechanics 3. Thermomechanics 4. Geochemistry

Key parameters for each topical area are identified in each of accompanying topical subsections. It is essential to recognize the considerable overlap of information needs between these areas. Fundamental to all is the knowledge of the overall geological framework.

Key methods: surface investigations (including holes drilled from surface) and underground investigations.

Surface investigations include remote sensing, surface mapping and geophysical surveys. These must cover the full area of the potential repository, and extent laterally to a point indicated by geological knowledge of the area. This work must be completed for a license application. The results must be presented in the form of geological/hydrological cross sections giving the best interpretation of the site geology backed up by all available factual information on which it is based. All holes drilled in support of surface site investigations must be logged (photographed, geophysical) and used to the greatest extent possible (i.e. continuously or until data becomes excessively redundant) for gathering water flow information, i.e. piezometric monitoring; pumping tests; pressure tests; pulse and tracer tests. The major expenditure (drilling) has been made and full benefit should be gained from these available facilities.

Underground testing is essential for resolving key uncertainties in all major subtopics. It is needed to establish the geological framework at the repository horizon. This requires, as a minimum, detailed mapping in three directions (vertical and two nearly perpendicular horizontal) for a distance of several hundred feet (minimum requirement to guarantee the possibility-not-certainly-of having a representative sample). Collection of uncontaminuted samples, testing on a realistic sample scale and in-situ testing requirements necessitate that some of this work-a minimum of several hundred feet in two directions-be a tunnel-type excavation. Access by one shaft only an extremely small one at that, severely

restricts the practical options for work to be performed at depth. It poses serious safety and health risks, in addition to complicating greatly logistics and environmental control. Although one-shaft access might allow the required in-situ work it will increase its cost drastically as well as increase the time required to perform the bare minimum testing essential for meeting information needs.

Key information needs: initial (pre-construction) flow characteristics (permeability); constructive influence on permeability; waste (heat) influence on permeability. Construction influence includes both stress redistribution and excavation damage. (Part of geochemical study). These information needs require full-scale in-situ testing, hence need for tunnels, in order to reduce the uncertainty to an acceptably narrow range to permit licensing.

Our entire discussion has totally (and inexcusably) omitted indirect geophysical investigation: low cost non-destructive large volume methods.

It should be obvious that the panel has expressed extremely serious reservations about current DOE site characterization proposals. If NRC agrees, I would strongly recommend assembling an outside board of consultants, without ties to either the DOE or NRC projects, with national and worldwide reputation for knowledge and experience in site investigations for major (multibillion)deep mining and civil construction projects. This board should be told clearly what the license application approval requires. This board should be asked whether the current DOE plans can provide the necessary information within the proposed time frame.

It must be clearly recognized tha the <u>timing</u> of gathering the technical information is the crucial <u>problem</u>. According to DOE plans the technical information needed for an extremely comprehensive performance assessment will be obtained, but only during and after the currently planned licensing and public hearing time period. If NRC could build into the licensing procedure a mechanism for incorporating information as it develops, the time constraints would be reduced greatly.

J. Daemen (4-15-82)

Integration/overview

Any site that is proposed by the License to be a repository must, at the time of submittal of their license application must have reduced the uncertainty of meeting EPA performance criteria to the point that NRC can prepare a safety evaluation report for that site with "reasonable assurance" that the EPA Criteria will be met. Future updating of the license or amendments may only confirm the reasonableness. The four key issues discussed above cannot be taken up individually because mother nature does not take them up individually. The needed information and methods for obtaining that information must recognize the leakage or coupling of one to the other. There is no way that the information required for a safety evaluation report for 2-4 billion $ repository facility can be obtained with surface drill holes and a shaft with a small bell. No client working underground would make such on investment with so little information. I feel tunnels must be excavated at the proposal repository depth to improve our knowledge of the extent of the proposed repository horizon and the variability of the information needs (characteristics, parameters and factors). Some of these tunnels of test section need to be full scale to the openings in the proposal design. At least 2 orthogonal directions should be tunneled; enough tunnels excavated to conduct the test methods proposed below without adversely effecting the results of individual tests, but staying within MSHA standards for working underground with only one shaft. Five hundred to one thousand feet seems to be a reasonable range of tunneling with size options from 12' x 12' to full scale (18' x 17' at Hanford). The following table of tests integrates the methods proposed to get the information needed to adequately address the key issues discussed prior to License Application for a selected site.

