see ltr to Linehan fm. Hinchman 1/4/85 106.1

REVIEW AND EVALUATION OF THE GIBSON DOME HIGH LEVEL NUCLEAR WASTE REPOSITORY ENVIRONMENTAL ASSESSMENT: GEOHYDROLOGIC ISSUES

by

Christopher J. Duffy
and
Brad Hall

Utah State University
Logan, Utah 84322

December 8, 1984

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background/Authorization

This report is meant to provide a technical review and evaluation of Department of Energy documents concerning groundwater, radionuclide travel time and monitoring issues relative to siting a high level nuclear waste repository in the Gibson Dome area in Southern Utah. In so doing we have, during a relatively short period of time, examined in detail the Department of Energy Guidelines concerning high level nuclear waste disposal (1983) including revisions (1984), and each draft of the Environmental Assessments for Davis and Lavender Canyon, up to and including the fifth draft (dated July 27, 1984). In addition, a large body of supporting DOE documents and relevant published research literature was carefully examined and incorporated into this report.

Our approach to the review and evaluation process has been to examine the assumptions analysis procedures, conclusions and supporting data regarding groundwater, radionuclide travel time and monitoring issues for the Davis and Lavender Canyon Environmental Assessments, and to provide an independent appraisal of the DOE approach and assessment of these issues.

This work is carried out under a contract with the State of Utah Office of Planning and Budget (Contract No. 85-0205).

2.0 REVIEW AND EVALUATION OF GROUNDWATER ISSUES

2.1 Summary of Groundwater Issues

In general, our most serious concern about the groundwater issues in the Davis and Lavender Canyon Environmental Assessments has to do with the very minimal effort that has been made to date to characterize hydraulic conditions in the region surrounding the proposed repositories and along expected travel paths. It seems remarkable that the siting procedure has come so far based on a single observation well in the impacted area. It appears that no other proposed repository site has this little information on which to make quantitative assessments. In our estimation, part of the problem stems from the mistaken view that, because the flat-lying hydrostratigraphic units of the Colorado Plateau can be identified and correlated over large distances, hydraulic properties can be inferred or extrapolated over large distances (1-10's of km) as well, and therefore additional field data are unnecessary or redundant. In other words, because a satisfactory geologic model is available for the western Paradox Basin, the hydraulic model is also "realistic" and well-defined. It is our opinion that because of the large degree of spatial variability of hydraulic properties evident in the regional data base and in GD-1, and the likelihood of the existence of discrete hydraulic features (such as joints, fractures and dissolution conduits), that hydraulic characterization in the impacted area is premature. We feel that, at present, the data base available for the Gibson Dome sites is inadequate to make quantitative predictions and assessments about the hydrologic performance of these sites.

A second concern we have is with regard to the use and application of groundwater model predictions as a substitute for "hard field data" in the region surrounding the proposed repository. It is our opinion that the use of sophisticated models with a generic data base does not constitute a "realistic" prediction of performance. Here again we feel that the only way to make quantitative and reliable assessments of hydrologic performance (velocity and travel time) is on the strength of reliable field data and supported by verifiable model studies. Model results provide no substitute for field data.

2.2 Hydraulic Properties of Hydrostratigraphic Units

An early comprehensive regional study of the hydrodynamics of the Paradox Basin can be found in Hanshaw and Hill (1969). The hydrogeologic interpretations of these authors seem to provide the basic conceptual framework on which subsequent studies have been based. Huntoon (1979) and Weir et al (1983) provide additional valuable interpretations of the hydrogeology of the western Paradox Basin. The three hydrostratigraphic units defined in the Environmental Assessments of Davis and Lavender Canyon and described in ONWI 290 and 491 are the same as those suggested by Hanshaw and Hill (1969) with slight modifications. However, the description of the three hydrostratigraphic units in the Environmental Assessments rely almost totally on the data from GD-1, a single borehole located several miles from either repository site. Because the hydraulic conductivity and porosity of the consolidated hydrostratigraphic units of the Colorado Plateau are likely the result of secondary, fracturing, faulting and solution, we can expect large blocks of low hydraulic conductivity in the region (Huntoon, p. 45, 1979),

interspersed with zones of higher hydraulic conductivity. A single borehole would not be considered representative of regional aquifer properties under almost any field situation, but especially not here where the fluid transport properties were developed subsequent to deposition and burial. Evidence for secondary permeability and porosity is found in data from GD-1. Laboratory measurements on cores of the rock matrix are consistantly lower than the drill stem tests (Figure 3-38, Davis Canyon E.A.). The drill stem tests are effectively measuring the total permeability (and porosity), which apparently is controlled by jointing, fracturing and/or dissolution. The reliance of the environmental assessment on data from a single borehole, is not in our opinion good hydrogeologic judgment.

There is an overall failure in the E.A.'s to recognize that presently, the only way to make realistic or conservative estimates of the hydrologic performance of the potential repository, is from a statistical analysis of the regional data base (Table 3-11, Davis Canyon, Table 3-11, Lavender Canyon). Hydraulic conductivity data for a single observation well (such as GD-1) could fall anywhere within a 6 order of magnitude range (see Fig. 3-38, p. 3-185, David Canyon E.A.). This is obviously inappropriate for assigning velocities or travel time over the entire the impacted area. A statistical methodology incorporating regional data statistics for hydraulic conductivity and porosity would be an appropriate approach to preliminary velocity--travel time estimation. Using regional data for hydraulic conductivity and porosity would not underestimate the quality of data derived from petroleum exploration. This is discussed in greater detail in Section 3.3.

The second point of concern regarding the hydraulic data base has to do with the statement in both the Davis (p. 6-87) and Lavender Canyon (p. 6-90) E.A. that "geologic correlation between boreholes spaced as much as 32 kilometers (20 miles) apart is an acceptable practice with a fairly high confidence level in this particular setting."

Although the unique geology of the Colorado Plateau is such that geologic correlation over large distances is possible, the context of the above statement in the text should not be construed to mean that geologic correlation and the correlation of hydraulic properties (porosity, hydraulic conductivity) over large distances are the same, as is done in the E.A.'s and in the groundwater modeling study (ONWI/TR32/TR17, 1983, 1984). It is safe to say that each of the hydrostratigraphic units in the Gibson Dome area are subject to several orders of magnitude change in hydraulic conductivity, even over relatively short distances between boreholes (say 10-100 meters). Again, the E.A. does not discuss uncertainties in data or processes using any recognized framework of risk and/or statistical analysis.

A third point of general concern is that the Environmental Assessments make no attempt to resolve the potential impact of discrete hydraulic features such as fractures, faults, joints and dissolution conduits. The potential of these features to dominate the rate of groundwater flow and contaminant transport along expected flowpaths would seem to be extremely significant in this geologic environment. Neglecting the possibility of flow in discrete hydraulic features, and estimating velocities based on the matrix permeability and porosity of the consolidated rocks will drastically underestimate the velocity and overestimate the travel time of contaminants in the impacted hydrogeologic zones.

