ATTACHMENT 3

Basalt Waste Isolation Project

Comments on
Exploratory Shaft Drilling and Sealing

ENGINEERS INTERNATIONAL, INC.

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1.0 INTRODUCTION

The Basalt Waste Isolation Project (BWIP) is planning an exploratory shaft (ES) within the Reference Repository Location (RRL) at the Hanford Reservation, Washington. This shaft is to be blind bored to a finished inside diameter of six (6) feet, and will be about 3900 feet deep. During the first half of 1983, the Department of Energy (DOE) submitted 21 documents to the Nuclear Regulatory Commission (NRC) on the drilling and sealing program for the ES. A reference list for these documents is included with this report as Attachment 1.

Engineers International, Inc. (EI) has critically reviewed these documents with respect to four major areas of concern to the NRC:

- Shaft construction considerations
- Site characterization plans
- Long term sealing considerations
- Quality Assurance.

A discussion of these four areas of concern is provided in this report.

2.0 SHAFT CONSTRUCTION CONSIDERATIONS

2.1 Findings From Borehole RRL-2

The Principal Borehole Report for Borehole RRL-2 (see Attachment 1, DOE reference 10) was reviewed and those findings that impact the exploratory shaft are discussed in this section of the report. The RRL-2 report indicates that the actual lithologic and ground water conditions observed in the Grande Ronde Formation differed in several important respects from conditions predicted on the basis of earlier boreholes. The large mud losses and high permeabilities found in some zones raised additional concerns about shaft drilling and the effects of shaft drilling on the site.

2.1.1 Lithologic Predictability

Corelogs from RRL-2 indicate that previous predictions of the elevations and thicknesses of the individual flow sequences within the Pasco Basin were generally valid. However, one crucial variation in lithology found in Borehole RRL-2 was that the interior of the Umtanum flow was not as thick as expected.

The Umtanum had been identified as a prime candidate for the repository horizon because of the thickness and low permeability of its interior zones. But the Umtanum interior in RRL-2 was found to

be only 84 ft thick, 66 ft less thick than predicted, which considerably lessens the Umtanum's desirability as an emplacement horizon.

Another important lithologic finding was the thickness and "tightness" of the McCoy Canyon flow. This development has led to the consideration of the McCoy Canyon flow as a possible target horizon. However, the areal extent of desirable conditions in the McCoy Canyon flow should be thoroughly investigated. If the McCoy Canyon Flow is desirable at RRL-2 but less desirable in other boreholes, questions can be raised regarding the assumption that desirable conditions will extend throughout the reference repository location. Also, how thoroughly can the extent of desirable conditions in the McCoy Canyon flow be investigated from the exploratory shaft? The issue of lithologic predictability was identified in the SCA (DOE, 1982), and continues to be significant for future site characterization.

2.1.2 Mud Losses And Hydrologic Conditions

According to the Mud Loss Summary in the RRL-2 report, over 300,000 gallons of drilling mud were lost during the drilling of the principal borehole. Mud loss is an approximate indicator of formation permeability, and the Mud Loss Summary presents the quantities of mud that were assumed to be lost to each of the permeable formations encountered. Most significant is the large quantity of mud loss attributed to the Umtanum flow. Correlation between the mud losses in RRL-2 and other boreholes apparently has not been made. In addition, the RRL-2 report does not indicate how the mud losses within individual formations were determined or over what time span the losses occurred.

Hydrologic testing in RRL-2 indicates that permeabilities in most tested zones were slightly higher than had been estimated previously. There is no mention in the report regarding what effect the considerable mud losses might have had on subsequent permeability measurements. Accumulated clay and other drill mud materials could tend to decrease fracture permeability as determined by downhole testing (Greenslade et al, 1981). Figure 1 shows the location of the severe mud loss zones and the quantities of mud lost.

While an in-depth analysis of the geochemical testing performed in RRL-2 is beyond the scope of this report, some brief comments on areas that should be studied further are in order. The most important finding from the geochemical testing was that the previous ground water model, which assumes that Grande Ronde flows are hydraulically separated from overlying flows, was not supported by the test results from RRL-2. Past investigations had indicated that sodium bicarbonate-chloride type ground water was typical of the Wanapum

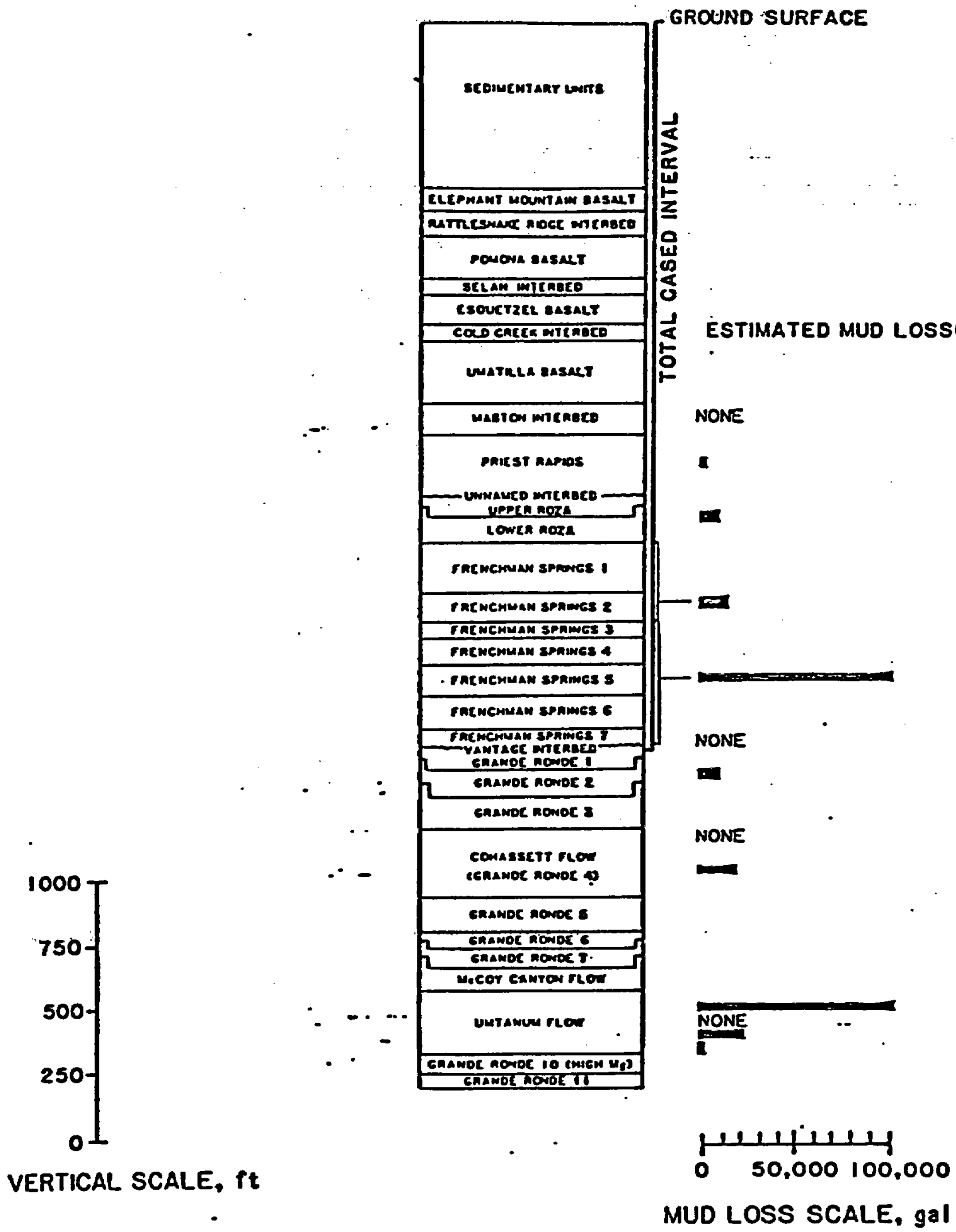

Figure 1. Stratigraphy and mud losses, found in Borehole RRL-2 (from information provided in DOE ref. 10)

Formation and that sodium chloride type ground water was distinctive of Grande Ronde flows (Grahm, et al., 1982). However, sodium chloride type ground water was found within lower Wanapum Formation flows in RRL-2. Hence, the previous belief that Grande Ronde Formation ground water is separated from the Wanapum Formation should be reexamined.

2.1.3 Fracturing Measurements and Core Loss Zones

Fractures found in the basalt from RRL-2 seem typical of the fractures described previously within the Hanford Reservation (DOE, 1982). Most fractures appear to be filled, usually with silica and clay. Summary tables of general fracture properties of the Cohassett, McCoy Canyon, and Umtanum flows are contained in the RRL-2 report. These tables indicate that with depth, the number of fractures and the percentage of intact fractures increase but the thickness of fracture filling decreases.

Two core loss zones totalling 13 feet were found in the Umtanum entablature. The largest of these is a 10-foot zone between the depths of 3773 feet and 3783 feet. In documents provided to the NRC (DOE reference 20), the 10-feet of core loss was attributed to drilling slightly undersized core which could not be retained by the core lifter. The core was dropped in the hole and subsequently ground up, as indicated by unusual bit wear and a decrease in the drilling rate. The core loss occurred immediately following a bit change, and it appears that the new bit was of a slightly different size resulting in the undersized core. At present, the Diamond Core Drilling Manufacturers Association has not standardized threads, core barrels, or core sizes; hence, such confusion is possible.

