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Subject: Review of "Assessment of Conducting a Large Shaft Demonstration Test Utilizing Geodril 32, Morrison-Knudsen Company, Inc., September 20, 1984."

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I. Introduction

The primary objective of the Morrison-Knudsen/BWIP (M-K) report is to comment on the various parameters associated with the Rockwell-recommended Large Shaft Demonstration Test (LSDT) at Hanford. This shaft, characterized by a 20-foot diameter and a depth of 450-500 feet, will provide information for the full scale repository construction, where shafts of similar diameter will be sunk to greater depths (3,400-3,900 feet). The information obtained from the LSDT will include results from:

(1) testing of the proposed shaft drilling methods and procedures (e.g., use of the modified Geodril 32 in basalt formation, test of the cost-effectiveness of the single- or two-pass technique, test of the bit configuration and resistance to required torques and weights, determining the best circulation systems, testing the effectiveness of the lining of shafts, identification of geologic hazards and testing the control practices associated with them), and

(2) geologic data collection.

After consideration of all the factors involved in the LSDT, the M-K comments will:

(1) shed more light on realities of budgetary restraints for the full scale repository construction,

(2) identify more clearly the potentially adverse conditions

at the Hanford site, such as the ones stated by DOE in 10CFR 960.4-2-3-c(1), and

(3) determine whether the proposed shaft excavation methods and procedures can be easily modified to achieve their objectives for deeper shafts.

The Rockwell-recommended location of the LSDT is approximately one mile away from the borehole DB-15 (see Figure 1). Considering the distance between the LSDT and the Reference Repository Location (RRL), confidence level and utility of the geologic data generated by the LSDT may not be extrapolated to the full scale repository shafts in the RRL. Furthermore, well logs from RRL-2, a drill hole located approximately nine miles away from the LSDT Site, show poorly cemented or uncemented gravels and clays to a depth of 640 feet; below this depth, a repetitious sequence of moderately hard to extremely hard basalt flows and interlayered sedimentary horizons can be found (Morrison-Knudsen, 1983). Because of this fact and the depth planned in the LSDT, it is not certain if the LSDT hole can be used to check the effectiveness of available excavation technology in basalt flows, and to objectively extrapolate geologic hazards encountered at the LSDT site at depths greater than 500 ft.

Despite the above limitations, M-K proceeded in providing comments without consideration of the advantages that the test would <u>directly</u> bring to the drilling of shafts in the RRL area. However, the M-K comments did attempt to point towards answering the following questions:

(1) Can a 20 foot (nominal) diameter drilled shaft be successfully drilled through the Columbia River Basalts?

(2) Are the Geodril Rig 32 (with stated modifications) and the existing Government-owned drilling tools adequate for drilling the LSDT (and potentially deeper shafts of like diameter)?

(3) The two-pass drilling method has been demonstrated as a viable shaft drilling method in other environments, including the Beatrix Mine, Holland (25 foot diameter), the Kerr-McGee Mine, New Mexico (16 1/2 foot diameter), and the AEC Test Shaft in the Yucca Flats Area, Nevada Test Site (14 foot diameter). Is it reasonable to conclude then, that the two-pass drilling method is viable for use in basalt?

(4) Can large basalt fragments that may become dislodged from the shaft walls (by sloughing or other mechanisms) be coped with successfully during the course of drilling, casing, and cementing operations?

(5) What are the relative hole cleaning advantages of a tapered-bottom versus a flat-bottom bit, and by extrapolation, what affect does bit configuration have on penetration rate?

(6) What are the trade-offs between using single-pass and two-pass drilling methods?

Issues #2,3,5 and 6 are discussed in section II, whereas section III addresses issue #4 and other geologic hazards that could make drilling at depth unfeasible. Issue #1, which is the most difficult to justify, should be determined prior to any shaft construction at the Hanford Site. A determination will certainly require additional geologic data (among others) from reference holes near the the LSDT location.

