TRANSPORT IN THE WOLFCAMP BY HORIZONTAL POROUS MEDIA FLOW

DEAF SMITH COUNTY SITE, PALO DURO BASIN

Numerical Evaluation of Conceptual Models
Subtask 3.5
Mini-Performance Assessment Report #4

July 31, 1986

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1.0 INTRODUCTION

1.1 General Statement of the Problem

This analysis is a mini-assessment of a particular aspect of the hydrogeology of the Deaf Smith County Salt Site as it pertains to the NRC's licensing criteria, or more specifically, to the requirements outlined in 40CFR191 and 10CFR60. Certain simplifying assumptions have been made in this evaluation that should be considered when comparing the results of this case study to any other.

This case study is aimed at determining the range of permeability values that would be required in the Wolfcamp aquifer, below the repository horizon in the HSU C zone, that would make horizontal flow to the accessible environment significant. Comparing this result with the estimated range of permeabilities presented in the Environmental Assessment (EA) should allow us to qualitatively evaluate the level of effort needed for additional site characterization. For example, if the limiting permeability of the Wolfcamp determined from this analysis is much greater than values reported in the EA, then we may conclude that the average travel time of nuclides through the Wolfcamp to the accessible environment is in excess of 10,000 years, given the assumptions made herein. Therefore one might conclude that the amount of site characterization work needed to quantify horizontal permeabilities in the Wolfcamp is limited. However, if the limiting permeabilities determined in this analysis are on the same order of magnitude as those reported in the EA, then one might conclude that a substantial amount of work was needed to quantify horizontal permeabilities to ascertain whether or not the travel path and travel time criteria specified in 10CFR60 is met. Assumptions made in this analysis, such as length of travel path and travel time, are based upon the criteria specified in 10CFR60.

1.2 Relevance to the NRC Waste Management Program

DOE General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, 10CFR960, indicates that in order for the site to qualify for characterization, the pre-emplacement ground-water travel time to the accessible environment must exceed 1000 years. NRC and EPA regulatory requirements, 10CFR60 and 40CFR191, for license approval list maximum allowable cumulative quantities of radionuclides which could be released to the accessible environment over a 10,000 year period. This mass flux is controlled to a great extent by ground-water travel time. Numerical and analytical models can be used to calculate ground-water travel times. In the analysis presented here we are in effect determining the extent to which horizontal flow paths through the Wolfcamp formation below the repository horizon contribute to meeting the 10,000 year criteria.

1.3 Relationship to Other Subtasks, Analyses, and Documents

The analysis presented here is very simplified, but nevertheless useful toward guiding, or evaluating, the site characterization phase of work that is to come. Identifying the hydrogeologic parameters of prime importance to be used in evaluating the travel time and travel path criteria outlined in 10CFR60 should aid in directing the testing and sampling strategies during site characterization.

2.0 OBJECTIVE

This analysis is intended to address what range of horizontal hydraulic conductivity values would be necessary in the Wolfcamp aquifer, beneath the repository in the HSU C zone, to allow the release of nuclides to the accessible environment 5 km down-gradient from the repository and over a 10,000 year period to meet the EPA limit for the subject case of horizontal flow alone, given our current understanding of the porosity and potential head gradients.

3.0 GENERAL APPROACH

3.1 Hydrogeologic Setting

The Palo Duro Basin is comprised of three zones of hydrostratigraphic units (HSU). Figure 1 depicts a generalized cross-section in the area of the proposed repository. The HSU A zone is a fresh-water aquifer. The HSU B zone is comprised of a series of sedimentary interbeds, with the proposed repository located in the San Andres Formation Unit 4 salt bed. The HSU C zone is chiefly considered a brine aquifer, which is underlain by