Information obtained from core logs, geophysical logs and hydrologic tests indicates that the rock mass properties within the 10-foot core loss zone are similar to those observed above and below the zone. The results of a hydrofracture test performed at the bottom of the zone also supports the conclusion that no major anomalies are present. However, the rock quality within the core loss zone still cannot be determined with the confidence that would be possible had the core been recovered. It is imperative that effective QA procedures be developed and followed so that similar problems do not occur during future core drilling.

The second core loss zone, which occurred between the depths of 3822 and 3824 feet, is of potentially greater significance. In this case, the lost core apparently indicates a region of intense fracturing, and in fact is referred to as the "Umtanum Fracture Zone" in the RRL-2 Report. It is estimated that 25,000 gallons of drilling mud may have been lost to the fracture zone during the drilling of RRL-2. Hydrologic tests indicate that the hydraulic conductivity of the fracture zone ranges from 10^{-4} to 10^{-3} feet/second, which is far

greater than the values of 10^{-12} to 10^{-11} feet/second that were measured in the rest of the entablature. Significant anomalies in the neutron, resistivity, and other geophysical logs also occur in this zone, indicating a higher porosity than the surrounding rock. Care should be taken to fully characterize the fracture zone and determine its importance to horizon selection.

2.1.4 Horizontal In Situ Stresses

Hydraulic fracturing tests indicated lateral to vertical stress ratios of 2.27:1 in the Cohassett flow and 2.30:1 in the Umtanum flow. These ratios are consistent with earlier predictions based on other hydrofracturing results. The McCoy Canyon flow had not yet been identified as a potential target horizon when testing was performed, and hence, no in situ stress results are available for this flow. In general, the measurement of lateral stresses yielded no surprises, but stress directions remain to be determined.

2.2 Discussion of DOE Plans to Drill Shaft

2.2.1 Discussion of Drilling Technique

The technique of blind drilling large diameter shafts was originally derived from oil well drilling methods. The technique employs a large drill bit connected by a drill string to the surface, with the cuttings removed by the circulation of drill mud. Various additives and conditioners can be added to the mud to aid in hole cleaning, cuttings removal, bit cooling, and control of mud losses (LeRoy, 1977). Blind shaft drilling technology has been developed primarily at the Nevada Test Site where over 500 holes ranging in diameter from three to ten feet have been drilled over the past 20 years (Lackey, 1982). Shafts of up to 16½ feet in diameter have been drilled in the United States (Cobbs, 1979), and the technology is considered to be available to drill a 20-foot diameter shaft to a depth of 3000 feet (Carone and Whitley, 1981).

The main reason for BWIP's choice of shaft drilling over conventional shaft sinking methods is the presence of prolific aquifers above the horizon of interest. Disturbance to the rock is minimized because no explosives are used, and the shaft drilling technique is faster because rock breakage and muck removal are performed simultaneously. No workers are downhole during construction, so the technique is also inherently safer than conventional methods. A problem with shaft drilling, which hinders site characterization, is that it is not possible to directly observe the wall rock at any time.

Several mud circulation systems have been developed for large diameter drilling. The most common is the reverse air assist system (Lackey, 1982) which will be used in the construction of the ES (DOE

reference 1). The reverse air assist circulation system is illustrated in Figure 2. Drilling fluid is pumped into the hole and returns with the cuttings through the hollow drill string. Compressed air, which is introduced into the return mud through a "jet string" of small diameter pipe, lightens the column of fluid and provides the necessary lift. The principle of the air assist is shown in Figure 3.

With the reverse air assist circulation system, the hole must be kept filled with drill mud. The full column of mud has the beneficial effects of controlling water flow into the shaft and limiting wall rock sloughing. It is desirable to control the mud density so that the mud pressure is slightly greater than the formation pressure; hence, there is generally some mud lost to the formation.

Where excessive mud losses are anticipated, the dual-string circulation technique may be more effective. With the dual-string circulation technique, shown in Figure 4, mud mixed with compressed air travels to the drill bit through the annulus between the outer drill pipe and the inner string and returns up the inner string. A major advantage of this system is that the hole need not be kept completely filled with fluid, reducing the head driving the mud into the formation. Lackey (1982), feels that the dual-string system does a better job of cleaning the hole. However, for deep holes, high pressure compressed air is required to overcome losses and the hydrostatic head. This requires the use of large capacity compressors.

2.2.2 Drilling Concerns and Contingency Plans

Drilling concerns can be divided into two categories. The first category is related to the feasibility of the drilling operation itself, including problems that may arise during drilling, scheduling, etc. These concerns are discussed in this section. Concerns about the effects of shaft construction on the host rock, which may be important for site characterization activities and for rock mass sealing, are discussed in section 2.2.3.

Many of the concerns that will be discussed in this section have been addressed in the BWIP document "Contingency Plan for Anomaly Detection and Resolution During Exploratory Shaft Construction" (DOE reference 7). The approach taken by the BWIP document is that preparation for most anamolous events is routinely incorporated into construction activities, and that "professionally conducted drilling operations" will be relied upon for their prevention. While we feel that this approach is generally appropriate, it seems that there are certain areas in which enough information is available for more specific planning.

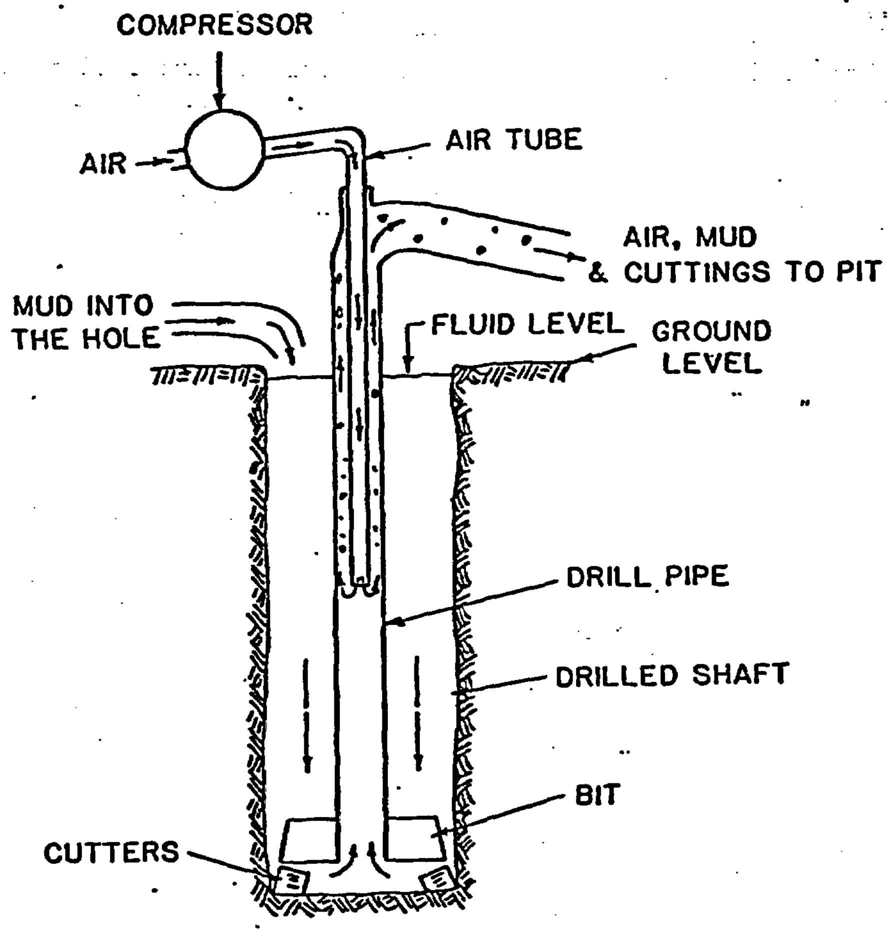

Figure 2. Schematic of the reverse air-assist circulation system (after Lackey, 1982)