Test	Quantity	Key Issued Addressed	Priority
Plate test	6	geomechanical response	2
Block test	2	geomechanical, thermo-mechanicals hyrdrological response	3
Pressure Chamber	1	geomechanical, hydrologi-	2

test		cal and geochemical response	
Detailed Mapping of all openings	Continuous	geomechanical,hydrological	1
Mine by test	1	geomechanical response	1
Heater tests			
Larger Scale	1	thermechanical and chemical response	2
Small Scale	6	thermechancial and chemical response	3
Permeability and tracer test (multiple borehole)	3	hydrological and Geochemical response	1
Permeability test (single borehole)	450	hydrological response	1
Overcoring	27	geomechanical response (in situ stress)	1
Flatjack test	9	geomechanical response (in situ stress)	3
Groundwater sampling and Temp. logs	20	hydrological, thermechanical, and goechemical response	1
Pore pressure and mine drainage monitoring	Continuous	hydrological response	1

The proposed program is cost effective and practical. Good planning can allow for future use of the tunnels and test areas. A second shaft would be desirable and would allow for more comfort and efficiency and could be constructed conventionally and be one of the shafts of the final repository. A second shaft could accelerate expenditure of some planned funds, but would not increase total costs <u>if</u> the site became a repository. The exploratory shaft should cost much less than $50 million and the testing problem and excavation proposed above could cost less than $20 million. Probably any testing for engineered barriers and retreivablity needed at this time could also be accomplished within the above estimates. The attached table shows the subjectively assessed acceptable level of uncertainty for each information need (characteristics) in the opinions of Golder Associates (D. Pentz and R. Gates).

R. Gates (4-15-82)

ACCEPTABLE LEVEL OF UNCERTAINTY IN THE ASSESSMENT OF EACH CHARACTERISTIC

Table 3.3

CHARACTERISTIC	ACCEPTABLE LEVEL OF UNCERTAINTY* (See Figure 3.3)								
	Very High		High		Moderate		Low		Very Low
GEOLOGIC FRAMEWORK									
Stratigraphic/structural							●	—	—
Tectonic						●	—	—	—
In situ stress field							●	—	—
In situ hydraulic field								●	—
In situ temperature field								●	—
MECHANICAL									
Rock mass strength						●	○	—	—
Deformation moduli						●	○	—	—
Creep/plasticity					●	—	—	—	—
THERMAL									
Thermal conductivity					●	—	—	—	—
Specific heat (etc.)					●	—	—	—	—
Thermal expansion					●	—	—	—	—
HYDROLOGIC									
Hydraulic conductivity							●	○	—
Effective porosity					●	—	—	—	—
Specific storage					●	—	—	—	—
GEOCHEMCIAL									
Dispersivity		●	—	—	—	—	—	—	—
Adsorption/retardation						●	—	—	—
Pore fluid composition						●	—	—	—
Alteration/solubility						●	—	—	—

*Note: Acceptable levels of uncertainty have been subjectively assessed, based on experience. However, these levels are qualitative indicators only, as the characteristics are not independent of each other or of media.

● Acceptable level of uncertainty for undisturbed rock mass characteristic

o Acceptable level of uncertainty for disturbed (due to excavation) rock mass characteristic

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Hydrological Response (top priority for testing)

The hydrological response of a repository is the most critical issue and reasonable low uncertainity at License Application is justified because water is the escape mechanism for radionuclides upon which EPA has established (draft) the ultimate long term isolation performance criteria. Much of the natural in-situ hydraulic field will be learned during site characterization, by pore pressure monitoring but more must be and can be learned prior to construction application. We must know directional permeability (hydraulic conductivity), effective porosity and specific storage for both undisturbed and disturbed (damaged) host rock. Continuous mine drainage (by water and air moisture removal) monitoring. More pore pressure monitoring during initial tunnel construction is essential because this is the first time the pressure difference will be applied to the rock unlocking its secrets, multi-directional single and multiple borehole permeability tests are needed to get large representative samples of rock mass behavior in various locations to evaluate variability. A block test will help to learn coupled hydrological response to thermal and stress loading. All the needed information cannot possibly be obtained with surface drill holes and a shaft with only a bell.

R. Gates (4-15-82)

Geochemical Response - Priority 4 for testing

Much of the uncertainty remains at decommissioning will be geochemical response. Most of what we know now and probably then will be based on laboratory results. The information needed to assume any credit for natural retardation of radionuclides is dispersivity, retardation (including adsorption), pore fluid composition, and fracture filling materials (substrate). Because of the large variability in assumptions in this key issue, any reasonable testing that can be done should be done. Example methods are adding to the scope of the proposed block test, chamber test, heater tests, and adding tracer tests to the three proposed multiple borehole permeability tests. A "single fracture retardation test" described by NRC"S Alexander is a "nice to have" test. The Ph and Eh, of groundwater are critical and will be changed by the construction of the repository. They must be monitored continuously to confirm assumptions if they are critical to DOE's design assumptions. My input on this issue is limited by my personal lack of training and experience, but I am convinced surface boreholes and a shaft with a bell will not provide the needed information.

