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Communication No. 21

U.S. Nuclear Regulatory Commission
Division of Waste Management
Geotechnical Branch
MS 623-SS
Washington, DC 20555

Attention: **Mr. Jeff Pohle, Project Officer**
Technical Assistance in Hydrogeology - Project B (RS-NMS-85-009)

Re: **BWIP Document Review - SD-BWI-TP-007: EXPLORATORY SHAFT TEST PLAN**

Dear Mr. Pohle:

Please find attached the Nuclear Waste Consultants/Terra Therma Inc. document review of the draft BWIP Exploratory Shaft Test Plan (SD-BWI-TP-007). This document review was prepared by Adrian Brown and Mark Logsdon (Nuclear Waste Consultants) and Mike Galloway and Fred Marinelli (Terra Therma), under Subtask 2.3 of Contract No. RS-NMS-85-009, per the instructions of the NRC Project Officer in his letter, dated November 26, 1985. The document review has received a management review by Mark Logsdon, NWC Project Manager.

If you have any questions about this document review, please contact me immediately.

Respectfully submitted,
NUCLEAR WASTE CONSULTANTS, INC.

Mark J. Logsdon

Mark J. Logsdon, Project Manager

Att: NWC/TTI Document Review - SD-BWI-TP-007

cc: US NRC - Director, NMSS (ATTN PSB)
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1.0 INTRODUCTION

TITLE: SD-BWI-TP-007 - "EXPLORATORY SHAFT TEST PLAN: EXPLORATORY SHAFT TEST PROGRAM" (Revision 1, Draft)

AUTHOR: Rockwell Hanford Operations; Staff

DATE: December 7, 1984

REVIEWERS: Adrian Brown, Mark Logsdon (Nuclear Waste Consultants); Michael Galloway, Fred Marinelli (Terra Therma)

DATE: January 31, 1986

PURPOSE: General review of proposed BWIP ESTF hydrology program.

SCOPE: General review of concepts presented in document, for conformity with NRC licensing requirements with respect to the proposed hydrology investigation that results from the document. General review of specific hydrogeology tests presented in document, and preparation of an evaluation of the extent to which the outlined program is likely to produce information needed for the preparation of NRC license documents and evaluations supporting them.

KEYWORDS: BWIP, ESTF, hydrology, test program, data needs, objectives, site characterization, in situ, chamber test, borehole test, piezometer, tracer test, coupled stress/flow phenomena.

DATE APPROVED: Mark J. Logsdon - NWC Project Manager 1/31/86

2.0 SUMMARY OF DOCUMENT AND REVIEW CONCLUSIONS

2.1 SUMMARY OF DOCUMENT

Volume I of the report sets out the concepts which drive the BWIP planning process for the activities proposed in the Exploratory Test Shaft at BWIP. The process used for the planning of the testing activities has been changed (apparently in late 1984) from an issue oriented approach to a "systems management approach", which focuses on the achieving of a "system mission". This is defined (belatedly, on page B-13, paragraph 4) as "..to permanently isolate high level water from the accessible environment.". This approach is presented in an appendix, and the data needs that derive from its use are presented in the report. These are alledged to form the basis for the program proposed for the ESTF at BWIP, which are presented in Volume II of the report.

Volume II of the report sets out details of the Exploratory Test Shaft Phase I and II design concepts, and describes the tests that are currently planned for the facility in order to provide data for the site characterization process. The report deals with the geology, hydrogeology, geomechanics, and constructability tests proposed. This review addresses the geohydrology tests.

2.2 SUMMARY OF REVIEW CONCLUSIONS

The details of the following review document a number of perceived major weaknesses in the proposed testing approach and in the details of the proposed testing program, as well. These problems and concerns include:

1. Lack of considiration of existing information.

2. Lack of consideration of potential fatal flaws.

3. Relationship of scale of proposed tests to data needs.

4. Utility of the chamber test.

5. Potential piezometric effects of the exploratory shaft.

Based on the concerns identified in this review, NWC/TTI recommend that the NRC staff prepare a Site Technical Position on testing for geohydrologic parameters and performance to be conducted from the exploratory shaft test facilities. We consider that such an STP should be part of a comprehensive document that addresses design, rock mechanics and hydrogeologic aspects of the ESTF program, based, in all cases, on a specific analysis of data needs.