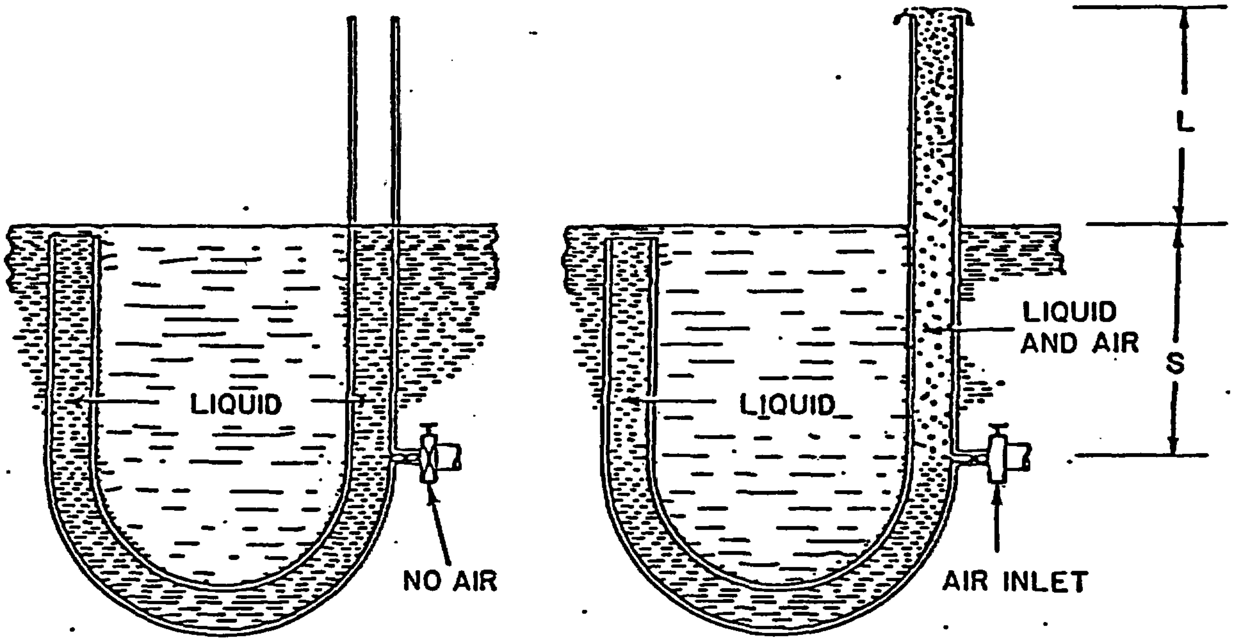

Figure 3. The principle of air assist circulation
(after Lackey, 1982)

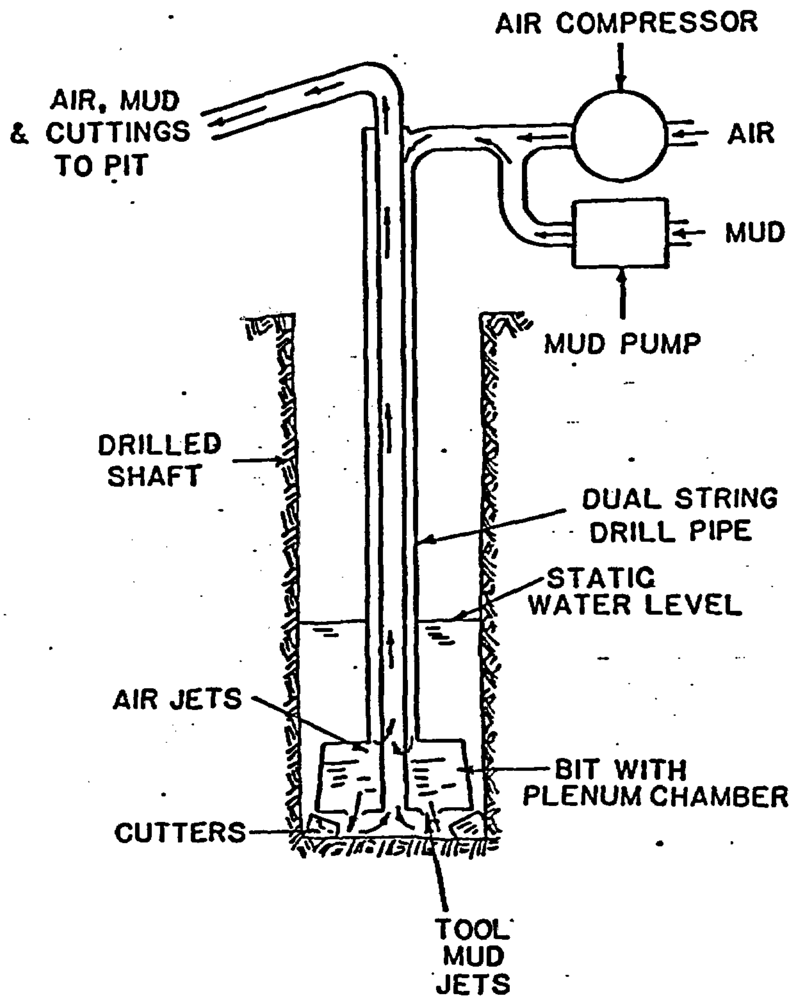

Figure 4. Schematic Dual-String circulation system (after Lackey, 1982)

2.2.2.1 Excessive Hole Deviation From Verticality

Excessive hole deviation from verticality would cause major problems for shaft lining operations. The Contingency Plan document sets two acceptance criteria for verticality:

1. "Shaft verticality should not deviate by more than 5 minutes per 100 feet."

2. "Excessive hole deviation is ... a trend which if not corrected would result in axial deflections of greater than 0.38 feet in 180 feet."

The second criteria is apparently standard for shaft drilling, as an identical criteria was successfully used in a shaft drilled in Colorado oil shale for the U. S. Bureau of Mines (Gibbs et al, 1978). The first criteria is however unclear, as an angular deviation of 5 minutes per 100 feet would result in an unacceptable total angular deviation of more than 3° at a total depth of 3,960 feet.

Another BWIP document, "Construction Specification for Shaft Drilling and Rig Services" (DOE reference 1) sets forth two different criteria for hole verticality. These are that the shaft must not deviate more than a total of 3 feet from vertical at the total depth of 3960 feet, and no more than 0.4 feet from vertical in any 180 feet. It seems reasonable to assume that the specifications in the Construction Specifications document override those presented in the Contingency Plan but there is no statement to this effect.

The criteria of a total deviation from vertical of 3 feet at total depth is a very close tolerance but apparently within the reach of available technology. Lackey (1982), states that 1 foot in 1000 feet is not an unreasonable specification for big holes drilled at the NTS, and Gibbs et al. (1978), reported that the total deviation for the USBM shaft was 1.68 feet at a depth of 2,350 feet. The BWIP specifications call for running directional surveys downhole after every 30 feet of advance, which should be adequate to insure that the close tolerances are met. At the USBM shaft, directional surveys were run every 46 feet on average.

2.2.2.2 Loss of Equipment Downhole

Loss of equipment downhole presents a potentially major problem for scheduling. Usually drilling must be stopped while the "fishing" operation is performed to retrieve the lost equipment. The BWIP Contingency Plan discusses the possibility of drill stem separation resulting in equipment being lost downhole. Their prevention plan

emphasizes frequent checking and quality control of critical joints. While this procedure seems appropriate, the document does not make clear that many highly unpredictable events may result in equipment being lost downhole. For example, at the USBM shaft two different failures of the cutter head assembly occurred resulting in a total downtime of over 2 months. Hence, the DOE should thoroughly analyze all potential situations that may result in loss of equipment downhole, and implement strict quality control procedures to minimize the need for fishing.

2.2.2.3 Loss of Drilling Fluid to the Formation

As discussed earlier, the blind hole drilling technique usually results in the loss of drilling fluid (mud) to the formation. Some concern was expressed about the effects of mud losses after approximately 300,000 gallons of mud were lost during the drilling of the principal borehole. The present section limits itself to a discussion of the possible effects of mud loss on the drilling operation. Effects on sealing and site characterization are discussed in section 2.2.3.2.

Loss of mud should not pose a major threat to the shaft drilling operation. In fact, the shaft drilling technique almost requires some mud loss for effective control of water bearing formations. Remedial action is taken only if excessive mud losses occur, as outlined in the BWIP Contingency Plan. Possible remedial actions in the BWIP Contingency Plan include: 1) modifying (increasing, presumably) the mud viscosity, 2) charging the drilling fluid with lost circulation materials (LCM's) such as cedar chips, nut hulls or shredded cellophane that would clog the porous media, and 3) as a last resort, setting a concrete plug to seal the problem area.

All the listed remedial actions are routine procedures that have been used successfully in the past. At the USBM shaft (Gibbs et al, 1978) and the Amchitka shaft in basalt (DOE reference 6), LCM's were the major means used to control mud loss. Cement plugs are apparently more commonly set to control sloughing of wall rock (DOE reference 6), which is discussed in the next section.

Another approach to mud loss control, which is not discussed in the Contingency Plan, is to reduce the weight of the column of drilling fluid, thereby lowering the head driving the mud into the formation. The weight of the column of fluid can be lessened either by lowering the density of the drill mud or by lowering the height of the mud column. The latter alternative is only available when dual-string circulation techniques are used, and therefore, cannot be used at the ES as presently planned. At the USBM shaft, which was drilled

with the dual stem technique, the mud level in the hole was allowed to drop to 200 feet below surface after serious mud losses were encountered. The adjustment in mud level was successful in reducing loss of the mud (Gibbs et al., 1978).

The Contingency Plan states that "borehole stratigraphic information will permit anticipation of the horizons where circulation may be lost." As the borehole information is currently available, it would seem that more specific information regarding the depths where problems are anticipated and the procedures that will be used could be presented.

2.2.2.4 Sloughing of Wall Rock

Sloughing of wall rock into the drilled hole could have adverse effects on drilling (Lackey, 1982, and DOE reference 6). The Contingency Plan does not discuss the possibility of sloughing as related to drilling, but does mention that sloughing could hinder insertion of the casing.

In most instances hole wall stability is maintained by the pressure of the drilling fluid and the repeated passing of the working drill bit. Where further support is needed, a cement plug can be set. At the Amchitka basalt shaft, eight separate plugs were set to control wall sloughing (DOE reference 6).