R. Gates (4-15-82)

Geomechanical Response Priority 2 for testing

Although less critical than hydrological response and thermomechanical response for long term performance of the repository, it is the most critical for short term performance and has a major impact on long term performance. Overall design will be driven by geomechanical response and will thus directly impact long term performance. The top priority for testing for this issue is the information needs related to geologic structure and lithology. How thick is the repository horizon (Untanum flow at Hanford)? What is its extent? How uniform is the thickness? How variable are the properties within the flow? The second priority for testing is in-situ stress determination and deformation response. If the in-situ stress in unknown, the impact on making openings cannot be determined. The impact on making opening can have a major impact on the stability of the opening for short and long term performance. In situ stress can be determined by overcoring holes from tunnels at depth. Some of this could be learned from a shaft with a bell. Deformation response to tunnel openings can only be learned by measuring during tunnel openings, i.e. mine-by testing. The proposed plate test and flatjack tests add critical information about deformation properties form one spot to another, i.e. variability. Tunneling in excess of 500 feet, some full scale, is essential prior to License Application. Thus, a shaft and bell are inadequate.

R. Gates (4-15-82)

Thermechanical Response Priority 3 for testing

Thermally induced head on hydrology is a major vehicle for radionuclide movement. Without heat, the groundwater would have little reason to pass through a repository carrying away radionuclides. The information needed by license application is thermal conductivity, specific heat, thermal expansion, and effect on rock fractures and engineered barriers to reduce uncertainty to the level of "reasonable assurance." Testing procedures are not as well developed as in other key issues. This lack of development causes us to know less now than we would like for site suitability at all proposed sites, thus, testing prior to NRC's Safety Evaluation Report and thus DOE's License Application is all the more critical. Testing procedures (and instrumentation) are improving and most likely will be better by that time. At BWIP's NSTF for example, tests are being conducted now and they are making improvements. However, since the in-situ stress is different, the NSTF is in a different basalt flow, and the NSTF host rock is unsaturated the results cannot be used in lieu of at-depth in situ testing where the Umtatum is saturated. The proposed block test, chamber test, and large and small scale heater tests are a reasonable minimum to learn what is needed for license application. Surface drill holes and a shaft with a bell will not produce the needed information.

R. Gates (4-15-82)

INTEGRATION/OVERVIEW

It is essential to emphasize that no test should be required unless it can be demonstrated that it will cause the performance objectives (standards in 10 CFR 60) for a particular site to be reached. Thus, clearly to test purely for the sake of compileing the total range of possible values is unnecessary if the existing data of assumptions already meet the standards. The test program suggested, in my view discussed over the last few days should be at least (illegable) for better in schedule and terms of cash.

As stated previously the prime issue forcing a License Application is both a question of variability and uncertainty in "modeling". thus specifically the amount of excavation at BWIP could if required certainly reach some 500 feet of lateral excavation from a single shaft. With a small additional ventilation shaft this could reach perhaps 1500 feet of excavation. Assuming a shaft is started to be sunk in Jan. 83 all this excavation plus all testing with some modifications to the LBL test could be completed prior to 88.

The costs of such exploration should not exceed $50 million in 82 dollars. Which should be compared with an estimated cost of $50 million dollars for the 6 ft. shaft. Thus the estimated cost of site characterization (i.e., shaft plus in situ testing) would be about 2% of total capital cost of a repository.

Pentz (4/15/82)

Hydrological Response

Hydrological Response is a key issue for a license application since this dominantly defines ultimately the response of the entire system. Thus the basis for the assumptions of performance modeling will dominantly lie in the supporting hydrologic data. The key issue could thus be described as what is the variability throughout the site and what is the uncertainty associated with explicit hydraulic tests to characterize the parameters and finally what is the uncertainty associated with the models, experience, physical laws which couple the parameters together to describe the hydrologic response.

The parameters must therefore address these issues. Vertical, and horizontal permeability are different if preferential structural geological conditions prevail (dominantly vertical structures are expected within Umtanum at BWIP). Vertical permeability is very difficult if not practically impossible to determine from vertical boreholes. Thus, measurements must be made from subsurface locations particularly within the repository horizon. In my opinion, once an exploratory shaft reaches the proposed repository horizon the construction of a 20 ft. bell is very unlikely to either expose enough rock to establish the variability limits of the entire site and also is inadequate to hydraulically stress a representative volume of rock.

If the applicant cannot satisfy standards (EPA, etc.) by assuming the worst credible assumptions relating to construction induced (increased) permeability around the openings. Then it will be necessary at least to establish with reasonable assurance the lower bound of such effects. This clearly cannot be established from a bell sized opening at thge shaft.

With these reasons stated above the following hydrological advice can be offered.

1. The prime issue is the hydrological variability, particularly the vertical permeability of the repository horizon.

2. This variability must be established by producing sufficient physical access to the repository horizon to the extent that the applicant will be able to adequately assure NRC that the site can meet the standards. This may be done by comparing a series of localized geological, and hydrological tests with measured response of the entire subsurface excavation within the repository horizon.

3. The number of tests discussed in supporting documents are based on our imperfect understanding of conditions at depths. Thus the tests, and indeed the number should not be taken as statement concerning the required tests or testing.

4. Coupled thermal hydraulic tests of the type suggested by Golder, LBL or variations of these are in our opinion important to bound the uncertainty associated with models.

