ATTACHMENT 1

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

In Reply Refer To:
WGS-Mail Stop 410

May 29, 1987

Dr. Robert E. Browning
Director, Division of Waste Management
Office of Nuclear Material Safety and
Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Browning:

This is in response to your request of February 18, 1987, for a technical review by the U.S. Geological Survey of the document "Report to Nuclear Regulatory Commission on Re-Review of Clifton's Groundwater Travel Time Evaluation" by Nuclear Waste Consultants (NWC), January 13, 1987. The time for our review was somewhat greater than anticipated because it became necessary for our reviewers to be technically familiar with the supporting documents, the first NWC review, and the original Clifton report.

Geological Survey contributors to this review were Paul Hsieh, Menlo Park, California; Ren Jen Sun, Reston, Virginia; Brian Drost, Tacoma, Washington; and Ken Kipp, Denver, Colorado. The reviewers comments are summarized in the enclosed review document.

Sincerely,

George A. Dinwiddie
Chief, Branch of
Nuclear Waste Hydrology

Enclosure

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COMMENTS BY THE U.S. GEOLOGICAL SURVEY ON "REPORT TO NUCLEAR REGULATORY COMMISSION ON RE-REVIEW OF CLIFTON'S GROUNDWATER TRAVEL TIME" PREPARED BY ADRIAN BROWN, NUCLEAR WASTE CONSULTANTS (Report 1074/86/2, January 13, 1987).

The principal focus of our comments is on the subject report (Brown, 1987) from Nuclear Waste Consultants (NWC); however, other documents pertinent to understanding the subject report include the original Clifton (1986) report, the first review by NWC (Kreager-Rovey and Brown, 1986), a review of Clifton (1986) by Djerrari, et al. (1986) of Earth Water Air, Inc. (EWA), and reviews of NWC reviews by Dagan, et al. (1987) of EWA.

The main issue to be addressed in our comments is the difference between the ground-water travel times (GWTT) calculated by Clifton (1986) and by Brown (1987). Clifton (1986, p. 46) concludes that "the exceedance probability for a pre-waste-emplacement ground-water travel time of 1,000 years is at least 0.97" and "the exceedance probability for a pre-waste-emplacement groundwater-travel time of 10,000 years is at least 0.78." In contrast, Brown (1987, p. 40) concludes that "there is a significant likelihood that the BWIP site will fail the 1,000 year groundwater travel time requirement as currently interpreted in the staff's draft technical position." In Appendix D, Brown (1987, p. D-7) states that "the probability that the GWTT...would actually exceed 1000 years was computed to be 49%..." This indicates that the expected probability would be 51 percent that the calculated GWTT is less than or equal to 1,000 years. Such disagreement in calculated GWTT results from different values for effective porosity, as mentioned both by Brown (1987, p.9) and by Dagan, et al. (1987, p. 16).

Clifton (1986) actually works with transmissivity and effective thickness. However, by dividing both quantities by an assumed thickness of flow top, one can also work with hydraulic conductivity and effective porosity. Clifton (1986, p. 20-21) assumes that the effective thickness is a random variable with a uniform probability distribution over the range from 0.001 to 0.1 meter. By assuming a flow top thickness of 10 meters, Brown converts Clifton's effective thickness range to an effective porosity range from 0.0001 to 0.01. Since Clifton assumes that the effective thickness is uniformly distributd, it follows that the effective porosity is also uniformly distributed. The arithmetic mean of the effective porosity is about 0.005, while the geometric mean is 0.0039. As pointed out by Dagan, et al. (1987, p. 18), Brown (1987, p. 34) incorrectly states that the geometric mean of Clifton's effective porosity range is 0.005 and that the probability distribution is normal. Brown (1987) assumes a geometric mean effective porosity of 0.00016. This value is 1/24th of the geometric mean used by Clifton. Thus, one would expect that the mean GWTT computed by Brown should be about 1/24th of that computed by Clifton. In fact, the mean GWTT computed by Brown (1987, Appendix D, p. D-6) is 1,057 years. Clifton does not compute the mean GWTT but reports the median. For his Model 1 with 0 km log-transmissivity correlation range (equivalent to the analysis of Brown), the median is given as 22,000 years (see Clifton, 1986, p. 26). Assuming that the median is close to the mean, one can see that the mean GWTT calculated by Brown is about 1/20th of that calculated by Clifton.

The sole tracer test at the site yielded an effective thickness of 0.002 meter. Clifton considers this value to be at the lower end of the effective thickness range. To support this contention, Clifton (1986, p. 20) sites higher values of effective thickness inferred from core samples as well as the result of a survey of expert opinions. Brown, on the other hand, considers the effective thickness of 0.002 to be a mean value (specifically, a geometric mean). Using a flow top thickness of 12.5 meters, he therefore obtains a geometric mean effective porosity of 0.00016. Brown (1987, p. 31-32) sites two studies to support his position. The first is a study of effective porosity of fractured granodiorite by Brotzen (1986). However, it is not clear how this study supports Brown's contention. In fact, Brown (1987, p. 31) states that "The geometric mean hydraulic conductivity of the flow tops of interest in basalt at Hanford is 1E-7, which would suggest a porosity value in the order of 0.1%" (based on Brotzen's study). This value (0.001) is an order of magnitude larger than the geometric mean effective porosity used by Brown. The second study sited by Brown is the parallel plate model of fracture flow. Brown (1987, p. 31) writes that "For an average hydraulic conductivity of 1E-07, the parallel plate theory porosity would be about 1E-04, about the same as the value reported for the basalt test." However, what Brown fails to mention is that according to the parallel-plate model, the porosity is a function of hydraulic conductivity as well as fracture spacing (see Snow, 1968, p. 80). Brown apparently based his calculation on a fracture spacing of 0.05 meter, as noted in Figure 2, but he sites no basis for this value. If this value is chosen so that the computed porosity is 0.0001, then the reasoning is circular and does not support the contention that 0.00016 should be a mean value for effective porosity. In addition, Dagan, et al. (1987, p. 19) question the appropriateness of the parallel-plate model, noting in particular that the model does not consider clay filled fractures, which are commonly observed at the Hanford site.