3.0 SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM

This report sets out the basis for the main part of the next five years geohydrology testing at BWIP. It is a major program document, and will form the blueprint for the test strategy to be adopted if there is no discussion. Due to the length of time needed for the program, and the timetable for waste emplacement mandated in the National Waste Policy Act of 1982, it is clear that little further work will be possible between the completion of this program and the application for the authorization for construction.

4.0 GENERAL COMMENTS ON REPORT

4.1 DATA NEEDS ASSESSMENT CONCEPT

The concept described in the report for the development of the proposed program for investigation at BWIP appears to the reviewers to have considerable merit. It defines the primary objective of the Site Characterization Program at BWIP as being "..to produce the information necessary and sufficient to assess performance and to support a license application.." (page B-7, para 4). It goes on to say that "..the information to be collected in the Site Characterization Program has a variety of applications including support of siting studies, facilities design, performance assessment, resolution of issues, establishing satisfactory conformance to regulatory criteria, and supporting license applications." (page B-9, para 3)

The report seems to take a major policy position when it continues, stating that "..BWIP must show that the information to be developed by the Site Characterization Program is truly necessary for these applications; i.e. it must demonstrate that the information is not merely of academic interest." A little later it states that "..It is equally important to ensure that the information to be collected is sufficient to satisfy the needs of these applications. This can best be accomplished through exhaustive analysis of

their information requirements." (page B-9, para 4 and para 5, emphasis added).

The report summarizes its position in the following words:

> "The key concept embodied in the BWIP site characterization planning is that data needs can and should be derived from the mission success statement to provide the complete and sole justification for the tests and studies to be conducted."

Finally, the report identifies a distinction between information and data needs, as follows (page B-10, para 2):

- "Information: Those facts required for performance assessment and system design and to support the licensing process. Information is generated by such activities as direct observation, data analysis and interpretation, modeling and simulation, and engineering studies."

- "Data needs: The individual site properties, site related events, and engineered system design variables which must be quantified in order to produce the information needed for site characterization, performance assessment, development of site-specific designs and resolution of performance-related issues."

The reason that this approach to data needs assessment (however data needs are defined) is attractive to the reviewers is that it is system performance based. This approach allows an evaluation of the completeness of data on the

basis of the impact that additional data would have on the precision of the knowledge of the performance of the system.

Unfortunately, the report in general fails to build on this promising framework. This is evidenced in the following apparent weaknesses in the hydrology portion of the program that is proposed for the ESTF, presumably as a result of the application of the approach.

4.2 PERCEIVED WEAKNESSES IN THE PROPOSED TESTING APPROACH

There appear to the reviewers that there are a number of significant weaknesses in the proposed approach to the testing in the ESTF. These are discussed below:

4.2.1. Lack of consideration of existing information

It appears that the program which is proposed for the test facility is based on the presumption that essentially nothing is known of the hydrogeological parameters of the dense interior of basalt. As a result, the testing which is proposed to be performed is a "soup to nuts" evaluation of the behavior of the material, consuming five years of the total program (ending in the middle of 1990). This testing activity seems to be proposed without apparently using the data collected from past testing activities to determine the need for the tests for the purpose of the project: to evaluate the extent to which the

proposed repository structure is capable of satisfactorily containing high level waste.

Need must be defined in terms of the following aspects:

a. Present absence of the information;

b. Ability to collect the information needed;

c. Ability of the information which is to be collected to allow needed improvement of predictive accuracy to be achieved.

If any of these elements is missing, then there is no point in performing the proposed test. Data exists at present; it should be used to evaluate the need for further testing, and this evaluation should be presented if the testing is to be conducted. It has not been.