Cement plugs are set by withdrawing the drill bit and extruding a quick setting grout at the bottom of hole which displaces the drill mud. After the cement has hardened, drilling continues through the plug.

The Contingency Plan states that the interbed horizons are the areas where sloughing is most likely to be a problem. The specific depths at which it may be necessary to set plugs could be identified from Borehole RRL-2, and the accompanying delays could be incorporated into the schedule.

2.2.2.5 Scheduling

At present no schedule of shaft construction related activities has been provided. Such a schedule would be necessary for determining whether sufficient delay time has been taken into account. Also, a critical path analysis of the schedule should be performed that would include fabrication, procurement and shipment of casing, as well as shaft drilling.

2.2.3 Effects of Shaft Drilling on the Rock

The potential effects of shaft drilling on the rock mass are of major concern for short-term sealing, long-term sealing, and site characterization. The first concern is that shaft drilling will

create a "disturbed rock zone" (DRZ) around the shaft which, if untreated, could constitute a preferential pathway between the repository horizon and the surface. A second concern is that the loss of drilling fluids to the formation may result in changed permeabilities and potential sealing problems. The DRZ is discussed below in section 2.2.3.1, and mud losses are discussed in section 2.2.3.2.

2.2.3.1 The Disturbed Rock Zone

A major advantage of the blind drilling technique is that disturbance to the rock is minimized because no explosives are used. But even without blast damage, the rock properties in a zone around the shaft are disturbed owing to stress redistribution.

At present very little information is available on the character of the DRZ around shafts. The DOE's major reference on the subject, ONWI 411 (DOE reference 8), summarizes much of the work performed by other researchers, and also puts forth its own analysis of the rock mass disturbance resulting from shaft, tunnel, or borehole excavation. The rest of this section is devoted to a summary and a critical assessment of ONWI 411.

ONWI 411 suggests that three potential pathways for radionuclides are created by a penetration (borehole or shaft):

- The shaft itself
- The micro-annulus between the shaft seals and the wall rock
- The stress-relieved zone of disturbed rock (the DRZ) around the shaft.

With a small diameter borehole, the DRZ created is insignificant. The major potential pathway, other than the borehole itself, is the micro-annulus. In the case of a shaft, the large size of the shaft relative to the fracture spacing in the rock mass results in a significant thickness of DRZ. As the ground stresses are redistributed around the shaft, fractures open and result in increased vertical permeability.

ONWI 411 provides an estimate of the increase in permeability occurring in the DRZ around a shaft excavated in an hydrostatic in situ stress field. Their estimate is derived from assumed relationships between stress and fracture aperture, and between aperture and permeability. The stress-aperture relationship is based on laboratory work performed on single fractures by Iwai (1976) at Berkeley. The aperture-permeability relationship is the so-called "cubic law" which states that a linear increase in fracture aperture results in a cubic increase in permeability.

A review of available case histories where the DRZ around tunnels was actually measured is also presented in ONWI 411, and these field results are compared with their theoretical analyses.

The results of ONWI 411's analyses are:

- Changes in permeability will be due to the opening of pre-existing fractures. Stress redistribution is unlikely to cause new fracturing of intact rock at the repository depth.

- Under elastic conditions (shallow depths), radial permeabilities will decrease somewhat but tangential permeabilities will increase to a greater degree, resulting in an overall permeability increase. However, the zone where permeability is increased by more than one order of magnitude is very small (approximately 0.1 shaft radii).

- At greater depths, a "plastic zone" may form around the shaft and permeability increases of up to one order of magnitude may extend to a distance of about one shaft radius from the shaft wall.

- Decreases in radial permeability have been measured in tunnels at shallow depth. Other investigations in tunnels constructed by drill and blast methods have found that the overall disturbed zone thickness varies from 0.3 to 0.7 times the tunnel radius.

The applicability of the ONWI 411 analysis to the exploratory shaft (ES) site is limited because it does not take into account the effects of a non-uniform stress field. The actual stress field at the ES site is highly non-uniform, with a maximum to minimum horizontal stress ratio of 1.5:1, and a maximum horizontal to vertical stress ratio of 2.3:1 (DOE, 1982). ONWI 411 predicts that a biaxial horizontal stress field might result in tensile failure of intact rock. Prediction of the actual magnitudes of the stresses and displacements around the shaft would best be performed using models which incorporate the effects of jointing as well as non-uniform stress fields. The detailed study required should take into account the many other uncertainties associated with the analysis, including the effect of pore pressure and the validity of the stress-aperture-permeability relationships.

Our feeling is that ONWI 411 provides a useful starting point for the characterization of the DRZ around the ES. Its conclusions have not been confirmed in the field. Site characterization activities should be planned to investigate both radial and tangential permeabilities and changes in the DRZ with depth. Some portholes from the shaft should be oriented perpendicular to the minimum horizontal stress to determine if new fracturing has occurred.

2.2.3.2 Mud Losses to the Formation

Drilling fluids lost to the formation will coat or fill the fractures, vugs, and other open spaces that they pass through. The mud reduces permeabilities in the invaded zone, especially when LCM's are used, and this effect must be taken into account during hydrologic testing. The presence of mud may also affect the bonding between grout or other sealing materials and the rock. The actual effect of mud coatings on grout bonding would depend on the type of drill mud, the type of the grout and the thickness and extent of the coating. In situ testing will be required to accurately assess the effect of drill mud on shaft sealing.

A prediction of the extent of the invaded zone around the shaft would aid in evaluating the effect of the mud on permeability testing and sealing. The extent of the invaded zone will be a function of the volume of the mud loss and the permeability of the formation. More specific information about BWIP mud loss control plans, such as estimates of the maximum mud losses that will be tolerated before a cement plugs are set, would be helpful in this regard.

It is possible to use the presently available RRL-2 data to estimate the extent of the infiltrated zone around RRL-2. According to the RRL-2 report, two areas where major mud losses occurred were the Umtanum flow top and the four Lower Frenchman Springs flow tops. If it is assumed that the lost mud completely saturated the pore spaces in a volume of rock of circular cross section around the borehole, then the radius of the invaded zone can be calculated as follows:

$$V_m = \Pi r_i^2 tp$$

where: V_m = volume of mud lost to formation

t = total formation thickness

P = porosity of flow top

r_i = radius of the invaded zone

Solving for r_i:

$$r_i = \sqrt{\frac{V_m}{\Pi tp}}$$

Using the information given in Table 1, the radius of the invaded zone is 12 feet in the Umtanum flowtop and 17 feet in the lower Frenchman Springs flowtop.

Geophysical logs might also be useful in estimating the extent of the invaded zone around RRL-2 and also potentially around the ES.

2.3 Short-Term Sealing Considerations

In the NRC's original letter to the DOE (Miller to Anttonen, 13 January, 1983), the NRC asked whether the present shaft design "accounts for limitations and uncertainties in long-term sealing considerations." The DOE interpreted this question as referring to the "long- term operation" of the shaft (DOE reference no. 21). It appears that the DOE has a two-stage concept of sealing. In the DOE concept the purpose of the short-term seal is to simply keep water out of the repository during the operating life of the shaft, which will be a maximum of about 80 years. Upon permanent closure of the shaft, DOE apparently intends to replace the short-term seals with long-term isolation seals which will limit radionuclide transport through the shaft to the accessible environment. The long-term seals have not been designed at this time, however.

2.3.1 Construction Plans for the Short-Term Seal

The current DOE design calls for a short-term seal consisting of a steel casing grouted in place by a 20-inch cement annulus. Some details of short-term seal construction are provided in DOE references 18 and 19.

The first step in the construction of the short-term seal will be welding and lowering the casing. Upon the completion of drilling, the casing will be lowered section by section into the still mud-filled shaft. As each 40 foot section is lowered the next will be welded on to it. Grout line guides, support plates, utility lines, and other items will also be welded to each casing section. The first section of casing will have a closed bottom so that the entire shaft will be watertight, and water will be pumped into the casing as it is lowered to overcome buoyant forces.

When the last section of the casing has been welded and lowered into position, the shaft will be ready for cementing. The shaft will be cemented from the bottom up with the cement supplied through grout lines run through guides attached to the outside of the casing. The cement will be poured in lifts not exceeding 350 feet in height (DOE reference 18). As the cement fills the annular space between the

Table 1. - RRL-2 Data for Calculation of the Radius of the Invaded Zone

FORMATION	Mud Loss[1] In RRL 2-(gallons)	Thickness[2] Of Formation (ft)	Porosity[3]
LOWER FRENCHMAN SPRINGS	100,000	150 ft	20%
UMTANUM FLOWTOP	100,000	70 ft	20%

[1] From "mud loss summary", in the RRL-2 report, page A-23

[2] From Table 10, "Hydrologic Properties," in RRL-2 report, pages 57-58

[3] Representative values for flowtop porosity, from Table 18, pages 75-76, RRL-2 report

casing and the shaft wall the drilling fluid will be displaced. While a lift is being poured, the bottom of the grout line will be kept at least 30 feet below the theoretical top of the grout in the annulus. A log is run at regular intervals to determine the true grout surface elevation. After cementing is completed the casing will be dewatered and the shaft will be ready for use.

