EEG-23

HEALTH & ENVIRONMENT department

EVALUATION OF THE SUITABILITY OF THE WIPP SITE

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FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill

Robert H. Neill
Director

EXECUTIVE SUMMARY

The determination of the suitability of the site for WIPP is only the first major phase in the evaluation of the radiological impact of the repository on the public health and safety. The Environmental Evaluation Group (EEG) will continue to independently review the design of the facility, the operational procedures (including safety criteria and quality assurance), the criteria for packaging and shipment of the waste, the plans, procedures and results of the WIPP experiments, emergency preparedness, adherence to EPA and pertinent NRC regulations, and other important features of the project.

EEG has concluded from existing evidence that the Los Medanos site for the WIPP project has been characterized in sufficient detail to warrant confidence in the validation of the site for the permanent emplacement of approximately 6 million cubic feet of defense trasuranic waste. This conclusion is based on the assumption that the maximum surface dose rate for the unshielded remote-handled transuranic waste (RH-TRU) canisters will be 100 rem per hour with a maximum radionuclide concentration of 23 curies per liter as indicated in Table E-3 of the Final Environmental Impact Statement for WIPP. The Site and Preliminary Design Validation (SPDV) program, through the drilling of two shafts to the selected repository level at 2160 feet below the surface and excavation of about 9000 feet of tunnels, has confirmed the interpretations made about the subsurface geological conditions at the site.

For an assessment of the potential radiation effects of the nuclear waste repository on the public health and safety, it is necessary to understand the regional geological and hydrological setting. A large amount of work has been done to understand these conditions and to address several specific issues which have arisen as a result of such studies. However, in an assessment effort of this magnitude, it is almost inevitable that some questions remain unanswered at a given time in the decision-making process. EEG has identified work which still needs to be done at the Los Medanos site in order to improve confidence in the worst case scenario models of possible breaches of the repository. Also, it is anticipated that some of the additional information will be necessary to assure compliance with the EPA standard when it is promulgated.

EEG strongly recommends that the following important commitments be obtained from DOE prior to beginning the full facility construction.

Recommended Commitments from DOE Prior to Beginning the Construction

1. The WIPP will comply fully with the U.S. Environmental Protection Agency standard for the disposal of transuranic wastes, when it is promulgated. WIPP does not appear to meet some parts of the proposed standard.

2. The maximum surface-dose rate for the unshielded Remote Handled Transuranic Waste (RH-TRU) canisters will be 100 rem per hour with a maximum radionuclide concentration of 23 curies per liter as indicated in Table E-3 of the Final Environmental Impact Statement for WIPP.

3. No potash mining will be allowed in Zones I, II and III of the WIPP site. Deviated drilling for oil and gas from outside the WIPP site to reach under the WIPP site at depths greater than 6000 feet may be allowed. The federal government shall exercise active institutional control at the site for this purpose for at least 100 years after repository decommissioning.

4. DOE shall provide to the State certified data and final reports as appropriate for the studies and investigations listed herein by July 1, 1985, and allow for a 60 day review and comment period by the State and general public. DOE shall consider and respond to such comment within 30 days.

The following lists certain investigations currently in process or planned by DOE and additional work which EEG recommends that the State should demand if the construction is allowed to proceed.

Studies Recommended by EEG

1. Investigate the depression of the marker beds in the lower part of the Salado formation, centered two miles north of the WIPP shafts.

2. Perform computer modeling of groundwater flow in the Rustler aquifers.

3. Conduct the following hydrology tests:
   a) A long duration pumping test at the well H-3.
   b) Measure the anisotropy of the hydraulic conductivity at test pads H-1, H-2, and H-3.
   c) Perform convergence tracer tests at wells H-1, H-3 and H-4.
   d) Perform convergence tracer tests at well H-6 using sorbing tracers.

Continuing or Planned DOE Studies

1. Evaluate and field test non-invasive geophysical methods to identify possible occurrence of brine under the repository.

2. Analyze the drawdown data in test holes H-1, H-2 and H-3 caused by the excavation of WIPP shafts.

3. Publish the results of solute transport modeling in the Rustler aquifers.

4. Analyze the Rustler aquifer waters for environmental isotopes (Carbon-14, Chlorine-36, Uranium-234, Uranium-238) to aid in understanding the groundwater flow direction and relative velocity.

5. Drill the planned additional wells for hydrologic testing, viz. H-11 and H-12. Obtain the cores while drilling these wells to determine the extent of fracturing and solution residues throughout the Rustler formation.

6. Conduct a water balance study for the WIPP site.

7. Study the mechanics of removal of salt from the Rustler formation at and near the site.

8. Drill a shallow auger-hole in the depression in the SW corner of Sec. 30, T225, R 31E in Zone III to address the suspicion of this depression being a doline.

9. Further study marker bed 139 (MB139) underlying the repository horizon to determine its origin and its effect on the repository.

List of Figures

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INTRODUCTION

On March 31, 1983, the Department of Energy issued the "Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program" (WIPP-DOE-161). This publication contains a "Summary of the Evaluation of the WIPP Site Suitability" by W. D. Weart of Sandia National Laboratories and an Executive Summary of the Preliminary Design Validation Report by Bechtel National, Inc. The report concludes that the Los Medanos site fulfills the intent of all the site qualification factors and should, therefore, be used for the Waste Isolation Pilot Plant project. It also concludes that "the major WIPP design elements and design bases have been validated by observation or measurement."

The Environmental Evaluation Group (EEG) is charged with the responsibility of evaluating the suitability of the site for carrying out the mission of WIPP by analyzing all the reports and other information which form the background to the DOE evaluation of the site. The results of this evaluation are being conveyed to the appropriate State authorities to help them formulate the State's position on whether to oppose the beginning of construction of the Waste Isolation Pilot Plant project.

A summary of EEG's involvement since November 1978 is provided in the Appendix to indicate the extent of evaluation process for the past 4 1/2 years. During the past year alone, EEG has received approximately 40 major and numerous supporting reports from DOE concerning various aspects of the evaluation of the site.

The "Summary of the evaluation of the WIPP Site Suitability" by W. D. Weart of Sandia National Laboratories, contained in the U. S. Department of Energy document (WIPP-DOE-161, March, 1983) is based on the 21 site qualification factors formulated in the Site Validation Program (WIPP-DOE-116, October 1982). The specific issues on which EEG has expressed its concerns in the past (EEG-3, EEG-6, EEG-7, EEG-10, DOE/State Stipulated Agreement, 1981) are included in the 21 site qualification factors. Rather than comment on the adequacy of the WIPP site with respect to each of the 21 factors, the discussion in this report is arranged according to issues which EEG considers important in evaluating both the operational and the long-term integrity of the site. The section on Conclusions and Recommendations provides a summary of EEG analyses of the issues of site suitability.

The Environmental Evaluation Group organized a meeting on "Evaluation of WIPP Site Suitability" at Carlsbad on May 12 and 13, 1983. The purpose of the meeting was to present EEG's tentative conclusions on the issues of WIPP site suitability to a group of 40 invited scientists and engineers which included scientists from State agencies, members of the National Academy of Sciences Panel on WIPP; several University professors from New Mexico and from Stanford, University of Arizona and Pennsylvania State; U. S. Geological Survey scientists; scientific personnel from DOE and its contractors e.g. Sandia, and D'Appolonia. While the discussions, comments and recommendations made at this meeting were considered in the preparation of this report, the conclusions reflect the views of the Environmental Evaluation Group and do not necessarily reflect the views of others.

As the title of this report suggests, only the issues directly related to the suitability of the site are addressed here. Other issues including transportation, waste acceptance criteria, the absence of engineered barriers, and adherance to EPA and NRC regulations will be dealt with separately.

RESOLUTION OF SPECIFIC ISSUES

DISSOLUTION

1.0 Blanket Dissolution

Geologists who have studied the Delaware Basin generally agree that the Ochoan evaporite deposits of upper Permian age have undergone erosion and shallow dissolution in the Basin. This regional dissolution must have been initiated with the tilting of the basin and injection of water from the Capitan aquifer downdip to the east into the evaporite deposits. Since halite is the most soluble of the ochoan evaporites, it has been dissolved where the unsaturated waters have managed to attack it. The sequence from the oldest to the youngest of the Delaware Basin evaporites is Castile, Salado and Rustler formations, respectively. Figure 1 shows the western edges of the Castile and Salado halite. The edge of the salt in the youngest, i.e., the Rustler formation, is farther east and it criss-crosses the WIPP site in a general north-south direction (Fig. 2).

The effects of the regional dissolution nearest the WIPP site can be observed in Nash Draw, a dog bone shaped depression immediately west of the WIPP site. Nash Draw is approximately 15 miles long in the north-south direction and its width ranges from approximately 5 miles to as much as 12 miles. Bachman (1980, 1981) studied and mapped this depression in detail and concluded that it has been formed by a process of "solution and fill," which is active today. Based upon the dating of a volcanic ash layer associated with the Gatuna formation which is exposed at the ridge on the eastern margin of Nash Draw and using the marker beds in Salado, Bachman (1980) concluded that about 200 feet of subsidence has occurred in this depression during the past 600,000 years. Using this observation, Bachman (1974) calculated an average rate of 330 feet per million years for the vertical dissolution. Assuming that the edge of the Salado salt has moved from the Capitan Reef front to its present location during the past 7 to 8 million years (since the Ogallala time), Bachman and Johnson (1973) concluded that the horizontal rate of movement of the blanket dissolution front is about 6 to 8 miles per million years. It should, of course, be recognized that these are very rough average rates of movement of the dissolution front. The front itself may be expected to move faster under less arid climatic conditions. Also, an advancing "tongue" of the front may reach a point faster than the front itself.

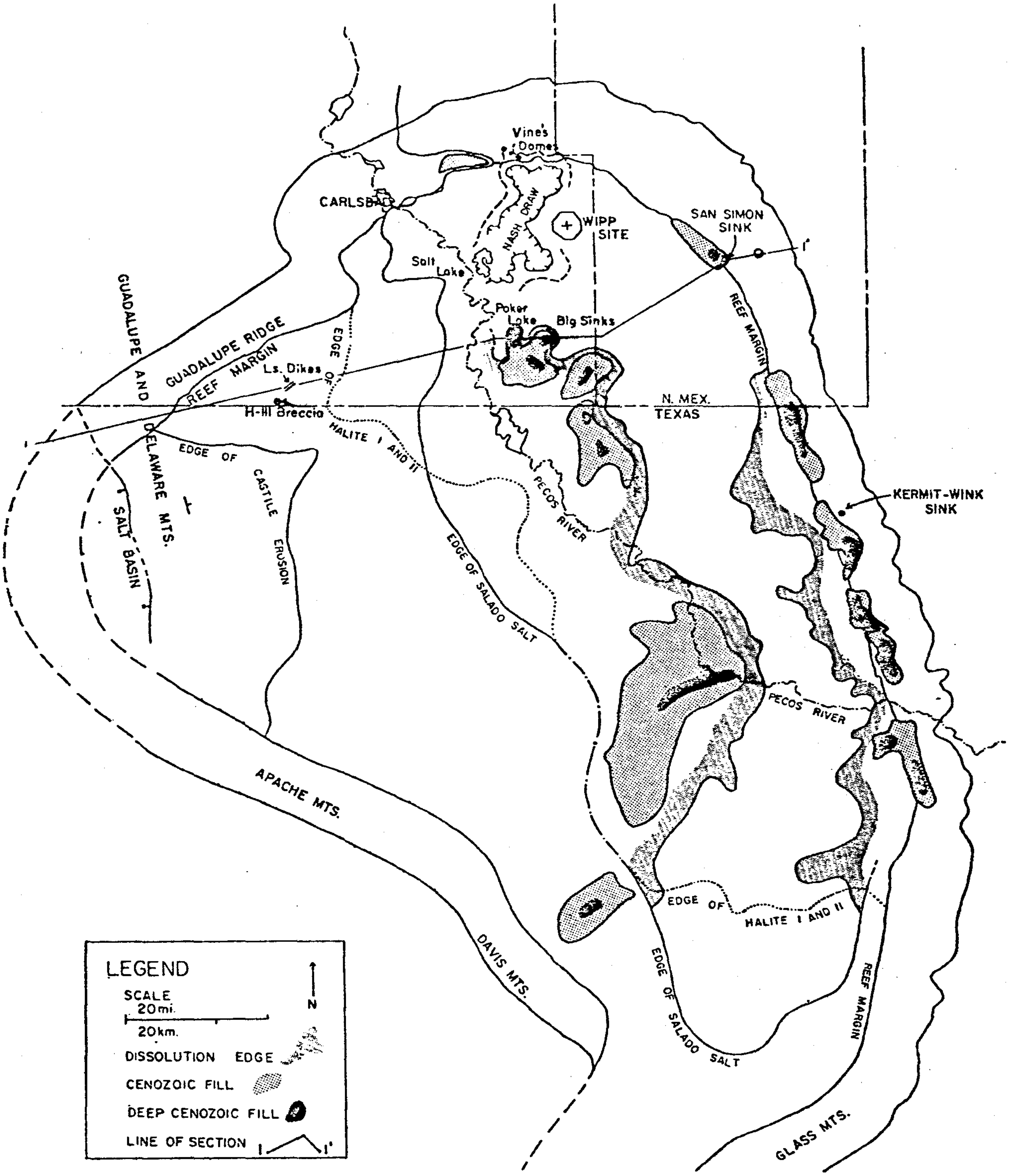

Figure 1. Map of Delaware Basin showing location of Capitan reef, major dissolution depressions, and western dissolution of evaporites and of major salt units (from Anderson, 1981)

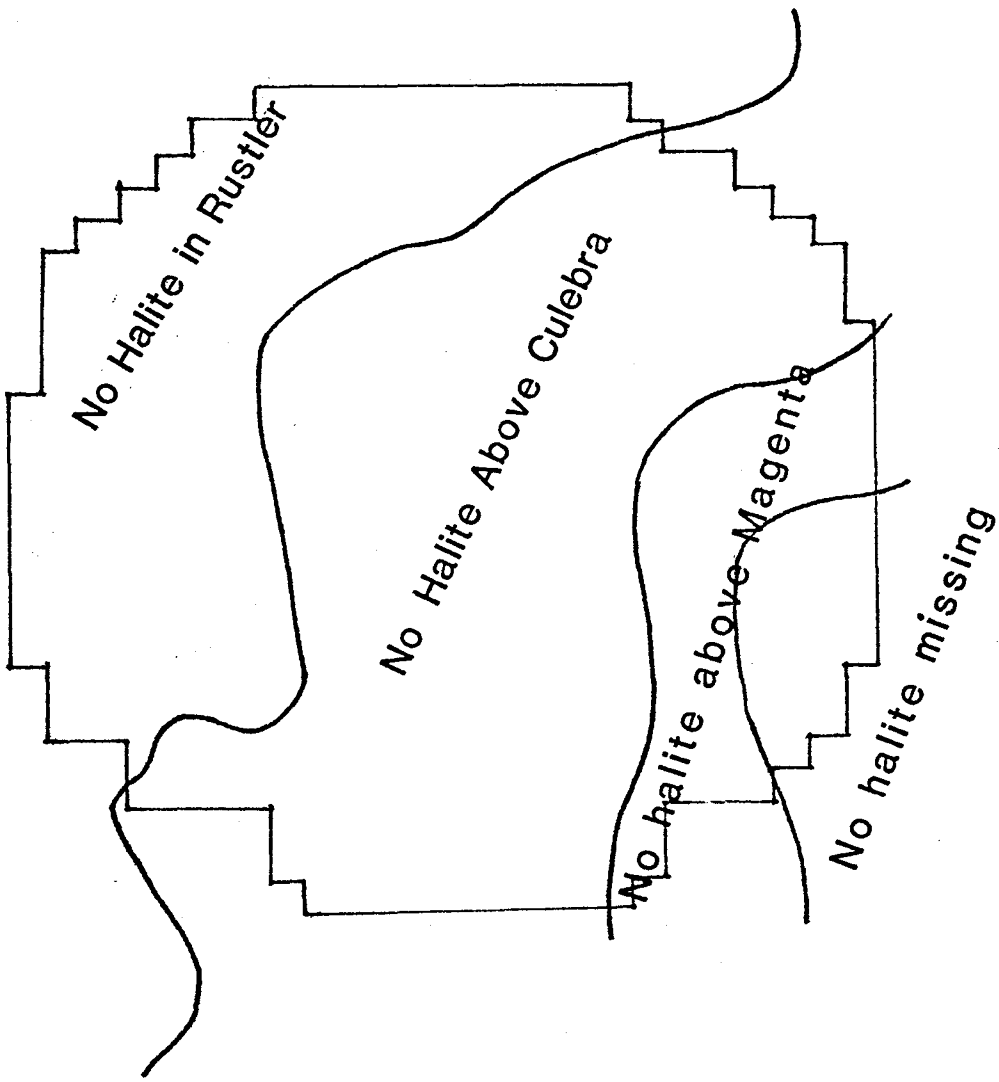

Figure 2. Extent of removal of salt from the Rustler formation at the WIPP site (Modified from Snyder, 1983)

Using the above rates for horizontal and vertical dissolution, it can be shown that it would take approximately 225,000 years for the front to travel approximately two miles to reach the western edge of the WIPP repository and would start dissolving salt from upper Salado, about 1500 feet above the repository horizon. It would then require at least 2 to 3 million years for the removal of 1500 feet of salt by dissolution, at the rate of 330 to 500 feet per million years. In spite of the very approximate nature of the estimated rates of advance of the dissolution front, and the possibility of a more rapid advance of a segment of the front, these calculated rates provide sufficient safety from an advancing front of blanket shallow dissolution of salt towards the WIPP site.

2.0 Deep Dissolution

The hypothesis of preferential removal of salt from the lower Salado and Castile formations has been called "Deep" dissolution. In attempting to correlate the varved evaporite sequence of the Castile formation and the overlying Salado, Anderson et al.(1972) concluded that large quantities of bedded salt were missing from the middle of the evaporite sequence near the center of the basin. Using the correlation of acoustic logs across several lines in the Delaware Basin, Anderson et al. (1978) concluded that (a) the preferred dissolution horizons from which salt has been removed by dissolution occur between the Halite III salt of the Castile formation and the 136 marker bed of the Salado formation, and (b) the large depressions in the basin, first identified by Malley and Huffington (1953), were the result of selective dissolution of lower Salado salt beds. Anderson (1981) further developed the idea of deep-seated dissolution and concluded that deep-seated dissolution has occurred around the margin of the basin where the Capitan aquifer is in contact with the Permian evaporites and within the basin where selective dissolution in the lower Salado has undercut the overlying salt beds. He calculated that more than 70% of the original salt has already been removed from the lower Salado horizon in the basin.

For the mechanics salt removal salt through the process of deep dissolution, Anderson (1981) invoked the "brine density flow" which had been proposed earlier (Anderson and Kirkland, 1980) for the formation of breccia pipes. This mechanism requires a connection between the lower Salado and the underlying Delaware Mountain Group aquifer. It was hypothesized that this aquifer supplies unsaturated water to the overlying evaporites through a fracture system and the brine produced after dissolution of the salt is also removed through this aquifer. Using the reported (Hiss, 1975) values of hydraulic conductivity of 0.0049 m/day and a chlorinity of 150 g/ℓ for the DMG aquifer, Anderson (1981) calculated that this aquifer, where it is in contact with the reef, can remove the volume of salt missing from the Salado in 1.5 million years.*

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*There appears to be a discrepency in Anderson's calculation here.

According to Anderson (1981), Figure 3, $[(10 - 49) + (13.9 - 3.8)] \times 10^{11}\ m^3 = 7.11 \times 10^{12}\ m^3$ of salt has been removed from lower Salado.

For hydraulic conductivity, K = 0.173 m/day (maximum measured value)
hydraulic gradient, i = 0.0025 m/m
Cl = 150 gms/liter = 247 g/ℓ of NaCl
= 247 kg/m^3 of NaCl

NaCl density ≈ 2.2 g/ml
= 2200 kg/m^3

Salt removal is $\frac{247\ kg/m^3}{2200\ kg/m^3} = 0.112\ m^3\ salt/m^3\ water$

If the thickness of the DMG aquifer is 100 m, the volumetric flux of water per one meter width of aquifer is

$Q = K.i.100$
$= 4.33 \times 10^{-2}\ m^3/d\text{-}m$
$= 15.8\ m^3/yr\text{-}m$

In 1.5×10^6 years, the flow is,
$15.8 \times 1.5 \times 10^6 = 2.37 \times 10^7\ m^3/m\text{-width}$

And the amount of salt removed is
$0.112 \times 2.37 \times 10^7 = 2.65 \times 10^6\ m^3\ salt/m - width$

In 1.5×10^6 years

Width of Flow	Volume of Salt Removed
50 km	$1.33 \times 10^{11}\ m^3$
100 km	$2.65 \times 10^{11}\ m^3$
150 km	$3.98 \times 10^{11}\ m^3$

Even with conservative assumptions, the volume of salt removed as calculated by EEG is 20 to 50 times less than that calculated by Anderson.

Wood et al (1982) conducted a detailed study of the potential of the DMG aquifer to remove the dissolved salt as hypothesized by Anderson (1981). They studied the potential dissolution mechanisms of diffusion and convection from the halite zones of Castile and Salado to the Bell Canyon (DMG) and the Capitan Reef aquifers, and reached the following conclusions.

- The diffusion and possibly very weak convection result in removal of halite from the Castile. Convection may be significant at locations adjacent to the Capitan Reef aquifer.

- Salt removal by the diffusion process would produce an advancement of the dissolution front of only 0.3 centimeter in 10,000 years.

EEG (1983, pp. 75-93) has questioned several assumptions and analyses contained in this study but has accepted the conclusion that the known properties of the DMG aquifer make it an unlikely pathway for supply and removal of water needed to carry out the dissolution at a massive scale as asserted by Anderson (1981).

Anderson (1982) countered that the interpretation of geophysical logs from hundreds of wells in the basin clearly shows that the upper Castile and lower Salado salt is missing under a large part of the basin and that it has been removed by dissolution during the Pleistocene time. If the DMG aquifer was not the pathway for the brine movement, then an alternate pathway must account for the missing salt. Anderson (1982) developed a case for the upper Anhydrite layer in the Castile formation as the conduit for the movement of unsaturated waters from west to east. The brine produced by such dissolution would escape through the Capitan Reef to the east. This mechanism is illustrated in Figure 3.

There are several unresolved questions in this postulated mechanism. Besides a very few isolated reports of minor quantities of water in the upper Castile, mainly near the Pecos river southwest of the WIPP site, the only liquid found in the Castile anhydrite is in the pressurized brine reservoirs. In spite of a large number of boreholes which have been drilled through the Castile, there is no indication of the existence of unsaturated water flowing through this zone. Therefore, the upper Castile is not an aquifer. Also, the two

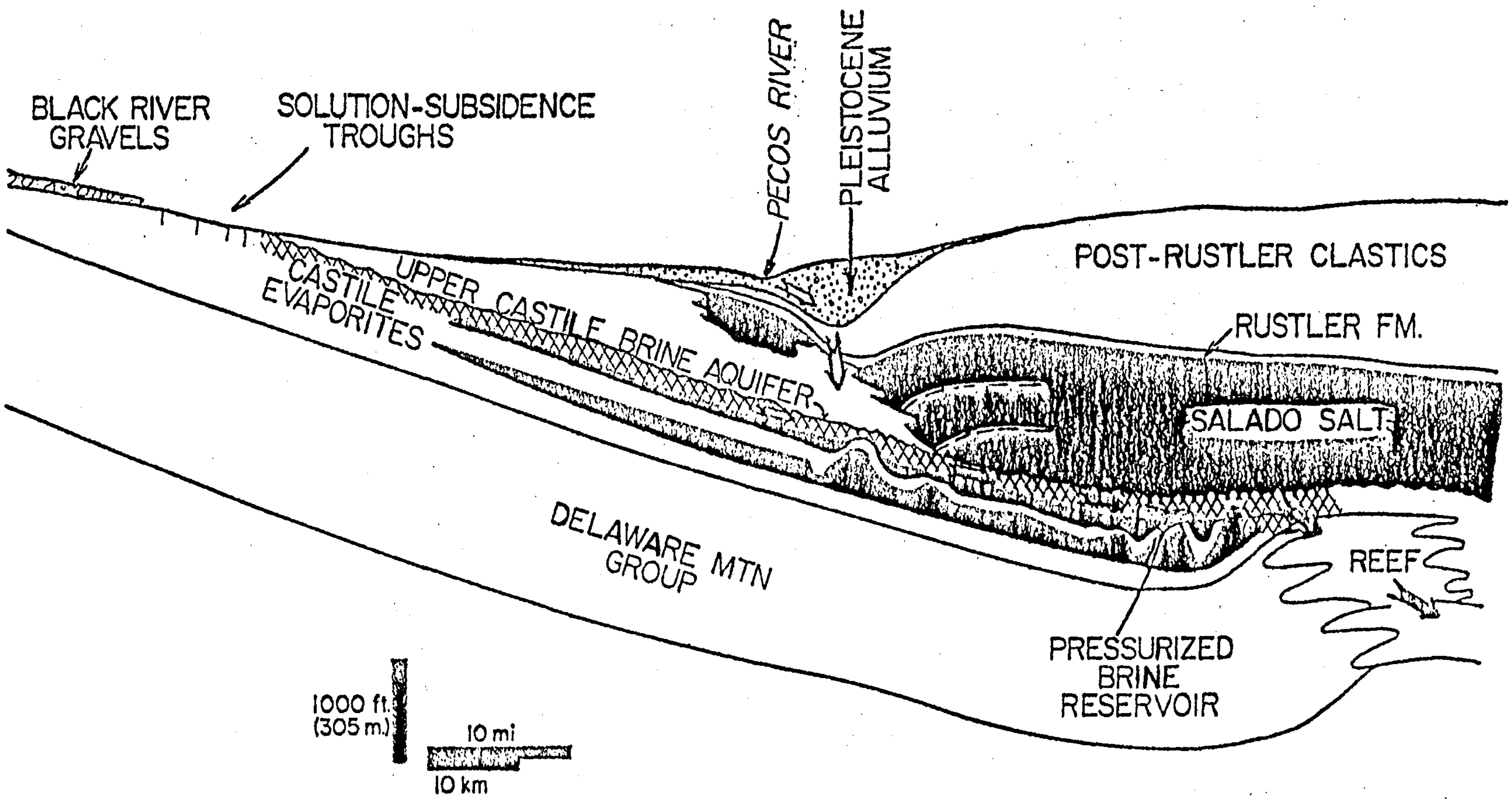


Figure 3. Diagrammatic cross section through the northern Delaware Basin, New Mexico, showing possible pathways of movement of water and brine drainage into and through upper Castile brine acquifer (from Anderson, 1982).

pressurized brine encounters which have been tested, display varied chemistry and pressures which suggests that the two encounters are not connected. Finally, the salinity of the Capitan Reef to the east is low indicating that if brines are being discharged into the Reef aquifer, the volume must be very small in comparison to the total volume of flowing water in the Reef.

It appeared in 1982 that the only way to address the question of deep dissolution was to reexamine the geophysical logs in the basin and provide alternate explanations, if any, for the missing salt. At EEG's suggestion, this work was done by Sandia National Laboratories. Lambert (1983) has drawn two isopach maps, one for the composite thickness of Anhydrite I, Halite I, Anhydrite II and Halite II of the Castile formation and another for the composite thickness of the Castile formation and the Salado formation beneath marker bed 136. These isopach maps are included here as Figures 4 and 5. Lambert (1983) has used these maps to argue that the total thickness of Castile anhydrite/halite paired units tend to remain the same throughout much of the Delaware Basin regardless of variations in thicknesses of individual halite or anhydrite beds; the observed variations in the individual beds are thus syndepositional or deformational, not dissolutional. Lambert (1983) finally concludes that there is no preferential removal of any salt horizon in the post-Permian time, aside from the dissolution in the Rustler and upper Salado.

EEG requested Anderson to comment on the Lambert (1983) work and its conclusions. In a report submitted to EEG in April 1983, Anderson (1983, a) claims that "(Lambert's) conclusions related to lower Salado dissolution are almost completely wrong." The main reason for the confusion, according to Anderson, is the lack of understanding of the nature of the boundary between the Castile and Salado formations. If one does not recognize the unconformity between the Castile and the Salado formations and thus ignores the episode of dissolution during the post-Castile/pre-Salado time, one is assuming the lower Salado and upper Castile to be a single unit. When this is done, the lateral thickness changes are compensated and evidence for later salt removal through dissolution disappears. Further, according to Anderson (1983, a), if the truncated relationships at the unconformity are recognized and used to establish a datum, the original facies variation is easily discriminated from later dissolution.