4.2.2 Lack of consideration of potential fatal flaws

There appears to be a relatively low level of attention being paid to matters which appear to have the ability to be fatal flaws for the establishment of a successful repository in Hanford basalts at the proposed depths. One area where fatal flaws are possible is in the area of mine inflow. The possible ways that inflow could become a problem include the following:

a. Roof or pillar collapse leading to connection of the repository opening to the overlying highly pressured aquifers.

b. Inflow due to the encountering of highly permeable natural conduits in the dense interior.

The proposed program does little to evaluate these possibilities. While there is to be an extensive geomechanics program in the project, there is little discussion of the use of the data to allow evaluation of the likelihood of piping to high pressure groundwater sources. In addition, there appears to be no concept of measuring the water that is made by the entire mined void system, or of attempting to estimate the water that is introduced to the mine (by the intake air and for construction and other purposes), or removed from the mine (by pumping or via the exhaust air). This seems to be a fundamental omission in the plan.

In addition, there is a possibile fatal flaw in the data collection proposed due to effects of areal variation of the basalt which have not been considered. There appears to be a tacit assumption in the proposed program that the conditions in the ESTF will represent conditions all over the proposed repository area. Leaving aside the proposed long holes, the ESTF will cover an area of less than 3 acres. The repository will cover an area of about 3 square miles. Basalt is a notoriously variable material, in all respects. Cooling features, changes in flow thickness, tectonic displacements, and other heterogeneities are normal. To extrapolate the proposed essentially point evaluation of the hydrogeology of the Cohassett flow interior to an area in excess of 500 times its size, with essentially no additional hydrogeological data, seems unwise.

There appears to be no consideration given in the program to the trade-off between intensive investigation in a single location, versus less intense investigation in a much more extensive set of test drifts. The proof of the repository site will, in the opinion of this review, be largely in the demonstration of a large area of stable, dry workings in the target horizon. The incremental comfort level generated by sophisticated hydrogeological modeling to extrapolate the detailed data generated by the proposed program will be small: the track record of such evaluations in predicting the inflow performance of underground openings in brittle, highly stressed rock is not good. In addition, the incremental comfort level developed as a result of drill hole testing in other locations will also be small, both because of the difficulty of obtaining meaningful hydrogeological data from drillholes in this material at these depths and also because of the disruptive nature of drilling into potential repository horizon locations.

4.3 PHASE I TESTING

The Phase I testing program is intended primarily to assure the safety of the workers in the initial breakout activities, and to provide enough information to allow the detailed design of the Phase II activities. It is considered that these objectives will be met by the program as proposed.

It appears to the reviewers that there is no significant program to allow for the possible breakthrough of water into the initial opening, which cannot be

ruled out based on present information, or on information that will be available at the time of the breakout from the bored shaft.

4.4 PHASE II TESTING

The proposed Phase II testing comprises an extensive borehole testing program, a chamber test, and a tracer test. Some consideration is given to the possibility of performing some tests at elevated temperatures. This section considers the proposed suite of tests, in order to evaluate the appropriateness of the technology proposed. It should be recognised that the relative detail of this evaluation is not necessarily an indication that the tests are needed, but is in line with the detail that the Rockwell document provides. This evaluation is general; specific details are presented in the appended detailed comments.

4.4.1 Scale of Tests.

Throughout the document, the cluster borehole and chamber tests are described as being "large-scale tests". It is also indicated that the scale of these tests are sufficient to meet data need requirements for Shaft Station Geohydrology (Objective I-4) and Hydrologic Characterization (Objective II-2). Nowhere in the document is there a discussion regarding the utility of these tests in the event that material inhomogeneities exist on a scale larger than that measured by the tests.

Nineteen single borehole tests have been conducted within flow interiors at the Hanford Site (Strait and Mercer, 1984). Sixteen of these tests indicated very low hydraulic conductivity in the range of 10^{-11} to 10^{-15} m/s. Three tests, however, measured much higher hydraulic conductivity values as summarized below:

RRL-2	Umtanum Flow Interior	$K = 5 \times 10^{-4}$ m/s
DC-16A	Cohassett Flow Interior	$K = 2 \times 10^{-8} - 2 \times 10^{-9}$ m/s
DC-16A	Untanum Flow Interior	$K = 6 \times 10^{-9} - 6 \times 10^{-11}$ m/s

This could be interpreted to mean that while most dense basalt within flow interiors has very low hydraulic conductivity, rather isolated inhomogeneities with much higher hydraulic conductivity could potentially exist. If these features are not laterally extensive, they would be intercepted by only a small proportion of vertical boreholes drilled within the Hanford Reservation.

