Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

October 25, 1982 Our ref: G/82/345

U.S. Nuclear Regulatory Commission
High Level Waste Technical Development Branch
Division of Waste Management
Washington, D.C. 20555

Attention: Mr. Lud Hartung, Project Manager

Subject: Contract No. NRC-02-81-037
Technical Assistance for Repository Design
Task 6, Project No. 18
Letter #76

Gentlemen:

Pursuant to your request (reference NRC letter #55 dated August 25, 1982 and NRC letter of October 8, 1982), this letter report is submitted in accordance with the subject contract, Task 6, Project 18, consisting of Golder Associates' participation in a workshop on Repository Design held at Richland, Washington on October 4-9, 1982 and preliminary meetings for input to the workshop. Golder Associates was represented at this workshop by Mr. David Pentz and Dr. Jaak Daemen, consultant. Attached are Mr. Pentz's and Dr. Daemen's comments on the workshop.

Golder Associates trusts that the NRC will find the enclosed comments, as well as our participation at the workshop, useful in their role of regulating repository development. Should you have any questions or desire further assistance, please feel free to call on us.

Sincerely,

GOLDER ASSOCIATES

Richard H. Gates, Ph.D., P.E.
Project Manager

WJR/lw

Enclosures (2)

ENCLOSURE 1
COMMENTS BY DAVID PENTZ

SUBJECT: WORKSHOP ON REPOSITORY DESIGN (BWIP)
RICHLAND, WASHINGTON
OCTOBER 4-7, 1982

Introduction

This workshop accomplished the following factors:

1. We were shown segments of preconceptual and conceptual designs at BWIP.

2. We were shown segments of the developing in situ test plan in ESI and ESII with particular reference to rock mechanics.

3. We were presented with an overview on the current methodology to be used in assessing the nature and need for shaft and borehole sealing required to meet long term performance standards.

4. We were presented with a discussion on the elements of the developing plan to sink and seal the lining of the exploratory shaft. The latter is proposed to be sunk starting in early 1983.

General Comments

This work shop was a useful information meeting. The author of this trip report was not clear how much, if any, of these data and logic would be presented in the upcoming SCR. While we received a series of viewgraph slides, some which contained preliminary data or assumptions, it was not always clear which of these would or had been used in the current design process.

The exploratory shaft program ESI and ESII at BWIP is perceived by many observers to be essential prior to a LA. The detail of this program is currently lacking in the number, extent, and nature of such in situ tests. This lack of specific detail should be expected, and to some extent, encouraged since the actual test program should be an evolving iterative process. Neither BWIP nor NRC should tie themselves down to a precise set of tests prior to presenting a LA. BWIP should, however, set up a clear methodology in advance for demonstrating how decisions will be made and a defense as to the number, extent, and type of tests. This decision process may well be as, or more important than the results of the individual in situ tests. Program criteria should be carefully assessed before being presented during the process since point estimates/or assumptions of parameters may well change as a result of further tests and/or analyses and the changes could unnecessarily damage the credibility of the process. Range of expected values or better still, more accurately prior subjective probability distributions will allow updating of the data base without damaging credibility.

The future program should thus emphasize the importance of demonstrating the predictability of the in situ test facility and surface borehole data to the entire repository. Predictability is a direct function of understanding variability, primarily of the geology, and secondarily hydrological, geochemical, and geotechnical characteristics.

The following are specific comments.

Conceptual Design

The current conceptual design will undoubtedly change as a result of data obtained from the essential in situ test program at BWIP. As stated above, any program assumptions established at this stage should be sufficiently broad not to unduly inhibit any data acquisition program planned for Site Characterization Program. The current conceptual design appears to be designed primarily with respect to good civil underground feasibility level practice. The design criteria are such as minimizing the volume of excavation, and keeping stress and temperature levels below specific point values. There was no evidence that any attempt had been made to correlate such criteria with performance assessments. While there is an argument to be made that such assessments are premature, it should be a matter of concern that the nature of the assumptions themselves may not be subject to continued evaluation. For example, in situ stress levels themselves should not be a controlling criteria. Allowable deformability (specified mechanically and hydraulically) is a controlling criteria. Thus an in situ stress level where the vertical to horizontal ratio exceeds even say, 1:3, does not mean that the deformational effects around the openings would be intolerable either from a constructability or long term standpoint. The current conceptual design appears to be a design based on a comparison of elastic and temperature induced stress concentrations and intact rock strength. Undoubtedly, this will change in the SCR process and will be reflected in a requirement for different tests including the mine-by test or similar tests. The in situ stress (hydrofracturing) program, as presented, is well thought out and apparently well executed. The other methods of stress measurement are currently being tried out at the NSTF to establish the methodology for in situ stress measurements at depth in ESII.