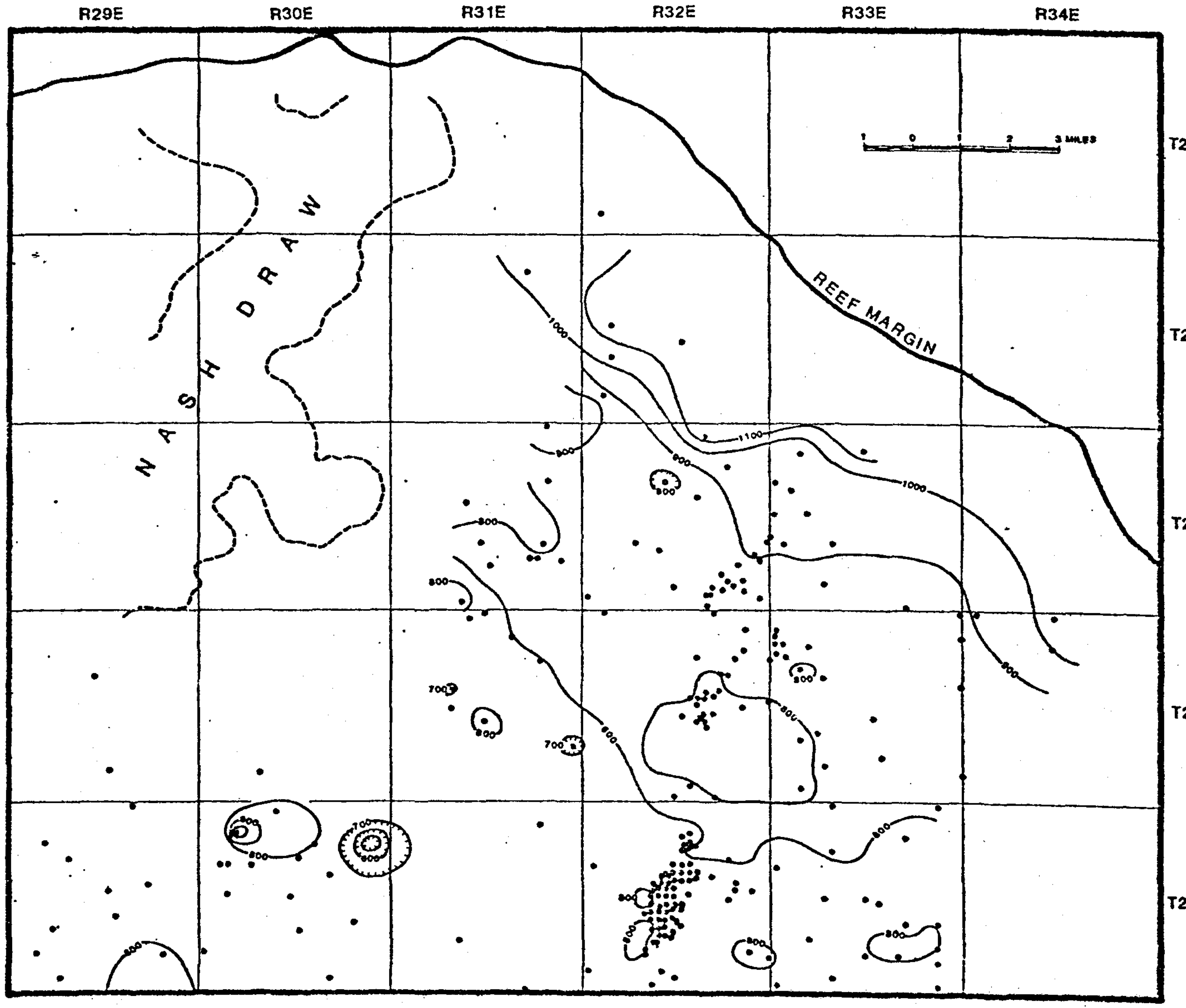


Figure 4. Isopach map of Anhydrite I, Halite I, Anhydrite II, and Halite II in the Castile Formation in the northern Delaware Basin (from Lambert, 1983)

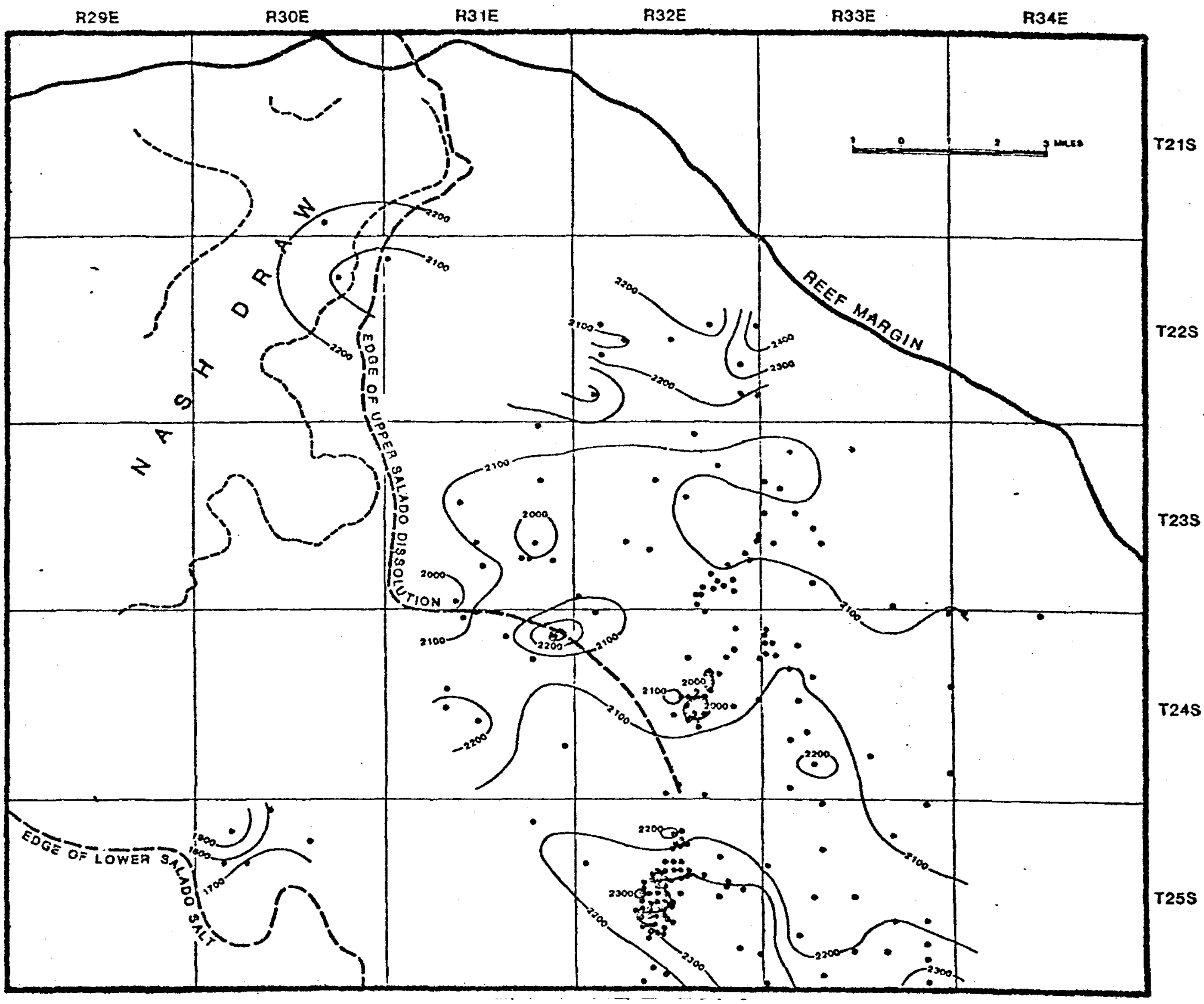


Figure 5. Isopach map of the Castile and lower Salado formation in the northern Delaware Basin (from Lambert, 1983)

In another report, Anderson (1983, b) has used a north-south cross-section in the eastern part of the basin to illustrate a one by one truncation of the salt beds in the upper Castile as one moves to the north. This line of truncation is the unconformity between the Castile and the Salado. Anderson (1983, b) has used this unconformity as an evidence for erosion and dissolution during the post-Castile/pre-Salado time. By using two other cross-sections, Anderson shows his evidence that the missing salt is in lower Salado and that the effects of facies change are separable from the effects of preferential removal of salt. By correlating the area of the bulk of the missing salt with the Malley and Huffington (1953) depressions, Anderson concludes that the dissolution occurred during the Pleistocene time since the fill in the upper part of the depressions is Gatuna, i.e. Pleistocene in age.

3.0 Conclusions

Roger Anderson has studied the Ochoan evaporite sequence in the Delaware Basin in great detail over a period of almost 20 years. He has advanced some very compelling evidence that a large amount of salt from the upper Castile and lower Salado units is missing, that the absence of salt follows a pattern which distinguishes it from facies changes within individual units and that the removal of salt is preferential, stratawise. The weakest argument in the Anderson hypothesis is the timing of deep dissolution. Since the assumption of timing of predominant dissolution as late Cenozoic is based on an assumed age of the Malley and Huffington (1953) depressions and the age of the basin uplift and tilting, there is room for different interpretations of the timing of deep dissolution.

On the other hand, the argument against the removal of salt, by assuming that any absence of salt is due to facies change, is not convincing. It is true that there does not seem to be a viable mechanism for preferential removal of salt at depth during geologically recent time or for this to be an active process. However, the lack of understanding of a mechanism should not be a reason to ignore the evidence for a phenomenon. EEG, therefore, accepts the existence of deep-seated dissolution as a strong hypothesis to explain the missing salt at depth.

Figure 1 shows the deep dissolution edges for the salt units, as interpreted by Anderson (1981). It should be noted that the WIPP site is situated in the northern part of the basin, away from the dissolution fronts, in a region where deep dissolution has not yet reached. The nearest point of the dissolution edge from the WIPP site is about 15 miles away. It would seem ironic to worry about the "deep dissolution" front when the front of shallow "blanket dissolution" lies only 2-3 miles west of the site and is known to be moving towards the WIPP site. The reason for this ironic concern is, of course, the lack of understanding of the deep dissolution process. According to Anderson, the basin has reached an advanced stage of dissolution and should, therefore, be rejected for nuclear waste disposal, as a whole. The EEG does not subscribe to this point of view.

There are five boreholes at the WIPP site (WIPP-9, 11, 12, 13 and DOE-1) which have penetrated the lowermost anhydrite bed (Anhydrite-I) in the Castile formation. These holes have been cored at selected intervals and geophysical logs for the entire depths have been obtained. In addition three holes outside the WIPP boundary, AEC-7 and 8 to the northeast and ERDA-10 to the southwest were drilled, cored and logged through the Castile formation. None of these seven boreholes (Fig. 6), not to mention several industry boreholes around the WIPP site, show any evidence of extensive dissolution. This points to the fact that at least the immediate area surrounding the WIPP site has not been affected by deep dissolution and is not expected to be affected in the immediate geologic future.

Anderson (1983) has pointed out two features, one on and the other near the WIPP site, which may indicate the possibility of point source dissolution. One of these is the encounter of the lower Salado marker beds e.g. MB 124, 75 feet below their expected level in an industry potash hole (F-92) 2 miles north of the center of the site. According to Davies (1983), this anomaly extends to the well WIPP-34. WIPP-14 was drilled to explore this area but was located 0.6 mile to the east of F-92 on the basis of a marked low in the gravity data which coincided with a seismic anomaly as well as a topographic low. WIPP-14 found the beds in Rustler and upper Salado essentially at the expected depths and did not find any evidence of brecciation or dissolution. However, it was drilled only 50 feet into the Salado and did not encounter any marker beds in the Salado. The other feature is five miles southeast of the center of the WIPP site. The acoustic log of the Perry Federal # 1-31 well in that area (Sec. 31, T225, R32E) shows, according to Anderson, that 200 feet of infracowden salt is missing.

In EEG's view, a single hole anomaly out of hundreds of wells drilled through the Salado horizon in the northern Delaware Basin, especially when it is outside the WIPP repository area, may not be very significant. The safety of the WIPP site from deep dissolution can be assured on the basis of the deep dissolution fronts (Fig. 1) being a safe distance away from WIPP and on the results of excavations at the repository horizon already completed under the SPDV program. The 9000 ft. of drifts already completed include a one-mile north-south drift (12 feet high and 25 ft. wide), another north-south drift (1840 ft. long, 8 ft. high and 25 ft. wide), six east-west drifts (each 140 ft. long, 8 ft. high and 25 ft. wide) and four rooms (each 13 ft. high, 33 ft. wide and 300 ft. long). The thickness and continuity of strata displayed in all this excavation is dramatically uniform, and there is no evidence for dissolution at the repository horizon as seen in SPDV excavations.

The only remaining anomaly within the WIPP site is the depression of lower Salado marker beds in the well F-92. Anderson (1983) and Davies (1983) propose that this feature may have resulted from point source dissolution at depth.

4.0 Recommendations

The Department of Energy should evaluate the depression exhibited by the stucture contours on lower Salado marker beds, centered two miles north of the center of the site and should first attempt to provide a reasonable explanation for this feature. If the possibility of lower Salado dissolution causing this feature cannot be eliminated, then a drill hole should be drilled through the entire Salado and selected horizons cored to investigate the cause for this anomaly. The feature appears to be confined to F-92 and WIPP-34 area and WIPP-14 is outside of it. Therefore, a deepening of WIPP-14 will not answer the question.

R. Y. Anderson made four other recommendations at the May 12 and 13 meeting in Carlsbad, viz., core Slick Sink, core one of the Maley and Huffington depression, core a deep dissolution margin and investigate the regional hydrology of deep dissolution. EEG has examined these suggestions carefully and has determined that in view of our acceptance of the possibility of deep dissolution in the Basin, away from the WIPP site, it is not necessary to further prove or disprove the hypothesis. Only the feature, close to the repository, which may indicate a point source deep dissolution, should be investigated.

5.0 References Cited

Anderson, R. Y., Dean, W. E., Jr., Kirkland, D. W. and Snider, H. I., 1972, Permian Castile varved evaporite sequence, west Texas and New Mexico, Geological Society of America Bulletin, v. 83, p. 59-86.

Anderson, R. Y., 1978, Deep dissolution of salt, northern Delaware Basin, New Mexico, Report to Sandia Laboratories, Albuquerque, New Mexico, 106 p.

Anderson, R. Y. and Kirkland, D. W., 1980, Dissolution of salt deposits by brine density flow, Geology, v. 8, p. 66-69.

Anderson, R. Y., 1981, Deep-seated salt dissolution in the Delaware Basin, Texas and New Mexico, N.M. Geol. Soc., Spec. Publ. no. 18, pp. 133-145

Anderson, R. Y., 1982, Upper Castile brine aquifer, Northern Delaware Basin, N.M., Unpublished manuscript, 11 p.

Anderson, R. Y., 1983 a, Review comments related to dissolution of evaporites in the Delaware Basin, Prepared for E.E.G., 13 p.

Anderson, R. Y., 1983 b, Evidence for deep dissolution in the Delaware Basin, Prepared for E. E. G., 7 p. + illustrations.

Bachman, G. O., and R. B. Johnson, 1973, Stability of salt in the Permian salt basin of Kansas, Oklahoma, Texas, and New Mexico (with a section on "Dissolved Salts in Surface Water" by F. A. Swenson), USGS Open-File Rpt 4339-4.

Bachman, G. O., 1974, Geologic processes and Cenozoic history related to salt dissolution in southeastern New Mexico: U.S. Geological Survey Open-File Report 74-194, 81 p.

Bachman, G. O., 1980, Regional geology and Cenozoic history of Pecos region, southeastern New Mexico, U.S. Geological Survey Open-File Report 80-1099, 116 p.

Bachman, G. O., 1981, Geology of Nash Draw, Eddy County, New Mexico, USGS Open-File Rpt 81-31

Davies, Peter, 1983, Presentation at the EEG Carlsbad Meeting, May 12, 1983.

Environmental Evaluation Group, 1983, EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement, EEG-22, 268 p.

Hiss, W. L., 1975, Stratigraphy and ground-water hydrology of the Capitan aquifer, southeastern New Mexico and western Texas, University of Colorado, Boulder, unpublished Ph.D. dissertation, 396 p.

Lambert, S. J., 1983, Dissolution of Evaporites in and Around the Delaware Basin, Southeastern N. M. and West Texas, SAND 82-0461.

Maley, V. C. and Huffington, R. M., 1953, Cenozoic fill and evaporite solution in Delaware Basin, Texas and New Mexico, Geological Society of America Bulletin, v. 64, p. 539-546.

Snyder, R. P., 1983, General site geology, Chap. 2 in Deformation of evaporite near the WIPP site, by Borns, D. T., et al., SAND 82-1069 (Draft).

Wood, B. J., R. E. Snow, D. J. Cosler, and S. Haji-Djufari, 1982, Delaware Mountain Group (DMG) Hydrology - Salt Removal Potential, TME-3166.

BRECCIA PIPES

1.0 Definition

Breccia pipes are vertical chimneys of brecciated rock which extend through several layers of intact rock strata to root in a collapsed cavity. These features are found in many evaporite basins of the world. The diameter of a breccia pipe is generally less than 1000 feet.

2.0 Confirmed Breccia Pipes

Vine (1960) identified several domal structures in the Delaware Basin which have been explored during the investigations for WIPP, as possible breccia pipes. After extensive investigation, the existence of only two pipes (Hills A and C) has been confirmed. Geophysical and geological studies show that two others (Hills B and Wills-Weaver) are also most likely breccia pipes, although they have not been cored. All four of these features appear to be situated over the Capitan Reef limestone, which is a prolific aquifer in the area. These four features as well as other features, previously suspected to be breccia pipes in the Basin, are shown in Fig. 6. Davies (1983) has pointed out that the Hill 'C' breccia pipe is located at the southern edge of the buried Capitan Reef and since the borehole (WIPP-16), drilled to explore this pipe, was drilled only to the level of the McNutt Potash Zone of the Salado formation, it is not clear whether the Hill 'C' breccia pipe roots in the Capitan aquifer. This is a valid argument, but although it is true that the borehole WIPP-16 was not drilled deep enough to answer this question unequivocally, the feature being at the edge of the reef is sufficient cause to believe that the Capitan Reef aquifer is responsible in the creation of this feature.

3.0 Suspected Breccia Pipes

Besides boreholes WIPP-31 and WIPP-16 which were drilled at hills A and C respectively to investigate the breccia pipes, three other boreholes were drilled at suspected breccia pipe locations in the Basin. Borehole

WIPP-32, 12 miles west of the center of the WIPP site, was drilled in a small topographic high which had been described by Vine (1963) as a domal karst feature. These features (domal karst) have been extensively studied by Bachman (1982). The boreholes WIPP-13 and WIPP-33 were also drilled to explore the presence of possible breccia pipes. There was a marked electrical resistivity anomaly at WIPP-13 and a prominent topographic depression exists at the location where WIPP-33 was drilled. Collapsed breccia was not found at either of the wells.

Anderson and Kirkland (1980) have described the occurrence of collapse breccia in a borehole in Culberson County, Texas, about 55 miles south of the WIPP site (see Fig. 6). Anderson (in Chaturvedi, 1980) has described occurrences of "Castiles" which are mounds of brecciated rock that outcrop a few miles south of the New Mexico-Texas border, south of the WIPP site. Both these occurrences are in the exhumed western part of the Delaware Basin which has already undergone extensive dissolution. These are not "active" features.

4.0 Mechanics and Time of Formation

Snyder and Gard (1982) have studied the known occurrences of breccia pipes. The one studied in most detail is the Hill 'C' breccia pipe which is also encountered at the McNutt Potash Zone of the Salado formation in the Mississippi Chemical Company potash mine, 1200 feet below the surface. From the study of this exposure, the core of WIPP-16 drilled in this pipe and the core of WIPP-31 drilled in the Hill 'A' breccia pipe, Snyder and Gard (1982) have concluded that the breccia pipes are formed due to the collapse of overlying rocks in solution cavities in the Capitan Reef aquifer. This appears to be a reasonable explanation. Bachman (1980) has hypothesized that the location of all the known breccia pipes in a small area over the reef is due to the presence of an old submarine canyon in the reef in this area. On the basis of the presence of Mescalero Caliche over the breccia pipes, Bachman (1980) also concluded that the collapse occurred prior to the deposition of this caliche layer, i.e., more than 500,000 years ago.

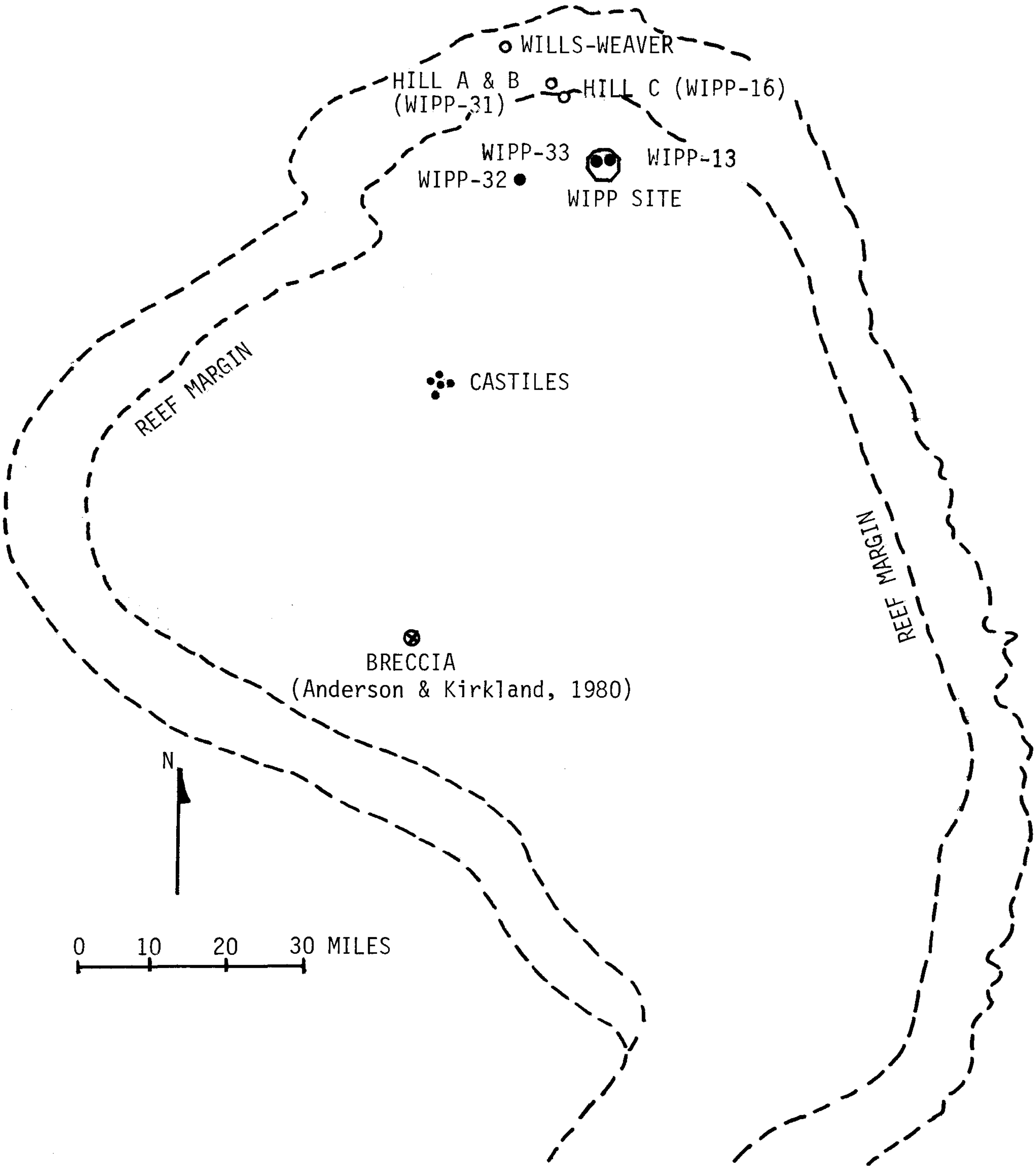


Figure 6. Map of the Delaware Basin showing features related to the Breccia Pipe issue.

5.0 EEG Conclusions

After considering all the available evidence on this question, EEG has concluded that the breccia pipes, by themselves, do not pose a threat to the WIPP repository. This conclusion is based on the following observations.

- After extensive investigation in the Delaware Basin area, the existence of only two pipes (Hills A and C) has been confirmed. Geophysical and geological studies show that two others (Hill B and Wills-Weaver) are also most likely breccia pipes, although they have not been cored. All these pipes are located over the Capitan Reef limestone, which is a prolific aquifer in the area. The exhumed breccia pipes in the basin, e.g. the Castiles, are not actively developing.

- Extensive potash mining operations in the Delaware Basin have encountered only one breccia pipe (Hill C) in the subsurface, and it also is most likely located over the Reef; although due to the lack of sufficient borehole control around Hill C, its location over the reef is not confirmed.

- Several features in the Delaware Basin (Vine's Domes--Vine, 1960) are clearly the result of either near-surface dissolution or surficial erosion (Karst domes or mounds--Bachman, 1980).

- Three holes (WIPP-13 and 32 and 33) were specifically drilled to explore suspected breccia pipes in the basin but did not encounter brecciated strata in the subsurface.

- The explanation (Bachman, 1980) that the known breccia pipes were formed in the area near an old submarine canyon in the Capitan Reef, about 500,000 years ago, seems to be a reasonable explanation for the formation of breccia pipes.

- EEG has calculated the effect of a hypothetical breccia pipe developing under the repository and has concluded that the radiological impact of such a feature returning radioactive materials to the biosphere would be insignificant (Spiegler, 1982).

The question of breccia pipe formation representing deep dissolution through brine density flow (Anderson and Kirkland, 1980) is discussed in the section on Deep Dissolution.

6.0 References Cited

Anderson, R. Y. and Kirkland, D. W., 1980, Dissolution of salt deposits by brine density flow, Geology, v. 8, no. 2, p. 66-69.

Bachman, G. O., 1980, Regional geology and Cenozoic history of Pecos region, Southeastern N.M., U.S. Geological Survey Open-File Report 80-1099, 116 p., 20 figs.

Chaturvedi, L., 1980, WIPP Site and vicinity geological field trip, EEG-7, 148 p.

Davies, P. B., 1983, A review of the USGS Open File Report 82-968, "Evaluation of Breccia Pipes in Southeastern New Mexico and Their Relation to the WIPP Site" by R. P. Snyder and L. M. Gard, Jr., prepared for EEG, 7 p.

Environmental Evaluation Group, 1980, Geotechnical considerations for radiological hazard assessment of WIPP, EEG-6, 69 p.

Spiegler, P., 1982, Analysis of the potential formation of a breccia chimney beneath the WIPP repository, EEG-13, 25 p.

Snyder, R. P. and L. M. Gard, Jr., 1982, Evaluation of breccia pipes in Southeastern New Mexico and their relation to the WIPP site, U.S. Geological Survey Open-File Report 82-968, 73 p.

Vine, J. D., 1960, Recent domal structures in Southeastern New Mexico, American Assoc. of Petro. Geologists, Bull, v. 44, no. 12, pp. 190.

BRINE RESERVOIRS

1.0 Introduction

Within a few miles of the WIPP site there have been thirteen reported brine encounters during drilling in the upper anhydrite layer of the Castile Formation with sufficient pressure to produce significant flow at the land surface (Figures 7 and 8). Additionally, Snyder (1983) documents brine occurrences in the upper anhydrite layer of the Castile formation without sufficient pressure to produce a significant surface brine flow. These nonflowing artesian brines (labeled as sub-artesian on Figure 7) are generally concentrated along and west of the Pecos River; however, a few scattered occurrences are reported east of the Pecos River. The flowing artesian brines are of most concern and will be discussed in detail.

During the characterization of the WIPP site, two wells encountered pressurized artesian brine which flowed to the surface at test holes ERDA-6 and WIPP-12 (Figure 8). At EEG's insistence, DOE has tested both encounters to obtain hydrological and geochemical data (D'Appolonia, 1982). Both DOE and EEG have independently analyzed these data. DOE has reported its findings in Popielak, et al. (1983) while EEG has reported its findings in Spiegler (1982), Spiegler (1983) and Faith et al. (1983). Although the studies of these two encounters undoubtedly have improved the scientific understanding of such phenomenon, conclusions drawn from the ERDA-6 and WIPP-12 testing are applicable to only those two encounters.

2.0 Occurrence

From Figure 7, it appears that the brine encounters in boreholes do not occur randomly. Two large groups of encounters are observed northeast and east of the WIPP site. The location of these two groups appears to indicate a relationship between the pressurized brines and the Capitan Reef. The WIPP-12, Belco, and Danford encounters are isolated and away from the Reef. Although non-random, the occurrences do not follow a consistent pattern.

In each borehole that encountered pressurized brine, the brine was located in the upper anhydrite of the Castile Formation, generally anhydrite III. The

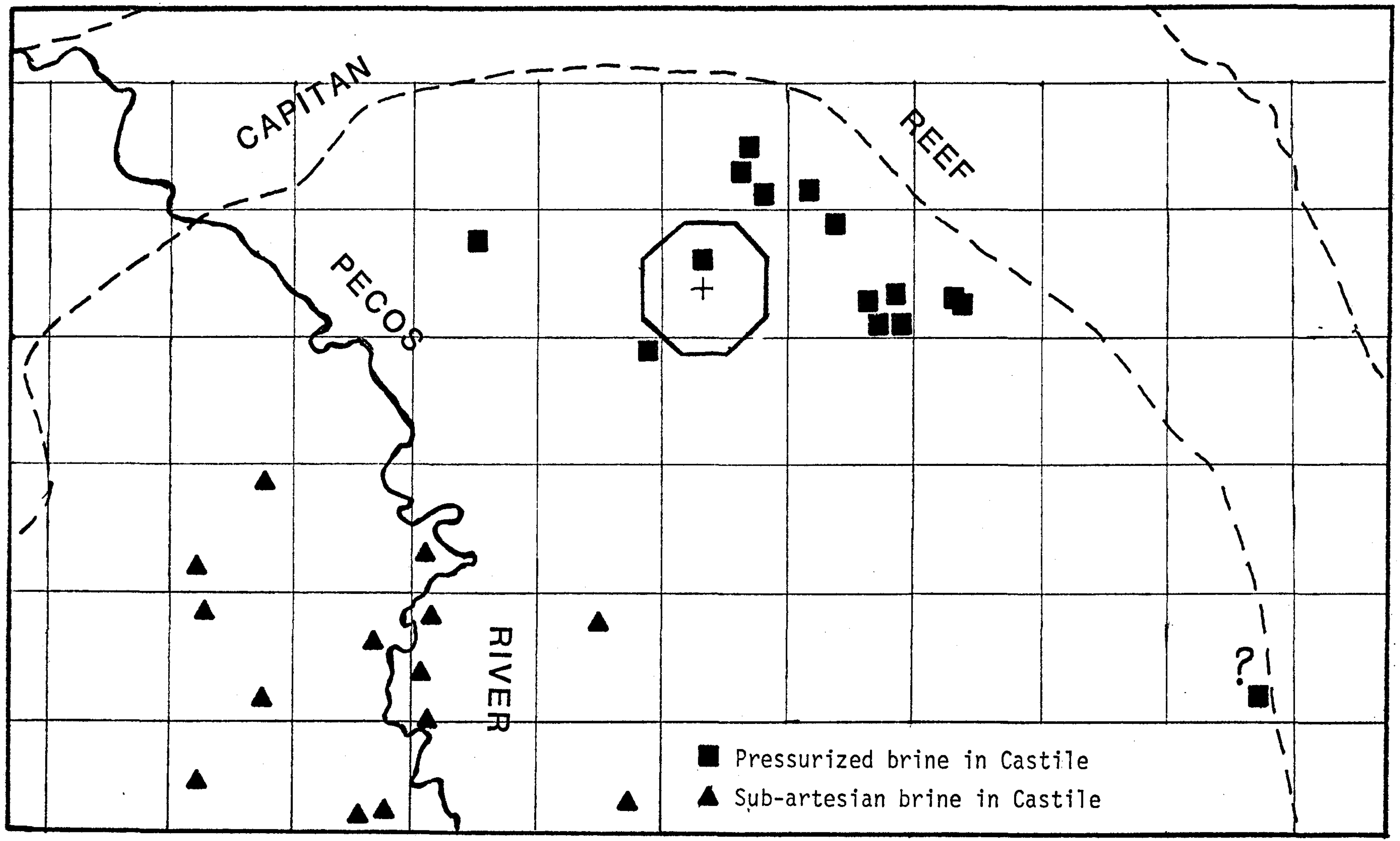


Figure 7. Encounter of brine in the Castile Formation.