Anomalies and structures potentially having high permeability include:

1. Flow-top thickness irregularities
2. Tectonic breccias and fault zones
3. Jointing structures
4. Vesicular zones
5. Spiracles.

Descriptions of these structures are presented in Appendix E of the DESTP. However, the discussion in the text is limited to the potential impact of these features on mine safety, rather than also addressing the potential hydrologic significance of such features on the present flow system and on the likely performance of a repository.

In heterogeneous aquifer/aquitard systems, it is possible for the bulk vertical hydraulic conductivity of the aquitards to be controlled by rather isolated features having relatively high hydraulic conductivity. Since the current BWIP data base does not address either vertical hydraulic conductivity of the presumed aquitards or the bulk hydraulic properties of the flow system, it is probably necessary (although no evaluation has been presented by DOE to support or deny the need for any data) that the design of the in situ test program identify, locate, and characterize isolated high permeability features should they exist. It is also apparent that an accurately measured hydraulic conductivity for aquitard material between such features would be of limited use in characterizing the hydrologic behavior of the aquitard at the repository scale.

As noted previously, it is considered that the hydrologic testing strategy presented in the ESTP places too much emphasis on performing sophisticated tests at a very limited number of locations and too little emphasis on conducting numerous, less sophisticated tests within a substantial volume of the Cohassett Flow Interior. Although the borehole cluster and chamber tests are certainly larger scale and perhaps more accurate than single-borehole

tests, they will have an effective radius of influence on the order of only tens of meters. If isolated high permeability features have a general separation exceeding this range, it is possible that they may not be identified by the foregoing tests. If high permeability features exist and are not identified, the parameter values determined from the borehole cluster and chamber tests may lead to erroneous and nonconservative conclusions regarding site conditions (e.g., underestimate the bulk vertical hydraulic conductivity). We would recommend that the area covered by testing (in further drifts or in additional long, horizontal boreholes) be greatly expanded, even if at the expense of performing some of the more sophisticated tests. Based on this larger data base, appropriate locations for cluster tests could be selected in a more defensible fashion (see below).

4.4.2 Utility of the Chamber Test

The utility of a chamber test conducted within the Cohassett flow interior appears questionable. As proposed, this test will be, by far, the most time consuming (and costly) hydrologic test performed during the ES testing program. Although the chamber test is a larger scale test than the cluster test, preliminary calculations indicate that its radius of influence will exceed that of the cluster test by only a factor of 2 to 3. In the event that the scale of heterogeneities exceed the scale of the test, the chamber test would provide the same or only slightly more information than a cluster test conducted at the same location. In order for this major commitment of time and financial resources to be justifiable, it would appear necessary for

the test to provide significant information that will not be developed in other ways. Whether this will in fact occur can be briefly evaluated as follows.

Based on equations presented in Roberds et al. (1982; Appendix A3) the effective radius of influence of the chamber test for different values of hydraulic conductivity have been calculated. These calculations assumed the following values:

L = length of chamber = 50 m

rw = chamber radius = 1.7 m

m = 1 (isotropic conditions)

t = time = 180 days

Ss = specific storage = 10^{-9} cm^{-1}

z = 0 (point of interest radially outward from the middle of the chamber)

Radius of influence was defined as the radial distance (at z = 0) for which hydraulic drawdown was equal to 2 percent of the drawdown imposed within the chamber. The results are summarized below:

Hydraulic Conductivity K (m/s)	Radius of Influence r_o (m)
10^{-11}	75.0
10^{-12}	29.4
10^{-13}	9.6

If the flow interior is anisotropic, with vertical hydraulic conductivity greater than that in the horizontal direction, the lateral (horizontal) influence of the test would be smaller than values given above. Since the range of hydraulic conductivity for flow interiors is stated in the ESTP to be less than 10^{-11} m/s, it is apparent from these calculations that the radius of influence of the chamber test is not likely to exceed 75 meters after six months and could be substantially less than this value. Considering the degree and scale of heterogeneities potentially existing in the Cohassett Flow Interior, there is a great possibility that the chamber test will not be able to identify or characterize high permeability features if they exist.