Detailed Comments: The Pinkerton Trail Formation, the upper-most formation of the lower hydrostratigraphic, unit is suggested to be aquitard in both E.A.'s Although the hydraulic conductivity for the Pinkerton Trail Formation is low in GD-1, on a regional basis Hanshaw and Hill (1969) refer to it as the Pinkerton Trail Aquifer, a limestone characterized by low potentiometric gradients, and "indicates favorable conditions for petroleum accumulations." This would indicate that at least locally, the Pinkerton Trail Formation would not serve as an aquitard.

The assumption is made that the middle hydrostratigraphic unit is impermeable with the conclusion that essentially no groundwater moves through the proposed repository rock. This assumption is not necessarily supported by regional data or even with the data from GD-1, where the hydraulic conductivity ranges between 10^{-5} cm/sec and 10^{-10} cm/sec (Fig. 3-38, Davis Canyon E.A.). Obviously these would be considered low values of hydraulic conductivity, however, they do not suggest impermeability.

2.3 Regional Potentiometric Surfaces

General Comment: Regional potentiometric surface maps for each of the important hydrostratigraphic units in the Paradox Basin were orginally presented by Hanshaw and Hill (1969). In this study the potentiometric contours were constructed by interpolation of point data from widely spaced (1-10's of miles) oil and gas exploration wells. The authors of this study, recognizing the uncertainty in the contoured potentiometric surfaces, confined their interpretations of the hydrodynamics of the Paradox Basin to large scale conceptualizations of the flow paths, aquifer interconnections and boundaries of the system.

This approach is quite useful for establishing the regional hydrologic framework such as boundary conditions, recharge and discharge areas, generalized flow directions, etc., however it does not provide the detailed hydraulic head data necessary for estimating the direction and magnitude of local velocities associated with potential contaminant transport from a waste repository. With the exception of GD-1, essentially no hydraulic head data exist between the potential repositories and the accessible environment (Colorado River). In addition there is no plan to collect this data since the site characterization plan (Chapter 4) suggests that drilling will not be performed or will be performed in a limited way within the national park boundaries, which comprise most of the expected travel path from the sites.

Having carefully read the first and second status reports (ONWI/E512-02900/TR-32 . . ./TR-17, 1983, 1984) concerning regional groundwater flow modeling, it is apparent that simulated hydraulic head contours will be substituted for actual field data in the region to the west of the repository sites. It seems reasonable to point out here that model results are no substitute for field data, and performance estimates based on modeling results without field data for model verification are essentially meaningless. This is discussed in a following section in more detail.

Detailed Comments: The E.A.'s for Davis and Lavender Canyon sites go to great lengths to argue that the upper and lower hydrostratigraphic units are hydraulically isolated by the middle unit (taken to be impermeable except at the Shay Graben and Lockhart Basin). Other authors provide differing interpretations of the relative interconnection of these strata (Hanshaw and Hill, 1969, p. 285): "The potentiometric

surfaces of Mississippian and Pennsylvanian (lower and middle hydrostratigraphic units respectively) aquifer systems (their Figs. 2, 5, 6, 7) are quite similar in their major aspects. Because Mississippian strata crop out in very few places and over limited areal extent, we suggested previously that this aquifer (Leadville) receives most of its recharge from cross-formational flow from overlying strata." The above situation may very well be occurring in the region surrounding the Davis and Lavender Canyon sites given that the higher potentiometric level in the upper hydrostratigraphic unit indicates recharge and the water quality of the Leadville limestone (lower unit) is apparently similar to the Paradox (middle unit) at GD-1.

The hydraulic gradient used to estimate the movement of water through the salt strata (p. 3-192 Davis Canyon E.A.) is based on fresh-water potentiometric heads, uncorrected for density gradients. A dense fluid, such as a brine, overlying a less dense fluid, creates natural density gradients which should not be neglected in calculating hydraulic head. Neglecting density gradients between the middle hydrostratigraphic unit (salt strata) and the lower hydrostratigraphic unit may drastically underestimate the vertical velocity through this zone, and overestimate the travel time.

Davis Canyon 3-189 and Lavender Canyon 3-214: "Potentiometric levels within the Paradox Formation interbeds do not create a consistent areal pattern in the bedded salt area of the western Paradox Basin." This statement in both E.A.'s is misleading and is not consistent with what has been found by other authors (Hanshaw and Hill, 1969) who have constructed regional potentiometric maps of the Paradox. As stated earlier, the potentiometric maps of Hanshaw and Hill demonstrates

the similarilty between contours in the Honaker Trail, Paradox and Mississippian Leadville formation, further illustrating their consistency and potential interconnection. The above interpretation that potentiometric levels are not consistent in the Paradox is primarily based on what was found at a single well GD-1, and neglects the regional evidence that flow in the Paradox is under hydrodynamic conditions (i.e. a regionally consistent slope to the potentiometric surface).

Another indication of the problem encountered when data are sparse can be observed by comparing the difference in potentiometric surface maps developed for the region near the repository. Figure 2.1, after Hanshaw and Hill (1969), shows that the repository is located on or near a ridge of the 4400 foot contour line. Figure 2.2 from both the Lavender and Davis Canyon Environmental Assessments shows the repository on a relatively straight section of the 4400 foot contour line. This demonstrates the arbitrary nature of potentiometric maps where essentially no data are available.

2.4 Recharge/Discharge

Throughout the Davis and Lavender Canyon Environmental Assessments and supporting documents, we found arbitrary assumptions and statements of fact unsubstantiated by field data. This is also true for their assessment of the locations, modes and rates of recharge and discharge. For example, "hydrogeologic judgment favors the conclusion that essentially no movement of groundwater exists through the proposed repository rock" (Davis Canyon, 3-191). Statements such as this are obviously not based on experience at other salt sites (i.e. the WIPP site; Isherwood, 1981, nor is it evident from data itself, such as