Pentz 4/15/82

Geomechanical Response

Geomechanical Response is a key issue since this encompasses the geological framework, mechanical deformation, the limits of construction induced effects, the effects induced by in-situ stress.

As with all parameters they are only important if they are deemed to effect the overall response of the system. If this is chosen to be the case their lateral variability must be established. Based on current knowledge at BWIP for example it would strongly appear that there is very limited data to even bound some of these parameters from the surface. Tests carried out at NSTF are not subject to either the effective stress conditions which will act on rock surrounding the openings at the repository horizon.

The geomechanical variability of the rock should be tested by drilling pilot core holes down the axis of the proposed excavation at the repository horizon and comparing these interpretations with that resulting from exposure of drift. The degree to which testing is required prior to L.A. will be a function of variation in the exposed geological framework.

Thus it is possible to conclude based on published data that some geomechanical testing will be required at depth which cannot be determined from the surface 20 ft. bell.

Typical tests concluded: - a Mine-By Test which establishes directly the geometry of the construction induced fractures; in situ stress determination using stress relief methods, "It should be noted this could be done with difficulty within a shaft-bell but the stress tensions cannot be determined from the surface. Hydraulic fracturing methods only determine the ratio of average vertical stress with the average horizontal stress. Flat Jack Tests are similar to stress relief tests and depending on the complexity can be based to determine 3D state of stress.

Comparison with in-situ tests should be made with small scale borehole and laboratory tests on samples from exploratory holes. These index tests are necessary to establish the degree of geomechanical variability.

Pentz 4/15/82

Thermomechanical Response

Thermomechanical response is a key issue since the emplacement of waste has several effects. Currently at BWIP it is the emplacement of waste which is predicted to cause the only credible driving head gradients by inducing conventional cells. Thus it is necessary to characterize the thermal properties (conductivity, specific heat, thermal expansion) of the host rock and to a lesser extent for field geology.

In addition to heat induced gradients there is the further effect of the waste superimposed on natural rock temperature related to deformation and in the extreme, fracturing of rock. There is also a potential positive phenomenon of heat causing natural or construction induced fractures to close reducing the aperture and thus permeability.

Thus with these issues in mind the applicant should address these and determine for the specific site whether it is necessary to provide a numerical basis for the thermomechanical parameters and assumptions.

It is my opinion that the level of detail of the fractured rock mass at BWIP require that in-situ tests are carried out at the repository horizon. It is self evident that none of these tests could be performed within the proposed 20 X 20 ft. bell; substantial time and space will be required for those tests. These tests while they cannot be expected to define the complete thermomechanical response should be sufficient to bound the problem.

Pentz 4/15/82

Geochemical Response

In the basalt of BWIP it is my judgement that while retardation and pore fluid composition are extremely important potential benefits to enabling the standards to be met. However, it appears that in-situ tests are with one possible exception unlikely reduce the uncertainty in geochemical parameters. My knowledge however in this area is limited.

The only test proposed in addition to tests carried out primarily for other purposes (heater tests, block tests, etc.,) is a tracer test within the underground test facility.

Pentz 4/15/82

Hydrology

1. Key Issue: The regional hydrologic setting: the vertical permeability of the stratigraphic sequence encompassing the candidate repository site must be assessed to predict the effects of introducing the repository and to discern possible groundwater flow paths from the repository into and through the stratigraphic sequence.

   Existing holes from the surface that penetrate into and through the candidate repository horizon should be utilized fully for appropriate hydrologic testing to determine components of groundwater flow near and away from the candidate site. This should be accomplished as an important part of the site characterization stage.

2. Key Issue: Permeability and storage coefficient of zone of excavation and/or thermally induced fractures:

   The effect of the construction and operation of the repository on the permeability of the rock within about 10 m of the walls of the repository galleries (the zone of possible 'short circuit' to the accessible environment) must be determined. The permeability of this zone can be determined by ventilation tests in sealed off portions of drifts and in part by monitoring the water balance of the underground workings. The ventilation test will serve to establish the baseline for a chamber test to investigate the effects of heating on the permeability of the excavation-affected zone and a significantly large volume of relatively unaffected rock. A coupled hydrological-thermomechanical chamber test, where water in a cylindrical chamber is heated to approximately 100°C and allowed to form a continuim with the groundwater regime would provide definitive information on the response of the fracture-controlled hydrological system to heating. The test, scoped at approximately $11 million, should begin following establishment of baseline conditions during the site characterization stage. If started in a timely fashion, results of the heating phase of the chamber test would be available for license application evaluation.

3. Key Issue: Directional permeability and storage coefficient in host rock

The permeability vectors in the rock mass encompassing the candidate cite must be determined. A multiple borehole test incorporating pumping of a packed-off interval of a drill hole and observing pressure in a set of monitoring holes may best address this issue. As in the chamber test, the orientation of the drill holes depends on results of detailed mapping of the workings. Estimated cost is $1M for a test incorporating sets of holes in 3 directions. This test could be accomplished in the site characterization stage.