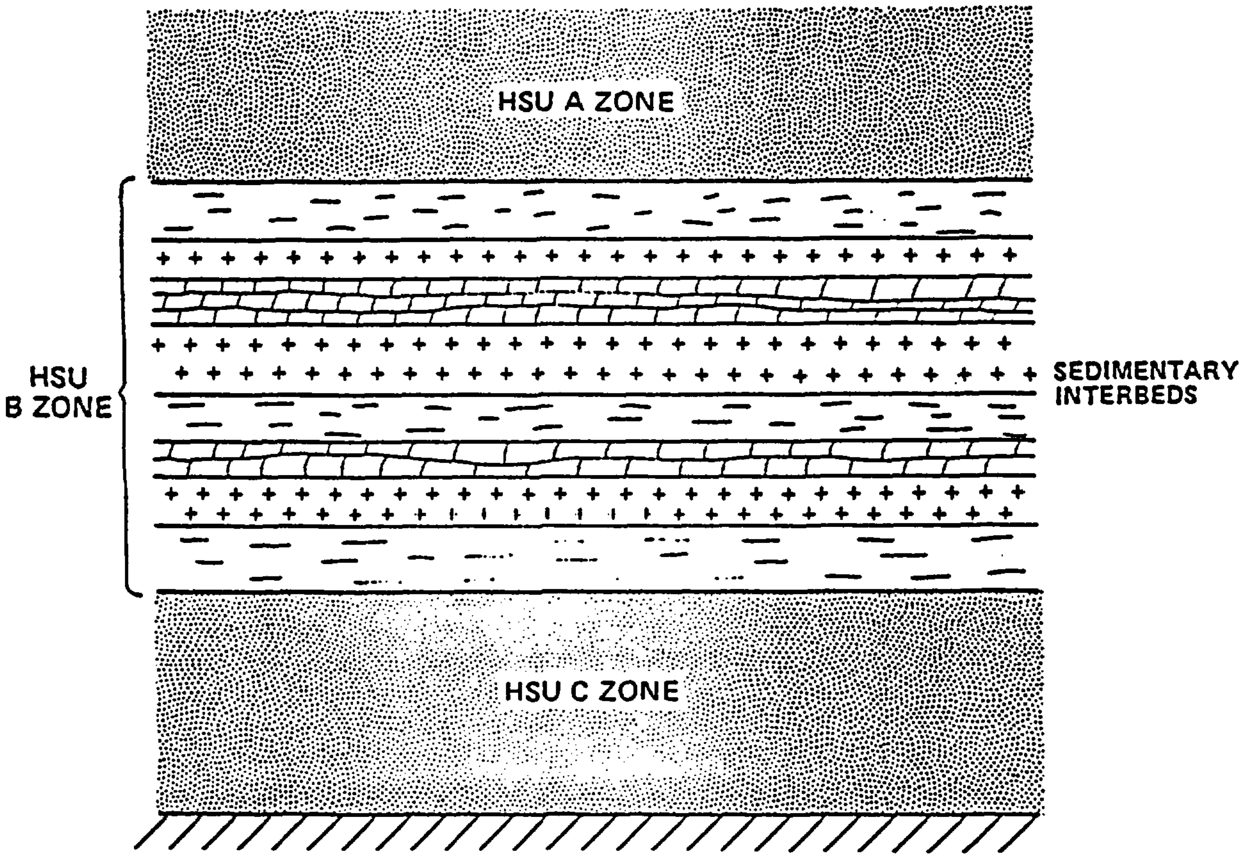

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Figure 1. Idealized cross-section of the Palo Duro basin stratigraphic units.

bedrock.

3.2 Concepts Used for Analysis

In this analysis, we will assume that horizontal porous media flow can occur through the Wolfcamp aquifer, the uppermost unit of the HSU C zone, and that vertical flow from the repository through the sedimentary interbeds is negligible. Nuclides emanating from the repository will therefore travel vertically downward to the Wolfcamp instantaneously. Upon contacting the Wolfcamp, it is assumed that the nuclides are transported 5 km horizontally to the accessible environment. Figure 2 represents the generalized cross-section for this transport mechanism. The acceptable travel time under these criteria would be 10,000 years. Applying a darcian approach to this ground-water flow problem would allow us to use existing porosity and hydraulic gradient data to estimate the range of hydraulic conductivity values necessary to meet the requirements of 10CFR60.

4.0 TECHNICAL APPROACH

4.1 Statement of Problem

Given the three layer system described above, where the middle zone is comprised of less permeable material which acts as an aquitard between two aquifers, in which the upper aquifer has a higher head potential than the lower aquifer, we can assume that water moving through the aquitard is moving vertically downward, and then horizontally when it reaches the Wolfcamp. A