Three types of grout will be used for casing cementing. Regulated Fill Cement (RFC) will be the primary cementing agent from the shaft bottom to a depth of 2600 feet below surface. Also in this interval, 15-foot thick Chemical Seal Rings (CSR) will be poured above and below each of two proposed breakout horizons. Finally the remainder of the shaft, including the surface casing, will be grouted with standard prehydrated filler cement.

Both RFC and CSR are proprietary products of the Dowell Division of Dow Chemical Company. RFC is an expanding cement and CSR is an elastic polymeric seal (DOE reference 2). RFC creates a good seal by applying pressure to both the casing and the wall. CSR is designed to act as a gasket, and can swell to more than 150% of its original volume by imbibing water.

2.3.2 Concerns Related to Short Term Sealing

The short term sealing program is designed to restrict ground water flow into the repository during the "operating phase". The "operating phase" may be either the testing period or the life of the repository, depending on whether the ES is incorporated into the repository. If the ES is incorporated, then the short-term sealing materials must remain functional for a time period of about 80 years.

When the shaft is dewatered in the final stage of construction, the casing will contract in response to the reduction in internal pressure. The temperature reduction that occurs after the cement sets can also cause the casing to contract. Casing contraction can result in the formation of separations at or near the interface between the casing and the cement. If the bond between the cement and casing is poor, an actual micro-annulus can be formed. If the bond is good, micro-separations may occur in the cement. Micro-separations are not likely to contribute to annular fluid migration but they may adversely affect cement bond log interpretation (McGhee and Vacca, 1980).

One advantage of an expanding cement such as RFC is that it might compensate for casing contraction (DOE reference 2). It is our opinion that casing contraction is probably not a major short-term sealing concern, assuming that correct cementing and strict quality assurance procedures are followed. However, investigation of the phenomena might be necessary if the short-term seal is incorporated into the long-term seal.

Case histories on the use of RFC indicate that the cement is designed to minimize or eliminate water flow through the cement and at the interfaces. To maintain a proper bond, the RFC must be compatible with the mud residue left on the casing and wall rock. In borehole sealing, bonding is very important to prevent the formation of a permeable micro-annulus at the interface. However, for a shaft, the major potential flowpath is the DRZ. The penetration capability of RFC into the DRZ needs to be assessed. It may be necessary to grout the DRZ. The necessary size distribution of the grout material and grout injection pressures are dependent on the fracture aperture in the DRZ. Penetration of the RFC into the DRZ may be limited if the radial permeabilities decrease in the DRZ as predicted by ONWI 411.

It appears from Dowell's letter report (DOE reference 2) that RFC and CSR have only been in use for less than 20 years. It does not appear possible to extrapolate this experience to the life of the repository, especially in the light of Dowell's opinion that a "credible short-term accelerated test of CSR is not possible" (DOE reference 2). Apparently the durability of CSR can best be judged through case histories. CSR has been used for shaft sealing under difficult conditions at several potash mines (Storck, 1968; Pence et al., 1971; and Cleasby et al., 1977). Recent personal contacts with mine staff at both the Lanigan and Rocanville divisions of the Potash Corporation of Saskatchewan (PCS) indicate that the CSR is successfully performing its function at the shafts discussed by Storck (1968) and by Pence et al. (1971). Further follow-up investigations on the performance of CSR, and of RFC, appear warranted.

While CSR has been used to seal both conventionally-sunk and small-diameter drilled shafts, it does not appear that CSR has ever been used to seal a drilled shaft as large as the ES. A concern is whether the relatively large chemical seal rings can be emplaced effectively during the remote casing cementing operation. DOE reference 18 states that "the CSR shall be of the type specially developed to seal shafts" and that "the CSR will be installed in strict accordance with the recommendations of the supplier."

Remedial grouting may be required after the main lining is in place. No specific remedial grouting procedures have been detailed in the Dowell report (DOE reference 2), except that they will be performed from inside the shaft. The presence of horizontal stiffener rings and utility lines on the exterior of the casing enhance the likelihood that mud pockets requiring remedial grouting will be left in the cement liner. Such remedial grouting would have to be performed from the limited space available in the shaft. Follow-up investigations appear warranted on any remedial measures that may have been performed in shafts where RFC and CSR are currently in use.

2.4 Concerns Yet to be Resolved by DOE

2.4.1 Concerns from Borehole RRL-2

- The lesser-than-predicted thickness of the Umtanum interior indicates that the lateral predictability of basalt bed continuity is of concern.

- The loss of 10 feet of core within an apparently competent section of the Umtanum interior has raised concerns about QA procedures for drilling. A second core loss zone below the 10-foot core lose zone within the Umtanum may be a major fracture zone which may be important for horizon selection.

- Large mud losses during drilling of the borehole may have affected hydrologic testing, and have raised concerns about mud losses during shaft drilling.

2.4.2 Drilling Concerns

- The use of data from RRL-2 in anticipating problems and developing contingency plans is not fully discussed.

- There is a conflict between shaft verticality specifications in two DOE documents, but in general the specifications seem reasonable.

- Loss of equipment downhole could lead to serious delays in drilling, but this aspect is not fully discussed by the DOE.

- The use of a single string mud circulation technique does not allow for lowering the fluid level in the hole to limit mud losses. The reasons for the choice of the single string over a dual-string technique should be explained.

- Specific areas where large mud losses or wall sloughing are anticipated based on available data could be identified, along with indications of what specific steps are anticipated to control these problems.

- No construction schedule is provided

2.4.3 Concern About the Effect of Drilling on the Rock

- A disturbed rock zone (DRZ) of increased vertical permeability is likely to be created around the shaft due to stress redistribution. At present only theoretical approaches have been used to characterize the DRZ. A major drawback to the theoretical analysis is that only hydrostatic in situ stress conditions were considered. Site characterization activities from the exploratory shaft should concentrate on investigating the DRZ. More detailed modeling of the DRZ should be performed.

- Mud losses to the formation may affect permeability testing and sealing. Potential mud losses cannot be estimated at present because they are largely dependent on specific mud loss control activities, the plans for which are not available.

2.4.4 Short-Term Sealing Concerns

- The DOE apparently does not intend the short-term seal, consisting of the steel casing, cement lining, and chemical seal rings, to be a functional part of the long-term seal installed at permanent closure. However, because portions of the short-term seal will be present at the time the long-term seal is installed, short-term seal design must take into account long-term sealing considerations.

- It should be possible to remedy any sealing problems that occur during installation from inside the shaft as proposed, but the limited space available inside the shaft is a severe constraint.

- Specific sealing plans for mud loss zones are not addressed.

- The expected life of the ES is not clear, and the long-term durability of the seal materials has not been established. Therefore it is difficult to judge whether the short-term seal will last through the operating life of the shaft.

3.0 SITE CHARACTERIZATION PLANS

The blind hole drilling technique precludes any visual inspection or geologic/geotechnical mapping of the wall rock. Nevertheless, shaft construction provides some unique possibilities for site characterization which should not be ignored. Information obtained during shaft drilling could be used to confirm data from RRL-2 and also to begin to characterize some of the unique aspects of the shaft, e.g. the DRZ. Monitoring the penetration rate, bit thrust, rotation speed, and other standard drilling information will permit correlation of soft and hard zones with the stratigraphy of RRL-2, but will not provide a detailed description of the rock. Collected drill cuttings might be used to identify some marker horizons, but their use in monitoring shaft lithology is not described in the DOE Letter Report. (DOE Letter Report, "Comments on Shaft Drilling and Sealing," April 1, 1983).

Geomechanical and hydrologic test plans for the shaft will not be published until late 1983, and no description of either of the test plans is provided in the April 1, 1983 DOE Letter Report.

3.1 Hydrologic Testing

Monitoring the hydrologic response of the formation to shaft drilling from borehole RRL-2 has been proposed. Information about the hydrologic response could greatly aid in understanding the ground water regime in the vicinity of the ES, particularly about the presence of vertical connections between aquifers. It is, however, doubtful that meaningful interpretation of data from just RRL-2 could be made, owing to the distance of RRL-2 from the shaft, the fact that RRL-2 has been cased to below the Vantage interbed, and the uncertainties that exist about the direction of ground water flow at the RRL. Consideration should be given to the possibility of drilling additional holes with locations specifically chosen for hydrologic monitoring. Piezometers could be located at several important stratigraphic units in each of these holes. It might also be possible to perforate selected sections of the casing in RRL-2 which would increase its usefulness.

3.2 Geophysical Testing

The planned geophysical logging of the shaft is restricted to caliper surveys, grout level monitoring, and cement bond logs. We feel that further geophysical logging would be a very helpful addition to the site characterization program at the ES. In addition, the accuracy of the cement bond log in identifying grout bridging in the annulus between the shaft wall and the liner should be explored, and any improvements necessary in running this log should be implemented.

At the Nevada Test Site (NTS), equipment has been developed for running the gamma density, epithermal neutron, and natural gamma logs in large drilled shafts (recent personal communication, T. Grover, Birdwell Company in Las Vegas). Geophysical logging of the entire length of the shaft could aid site characterization in two main areas:

- Stratigraphic correlation between RRL-2 and the ES
- Preliminary characterization of the DRZ.