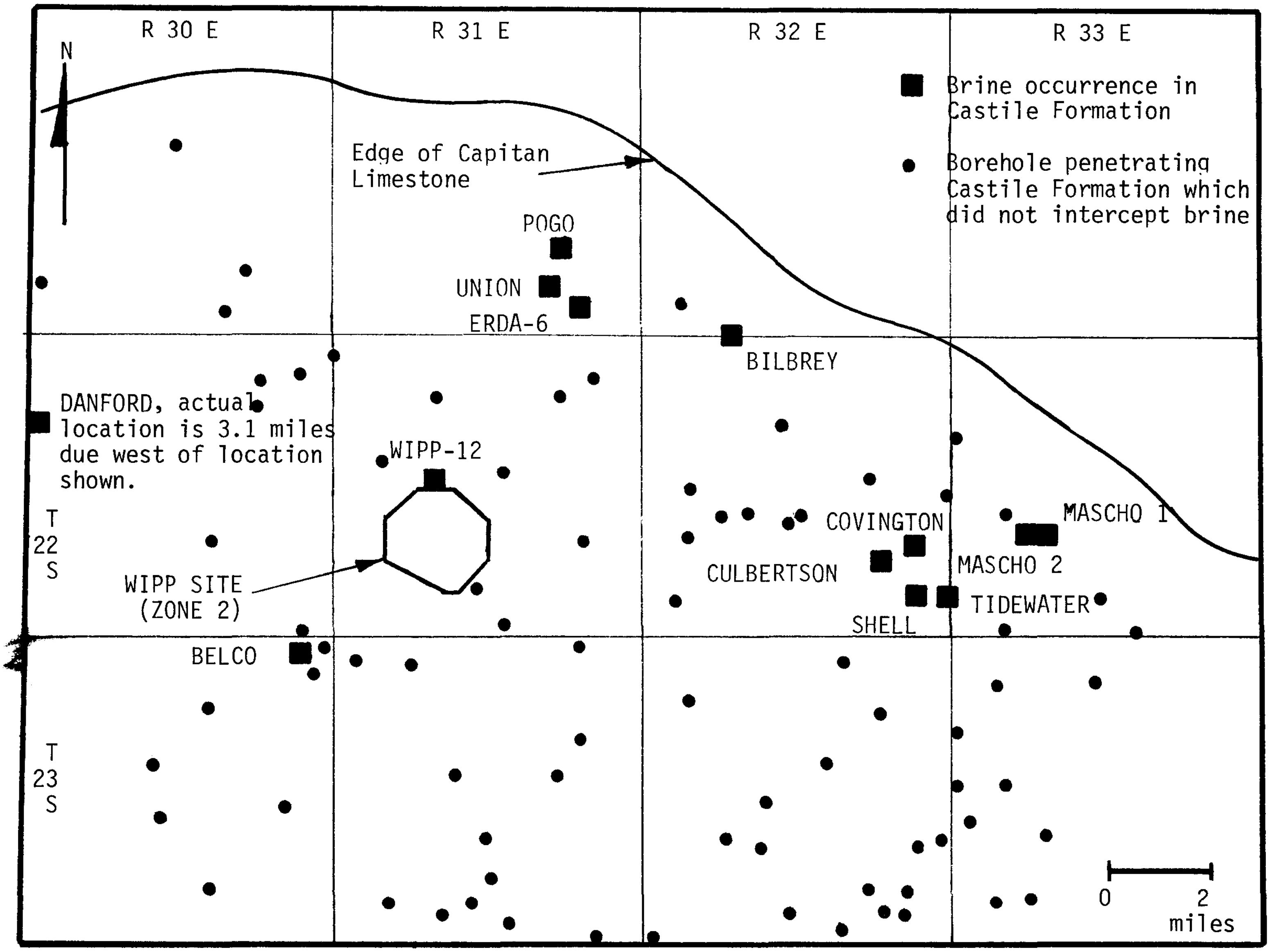


Figure 8. Location of brine encounters and deep boreholes penetrating the Castile Formation. Figure obtained from reference 1.

occurrence appears to be associated with structural features in the Castile. However, every drill hole into a structure has not encountered brine. The general consensus is that the brines occur within the fractured upper Castile anhydrite in areas of structural deformation.

3.0 Hydraulics

Extensive drill stem and flow testing of both ERDA-6 and WIPP-12 have yielded data on the permeability of the two reservoirs. In both wells heterogeneity of permeability was observed. Short tests produced high flows of brine and associated high permeabilities. The longer flow tests were characterized by smaller flows and smaller permeabilities.

The representative calculated permeabilities (Popielak et al, 1983; Spiegler, 1982) for the short and long tests in ERDA-6 and WIPP-12 are listed below.

	Long tests	Short tests
ERDA-6	1 - 3 md	10 - 13 md
WIPP-12	6 - 17 md	2000 - 5000 md

In each well, the brine was produced from fractures. Therefore, the calculated permeabilities based on porous media radial flow theory are rough approximations. In addition, the permeabilities were calculated from the permeability - thickness product, where the thickness was not the length of a fracture encountered, but rather the interval isolated by the packers. Although approximate, the data clearly indicate the greater permeability associated with the WIPP-12 encounter.

The hydraulic testing showed that the high initial flows from the two tested reservoirs are sustained for only a short time.

The wellhead pressures on March 19, 1983, at ERDA-6 and WIPP-12 were 552 and 162 psig, respectively. These pressures correspond to a column of brine extending above the wellhead for 1047 ft. and 307 ft., for ERDA-6 and WIPP-12, respectively.

4.0 Size

DOE (Popielak, et al., 1983) estimates the representative volumes of the ERDA-6 and WIPP-12 brines as 630,000 bbl and 17 x 10^6 bbl, respectively. Based on preliminary data EEG estimated the volumes to be between 60,000 bbl and 120,000 bbl for ERDA-6 and between 5 x 10^6 bbl and 10 x 10^6 bbl for WIPP-12 (Spiegler, 1982). Using the most recent data provided by DOE, EEG calculates the ERDA-6 brine volume to be between 170,000 bbl and 340,000 bbl. The WIPP-12 volume remains unchanged.

The volume is calculated by

$$V = \frac{\Delta V}{\Delta P\ C_t} = \frac{\Delta V}{\Delta P\ (\phi K)^{-1}}$$

where ΔV = volume of fluid discharged

ΔP = reservoir pressure depletion

C_t = total system compressibility which in most situations can be approximated by the pore-volume compressibility

$(\phi K)^{-1}$ = inverse porosity-rock bulk modulus product; used by DOE to calculate the pore-volume compressibility

The smaller EEG estimate for the ERDA-6 volume is due to the assumption of a larger compressibility. Compressibility will be discussed later. The smaller EEG estimate of the WIPP-12 volume is due to EEG's utilization of a subset of the WIPP-12 data and a larger compressibility. The volume discharged and pressure depletion used by EEG were those as of January, 1982 whereas DOE uses the data through March, 1983. Since the WIPP-12 brine encounter is closer to the site, larger in volume, and has a larger permeability than the ERDA-6 encounter, subsequent discussion will concentrate on WIPP-12.

The compressibilities used by both EEG and DOE are largely crude estimates. Figure 9 depicts the variation in DOE's calculated reservoir volume as a function of porosity (ϕ) and rock bulk modulus (K), where $C_t \simeq (\phi K)^{-1}$. The representative volume presented by DOE falls near the center of the regions.

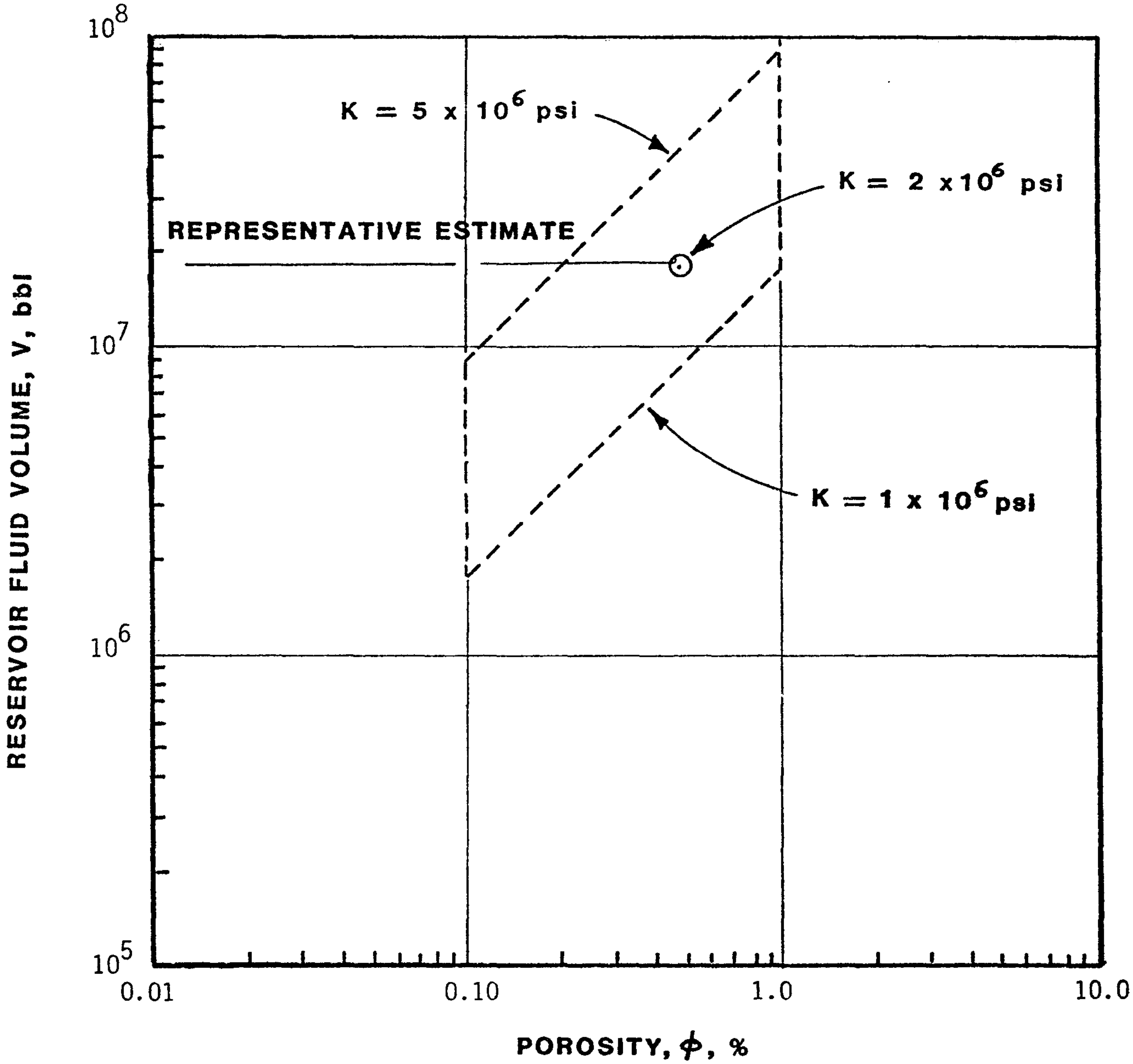


Figure 9. Total reservoir fluid volume WIPP-12
(from Popielak et al., 1983)

EEG has adopted the larger DOE estimates as reasonable, recognizing the approximate nature of the volume estimates.

Given an estimate of the brine volume, albeit a rough one, the next logical step is to estimate an area over which the brine is contained. The area is obtained from Popielak, et al. (1983), as,

$$A = \frac{V}{H\phi} = \frac{\Delta V \phi K}{\Delta P H \phi}$$

where A = area

V = volume of brine

H = thickness of anhydrite that contains brine

ϕ = porosity

It is interesting to note that because the total compressibility (C_t) is calculated as the porosity - rock bulk modulus product, the calculated area is independent of porosity. The only variable in the area calculation is the thickness of anhydrite that contains brine. The area of the WIPP-12 brine as a function of thickness and rock bulk modulus is presented in Figures 10.

Figure 11 is a map of the WIPP site showing the area of the WIPP-12 brine assuming the bulk modulus $K = 2 \times 10^6$ psi for various reservoir thicknesses. Also included on Figure 11 is the seismic time structure on the middle of the Castile. The calculated areas for WIPP-12 all extend well beyond the limits of the apparent domal structure.

In summary it is apparent that any volume or areal extent estimate for the brine encounters is of limited accuracy. However, these estimates indicate that the WIPP-12 brine could extend beneath the repository.

5.0 Geochemical Data

Extensive chemical analyses (D'Appolonia, 1982) have produced a wealth of data. In addition to major and minor element chemical determinations, trace and isotopic chemical analyses were performed.

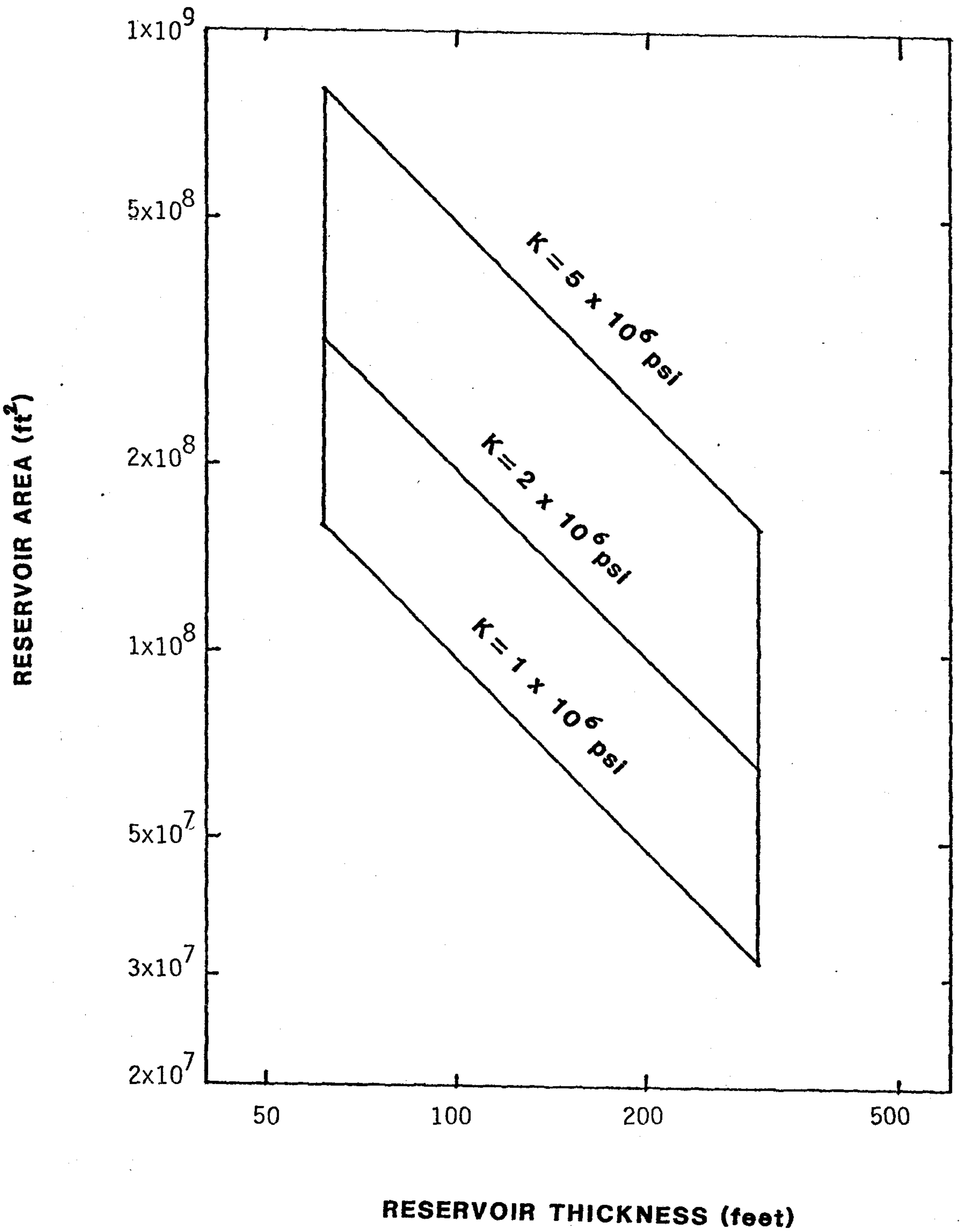


Figure 10. Reservoir area for the WIPP-12 brine as a function of reservoir thickness and rock bulk modulus.

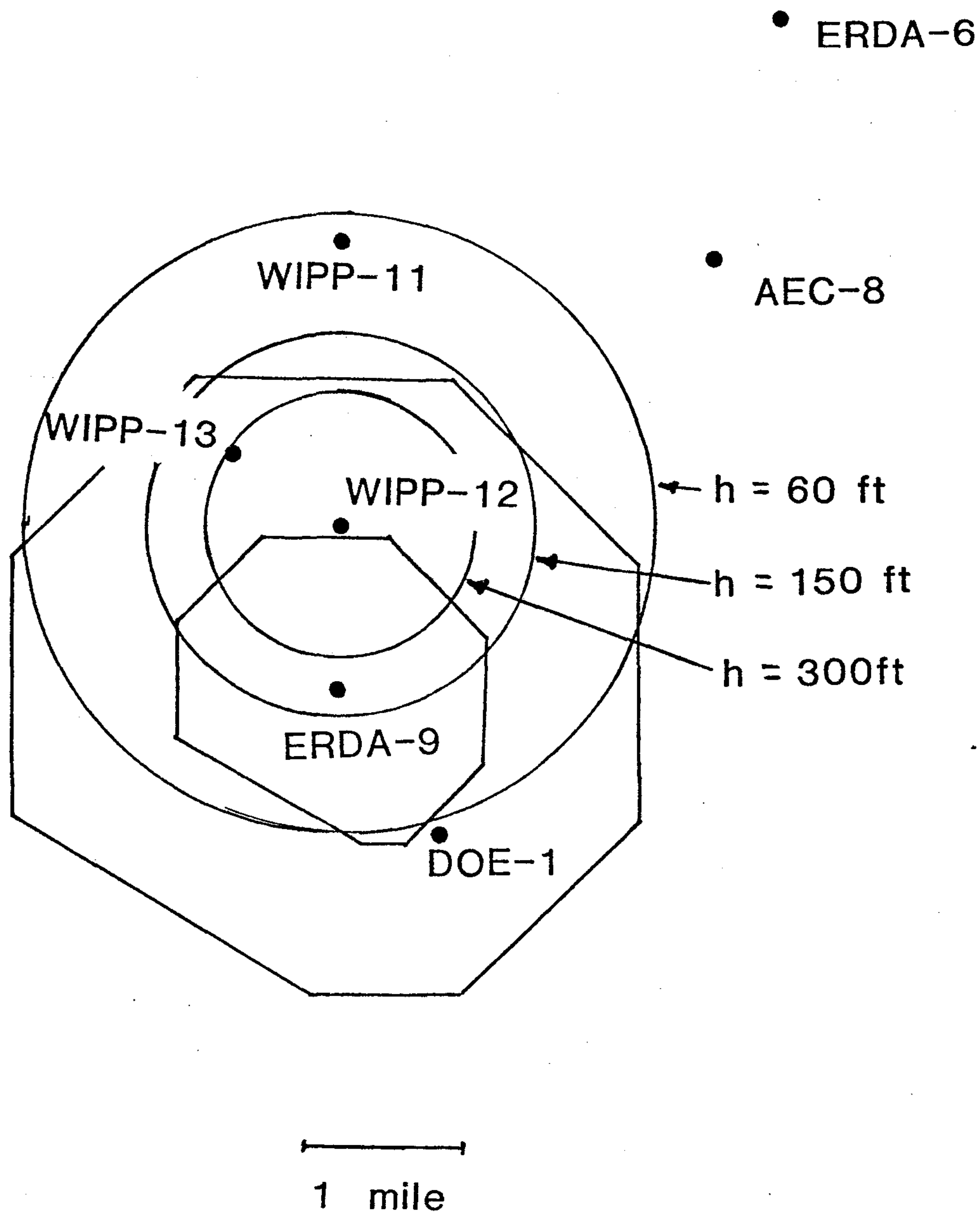


Figure 11. Aereal extent of the brines assuming a circle centered at the borehole for various reservoir thicknesses, $K = 2x10^6$ psi.

Interpretation of the major and minor element chemical data by EEG (Faith, et al., 1983) has led to the following conclusions.

- Small, yet statistically significant differences in the chemistry of the ERDA-6 and WIPP-12 brines are evident.

- Within the accuracy of thermodynamic equilibrium modeling, the ERDA-6 and WIPP-12 brines are saturated with calcite, anhydrite, glauberite and dolomite. The ERDA-6 brine is slightly undersaturated with halite and the WIPP-12 brine is nearly saturated with halite. The potential for dissolving additional halite or anhydrite is considered to be minimal.

- The relationship between the bromide content and the total dissolved solids in the brines indicates the brines are attributable to seawater evaporation and additional halite dissolution. The source of water for the halite dissolution is unclear.

The ERDA-6 and WIPP-12 brines appear to be nearly saturated with halite, therefore, the need to determine the original mechanism of halite dissolution may be of academic interest only. Suggested mechanisms for additional halite dissolution include: (1) dehydration of gypsum at depth, (2) introduction of meteorically derived water during Permian exposure, (3) mixing of groundwater from the underlying Bell Canyon aquifer with subsequent isolation by recrystallization or healing of fracture pathways, and (4) combinations of the above.

Interpretation of the isotopic data by EEG (Spiegler and Updegraff, 1983; Faith, et al., 1983) suggests the following conclusions:

- Many of the stable isotope fractionations indicate equilibrium. However, the calcite water fractionation, which does not indicate equilibrium, suggests that the water was not enriched in 18-oxygen by exchange with carbonates of the Castile formation. The fractionation of carbon between dolomite and calcite for WIPP-12 suggests that the dolomite and calcite are not cogenetic in the sense of having been precipitated from the same solution under the same conditions.

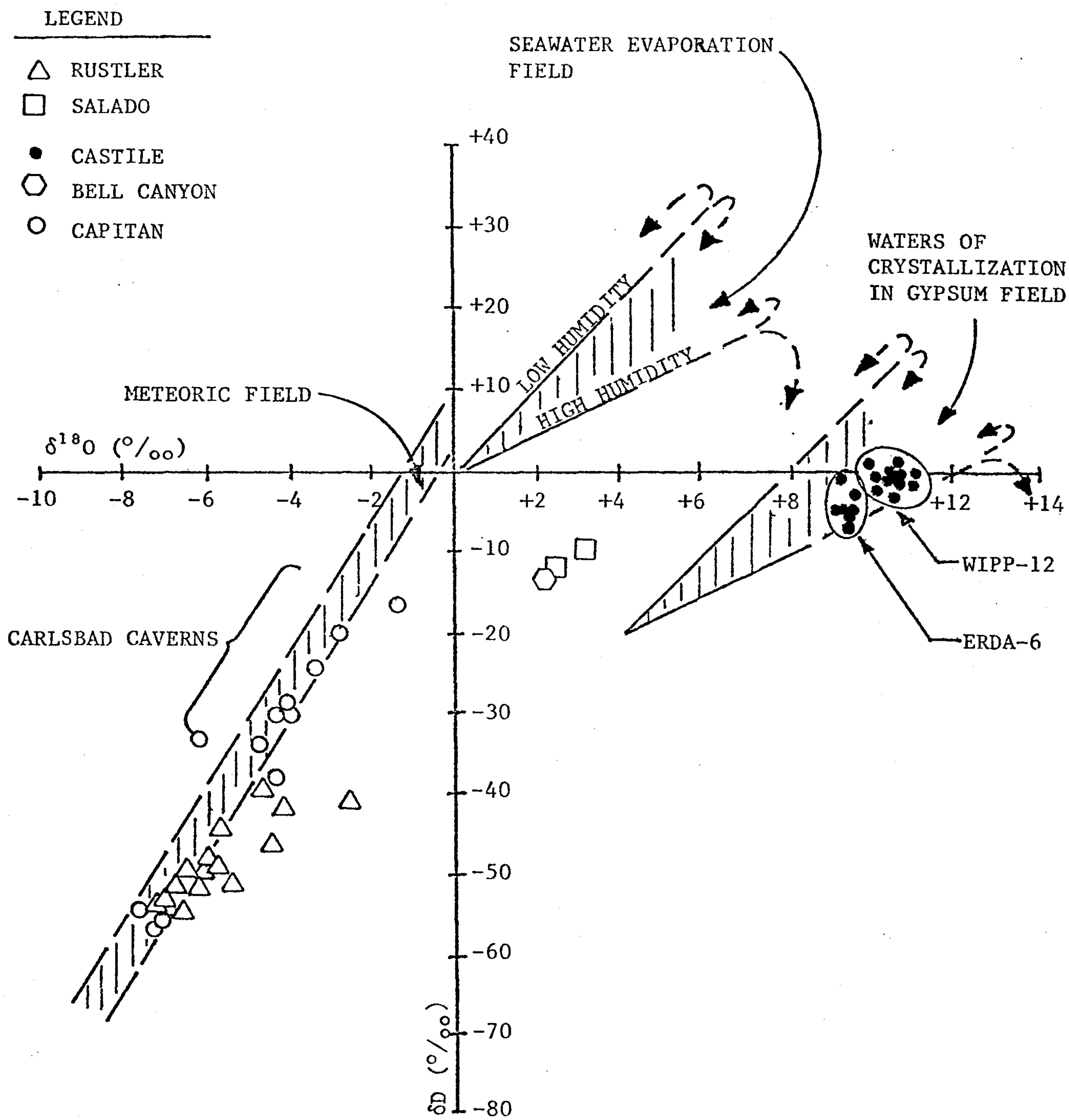


Figure 12. Isotopic compositions of the water/brine from the Delaware Basin (Spiegler and Updegraff, 1983)

- The oxygen-18 and deuterium concentration of the brines is unique compared to water in other nearby aquifers (Figure 12). A variety of source waters and isotope alteration pathways were considered. The hypotheses that the brines could have originated from waters of the Bell Canyon Formation or Capitan Reef in recent geologic time did not seem plausible. The ERDA-6 and WIPP-12 brines were probably derived from ancient ocean waters that have been isotopically enriched in oxygen-18 by exchange interaction with rock. The dehydration of gypsum as a process of brine origin cannot be ruled out.

- Analyses of uranium disequilibrium data yield only general conclusions. The ^{234}U in the ERDA-6 and WIPP-12 brines is not in secular equilibrium with ^{238}U. The disequilibrium probably results from the preferential leaching of ^{234}U from fractures in anhydrite. This leaching may be an ongoing process. Neither the true age of the brine, nor the age of fracturing is determinable with any degree of confidence.

6.0 Interconnection of Brine Occurrences

Based on the following evidence, the WIPP-12 and ERDA-6 brine occurrences are not likely to be connected to each other.

- The pressure potentials of the two encounters are significantly different. However, this in itself does not constitute proof of separation as pressure potential differences within reservoirs is an indication of fluid movement.

- The calculated areas, albeit approximate, for WIPP-12 and ERDA-6 do not overlap.

- The geochemical data suggest a lack of communication between the ERDA-6 and WIPP-12 reservoirs.

The lack of communication between the ERDA-6 and WIPP-12 brines does not imply that all brine encounters represent isolated brine pockets.

7.0 Origin of Brine

The tests performed on the brines of ERDA-6 and WIPP-12, which include hydrological tests, major and minor element chemistry analyses, isotope geochemical analyses, uranium disequilibrium measurements, and helium concentration in gases of brines, have yielded data which allow a discussion of the following possibilities of the origin.

Ancient seawater. Major and minor element geochemical data and stable isotope data favor this hypothesis.

Delaware Mountain Group aquifer water. Not likely because of geochemical and stable isotope data.

Capitan Reef water. Still implicated when estimating the age of brines using uranium disequilibrium data. Also implicated by proximity to a majority of brine encounters. Less likely based on geochemical and stable isotope data.

Water from dehydration of gypsum to anhydrite. Stable isotope composition of water in brines favors this hypothesis.

Meteoric water. Not likely because of geochemical and stable isotope data.

7.1 Age of Brine

There is no consensus on estimates of the age of the brine. The major and minor element chemistry data and the stable isotope data indicate ancient seawater. This hypothesis indicates that the water has been separated from the biosphere for tens of millions of years. The uranium disequilibrium age dating is very speculative since it requires numerous assumptions. With a range of parameters and initial conditions, The calculated brine "age" range from a negative age to 2 million years (Faith, et al, 1983).

8.0 Brine Reservoirs as a Threat to the Proposed Repository

The southern part of Zone II of the WIPP site appears to be more geologically predictable based on seismic and core hole data than the disturbed zone to the north. As no structure other than the WIPP-12 anticline is seen in the seismic profiles in zone II, the probability of the presence of brine in the southern part of Zone II appears to be low. Estimates of the area of brine include the zone beneath the proposed repository. Because there is no currently available method to prove a brine reservoir does not exist beneath the repository, other than by drilling boreholes into the Castile formation, EEG has taken the position of assuming a brine reservoir does exist beneath the repository and quantifying the consequences (Bard, 1982; Channell, 1982).

Human intrusion scenarios are believed to be the limiting cases because no plausible natural causes that will allow brine to bring wastes to the biosphere are envisioned. From its scenario analyses, EEG concludes that plausible radiation doses to the public (Bard, 1982; Channell, 1982) are below the limits that Protective Action Guides recommends for low probability accidents. DOE (Woolfolk, 1982) has reached similar conclusions.

9.0 Recommendations

In order to achieve more confidence and understanding of the subsurface below the repository, at least from an operational viewpoint, EEG recommends further evaluation and testing of the geophysical methods such as controlled source audio Magneto-Telluric (CSAMT) for the detection of brine in Zone II.

10.0 References cited

Bard, S. T., Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon - A Single Hole Scenario, Report EEG-15, February 1982.

Borns, D. J., Barrows, L. J., Powers, D. W., and Snyder, R. P., Deformation of Evaporites Near the Waste Isolation Pilot Plant (WIPP) Site, Report SAND 82-1069, March 1983.

Channell, J. K., Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, Report EEG-11, January 1982.

D'Appolonia Consulting Engineers, Inc., Data File Report. ERDA-6 and WIPP-12 Testing. Waste Isolation Pilot Plant, Westinghouse Electric Corp. Project No. NM 78-648-811A/812B, 7 vols., February 1982.