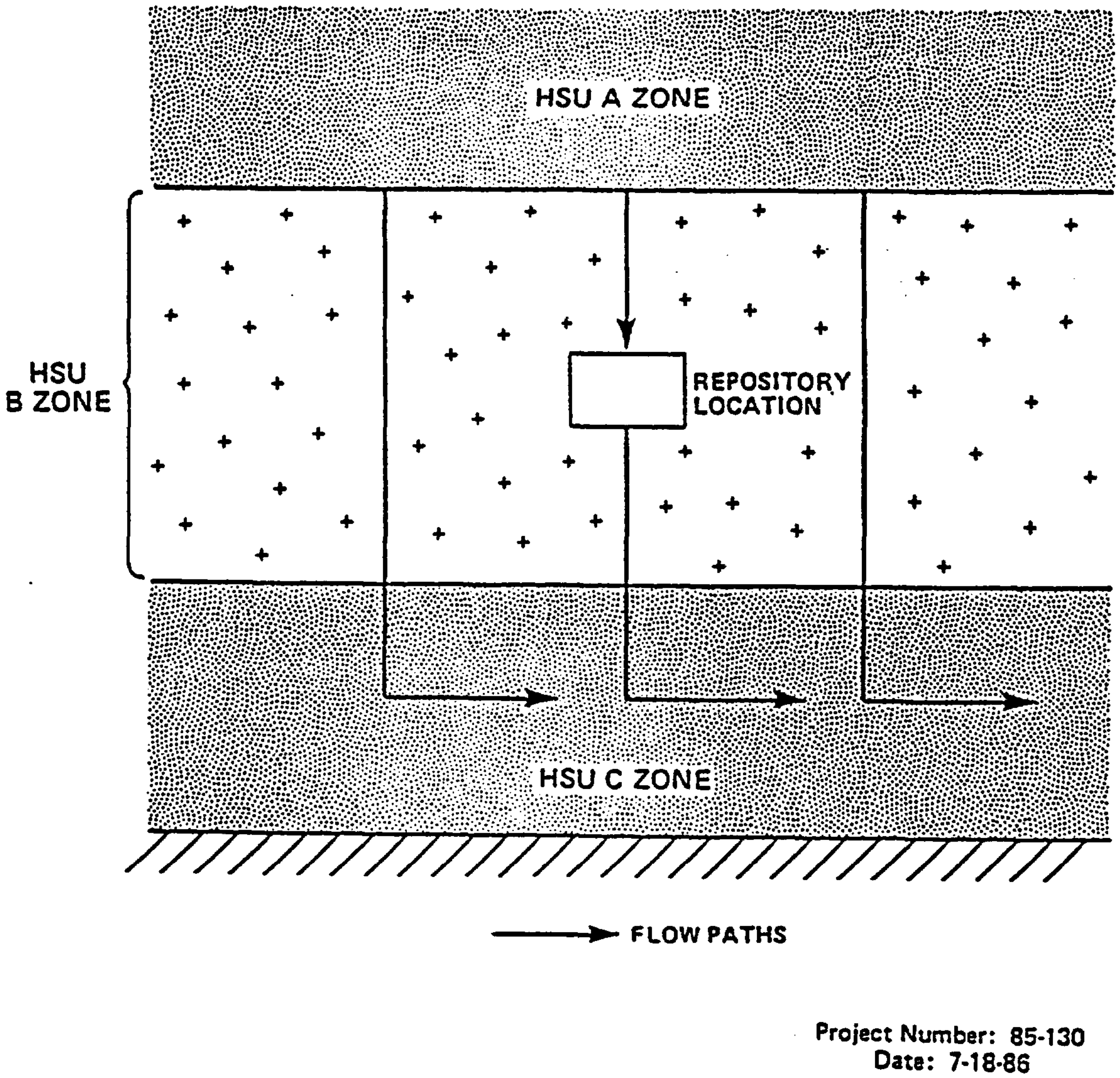

Figure 2. Idealized flow paths for horizontal porous media flow through the Wolfcamp.

darcian approach to estimating the flux of water through the Wolfcamp can then be applied, assuming that nuclides travel from the repository horizon vertically downward to the Wolfcamp instantaneously. Given the current knowledge of porosity and head gradients within the Wolfcamp, combined with the limiting travel path and travel time criteria from 10CFR60, will allow us to solve for the limiting hydraulic conductivity values that would classify this site as favorable.

4.2 Solution Technique

We have assumed that horizontal darcian flow occurs within the Wolfcamp aquifer. The governing equation describing the pore velocity is:

$$V = q/n = Ki/n = L/t$$

where:
- V = pore velocity [L/T]
- q = darcy flux [L/T]
- n = effective porosity
- i = hydraulic gradient [L/L]
- K = hydraulic conductivity [L/T]
- L = length of travel path [L]
- t = travel time [T]

This equation can then be rearranged to solve for K, and estimates made for the remaining parameters based upon data presented in the EA and the regulatory criteria of 10CFR60.