In summary, the resolution of issues 2 and 3 requires access to underground workings, while issue 1 requires continued testing in existing drill holes from the surface.

H. Wollenberg 4/15/82

Geomechanical Response

The key issue here is the geologic setting; its structural and lithologic variability

Information required is primarily the degree of variability of fracture orientations and variability in lithology of the rock mass. This demands that drifts be excavated from the bell to a length that can be accomodated by the ventilation and muck-hauling capabilities of a 6 ft. diameter shaft. The drifts, encompassing 2 orthogonal directions, and long (300-500m) drill holes will cover a significant area that should include the range of variability in structure and lithology to be expected in the repository. Activities should include detailed geologic mapping of openings and detailed logging of core from the long holes.

This activity should characterize the variability to be expected, and its results will serve as the baseline for planning and interpretation of the thermomechanical and hydrologial tests.

A good portion of the understanding of the geological setting will be derived from site characterization activities currently underway. However, drifts from the bell are mandatory to assess the key issue of variability.

H. Wollenberg 4/15/82

Thermomechanical Response

The key issue is the response of the rock mass mechanical properties to the heating imposed by the repository.

Scale of tests vary to accomodate responses of near to far field. The largest volume of rock can be affected by chamber tests whose principal value is to verify and provide input for models predicting the thermomechanical response. This test incorporates a water filled chamber, heated to approximately 100°C, with its effects monitored by thermocouples, extensometers and pressure transducers in radial and longitudinal drill holes emanating from and roughly parallel to the chamber. (Further aspects of this test are discussed in the Hydrology write-up).

Full-scale heater tests can best evaluate the effect of heating by waste canisters on the mechanical properties of the rock in the near field. In this test the heaters simulate waste canisters and temperatures at the heater wall are those expected in repository operation.

These tests should be conducted in drifts away from the bell, and started as early as possible so that results of the heating phase may be available for evaluation of the license application. Holes drilled from the bell would be necessary to determine the orientation of drifts to accomodate for chamber and heater tests.

H. Wollenberg 4/15/82

Geochemistry

Key issues: The composition of groundwater and fracture-filling material: It is necessary to determine the geochemical setting of the candidate repository horizon, 1) to discuss whether the hydrologic regime of the horizon is isolated from the regimes above and below, 2) to help determine the age and flow rate of the groundwater and 3) to determine the sorptive characteristics of material lining and filling the fractures.

Horizontal or inclined holes drilled from the bell and from the drifts will provide essentially uncontaminated water samples, compared with water samples from surface drill holes.

Samples of fracture-filling material will be obtained from cores of surface drill holes, as well as from subsurface horizontal inclined holes and exposures in the workings. Analyses of major-trace-and radioelement contents, stable-and radioisotope ratios will provide the data for items 1, 2 and 3 above. Sampling would commense in early portions of site characterization stage and continue as openings and holes were developed.

Key issues: Retardation: It is necessary to evaluate the "natural barrier" system's ability at a candidate site to retard the migration of radionuclides from the canister into and through the fracture controlled hydrologic system.

To address this, laboratory analyses of the cation exchange capacity of rock matrix and fracture coating and filling material will be required, using appropriate radioelements and formation water compositons.

Retardation studies are already underway at BWIP and NTS. It is important that they be continued, to assess changes in retardation that might be observed when samples of uncontaminated water and fracture material are obtained from underground openings and drill holes.

Dispersivity is not considered a key issue, though it would be desirable to investigate it by tracer tests in drill holes from the drifts, primarily to aid in design of the engineered barrier system.

In summary, resolution of the key issues of groundwater and fracture filling material composition requires samples from underground openings and drill holes. Holes from the bell would suffice for the initial water sample. The key issues of retardation can be addressed by laboratory measurements, but it will be necessary to know water and rock compositions based on subsurface samples.

H. Wollenberg (4-15-82)

Integration Overview

It should be recognized that the hydrological, geochemical, thermomchanical and geomechanical considerations are all strongly linked. Certain tests can address specific aspects of these considerations, while others can assess the coupled effects of several considerations. The overriding concern here is that little can be learned by examination of the bell alone; drill holes must emanate from the bell initially, to be followed by drifts and long holes to accommodate specific tests and to cover the range of variation in a significant sized block of the candidate repository horizon.

Ranking of priority of the major considerations:

1. Hydrologic response
2. Geochemistry
3. Thermomechanical response
4. Geomechanical response

H. Wollenberg (4-15-82)

Hydrological Response

Basalt is not a massive rock but is generally characterized by vertical columnar jointing. A spectacular example of this is the giant's causeway in Northern Ireland. Intact basalt has a low permeability, thus, the rock mass permeability is dependant on the jointing. The key hydrological parameters are:

- directional permeability, especially vertical and storage coefficient in the host rock

- permeability and storage coefficient of excavation or-thermally-induced fractures

- hydrological portion of geological framework

The in-situ permeability of the host rock is required when it is difficult to extrapolate from small intact samples tested in the laboratory to full-scale where fractures govern. Some limited test work could be performed in surface boreholes but conditions would be largely uncontrolled and unknown so interpretation would be difficult. Somewhat better information would be obtained by testing in holes drilled from the bell coupled with the low probability that work performed in the bell or from the bell could be considered representative of the repository as a whole. If it can be shown that testing of the host rock is adequate to characterize hydrologic conditions to the extent that EPA standards can be met then needs are satisfied at this stage and tests at damaged forms would be for verification only. This, however, is unlikely.