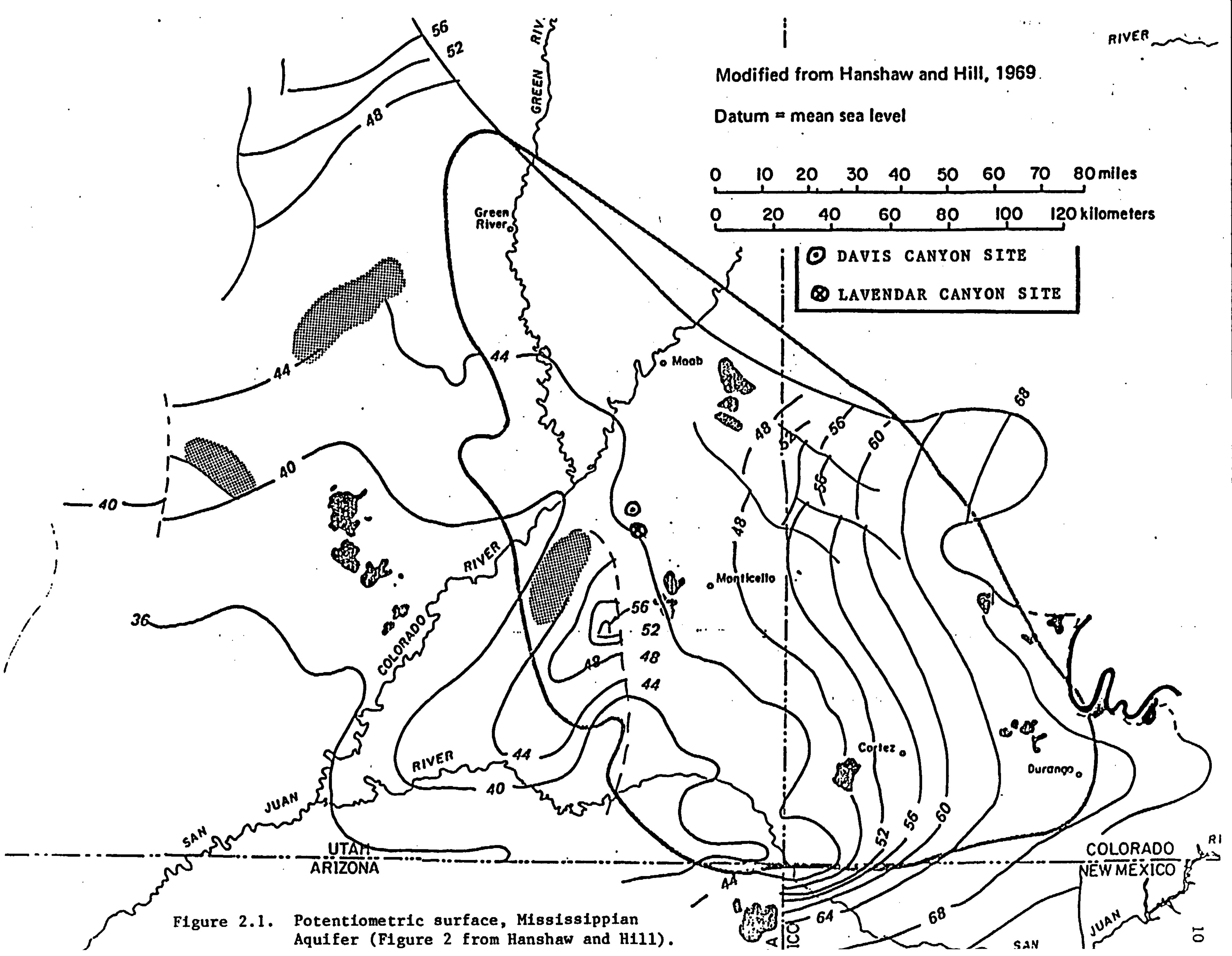


Figure 2.1. Potentiometric surface, Mississippian Aquifer (Figure 2 from Hanshaw and Hill).

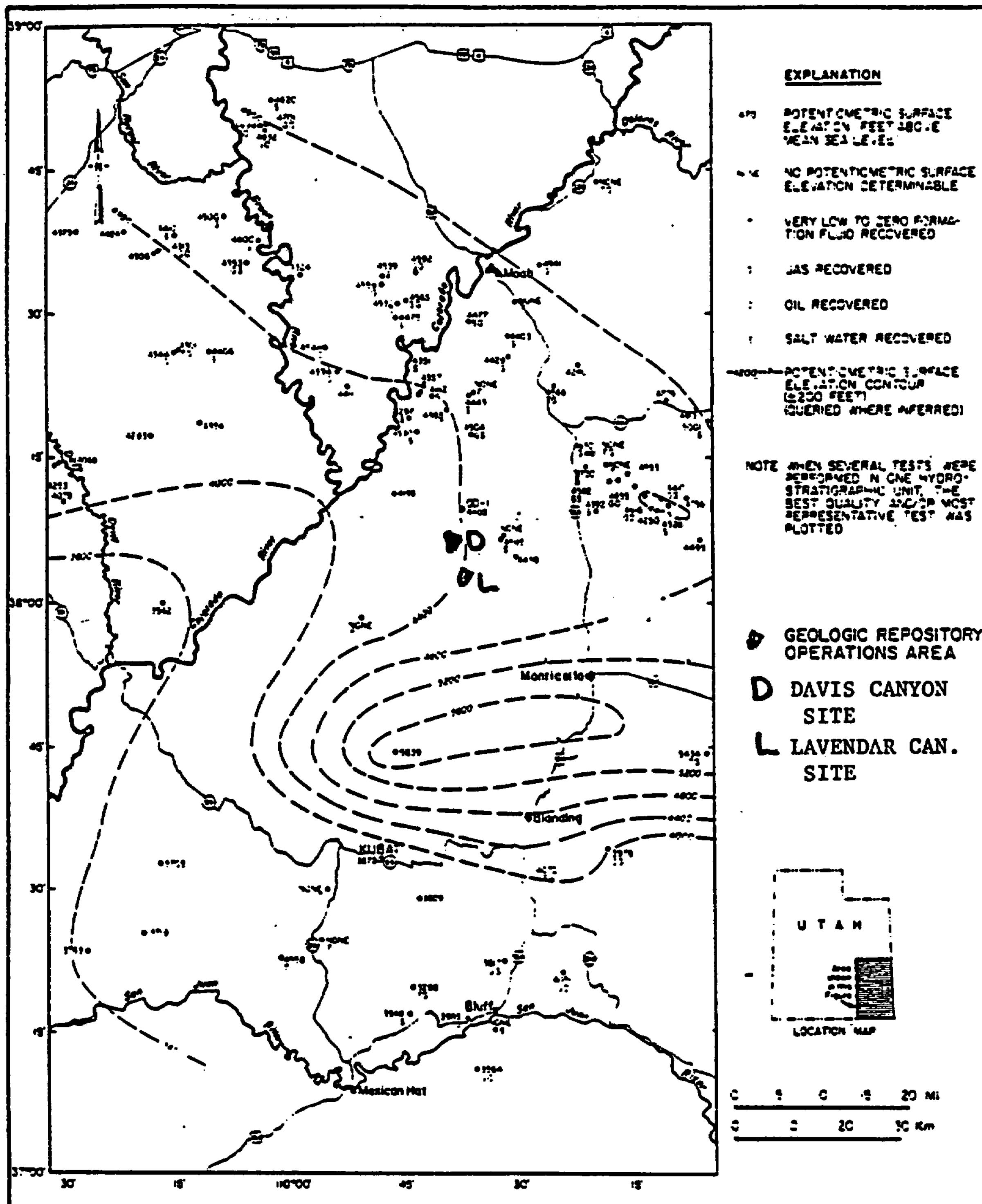


Figure 2.2.

Potentiometric Surface, Lower Hydrostratigraphic Unit

Figure 3-40

GD-1 or other regional data (ONWI 290, 1982)). Similar undocumented assumptions and statements concerning site performance where based on almost no hard field data serve no useful purpose in the environmental assessment, except possibly to foster erroneous preconceptions at later stages of the study. Unsubstantiated claims should be deleted from the environmental assessments. Davis Canyon 3-186, Lavender Canyon 3-214: The following argument is offered as evidence of no recharge from the upper hydrostratigraphic to the lower unit. "Because the potentiometric surface of the upper hydrostratigraphic unit appears to be higher than the lower unit at the site (actually GD-1), and considering the extensive thick sequence of evaporite beds, hydraulic interconnection is probably restricted between the upper and lower units."