Current plans in the ESTP call for a ventilation type chamber test of the type conducted at the Stripa Mine in Sweden. This will result in substantial depressurization of the medium adjacent to the chamber. The decrease in formation pressure is likely to be on the order of 1000 - 1500 psi. It is well documented that in situ hydraulic conductivity of many fractured materials are pressure dependent. This results from variation in the apertures of deformable fractures due to changes in pore pressure. In most cases, hydraulic conductivity is observed to decrease with a reduction of pressure. Since the chamber test would involve substantial depressurization of the medium, and an associated considerable increase in the effective stress in the vicinity of the opening when compared with the repressurized repository void in the operational phase, it is possible that the value of hydraulic conductivity calculated from the test will be an underestimate of the in situ value existing under natural pressure conditions. An underestimate of

hydraulic conductivity would be nonconservative for far-field performance assessment and most engineering calculations.

4.4.3 Piezometric Effects of the Exploratory Shaft

The ESTF states that the shaft will be blind-bored to total depth using reverse circulation rotary drilling with mud. Large mud losses during rotary drilling have been documented in several holes on the Hanford site (e.g., RRL-2). Potential impacts on the piezometric conditions in the vicinity of the shaft could include:

1. Pressure perturbations in formations near the shaft due to injection of fluids during drilling.

2. Inter-aquifer-connections due to faulty shaft seals after construction is completed.

These two classes of potential impacts were addressed in a detailed technical memorandum from Jerry Rowe (Golder Associates) to Mark Logsdon (NRC) (Contract No. NRC-02-82-045, Letter #60, dated October 27, 1982). The Golder analysis showed that the impact of shaft construction on existing hydraulic heads is strongly dependent on the effectiveness of the mud cake and lost circulation material forms around the bore. The radius of influence for leaky shaft seals is dependent on the vertical hydraulic conductivity of the aquitard layers, a subject of considerable uncertainty at this time. However, for a reasonable

range of vertical hydraulic conductivities, it is possible for the piezometric effects to extend for hundreds to one thousand meters from the shaft.

The ESTF document does not appear to present any real consideration of the rationale for the proposed testing program with respect to the impact of these technical concerns on the hydrology of the area around the ES, nor, fundamentally for the impacts of the ES test program on the ability to characterize the site, particularly with respect to pre-emplacement groundwater travel time.

5.0 RECOMMENDATIONS

It is recommended that the basis for the selection of the testing methodology to be used in the ESTF be completely reviewed by the NRC as soon as possible.

It appears appropriate for the NRC to develop a Site Technical Position for the testing of the ESTF for geohydrological parameters and performance. This position would begin with an exploration of the NRC's view of data needs assessment, and would apply the approach outlined to the remaining needs at BWIP, based upon the available data, the requirements for additional data, and the uncertainties remaining in the performance assessments of the BWIP repository system. It is recommended that the schedule required for such a program also be developed. Such a technical position would serve the same function as BWIP STP 1.1 except as applied to the hydrogeology of the proposed repository emplacement layer and its immediate surroundings, rather than the far field hydrogeological setting. (Note that it would make sense for the technical position to address the full range of testing - design and rock mechanics, as well has hydrogeology - to be conducted from the ESTF. However, since this is a review for the hydrogeology staff of the NRC, the formal recommendation at this time is for an STP on hydrogeologic testing.)

It is further recommended that the program that results from this evaluation be compared with that proposed by Rockwell, with respect to the extent to which each meets the various information needs of the program in a time and resource efficient way.