Preliminary characterization of the DRZ with geophysical logs is not as straightforward as stratigraphic correlation. The neutron log is usually responsive to changes in fracture porosity, and a comparison between the neutron logs of RRL-2 and the ES might indicate where a DRZ has formed. Rigby et al. (1980) reported that open fractures in basalt could only be identified by relating the self-potential (SP), density (gamma-gamma) and neutron logs, because mineralization in fractures made analysis of the neutron log alone difficult. Whether their technique would be feasible or necessary at the ES is not clear.

Various visual and acoustic methods, including the Borehole Televiewer and the Circumferential Acoustic Device (CAD), can be used in small diameter boreholes to better characterize fracturing (Wylie, 1980; and Vogel and Herolz, 1981). Thermoplastic film has also been used to take impressions of borehole walls (Hoek and Brown, 1980). It seems doubtful that any of these techniques could be readily scaled up for use in the ES, but the possibility could be explored.

3.3 Porthole Testing

The planned porthole locations and the orientation of the coreholes drilled from those portholes are expected to be published by the DOE in late 1983. Apparently, more than 36 portholes are planned for the shaft (DOE ref. 7). Descriptions of the tests to be performed through the portholes and the limitations of the test data will not be available until late in 1983.

According to the Contingency Plan (DOE ref. 7), the primary function of the portholes is to verify the grout bond at the shaft wall and liner. In our opinion, characterization of the DRZ should be given at least equal importance. ONWI 411 suggests that crosshole seismic surveys taken from parallel horizontal drillholes would be very useful in identifying the depth of the DRZ. Any expected difficulties in geophysical logging of horizontal or slightly-inclined coreholes in the shaft are not described by DOE.

The manner in which RRL-2 data was used in selecting the porthole locations should be identified by the DOE. DOE reference 19 refers to the welding of inspection porthole assemblies as being included in the scope of work for the welding contractor. The portholes are not referred to again; hence, it is not clear when the protholes are put into the casing or when the decision about their location is made. Since the portholes will be integral parts of the steel liner, it is of some concern that the ability to adjust porthole locations in response to conditions found during shaft sinking could be lost. It is assumed that new portholes could be put into the installed liner if necessary, but further clarification of porthole placement is required.

3.4 Conventional Shaft Sinking Through Potential Repository Horizons

The importance of fully characterizing potential repository horizons during shaft construction suggests that consideration be given to the possibility of blind drilling the ES to the top of the Cohassett, and then switching to conventional shaft sinking (drill-and-blast) techniques. It would then be possible to directly observe the dense interiors of the candidate flows and perform detailed fracture mapping.

If this option were adopted, drilling would be halted at a predetermined depth. The shaft would then be cased and lined in a similar fashion to the description provided in Section 2.3.1. After a delay for removing the drill rig and installing a headframe with a skip, sinking would continue by conventional means with lining occurring simultaneously.

Conventional sinking of the ES through potential repository horizons would be slow due to the small size of the shaft and the presence of aquifers. The cramped working space would hinder drilling and lining. Data from RRL-2 indicate that four mud loss zones including the 165-foot thick Umtanum flow top, would be encountered if sinking continued to the base of the Umtanum. Grouting these zones would be both necessary and time consuming.

A possible alternative to conventional sinking would be to bore a small diameter raise in the horizons of interest for site characterization. With this approach the ES would be blind drilled to depth as currently planned. Then, after a breakout tunnel had been driven some distance from the shaft, a raise could be bored which would allow direct observation of the entire thickness of the horizon above the breakout elevation.

3.5 Site Characterization Concerns

- No visual inspection of the wall rock is possible. It would probably be feasible, although time consuming, to change over at depth from

blind drilling to conventional shaft sinking in order to better observe the potential repository horizons. A second possibility would be to bore a small raise from the breakout station(s).

- Information gained from RRL-2 will be insufficient to characterize the hydrologic response of the formations to shaft drilling. Consideration should be given to drilling additional holes for more systematic hydrologic monitoring.

- No geophysical testing is planned at present for the ES. Geophysical logging could be useful in stratigraphic correlation with RRL-2 and identifying the DRZ over the length of the shaft.

- Porthole locations and installation timing are not specified, and the planned hydrologic and geomechanical tests from portholes are not available.

4.0 LONG-TERM SEALING CONSIDERATIONS

4.1 Sealing Materials and Plans Proposed by DOE

DOE has presented a preconceptual plan for permanent sealing of the exploratory shaft, (DOE Letter Report, comments on Shaft Drilling and Sealing, April 1, 1983). The DOE proposes to construct a minimum of two 15-foot thick primary isolation annulus seals in competent basalt, one above and one below the tunnel openings. The primary isolation seals will be constructed of cement with basalt aggregate. The liner at each primary seal location is to be removed, any grout and debris cleaned out, and the exposed shaft wall characterized as to the depth and permeability of the DRZ. The DRZ will then be injection grouted or removed as necessary, and the seal constructed. Finally, the remainder of the shaft will be backfilled with crushed basalt. Construction details have not been provided in any DOE document.

4.2 Concerns Related to Long-Term Sealing

In our opinion the DOE's long-term sealing program is deficient in several respects. The conceptual design summarized above appears inadequate, but it is understood that more complete designs will be forthcoming as information on the site and on sealing materials becomes available. A more serious problem is that long-term sealing

concerns have not been fully integrated into the present ES construction program. Shaft construction activities may affect future long-term sealing capabilities, and these effects should be considered in shaft design.

4.2.1 Discussion of Long-Term Seal Design

The major problem with the DOE conceptual design is the proposal to backfill the shaft with crushed basalt. Although basalt rock possesses a certain degree of radionuclide adsorption capability, crushed basalt would be highly permeable and most of the length of the shaft could provide a preferential pathway for ground water. The permeability of the backfilled shaft should be reduced to the greatest extent practicable and this could best be accomplished by cementing the entire shaft, or utilizing a mixture of crushed basalt and cement. Special consideration must be given to the DRZ along the length of the shaft, and the long-term characteristics of the seal at the interfaces with the steel liner (if left in place) and wallrock.

If the shaft itself is effectively sealed, then the major purpose of the primary seals would be to prevent the DRZ from becoming a preferential pathway for ground water. It would seem that the rationale for primary seals should be the prevention of hydraulic connection between major water bearing zones through the DRZ. The DOE should present a rationale for the number, location, and type of seals required, based on information obtained from site characterization, porthole tests, and hydrologic modeling.

The DOE has not specified any special properties for the seal cement although some research on this subject has been performed (Coons et al, 1982). The cement used in the seals should be capable of both limiting ground water movement and adsorbing radionuclides. The seal materials, including the substance that is used to grout the DRZ, must also be compatible with the rock, drilling mud coatings, and ground water chemistry. In particular, the seals and backfill for the ES must be designed and constructed such that the long-term isolation capability of the whole repository is not compromised. Seal design must be derived from performance assessment analyses and must satisfy NRC and EPA criteria for radionuclide release. Uncertainty in the models used should be documented through sensitivity analyses. The question of whether the DRZ is a major pathway for radionuclides will only be answered through careful site characterization and modeling.

4.2.2 Immediate Long-Term Sealing Concerns

Some aspects of shaft construction may later affect long-term sealing. Of immediate concern are effects resulting from drilling and from the construction of the short-term seal.

As previously discussed in Section 2.0, the two major effects of shaft drilling on the integrity of the site are the creation of a DRZ and the loss of drilling fluids. The DRZ is potentially the major pathway for radionuclide release, and extensive site-specific investigation of the DRZ will be necessary to collect information essential to long-term seal design. Lost drill mud and use of LCM's could hinder grout bonding and limit grout take, and so could have a deleterious effect on long-term sealing. Tests in mud loss zones may be required to assess their impacts on radionuclide isolation.

Another issue that should be addressed is the compatibility between the short-term seal (the steel casing and the cement lining) and the long-term seal. The DOE conceptual design states that "the liner will be removed at each seal location (DOE Letter Report "Comments on Shaft Drilling and Sealing, April 1, 1983), but the liner and casing will still be present along most of the shaft's backfilled length. A major concern is the effect of possible corrosion of the steel casing on the isolation capacity of the backfill. The durability of the RFC and RFC bonds are also of interest. These issues are important because the short-term seal will be present at permanent closure, and so plans for its removal or incorporation into the long-term seal must be addressed in the long-term seal design.

It is clear that a final long-term seal design will require extensive study of sealing materials. The ES itself provides a unique opportunity to perform long-duration tests on sealing materials under actual repository conditions. Consideration could be given to using several different materials in the short-term seal to help determine which might be most effective as a long-term seal.

5.0 QUALITY ASSURANCE PLANS

5.1 Quality Assurance Considerations

Preparation and implementation of a workable Quality Assurance (QA) program is an essential part of the success of the BWIP. The quality assurance program must be applicable to all activities (both hardware-related and geoscience-related activities) that prevent or mitigate events that could cause unreasonable risk to the health and safety of the public.

All of the various quality assurance programs are based upon 10CFR50 Appendix B and the ANSI/ASME NQA-1 standards. It must be recognized that not all elements of these standard documents are applicable or appropriate in every phase of the BWIP. However, not only must each prime contractor have a workable program, but the individual programs must be compatible. Our review has been directed toward comparison between programs and adaptations necessary to assure quality of the geoscience- related aspects.