The permeability of excavation or thermally-induced fractures is important because a fractured zone will exist around the openings in a repository. The extent of the fracturing is highly dependent on blasting practices - unless controlled blasting is employed, overbreak in a jointed rock can be severe and the radius of the damaged zoned quite large. Thus, it is important to determine the permeability of these fractures. Since the temperature in the rock surrounding the storage rooms will ultimately be elevated, it is essential to verify prior to license application that elevated temperature would adversely affect the permeability of fractures to the extent that EPA standards could not be met.

The directional permeability in host rocks could be obtained from single and multiple borehole tests. These tests would be required at the repository level since, as stated previously, it is unlikely that sufficient control could be exercised in holes from the surface to make results meaningful. A few short holes could be drilled from the bell, however, only short lengths are practical.

The permeability of the excavation-or-thermally-induced fractures can likely best be determined from a chamber test in which the conditions can be closely controlled, and in which the thermal and pore pressure parameters can be varied. Thus tests can be carried out which bound the range of expected conditions over the life of the repository.

It would be virtually impossible to carry out any exploration from the 6 ft. diameter shaft and as indicated only very limited work can be carried out from the bell - not enough to characterize the hydrological response.

D. F. Hambley (4-15-82)

Geochemical Response

Since the first requirement for a repository site is geologic isolation from the accessible environment, it is obviously necessary that the geologic structure is such that this is accomplished.

There are four key parameters, in general terms:

- geologic structure and lithology
- in-situ state of stress, deformational response and in-situ moduli
- rock mass strength and rock mass shear strength
- creep

In regards to basalt, only the first two aspects given above are of primary concern.

It is imperative that the geologic structure and lithology of the repository horizon be mapped in all exposures - all openings and cores. This will provide information on the jointing attitude, spacing, and extent - as well as some indication of the lateral variability. This information is required prior to license application, and will require more extensive exploratory workings than simply the "bell". Futhermore, at least a portion of the exploratory openings should be full size and headings should be driven in 2 orthogonal directions to minimize the blinding effect on a observed joint orientations. The orientation and spacing of joints should be taken into account in designing large scale tests to determine other in-situ parameters. To have sufficient joints available to satisfactorily characterize the rock mass would require a minimum of 500 ft of drift but preferably more.

The second important parameter is the in-situ stress state and deformation response. This is a basic design consideration and thus the information must be available at the time of license application. For all practical purposes this information can only be obtained underground. Hydrofracing could be perfomed from surface but this has fundamental drawbacks:

- it fractures the rock mass at repository level.
- certain assumptions are required regarding the direction of fracturing in-situ tensile strength, vertical stress level at the fractured horizon.

The most reliable method for determining the in-situ stress is overcoring of which there are several possible methods. The best methods would be the CSIRO "Hollow Inclusion" gage and the CSIRO triaxial cell, both of which provide the triaxial state of stress from 3 measurements in a single borehole. Tests using the USBM Deformation Gage or the CSIR Doorstopper Gage would be cheaper but would require three boreholes for each triaxial stress determination as they only measure the stress state in the plane perpendicular to the borehole. The deformational behavior can be determined by mine-by tests, plate jacking tests and flatjacks. The most practical method is likely the mine-by test. However, one could perform many plate-jacking and flatjack tests for the cost of one mine-by test. The data from the former tests is, however considerably less reliable.

There is not sufficient space in a 6ft shaft to carry out overcoring tests. Overcoring tests cannot be carried out in highly fractured rock.

D. F. Hambley (4-15-82)

Thermomechanical Response

Since the planned of the canisters will result in heat transfer to the surrounding rock and thus, elevated temperature, it is necessary to know the effect of the elevated temperature on the properties of the host rock mass and on the engineered barriers as well as the thermal properties of the rock. The thermal properties of the rock include:

- Thermal conductivity
- Thermal diffusivity
- Thermal expansion
- Specific heat

These properties can be measured by heater tests, lab tests and temperature logging. Lab tests are relatively inexpensive, however, it is quite difficult to extrapolate from lab to macro scale, so the lab tests are of limited usefulness. Heater tests can be used to obtain in-situ thermal properties with a high-level of confidence; however these tests are not inexpensive.

The temperature effects on rock properties can be determined using chamber tests and block tests. Large scale chamber tests can provide a large amount of information. This information is especially important in regard to retrieval since scenarios exist in which the heat is allowed to build up. This has a profound effect on the equipment required. It also affects the allowable spacing and pitch of canisters since there is an maximum allowable threshold temperature for a given rock type.