From the M-K discussion, it is concluded that:

(1) the two-pass drilling method is recommended as a viable and cost-effective procedure for future repository shaft construction,

(2) all drilling related parameters, except for the hole cleaning case using flat-bottom bit, can be determined or reasonably

extrapolated to the full scale repository shafts, by performing the large shaft demonstration test using the two-pass concept, and

(3) the LSDT can be conducted with the modified Geodril Rig 32, as recommended by Rockwell.

It is unclear how the above conclusions have been reached. To date, no shaft with the size and depth specified in the repository plans and specifications has ever been constructed. The only shaft of somewhat similar scale to the repository shafts drilled in rock, with compressive strength approaching the Hanford Site, is the Agnew Mine in West Australia (DOE, 1984b). This was drilled using a single-pass method and experienced failure at 2,460 feet. The diameter in that case was 14 feet, as compared to the shaft diameter at the Hanford Site which may have a diameter larger than 20 feet and depth of 3400-3900 feet (DOE, 1984b). Finally, it should be noted that the successful completion of the LSDT does not warrant that the method and drilling parameters determined, will be directly applicable to shafts at greater depth.

II. Drilling Equipment and Methods

Two methods of drilling were considered, the single-pass and double-pass methods. The single-pass method involves one pass of the drill bit to drill the hole diameter to size. The two-pass method involves a first pass with a bit diameter smaller than the final diameter desired. The resulting hole is then reamed out to the desired diameter with a second pass using a larger reamer bit. The two-pass method does not require as large a rig as the single-pass method. This is the main reason cited for using the two-pass method.

The Geodril Rig 32 is directly available equipment. For the LSDT, it will be modified by increasing the rotary table to a 400,000 foot-pound torque capability. The existing C-95 quality, 13-3/8 inch diameter drill pipe with a yield strength of 2,013,000 pounds, is also considered adequate. This latter equipment may need further modifications for repository shaft drilling. The largest surface drill designed and built to date, the Hughes CSD-300, is capable of applying 500,000 foot-pounds of torque and has a lifting capacity of 2,000,000 lb. It was designed to drill a 20-foot diameter hole to a depth of 2,000 feet for the Agnew mine in Leinster, Western Australia. This drill failed while drilling a 14-foot diameter hole using the single-pass drilling method at 2,460 feet in rock with very similar compressive strength as the basalt at the Hanford Site (DOE 1984b). Even with Geodril Rig 32 using the two-pass method, the 12-foot pilot hole would have to reach 940-1440 feet below the failure depth of the CSD-300, i.e., to reach a 3400-3900 foot depth (DOE 1984b, RKE/PB, 1984). The failure of the CSD-300 was claimed to have not been caused by insufficient torque, but from structural problems, with the mast and rotary support beams causing excessive lateral vibration in the rig superstructure. If failure was due to lateral vibrations, a solid drill pipe would become an important factor to consider. Too large of a drill pipe would then necessitate excessive pressure and fluid needs, since this is the only route the drilling fluid takes to the surface. Despite that a larger drill pipe has to be recommended at the LSTD site and at the fullscale repository, it should be noted that this precaution may not suffice, as experienced in the failure of the CSD-300 where a pipe characterized by an available diameter between 13-3/8 inch and the 20-inch was used (RKE/PB, 1984). No further attempt to propose a full and adequate solution has been given or discussed.

Since a two-pass concept is suggested , M-K then suggests the use of a flat-bottom 12-foot diameter bit for the first pass. The second pass would use a 20-foot diameter tapered-bottom stage bit. The flat-bottom bit has been used more extensively in large-diameter shaft drilling. A conical bit, with a cone angle between 27° and 45° to horizontal, has also been used recently in large-diameter shaft drilling. It has been used in the previously mentioned Agnew mine. The disadvantage of using the conical bit is that the larger surface area requires more cutters to cover it. This increases the bit weight and torque requirement over the flat-bottom bit, and creates problems due to the lack of control of expected deviations in single-pass drilling (RKE/PB, 1984).

The proposed circulation system is the simple reverse circulation. The circulating fluid flows down the annulus (space between the drill pipe and outside shaft circumference), and vertically up through the drill pipe. M-K states that if a single-pass method was going to be used in the full scale repository, the circulation system determined from the use of a two-pass drilling method in the LSTD could not be applied.