Dagan, et al. (1987) raise a number of comments that are worthwhile to summarize here. In general, these comments point out that Brown's (1987) analysis is not "conservative" as he had claimed. Both Brown (1987, pp. 11-12) and Dagan (1987, p. 6) clearly state what is meant by conservative. In the case of Clifton's analysis, the hypothesis being tested is that there is a high probability that the GWTT exceeds 1,000 years. Thus the conservative approach in Clifton's analysis is to adopt assumptions that tend to underestimate the GWTT. In the case of Brown's analysis, the hypothesis being tested is that there is a high probability that the GWTT is less than 1,000 years. Thus, the conservative approach in Brown's analysis is to adopt assumptions that tend to overestimate the GWTT. Dagan, et al. pointed out that Brown's analysis is not conservative because the analysis adopts assumptions which underestimate, rather than overestimate, GWTT. These assumptions are: (1) zero correlation range (or vanishing integral scale) for log-transmissivity and (2) lack of correlation between log-transmissivity and log-effective thickness. In general, the comments of Dagan, et al. (1987) seem to be well thought out.

In summary, resolution of the difference in GWTT between Clifton and Brown, although necessary, is likely to be inconclusive until adequate, additional data on effective porosity are available from the controlled area. The data from which Clifton and Brown derive their effective porosity/effective thickness range are, at best, tenuous. The report by Clifton is merely a demonstration of technology (i.e., development of theoretical formulation and computor codes) with which to calculate GWTT. The approach of Brown is perceived as a simplified (using the Darcy formula) and more restrictive (in the sense that more assumptions are invoked) method that approximates Clifton's analysis.

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asymetrical lognormal distribution towards the lower effective porosities. This manipulation of the bounds (taken quite arbitrarily by Clifton (1986) for a rectangular distribution) is highly questionable.

D. MINOR COMMENTS

In Table 2 of TT/NWC (1987), under STATISTICS OF LOGARITHMS, GEOM MEAN should be replaced by MEAN. TT/NWC (1987) seem to refer to Figure 4 rather than 5 (p. 29, line 10 from the bottom). The geometric mean transmissivity is in units of m2/day and not in units of m2/s as mentioned on page 29 (TT/NWC, 1987, 8 lines from the bottom) and page 30 (8 lines from the top). On page 30, line 13 from the top of TT/NWC (1987), "log mean hydraulic conductivity" should be "mean of the log hydraulic conductivity". The same comment applies to page 31, "log mean gradient" should be "mean log gradient". Finally, the date of the report should be January 13, 1987 rather than January 13, 1986.

E. CONCLUSIONS AND RECOMMENDATIONS

The main differences between the TT/NWC reviews and Clifton's report are in the assumed geometric mean of the effective porosity. TT/NWC uses a value 24 times smaller than the value assumed in Clifton's report. As a result of this assumption groundwater travel times calculated by TT/NWC would be about 24 times shorter than those calculated by Clifton.

TT/NWC neglect spatial correlation in the log transmissivity and thus, overestimates effective log transmissivities. As a result, travel times calculated by TT/NWC are on the low side.

Although TT/NWC raise some valid points, the arguments they employed to refute the range of effective porosity adopted by Clifton are untenable.

There is a consensus among various investigators that additional field tests are needed in order to arrive at more reliable estimates of GWTT. It is obvious that additional information must be obtained regarding appropriate values and variability of effective thickness and porosity. However, at the same time, a more complete probabilistic analysis is required. This analysis would also suggest the kind of data that would be most useful in the analysis.

In view of the cost and duration of such tests, it is crucial to concentrate the efforts on those tests which have a large impact on the estimation of GWTT. As a result of their conclusions concerning the effective porosity, TT/NWC (1987, p. 39) recommend that field investigations focus on measurements of effective porosity.

In contrast, Clifton's (1986) simulations and the analytical approach of GWTT CDF (Djerrari et al., 1986) show that the probability distribution of GWTT is very sensitive to the assumed correlation length. Therefore, the determination of the transmissivity integral scale, by measurements of transmissivity, is regarded as of paramount importance. Although a few more values of measured $\bar{n}$ are recommended, by no means should they come at the expense of transmissivity. The danger is that if the porosity data are such that the site passes the GWTT requirement for a zero integral scale, as assumed by TT/NWC, the opposite might be true for a finite integral scale.

Uninformed conservativism does not necessarily lead to good decisions. In the case of the nuclear waste isolation projects, it could easily lead to the decision to disqualify all sites. For the Hanford Site, a combination of conservative assumptions about the flow path, the value of the effective porosity, the correlation length of the log transmissivity, lack of correlation between log transmissivity and log effective thickness, and the unconditional probabilities approach followed would yield results which would suggest that the site should be disqualified. Instead, what is needed is to pursue a more complete probabilistic analysis in parallel to site characterization efforts.

Regulatory agencies should specify the needed safety levels more accurately (e.g., in terms of probabilities that the pre-emplacement travel time exceeds 1,000 years). Then the nature of uncertainties should be understood and incorporated in the analysis. For example, no matter how many measurements are obtained, the uncertainty about the correlation length of log transmissivity would always be large.

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