The temperature effects on engineered barriers are also important. First, engineered barriers are part of the system isolating, the waste and hence, their behavior is critical to assuring satisfactory function of the repository. Second, the thermal effects on engineered materials such as backfills impact on retrieval methods for canisters in backfilled rooms. Lab tests are required prior to license application to ensure that the function can be modelled. In-situ tests would be desirable prior to license application but not necessary until construction authorization. How to conduct tests on engineered barriers in-situ is another difficulty.

D. Hambley (4-15-82)

Geochemical Response

The geochemical response has generally received only limited concern. The paramters of interest are:

- pore fluid composition
- fracture filling composition
- retardation
- dispersivity

The pore fluid composition is important since it determine the reactions between any radionuclide emissions and dissolved ions. The fracture filling composition is important because the substrates surface coatings) react with the water. Any reactions which result in flow channels cannot be permitted.

Retardation refers to the interference with radionuclide migration which results from reactions with pore water and fracture fillings.

These parameters are of great importance in determining the suitability of a repository. Not being as geochemist, I do not feel qualified to expand at any length on this topic.

D. F. Hambley (4-15-82)

Integration/Overview

The parameters and tests which have been discussed cannot be considered as isolated entities. The heater, chamber and block tests can all be used to determine parameters of more than one type i.e. geomechanical, hydrological and thermomechanical. That is, there is a fair degree of overlap and hence costs for a particular test will not be incurred solely for one type of information.

Engineered barriers have not received a large amount of consideration; however, assurance that a repository will function as required, requires a knowledge of the elevated temperature properties of engineered barriers. These properties are also important for retrievability especially if the rooms are backfilled.

D. F. Hambley (4-15-82)

Hydrology

The basalt flow is intended to be a container for solid waste disposal. Since it is broken its ability to contain the waste is critical to the entire problem. Also, since an area of about four square miles is to be used it should be verified that this area of suitable thickness exists. The permeability in both the vertical and horizontal directions will have an important impact on its suitability as a repository site. If water can penetrate the mined out repository zone, interact with the radioactive waste and then carry it away from the repository site the site cannot qualify. Some information can be obtained from surface drill holes. These can be use to define the lateral and vertical extent of the basalt at the repository horizon. They can provide diamond drill cores for establishing the existance of the basalt, its extent, the strength from core samples, the strength from core recovery, the frequency of fracture patterns, the fracture orientation, and the RQD index. Much can be determined from sinking the shaft including: the rock vs depth for a large visual sample, the porosity of the rock, the amount or water inflow vs depth, the geology with respect to structure relative to water channelways, the fracture filling material and its ability to retard water flow. The shaft to a depth of 3450 feet, 6 foot diameter may take a year to sink and cost 20 million. (A 2350 foot depth, 8 ft. diameter USBM in oil shale completed by oil well drill rig lined with steel 2" thick at bottom cost 8.2 million $ several years ago). A six foot diameter shaft is really not large enough, an 8 ft. diameter would be better. Tests from 500 feet or drift 12'x 12' in size would establish structural features of basalt and water inflow characteristics. Mine by tests (Golder) should be used to define structural damage to drift surface from blasting that may later make drift sealing difficult. LBL tests should be made to study heating and pressure effect on large volume of, rock. Cost with 1000 foot access drift and test chamber should be 12-14 million. If drift was also used for mine-by tests total would be 2 million less.

The use of the shaft alone with only a bell would not be suitable for all necessary tests. This would particularly restrict hydrological and thermal tests. A 500 foot drift would be a minmum and a 1000 foot drift would be desirable.

Negative conclusions are as follow. The use of a shaft along is only a pretext of site evaluation. If the extent of the basalt flow is not defined the assumption of a four square mile repository site is shaky at best.

C. Babcock (4-15-82)

Geomechanics

Since the mine to be used as a repository is a structure its behavior in terms of ground control problems and long time survival must be defined both experimentally and analytically. During the site characterization when the shaft is sink and the test drifts are driven many opportunities exist to experimentally measure structural behavior. This behavior can then be related through physical properties to assumed states of stress and failure. By means of mathematical, finite element, boundary intergral methods of analysis, the long term behavior of the basalt at elevated temperatures can be predicted. The physical properties of basalt at ambient temperatures (135°F) and at temperatures generated by nuclear waste may be very different. It is a critical need to establish this behavior. The most useful tests and also some of the least expensive relate to convergence measurements. If these are taken for openings of simple geometry (i.e. circular shaft) the behavior can be defined most easily, by closed form mathematical methods. The residual in-situ stress field as a function of depth should be measured. Variability of this field or of the physical properties should alert the site characterization people of potential ground control problems (i.e. is horizontal stess twice the vertical and if so where and for how much vertical depth?) Testing of in situ stress field from drifts should include the best established method-the USBM borehole deformation gages. The use of the CSIRO gage has been questioned with respect to bonding the inclusion sleeve to the rock mass. The physical properties in situ have received much emphasis recently. In that regard borehole shear tests (USBM-Handy, Iowa State) should be used. The Mohr-Coulomb stress condition and failure condition can be readily obtained in a few hours. Laboratory tests on core samples at elevated temperatures are also needed and are relatively inexpensive. Core discing of the Hanford Basalt should be duplicted in laboratory tests developed by the USBM Lobert, Stevenrson, Durelli) mine-by tests as proposed by Golder Associates could be done in other ways (i.e. using drill holes in advance of face advance in on top, sides, and bottom. Some testing of this type should be done. The physical property behavior at elevated temperatures could be done by heaters. Stress measuring gages and extensometers all need to be improved for other than ambient temperature use (LLL-Dex. 2, 3, 1981, Iowa). Finite element modeling of proposed mine for structure is necessary for a long term prediction of behavior at elevated temperature.