Faith, S., Spiegler, P., Rehfeldt, K. R., The Geochemistry of Two Pressurized Brine from the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, Report EEG-21, April 1983.

Popielak, R. S., Beauheim, R. L., Black, S.R., Coons, W. E. Ellington, C. T., and Olsen, R. L., Brine Reservoirs in the Castile Formation, Southeastern New Mexico, Report TME 3153, January 1983.

Snyder, R. P., private communication, 1983.

Spiegler, P., Hydrologic Analyses of Two Brine Encounters in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, Report EEG-17, December 1982.

Spiegler, P., and Updegraff, D., Origin of the Brines from the Drill Holes ERDA-6 and WIPP-12 Based on Stable Isotope Concentrations of Hydrogen and Oxygen, Report EEG-18, March 1983.

Woolfolk, S. W., Radiological Consequences of Brine Release by Human Intrusion into WIPP, Report TME-3151, July 1982

REGIONAL HYDROLOGY

1.0 Introduction

Knowledge of the regional hydrology near the WIPP is crucial because groundwater is the most likely path for radionuclide migration to the biosphere. In particular, modeling the solute transport characteristics of the water-bearing formations requires accurate determination of the direction and velocity of the groundwater flow.

The nearest perennial water course is the Pecos River, which at its nearest point is about 14 miles from the proposed repository. The only well developed ephemeral drainage is located about 4 miles west of the site at Nash Draw. The nearest surface water body, Laguna Grande de la Sal, is located within Nash Draw, about 10 miles southwest of the center of the site. The lake is fed by groundwater dicharging through springs, by local surface runoff following intense rainfall, and by discharge water from nearby mining operations (Geohydrology Associates, 1978).

Six water-bearing units have been identified near the proposed repository (Figures 13 and 14). Although defined as aquifers in this report, the units do not qualify as aquifers by strict definition. The three aquifers above the proposed repository (Figure 14) are contained in the Rustler-Salado contact, the Rustler Culebra Dolomite, and the Rustler Magenta Dolomite. Water is observed in two units underlying the level of the proposed repository; (Figure 13) as isolated brine occurrences in the upper anhydrite of the Castile Formation, probably anhydrite III, and in the Bell Canyon formation of the Delaware Mountain Group. The Capitan Reef aquifer which surrounds nearly the entire Delaware Basin, lies about 10 miles northeast of the site at its closest point.

2.0 Surface Water Hydrology

The nearest surface water body, Laguna Grande de la Sal, is located about 10 miles southwest of the center of the site (Figure 15). The lake is perennial and receives its water from precipitation, local surface runoff and from the

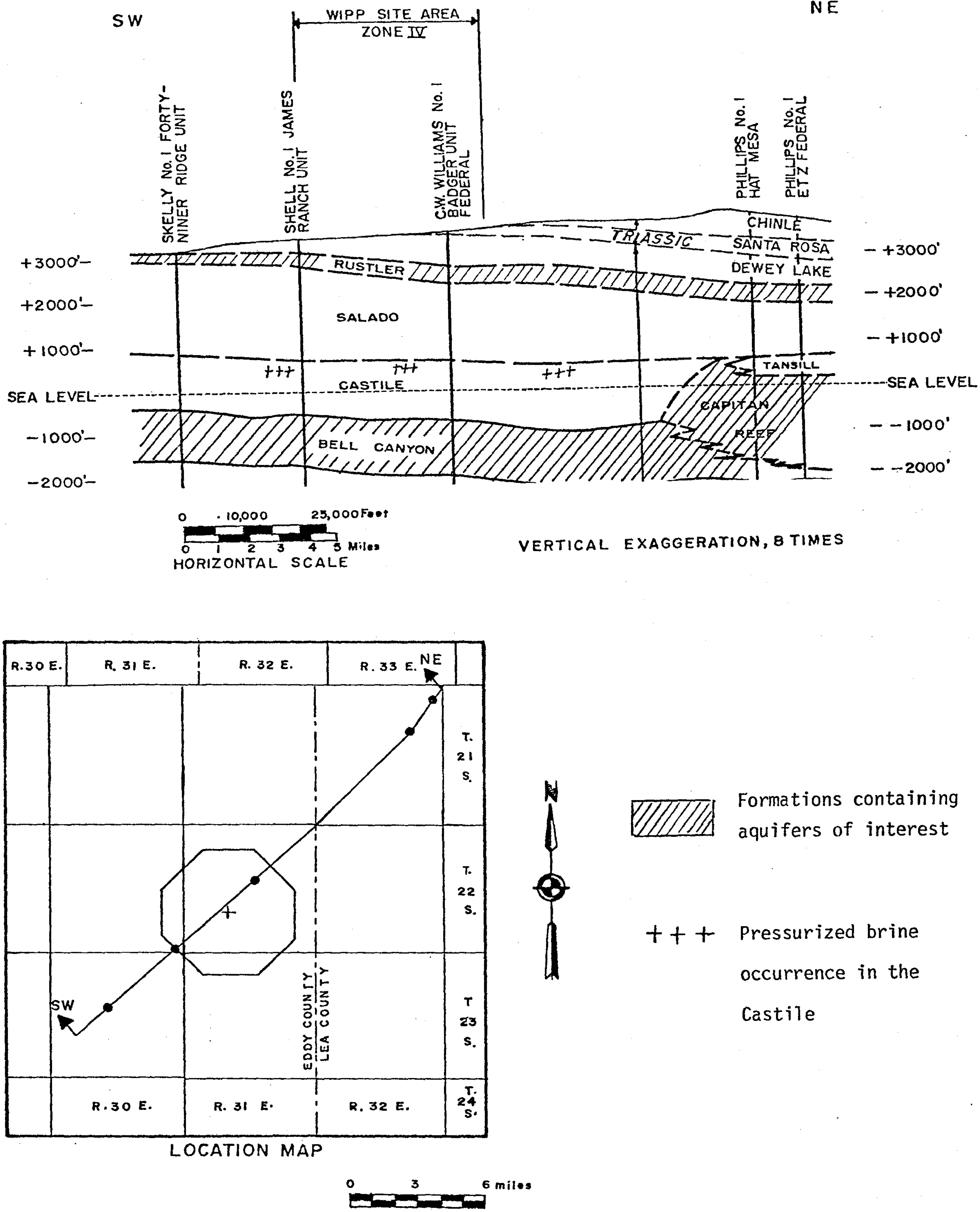


Figure 13. Generalized Site Stratigraphic Section
(from the Geological characterization Report, 1978)

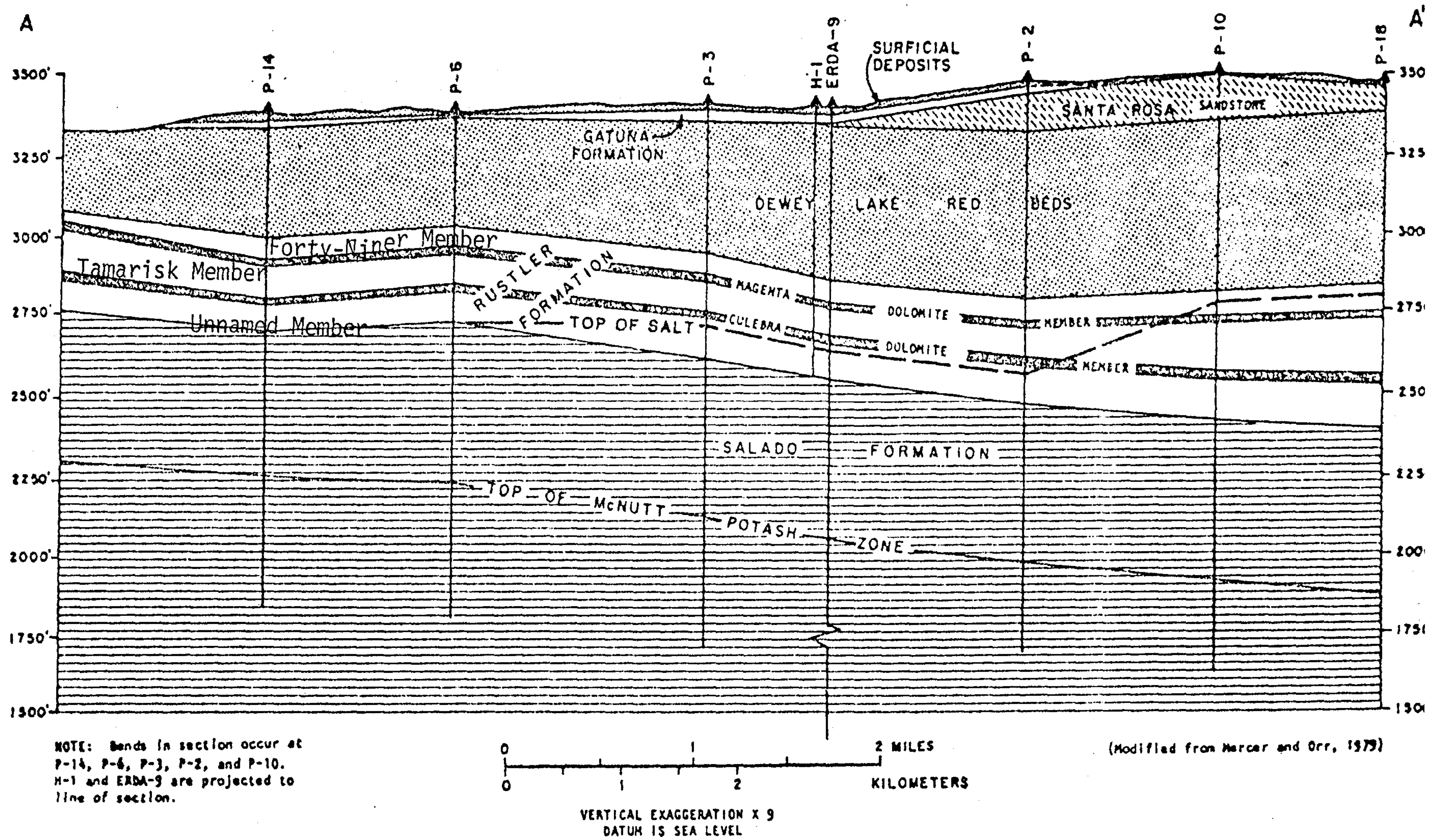


Figure 14. Geologic section across the proposed WIPP site (from Mercer, 1983)

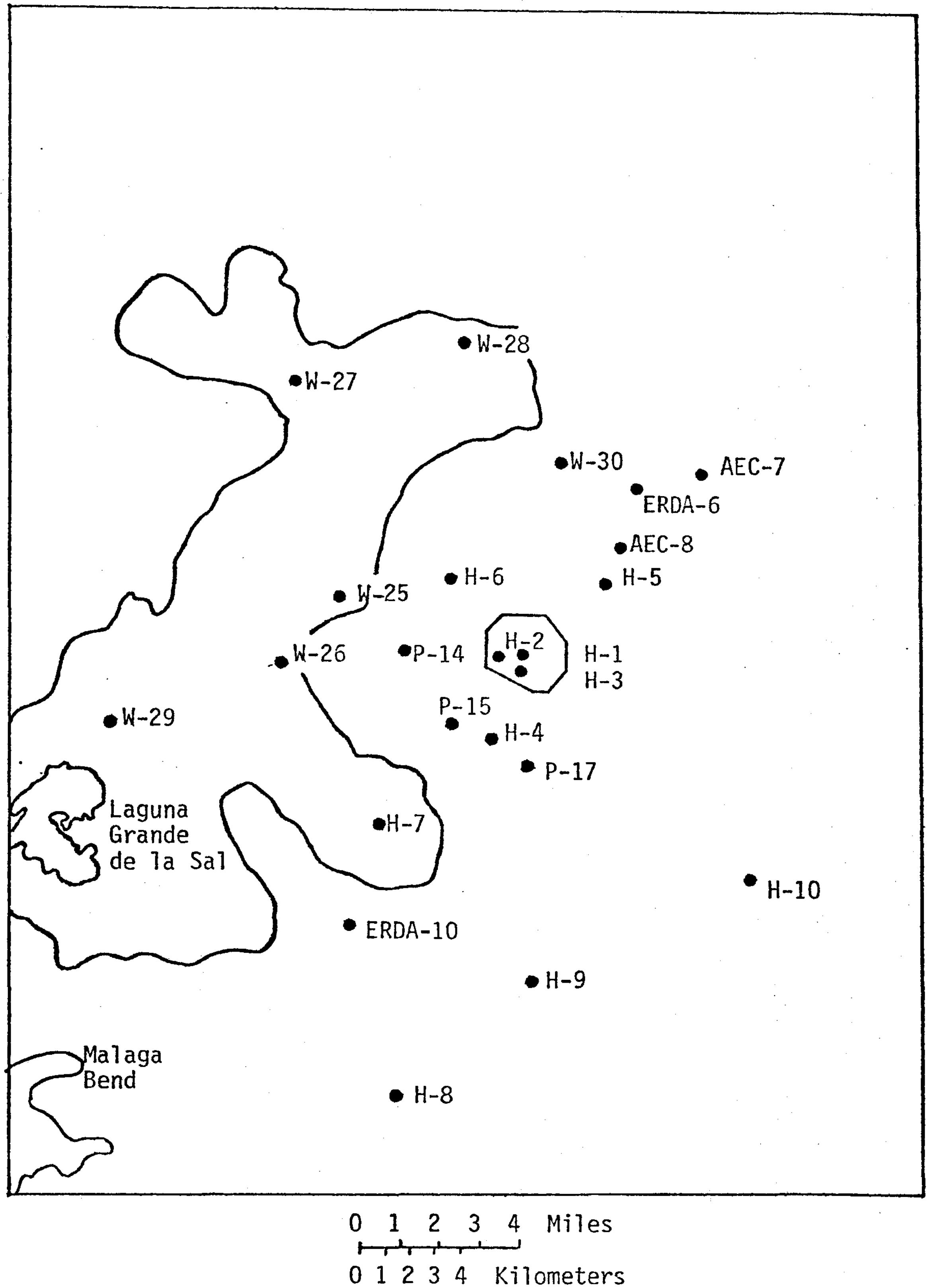


Figure 15. Location of test holes at and near the proposed WIPP site (from Mercer, 1983)

underlying Rustler formation, which may include discharge water from mining operations. The groundwater source is either the Culebra Dolomite, or an overlying anhydrite unit. The source is indeterminate at this time based on the limited chemical data available. However, on a piper diagram (Figure 16) two separate chemical analyses of water attributed to Surprise Spring are compared to Culebra water from selected surrounding wells (Mercer, 1983). One analysis (Geohydrology Associates, 1978) is similar to Culebra wells WIPP-27, WIPP 28, WIPP-29, WIPP-30, and P-17 while the second analysis (Lambert, 1983) is similar to wells P-14, WIPP-25, and WIPP-26.

The first chemical analysis of Surprise Spring (Geohydrology Associates, 1978) had a total dissolved solids content higher than any Culebra water sample. This may indicate that the sample was really from the lake and was not a representative sample of Surprise Spring. The second chemical analysis (Lambert, 1983), although similar to the Culebra waters, is dissimilar enough to make a postulated connection between the Culebra and Surprise Spring tenuous without further study. Surprise Spring is obviously not the only source of water to Laguna Grande de la Sal, but other specific locations of inflow to the lake are not identified.

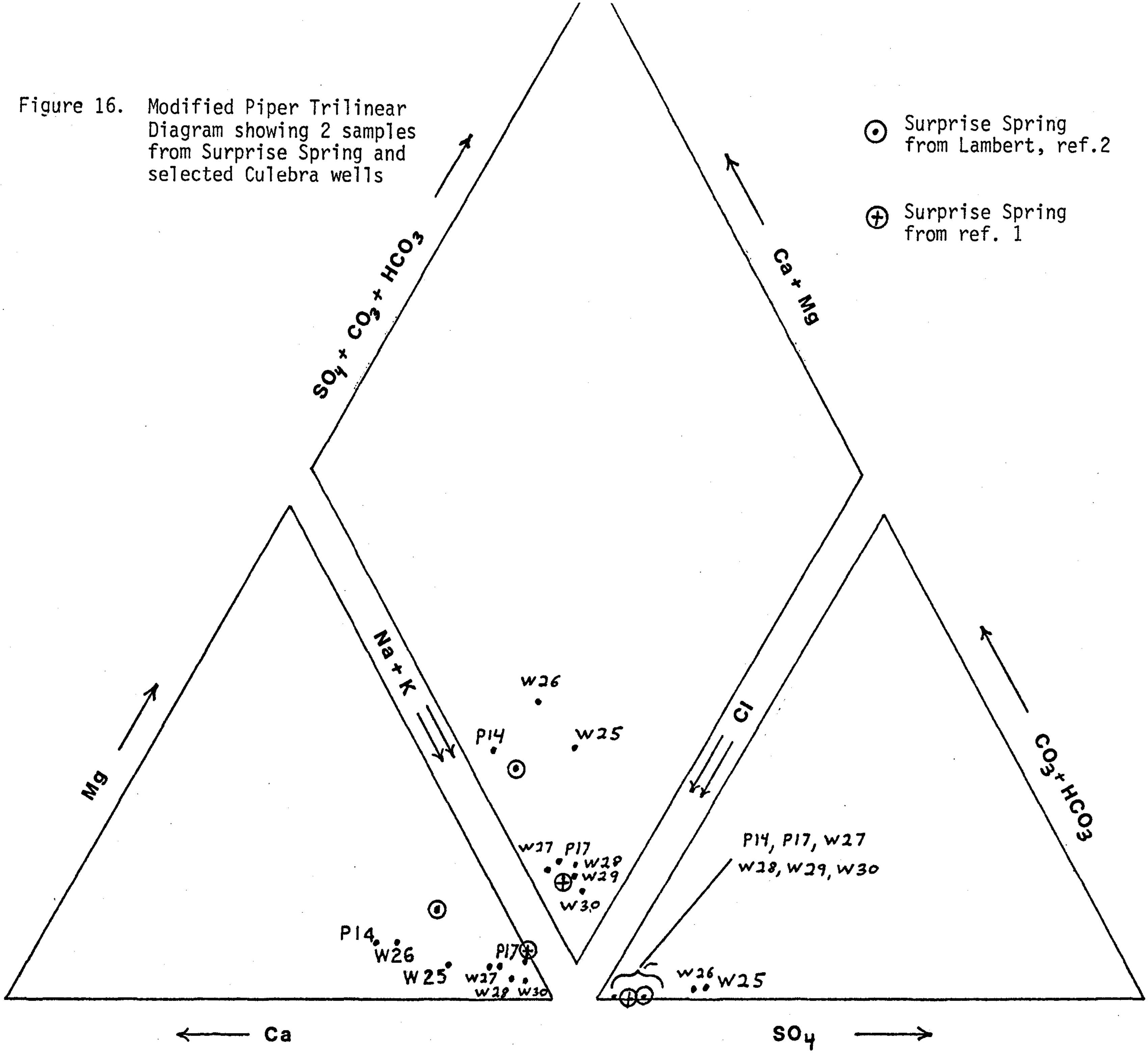
Mercer (1983) states that at a drill hole in Laguna Grande de la Sal, the hydraulic head in the Culebra was 21 feet above the lake level. The Culebra was overlain by 40 feet of gypsum mud at that location. These data are an indication that some leakage of Culebra water into the Laguna Grande de la Sal is occurring, but the leakage rates are unknown. In any event, the lake is a potential discharge point of the Culebra Dolomite.

The other currently recognized surface discharge point for the Culebra, or Rustler water in general, is the Pecos River. The large brine springs near Malaga Bend are the likely Pecos discharge locations nearest the WIPP site.

3.0 Groundwater Flow in the Bell Canyon Aquifer

The Bell Canyon Formation is of interest in relation to deep dissolution and as a transport mode for bringing radioactive waste to the biosphere.

Figure 16. Modified Piper Trilinear Diagram showing 2 samples from Surprise Spring and selected Culebra wells



The question of dissolution has been addressed elsewhere in this report. Studies by EEG and Wood et al. (1982) indicate that groundwater flow in the Bell-Canyon is insufficient to remove enough salt to pose a threat to the repository. In the unlikely event that a local dissolution feature (such as a breccia pipe) rooted in the Bell Canyon below the site were to form, Spiegler (1982) has shown the radiological consequences to not be significant. Additional analyses by EEG indicate that the representative solute transport characteristics of the Bell Canyon are such that water transport times to the accessible environment, assumed to be the Capitan Reef, are in excess of 165,000 years. If the most conservative parameters (Williamson, 1979) are used, then travel time could be as low as 9000 years. Solute transport times would likely be much longer due to solute retardation.

A significant point is the hydraulic head (uncorrected for salinity) of the Bell Canyon. Mercer (1983) and Gonzalez (1983) present extrapolated static bottom hole pressures and fluid densities for petroleum drill tests conducted over various intervals in three test holes (Table 1). Mercer (1983) and Weart (1983) state that the head of the Bell Canyon is insufficient to cause an upward flow of water into the overlying Culebra Dolomite aquifer, should such a connection occured, based primarily on the data of the three deep test holes (AEC-7, AEC-8, ERDA-10). EEG questions the contention of insufficient head in the Bell Canyon based on the limited borehole test data for the following six reasons.

1. Measured hydraulic head is only available for test hole AEC-8. For test holes AEC-7 and ERDA-10 only downhole pressure and fluid density are available from which hydraulic head can be calculated.

2. When calculating the hydraulic head based on bottom hole pressure and fluid density, the resulting heads are very sensitive to changes in density or pressure. At test hole ERDA-10, test number 10, a change in fluid specific gravity from 1.165 to 1.164 results in a 3 foot calculated head increase. A change in static downhole pressure from 1820 psig to 1821 psig yields an increase in calculated head of two feet. Therefore, if the measured fluid densities and pressures are not an accurate representation of the in-situ conditions, substantial errors in calculated hydraulic head may result.

Table 1. Summary of drill-stem tests at test holes AEC-7, AEC-8, and ERDA-10, upper Bell Canyon Formation, in the vicinity of the WIPP site (from Mercer, 1983).

Test number	Date of test	Tested interval, in feet below	Type of test	Hydrostaic pressure, in pounds per square inch (gage)		Flow period in minutes	Bottom hole flowing pressure, in pounds per square inch (gage)		Shut-in period, in minutes	Bottom hole shut-in pressure, in pounds per square inch (gage)		Calculated hydraulic conductivity, in feet per day	Static bottom hole pressure (extrapolated), in pounds per square inch (gage)	Fluid density, in grams per cubic centimeter
				Initial	Final		Initial	Final		Initial	Final			
Test Hole AEC-7														
1	4-23-79	4520- 4583 (Lamar)	Standard	2,841	2,462	30 120 360	30 23 25	23 23 21	60 360 480	23 23 21	23 25 23	Insufficient Data to Make Calculation	-	-
2	4-27-79	4609- 4714 (Ramsey)	Standard	2,547	2,531	25 60 120	127 460 861	395 804 1,270	60 120 335	395 804 1,270	1,814 1,808 1,839	4×10^{-2}	1,883	1.130
3	4-28-79	4493- 4714 (Upper Bell Canyon)	Standard	2,479	2,466	10 60 120	120 352 770	314 717 1,188	60 120 350	314 717 1,188	1,764 1,737 1,768	4×10^{-2}	1,811	1.130
Test Hole AEC-8														
1	8-15-77	4844- 4800 (pre Ramsey lower sand)	Modified	-	-	-	-	-	-	-	-	2×10^{-2}	2,037	1.147
2	9-27-77	4821- 4827 (upper sand)	Modified	-	-	-	-	-	-	-	-	7×10^{-3}	2,044	1.060
7	7-24-76	4304- 4405 (Lamar)	Standard	2,445	-	30 58	13 24	18 32	121 748	18 32	1,761 1,788	2×10^{-6}	1,813	-
Test Hole ERDA-10														
9	9-19-77	3860- 3927 (Lamar)	Standard	2,083	2,054	30 120 480	51 75 112	58 106 215	120 360 240	58 106 215	1,708 1,684 1,511	4×10^{-4}	1,783	-
10	9-29, 30-77	4127- 4430 (Ramsey)	Modified	-	-	-	-	-	-	-	-	5×10^{-2}	1,820	1.165

3. Large variations in reported fluid densities are observed. For test hole AEC-8, test number 1, two different fluid densities are reported; 1.147 g/cm^3 (Mercer, 1983) and 1.11 g/cm^3 (Mercer and Orr, 1979). For test number 2, the densities are 1.060 g/cm^3 (Mercer, 1983) and 1.12 g/cm^3(Mercer and Orr, 1979). The measured hydraulic head for test number 1 is 2979 feet (Mercer, 1983); the calculated heads are 2807 feet and 2944 feet., for densities 1.147 g/cm^3 and 1.11 g/cm^3, respectively. For test number 2 the measured head is 2964 feet (Mercer, 1983). The calculated heads are 3186 feet and 2948 feet for densities 1.060 g/cm^3 and 1.12 g/cm^3, respectively.

4. There are large variations reported for static bottom hole pressure. For test hole AEC-8, test number 7, extrapolated static bottom hole pressures of 1813 psig and 1962 psig are presented in the Basic Data Report for AEC-8 (SAND 79-0269). For test hole ERDA-10, test number 9 extrapolated static bottom hole pressures of 1783 psig and 1816 psig are recorded in the Basic Data Report for ERDA-10 (SAND 79-0271). For both test holes, only the lower pressure is presented by Mercer (1983) and Gonzalez (1983). Fluid densities are not available, so hydraulic heads cannot be calculated.

5. The calculated freshwater head in ERDA-10 is not consistent with previous studies (Hiss, 1976; McNeal, 1965). The freshwater head relative to mean sea level is defined by

$$h_f = \frac{P \cdot 144}{\gamma_f} + sg\ (e_s)$$

where h_f = freshwater head (feet above sea level datum)

e_s = elevation of the pressure measurement (feet)

sg = fluid specific gravity; assumed numerically equal to fluid density

P = measured pressure (lb/in^2)

γ_w = the weight density of the water (lb/ft^3)

γ_f = 62.4 lb/ft^3 for fresh water

The calculated fresh water hydraulic head, pressure measurement elevation, pressure, and specific gravity for well tests in the Bell Canyon sandstones in the three test holes are presented in Table 2.

Table 2. Calculated Fresh Water Hydraulic Head in the Bell Canyon Sandstones at Test Wells AEC-7, AEC-8 and ERDA-10 Using Published Static Bottom Hole Pressures and Densities.

Test Hole	Test Number	Pressure Measurement Elevation (msl datum) (feet)	Static bottom hole pressure (psig)	Fluid specific gravity	Fresh water head (feet above msl) Calculated	Ref. 11
AEC-7	2	-941.6*	1883	1.130	3281	3280
AEC-7	3	-827.6*	1811	1.130	3244	
AEC-8	1	-1291.3[1]	2037	1.147[3]	3220	
AEC-8	2	-1264.0[1]	2044	1.060[2]	3377	3310
AEC-8	1	-1291.3[1]	2037	1.11[1]	3267	
AEC-8	2	-1264.0[1]	2044	1.12[1]	3301	
ERDA-10	10	-742.8*	1820	1.165	3335	3490

*Pressure measurement elevation is assumed to be the top of the tested interval given in Table 1.

[1]from Mercer and Orr (1979)

[2]from Table 1

[3]interpolated from Figure 22 of Hiss (1976)

The calculated fresh water heads for AEC-7 and AEC-8 are generally consistent with the work of Hiss (1976). The calculated fresh water head for test hole ERDA-10 appears to be too low compared to Hiss (1976). Errors in fluid density or bottom hole pressure of the magnitude observed in reasons 3 and 4 could easily account for the unusually low freshwater head in test hole ERDA-10.