Exploratory Shaft

Part 60.11(a) of the NRC rule requires an applicant to describe "provisions to control any adverse safety-related effects from site characterization, including appropriate quality assurance programs." This clearly relates to an exploratory shaft. The conceptual design of the exploratory shaft discussed at the workshop seems adequate and is a substantial increase in our knowledge on the extent of the design. This information will clearly have to be documented in the SCR. There appears however, to be a requirement for further discussion and documentation of what measures in exploratory shaft can be taken to replace or enhance the seals, if subsequently required. The need to actually implement such changes to the grout seals and liner will only be necessary if the ESI and ESII effect the licensability of a repository (i.e., long term performance). Thus, serious consideration should be given to monitoring the heads at several key depths in the immediate vicinity of the exploratory shaft prior to sinking the shaft. BWIP would then be able to address any questions relating to what had happened at least during the life of repository as a result of this shaft sinking operation. If the monitoring was only initiated during the production shaft sinking, then it may not be possible to demonstrate unequivocably that the site was not already perturbed.

The above comment should be treated with some sceptism, however, until further pre-analysis has been completed.

In summary, the exploratory shaft program appears to be practical for at least the short term. Longevity and performance of seals should be examined with care, including the effects of differential stress at the breakout zone(s). Details of compliance with 60.11 cannot be judged, in our opinion, until documented in the SCR.

ENCLOSURE 2
COMMENTS BY DR. JACK DAEMEN

SUBJECT: WORKSHOP ON REPOSITORY DESIGN (BWIP)
RICHLAND, WASHINGTON
OCTOBER 4-7, 1982

General Comments

The Exploratory Shaft-Phase II program looks good, and all indications are that it will be improved further. This is the crucial step for preparing the License Application at BWIP, and should be especially true in light of the fact that the implied SCR may be deficient with respect to actual detailed design input, criteria and data for the shaft seals and construction.

From the presently available information, with an optimistic interpretation, one can conclude that a repository might be feasible at this site. It will require considerable engineering, continuing site reconnaissance and corresponding design adjustments, as well as carefully controlled construction to reduce the (presently very large) uncertainty in performance.

Because of the inherent unpredictability of deep underground construction it would be very difficult to provide a narrow uncertainty range in the initial SCR. Because of the long level time required for gaining underground access, it is essential that maximum benefit be gained from access gained. It appears that the ES-II is going very strongly in the right direction, which suggests that comprehensive information will be available for the License Application.

Comments on Individual Sections

Two essential criteria dominate the conceptual design:
- 20 ft. wide rooms are needed.
- 27 in. diameter emplacement holes are needed.

Design input parameters include rock strength, in situ stress, waste heat load. Stability analysis consisted of elastic stress concentrations and temperature distributions. Support design was derived empirically, and constructability was considered (e.g., in room shape selection).

The conceptual design is marginally acceptable as a guide to focus the site investigations, especially during ES-II. This acceptance is based on the fact that essential stability factors were considered. Extensive verification during ES-II will be necessary in order to assess the validity of the numerous design assumptions.

The following concerns need to be expressed about the conceptual design:

- very little attention appears to have been paid to radionuclide confinement or waste isolation; e.g., in terms of joints opening up as a result of excessive displacements, development of excessive stress relieved zones about holes or rooms, reconnaissance of repository flow thickness.

- very little attention has been paid to retrievability, especially with regard to excessive rock mass deformations that could complicate retrieval.

- The entire design is based on extremely limited information. The considerable uncertainty, unavoidable at this stage, is never recognized explicitly. Instead of a single narrowly focused design, it would seem desirable at this stage to allow for considerable flexibility at this stage.

<u>In Situ Stress/Rock Strength</u>

The in situ (hydraulic fracturing) stress measurement program is conducted very well, and is going in the right direction by obtaining data in as many locations as possible.

It is unclear how the present strength testing program fits within the objective of demonstrating the feasibility of isolating HLW at this site. In jointed rock, especially in an extremely strong basalt, the intact rock strength is largely irrelevant; yet it clearly is receiving the highest, if not only, priority.

The primary objective of the combined, integrated stress and strength measurement programs should be to enable prediction of repository performance. This will be feasible only on the basis of full-scale in situ performance assessment. This points out the crucial role of ES-II.

If small-scale strength tests are deemed necessary, at the present stage, or later, they should concentrate on joints, and attempt to develop a large representative data basis.

<u>Opening Design Methodology</u>

Understandably, little hard data presently is available for design. It is therefore justifiable to stay with very simple design approaches. There is considerable uncertainty in the input variables. It would be highly desirable to see this uncertainty reflected in the design. This could include ranges of potentially acceptable or necessary shapes, support methods, orientations, etc. based on ranges of likely input parameters.

Two specific design methodologies are used:

- thermoelastic stress concentration calculations
- empirical support design.

No details were given on the empirical support design, which therefore is difficult to assess. It can be pointed out that the empirical methods used (Barton, NGI Bieniawski, SCIR) include few case studies in their data bases at depths similar to those considered here. Traditionally, very limited information was available about stress fields, so that these methods are very uncertain with respect to accounting for stress fields.