4.3 Assumptions

The following assumptions were made for this analysis, and should be considered when comparing the results of this study to any other:

- one-dimensional, steady horizontal flow
- isothermal conditions
- constant fluid density
- homogeneous and isotropic medium
- no fracture permeability, strictly porous media flow
- radionuclides emanating from the repository are instantaneously transported vertically downward to the Wolfcamp

4.4 Application of Solution

The travel time assumed for nuclides to move from the repository to the accessible environment 5 km away is 10,000 years. The resulting estimates of hydraulic conductivity can then be compared to the measured or calculated values reported in the EA. If the predicted range of hydraulic conductivity values from this analysis is much greater than the values reported in the EA, and those values reported in the EA are considered statistically representative, then it might be concluded that only minimal assessment of the hydraulic conductivity of the HSU C units is necessary in the future. In other words, if the values of permeability reported in the EA are considerably less than the limiting values calculated in this analysis, then the darcian flux through the HSU C zone should be of such a magnitude that the average travel time through the Wolfcamp to the accessible environment is in excess of 10,000 years. On the other hand, considering the simplicity of this analysis, or the sparcity of field data, it may be advisable to put together a more detailed site characterization plan.

5.0 ANALYSES

Based upon the preceding assumptions and governing flow equation we need to obtain estimates of the effective porosity and the horizontal hydraulic gradient through the Wolfcamp aquifer.

According to the EA, effective porosity values for the Wolfcamp in the HSU C zone range from 3.4% to 21.3%.

Figure 3-61 in the EA depicts the estimated potentiometric surface for the Wolfcamp. From this figure we can estimate the hydraulic head gradient within 5 km of the repository to be approximately 0.0052.

Table 1 presents a summary of the input data to this model.

6.0 RESULTS

Based upon a travel time of 10,000 years and a travel path of 5 km, the average pore velocity of nuclides in the Wolfcamp would be about 1.64 feet/year. Using the low estimate of effective porosity, the estimated maximum acceptable value of K would be 11 feet/year (11 md). With a porosity of 21.3%, the estimated K would be 67 feet/year (67 md).

7.0 CONCLUSIONS

The results just presented show that given our current

TABLE 1 - ESTIMATED HYDRAULIC PARAMETERS FOR MODEL #4 INPUT

PARAMETER	VALUES
Length of Travel Path	16,400 feet
Travel Time	10,000 years
Horizontal Head Gradient	0.0052 feet/feet
Effective Porosity	3.4% to 21.3%

understanding of the gradient across the Wolfcamp, and a possible range of effective porosity values between 3.4% and 21.3%, the effective hydraulic conductivity could range from 11 to 67 md, respectively. The limited amount of permeability testing that has been done in the HSU C zone suggests that the permeability of the Wolfcamp ranges anywhere from 0.03 to 262 md. Therefore it cannot be shown that horizontal flow in the HSU C zone alone would allow a demonstration that the site meets the EPA release limits required by 10CFR60 with the data currently available, given the assumptions applied in this analysis.

8.0 DISCUSSION

Because the preceding analysis did not appear to yield a definitive difference between the predicted hydraulic conductivity range and that which was obtained through testing or calculations and presented in the EA, it would appear that additional site characterization with reqard to quantifying the horizontal permeability of the HSU C units might be needed if the assumptions used in this analysis are warranted. Also, the hydraulic data used in this analysis, as reported in the EA, was not obtained from the near field, but taken from wells off-site or from generic values in the scientific literature. On this basis it might be appropriate to consider additional site characterization of the permeability of the HSU C units, as well as additional porosity and head data.

It should be noted, also, that the assumption of instantaneous travel time of nuclides from the repository at the HSU B/Wolfcamp boundary is conservative. Another mini-performance assessment coupling vertical flow through the HSU B zone and horizontal flow through the Wolfcamp to the accessible environment might not conclude that a significant amount of additional data is needed to characterize the permeability of the Wolfcamp.

Also, the permeability values reported in the EA covered a very wide range (four orders of magnitude). The EA values reported above, 0.03 to 262 md, were from the Texas Bureau of Economic Geology (TBEG) analyses of Drill Stem Test data. The DOE values of permeability cover a much smaller range, 0.1 to 26.6 md (a little over two orders of magnitude). Presumably both the DOE and TBEG values were derived from the same data base. Additional work might be warranted with regard to re-analyzing the existing permeability test data to determine what range of values might be representative. At that time the case study just presented could be re-evaluated to better determine the need for, or amount of, additional site characterization work to be carried out.

9.0 REFERENCES

U.S. Department of Energy, 1986, Environmental Assessment, Deaf Smith County Site, Texas, DOE/RW-0069, Vol. 1.