6. The intervals tested in test hole AEC-8 appear to completely bypass the Ramsey sandstone member. Geophysical logs of the upper Bell Canyon including the 2 tested intervals are presented in Figure 17. The two sand units were chosen for testing because "The natural gamma log indicated that the two units were predominantly sandstone and the porosity log indicated that they

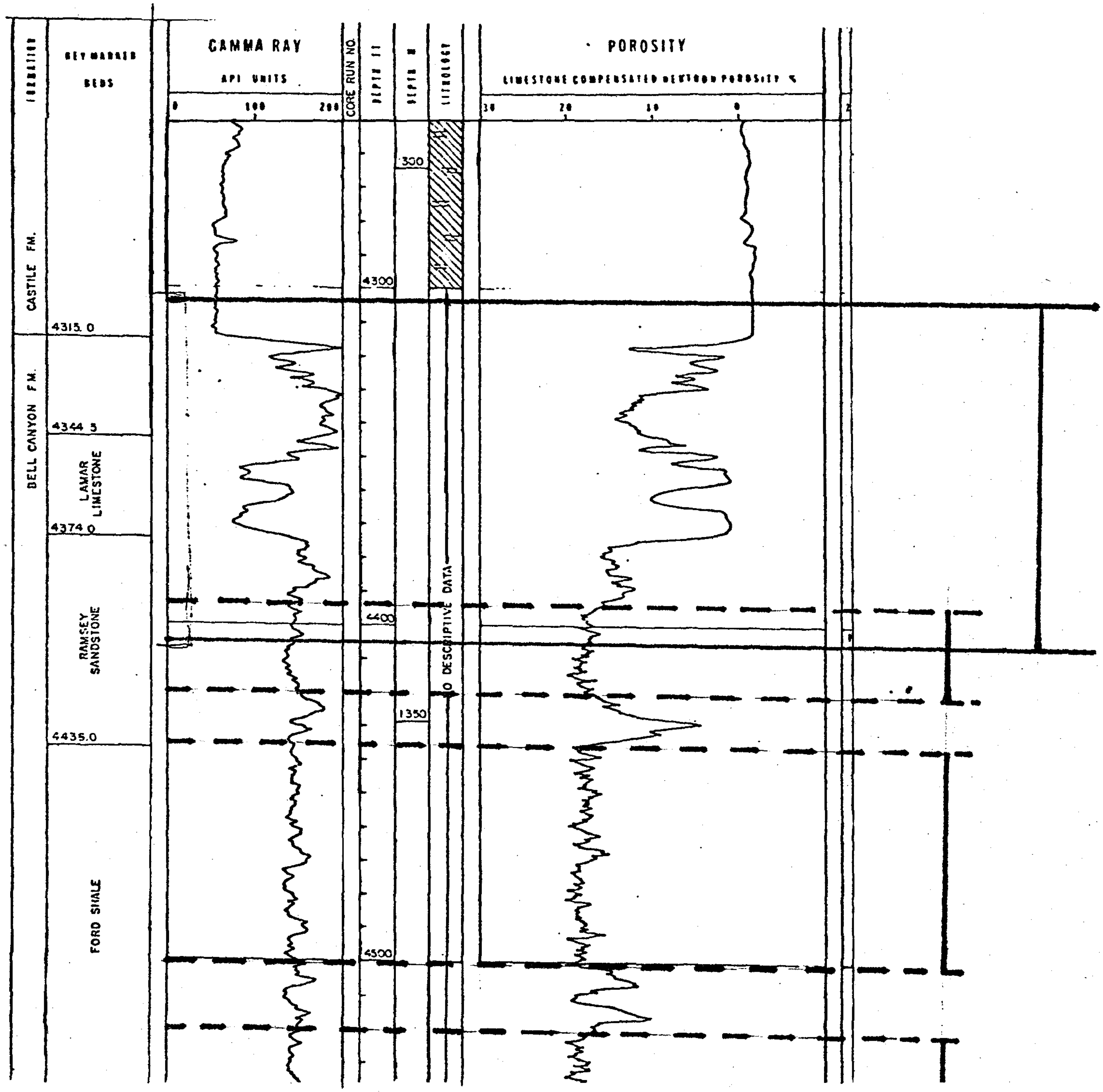


Figure 17a. Geophysical logs of borehole AEC-8 and intervals that EEG contends should have been tested (logs adapted from SAND79-0269, 1983)

intervals tested by DOE

intervals EEG contends should been tested

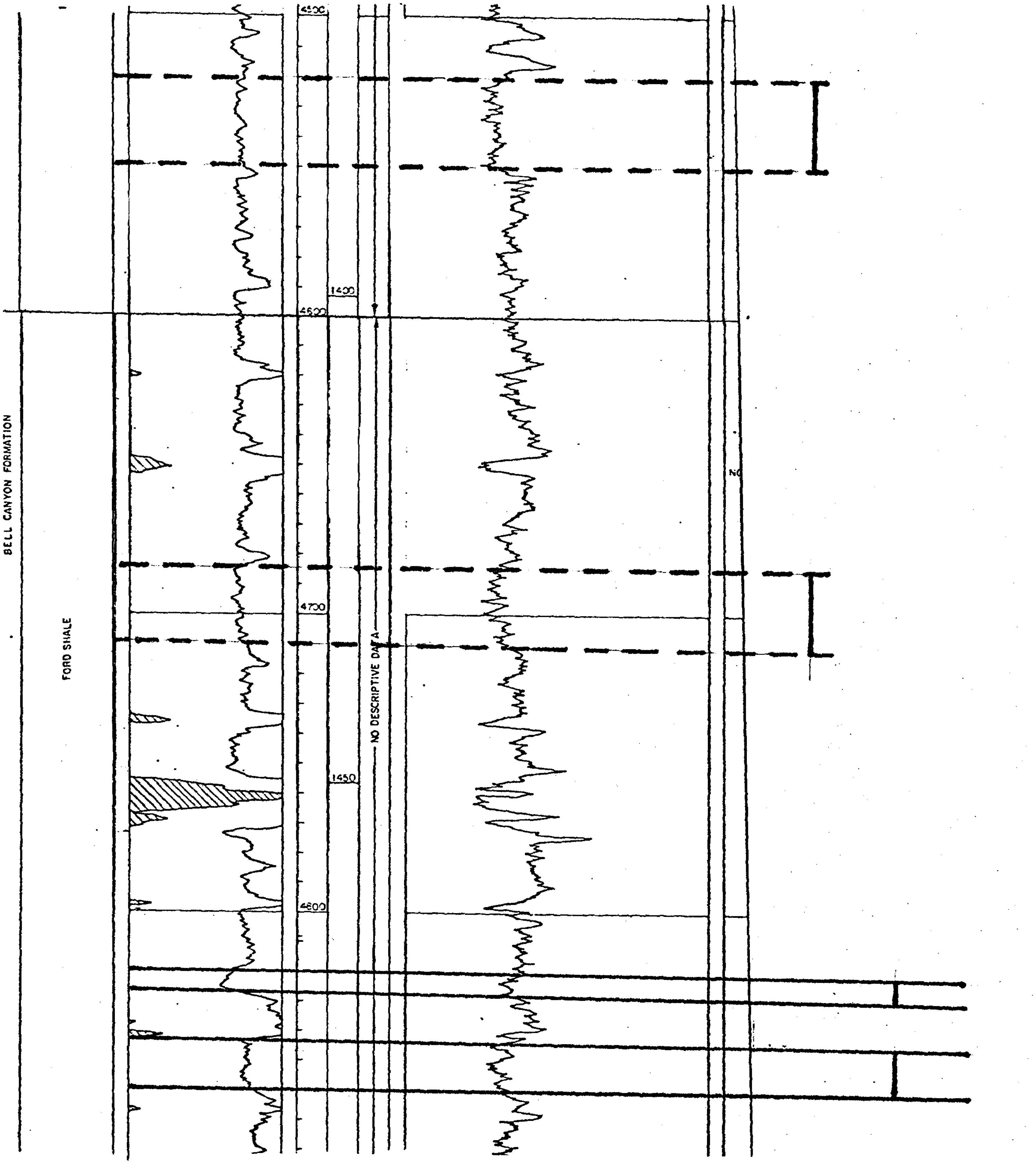


Figure 17b. Geophysical logs of borehole AEC-8 and intervals that EEG contends should have been tested (logs adapted from SAND79-0269, 1983)

intervals tested by DOE

intervals EEG contends should have been tested had greater porosities than other Bell Canyon sand units." (Mercer and Orr, 1979, p. 127). Four other sand units, not tested, which possess very similar geophysical log signatures as the intervals tested are indicated on Figure 17. These other untested sand units with a combined thickness of 150 feet, are stratigraphically closer to the repository and would have been logical intervals to test.

The calculated hydraulic head data for AEC-7 and ERDA-10 appear unreliable. From reason 2, a 5 foot error in hydraulic head results from a 1 psig error in pressure and a 0.001 g/cm^3 error in fluid density. From reasons 3 and 4, inconsistencies in both fluid density and pressure can be quite large. In addition, the intervals tested in AEC-8 do not appear to be representative of the upper Bell Canyon because from reason 5 it appears that 150 ft. of stratigraphically higher sands should have been tested.

In summary although EEG disagrees with some details presented by DOE concerning the salt removal and transport characteristics of the Bell Canyon, it does not appear to pose a threat to the repository either through the dissolution of salt or as a medium of radionuclide transport to the accessible environment.

Knowledge of the true hydraulic head in the Bell Canyon is essential to determining the direction of groundwater flow between the Culebra Dolomite and the Bell Canyon should such a connection occur in the future. If the flow is downward into the Bell Canyon, the radiological consequences of a repository breach would probably be much less than if the flow is upward into the Culebra.

The most conservative scenario modeling of a connection between the Bell Canyon and Culebra aquifers assumes the flow to be from the Bell Canyon to the Culebra. If DOE insists on establishing a downward flow from the Culebra to the Bell Canyon, the water level in at least one other well in addition to AEC-8 should be monitored. The well could be any borehole of opportunity located southwest, south, or southeast of the proposed repository. In addition, AEC-8 should be perforated in sandstones above the currently monitored intervals.

4.0 Castile Formation

Scattered occurrences of artesian and flowing artesian brines in the upper anhydrite layer of the Castile formation are recorded in the Northern Delaware Basin (see the section on Brine Reservoirs for more detail). To date, there is no evidence to suggest that a brine aquifer exists in the Castile Formation east of the Pecos River. In fact, the existence of highly pressurized brines provides evidence that an aquifer does not exist because the hydraulic head associated with such an aquifer should be consistent with the hydraulic head in the other aquifers, namely the Bell Canyon and the Capitan Reef. The observed hydraulic heads of the highly pressurized brines are much above the hydraulic heads in either the Capitan Reef or the Bell Canyon. Also, the geochemical data of the ERDA-6 and WIPP-12 brines indicate that the brines are immobile and not part of an aquifer system.

In the outcrop area west of the Pecos River, localized flow systems containing relatively fresh water are observed in the Castile Formation. The eastern extension of these fresh water systems is unknown, but it is assumed to be limited to the area west of the Pecos River.

Aquifers have not been observed near the WIPP site in the Castile Formation and consequently it is not considered a viable mode of radionuclide transport. The observation of only brines in the Castile near the WIPP would indicate that salt dissolution by the water in the Castile is not likely.

5.0 Groundwater Flow in the Rustler Formation

Groundwater in the Rustler Formation is observed in 3 distinct units: the Rustler Salado contact, the Culebra Dolomite, and the Magenta Dolomite (Figure 14). At the site the three aquifers are distinct and separate, but in Nash Draw, the distinction is less apparent to the southwest toward the Pecos River. Table 3 contains measured transmissivities for the Rustler aquifers.

5.1 Rustler-Salado Contact

The Rustler-Salado contact aquifer exists in solution residuum at the top of the Salado formation. From the site, the groundwater in the Rustler-Salado residuum

Table 3. Values of transmissivity and storage coefficient for water-bearing zones in the Rustler Formation penetrated by selected test holes at and near the WIPP site (from Mercer, 1983)

(Tansmissivity is expressed in feet squared per day)

Test hole	Magenta Dolomite Member		Culebra Dolomite Member		Rustler-Salado Contact	
	Transmissivity	Storage	Transmissivity	Storage	Transmissivity	Storage
H-1	0.05	–	0.07	10^{-4}	0.0003	–
H-2a	.01	10^{-4}				
H-2b			0.4	10^{-9}		
H-2c					0.0001	–
H-3	.1	10^{-5}	19.0	–	0.0003	10^{-4}
H-4a	.06	10^{-6}				
H-4b			0.9	10^{-9}		
H-4c					0.0006	10^{-4}
H-5a	.1	10^{-5}				
H-5b			0.2	10^{-5}		
H-5c					.00003	10^{-3}
H-6a	.3	10^{-5}				
H-6b			73.0	–		
H-6c					.003	10^{-6}
H-7a	Dry	–				
H-7b			1000+	–		
H-7c					0.73	–
H-8a	.006	10^{-5}				
H-8b			16.0	–		
H-8c					0.003	–
H-9a	1.0	10^{-9}				
H-9b			231	–		
H-9c					0.0002	–
H-10a	0.01	10^{-3}				
H-10b			0.07	10^{-4}		
H-10c					0.00009	–
P-14			140	–	0.05	–
P-15			0.07	10^{-4}	0.0004	–
P-17			1.0	10^{-6}	0.0002	10^{-4}
P-18			0.001	–	0.00003	10^{-5}
W-25	375	–	270	–	5.0	10^{-3}
W-26	Dry	–	1250	–	0.4	–
W-27	53	–	650	–	0.0002	–
W-28	Dry	–	18	–	0.87	–
W-29	Not present		1000	–	8	–
W-30	0.004	–	0.3	10^{-4}	0.2	10^{-4}

flows generally southwest with a possible discharge at Laguna Grande de la Sal, but the major discharge point nearest the WIPP site is the Pecos River near Malaga Bend. In Nash Draw, the Rustler-Salado contact is an aquifer with a transmissivity as high as 8000 ft^2/day. The transmissivity of the aquifer is very small (less than $3 \times 10^{-4} ft^2$/day) within 2 miles of the center of the site.

The water in the aquifer is characterized by extremely high total dissolved solids, the lowest being around 70,000 mg/l. In, and near Nash Draw the TDS is dominated by NaCl indicating flowing groundwater and active dissolution. Within zone II and most of zone III, the Rustler-Salado aquifer is very thin, has an extremely high TDS concentration and a disproportionately high potassium and magnesium concentration (Mercer, 1983). The extremely small transmissivity east of the western edge of zone II, in conjunction with the high magnesium and potassium concentration indicates a very restricted flow system at the Rustler-Salado contact at the site. Therefore, the Rustler-Salado contact residuum aquifer does not appear to be an important consideration for waste transport following a repository breach.

5.2 Culebra Dolomite Aquifer

The Culebra Dolomite aquifer is the most hydraulically conductive of the Rustler-water bearing units. As such, the Culebra may represent the bounding transport mode for contaminated water following a repository breach and subsequent water movement upward into the Rustler. In this section, the general hydrogeological characteristics of the Culebra are presented. Maps of the Culebra potentiometric surface and major chemical constituents are presented in Figures 18 and 19. The inferred direction of flow from the center of the site is from north to south and then west to Malaga Bend passing somewhere near to the Project Gnome site. Determinations of anisotropy of hydraulic conductivity at H-4, H-5, and H-6 by Gonzalez (1983), when incorporated into the flow analysis, indicate an initial southeasterly direction of flow from the WIPP site center before turning west to Malaga Bend. No data on anisotropy are available at the center of the site or to the southeast. In any event, the discharge point of Culebra water at the site would appear to be Malaga Bend.

The above picture of flow from the site passing in the vicinity of the Project Gnome site and discharging into the Pecos River is inconsistent with the observed

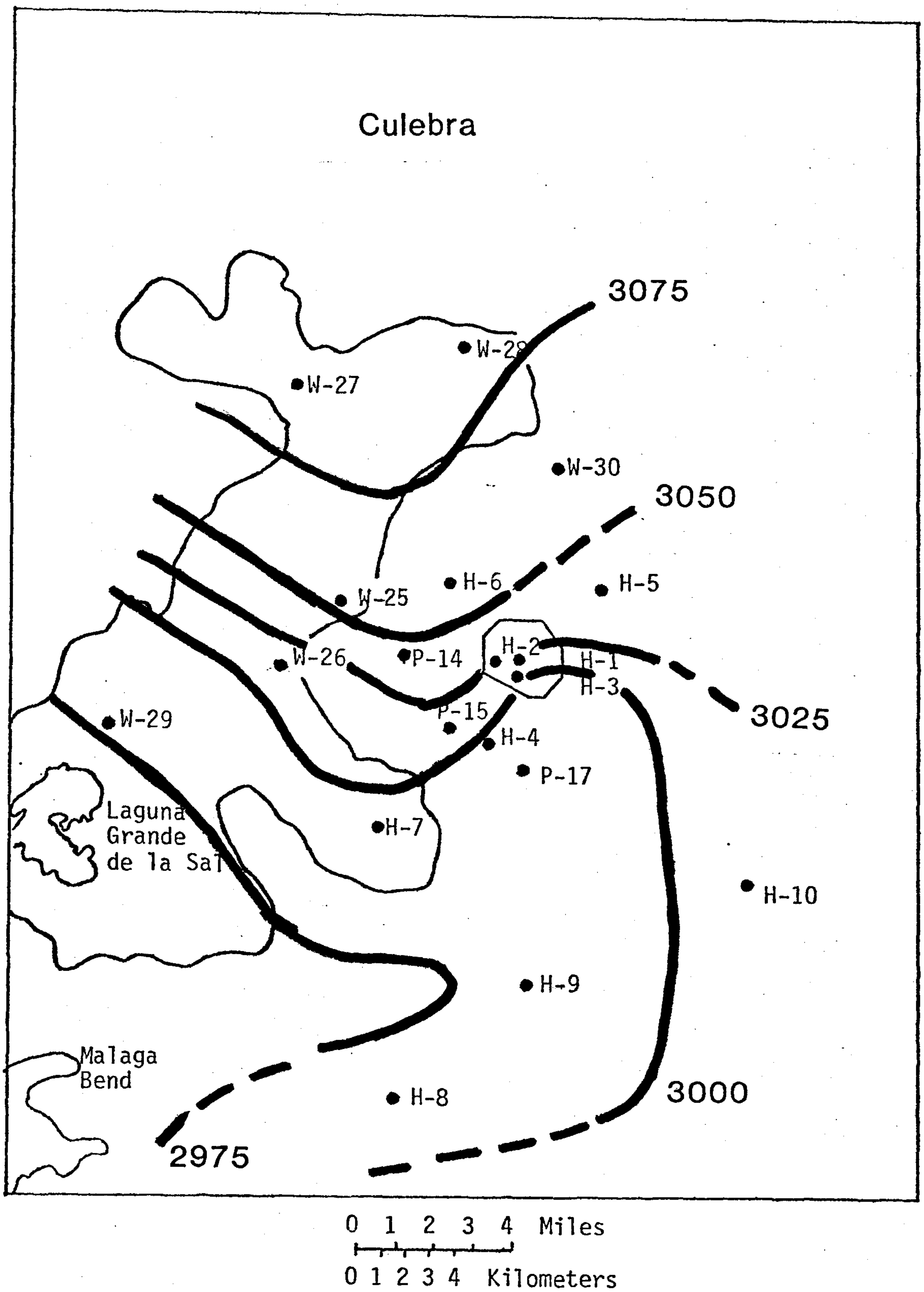


Figure 18. Adjusted potentiometric surface of the Culebra Dolomite Member of the Rustler Formation (1982) at and near the proposed WIPP site (from Mercer, 1983)

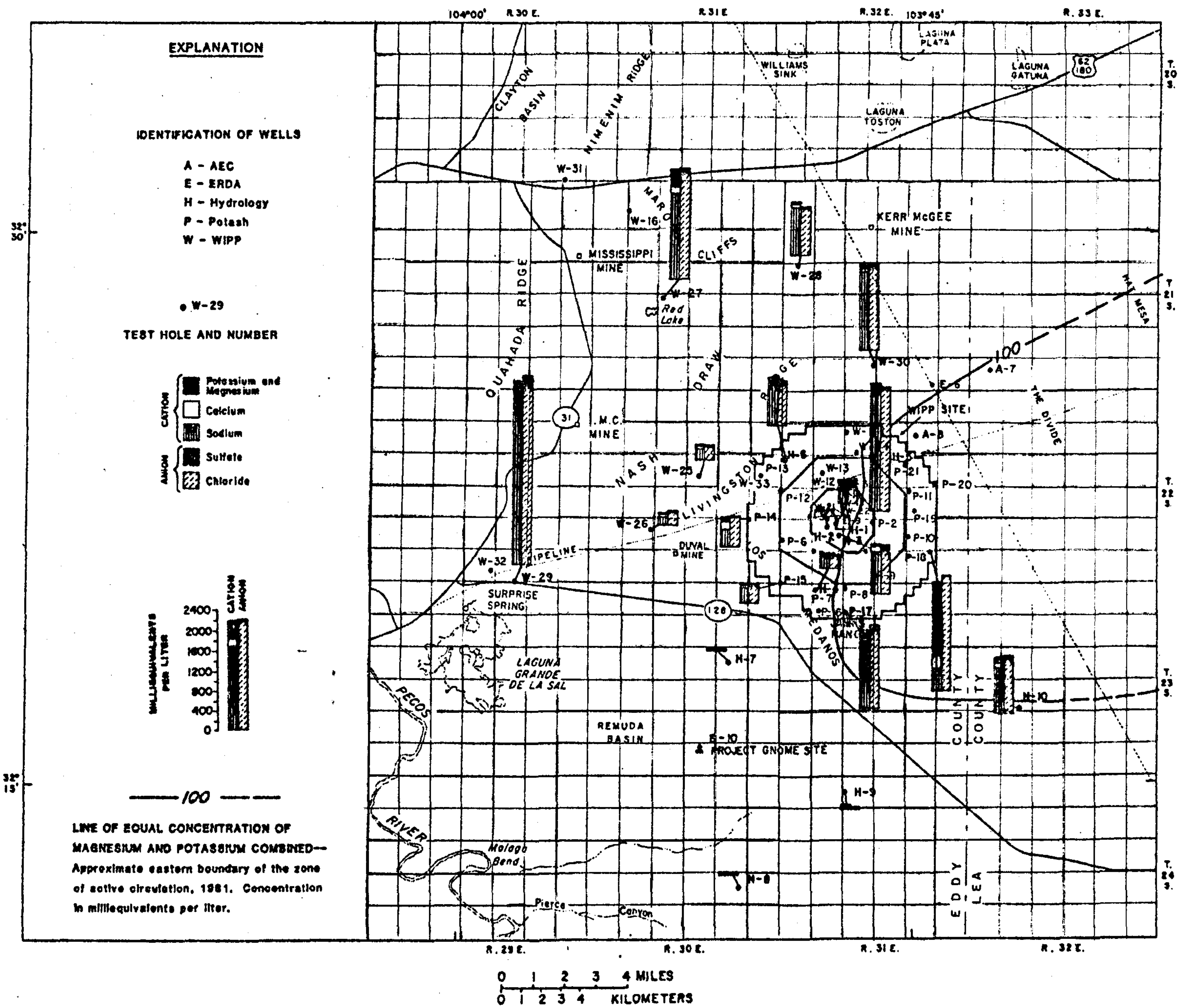


Figure 19. Concentration of major chemical constituents in water from the Culebra Dolomite Member of the Rustler Formation at and near the proposed WIPP site (from Mercer, 1983)

water chemistry in the Culebra. Figure 20 is a modified Piper Trilinear plot of all the Culebra water chemistry data. From the plot, the chemical constituents of wells at the center of the site H-1, H-2, H-3 are predominantly Na and Cl and have total dissolved solids concentrations (TDS) of 30,100 mg/l, 9700 mg/l and 62,000 mg/l respectively. The chemical constituents of wells down flow, H-7, H-8, H-9 are predominantly Ca, Mg and SO and have total dissolved solids concentrations of 3610 mg/l, 3200 mg/l and 3590 mg/l respectively. There is no credible mechanism, other than mixing, to account for a decrease in TDS and a change in chemical constituents from Na and Cl to Mg, Ca and SO in the direction of apparent flow. Mixing with the overlying Magenta aquifer appears unlikely because the TDS in the Magenta is everywhere greater than the TDS in H-7, H-8 and H-9 of the Culebra. Continued investigation into the hydrology of the Culebra Dolomite by Sandia National Laboratories will hopefully clarify the current inconsistency between the apparent water flow direction and water chemistry.

EEG's tentative conclusion is that there is insufficient well data south and southeast of the site to accurately estimate the direction of groundwater flow from the site. As additional information is made available, EEG will modify its conclusions accordingly.

5.3 Magenta Dolomite Aquifer

The Magenta Dolomite aquifer lies stratigraphically above the Culebra Dolomite. Figures 21 and 22 show the potentiometric surface and major chemical constituents for the Magenta. In general, water in the Magenta at the center of the WIPP site will flow westward to Nash Draw where it likely discharges into underlying units. The Magenta has been largely ignored by DOE for solute transport scenarios because of the small transmissivities associated with that aquifer. However, due to the uncertainty associated with the direction of flow in the Culebra, the possible transport of contaminants in the Magenta should be given consideration. This will be discussed in detail in the section on "Hydrologic Transport Characteristics in the Rustler Formation."

6.0 Capitan Reef Aquifer

The Capitan reef aquifer, one of the most productive freshwater aquifers in southeastern SE New Mexico, extends in an arcuate band around most of the

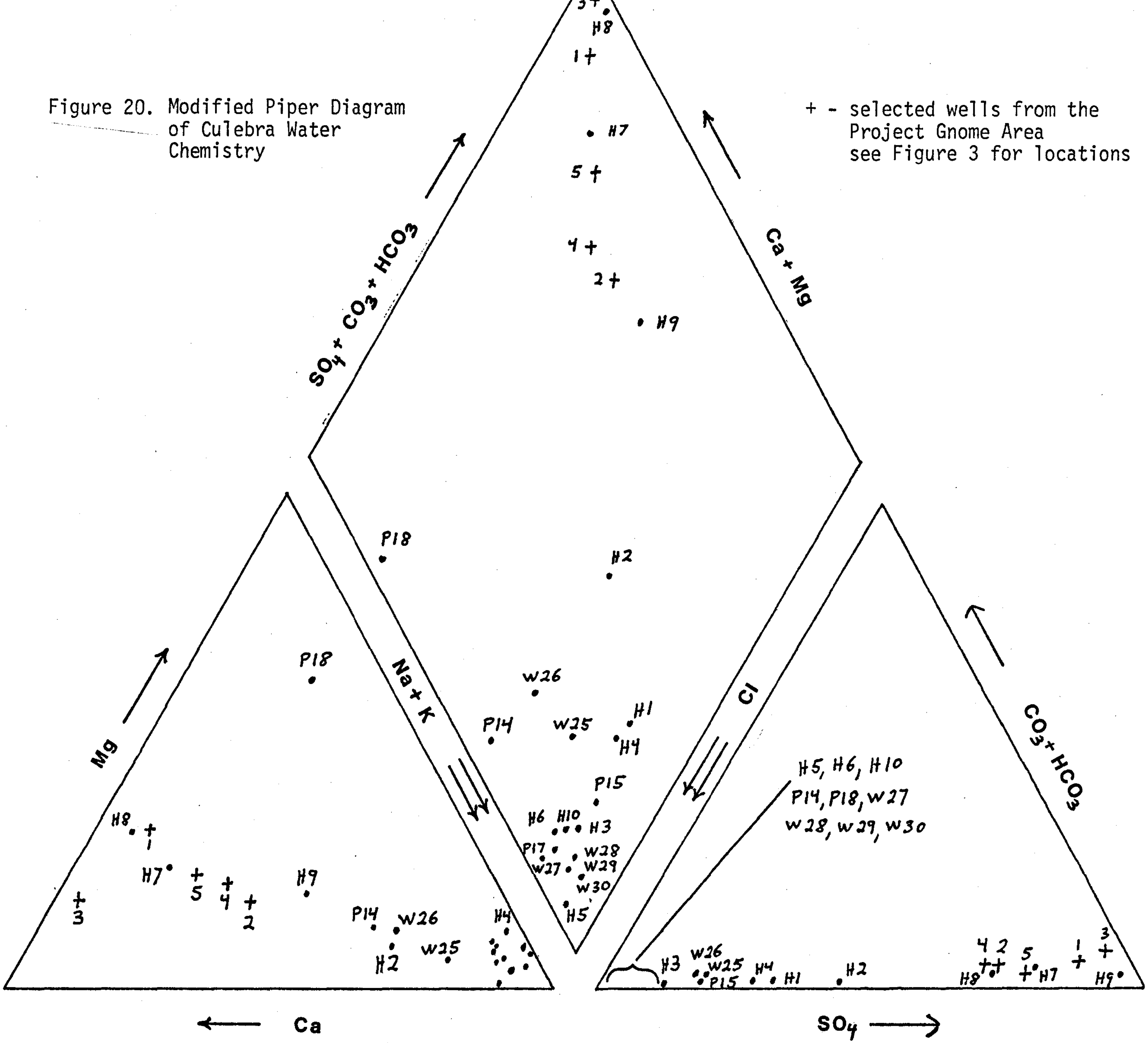


Figure 20. Modified Piper Diagram of Culebra Water Chemistry

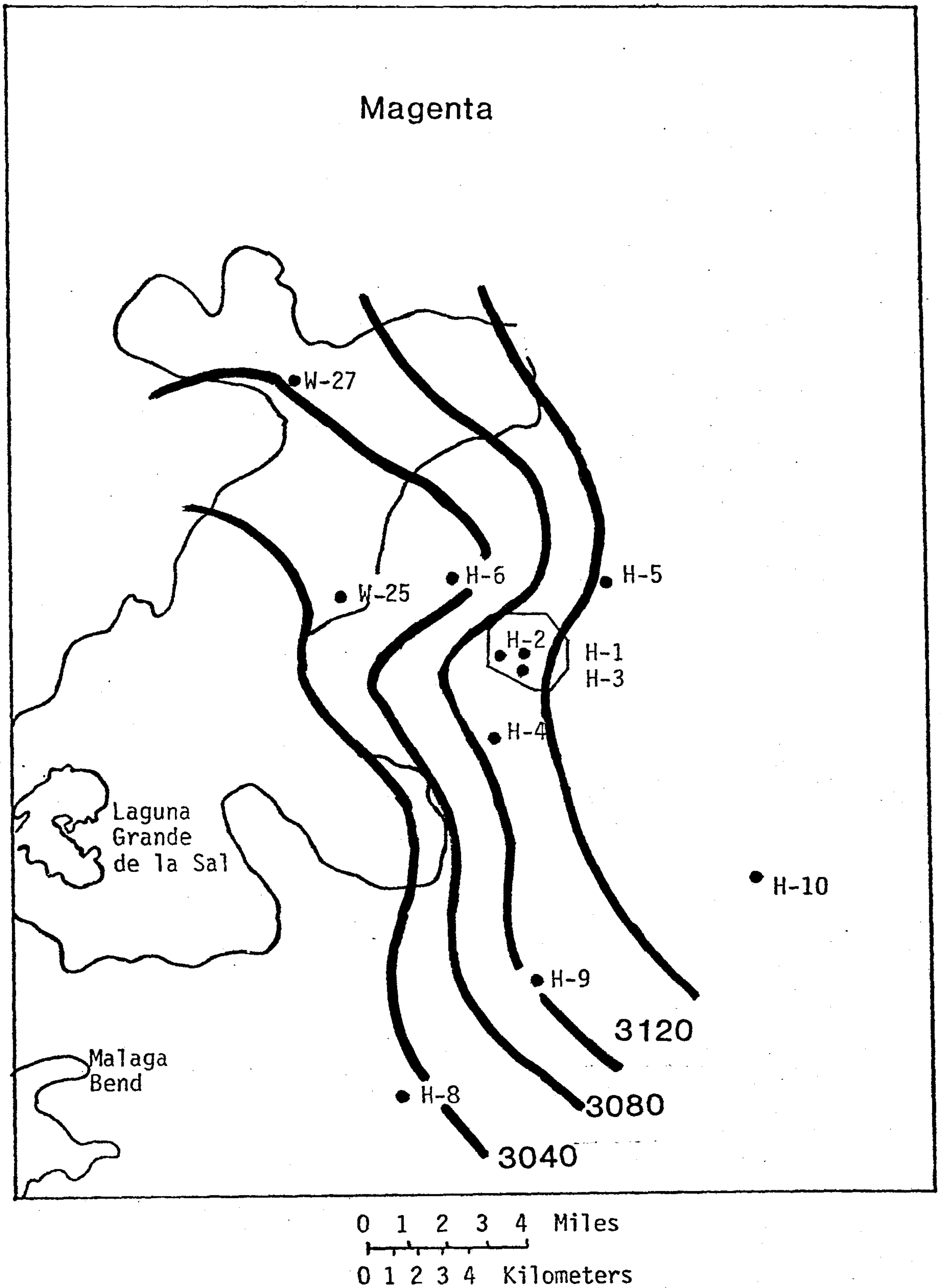


Figure 21. Adjusted potentionmetric surface of the Magenta Dolomite Member of the Rustler Formation (1982), at and near the proposed Waste Isolation Pilot Plant (WIPP) site (from Mercer, 1983)

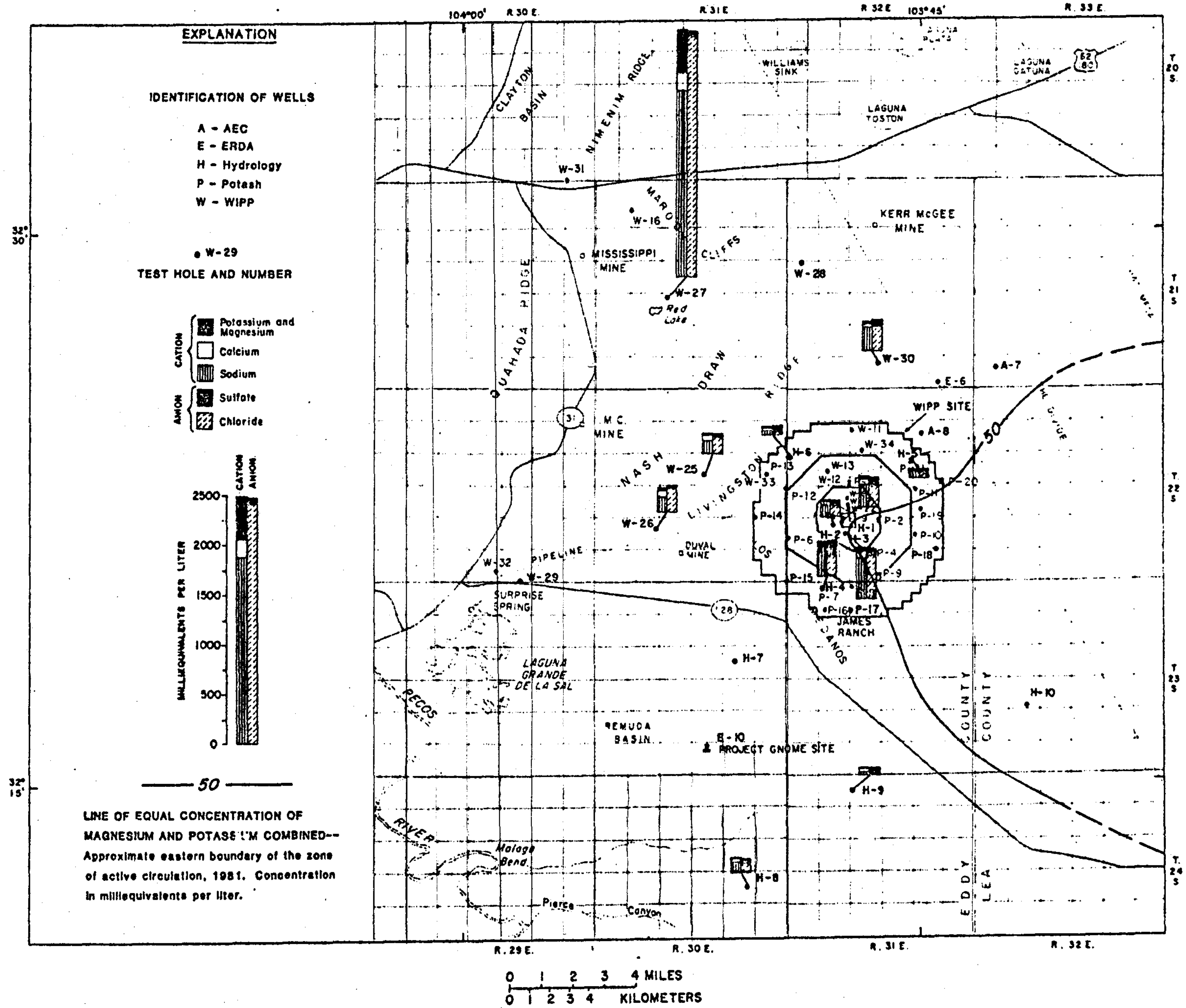


Figure 22. Concentrations of major chemical constituents in water from the Magenta Dolomite Member of the Rustler Formation an near the proposed WIPP site (from Mercer, 1983).