5.2 Procurement Specifications

These documents are typically hardware related. They deal with procurement of such items as:

- 72-inch ID steel Casing (DOE ref. 3)
- 112-inch ID steel casing (DOE ref. 4)
- Drilling mud (DOE ref. 5).

The procurement specification for the steel casing provides adequate definition of applicable standards to be followed, appropriate terms, and QA requirements for subcontractors. The kinds of tests and level of documentation are described along with acceptance criteria, and documentation controls.

The procurement specification for drilling mud provides adequate definition of terms and outlines which testing methods should be utilized. Tolerances (usually ± 5%) are specified for all container labels and for control of various formulas. However, under the Fluid Loss and Caving Control (Section 7.0), general terms, such as, "excessive drilling fluid loss" or "excessive hole instability" are used without attempting to quantify the term "excessive". Our concern is that this is subjective and determination is to be made on a case by case basis in the field by the professional mud engineer. No mention is made as to how the information from RRL-2 has been used to assess potential mud loss zones and areas of instability. It would be helpful if standards were instituted whereby decision analysis would be less subjective. This is discussed further in the following sections.

5.3 Contingency Plan For Anomaly Detection and Resolution During Exploratory Shaft Construction

Some of the items discussed in the contingency plan (DOE ref. 7) have been previously discussed in Section 2.2.2. This section provides a discussion of the specific QA concerns.

In general the contingency plan provides an adequate summary of the potential problems which could occur during construction of the exploratory shaft. Fourteen (14) potential problems are identified and discussed. In some instances, prevention of the problem is assumed by proper selection of personnel. For example, Excessive Wall Cave In During Surface Sediment Penetration will be prevented by use of experienced professional personnel. However, the use of professionals cannot guard against the unknown and possible occurrence of flowing sediment zones. The professionals can only react to such occurrences.

With respect to Lack of Adequate Penetration, the statement is made that drill and blast techniques could be used if penetration rates are too low. Such statements should be made with extreme caution. Some of the problems associated with a switch to drill and blast methods are described in Section 3.4. In summary, shifting to drill and blast methods would probably require a complete revision in tools, techniques, and schedules.

In the section on Excessive Water Inflow, two possible causes are given:

- Loss of drill fluid to aquifer which upsets balance of forces
- Unexpected artesian conditions.

The solutions offered to correct these problems are:

- Correct loss of mud by adding additional mud
- Pressure grout to seal artesian conditions.

These solutions are provided without any backup information. For example, at what point does mud loss in itself become a critical problem? Suppose 10% of the original volume is replaced with new mud (charged with LCM) and loss continues, is it then necessary to switch to pressure grouting? Are pressure grouting rigs to be on permanent standby? Would operations have to be shut down while such equipment is mobilized? Suppose loss of mud in one area upsets the balance and leads to excessive wall cave-in in another previously stable area?

In short, it appears that additional detail in describing contingency procedures is necessary if the project is to be monitored and evaluated by QA personnel. In other words, if the site QA engineer has no recourse but to depend upon the professionalism and experience of the driller and/or mud engineer, and has no specifications or procedure manual to consult, then the site QA engineer is essentially powerless. Without standards or references, he can only provide the clerical function of assuring that activities are properly documented and filed.

One potential solution to this problem is to have the QA engineer qualified in the specific geoscience function to be monitored. More than likely, this would require a QA staff instead of a QA engineer, due to the many functions which require experienced surveillance. In addition, the QA engineer should be provided access to outside, independent experts who would function as QA Technical Advisors on an as-needed basis. In this way, the QA engineer could obtain an occasional second opinion.

With respect to Excessive Non-Verticality of Liner, the cause is listed as alignment error. The solution is listed as alignment correction by hoisting the liner and repairing as necessary. Stringent quality assurance precautions need to be taken to avoid damage to the approved liner sections during storage and hoisting. Also, regarding the practicality of having spare liners available at the site, we understand that eleven liner thicknesses will be required in order to complete the ES. DOE does not feel that having spares for all eleven thicknesses would be cost effective. However, since additional liner segments are added to the top segment, the thickest sections would be placed first. It is possible, therefore, that a spare 1-inch liner could be used to replace a damaged 3/4-inch liner such that spare 3/4-inch liners would not be necessary. This would alleviate the problem of having spares at the site for each of the eleven liner thicknesses. It should be possible to get by with only every other thickness increment (i.e. five or six, instead of eleven).

An additional precaution with respect to liner installation concerns the orientation of the portholes. As discussed in Section 3.3, the portholes will primarily be used to check the grout seal. Other testing, however, is also planned. Some of this testing could require very specific orientation of the portholes with respect to anticipated geologic features. Strict QA procedures are necessary to assure that the sections with portholes arrive at the assigned depth with the proper porthole orientation.

With respect to Loss of Equipment Downhole, the fishing operation is by no means routine. The type of fishing equipment used depends on what was lost downhole as well as on the driller, and a trial-and-error approach is often necessary for retrieval. The Contingency Plan states that "timely acquisition of fishing equipment from DOE facilities in Nevada has been assured." This is essential. However, we would also suggest that all the case histories of fishing operations be reviewed so that further QA procedures can be adopted to prevent such occurrences at the ES.

Another contingency item concerns Inadequate Grout Seals. Prevention of such an occurrence is listed as a subject of ongoing studies. Discovery of grout shrinkage, inadequate bonding, or defective grout coverage could threaten QA approval for the entire shaft. From a QA point of view, any sort of discrepancy could render the entire grouting operation suspect. The grouting operation should be watched very carefully to ensure that adequate QA checkpoints, and strict approval procedures, are instituted. For example, how will the volume of the annular space be calculated so that the grout take can be confirmed? At what point does excessive grout take become alarming? These are the sort of questions that cannot be answered simply by stating that prevention will be assured by careful selection of professionals. This is another area where "second opinion" assistance for the QA engineer would be very helpful in obtaining final QA approval for the ES.

In the discussion concerning Rock Instability After Breakout one potential solution is listed as pressure grouting. Such grouting after breakout could actually accelerate instability. Therefore, such statements should be viewed with extreme caution. Detailed quality assurance procedures should be available to determine which preventive measure is best for a given set of circumstances. Also, any equipment which may be used in the breakout area (e.g. rock bolting and/or shotcreting equipment) must be available at the site and must be carefully selected for use in the limited work area.

5.4 Quality Assurance Plan for 144-Inch Diameter Surface Hole Drilling

The Quality Assurance Plan for 144-inch diameter surface hole drilling basically outlines what information is to be maintained in the QA Files. The plan appears reasonable for drilling to the top of bedrock. The personnel responsible for acquisition of the information are identified. The QA Manager only maintains the files.

The information to be maintained by the M-K BWIP QA Manager is presented in the Drilling Program for the 144-inch surface hole (DOE ref. 11). However, the drilling program simply states under Records and Submittals that, "Records and observations will be kept and submitted in accordance with the approved Construction Specifications (DOE ref. 1)." More detail should be provided or at least more detailed cross referencing. For example, the Drilling Mud Program (DOE ref. 12) clearly describes the required documentation, frequency of testing, and provides example forms. The information to be maintained by the M-K BWIP QA Manager concerning the Drilling Mud Program is to be provided by the Mud Engineer. In order to streamline the QA process, similar forms and procedures should be provided for the documentation regarding the drilling of the 144-inch diameter surface hole without having to review other documents.

The M-K BWIP QA Manager must review the information that is submitted by various responsible parties, and:

- Verify that records are complete and legible
- Perform and document surveillances of the drill operations.

The drilling information required is briefly outlined. Such information as rate of penetration, lost circulation intervals, and mud consumption is part of the required documentation. However, no mention is made concerning responsibility for analysis of such data. For example, what are the implications of ever-increasing mud consumption? Who is responsible for flagging anomalous conditions? The QA Plan does not delineate these responsibilities. The chain of command for handling anomalous conditions should be identified. Also, the QA plan does not provide for QA Technical Advisors to assist the QA engineer.

5.5 Comparison Between M-K QA Plan and DOE/RHO QA Plan

The M-K QA Plan is supposed to be designed to meet the requirements of the Rockwell BWIP QA Program Plan (DOE ref. 15 and 16). As such, the QA plan is comprehensive and covers all pertinent aspects. At present only the Grout and Grouting Operations and the Shaft Liner Plate aspects have been designated as QA Level I. Other aspects may be upgraded to QA Level I, in the future. QA Levels I, II, and III are clearly defined.

The Rockwell QA Plan specifically moves away from the standard "hardware" QA Plan and incorporates procedures for control of the "geoscience" aspects of the QA Plan. The M-K QA Plan tends to address only hardware related issues without specific reference to geoscience issues, such as control of grout batch plant samples, etc.

Having access to the complete DOE/RHO QA procedures would help in evaluating the overall effectiveness of the QA program.

The M-K organization provides DOE/RHO direct access to M-K executives via the Waste Isolation Division Manager. It is not clear if there is any other communication path between DOE/RHO and the M-K QA organization at the grass roots level.