The thermoelastic stability analysis of rooms and waste emplacement holes was presented in considerable detail. The methodology consists of calculating the most extreme stress (on the vertical diameter of the emplacement holes) and limiting this to somewhat below the assumed in situ rock strength.

This methodology leaves a great deal to be desired, although it must be recognized that this is the most logical and rational first step in the design. The method, as implemented here, makes it difficult to assess the degree of conservatism or non-conservatism in the design, because one aspect is very conservative, one aspect is very non-conservative, and with the information presented here it is impossible to determine which of the two aspects dominates:

- conservative: the maximum stress at a single point (top or bottom of horizontal emplacement holes) is compared with the uniaxial strength. There is considerable experimental evidence, from testing holes in rock blocks, that rock does not fail when the unimaxal strength is reached at a point. (This is due to the fact that the stress concentration drops off very rapidly.) Experimental evidence, on intact rock, suggests this introduces a safety factor of between 2 and 4.

- non-conservative: The strength used appears to be extremely high (30,000 psi). This is approximately equal to the intact-strength obtained in earlier measurements on small samples, and is about half of strengths measured recently on five samples. Insufficient evidence presently is available to assess whether this is a realistic strength value for large scale intact rock. Nevertheless, it must be considered likely that the strength of the in situ rock will be determined by the weakening effect of the discontinuities. If these are present in significant numbers, it is difficult to envision an in situ strength even approximating the 30,000 psi design assumption.

The travel time-flow rate-release assessment calculations all appear to assume that the "disturbed" zone will have greater permeability than the virgin rock. There are good reasons to expect that, if displacements are minimized, the permeability of the near-excavation zone might be smaller. It would seem highly desirable to evaluate this experimentally.

Sealing Program

The sealing program appears to be designed entirely and exclusively to meet EPA requirements.

The first step in the sealing program, identifying sealing requirements by calculating release rates in various situations appears eminently reasonable. Specifically for shaft seals, the simplified calculations should provide highly valuable information about sealing requirements.

It is clear that the program postulates that sealing requirements will be satisfied easily, as no experimental work is planned for the foreseeable future. This could result in relying entirely on computer program assessments of release rate predictions, up to and beyond the time of the License Application.

The apparent lack of experimental work is especially obvious in the ES-II phase. Some very valuable work is planned along the shaft, and at the time of station breakout. This will provide valuable information about the disturbed zone and about the grout performance in vertical shafts. It would be highly desirable to complement this by studies in (near-horizontal) tunnels, which are far more difficult to seal. Of serious concern should be the disturbed zone about these tunnels/rooms, potentially the most direct pathway from waste to aquifers. If excessive deformations are allowed, e.g., with a support that allows 5 percent of the roof to collapse, the permeability of this zone is likely to be orders of magnitude higher than that of the virgin rock. ES-II provides a unique opportunity to provide hard data on this zone, at an (experiment, instrument) cost equal to a small fraction of the access and construction cost.

Exploratory Shaft

In light of the very limited data basis that appears to be available at present (and probably at the SCR time as well), this work, especially Phase II, will be crucial in establishing credibility, reducing uncertainty and demonstrating practictability by the time of LA.

The overall program, especially for Phase II, appears to be very good. Again, I would put the emphasis heavily on total performance assessment, rather than on highly detailed study of separate subelements such as strength, stress, fracture flow. The best possible determination of rock mass response is careful in situ monitoring, combined with comprehensive back-analysis, full scale excavations. The proposed program comes very close to approaching this optimum testing.

The mechanical-hydrological in situ response studies will have to be complemented by large scale assessment of the predictability of the thermal response of the rock mass.

Exploratory Shaft Grouting

The proposed shaft grouting is a conventional shaft grouting job. Very little attention is paid to potential disturbance around the shaft. Essential problems are to be identified during (and after) Phase ES-II. Remedial action is always considered possible, and is given as the answer to all potential problems.

Based on past experience, it appears that the short term sealing performance of the shaft will be satisfactory, if no unusually severe problems (e.g., large ground displacements, high water pressures or volumes) are encountered. It is also likely that long-term performance will need installation of seals at several locations, requiring grout excavation and liner removal.

Some specific comments:

- information gathering at breakout looks very good, and will be very valuable

- testing from portholes is a good program, but should be complemented by visual inspection, preferably photographing, of all holes (including steel-grout/grout rock interfaces).

- information is needed on chemical seal performance, especially durability.

NSTF

The potential value of the NSTF work is to assess various instruments and technologies, and to obtain "generic" type information about rock mass behavior, excavation technology, predictability, etc.

There appears to be a very serious risk that some instruments might be rejected for reasons not germane to their potential value and applicability for the at-depth facility, e.g., if stress measuring methods are rejected because they do not give satisfactory results in a very low stress environment, while they actually will be used in a high-stress environment (where errors that are dominant at low stress might become acceptable).

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