Delaware Basin and lies at its closest point about 10 miles north of the WIPP. The hydraulic head in the Capitan Reef aquifer is less than that in the Bell Canyon (Hiss, 1976) indicating a flow into the reef if the two aquifers are connected. The relatively impermeable anhydrites of the Castile Formation restrict the lateral movement of freshwater away from the reef (Mercer, 1983). Numerous collapse phenomena are associated with the Capitan Reef and some near reef salt dissolution is probably attributable to the Capitan Reef aquifer (see the section on Dissolution). However, salt dissolution associated with the reef does not appear to pose a threat to the repository. The solute transport characteristics of the Bell Canyon are such that a minimal radiological hazard would result from a repository breach and subsequent transport of radionuclides to the Capitan Reef by the Bell Canyon aquifer.

7.0 Summary of Conclusions

The degree of understanding of the regional hydrology, although far from complete, is sufficient to reach some general conclusions.

7.1 Waters in the Bell Canyon formation and the Castile formation do not pose a significant threat to the repository. The salt removal potential is too low and the radionuclide transport time is too long.
However, both formations may be a source of water for some breach scenarios that result in the injection of radionuclides into the Rustler.

7.2 The Capitan Reef Aquifer is at its nearest point about 10 miles from the site. Water in the aquifer is largely prevented from moving laterally into the basin. Although there is some localized dissolution associated with the reef, the basinward dissolution north of the site appears small. Therefore, the Capitan Reef Aquifer poses a minimal threat to the repository.

7.3 The groundwater in the Rustler Formation is the likely bounding conduit following a repository breach for radionuclides to reach the accessible environment. Within the Rustler, the Culebra aquifer is of most concern, because of higher transmissivities. However, there are insufficient data to characterize the flow system in the Culebra south of the site and hence additional experiments are needed. EEG hopes the solution will come from ongoing hydrologic studies concentrated in the Culebra.

7.4 The various nuclear waste repository criteria that relate to groundwater generally are directed toward solute transport characteristics of the aquifers. How well WIPP meets these criteria is discussed in the section on hydrologic transport in the Rustler.

8.0 References Cited

Geohydrology Associates, Inc., Ground-Water Study Related to Proposed Expansion of Potash Mining near Carlsbad, New Mexico, June, 1978.

Gonzalez, D. D., Hydrogeochemical Parameters of Fluid-Bearing Zones in the Rustler and Bell Canyon Formations: Waste Isolation Pilot Plant (WIPP), Southeast New Mexico (SENM), Sandia National Laboratories, Report SAND 83-0210, March, 1983.

Gonzalez, D. D., Groundwater Flow in the Rustler Formation, Waste Isolation Pilot Plant (WIPP), Southeast New Mexico (SENM): Interim Report, Sandia National Laboratories, Report SAND 82-1012, March 1983.

Hiss, W. L., Stratigraphy and Ground-Water Hydrology of the Capitan Aquifer, Southeastern New Mexico and West Texas, University of Colorado, Boulder, Ph.D. dissertation, 1976.

Lambert, S. J., Dissolution of Evaporites in and Around the Delaware Basin, Southeastern New Mexico and West Texas, Sandia National Laboratories, Report SAND 82-0461, March, 1983.

McNeal, R. P., Hydrodynamics of the Permian Basin in Fluids in Subsurface Environments -- A Symposium, American Association of Petroleum Geologists Memoir 4, p. 308-326, 1965.

Mercer, J. W., and Orr, B. R., Interim Data Report on the Geohydrology of the Proposed Waste Isolation Pilot Plant Site Southeast New Mexico, U.S. Geological Survey, Water - Resources Investigations Report 79-98, July, 1979.

Mercer, J. W., Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico, U.S. Geological Survey, Water Resources Investigations Report 83-4016, 1983.

Sandia National Laboratories, Basic Data Report for Drillhole AEC-8 (Waste Isolation Pilot Plant - WIPP), SAND 79-0269, January 1983.

Sandia National Laboratories, Basic Data Report for Drillhole ERDA-10 (Waste Isolation Pilot Plant - WIPP), SAND 79-0271, February 1983.

Spiegler, P., Analysis of the Potential Formation of a Breccia Chimney Beneath the WIPP Repository, Environmental Evaluation Group, Report EEG-13, May, 1982.

Weart, W. D., Summary Evaluation of the Waste Isolation Pilot Plant (WIPP) Site Suitability, Sandia National Laboratories, Report SAND 83-0450, March 1983.

Williamson, C. R., 1979, Deep-sea sedimentation and stratigraphic traps, Bell Canyon Formation (Permian), Delaware Basin, in Sullivan, N. M., ed., Guadalupian Delaware Mountain Group of west Texas and southeast New Mexico: Society of Economic Paleontologists and Mineralogists (Permian Basin Section), Publication 79-18, p. 39-74.

Wood, B. J., Snow, R. E., Cosler, D. J., and Haji-Djafari, S., Delaware Mountain Group (DMG) Hydrology - Salt Removal Potential, U.S. Department of Energy, Report TME 3166, prepared by D'Appolonia Consulting Engineers, December, 1982.

THE DISTURBED ZONE

1.0 Definition

The northern part of the WIPP site is an area of poor seismic reflections. The first direct evidence of the structural complexity of this area was obtained in 1975 when ERDA-6 encountered very high dips of the upper Castile anhydrite beds and pressurized brine. On the basis of seismic reflection data then available, Long and Associates (1977), showed a "highly disturbed area (Castile)" in the northern part of the WIPP site (Fig. 23). Several more seismic reflection surveys were conducted in 1978 and 1979 and the boundary of the disturbed zone was broadened to include the northern part of Zone III in a "zone of Anomalous Seismic Reflection Data" (SAR, 1980, Fig. 2.7-23). The same figure (Fig. 23) also shows a "Line indicating steepening of dip of Castile strata to the north" More recently, Borns et al, (1983) have delineated the "Disturbed Zone" (DZ) on the "combined basis of structure exhibited in boreholes and by the chaotic seismic reflection data in the northern part of the site" (p. 10). This figure, reproduced here as Fig. 24, shows a band of DZ bordering the Capitan Reef and passing through the northern part of the WIPP site. Since the zone of WIPP is not identified in this figure and there is no scale, it is difficult to estimate the part of WIPP covered by this band of DZ. The text of Borns et al., (1983, p. 11) however, explains that the southern boundary of DZ approximately coincides with the "line indicating steepening of dip of Castile strata to the north," which is about 2/3 mile north of ERDA-9. Of more interest are the two other areas identified as DZ in this figure. The circular area to the southwest appears to be based on the structure observed in the Belco-Hudson Well. The other oblong area, south of the highway, appears to include the Poker Lake anticline. The report (Borns et al 1983) does not contain an explanation for the inclusion of these two areas in the "Disturbed Zone."

Other than being an area of poor seismic reflections, the Disturbed Zone has never been properly defined. Borns et al (1983) have variously defined it

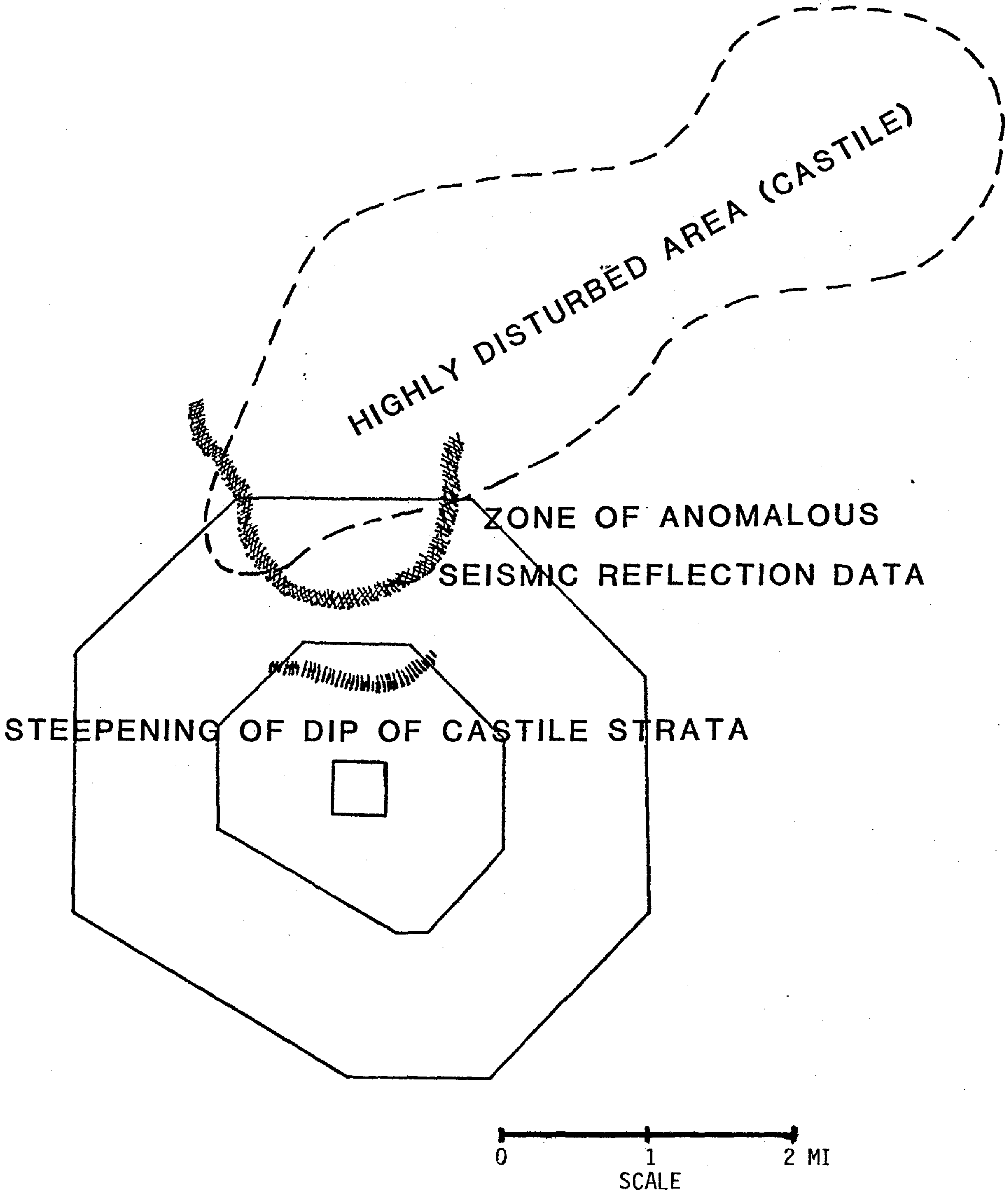


Figure 23. WIPP Site and the southern limits of the "Highly Disturbed Area" (GCR), the "Zone of Anomalous Seismic Reflection Data" and the "Steepening of Dip of Castile Strata" (SAR).

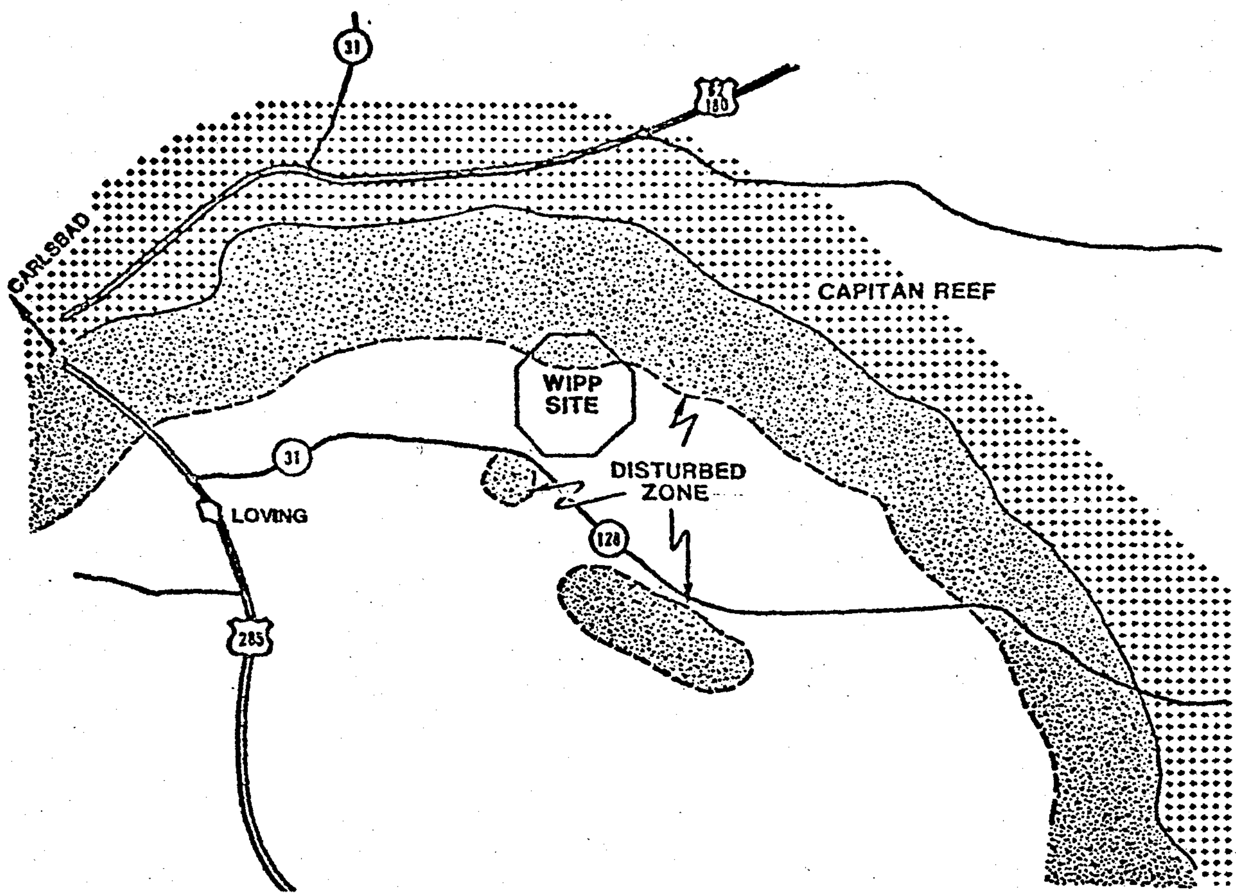


Figure 24. Aereal extent of the disturbed zone, northern Delaware Basin (from Borns et al., 1983)

as, "the area where the Castile/lower Salado departs from generally parallel beds with slight dip" (p. 11) and "The outer edge of the mapped flow structures is here taken as the limit of the DZ. This definition is necessarily ambiguous. It includes the anticline at WIPP-12, and may or may not include the anticline in Sec. 19" (p. 69).

2.0 Areal Extent

In earlier DOE publications, e.g. Powers et al (1978) and Register (1981)*, the disturbed zone was presented as a zone bordering the Capitan Reef. Borns et al (1983) have widened this zone to include the WIPP-12 structure where brine was encountered. In addition, they have shown two more areas, to the southwest and south of the WIPP site (Fig. 23), as part of DZ. No rational explanation has been provided for separating these two areas from the band bordering the reef. The seismic profiles do show structures between WIPP-12 and Belco-Hudson well, but there are no wells penetrating the Castile formation between these two and, therefore, the boundary of the circular DZ shown southwest of the site in Figure 23 is arbitrary.

Concerning the explanation for the limited areal distribution of the disturbed zone, Borns et al (1983) state, "no hypothesis adequately answers why the deformation has a limited areal distribution" (p. 4). However, a hypothesis has been offered by them (on p. 87-88) to explain this phenomenon. It concerns the difference in the yield strength of the rock due to anomalously high water content which would facilitate grain boundary pressure solution.

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*Register (1981) showed the DZ as a 6 mile wide "Deformation Front" bordering the reef. Popielak et al (1983) simply refer to it as, "this band or belt extends underneath the WIPP site" (p. G-38) and avoid assigning a southern limit to it.

Because of the absence of identifiable boundaries of DZ and the lack of an adequate explanation for a limited areal extent, it seems logical to conclude that some structural complexity in the Castile formation may exist to varying degrees anywhere in the northern Delaware Basin including the WIPP site.

3.0 Geophysical Data

3.1 Seismic Reflection

The disturbed zone has been delineated primarily on the basis of seismic reflection data. The seismic data indicate a "blocky structure with abrupt dip changes and offsets (faults) between units" and "the seismic character (wiggle shape) changes, which indicates variations in thicknesses and/or acoustic properties." (Borns, et al, 1983, p. 69). The seismic data at the disturbed zone shows that the geologic structures within the Castile formation are too complex to map with the seismic technique. It is this complexity of geologic structures within the Castile that identifies the DZ from the "undisturbed" strata. The interpretations from the seismic profile are supported by "the steep lamination dips, variable stratigraphic thicknesses and petrographic features (e.g. recumbent folds, shear zones) exhibited by core" (Borns, et al 1983).

3.2 Gravity Survey

Since most of the deformation in the disturbed zone is restricted to the Castile formation and involves a redistribution of the massive anhydrite and halite beds within this formation, it was thought that the gravity survey should pick out the lateral density variations resulting from the deformation. The interpretation of the gravity survey is described in Chapter 3 of Borns, et al (1983). According to this interpretation, "the (gravity) anomalies are much too sharp (shorter double half-width) to originate within the Castile formation. They extend into areas that are indicated by the seismic profiles as undeformed. The negative gravity anomalies were established by drilling to originate from lateral density variations within relatively flat strata." (p.73).

The only explanation of lateral density variations within a shallow zone as interpreted from the gravity survey, provided by Borns et al (1983) is that the negative anomalies represent, "decreased rock densities near karst channels, primarily in the Rustler formation" (p. 73). The question of karst hydrology in the Rustler formation is discussed in the section on "Rustler Hydrology".

4.0 The Origin of the Disturbed Zone

Borns et al (1983) discusses the following hypotheses of origin for the disturbed zone:

- Gravity Foundering
- Dissolution
- Gravity Slides
- Gypsum Dehydration
- Depositional Processes

Out of these, they appear to favor the gravity foundering and, to a lesser extent, gravity sliding, as the mechanisms which are most consistent with the available observations. As far as the movement of salt within the Castile formation is concerned, gravity foundering appears to be a reasonable hypothesis to explain the phenomenon. The difficulty with this hypothesis is, of course, in explaining the areas which remained undeformed, adjacent to the deformed or "disturbed" areas.

5.0 The Age of Deformation

The geological time during which the deformation in the DZ occurred has been a question of debate in the literature. The following account provides a summary of various approaches to answer this question.

Kirkland and Anderson (1970) studied the microfolding in the Castile strata exposed in the western part of the basin. By noticing the relationship between the orientation of microfolds and the larger folds, which in turn correspond with the basic Cenozoic structural grain of the basin, they concluded that the Castile microfolds postdate the late Cenozoic regional tilting. Anderson (in

Chaturvedi, 1980) showed that the ERDA-6 core has a similar stretching of microfolds as seen at the stateline Castile outcrop, and inferred from this, that the deformation in the DZ would also be post Cenozoic-tilting of the basin.

Borns et al (1983) have examined the possibility of dating the deformation by applying the axiom that the deformation must predate deposition of the oldest underformed strata. However, this axiom cannot be applied to a situation where the deformation is clearly stratabound in Castile and becomes dampened upward and downward in the section.

Consideration of the mechanism of gravity foundering, the preferred hypothesis for the deformation in the DZ, led Barrows (1983) to the conclusion that the deformation would remain active until all the anhydrite has settled beneath the halite. Since this has not yet happened in the DZ, the implication is that the deformation in the DZ is an active, ongoing process.

6.0 The Rate of Deformation

Barrows (1983) has calculated that the time required for the deformation in the Castile through the process of isostatic movement of salt would range from 10^4 to 10^7 years. Borns et al (1983) have calculated that, by this mechanism, a structure of the size of WIPP-12 anticline could develop at the WIPP site in a time frame of approximately 10,000 years to 250,000 years. Such a structure, developing in the Castile anhydrite, would produce fractures and may result in the development of a brine reservoir. Although theoretically possible, Borns et al (1983) argue that the development of a structure directly under the site would be a random event and given that the conditions for such an event have existed for the past several millions of years, it would be very unlikely for a structure to develop directly under the site during the next 250,000 years.

Borns et al (1983) have calculated the effect of the "deformation front" progressing toward the site. By assuming an average width of 10 km of the DZ adjacent to the reef and 30 m.y. as the time since basin tilted and the deformation began, they calculate that the belt has grown at a rate of 0.3 mm/yr and "At this rate 4.6 m.y. would be required for the deformation front to progress over the site."

The assumptions made in this calculation may not be valid. Fig. 1 of Borns et al shows the width of DZ bordering the reef, near the WIPP site, to be about 16 km (≈10 miles). The main phase of the uplift occurred in late Pliocene to early Pleistocene time (King, 1948; Hayes, 1964) or about 2 to 6 m.y. ago. Therefore, a more realistic assumption would be that the deformation has progressed 16 km in 2 to 6 m.y., or 2.7 to 8 Km per million years. The edge of the WIPP-12 structure is about 1 Km north of the center of the site. Using these assumptions, the deformation front would reach the center of the site in 125,000 years to 375,000 years.

7.0 Conclusions

It is clear that the structural deformation is most pronounced within the Castile formation and near the Capitan Reef. However, there is no rational basis to assume a 10 km band of deformation bordering the Capitan Reef. The WIPP-12 structure clearly shows that the "front" extends to at least the northern part of the WIPP Zone II. A more conservative approach would be to assume that the entire WIPP site is within the zone where the Castile beds have been deformed to varying degrees and include the Belco-Hudson structure within this zone. Further, the interpretation of the structure at WIPP-11 shows that the involvement of the Delaware Mountain Group formation with the deformation in Castile, at least locally, is possible, and at this drill hole the Castile structural deformations appear to extend into the lower Salado as well.

The gravity foundering hypothesis provides a reasonable explanation for the style of deformation present in the Castile formation in the northern Delaware Basin. By using this hypothesis, Borns et al (1983) have calculated that if the deformation is progressing towards the WIPP repository area, it would take 4.6 m.y. for the deformation front to reach the area directly under the WIPP repository. EEG's calculations show that this may happen in 125,000 to 375,000 years. The progression of a structure such as that located at WIPP-12, however, requires conditions which facilitate the gravity foundering mechanism and these conditions (e.g. high trapped fluid in rock, low yield strength, etc.) may not exist under the southern part of Zone II of the WIPP site. The borehole DOE-1 drilled just outside the Zone II, to the southeast, certainly does not exhibit the Castile deformation structures except some minor lateral flow textures in the Castile halites. Further, with the reorientation of the WIPP repository to the south within Zone II, the repository would now be in a relatively undeformed region as interpreted from the seismic reflection data. EEG, therefore, concludes that the proposed WIPP repository in the southern part of Zone II is located in a relatively undeformed area.

8.0 References Cited

Barrows, L., 1983, Halokinetic development of the Disturbed Zone, Appendix, in Borns, et al Deformation of Evaporites Near the WIPP Site, SAND 82-1069 (Draft)

Borns, D. J., L.J. Barrows, D. W. Powers, R. P. Snyder, 1983, Deformation of Evaporites Near the WIPP Site, Report SAND 82-1069 (Draft)

Chaturvedi, L., 1980, WIPP Site and Vicinity Geological Field Trip, EEG-7

Hayes, P. T., 1964, Geology of the Guadalupe Mountains, N.M., USGS Prof. Paper 446

King, P. B., 1948, Geology of the Southern Guadalupe Mountains, Texas, USGS Prof. Paper 214

Kirkland, D. W. and R. Y. Anderson, 1970, Microfolding in the Castile and Todilto evaporites, Texas and New Mexico, GSA Bull 81, pp. 3259-3282

Long, G. J. and Associates, 1977, Interpretation of geophysical data, Los Medanos and vicinity, Lea and Eddy Counties, N.M., Report to Sandia Laboratories

Popielak, R. S., R. L. Beauheim, S. R. Black, W. E. Coons, C. T. Ellingson and R. L. Olsen, 1983, Brine reservoirs in the Castile formation, S.E. New Mexico, TME 3153, D'Appolonia Counsulting Engineers

Powers, D. J., S. J. Lambert, S-E. Shaffer, L. R. Hill and W. D. Weart (Ed.), 1978, Geological Characterization Report, WIPP site, S.E. New Mexico, SAND 78-1596, Vols. I and II.

Register, J. K., 1981, Brine Pocket Occurrences in the Castile Formation, S.E. New Mexico, TME 3080, U.S. Department of Energy

HYDROLOGIC TRANSPORT CHARACTERISTICS OF THE RUSTLER AQUIFERS

The site validation report (DOE, 1983) concluded that the Culebra and Magenta Dolomite aquifers of the Rustler Formation are the only aquifers of significance at the WIPP site. Of the two, the Culebra is considered the most important and is the target of DOE's detailed hydrologic transport studies. Recent modeling studies (Barr et al., 1983), cited by Weart (1983) indicate that water will move less than 2 miles in 1000 years in the region near the site but the document (Barr et al, 1983) was unavailable for review by EEG on May 25, 1983.

While the general hydrogeology of the Rustler aquifers has been presented in the section on Regional Hydrology, specific aspects relating to a repository breach and the transport of radionuclides to the biosphere are discussed in this section. Neither the breach mechanism nor the mechanism to move radioactive material 1400 feet from the repository to the Rustler are addressed in the following discussion.

Figure 25 shows the WIPP site, the pertinent test holes, the location of Laguna Grande de la Sal, the Pecos River at Malaga Bend, and the approximate boundaries of Nash Draw. The three Rustler aquifers in ascending order are the Rustler-Salado interface residuum, the Culebra Dolomite, and the Magenta Dolomite.

1.0 Rustler-Salado Residuum

Groundwater in the Rustler-Salado residuum flows southwest from the site with a possible discharge at Laguna Grande de la Sal, but the major discharge point is the Pecos River near Malaga Bend. In Nash Draw the transmissivity is as high as 8000 ft /day (Hale et al, 1958), but it is less than 3 x 10^{-} ft /day within 2 miles of the center of the site. In addition, the high magnesium and potassium concentration of the water (Mercer, 1983) in zone II would indicate a very restricted flow system. Therefore, the Rustler-Salado contact residuum is not considered to be a major avenue for the transport of radionuclides to the accessible environment.

2.0 Culebra Dolomite

Where hydraulic conductivity has been measured in the Rustler, the Culebra has been the most conductive layer. Hence DOE has concluded that the Culebra is the limiting aquifer for modeling studies.