Bit configuration (not mentioned in the M-K report), cutter type and the circulation system directly affect the weight to be placed on the bit for controlling the penetration rate. The rate at which the rock is removed determines the drilling rate. Various components of the circulation system must be carefully designed and well coordinated should the overall performance goals be attained. Furthermore, should the LSDT project finally justify the use of specific drilling parameters (e.g., the circulation system, torque, weight to apply to the drilling bit, types of cutters for the bit and their configuration), its objective of consistent using similar equipment at the full scale repository shafts will have to be implemented. Since no drilling has yet been successfully tested in the construction of a shaft similar to the full scale repository shafts and in a rock with high compressive strength, such an extrapolation to the RRL area can hardly be justified. The best that one may plan for in the drilling of the full scale shaft is to use equipment, similar to that used in the LSDT, consistently with the LSDT findings and adapted to greater depths. This aspect has never been mentionned in the M-K discussion. More specifically, there was no mention on whether the two-pass method will be used for both the LSDT and repository drilling, and also if the Geodril Rig 32 will be modified for the final repository construction. Finally, the M-K report cites cost and time restraints as reasons for using existing equipment that might be inadequate for the final repository shaft construction. Cost is extremely important since it is linked to the feasibility of the project, and further discussion to clarify the meaning of budgetary restraints is required.

III. Geologic Hazards Encountered during Drilling

Clay layers that hydrate and expand upon contact with water could be a potential geologic hazard. The potential for this phenomenon exists at the Hanford Site. M-K concludes, from drilling experience elsewhere on the Hanford Reservation, that local clays have not created swelling clay problems. Data regarding clay swelling in these smaller holes cannot necessarily be extrapolated to a much larger 20-foot diameter shaft (NRC, 1985). Clay behavior could differ significantly in a 20-foot diameter shaft as compared to smaller shafts previously drilled on the Hanford site. Larger surface area increases the potential for the release of materials from shaft sides due to the high anisotropic stresses present in the basalt formations (DOE 1984b).

Drillhole wall sloughing occurs when flakes, slabs or columns loosen from the sides of the shaft and fall into the hole. It can occur in unconsolidated sediments, in fractured or brecciated zones within basalt flows, or in interlayered sedimentary rocks. Conditions favorable for drillhole wall sloughing are present at the Hanford Site.

Two methods are proposed by M-K to control sloughing. One is to form a binder by pushing clay particles into the wall with a specially formulated drilling fluid. A weakness in this technique is that it involves changing the specific gravity of the drilling fluid to a weight necessary to cause clay particles to cling to the sides of the shaft. However at the same time other geologic hazards may require the drilling fluid to be at a different weight and density. When artesian conditions, very typical at the Hanford Site (Morrison-Knudsen, 1983), are encountered, the drill fluid must be weighted in order to keep water from entering the hole and moving up the shaft.

When zones of circulation loss are found, the drilling fluid characteristics must be regulated, e.g., by using control agents. The effects of combining all of the above expected geologic hazards have not been determined accurately and must be discussed in more detail.

The other method proposed by M-K to control drillhole wall sloughing is to place a cement plug into the hole and then drill through this slug leaving the cement walls for support. The uncertainties involved in this method render it unreliable. Cement hardness is affected by moisture content and the time it takes to set. Temperature affects setting time and could be determined in the shaft, but moisture conditions in the shaft may be hard to monitor, and then difficult to control. Also, when drilling through the plug, uniform wall thickness cannot be guaranteed due to non-uniform axial deviations, from the center of the shaft, made by the drill bit as drilling progresses.

Spalling, a form of sloughing, occurs when flakes or slabs fall off the drillhole wall. High horizontal anisotropic stresses present at the Hanford Site, have contributed to deterioration of existing boreholes from spalling (DOE, 1984b). Bridging or collapse of the boreholes has not happened, but the high horizontal stresses have forced flakes and slabs off the walls. Morrison-Knudsen assumes spalling will occur shortly after bit penetration. The lower reamer stabilizer, a part of the bit assembly projecting outwards to the shaft wall, is then expected to break up the spalled rocks. Breaking rocks is not its main function.