The argument that the potentiometric surface of the upper hydrostratigraphic unit is above the lower unit simply indicates that GD-1 is in a local recharge area, which of course is well documented (3-189, Davis Canyon). The similarity of water quality between the middle and lower hydrostratigraphic units may also support the idea that slow, vertical downward flow presently exists at GD-1 through the entire sequence.

Davis Canyon 3-190, Lavender Canyon 3-217: "Significant recharge to or discharge from the middle and lower hydrostratigraphic units do not appear to occur in the Davis (Lavender) Canyon candidate area, except possibly where the normal stratigraphic sequence has been disrupted, such as in Lockhart Basin, and along Shay Graben. . ." This statement is unsubstantiated with field data within the candidate sites. No evidence is presented and no arguments are made to support the statement that recharge and discharge does not occur in the middle and lower units at

the site. Evidence should be presented or this statement stricken from the E.A. Davis Canyon 3-190, Lavender Canyon 3-218: "Lateral recharge to and discharge from the middle and lower units are limited by overlying strata of low permeability." Again we have a statement flatly made without supporting regional evidence. The conclusion is based on GD-1 alone, which cannot be considered representative of the entire repository area. Apparently the authors intend to ignore the fact that the Colorado River, in addition to serving as the drainage system for the upper hydrostratigraphic unit, also drains the middle and lower hydrostratigraphic units at the candidate sites.

No mention is made in either E.A. about the likely interaquifer connection between the lower and upper hydrostratigraphic units in the vicinity of the confluence of the Green and Colorado Rivers, where the salt strata have been significantly disturbed. Little reference is made of the Grabens to the south as to their impact within the E.A.'s. Since considerable disturbance of the salt strata are evident along the Colorado River, facilitating discharge from the upper and lower units, the impact of this area should receive additional consideration in the E.A.

2.5 Groundwater Modeling

The groundwater modeling effort (ONWI/512-02900/TR-17 and ONWI/512-02900/TR-32) is referred to in both the Davis and Lavender Canyon E.A.'s with the following brief statement,

> Preliminary numerical modeling of the groundwater flow system was performed for the region surrounding the candidate area (Dunbar and Thackston, 1984, pp. 1-3). The basic conclusions from the study at this time are that the groundwater flow system conceptual model is realistic and that additional data are needed to adequately quantify the flow system parameters, especially transmissivities, hydraulic conductivities, recharge amounts, and potentiometric levels.

This statement is apparently presented simply to satisfy the requirement in the technical güidelines concerning the ability to model the site. They state that their conceptual model is 'realistic' but that additional data are required to quantify the system. In our opinion the model effort presented here is an attempt to justify many of the unsubstantiated assumptions about the nature of groundwater flow made earlier in the E.A.'s and supporting documents. The model results are not based on sufficient, or in many areas, <u>any</u> data on which to justify their claim that the model result is realistic.

A <u>scientific approach</u> to modeling would be to use an appropriate physical model of a system along with available information and data about the system to provide an understanding about how the system performs. The <u>engineering approach</u> to modeling is to apply this understanding along with a satisfactory data base, to provide the best available answer to the particular engineering problem at hand. The model study of the Paradox Basin performed by the Intera group does not satisfy either of these approaches. Restrictive assumptions are made at the outset, in many cases unsupported by field evidence or sufficient data, which are favorable to the view, that the Davis and Lavender Canyon sites are suitable for waste isolation. The model study then sets about to 'prove' that these assumptions are "realistic" even though no data exists to calibrate and verify their conceptual model in the region of critical concern.

On page 6 of the first status report the authors state their purpose is to predict groundwater flow and travel times to the biosphere and "to define confidence limits on this prediction." This is an almost

unbelievable statement considering the almost total lack of data within the Gibson Dome area.

In our opinion, the groundwater model study implemented by the Intera group should not be viewed as having the capacity to predict anything. Its real value would have been as a screening model to test the viability of their basic assumptions, however, very little of this was done. Their approach has been to make restrictive assumptions concerning aquifer interconnnections and boundary conditions, input a generic data base (since hard data is essentially unavailable), and then call model output a prediction. I will include the following quotes from an editorial by Mary Anderson on groundwater modeling (Anderson, 1983).

> "It is also tempting to consider using models to judge the suitability of proposed waste sites, e.g., hazardous waste sites. A generic data base might be used for this type of modeling because it would be too costly and time-consuming to collect site-specific data for many different sites. The rationale is that it will be simpler to input model parameters from a generic data base and allow the model to calculate an array of numbers purportedly representing the concentration (or velocity--our statement) of contaminants in groundwater at any point in the subsurface. This type of modeling is valid only if it is recognized that models fashioned in this way are merely preliminary screening tools. Models that rely on a generic data base cannot be expected to produce results that are accurate for any specific site. Generic modeling can be a hazardous game because when the numbers from a computer output are plotted up in three-dimensional color graphics, it's easy to loose site of all the assumptions that went into the modeling effort. One tends to forget that "the Emperor has no clothes."
>
> It is clear that models must be used in conjunction with field studies and good hydrogeological field sense. In fact, field studies to help resolve the questions about dispersion and chemical reactions in the subsurface are in progress and in planning. Until the results of these studies are analyzed and accepted, the promotion of ground-water models for contaminant transport applications should be viewed with caution. Let's consider the experience of others:

'What were the scientific underpinnings of the National Environmental Protection Act that allowed it to demand scientific analyses that were not possible at that time, or maybe never possible? Why did the scientific community not refuse to collaborate with requests that were patently impossible? The legal or the administrative requirement to carry out modeling studies did, however, seduce many engineers and scientists, this reviewer included, to try to do the best they could under the situation. In retrospect, this was a great error because we have allowed air and surface water models to be adopted and be required (in some cases, models are even mentioned by name in the Federal Register), without regard to measuring the ambient environment before predicting effects of man-induced impacts. The engineering and scientific community are expected to perform analyses and prediction without a proper scientific data base.[1] (Rogers, 1983.)'

Some may disagree with a philosophy which implies that a "proper scientific data base" is required to make engineering decisions. Sometimes it is necessary to make decisions without complete data. Models can help in decision-making provided that the assumptions inherent in the model and the degree of uncertainty in the parameters used in the model are fully recognized."

3.0 REVIEW AND EVALUATION OF RADIONUCLIDE TRAVEL TIME/MONITORING ISSUES

3.1 Summary

This chapter describes the comments and concerns we have as to the pre and post closure site monitoring plans, and the methods used to calculate travel time and its variability. The Environmental Assessment clearly states that flowpaths are expected to be in a northwesterly to southwesterly direction from the repository. Several of the proposed site characterization wells are far removed from any expected flowpath, thus these wells give little information other than regional geohydraulic characteristics. Proposed monitoring along expected flowpaths is clearly inadequate.