The potentiometric surface map of the Culebra is presented in Figure 18. From these data one might conclude that the direction of flow from the site is due south to about the center of T 23S, R. 31E, and then southwest to a discharge point at Malaga Bend. Recent work by Gonzalez (1983) to define the anisotropy of hydraulic conductivity (Figure 25) has led to the conclusion by DOE that the flow from the site will be southeast and then westerly to Malaga Bend. The decrease in TDS and the change in water chemistry from sodium and chloride to calcium, magnesium and sulfate south of the site has been discussed in the Regional Hydrology section. Until the chemical inconsistencies are explained, the hydraulic head distribution shown in Figure 18 does not definitively show that the direction of groundwater flow is other than along a straight line to Malaga Bend. To date, the anisotropy of conductivity has been determined at only three locations; H-4, H-5, and H-6. The direction of the principal component of the transmissivity tensor is nearly identical at test pads H-5 and H-6. At H-4, the direction of the principal component of the transmissivity tensor is rotated about 50° counterclockwise in relation to H-5 and H-6. No data on anisotropy are available at the center of the site or to the southeast. Additional anisotropy tests are needed to accurately predict the direction of groundwater flow in the fractured Culebra Dolomite.

When the direction of groundwater flow and specific discharge are firmly established, the speed at which the solutes will travel is dependent on the effective porosity and the distribution coefficient. Gonzalez (1983) has performed a number of tracer tests to estimate effective porosity. The results of two tracer tests, at test pads H-2 and H-6 yield different results.

The recirculating tracer test at test pad H-2 yielded an effective porosity of 18 percent. The convergent tracer test at test pad H-6 yields effective porosities of 0.7 and 11 percent. These results point out some very interesting aspects of solute transport in the Culebra.

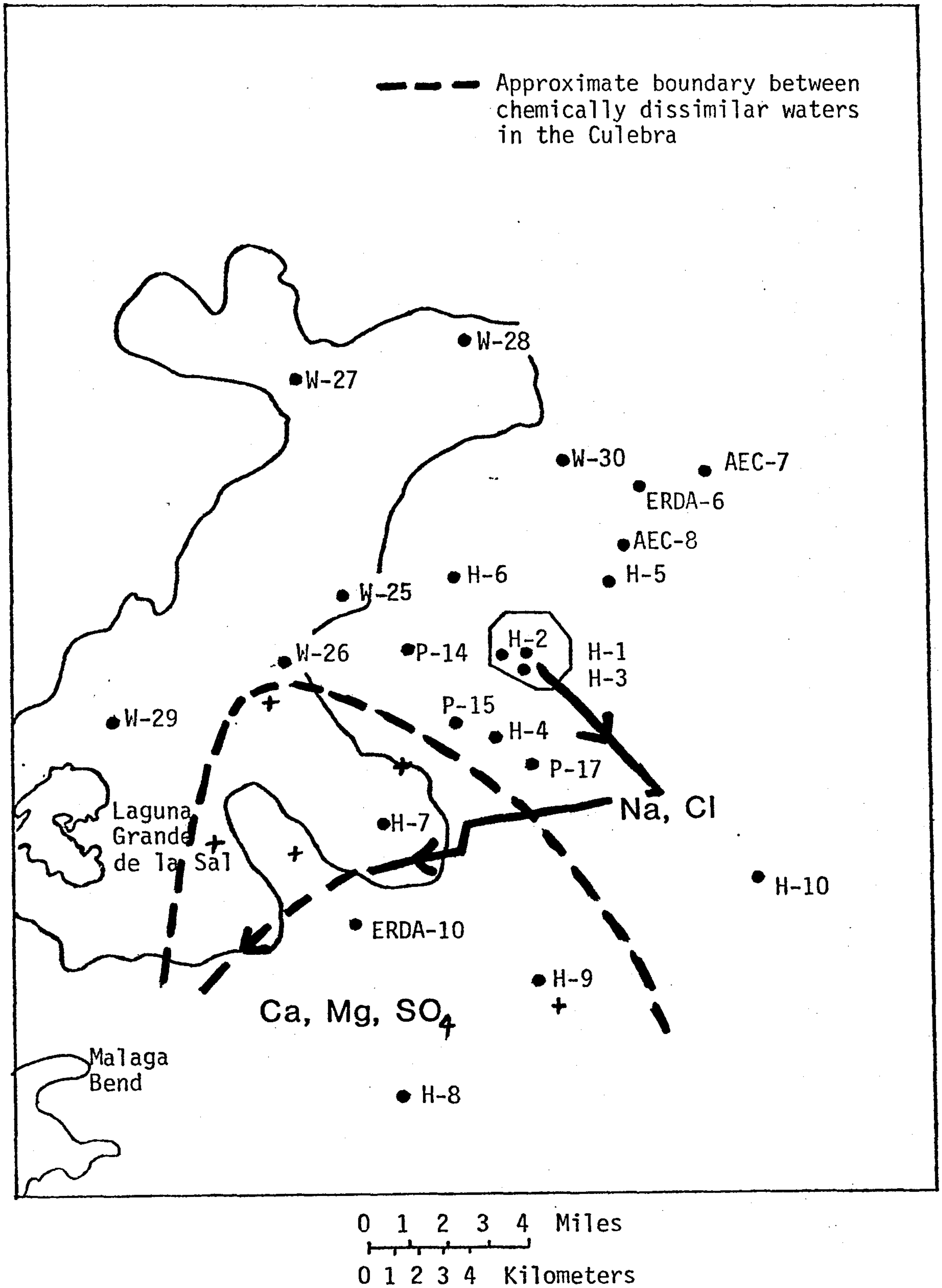


Figure 25. Particle flow path estimates 1983 in the vicinity of the WIPP site. Major chemical constituents of the Culebra water are indicated (based on Gonzalez, 1983)

Groundwater flow in the Culebra through fractures (Gonzalez, 1983; Weart, 1983; Mercer, 1983) is dramatically displayed by the H-6 tracer test. The three well configuration (labeled a, b and c) was an equilateral triangle, 100 feet on each side, with pumping from well "c" and tracer injection into the other two. The peak concentration in the b-c direction was 10 times greater and arrived 30 times faster than the peak concentration in the a-c direction. As the hydraulic conductivity in the b-c direction is at most 2.1 times greater than the hydraulic conductivity in the a-c direction, the travel time differences were attributed to differences in effective porosity. This assumption implies an equal flow path length, but this may be a poor assumption in fractured media.

While the b-c well pair may have intersected the same fracture, the a-c well pair may not. The b-c flow path would have been nearly a straight line whereas the a-c path could have been extremely tortuous thereby causing a long flow path. This interpretation would not be inconsistent with the hydraulic conductivity data. The water level response in well "a" due to pumping in "c" is a pressure response in the confined Culebra aquifer and does not signify the movement of large amounts of water.

Because the tracer tests force the groundwater and tracer to flow in a specific direction, the flow may or may not coincide with the preferred natural flow direction. Parameters derived from an artificial flow test may not be the appropriate parameters to use in a natural flow situation. The apparent variability of effective porosity in the H-6 tracer experiments is significant because effective porosity exhibits such a strong influence on calculated water velocities.

Although water transit times in Nash Draw are rapid, the controlling times are associated with the relatively small permeabilities observed near the center of the site. If the hydraulic conductivity at H-1 (0.003 ft/d) and an effective porosity of 0.18 (from the H-2 tracer test) are representative of the site, then transit times are long. If the hydraulic conductivity at H-3 (0.86 ft/d) and an effective porosity of 0.007 (from the H-6 tracer test) are representative, transit times are short.

The lack of anisotropy data at the site severely limits the confidence one can place in any model results. In fractured media, such as the Culebra, the hydraulic gradient does not necessarily indicate the direction of groundwater flow. In fact, the flow direction could be nearly parallel to the hydraulic head contours. The unexplained decrease in TDS and a change in the general chemical nature of the Culebra water from sodium and chloride at the site to magnesium, calcium, and sulfate south of the site indicates that insufficient data are presently available to adequately characterize the flow system south of the site. The anisotropy of hydraulic conductivity at the site must be determined before the flow direction can be postulated. The tracer tests provide information on the transport of conservative solutes, but these tests generate artificial flow systems. In fractured media, these tracer tests may not provide the proper data to use in modeling the transport of water and solutes in a natural flow system. However, the tracer tests are the only means currently available to estimate the solute transport parameters in a reasonable amount of time.

The hydologic testing program conducted by Sandia National Laboratories is ongoing. Future testing is planned at the site and to the south and southeast. These additional tests will hopefully provide adequate data to confidently model the groundwater flow direction and velocity at the site.

Until the Culebra groundwater flow system is adequately understood, consequence analysis scenarios that assume essentially a straight line connection between the site and the nearest probable discharge point, Malaga Bend are valid. EEG has modeled the consequences of 3 scenarios in which a repository breach injects radioactivity into the Culebra aquifer (Greenfield, 1979; Wofsy, 1980; Spiegler, 1981). In two scenarios transport is assumed to be straight from the site to Malaga Bend with discharge into the Pecos River. Both analyses are conservative, but may not be bounding. The largest calculated one year exposure for an adult drinking Pecos River water containing radionuclides is less than 10 mrem to the bone (Greenfield, 1979). This scenario is conservative in that a large rate of waste dissolution was assumed, but it is not conservative in terms of groundwater velocity. The second scenario (Wofsy, 1980) is a sensitivity analysis which examined the consequences of plutonium transport only. The maximum exposure for the adult whole body 50-year dose commitment from drinking Pecos River water is less than 1 mrem. Neither scenario uses concentration (pCi/ℓ) as an input initial condition, but rather uses rates (pCi/sec). Concentration scenarios may be more appropriate for some scenario analyses.

The third scenario examined the consequences of using contaminated water from a well located three miles from the site. Accounting for desalinization, radioactive decay, secondary water treatment, and solute retardation in the aquifer, the 50-year bone dose commitments from one year of drinking treated water contaminated with U-233 or Pu-239 and Pu-240 were found to be 132 mrem for an adult and 217 mrem for a child.

These doses are not significant when one considers that doses from natural background radiation are between 60 and 100 mrem per year. The dose calculated from scenario 1 (Greenfield, 1979) could be slightly higher than 10 mrem if faster travel times are used. In any event, precise knowledge of the groundwater flow regime in the Culebra Dolomite is needed to insure that the scenarios are bounding. If the flow from the site is to the southeast then the consequences at a Pecos River discharge point should be less than those obtained from the above scenarios. If, however, the fracture network at the site directs flow to the southwest into Nash Draw, rapid transport times could result in larger doses than indicated by the scenarios.

3.0 Magenta Dolomite

The potentiometric surface map for the Magenta is presented in Figure 21. This aquifer has not been considered as a major vehicle for solute transport by DOE largely because of its relatively low hydraulic conductivity (Gonzalez, 1983).

There are no data for the Magenta on effective porosity, anisotropy of hydraulic conductivity, or dispersivity near the site. It appears that fracture flow in the Magenta is less prominant than in the Culebra (Mercer, 1983). Therefore, the Magenta may be best represented by porous media flow analyses. Magenta water at the site appears to discharge into underlying units near Nash Draw (Mercer, 1983), however, there are no direct observations of such discharge.

The Magenta is not the major avenue for radionuclide transport in the Rustler based on the currently available data. However, if ongoing studies of the Culebra lead to extremely long radionuclide travel times to the accessible environment then hydrologic transport in the Magenta should be considered.

4.0 Solute Retardation

Many radionuclides do not travel at the same velocity as the water, but move at a slower, retarded velocity. The low radiation doses calculated for the hydrologic breach scenarios (ref. Greenfield, 1979; Spiegler, 1981) result in part from the fact that the K_d value greatly retards the rate at which plutonium travels. A sensitivity analysis (Wofsy, 1980) showed that if K_d of plutonium were greater than 10, the effective porosity had little effect on the radiation doses at the Pecos River.

The laboratory measurements are generally performed on powdered rock samples thereby greatly inceasing the rock surface area (Dosch and Lynch, 1978; Dosch, 1980; Lynch and Dosch, 1980)). K_d is generally reported as the mass of solute on the solid phase per unit mass of solid phase divided by the concentration of solute in solution. In fractured media it is better to report the distribution coefficient on a per-unit-surface-area basis (Freeze and Cherry, 1979). Porous secondary material filling some fractures in the Culebra may justify the use of K_d on a per-unit-mass-basis. Laboratory measurements of K_d values may not reflect field conditions. For example, small amounts of plutonium or other elements will decrease the capacity of the rocks to adsorb more plutonium; thus a "loading effect" can reduce K_d values. Chelating agents like EDTA can also reduce K_d values, as can temperature, pH and other physical and chemical factors. The appropriate K_d to use for scenario analyses is not established. Therefore, until in-situ K_d data are available, the smallest reported K_d value should be used to have truly conservative scenarios.

5.0 Possibility of Karst Hydrology in Rustler

A gravity survey was carried out at the WIPP site by Sandia National Laboratories, during 1981-82, with a primary purpose of delineating the "Disturbed Zone" structures within the Castile formation. The field parameters for this study were selected to resolve low-amplitude, broad-wavelength anomalies originating from structures within the Castile formation, more than 3000 ft. below the surface at WIPP (Barrows, 1982). Instead of the anticipated signals, the survey revealed a complex pattern of high-amplitude and short-wavelength negative anomalies. Barrows (1982) interpreted these anomalies as resulting from density (and acoustic velocity) alterations in the vicinity of karst channels. Borns et al. (1983) have presented this as the only interpretation of the gravity data with a disclaimer that the other authors of that report do not necessarily agree with it and it also does not imply endorsement by Sandia National Laboratories. The discussion presented in Borns et al. (1983, p. 3-9) rules out the possibility that the lateral density variations interpreted from the gravity data are caused by facies variations. Weart (1983) states that the negative gravity anomalies might be caused by low-density channel fillings in the Dewey Lake Redbeds.

5.1 Observations Supporting the Presence of Karst

Barrows (1983) compiled other observations besides the negative gravity anomalies to support his conclusion that karst channels exist in the Rustler formation. His observations are summarized below.

5.1.1 Rustler Thinning: The Rustler formation is about 475 feet thick in the southeast corner and about 300 feet thick in the northwest corner of the WIPP site (GCR, Fig. 4.3-8 and Snyder 1983, Fig. 2.25). Barrows cites this "thinning" of Rustler as an example of, "a complex interstratal blanket karst involving halite, anhydrite-gypsum, and, to a lesser extent, dolomite." According to him, if the thinning were caused by dissolution by confined water, it should have proceeded in the direction of flow of the aquifers, which is to the southwest. Therefore, he argues, that "a more likely process involves easterly progressing karst development with downward infiltration of fresh water through feeders in the overlying Dewey Lake formation to karst channels in the Rustler formation.

5.1.2 Closed Depressions: There are a large number of depressions at the WIPP site. The smaller ones may be due to wind deflation but the larger ones can only be reasonably attributed to alluvial dolines, which form when loose surficial material is washed into solution cavities in the underlying rocks. The WIPP-33 depression is a good example of such a doline.

5.1.3 The WIPP 33 Cavities: The borehole WIPP 33, located in Zone IV in the northwest part of the WIPP site, encountered four cavities totaling slightly over 20 feet in the forty-niner and Magenta Dolomite members of the Rustler formation. According to Barrows, these cavities are direct evidence of karst and they demonstrate the relation between alluvial dolines, negative gravity anomalies and karst channels in the Rustler formation.

5.1.4 Lack of Surface Runoff and the Water Balance: Barrows points out that there are about 12 inches of annual rainfall at the WIPP site, most of which falls between May and October. Since the WIPP site has almost no visible surface runoff, Barrows claims that the precipitation collects in the small topographic depressions and rapidly soaks into the ground.

5.2 Observations Doubting the Presence of Karst

Weart (1983, p.20) gives several reasons to doubt the existence of karst conditions over the WIPP site. These are briefly discussed below.

5.2.1 Lateral Movement of Water: The alteration in the Rustler formation is carried out by lateral movement of water along beds of fractured (permeable) anhydrite and should not be ascribed to vertically downward moving waters.

5.2.2 The WIPP-33 Cavities: Features such as WIPP-33 sink is a manifestation of the eastward growth of dissolution along fingers extending from Nash Draw.

5.2.3 Closed Depressions: The depressions interpreted as dolines by Barrows (1982) may have resulted by wind deflation.

5.2.4 Hydrologic Tests: The data from pump tests shows no indication of karst channels underlying the site.

5.2.5 Water Table: There is no free water-table at WIPP and karst development usually requires this condition.

5.2.6 Gravity Anomalies: The negative gravity anomalies might be caused by low-density channel fillings in the Dewey Lake Redbeds.

5.3 Implications of Karst Hydrology

Calculations based on the hydrologic parameters measured in boreholes and tracer tests yield extremely long (5000 years to 40,000 years) travel times of water through the Rustler formation at the WIPP site to the Pecos River at Malaga Bend (Gonzalez, 1983). If karst channels exist in the Rustler formation, the travel time for the tranport of radionuclides in the Rustler formation might be drastically reduced if a breach occurred that would bring radioactive material up into the Rustler.

5.4 Discussion

EEG organized a field trip on May 11, 1983 to afford Larry Barrows an opportunity to point out the field evidence for the presence of karst at the WIPP site. The field trip was attended by 20 geologists and geohydrologists including some of the well known experts in this area. In addition, Harry Legrand has written two brief reports for EEG on this question. The following discussion is based on the views expressed by LeGrand and others in writing, during the field trip on May 11 and during the discussions at the meeting in Carlsbad on May 12 and 13, 1983.

The most direct evidence for karst features near the WIPP site is the sink hole at WIPP-33, approximately 3 miles northwest of the center of the site. The few closed depressions near the site seem to be too conspicuous to have been caused by wind deflation, yet do not show features of typical sinkholes. The hydrologic tests may not detect the presence of fine karst. Even though the Rustler aquifers are under artesian conditions, there are examples at several locations worldwide where karst can develop under such conditions. The gravity anomalies at the site can be interpreted in more than one way. There is sufficient sand and vegetation at the site that very little, if any, water may percolate down into the fractured rock, although careful water balance studies have not yet been conducted. The unconsolidated sand deposits at the surface of the site would facilitate rapid infiltration of precipitation. The depth of infiltration will determine whether the water returns to the atmosphere by evaporation or recharges the groundwater. Most of the hydrologic testing in Zones III and IV of the WIPP site shows the Rustler aquifers to be extremely tight with very low hydraulic conductivities, but the Well H-3, in Zone II shows an anomalously high hydraulic conductivity compared to H-1 and H-2. However, preliminary flow net analyses by EEG indicate that the H-3 hydraulic conductivity is consistent with the potentiometric surface and that the H-1 and H-2 data are anomalous. Finally, the mechanics of removal of halite from the Rustler formation, without invoking vertical infiltration of water at the WIPP site, should be understood.

EEG concludes that although there is very little evidence for the presence of karst conditions east of the western margin of Zone III of the WIPP site, some additional work should be done to completely settle this issue. Recommendations for the additional work include the water balance study, the understanding of the mechanics of salt removal from the Rustler formation, exploration of at least one depression e.g. in Sec. 30, about two miles SW of the center of the site and continued evaluation of the Rustler aquifer hydrology. These recommendations are outlined in more detail at the end of this chapter.

6.0 Dispersion

Dispersion in groundwater flow is a spreading phenomenon that leads to a dilution of the solute. This generally leads to reduction of the peak concentration in comparison to models where dispersion is ignored. An additional phenomenon of dispersion is that a portion of the solute travels faster than the mean velocity. This may be important in situations where first arrivals, rather than peak concentrations, are of paramount concern.

Dispersion is generally ignored in scenario analyses as a means of making the analyses more conservative. If more realistic results are desired, the dispersivity is required. It is not clear, however, that dispersivities obtained from tracer tests which create an artificial flow system are accurate estimates of the parameters applicable to natural flow systems.

7.0 Site Qualification Criteria

It is important for EEG to evaluate how well the WIPP satisfies proposed criteria for nuclear waste repositories. Of concern in this discussion are the criteria that specifically relate to groundwater.

7.1 DOE WIPP Site Qualification Factors (Criteria)

Weart (1982) lists four Site Qualifiction Criteria pertaining to groundwater. The criteria and EEG's determination of how well the WIPP satisfied the criteria are presented below.

Criterion 11.1:

> "Facility and related shafts must not adversely affect existing aquifers which are, or could be, sources of water supply for humans or animals."

Only two aquifers could be affected by the shafts; the Culebra and the Magenta. Perched groundwater, although present in scattered locations near the site, was not encountered during the sinking of either shaft. At the site, neither the Culebra nor the Magenta are likely to be sources of water to humans or animals. Irrespective of that, the sealing of the Rustler in the 12 foot exploratory shaft suggests that in the short term the aquifers will be unaffected. The WIPP appears to satisfy criterion 11.1.

Criterion 11.2:

> "The underground facility must be able to be isolated from waterbearing strata and must not, itself, be located in a water-bearing stratum (stratum which will yield water to a drillhole under the influence of gravity alone)."

The repository level is separated by about 1300 ft. of bedded halite from the overlying Rustler Formation. There is about 1900 feet of interbedded halite and anhydrite between the repository horizon and the top of the Bell Canyon Formation. If the borehole and shaft plugging programs are successful, the respository will be isolated from the water-bearing strata.

Potash mining operations have encountered relatively small pockets of brine in the Salado formation approximately 400 ft. above the level of the repository. These pockets would yield water to a drill hole under the influence of gravity, but to date no brine pockets are observed at the repository level. In any event, a small brine pocket or two would not define the repository horizon as water-bearing. The WIPP appears to satisfy criterion 11.2.

Criterion 11.3:

"The hydraulic conductivity of the facility stratum must be sufficiently low (10^{-6} cm/sec or less) to prevent the flow of water through that stratum from any source which could develop after facility construction."

Some of the layers in the repository horizon exhibit hydraulic conductivities of near 10^{-6} cm/sec under light loading (Black et al., 1983). Under loadings consistent with in situ conditions, the hydraulic conductivities were much less than 10^{-6} cm/sec. The WIPP appears to satisfy Criterion 11.3.

Criterion 11.4:

"Calculated hydrologic transport of radionuclides through the waste disposal facility and overlying strata must be slow enough that a significant hazard to humans would not exist even if the disposal stratum were breached."

Under some repository-breach scenarios, the transport of waste from the repository to the Rustler is rapid. Therefore, radionuclide transport in the Rustler aquifers is the critical factor to consider in determining whether a significant hazard to humans would exist if the disposal stratum were breached.

To adequately predict the radiological hazard to humans following a breach and transport of radionuclides in the Rustler, knowledge of the groundwater flow direction, anisotropy of hydraulic conductivity, effective porosity, and solute distribution coefficients are required.

There are no data on the anisotropy of hydraulic conductivity within 2 miles of the center of the site. These data are critical to determining the direction of groundwater flow in the fractured Culebra Dolomite. At present, the nearest observation well southeast of the site (H-10) is 8 miles away. Additional observation wells are planned. The proposed flow path in the Culebra southeast of the site and then west to Malaga Bend (Gonzalez, 1983) is based on insufficient data. Therefore, the WIPP has not yet been shown to satisfy criterion 11.4.

7.2 NRC Criterion on Travel Time to the Accessible Environment

The NRC is proposing criteria for the Disposal of High-Level Radioactive Wastes in Geological Repositories (10 CFR Part 60). One of their requirements concerns water travel time from a repository to the accessible environment. The proposed wording in a late draft (December 1982) of this regulation is:

> "The geologic repository shall be located so that pre-waste emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such travel time as may be approved or specified by the Commission."

Definitions pertinent to an understanding of the above requirement are:

1) The "disturbed zone means that portion of the controlled area whose physical or chemical properties have changed as a result of underground facility construction or heat generated by the emplaced radioactive wastes...."

2) "Accessible environment means (1) the atmosphere, (2) the land surface, (3) surface water, (4) oceans, and (5) the portion of the lithosphere that is outside the controlled area."

3) "Controlled area means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure."

The intent of this requirement is to have groundwater flow time as one of the multiple barriers to "act independent of overall repository performance to provide confidence that the wastes will be isolated at least for as long as they are most hazardous" (preamble to proposed rule, July 8, 1981). It is recognzied there are uncertainties concerning this proposed NRC requirement. For example: (1) it may be changed before promulgation of 10CFR60; (2) the manner in which dispersion should be included in the travel time; (3) the interpretation of the requirement that should be applied to a bedded salt repository where circulating groundwater is not expected in the host rock; and (4) to what extent it should be applicable to a transuranic waste repository. However, it is worthwhile considering whether aquifers at the WIPP site would meet this criteria.

First it is apparent from the definition that travel time from the repository to the Rustler aquifer would be included in the 1,000 year transport time unless it is interpreted that the disturbed zone includes shafts that penetrate the aquifer. The travel time from breach to arrival at the Rustler aquifer would be greater than 1,000 years itself in several of the scenarios that have been considered. However, with a direct hydraulic connection such as Scenario #2 in the FEIS, the travel time to the Rustler aquifer would be minimal.

Weart (1983) states that recent modeling results indicate that water will move less than 2 miles in 1000 years. The minimal distance from waste emplacement to the edge of Zone III is now estimated to be about 6900 feet due south or 9700 feet in a southeasterly direction. WIPP may not meet the proposed NRC criteria.

8.0 Conclusions

The regional hydrology appears to be adequately understood except for the Rustler Formation aquifers. Of the three aquifers recognized in the Rustler formation, the Culebra represents the bounding transport mode to the accessible environment should the repository be breached and radioactive material brought into the Rustler aquifers.

The work done so far indicates a lack of a clear understanding concerning the direction of flow and the velocity of groundwater in the Culebra aquifer at the site. Additional work is recommended to better define groundwater flow in the Culebra Dolomite aquifer. The question of karst is embodied in the need to better define the groundwater system. The karst phenomenon of concern is the development of open channels in the Culebra aquifer. The channels would greatly increase the groundwater velocity and hence reduce the groundwater travel time. Groundwater travel time refers to the time required for water to flow from the site to a discharge point at Malaga Bend. The time following emplacement that waste enters the groundwater system is the breach time.

The question of breach and radionuclide travel time is important because of the presence of short-lived radionuclides in the WIPP repository. The relative radiological ingestion toxicity hazard of the inventory decreases from approximately 1.00 at 100 years to 0.023 at 1000 years, and to 0.014 at 10,000 years. Therefore if breach and travel times to the accessible environment were only a few hundred years there would be a need to calculate the effect of the short-lived radionuclides on the dose received in the water transport scenarios.

The probability of human intrusion within 250 years after closure is low. In addition, groundwater travel times are currently estimated to be greater than 5000 years. However, the existence of karst channels could reduce groundwater travel times to less than 500 years. The probability of channeling at the WIPP site is also low, but there is still enough doubt to warrant additional testing as outlined below. The expected result of this testing will be to provide greater assurance that channeling does not exist in Zone II and, thereby, improve the confidence that the present scenarios are conservative.

9.0 RECOMMENDATIONS

9.1 Analysis of drawdown data in test holes H-1, H-2, H-3 caused by the open vent shaft. These data can be interpreted as a large scale pumping test and may yield estimates of average aquifer parameters. In addition, the presence of large karst channels should be detectable from the data. Small channels, however, will likely not be detected.

9.2 Computer modeling of groundwater flow in the Rustler Aquifers. This will help determine if the measured aquifer parameters through well testing represent the larger area. In addition, the model will help identify recharge to and discharge from aquifers, and leakage between aquifers.

9.3 Publish the results of transport modeling using concentration as an input.

9.4 Long duration pumping at test well H-3, in conjunction with careful monitoring of groundwater levels in H-3 and surrounding wells. This will indicate whether the relatively high hydraulic conductivity at H-3 is of limited areal extent or whether it represents a zone of high hydraulic conductivity extending over a large area.

9.5 Measure the anisotropy of the hydraulic conductivity at test pads H-1, H-2 and H-3.

9.6 Perform convergence tracer tests at H-1, H-3 and H-4. Items 9.4 and 9.5 will yield valuable data for the radionuclide transport modeling. In the March, 1983, Project progress Report (WIPP-DOE-156), DOE states that a tracer test at H-4 is in progress, but no data are yet available.

9.7 Perform tracer test (convergence) at H-6 using sorbing tracers. The K_d of such tracers from the H-6 field test will then be compared to laborator derived K_d using the same tracer and Culebra rock to determine if laboratory derived values are applicable to the field situation.

9.8 Analyze for environmental isotopes (Carbon-14, Chlorine-36, Uranium-234, and Uranium-238) to aid in understanding the groundwater flow direction an relative velocity.

9.9 Drill the planned additional hydrologic testing wells, viz. H-11 and H-12. Obtain the cores while drilling these wells and examine the cores to determine the extent of fracturing and solution residues, which may indicate possible movement of water through zones other than the two dolomite aquifers.

9.10 Conduct a water balance study for the WIPP site.

9.11 Study the mechanics of removal of salt from the Rustler formation at and near the site.

9.12 Drill a shallow hole in the depression in Sec. 30 (SW 1/4) using an auger to determine the depth of soil and the presence of the caliche layer. This would help answer whether it is a sink hole or a wind deflation feature.

10.0 References Cited

Barr, G. E., Miller, W. B., and Gonzalez, D. D., 1983, Interim Report on the Modeling of the Regional Hydraulics of the Rustler Formation, Sandia NationalLaboratories, Report SAND 83-0391.

Barrows, L., 1982, WIPP Geohydrology - The Implications of Karst, unpublished manuscript, May 1982, 21 p.

Black, S., Newton, R., and Shukla, D., eds., 1983, Results of SPDV Site Validation Experiments, Waste isolation Pilot Plant, TME-3177.

Borns, et al., 1983, Deformation of Evaporites Near the WIPP Site, SAND 82-1069.

DOE, 1983, Summary of the Results of the Evaluationof the WIPP Site and Preliminary Design Validation Program, Report WIPP-DOE-161.

Dosch, R. G., 1980, Assessment of Potential Radionuclide Transport in Site-SpecificGeologic Formations, Sandia National Laboratories, Report SAND 79-2468.

Dosch, R. G., and Lynch, A. W., 1978, Interaction of Radionuclides with Geomedia Associated with the Waste Isolation Pilot Plant (WIPP) Site in New Mexico, Sandia National Laboratories, Report SAND 78 - 0297.

Freeze, R. A., and Cherry, J. A., 1979, Groundwater, Prentice Hall.

Greenfield, M. A., 1979, Simple Model for Estimating Maximum Radionuclide Concentrations in the Pecos River, and Associated Ingestion Doses, due to the Release of Radioactivity from the WIPP Repository, Appendix VI in Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U. S. Department of Energy, ed. by Neill, R. H., Channell, J.K., Wofsy, C., and Greenfield, M. A., EEG publication EEG-3.

Gonzalez, D. D., 1983, Groundwater Flow in the Rustler Formation, Waste Isolation Pilot Plant (WIPP), Southeast New Mexico (SENM): Interim Report, Sandia National Laboratories, Report SAND 82-1012.

Hale, W. E., Hughes, L. S., and Cox, E. R., 1958, Possible Improvement of the Quality of Water of the Pecos River by Diversion of Brine at Malaga Bend, Eddy County, New Mexico; Pecos River Commission, New Mexico and Texas, and U. S. Geological Survey.