C. Babcock (4-15-82)

Thermomechanical

The repository site material (basalt) will have properties that are defined in part as thermal and in part as mechanical. For example, the structural behavior is modified by the fact that the presence of heat drastically changes things. What is brittle at ambient temperatures may be ductile or plastic at elevated temperatures (i.e. steel). If structural behavior is to be defined in terms of deformation then the temperature produced deformation must be separated from that produced by stress. This not only true of rock but also instrument behavior. Since the surface is at ambient temperature it offers few opportunities for heat produced behavior except in the laboratory. Such tests of heat related behavior can be made on core samples, especially with regard to stress and strain (Terra Tech contract). The cost of such tests is relatively high for tri-axial confinement tests ($1000/sample?) Such tests are practical but of limited use. Underground tests as those proposed by Golder Assoc. and LBL are costly but more realistic. Block tests on 2 meter block of basalt to measure borehole gage behavior under influence of stress applied by flatjacks and heaters proposed by Golder should be carefully examined as to purpose and results. The block is attached at the back and therefore constrains nearly all of the cube (St. Venant Principle) the assumptions of two and three stress states are unacceptable from a stress analysis standpoint. The interpretation of borehole gage results should also be analytically defined. The gage response is not the rock response. The thermal properties of the rock as thermal conductivity, specific heat, expansion, on engineered barriers can all be tests to an extent in the laboratory rather inexpensively. The composite system, large scale, must be evaluated underground where the sample size can be representative of the structure.

C. Babcock (4-15-82)

Integrated Overview

The use of a 6 foot diameter shaft with bell is an unrealistic attempt to characterize the site. A minimum of 500 feet of drift is better but still is only a 'point' sample in many respects. A mimimal effort should also be made to include four vertical drill holes on the four corners one mile outside the repository area to establish that the proposed horizon actually exists. If the site is developed with the expectancy that this area is available when it is not NRC credability may be questioned. The cost of about $2.5 million is small compared to the total expected cost of the repository. In a way this is insurance. Since the repository is actually a mine; structural behavior must be defined under the conditions of temperature and stress to avoid unnecessary ground control problems. Attempts to define variability of basalt should be made at every stage - surface diamond drill core in laboratory, shaft wall during sinking should be logged. Geologically, drill rate recorded, particle size produced studied, water inflow recorded, and water flow into drifts. Critical analysis of usefulness of results in terms of cost should be made on a continuing basis. Carry-over findings to characterization of other candidate rock types and sites. Use openings for as many purposes as possible, Test engineered barriers concepts.

Tests to be performed in geomechanics are: logging all geology encountered, overcore with USBM overcoring gage to define 3 dimensional in situ stress, measure convergence of shaft, boreholes, drifts; plate tests with adequate interpretation of three dimensional state of stress under constrained conditions; use USBM borehole shear. Test to define MOHR - Coulomb failure in situ.

Thermomechanical test should include the complexities of the structural behavior problem, produced by temperature. In addition, the temperature effects such as conductivity, specific heat, and effects on engineered barriers should be defined.

Hydrogeology tests should include the determination of directional permeability both horizontal and vertical, and the storage coefficient.

C. Babcock (4-15-82)

Geochemical

The transport of radio-nuclides by water to the boundaries of the repository would render the BWIP site unacceptable. This should be the case for 1000 years or until radio-active decay reduces the waste to a safe level for humans. The geology with respect to structure will be a critical factor. Therefore both the geology and the chemistry of any waste transfer through the basalt must be monitored to insure that such is the case. If radio-nuclides escape from the canisters and migrate through the fractured basalt an important factor for containment is the ability or lack of ability of the basalt to adsorb the nuclides. If not, the basalt must be tight enough to contain by itself or by engineered barriers that are added for that purpose. Tests including pore fluid composition, openness of joints, faults, etc. fracture filling impermeability, fluid transfer rates, effects of heat and pressure should be made both in the laboratory and underground. Cost and number of tests could extent from a limited number of could be very expensive.

C. Babcock (4-15-82)