6.0 REFERENCES

Roberds, W. et al., 1983, In Situ Test Programs Related to Design and Construction of High-Level Nuclear Waste (HLW) Deep Geologic Repositories (Two Volumes): NUREG/CR-3065.

Rowe, Jerry, 1982, Piezometric Effects of the Exploratory Shaft: Technical Letter # 60, Contract NRC-02-82-045, dated October 27, 1982.

Strait, S.R. and Mercer, R.B., 1984, Hydraulic Property Data from Selected Test Zones on the Hanford Site: SD-BWI-DP-051.

APPENDIX: DETAILED COMMENTS ON REPORT

This appendix provides detailed comments on the report. They are referenced to the report using the following shorthand:

volume/section/page

An example of this shorthand is as follows:

II/4.2.1/4-26

I/4.3/4-6 The statement is made that "Once data needs are known, the question of data collection arises." While this is true, the balance in the overall document is heavily in the direction of the data collection, rather than providing a justification of the data needs. Without such a justification that is based on some real need, it is impossible to rationally evaluate the appropriateness of the proposed tests.

I/4.3/4-9 The statement ".. the shaft does provide a unique opportunity to sample groundwaters in high transmissive zones under in situ temperatures and pressures." appears to ignore the fact that this is not an optimal location for such sampling, as the samples will likely be contaminated by the shaft drilling activities themselves.

I/4.3/4-9 The discussion of the opportunity to measure the seepage to the entire drift system as a way of evaluating the bulk hydraulic conductivity of the flow interior is excellent. Unfortunately, like many of the concepts in Volume I, it does not make its way into the planning detailed in Volume II. Instead highly sophisticated academic tests are substituted for these direct and obvious approaches, with the resulting loss of the very data that is being sought.

Interestingly, the flow from a long section of drift is an excellent and measurable indicator of effective bulk hydraulic conductivity of the material in which the drift is being driven. If the drift is a mile long, a flow of 1 gpm is indicative of an hydraulic conductivity of about 4×10^{-9} cm/sec, which is probably in the range where the Cohassett will provide an effective primary barrier to radionuclide migration, and an effective protection from inflow for the construction phase. Thus with a relatively crude flow evaluation in a long drift,

much of the information which appears to be needed would be available.

II/3.0/3-1 The second sub-objective of the ESTP is to "Assess the hydrogeologic properties of selected stratigraphic zones lying above the candidate horizon." (emphasis added). There is no mention of any proposed test in the plan that would extend out of the Cohassett, nor is there any affirmation that this sub-objective is being specifically ignored.

II/3.0/3-1 It is stated that the objective of the ES-II tests is to ".. evaluate the in-situ properties of (the Cohassett) horizon." This presumably would include the development of an understanding of the variability of the horizon on a scale in the order of the proposed repository. This is clearly not going to be achieved by the program as designed, which is essentially an inspection (albeit an intensly detailed inspection) of a single location in the horizon.

II/3.0/3-3 "Large scale measurement of hydrogeologic properties within the Cohassett flow interior is a primary data need driving the ES Test Program." Whether this is a genuine need is a function of the credit that the DOE plans to take for the containment capability of the Cohassett. In light of the possible damage to the Cohassett as a result of both mechanical changes induced by excavation, and heat effects resulting from the waste, it is debatable that pre-emplacement, pre-repressurization measurements of hydrogeological properties will provide very useful information for the evaluation of the containment capabilities of the unit. Data needs for this horizon should surely be developed at more than this "motherhood" level in a nationally significant program.

II/3.1/3-10 Tracer testing proposed in the shaft boreholes seems a waste of time, if the area is influenced by mud from the shaft. If such tests prove to be needed, they can be performed from the surface, which avoids tying up valuable time in the shaft, and frees the testing of the uncertainty of contamination from the shaft.