Travel time calculations are based on bulk matrix permeability and porosity values, while contaminant travel paths will likely be in joints, fractures, and along dissolution surfaces. The travel times quoted in the E.A. are thus not conservative, and virtually ignore the impact of discrete hydraulic features. Also, the issues of the variability of expected travel time is not addressed in the E.A.

3.2 Assumptions and Framework for 10,000 Year Travel Time Criteria

According to the Department of Energy's Siting Guidelines (May 1984) for High Level Nuclear Waste Disposal, one of the important characteristics of the geohydrologic setting which demonstrates the compatibility of a given site for waste containment and isolation is (960.4-2-1 Geohydrology, PZ):

(1) Site conditions such that the pre-waste-emplacement ground-water travel time along any path of likely radionuclide travel from

the disturbed zone to the accessible environment would be more than 10,000 years.

In this same document the DOE outlines the types of information they expect to be included as evidence for subsequent evaluations of the site including travel time (Appendix IV, p. 7, Guidelines). In addition to the data listed below the DOE will also "supplement this information" with the following: a) conservative assumptions or extrapolations of regional data, b) conceptual models (I assume this to mean numerical models), and c) analyses of uncertainties in data.

Geohydrologic data base:

(1) Location and estimated hydraulic properties of aquifers, confining units and aquitards.

(2) Potential areas and modes of recharge and discharge for aquifers.

(3) Regional potentiometric surfaces of aquifers.

(4) Likely flowpaths from the repository to locations in the accessible environment, as based on regional data.

(5) Preliminary estimates of ground-water travel times along likely flow paths from the repository to locations in the expected accessible environment.

We have serious concerns about two particular aspects of these guidelines concerning the framework for assessing site geohydrology.

(1) The guidelines, inadvertently or not, encourage the use of numerical models with generic data as a substitute for hard field data. As discussed earlier, model results in regions where no data are available (such as over the 1000 km^2 region adjacent to the Gibson Dome site) can be used to produce any desirable answer. It is impossible to assess the level of

uncertainty in these areas and thus the concept of conservatism cannot be followed either. Model results are very useful in regions where field evidence (data) exists and can thus be verified. But in our estimation, model simulated potentiometric contours and velocities are no substitute for real data since they cannot be verified.

(2) A second general concern involves the lack of any statement or qualification concerning what amount of hydraulic field data constitues a minimum allowable data base for site characterization.

For example: Can a single observation well and corresponding hydraulic head, porosity and hydraulic conductivity data, over a 1000 square km region encompassing "expected travel paths," satisfy the requirements of the guidelines with respect to evidence? If so, then the guidelines are essentially meaningless since any site of that size would have low conductivity zones. In our opinion these concerns should have been addressed in the guidelines and incorporated in the Environmental Assessments.

3.3 Data Availability/Needs

The data base presently available for calculating travel times consists of the following items:

(1) The GD-1 borehole; porosity and hydraulic conductivity data.

(2) Regional hydraulic conductivity and potentiometric level in ONWI-290, Vol. V, Appendices.

(3) Regional potentiometric contour maps as published by Hanshaw and Hill (1969).

As Hanshaw and Hill do not cite the data base used to develop their contour maps, it is likely that much of their data came from the same sources given in ONWI-290. It appears that most of the data cited in ONWI-290 comes from wells drilled several miles to tens of miles north, east, and south of the repository location.

Expected flow paths from the repository location and the Accessible Environment (the Colorado River) can be estimated from regional potentiometric surface contour maps given in Hanshaw and Hill (1969) or from the INTERA modeling study. In both cases, flowpaths could be expected to travel in a northwesterly to southwesterly direction from the repository location. This flowpath is through the region most lacking of data cited in ONWI-290, and indicates the need of additional hydraulic conductivity, porosity, and potentiometric surface data in the region between the Colorado River and the repository location.

Site characterization studies outlined in Chapter 4 of the Davis and Lavender Canyon EA's indicate that several deep boreholes will be drilled within a 3 miles radius of the repository location, as well as boreholes in the Lockhart Basin ($\sim$15 miles N of the repository), Beef Basin ($\sim$15 miles SW of the repository), and the Shay Graben ($\sim$10 miles SE of the repository). With the exception of the Beef Basin boreholes (2 boreholes), and the boreholes drilled to the NW and SW of the immediate vicinity of the repository, all the site characterization boreholes lie outside of any possible flowpath from the proposed repositories.

Granted that wells drilled to the east, northeast and southeast of the potential repositories help to characterize the range of expected values of porosity and hydraulic conductivity for the region, however they do not identify possible anomalies along expected flowpaths, or possible trends in geohydraulic parameters between the repository and

the accessible environment that would greatly effect travel times. Additional site characterization wells along "expected flowpaths" should be drilled to determine the variations and trends in geohydraulic parameters along possible flowpaths.

A sensitive issue is whether site characterization drilling should be carried out within the Canyonlands National Park directly west of the repository location. In our opinion, since flowpaths likely would flow across the southerly boundary of the park, additional boreholes along these flowpaths will be necessary. Section 4.3.1 in both EA's propose that 2 boreholes be drilled within the park boundaries directly west of the proposed repositories "if unanticipated conditions are encountered or the boreholes outside of the park do not provide data to adequately characterize the site area." Exactly what "unanticipated conditions" are, or what "inadequate characterization" entails, is not specified in the EA. It is our opinion that, if drilling activities cannot be carried out within the park boundaries due to aesthetic or environmental reasons, then the assessment of hydrogeologic performance will be inadequate to determine site suitability as a waste repository.

In summary, the number of proposed boreholes (47) is more than adequate for regional hydrogeologic characterization but does not address the problem of travel time determination along flowpaths. The regional data base will provide a good estimate of the likely flowpaths, and once these are established additional data along the expected travel paths is necessary to quantify travel time.

3.4 Travel Time Estimation/Uncertainty Evaluation

First of all, it is our opinion that the Department of Energy (DOE) guideline concerning the 10,000 year travel time to the accessible

environment may not be appropriate for high level nuclear wastes subject to dispersive/diffusive mixing processes. These dispersive/diffusive processes may make the initial arrival time of a contaminant much quicker than the arrival time of a contaminant that is traveling at the average fluid velocity. This concern is best summarized by Grisak et al. (1978)

> "It should be emphasized that arrival times using the average velocity may be misleading or irrelevant in the case of contaminants which exceed permissible levels at very low concentrations. In such cases the entire dispersed breakthrough curve is much more significant. In fact in some cases the first measurable arrival may represent excessive contamination."

It seems likely that for cases of flow and transport in discrete hydraulic features, such as fractures, joints and dissolution conduits, the above concern will be even more critical.

A serious criticism we have concerning the Environmental Assessment for both the Davis and Lavender Canyon sites is that there is no consistent quantitative framework established by the DOE or its consultants for estimating travel time. The travel times quoted in the EA (Section 3.3.2.1., 6.3.1.1.2) are based on rules of thumb or "best guess" of the hydraulic properties of the hydrostratigraphic units. A consistent framework of travel time estimation takes into account the variability of the hydraulic properties and the correlation of these properties.