Wall slabbing, another form of sloughing, occurs when columns or slabs that line the shaft, become unstable and slip into the hole. Morrison-Knudsen reports that (1) this is unlikely to occur because the basalt columns are not vertical, but rather are tilted due to the folding of the basalt; (2) the hexaganol shape of the columnar joints that characterize the basalt allows the "locking in" of various columns with each other; and (3) interstitial filling cements the members together which prevents slabbing.

These claims concerning slabbing are of questionable validity. The columns are not of constant hexagonal shape, different columns have 4,5, or 6 sides (Rockwell, 1979). Interstitial filling does not produce a constant and solid cementing action, but rather one with many irregularities (Long and Davidson, 1981). Because drilling will penetrate the columns of basalt in a random manner, it cannot be assumed that the locking of columns will prevent large pieces of rock from being released to fall into the hole. Also, if the area is folded enough for the columns to be tilted, the potential for slabbing is increased dramatically because of the presence of both tectonic and cooling joints.

If wall slabbing does occur, Morrison-Knudsen depends upon the upper reamer-stabilizers to crush and destroy the rock slab. If the reamer-stabilizers are incapable of breaking up the rock, drilling will have to be stopped while the rocks are fished from the hole. This could result in a considerable additional expenditure of time.

Morrison-Knudsen suggests the drilling of an exploratory shaft close to the location of the LSDT. At present the nearest hole from which to obtain geologic and hydrologic data is approximately one mile away. This distance is important because the nature of volcanic terrains are such that stratigraphy cannot be extrapolated over distances as long as a mile. Conditions and rock types (particularly sedimentary rocks) encountered a mile away may not be present at the proposed LSDT Site. This fact should be considered when reviewing comments concerning geologic hazards. Also the proposed exploratory shaft near the LSDT has a considerably smaller diameter and would not necessarily give accurate indications of the magnitude of geologic hazards that might be encountered in the larger shaft. "Geotechnical information and experience gained at Hanford from the small diameter drilling program are not directly applicable to situations likely to be encountered in large diameter shaft drilling" (NRC, 1985, p10).

V. Conclusion

M-K concludes that two-pass drilling with the Geodril Rig 32 is a feasible LSDT construction method. It is believed that all drilling parameters except hole cleaning under a 20-foot diameter flat-bottom bit can be obtained or extrapolated from drilling data after completing the LSDT with the two-pass method. M-K believes that the data gained in completing the LSDT in the manner described would clarify the arguable questions regarding torques, required weights, cutter and bit body configurations, and circulating systems.

It is reasonable to believe that the 20-foot diameter, 450 to 500 foot hole for the LSDT can be excavated with existing equipment (the modified Geodril Rig 32 and 13 3/8 inch drill pipe) if the two-pass drilling method is employed.

If the 450-500 foot interval for the shaft of the LSDT starts at the surface, and the sediment layer depth is similar to that found at RRL-2 drill hole one mile away (640-foot depth to hard basalt flows), the 20-foot diameter shaft would not encounter basalt, and no information useful for repository shaft drilling through basalt would be obtained. If no actual drilling through the hard basalt takes place, the technological data obtained would not be useful for repository shaft drilling.

Assuming basalt is encountered, some information regarding torque capability, rig weight-lifting capacity, types of bits, types of cutters and their configuration, and the circulation system could be utilized in the final drilling for the repository shafts. This information, however, would in no way insure that the repository shafts could be drilled without utilizing engineering measures beyond reasonably available technology. "It is theoretically possible to assess the total capability of a drilling system by analyzing the capability of its individual components. This method is not perfect because the components can be, and are, matched by different manufacturers in different ways so that the total system capability is not always a direct function of component capabilities" (RKE/PB, 1984,P.6-37). Also, with such a large diameter hole, reactions of the rock to drilling may be quite different than what has occurred during and after drilling of the smaller diameter holes. Therefore, the validity of extrapolating small diameter hole drilling information to a large hole is questionable.