Based upon Appendix A (DOE reference 16) the following documents should be forwarded to the NRC:

- PM - Policy Manual, RHO-MA-100
- BOP - Basalt Operating Procedures Manual, RHO-BWI-MA-4
- EPM - Engineering Procedures Manual, RHO-MA-115
- QAP - Quality Assurance Manual, RHO-MA-106
- MPP - Material Policy and Procedures Manual, RHO-MA-135
- QAA - Quality Assurance Administrative Guide, RHO-MA-152
- QAI - Quality Assurance Instruction Manual, RHO-MA-256

6.0 CLOSURE

The DOE program for the ES is generally acceptable and utilizes state-of-the-art blind drilling techniques. There are, however, some areas in which improvements could be made or on which further discussion is required. A brief summary of our comments follows.

The principal borehole report (RRL-2) indicates significant lateral lithologic variability, especially in the Umtanum flow. In addition, significant mud loss occurred at the Umtanum flowtop and in the lower portion of the Umtanum entablature. Further site characterization activities should investigate these findings, and attempt to resolve them.

The shaft construction documents and contingency plans generally seem to be adequate. However, we feel that there has not been enough discussion of the effect of the chosen circulation technique (single-string reverse air-assist) on the formation, specifically the effect of the potential large mud losses on future hydrologic testing. A dual-string circulation system might be considered as a means to limit mud losses.

The DOE's proposed short-term sealing program is adequate for keeping the shaft dry over its operating life. However, we feel that the short-term seal should be more specifically integrated into the long-term sealing program. Consideration should be given to using the short-term seal as a testing ground for long-term sealing materials.

The conceptual design for long-term sealing put forward by the DOE is incomplete. Numerical modeling of the hydrologic system at the RRL, and consideration of the DRZ and thermal effects, are required to estimate the location, thickness, and number of seals in the shaft. More importantly, present programs on sealing materials and site characterization should be specifically related to long-term seal design.

The major disadvantage of the blind shaft drilling technique is that site characterization is difficult because the wall rock cannot be directly observed. Geophysical logging, which has not been discussed in any DOE document we reviewed, would be one method of indirectly correlating lithology between the ES and RRL-2 and perhaps identifying zones in which a DRZ has formed. Geophysical logging tools for large diameter drilled holes are available and their use should be explored. Another possibility that would allow direct observation of the rock would be to switch to conventional sinking at the depth of the repository horizons. Such a switch would be feasible, but advance would be slow owing to the small size of the shaft and difficulties in controlling water-bearing formations. Finally, it appears that effective monitoring of the hydrologic impacts due to shaft drilling would require the drilling of more observation holes.

With respect to QA, in most cases, applicable standards, types of tests, acceptance criteria, and QA requirements for subcontractors are adequately described. In some cases, subjective words such as "excessive" are used which are open to some interpretation by the reader. Effective QA monitoring will require that QA engineers are qualified in the specific geoscience task to be monitored, and that QA Technical Advisors are available.

The ES QA Plans provide communication between M-K and DOE/RHO at the executive level but not at the field personnel level. Successful implementation of the QA program depends on efficient and accurate

communication at all levels. A review of the various DOE/RHO QA procedures is necessary to confirm that adequate communication is maintained at all QA levels.

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ATTACHMENT 1

BWIP EXPLORATORY SHAFT CONSTRUCTION REFERENCE DOCUMENTS

1. B-314-CX28018 (BWIP 7490)
   Construction Specification for Shaft Drilling and Rig Services, February 1983.

2. (No number available)
   Dowell letter report on their chemical seal describing available laboratory test data, performance experience in past applications, and recommendations for further testing/development, February 1983.

3. B-314-PS28005 (BWIP 7473)
   Procurement Specification for 72" ID Steel Casing, December 1983.

4. B-314-PS28004
   Procurement Specification for the 112" ID Steel Casing, November 1982.

5. B-314-B-X28028
   Procurement Specification for Drilling Mud, February 1983.

6. (No number available)
   Amchitka Mining History, Fenix and Scisson, January 1971.

7. Letter #R83-0283.1
   Contingency Plan for Anomaly Detection and Resolution During Exploratory Shaft Construction, January 1983.

8. NM 79-137
   Topical Report, "Preliminary Evaluation of the Rock Mass Disturbance Resulting from Shaft, Tunnel, or Borehole Excavation," D'Appolonia, July, 1982.

9. QAP 9.03
   Sperry Sun Survey Procedure, February 1983.

10. SD-BWI-TI-113
    Principal Borehole Report, January 1983.

11. SD-BWI-AR-003
    M-K Drilling Program (144" Hole), February 1983.

12. SD-BWI-AR-002
    M-K Mud Program (144" Hole), February 1983.

13. M-K Q. A. Plan for drilling 144" Hole (including mud), February 1983.

14. Rockwell Q. A. Inspection Plan for drilling 144" Hole (including mud), February 1983

15. RHO-QA-PL-3, Rev. 1 L
"Basalt Waste Isolation Project - QA Program Plan," March 1983.

16. RHO-QA-PL-3, Rev. 1 L
Appendix A, "QA Program Index," March 1983.

17. (No number available)
M-K QA Plan, December 1982.

18. B-314-C-X28048
"Construction Specification for Casing Cementing", February 1983.

19. B-314-C-X28038
"Construction Specification for Casing Field Welding Services", February 1983.

20. R-83-2000
Letter to O. L. Olson from R. A. Deju dated May 26, 1983, with two attachments.

21. (No number available)
Letter to R. J. Wright from O. L. Olson, date April 29, 1983, with three attachments.

DOE
REFERENCE DOCUMENTS

The following reference documents were transmitted to the Nuclear Regulatory Commission (NRC) on February 25, 1983 by U.S. Department of Energy-Richland Operations Office (DOE-RL):

Reference No.	Title
1	ONWI-411, Topical Report, Preliminary Evaluation of Rock Mass Disturbance Resulting from Shaft, Tunnel, or Borehole Excavation, D'Appolonia (7/82)
7	No Number Available, Dowell letter report on their chemical seal describing available laboratory test data, performance experience in past applications, and recommendations for further testing/development (published)
8	B-314-C-X28018, Construction Specification for Shaft Boring (published)
13	B-314-P-S28005, Procurement Specification for 72" ID Steel Casing (published)
15	B-314-P-S28004, Procurement Specification for 112" ID Steel Casing (published)
16	B-314-B-X28028, Procurement Specification for Drilling Mud (published)
20	No Number Available, Amchitka Mining History, Fenix and Scisson (1973)
21	Letter #R83-0283.1, Contingency Plan for Anomaly Detection and Resolution During Exploratory Shaft Construction (1/83)
24	No Number Available, Sperry Sun Survey Procedure (2/83)
25	SD-BWI-AR-003, M-K/BWIP ES Phase I Drilling Program for 144" Hole (published)
29	SD-BWI-TI-113, Principal Borehole Report, Borehole RRL-2 (1/83)
34	SD-BWI-AR-002, M-K/BWIP ES Phase I Drilling Mud Program, 144" Hole (published)

The following reference documents were transmitted to the NRC April 1, 1983 by DOE-RL:

Reference No.	Title
22	No Number Available, M-K QA Plan (4/83)
23	RHO-QA-PL-3, Rev. 1 L, Basalt Waste Isolation Project - QA Program Plan (4/83)

The following reference documents are submitted with this transmittal:

Reference No.	Title
6	B-314-C-X28048, Construction Specification for Casing Cementing (published)
9	B-314-C-X28038, Construction Specification for Casing Field Welding Services (12/82)
19	No Number Available, DuPont Blasters Manual (published)

The following documents will not be available until later in the program as indicated by the dates after each reference:

Reference No.	Title
2	SD-BWI-TP-007, Rev. 1-0, Test Plan for Exploratory Shaft in Basalt, Phase I and Phase II (10/83*)
3	SD-BWI-CR-015, Repository Seal Performance Requirements and Preliminary Seal Design Criteria for a NWRB (7/83*)
4	No Number Available, Exploratory Shaft Test Plan for Material Quality Control and Long Term Stability Assessment (7/83*)
5	No Number Available, M-K Procedure for Casing Handling, Aligning, and Running (Note: This procedure will be prepared for the 112" casing intially. A separate procedure will then be developed for the 72" casing.) (6/83*)
10	No Number Available, M-K Procedure for Cementing (5/83*)
11	No Number Available, Seal Test Procedure (9/83*)
12	No Number Available, Shaft Seal Report (1985*)

*Expected date when document will be available

Reference No.	Title
14	SD-BWI-TI-119, Exploratory Shaft Test Porthole Configuration (6/83*)
17	No Number Available, ES Acceptance Test Procedure (10/83*)
18	No Number Available, M-K Drilling Program, 110" Hole (6/83*)
26	No Number Available, Drill Bit Inspection Program (6/83*)
27	No Number Available, Post Drilling Inspection Procedure for 144" Hole (6/83*)
28	No Number Available, Post Drilling Inspection Procedure for 110" Hole (6/83*)
30	No Number Available, Hydrologic Test Report (1985*)
31	No Number Available, Geomechanics Test Report (1985*)
32	SD-BWI-TC-001, Rev. 1-0, Test Procedure for the Principal Borehole RRL-2 (6/83*)
33	No Number Available, Drilling Test Report (1984*)
35	SD-BWI-PMP-002, Project Management Plan for Exploratory Shaft-Phase I (ES-I) (6/83*)
36	No Number Available, Grouting Procedure (6/83*)
37	No Number Available, DOE Basalt Waste Isolation Project Quality Assurance Plan (9/83*)

*Expected date when document will be available