The data needs for estimating the travel time are:

(1) Vertical and horizontal hydraulic gradients: Vertical hydraulic gradients can be determined from one well. Horizontal hydraulic gradients require at least three wells to establish the plane of the potentiometric surface. Figure 3-40 in both the Davis Canyon and Lavender Canyon EA's show potentiometric surface contours in the vicinity of the repository. The problem with

these maps is that potentiometric surface data between the repository and the Colorado River is nonexistent. Thus there is no data to substantiate the DOE's travel time analysis along the expected flowpaths.

(2) A hydraulic conductivity-porosity relationships needs to be established from field data to assess travel time variability. Since travel time is a direct function of hydraulic conductivity and porosity, the variability of travel time is related to the variability and covariability of these parameters. Collins (1976) shows with the modified Kozeny equation, hydraulic conductivity is proportional to the cube of the porosity. Thus, a small increase in porosity will give a much larger increase in hydraulic conductivity.

(3) Due to the effect of anisotropy in a fractured porous media, the direction of the hydraulic gradient may not be the same as the flow direction. This factor could affect the delineation of "expected flowpaths" to the biosphere. This aspect needs to be quantified by field studies.

To illustrate the wide variability of calculated travel times, the following analysis was done based on the Darcian flow equation:

$$T = \frac{LP}{JK}$$

where T is the travel time, P is the porosity, J is the hydraulic gradient, and K is the hydraulic conductivity. For the Honaker Trail, Paradox, and Mississippian formations the following data sources were used:

(1) Flowpath lengths and hydraulic gradients were estimated from potentiometric surface maps given in Hanshaw and Hill (1969).

(2) Formation porosity was estimated from the laboratory effective porosity given in ONWI-491.

(3) Formation hydraulic conductivity was estimated from regional data given in ONWI-290, Volume V.

Statistical parameters and calculated travel time are defined on Tables 3-1 and 3-2, respectively. The travel times shown are calculated for 1) the arithmatic mean porosity and geometric mean hydraulic conductivity and 2) for values of these hydraulic parameters plus/minus one standard deviation from their respective means. The results show that the calculated travel times can vary over several orders of magnitude, depending on the choice of the values of the geohydraulic parameters. This analysis also indicates that travel times can be shown to be much less than the 10,000 year requirement simply by picking the geohydraulic parameters one standard deviation away from their respective means.

A "conservative" analysis would pick so called "worst case" parameters for its analysis. It is our opinion that the parameters used in the EA to calculate "worst case" travel times were arbitrarily chosen. As indicated by our simplified statistical analysis, it is likely that "worst case" travel times could be much less than 10,000 years.

The methods and data used in the EA to express variability of velocity and travel time are in our opinion inadequate. Methods such as First-order Uncertainty Analysis (Benjamin and Cornell 1970, pp. 180-186) or derived probability distributions are possible rational approaches to preliminary determine travel time variability. However, model sensitivity studies, supported by field data in the impacted area, would be the best ultimate approach.

Table 3-1. Geohydraulic parameters.

	Length (m)	Gradient	$\bar{Y}^a$	S_Y	$\bar{K}_G^b$ (m/d)	$K_{\bar{Y}+S_Y}$	$K_{\bar{Y}-S_Y}$	$\bar{P}$	SP	$\bar{P}$+Sp	$\bar{P}$-Sp
Honaker	$21.5(10^3)$	0.018	-5.8	2.4	$3.0(10^{-3})$	$3.3(10^{-2})$	$2.7(10^{-4})$	0.062	0.055	0.117	0.007
Paradox	$21.5(10^3)$	0.013	-6.2	2.0	$2.0(10^{-3})$	$1.5(10^{-2})$	$2.7(10^{-4})$	0.044	0.046	0.090	0.0001[c]
Mississippian	$21.5(10^3)$	0.005	-5.2	2.1	$5.5(10^{-3})$	$4.5(10^{-2})$	$7.1(10^{-4})$	0.14	0.02	0.16	0.12

a. $\bar{Y} = \frac{\sum \ln(Ki)}{n}$

b. $\bar{K}_G = e^{\bar{Y}}$

c. $S_P > \bar{P}$, use 0.0001 in calculations

Table 3-2. Travel time estimate in years.

Formation	$T_{\bar{K},\bar{P}}$	$T_{K+,P+}$	$T_{K-,P-}$	$T_{K+,P-}$	$T_{K-,P+}$
Honaker	72,000	12,000	90,000	70	1,500,000
Paradox	100,000	27,000	1,700	30	1,500,000
Mississipian	300,000	42,000	2,000,000	31,000	2,700,000

3.5 Relation Between Modeling Effort and Travel Time

In our opinion the regional modeling effort of Intera (1983, 1984) will not produce the required resolution to estimate contaminant transport from the potential repository sites to the accessible environment. The large scale over which the numerical model averages hydraulic conductivity (order of km's) assures that a low value of hydraulic conductivity will result. In regions of consolidated rocks where permeability and porosity are secondary, most of the flow will likely occur in localized zones of higher conductivity, from dissolution, jointing or fracturing. These zones will be separated by large blocks of extremely low conductivity material. If the spacing of the higher conductivity zones is wide (say 100's of meters) this will assure that block averages for the numerical model will be small. With regard to travel times, the regional numerical model has the same problem. It will provide a small average block velocity and large travel time estimate. However, contaminant releases will move in the high conductivity zones, governed by the local higher velocity. Thus we can expect any estimate of travel time (or velocity) based on regional averages, or estimated from large scale numerical models (by inverse techniques) to overestimate the travel time for contaminant movement on a local scale. Estimating reliable travel times without the benefit of detailed field data is an almost impossible task.

3.6 Consequence of Joints, Fractures, and Faults

Groundwater flow in discrete hydraulic features such as joints, fractures, faults and dissolution conduites is likely an important mechanism of groundwater flow within the deep sedimentary rocks of the

Paradox Basin. The drill stem permeability tests from GD-1 support this, indicating a hydraulic conductivity over 2 orders of magnitude greater than the laboratory rock matrix permeability (ONWI-491, Table 4-2). Travel time is thus greatly influenced by the total (matrix and fracture) rock permeability. The presence of these features will impact both site characterization studies and post closure monitoring.

For site characterization, the problem lies in assuring that a proper assessment of the fracture hydraulic characteristics and fracture frequency is made. The regional hydraulic conductivity data given in ONWI-290, Vol. V, show for the Mississippian formation the high value of hydraulic conductivity is 75,000 times greater than the low value, and for the Paradox formation the ratio of high/low hydraulic conductivity is 2,000. Given the low matrix permeability of the consolidated sedimentary rocks that make up these formations, the higher values are likely due to secondary fracture or dissolution permeability. The Davis Canyon EA page 3-184 states that fracturing is a minor influence in Paradox formation permeability. However, the regional and GD-1 permeability data seem to contradict this statement.

For post closure monitoring, the variety of possible flowpaths through the fracture network leads to a high probability that contaminant flowpaths will not be intercepted by a monitoring well. This topic will be addressed in greater detail in section 3.6 of this review.

The final comment here is that overall, the modeling approach taken by INTERA is appropriate for regional water balance assessment of the various aquifers that make up the Paradox Basin. However, in the case of

travel time estimation of contaminants, a much finer resolution will be necessary. The EA does not adequately address this fact.