The M-K report fails to mention the techniques used in the second reaming pass of the two-pass method. Multiple pass drilling is limited by cutter and flushing systems technology for conditions similar to Hanford (RKE/PB 1984). The LSDT report mentions that hole cleaning parameters cannot be obtained from a two-pass method. This would be unfortunate if a single-pass method was decided to be used in repository shaft drilling.

The geologic hazards possible at the Hanford Site may restrict or stop drilling of the LSDT shaft and repository shafts. No rock formation similar to that found at the Hanford Site has ever been proven capable of supporting a 20-foot diameter shaft like that proposed in the LSDT. A 20-foot diameter shaft, 3,400-3,900 feet deep, necessary for the nuclear repository, has never been constructed. The Agnew Mine in Western Australia, with a depth of 2,460 feet, and 14 feet in diameter is the only shaft of somewhat similar scale as those proposed at the Hanford Site, The Agnew Mine project, drilled through rock with as high a compressive strength as that found at Hanford, failed at 2,460 feet, and the shafts at the Hanford Site must reach 3400-3900 feet. The equipment necessary for the LSDT and repository shaft construction has not proven itself in any similar circumstances. Geologic hazards have never been handled in basalt of this high a compressive strength in a shaft with a diameter of 20 feet. The high horizontal anisotropic stress, brecciated and sedimentary layers, and possibility of artesian conditions allow many geologic hazards to exist. Therefore, there exists the potential of encountering rock conditions that could require engineering measures beyond reasonably available technology for the construction and operation of the repository.

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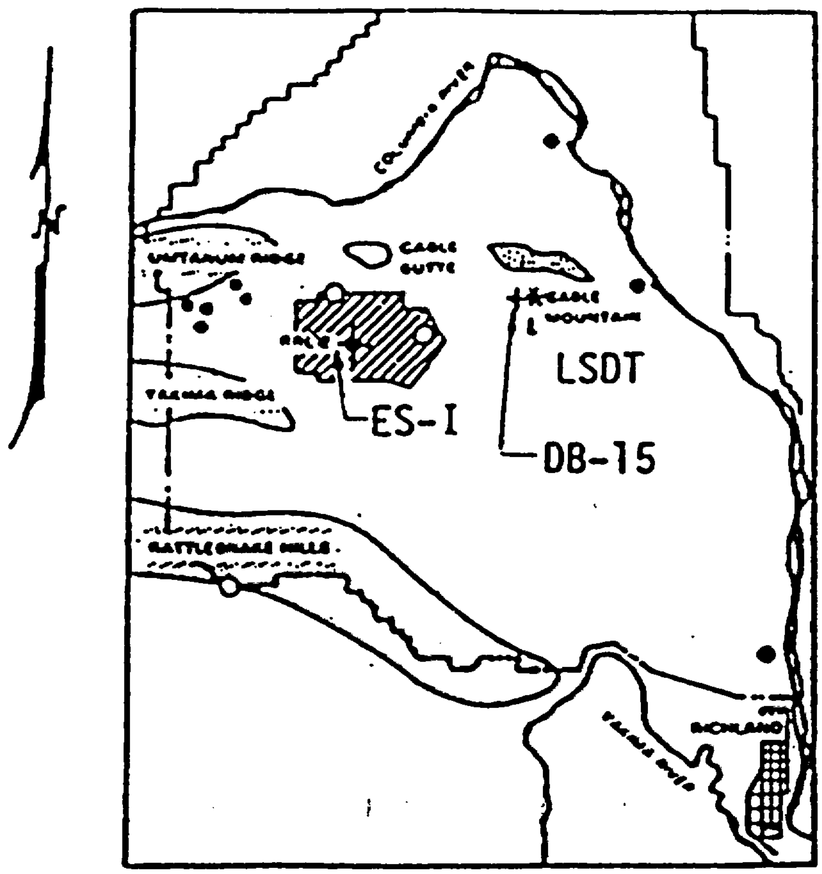

(Adapted from the M-K Report, 1986)

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ROCKWELL-RECOMMENDED
LOCATION OF THE LSDT

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