II/3.1/3-11 It is very unclear what will be achieved by a tracer test in the Cohassett. According to all computations that have been published (see for example NUREG-0960) the great bulk of the travel time is taken in the flow tops (generally in excess of 99%), and thus the porosity of the flow interiors is irrelevant to the travel time calculations. Additionally, the chemical interaction in these units need not be counted upon for radionuclide removal or retardation, as the great majority of this effect will also take place in the higher permeability

zones. The only reason it appears, that this testing is proposed for this facility is that it is "normal" to do this kind of test. However it should be borne in mind that the use of this facility is in no sense "normal" in groundwater hydrology.

II/3.3.1/3-16 The report states that one of the important considerations in borehole testing in the Cohassett flow interior is a knowledge of "compliance effects". This is an understatement. In materials of this permeability, the compliance effects are often entirely dominant, and a major test design problem. The proposed test program appears to consistently underestimate these effects in the designs for testing as presented.

II/3.3.2.1/3-17 It is not clear to the reviewers that storativity in the Cohassett is a "data need". It is agreed that it is possibly a descriptive parameter. However, the storage characteristics of a brittle, confined rockmass (in a geohydrologic sense) is not a prima facie data need; if it were to be evaluated, it would require support as a needed parameter.

II/3.2.2.1/3-17 The discussion on Representative Elemental Volumes will not be commented on here, as Carnahan et al (1983) has already been reviewed in detail by one of the present reviewers. The conclusion of that review was that the REV concept was not particularly useful in the BWIP context except as a philosophical construct to prevent an overly simplistic approach to data collection to be followed. It is the position of this review group that it is unlikely that direct testing of the Cohassett will ever satisfactorily resolve the REV issue.

II/3.2.2.1/3-19 The statement that storativity can be sensibly evaluated from single hole tests is challenged. Experience in both granular and fractured media strongly suggest that the storativity values obtained are meaningless, due to uncertainties associated with effective borehole radius.

II/3.3.2.2/3-20 The statement that "The strategy of the hydrologic testing program at the ES is based upon NRC's technical position (NRC 1983)." is incorrect. STP 1.1 did not consider the ES facility at all, except to the extent that the sinking of the shaft had programmatic impact on the timing of the large scale tests that were the subject of that document. It is true that the NRC strategy considered testing nearer the proposed repository location preferable to that remote from the facility. However the testing referred to in that document is far-field testing, and statements in it cannot necessarily be transferred to the inherently near-field testing proposed in the ES facility. In particular, the testing that is appropriate for the near field may differ dramatically from that in the far field, as the performance allocated to the near-field barrier may (and almost certainly will) be greatly different from the far-field barrier.

II/3.3.2.2.1/3-24 Why are the angled holes drilled from the shaft in a downward direction? If they were drilled upwards into the flow tops, then they would be self-cleaning, which would be of considerable assistance as they will be hard to open and flush.

II/3.3.2.2.1.1/3-31 It is agreed that a prime and needed objective of the single hole testing from the shaft is the evaluation of the safety of the break-out into the Cohassett.

II/3.3.2.4.1/3-35 The report states that "Each borehole will be cored, and fracture characterized (sic) to optimize packer setting and test designs.". This is worrying as there has been, in this program, a tendency to selectively test only those features that appear of importance to a geologist or hydrologist, rather than to test those features that have interest for performance assessment. The basis for test location selection should be detailed before the testing is performed, and the selection approach should be shown to be related to performance assessment utility of the results.

II/3.3.2.4.3/3-39 The proposal to pressurize the constant head injection test holes to between 40 and 120 psi above lithostatic pressure seems inappropriate. Surely if injection tests are to be performed, the pressure standard is local estimated static head, which is some 1800 psi less than lithostatic pressure. The wisdom of trying to initially ascertain what the in situ water pressure is and then trying to inject water at slightly greater pressure is questioned in this context.

II/3.3.2.6.2/3-53 The discussion of the errors in the analysis of single hole test results has the air of a discussion of a relatively precise measurement, which warrants detailed and exact analysis. This is far from the case in the tests being described. Little effort is warranted in the analysis of these tests, as individually they are almost useless. Only in the broadest statistical sense is the test significant at all. Accordingly if the tests are to be done at all, then 95% of the effort should go into the test, and 5% into the analysis.