3.7 Post Closure Monitoring

The EA indicates that the site characterization boreholes will also be used as monitoring wells during the post closure period. As was mentioned in the previous section, it seems likely that significant transport will occur within the fracture network of the rocks. The problem lies in assuring that the monitoring wells will intercept this contamination.

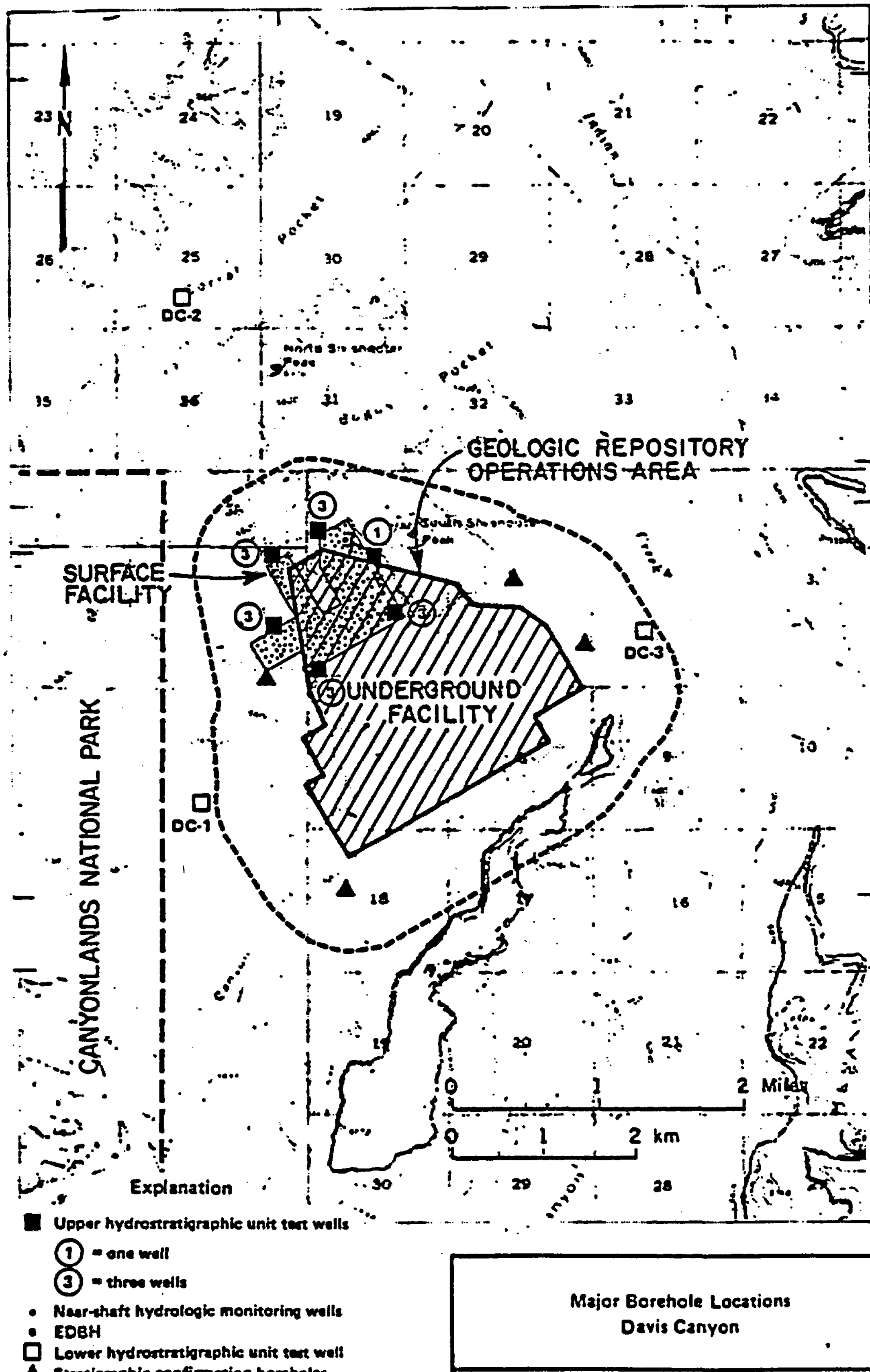
Flow is expected to be within a northwesterly to southwesterly direction from the proposed repositories. In the upper hydrostratigraphic unit, flow is expected to be more to the northwest and more to the southwest in the lower hydrostratigraphic unit. Referring to the enclosed figures from the 5th draft of the EA's, the following observations are made:

Lavender Canyon:

A. The lower hydrostratigraphic unit test wells leave wide gaps for contaminant flowpaths to the west and southwest of the repository. The sparcity of observation wells and uncertainty in precise flow directions provides little assurance that contaminant losses to the lower hydrostratigraphic units would ever be observed.

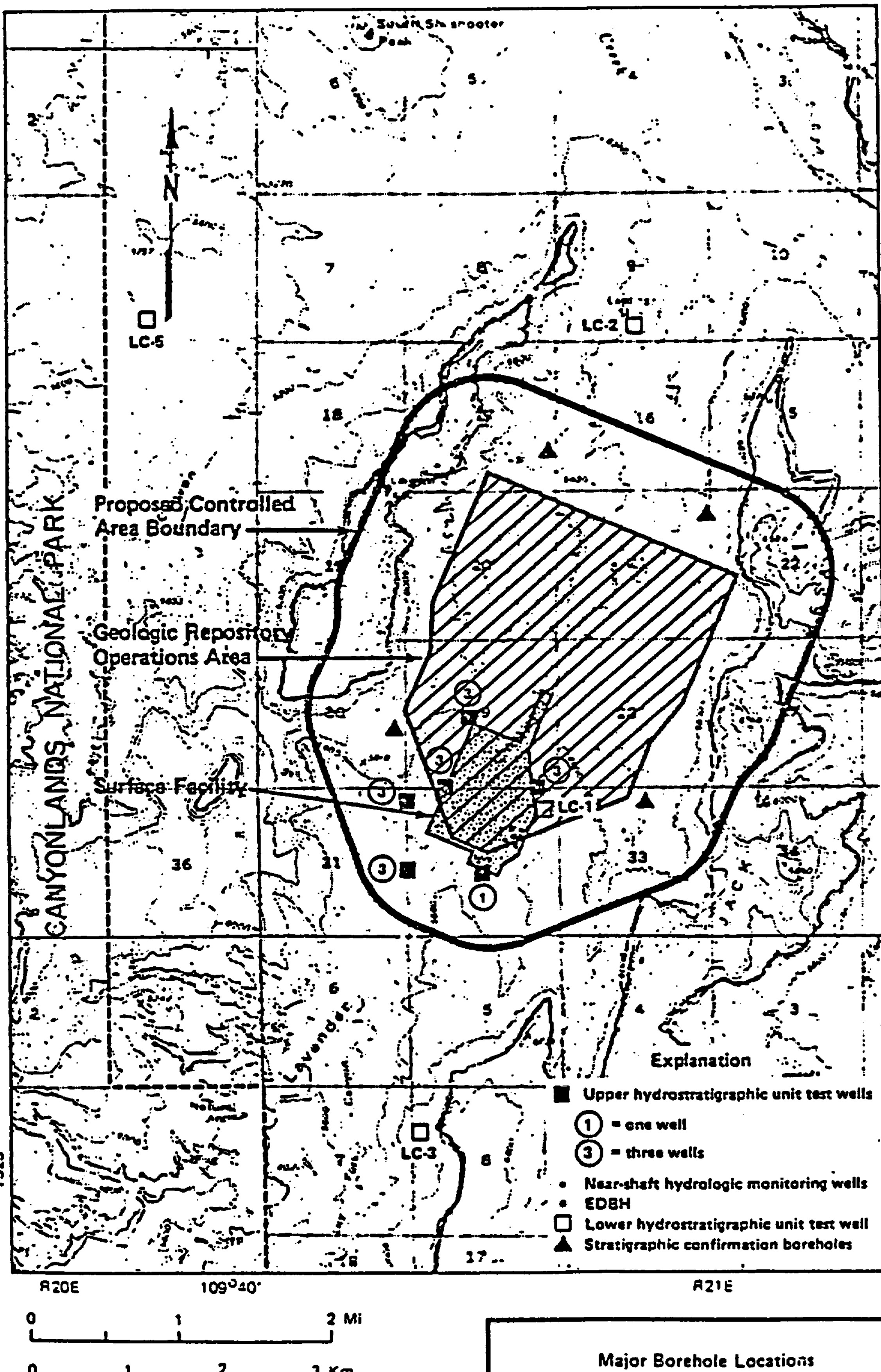
Davis Canyon:

A. Only two observation wells within the lower hydrostratigraphic unit are proposed to the west of the underground facility, which is clearly inadequate given the expected uncertainties in flow direction.



Major Borehole Locations
Davis Canyon

Figure 4-3



Major Borehole Locations
Lavender Canyon

Figure 4-3

B. Shaft seal leaks or vertical flows into the upper hydrostratigraphic unit would be expected to move to the north or northwest from the repository. The upper hydrostratigraphic unit test wells are clustered more to the south and west of the Engineering Design Borehole. Thus the majority of the proposed monitoring wells are not along expected flowpaths.

4.0 CONCLUSIONS AND RECOMMENDATIONS

In general it is our conclusion that the Environmental Assessments and supporting documents for Davis and Lavender Canyon, given the present data base and knowledge of the hydrogeologic sytem, do not provide satisfactory evidence that 1) groundwater conditions within the three hydrostratigraphic units are favorable for successful isolation of High Level Nuclear Wastes and 2) expected radionuclide travel times are in excess of 10,000 years from the operations area to the accessible environment.

The following recommendations concerning site suitability as a repository, site and post closure monitoring, and contaminant travel time are based on our analysis given in the previous sections.

1. The proximity of the site to the Colorado River and its tributaries has major implications to the downstream water users dependent on the Colorado River for water supply. Contaminant leakage along undetected fracture networks, or the possibility of transportation spills, may render useless the sole water supply of major agricultural development and municipal users downstream. The human health and economic risks associated with placing a high level nuclear waste facility within the drainage of an important river system should be addressed in the guidelines and evaluated in EA's.
2. Inadequate data in the region of expected contaminant flowpaths to the biosphere introduces extreme levels of uncertainty in calculated travel times. The only way to reduce this uncertainty and develop confidence in the accuracy of calculated

travel times is to gather additional hydrogeological and geophysical data along expected flowlines. However presently, the data base is not adequate even to determine the location of "expected flow paths."

3. Incorporation into the DOE guidelines and the Environmental Assessment of the potential impact on system performance by discrete hydraulic features (joints, faults, fractures and dissolution conduits).

4. Incorporation of the problem of spatial variability of hydraulic properties as one component of the uncertainty in travel time calculations. Even in the presence of an "adequate" data base, the effect of spatial variations of hydraulic properties on contaminant transport will be a critical factor to site performance. This is not addressed in the E.A.'s.

5. Implementing in the guidelines and the environmental assessment the use of groundwater modeling as a screening tool rather than predictive tool. Model results should not be substituted for "hard data" in regions where inadequate data would make verification impossible.

5.0 REFERENCES

Anderson, M. P. 1983. Groundwater modeling--The emperor has no clothes. Groundwater, 21(6):666-669.

Benjamin, J. R., and C. A. Cornell. 1970. Probability, statistics and decision for civil engineers. McGraw-Hill, New York. 684 p.

Department of Energy. 1984. Statutory environmental assessment for the Davis Canyon site, Paradox Basin, San Juan County, Utah. 5th draft.

Department of Energy. 1984. Statutory environmental assessment for the Lavender Canyon site, Paradox Basin, San Juan County, Utah. 5th draft.

Duffy, C. J., and N. Barton. 1984. Statement by Dr. Christopher Duffy, PhD, New Mexico Institute of Mining and Technology, and by Dr. Nicolas Barton, PhD, Imperial College, London, on behalf of the State of Utah, regarding review of certain technical aspects of DOE proposed guidelines for siting of nuclear waste repositories.

Grisak, G. E., R. E. Jackson, and J. F. Pickens. 1978. Monitoring groundwater quality: The technical difficulties. In Establishment of Water Quality Monitoring Programs. American Water Resources Association.

Hanshaw, B. B., and G. A. Hill. 1969. Geochemistry and hydrodynamics of the Paradox Basin region, Utah, Colorado, and New Mexico. Chemical Geology, 4:263-294.

Huntoon, P. W. 1979. The occurrence of groundwater in the Canyonlands area of Utah, with emphasis on water in the Permian Section. Four Corners Geological Society Guidebook, 9th Field Conference. Permianland, Durango, Colorado.

Intera Environmental Consultants, Inc. 1983. Status report on regional ground water flow modeling for the Paradox Basin, Utah. ONWI/E512-02900/TR-17.

Intera Environmental Consultants, Inc. 1984. Second status report on regional ground water flow modeling for the Paradox Basin, Utah. ONWI/E512-02900/TR-32.

Isherwood, D. 1981. Geoscience data base handbook for modeling of a nuclear waste repository. NUREG/CR-0912, Vol. 2. U.S. Nuclear Regulatory Commission.

ONWI-290. 1982. Geologic characterization report for the Paradox Basin study region, Utah study areas, Volume V, Appendices. Battelle Memorial Institute, Office of Nuclear Waste Isolation.

ONWI-491. 1984. Results of hydraulic tests at Gibson Dome No. 1, Elk Ridge No. 1, and E. J. Kubat boreholes, Paradox Basin, Utah. Battelle Memorial Institute, Office of Nuclear Waste Isolation.

Weir, J. E., Jr., E. B. Maxfield, and I. M. Hart. 1983. Reconnaissance of the geohydrology of the Moab-Monticello area, western Paradox Basin, Grand and San Juan Counties, Utah. U.S. Geological Survey, Water Resources Investigations Report 83-4098.