II/3.4.1/3-60 The discussion of the disadvantages of pressurizing as a method of performing the chamber test gives the impression that the author has made up his or her mind that the test will be done unpressurized, and is presenting those arguments that support such a position. The reasons given in general illustrate a lack of experience in mining technology: bulkheads designed to safely withstand 3000 feet of head are far from uncommon in mining, and have an excellent safety record when properly designed.

More importantly, there is no discussion of the question of whether data gathered in an unpressurized chamber test will bear any relation to the key questions that are being evaluated in the test. This is perhaps hardly surprising, as no mention is made of exactly what the test is supposed to contribute to the evaluation of the Cohassett interior that would not be evaluated by the simple fact of opening up the facility. The test plan appears inconsistent in that it agonizes over the coupling of stress, temperature, and flow in the geomechanics section, and makes no mention of the possibility that this same coupling would tend to invalidate the chamber test. We repeat: a pressurized chamber test most closely analogs the post-closure condition expected in the repository, and is in the opinion of the reviewers the most appropriate form of this test, providing that the chamber test is necessary at all.

Finally, it would appear to be relatively easy to heat the water in a pressurized chamber test, thus directly simulating the effect of cannisters in the room. This advantage of the pressurized approach was also not mentioned by the proposers of the test.

II/3.4.2.4/3-66 The discussion of the selection method of the location of the chamber test is at best foggy, and illustrates the problems inherent in the REV concept. To say that "Rock discontinuities ... will be avoided during drift construction." on the grounds that the test authors wish to be able to treat the tested volume as "..an equivalent porous medium" seems silly, and runs the very great risk of limiting testing to the least permeable material, which is patently unconservative. The paragraph then increases the confusion by stating that "If such discontinuities are found to typify basalt flow interiors, then a "representative" chamber test would incorporate them. It is the opinion of the reviewers that this is an entirely unsatisfactory way to plan any test.

II/3.4.2.4.2/3-68 et seq. The discussion of ventilation system design discusses the problems associated with methane, without any mention being made in the entire test plan to measure the inflow of methane. It seems clear that methane inflow is a matter of considerable importance in the prediction of whether the repository will be gassy, and whether the mine can be maintained in a safe condition during construction and waste emplacement. These matters are probably of critical importance in establishing whether the repository in Basalt is viable, as gassy conditions would probably gravely threaten the constructability of the repository. The failure to consider this potentially serious matter is difficult to accept as merely an omission.

II/3.4.2.4.3/3-74 The preference for rubber packers to seal piezometers appears to place operational convenience before data needs (presuming for this discussion that piezometers are needed). The compliance effects of piezometers in materials of very low hydraulic conductivity are usually sufficiently great that only the stiffest piezometer installation has any chance of measuring a "real" water pressure in time periods available to testing. This is particularly true in transient testing of these media. The preference for relatively "soft" completions is particularly troublesome as they produce an estimate of hydraulic conductivity that is lower than the actual, which will in general be unconservative.

II/3.4.2.6.2/3-84 The data presented in Figure 3-23 illustrates a classic result of performing sophisticated and complex tests of the style of the chamber test. All the effort of testing a large volume succeeded in achieving was the reduction of the uncertainty of the hydraulic conductivity of the rockmass at a single location at Stripa from the generic estimate of two orders of magnitude to about 10%. For practical purposes, the entire test did no more than illustrate that in this case the volume of rock above which the material appeared to behave like a continuum was less than the smallest test size of 7000 cubic meters. It is considered that it would be wise for BWIP to avoid similar conclusion after investment of a vast amount of time and effort.

II/3.5/3-90 et seq. The need for, and the possibility for success of a tracer test appear to be sufficiently low to make it questionable whether such testing should even be considered in this document. Calculations presented in NUREG-0960 suggest that no significant geochemical goodness or time delay to flow can be developed in the Cohassett. Its main function as a barrier appears to be in flux reduction from the repository. Its main utility to the program is the provision of a unit in which it may be possible to establish a repository safely and without major water inflow. Tracer testing will not aid in the demonstration of any of these properties.