Lynch, A. W., and Dosch, R. G., 1980, Sorption Coefficients for Radionuclides on Samples from the Water-Bearing Magenta and Culebra Members of the Rustler Formation, Sandia National Laboratories, Report SAND 80-1064.

Mercer, J. W., 1983, Geohydrology of the Proposed Waste Isolation Pilot Plant Site,Los Medanos Area, Southeastern New Mexico, U. S. Geological Survey, Water Resources Investigations Report 83-4016.

Spiegler, P., 1981, An approach to Calculating Upper Bounds on Maximum Individual Doses from the Use of Contaminated Well water Following a WIPP Repository Breach, EEG report EEG-9.

Snyder, R. P., 1983, General Site Geology, Chapter 2 in Deformation of Evaporites Near the WIPP Site, by Borns, D. T. et al., SAND 82-1069 (Draft).

Weart, W. D., 1983, Summary Evaluation of the Waste Isolation Pilot Plant (WIPP) Site Suitability, Sandia National Laboratories, Report SAND 83 - 0450.

Wofsy, C., 1980, The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP, EEG report EEG-8.

NATURAL RESOURCES AT WIPP

1.0 Introduction

This review discusses the extent of natural resources at the WIPP site, and the results of EEG's analysis of the potential effect of removal of certain of these resources on the integrity of the repository. To ensure consideration of all important aspects of the question of resources, the subject will be divided as follows:

- The nature and extent of resources at WIPP;
- Provisions of important criteria and standards which relate to resources;
- The U.S. Department of Energy's (DOE) Interim Policy on Resource Recovery at WIPP;
- The potential effect of exploration for or removal of resources on the integrity of the repository;
- Summary and conclusions.

The presence of scarce or easily accessible resources at a site under consideration for a nuclear waste repository is undesirable for two reasons: a) efforts at exploration or removal of the resources could lead to structural alterations of the site which over the long term would increase the potential for breach and release of the radioactive nuclides to the biosphere; or b) there is a possibility that it would be necessary to permanently prohibit access through institutional controls and therefore they represent an additional cost consideration. The question of resources is fraught with uncertainty because of the difficulty of assigning values to the resources and degree of technical sophistication to populations thousands of years into the future. Indeed, it may well be that the waste itself will prove to be a resource of the future. For this reason, it is not reasonable to conclude that any site is without resources or is free from the potential for human intrusion or damage.

2.0 Nature and Extent of Resources at WIPP

The known resources at WIPP include caliche, gypsum, halite, potash, possibly lithium, and hydrocarbons. (Most of the hydrocarbons are natural gas and distillate). Several contractors, both private and government, were involved in the evaluation of resources at the site. These are listed in Table 4, and the reports are further described in the references. Table 5 provides a summary of the known resources and the estimated quantities.

2.1 Caliche

Large quantities of caliche are used in New Mexico for road surfacing, however, because of extensive deposits in the region, and since it is near the surface and about 2000 feet from the repository horizon, it is not considered to be of potential consequence to the repository.

2.2 Gypsum

Gypsum is found mostly in the Rustler formation, but the quality and bed thickness is inferior to those deposits found west of the site, where it is readily mined by open pit methods. Very large deposits of gypsum are also found in California, Michigan, Iowa, and Oklahoma. These sources account for 62% of the U.S. production. Most of New Mexico's gypsum production is from mines located in Sandoval and Santa Fe counties (about 250,000 tons/yr.). Therefore, it is not likely that gypsum from the WIPP area will ever be of commercial interest, and because of its location in the Rustler, it could be removed without imposing a threat to the repository horizon.

2.3 Halite

Halite in the Salado underlies the entire area of the WIPP site from about 170 meters down to 870 meters below the surface. It is from 90 to 98% pure sodium chloride, but an even purer grade is found in portions of the Castile formation. The Salado salt is interbedded with anhydrite, polyhalite, sandstone and claystone in a regular succession, and in discrete layers that range from 2 cm. to several meters in thickness. The Salado at the WIPP site also includes a zone of potassium minerals, sylvite and langbeinite as discussed below. The total thickness of the Castile salt is about 170 meters at the WIPP site. The leading producers of salt are in Louisiana, Texas, New York, Ohio, and Indiana. About 80% of the annual production is used in chemical manufacturing, and from 12 to 25% for highway deicing. It has been estimated that as much as 61 trillion tons (Klingman, 1975) exist underground in the U.S. as rock salt or as brine. Also, sea water represents an almost inexhaustible source of salt. The U.S., therefore, has unlimited salt resources. There is some salt production in southeastern New Mexico, mostly from the Salt Lake Mine (about 108,000 tons/yr.). Salt is also produced from the Zuni Salt Lake in west central New Mexico. It is likely that brine lakes and potash tailing piles could meet New Mexico's salt needs indefinitely, and that bedded salt at the WIPP site probably will not become economically attractive for several reasons:

- These resources are more than 165 meters below the surface;
- There are plentiful surface supplies of salt in New Mexico;
- At the regional and national level there are virtually unlimited salt reserves which are more economically attractive;
- Water supplies for processing the rock salt are not readily available in the area.

2.4 Potash

The potash resources within the WIPP site are summarized in Table 6 and Fig. 26. Reserves are those resources which are economically recoverable at current prices and removable with existing technology. Most of the potassium ore at the WIPP site lies between 420 and 550 meters below the surface. The estimates of these resources have been reported by John, et al, (1978) of the U.S. Geological Survey (USGS) and are based on a total of 61 holes drilled by industry and 21 by DOE in the vicinity of the site. The U.S. Bureau of Mines (1977) evaluated the extent to which the resources defined by USGS could be classified as reserves.

Resources were considered to be ore zones of at least 4 feet and with sylvite (KCL) and langbeinite ($K_2Mg_2(SO_4)_3$) of at least 8% and 3% richness respectively in K_2O equivalent. Reserves are those deposits having at least 14 and 8% richness in K_2O equivalent. On this basis, the total potash resources within the four zones of WIPP was estimated to be 484 million tons. Of these resources, 132 million tons were considered reserves. Sixty-seven percent of the potash resources are within Zone IV. Sixty-eight percent of the langbeinite and 82% of the sylvite reserves are recoverable from Zone IV. Because of limited water in the area, and solubility considerations, the more likely method of removal would be by underground (room and pillar) mining.

In summary, the nonretrievable potash resources within Zones I, II and III is estimated as 38 million tons of sylvite and 122 million tons of langbeinite. The non-retrievable langbeinite represents 7% of the known U.S. resources of this mineral.

2.5. Lithium

Powers, et al, (1978), in the WIPP Geological Characterization Report (GCR), recognized the existence of brine reservoirs containing potentially economic concentrations of lithium (at that time thought to be 140 mg/l at ERDA-6 well, 6 miles northeast of the center of the site). Brine reservoirs have been encountered in the Castile formation on several occasions around the WIPP site (DOE, 1983). The DOE in the GCR concluded on the basis of seismic data that no brine pockets existed within the WIPP site, and therefore stated that lithium is not a potential resource at WIPP. In 1981, however, a brine reservoir was encountered at the northern boundary of Zone II and following extensive studies of the reservoir, it was estimated to contain 17 million barrels of saturated brine having a lithium content of 280 mg/l. ERDA-6 brine pocket was reassayed and found to contain 240 mg/l, and the brine pocket at Union Well (about 3/4 mile northwest of ERDA-6) contained 360 mg/l (DOE, 1983). On this basis, one might conclude that lithium is a potential resource and considering only the WIPP-12 reservoir, the extent of the lithium resources may be as high as 800 tons. It is also of interest to note that the lithium contents of the brine are not nearly as high as in Searles Lake and other non-marine evaporite areas. The United States has reserves in excess of 400 times the amount consumed (as of 1975), much of this Li is from brines in which the average Li content is well over 0.1 percent (as compared to the 0.03% in Delaware Basin brines). The U.S. also supplies about 60% of the World Common Market lithium as well. It is unlikely that the Li content of the Delaware Basin brines will be able to compete with other reserves. It also is likely that removal of the brine at WIPP-12 would not lead to a breach of the WIPP repository with transport of the waste to the accessible environment at a substantially accelerated rate. Therefore, the consequences of this resource recovery are bounded by scenarios already considered.

2.6 Hydrocarbons

Because of restrictions on deep drill holes within the site to preserve a buffer zone around the repository, the evaluation of the potential hydrocarbon resources was based on a statistical area survey around the site (Foster, 1974). The economic evaluation of these potential resources was then conducted by Keesy (1976). He concluded that there is a high potential for natural gas in the Morrow unit, but too much of an economic risk for other hydrocarbons. These results are summarized in Table 7. Of course, since Foster's study used a regional statistical approach, there may be considerably more or less than the average quantity of hydrocarbons if the site were actually drilled. Therefore, it is possible that significant reserves of oil also exist within the site.

3.0 Criteria and Standards

Although there are numerous criteria, regulations and guidelines which bear on the subject of site suitability, this report will examine only those which relate to the question of natural resources at a site under consideration for high-level or transuranic waste.

3.1 EPA Proposed Standards

On December 29, 1982, the Environmental Protection Agency (EPA) published proposed "Environmental Standards for the Management and Disposal of Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (47 FR 58196). These standards apply "to radiation doses received by members of the public as a result of the management (except for transportation) and storage of spent nuclear fuel, high-level, or transuranic radioactive wastes to the extent that these operations are not subject to the provision of Part 190 of Title 40." (Part 190 of Title 40 applies to environmental protection for nuclear power operations.) Section 191.14(f) of these standards states that:

> "Disposal systems shall not be located where there has been mining for resources or where there is a reasonable expectation of exploration for scarce or easily accessible resources in the future. Furthermore, disposal systems shall not be located where there is a significant concentration of any material which is not widely available from other sources."

Furthermore, there is no provision for a variance from this subpart of the proposed regulation. The above provision also is not as explicit as one might like, certain passages from the published preamble add to the uncertainty of the intended meaning:

> "This requirement (section 191.14(f)) would discourage the use of geologic formations which are often associated with resources or mining activity. For example, the frequent mining of salt domes either for their relatively pure salt or for use as storage caverns would argue against locating a repository in this type of structure. However, this same concern would generally not apply to bedded salt deposits because they are much more common."
> (Certain words are underlined for emphasis.)

Thus, one would conclude that EPA did not intend to prohibit use of geologic formations which are associated with resources, but only discourage such use. Also, the EPA either was not aware of the resources frequently associated with bedded salt (potash, hydrocarbons, etc.) or did not consider these resources to be as threatening to a repository as the commercial activities associated with salt domes.

3.2 NRC Proposed HLW Regulations.

The Nuclear Regulatory Commission (NRC) published on July 8, 1981 its proposed regulations for "Disposal of High-Level Radioactive Wastes in Geologic Repositories" (48 FR 35280). Subsection 60.122 (c)(18) of Siting Criteria of a draft of the final NRC regulation defines as one of several "potentially adverse conditions":

> "(18) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that: (i) economic extraction is currently feasible or potentially feasible during the foreseeable future; or (ii) such materials have greater gross value, or net value, than the average for other areas of similar size that are representative of and located in the geologic setting."

Although WIPP is exempt from NRC licensure and the NRC regulations, if the site were evaluated against these criteria, one would conclude that the WIPP site has adverse conditions as described with respect to natural resources and when adverse conditions exist, the NRC regulations would require additional analysis, specific site characterization or identification of compensating or mitigating factors before qualifying the site.

A comparison of the WIPP site to the two standards discussed above is summarized in Table 8. In conclusion, the WIPP site appears to have adverse conditions by virtue of the of the natural resources. It was on this basis that EEG recommended that DOE indicate its plans for control of exploration and recovery of the resources, and analyze the consequences of such exploration and recovery.

4.0 DOE Interim Policy on Resource Recovery at WIPP

By letter of January 6, 1983, from the Project Manager, WIPP Project Office, DOE provided EEG its revised Interim Policy Statement. This policy authorizes resource recovery from Zone IV (see Figure 26), but would prohibit mining or drilling within Zones I, II, or III. The policy also allows hydrocarbon recovery from Zone I, II, or III by deviated drilling from Zone IV provided the planes formed by the downward vertical projections of the Control Zone III boundary are not penetrated above 6000 feet.

The policy would also allow solution mining for potash in Zone IV, but is silent on whether castile brine reservoirs under Zone I, II, or III could be accessed from outside of Zone III (eg. to obtain brine for extraction of lithium). One would infer that the 6000 foot restriction would prohibit removal of brine from Zones I, II or III, but if the brine extends into Zone IV, it may be accessible without violating that restriction.

The EEG asked DOE to notify EEG of any requests for mining within one mile of the zone III boundary, but DOE replied that they would notify EEG of any unusual or advance technology planned resource recovery activities which are made known to them by Bureau of Land Management, Department of Interior (BLM).

For this reason, the State intends to negotiate with BLM to obtain notification from BLM of any applications for mining activity within 1 mile of the Zone III boundary. Upon notification, EEG plans to evaluate such proposals and provide appropriate comments, if any, to BLM and DOE, concerning the potential effects on the repository horizon.

5.0 The potential effects of exploration for or removal of resources on the integrity of the repository.

The DOE has considered the consequences of several breach and release events including some which may occur long after the repository is sealed and controls are discontinued and records lost (DOE, 1980, Woolfolk, 1982). Several of these scenarios could occur as a result of drilling activities associated with exploration or mining of resources. In all cases, it was concluded that the resultant radiation doses would be only a small fraction of that from natural

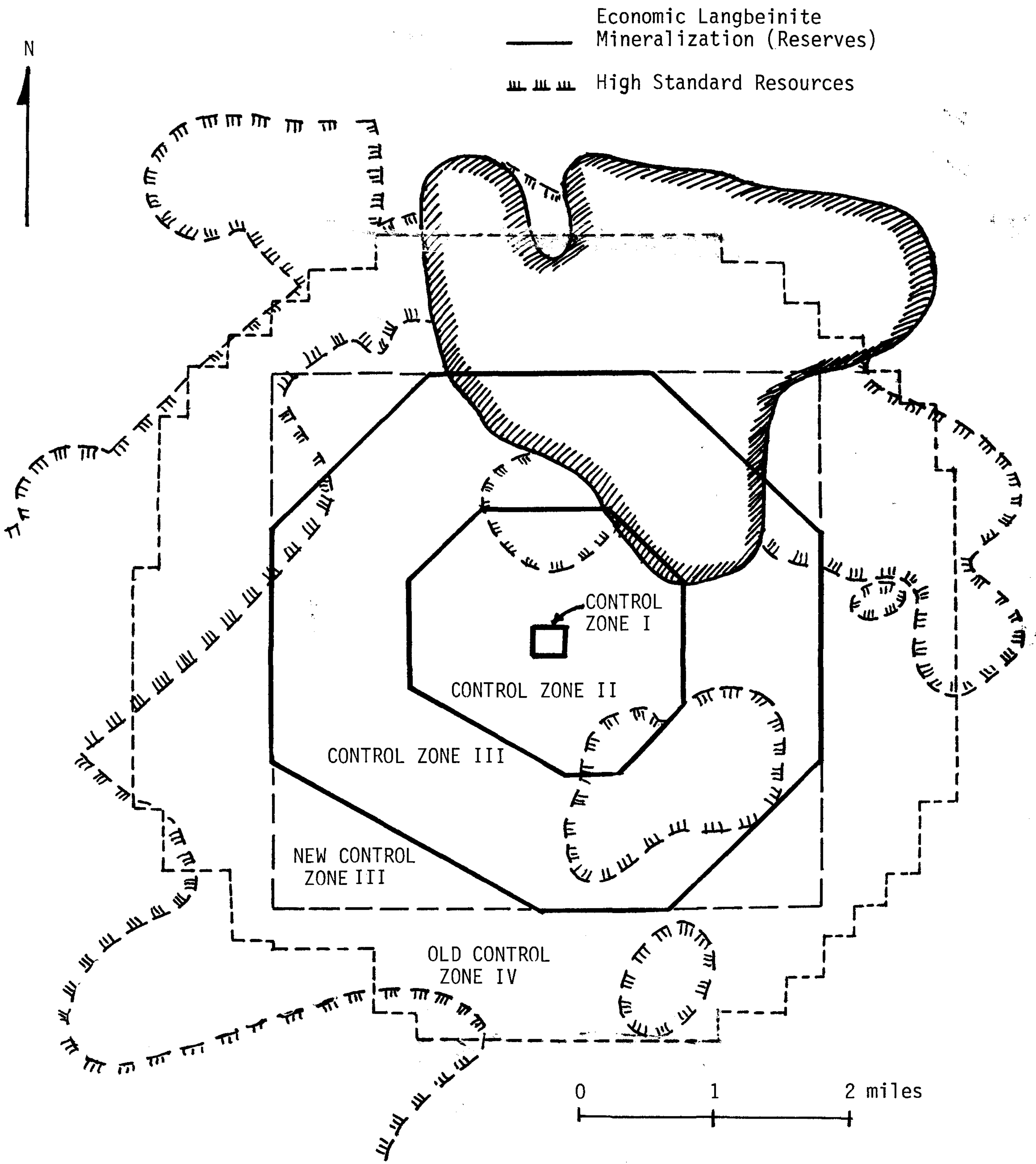


Figure 26. Potash deposits at the WIPP site.

background radiation. The proposed permanent TRU waste inventory (with no high level waste) was used for all such calculations. The EEG has evaluated certain of the models used in these scenarios (EEG-3), and independently considered several other hypothetical breach events associated with human intrusion (EEG-11, 12, 15, and 16). All of these involve low probability events, each associated with considerable uncertainty. Because of the differing assumptions used, the doses are not comparable, but they do suggest that even with conservative assumptions the associated long-term radiation risks of releases associated with natural resource recovery are generally only a small fraction of normal background radiation.

In compliance with one of the terms of the Stipulated Agreement between the DOE and New Mexico (Civil Action of the U. S. District Court for the District of New Mexico, 81-0363, July 1, 1981), the DOE has provided an analysis of the effects of resource recovery if carried out in accordance with the DOE Interim Policy (DOE, 1982). An earlier draft of this report was reviewed by EEG and the revised report (DOE, 1982) was responsive to the EEG comments and recommended changes. The report did not address the effects of brine removal from the WIPP-12 reservoir because at the time of this report, lithium was not recognized as a potential resource. It is likely, however, that such resource recovery is bounded by events already considered. The report also failed to consider bedded salt as a resource. Although EEG agrees that the probability of solution mining of halite from the WIPP site is unlikely, for reasons previously discussed, the potential consequences of such a conservative scenario were considered (EEG-12), and it was concluded that the associated risk is quite small.

Table 4*

Organizations Responsible for Resource Evaluation and Key Reports Concerning Resources

Organization	Responsibility	Reports
U.S. Geol Surv.	Potash Resources as related to ore grade and volume	John et al. (1978) Jones (1978)
U.S. Bur. of Mines	Determination as to what extent the potash resources reported by U.S.G.S. could be economically mined and refined under today's technology and market	USBM (1977)
N.M. Bur. of Mines	Definition of resources and economics for caliche, salt, gypsum, brine, sulfur and uranium	Siemers et al. (1978)
N.M. Bur. of Mines	Oil and gas resources of a four township area which includes the WIPP site	Foster (1974)
Sipes, Williams and Aycock, Inc.	Determination of the economic viability of hydrocarbons under the WIPP site	Keesey (1976)
G.J. Long & Assoc. Inc., Permain Exploration Co.	Interpretation of structure of Paleozoic sediments beneath Ochoan evaporites. These studies were useful in evaluation of hydrocarbons	Long (1976), McMillan (1976)

*From Powers, D. W., et al, 1978.

Table 5. Total Mineral Resources at the WIPP Site*

Resource	Quantity	Depth (ft)	Richness
Caliche[a]	185 million tons	At surface	21-69% insoluble
Gypsum[a]	1.3 billion tons	300-1500	Pure to mixed
Salt[a]	198 billion tons	500-4000	Pure to mixed
Sylvite ore[b]	133.2 million tons	1600	8% K_2O, 4-ft thickness
Langbeinite ore[b]	351.0 million tons	1800	3% K_2O, 4-ft thickness
Lithium[e]	800 tons	3050	240 mg/ℓ brine
Crude oil[c]	37.50 million bbl	4000-20,000	31-46° API[d]
Natural gas[c]	490.12 billion ft^3	4000-20,000	1100 Btu/ft^3
Distillate[c]	5.72 million bbl	4000-20,000	53° API[d]

[a]Data from Siemers et al. (1978).

[b]Low-grade resource and better. Data from John et al. (1978).

[c]Data from Foster (1974).

[d]The degrees API unit has been adopted by the American Petroleum Institute as a measure of the specific gravity of hydrocarbons.

[e]This resource is based on DOE (1983).

*DOE, 1980.

Table 6. Potash Within WIPP Site*

Deposit	Resources (million tons)	Reserves (million tons)	% of Resources recoverable in Zone IV	% of Reserves recoverable in zone IV
Sylvite	133	54	71	82
Langbeinite	351	78	65	68

*This table was prepared from data in Johns (1978)

Table 7.* Potential Natural Gas Within WIPP Site

	Total BCF**	In Zones I,II,III BCF**	In Zone IV BCF**
Resources 100%	490 (100%)	211 (43%)	279 (57%)
Reserves	44.6	21 (47%)	23.6 (53%)

* Based on data from U. S. DOE (1980)

**BCF = billion cubic feet

At a value of $4.40/1000 cubic feet, the total surface value of the natural gas reserves is about $200 million.

Table 8

The WIPP Site Natural Resources and Federal Standards and Criteria

Standard	DOE Conclusion	EEG Conclusion	Remaining Question
DOE			
a) Site criteria	Site meets.	Natural resources at site create adverse condition.	Lithium not considered.
b) NRC proposed regulations (10CFR60)	No opinion expressed.	Natural resources at site create adverse condition.	Lithium not considered.
c) EPA proposed standard (40CFR191)	No opinion expressed.	Natural resources would render site unqualified.	Language of standard not consistent with preamble. Clarification needed.

6.0 References Cited

Foster, R.W., 1974, Oil and Gas Potential of a Proposed Site for the Disposal of High-Level Radioactive Waste: Open-file report, New Mexico Bureau of Mines and Mineral Resources (work done under Contract No. AF(40-1)-4423 to ORNL).

John, C.B., Cheeseman, R.J., Lorenz, J.C. and Millgate, M.L., 1978, Potash Ore Reserves in the Proposed Waste Isolation Pilot Plant Area, Eddy County, New Mexico: U.S. Geol. Surv. Open-file report 78-828.

Jones, C.L., 1978, Test Drilling for Potash Resources: Waste Isolation Pilot Plant Site, Eddy County, New Mexico: U.S. Geol. Surv. Open-file report 78-592.

Keesey, J.J., 1976, Hydrocarbon Evaluation Proposed Southeastern New Mexico Radioactive Material Storage Site, Eddy County, New Mexico: Sipes, Williamson and Aycock, Inc., Vols. I and II.

Klingman, C.L., 1975, Salt: U.S. Bureau of Mines Mineral Facts and Problems, 12 pp.

U.S. Department of Energy, 1980, Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/0026, 2 volumes.

U.S. Department of Energy, 1982, Natural Resources Study, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico, TME 3156.

G.J. Long and Associates, Inc., 1976, Interpretation of Geophysical Data, Los Medanos and Vicinity: Report to Sandia Laboratories.

McMillan, C., 1976, Los Medanos Area: Permian Exploration Co., Report to Sandia Laboratories.

Powers, D.W., Lambert, S.J., Shaffer, Sue-Ellen, Hill, L.R., and Weart, W.D., 1978, Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, Sandia Laboratories, SAND78-1596 (2 volumes).

U.S. Department of Energy, 1983, Brine Reservoirs in The Castile Formation, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico, TME 3153.

Woolfolk, S.W., 1982, Radiological Consequences of Brine Release by Human Intrusion Into WIPP, TME 3151.

Siemers, W.T., Hawley, J.W., Rautman, C., and Austin, G., 1978, Evaluation of the Mineral Potential (excluding hydrocarbons, potash and water) of the Waste Isolation Pilot Plant Site, Eddy County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Report to Sandia Laboratories.

U.S. Bureau of Mines, 1977, Valuation of Potash Occurrences Within the Waste Isolation Pilot Plant Site in Southeastern New Mexico: Prepared for the ERDA.

SPDV RESULTS

1.0 Introduction

The Site and Preliminary Design Validation (SPDV) program consists of two phases: Site Validation and preliminary design validation.

The results of the site validation phase were released on 3/31/83 in TME 3177, Results of Site Validation Experiments (ref. 1) which has been reviewed by the Environmental Evaluation Group (EEG) since it comprises item 7 of Appendix B of the Stipulated Agreement. The objectives and activities of the site validation phase are summarized in Table 9 and were intended by DOE to raise the level of satisfaction from "partially" or "adequately" to "complete" of nine WIPP site qualification criteria. The WIPP site qualification criteria are described in WIPP-DOE-116 Rev. 1 (ref. 2).

The results of the preliminary design validation phase were also released on 3/31/83 in a report entitled Preliminary Design Validation Report. Waste Isolation Pilot Plant (WIPP) (ref. 3). The document has been reviewed by EEG since it comprises item 9 of Appendix B of the Stipulated Agreement. The objectives of the preliminary design validation phase are summarized in Table 10. They are intended to demonstrate that the WIPP can be operated safely over its projected lifetime of 25 years and to insure that the waste can be retrieved should such a step be necessary.

2.0 Background of SPDV Program

The first justification for the SPDV program is contained in WIPP-DOE-049 (ref. 4) as follows:

"During the Title I design efforts on WIPP (1979), it has become increasingly obvious that the earlier research and development activities performed primarily by Sandia Laboratories, which were limited by the prohibition of penetrating the salt with drill holes, must be extended to include additional site verification studies and studies to support critical design assumptions

Table 9 SPDV Site Validation Activities

Objective (To Determine:)	Activity
Thickness of Facility Horizon	Map and Log Shafts, Excavations, Horizontal and Vertical Drillholes
Lateral Extent, Continuity, Inclination of Facility	992-m Exploratory Drift to the South Visual and Geophysical Logs, Map Excavations, High-Resolution Gravity Surveys, Correlation With Drillhole Logs
Brine and Gas Content	TGA, Miscellaneous Analysis of Samples Fluid Probe
Mineralogical Content	X-Ray Fluorescence and Diffraction and Microprobe Analysis of Samples
Interbed Characterization	Constituent Analysis, Mechanical Tests, Permeability
Aquifer Characterization	Fluid Inflow to Shaft, Piezometers in Shaft, Water Samples
Fluid Potential of Facility Level	Inflow of Excavation, Solution Composition
Permeability of Facility Level	Tests on Laboratory Samples

Table 10 Preliminary Design Validation Objectives

- To validate the design for the WIPP access shafts and TRU waste disposal demonstration rooms.
- To evaluate the amount and rate of shaft convergence and room creep deformation and to correlate these data with model predictions.
- To perform a preliminary evaluation of creep in salt and of the steady-state creep model.
- To evaluate instrumentation systems for accuracy and the reliability of measurements made with them in rock salt and to document the suitability of the system for future measurements.
- To evaluate the response of in situ formations such as clay seams and other material layers in addition to the salt.
- To collect large numbers of samples of rock salt and other materials and to conduct laboratory and bench-scale tests to determine the mechanical properties of these samples.

associated with the stability of the underground openings. The rationale and support for the proposed DOE actions has come from three primary sources:

- The Nuclear Regulatory Commission, in testimony before the Runnels Oversight Committee, stated that their new proposed licensing process for HLW repositories will include the necessity of any repository applicant for license to have conducted early, detailed site exploration and evaluation at depth (i.e., exploratory shaft).

- The Panel on the WIPP of the Committee on Radioactive Waste Management of the National Academy of Science advised that continuing efforts to acquire the necessary additional information solely by means of surface exploration, including boreholes, have reached the point of diminishing returns and recommended that:

  a. An exploratory shaft be sunk at the site of one of the proposed shafts as soon as practicable, to the depth of the proposed repository horizon,

  and that

  b. Drilling be done, and tunnels developed in the salt as necessary to conduct the measurements and observations needed to resolve remaining site-specific geotechnical uncertainties and to ascertain the degree to which the site is suitable for the excavation of a repository.

- The USGS, in testimony before the Runnels Oversight Committee, stated that their position on the suitability of the proposed site for WIPP could not be provided until observations taken during shaft sinking, and the results of in situ tests at the candidate horizon, were available."

The SPDV program was designed by Sandia National Laboratories (SNL) to satisfy the above demands. It was categorized into three general areas with the following headings: 1) Site Acceptability Program; 2) Measurement for Design Verification and Repository Boundary Determination; 3) Early Non-Waste Experimental Program. Although there have been changes in the experiments, the three categories have remained and are known today as: 1) Site Validation Program; 2) Preliminary Design Validation Program, and 3) WIPP Research and Development Program (R & D). However, only items 1 and 2 have been retained in the current SPDV program; the WIPP R & D program has become a separate program. An environmental assessment (ref. 5) and a terse description of the SPDV program (ref. 6) were published in October 1980. The WIPP R & D program, which had already become a separate program was not included in the description.

A detailed description of the Site Validation Program, TME 2975, was published in April 1981 (ref. 7). It linked the experiments of the SPDV program with the WIPP site qualification criteria drafted by SNL and published in the Geological Characterization Report (GCR) (ref. 8). TME 2975 cross-referenced the WIPP site qualification criteria with the Office of Nuclear Waste (ONWI)'s criteria for high level waste (HLW) repositories (ref. 9). EEG commented on TME 2975, and these comments led to the issuance of a revised document (ref. 10). Another revision was published in October 1982 (ref. 2). This revision included the studies required under the Stipulated Agreement and the replacement of five proposed horizontal core holes at the repository horizon by an exploratory drift. EEG had taken the position that the horizontal core holes should be replaced by drifts in order to obtain more information than could be obtained from coreholes. The suggestion had first been made in the Golder Associates Report (ref. 11), an independent review of WIPP-DOE-049 commissioned by the Nuclear Regulatory Commission.

A detailed description of the Preliminary Design Validation Program first became available with the publishing of the draft report SAND 81-2628 (ref. 12) in March 1982. A report entitled Preliminary Design Validation Plan (ref. 13) was issued in January 1983; it was required as item 8 of the Stipulated Agreement. EEG commented on the drafts of this report.

3.0 SPDV Configuration and Instrumentation

Two shafts have been drilled and an underground experimental area has been mined. The layout of the experimental facility and the boundaries of zone 2 are shown in Figure 27. The 3.66-m in diameter shaft, the exploratory shaft, which was drilled to a depth of 702-m (2300 ft.), was outfitted to provide the

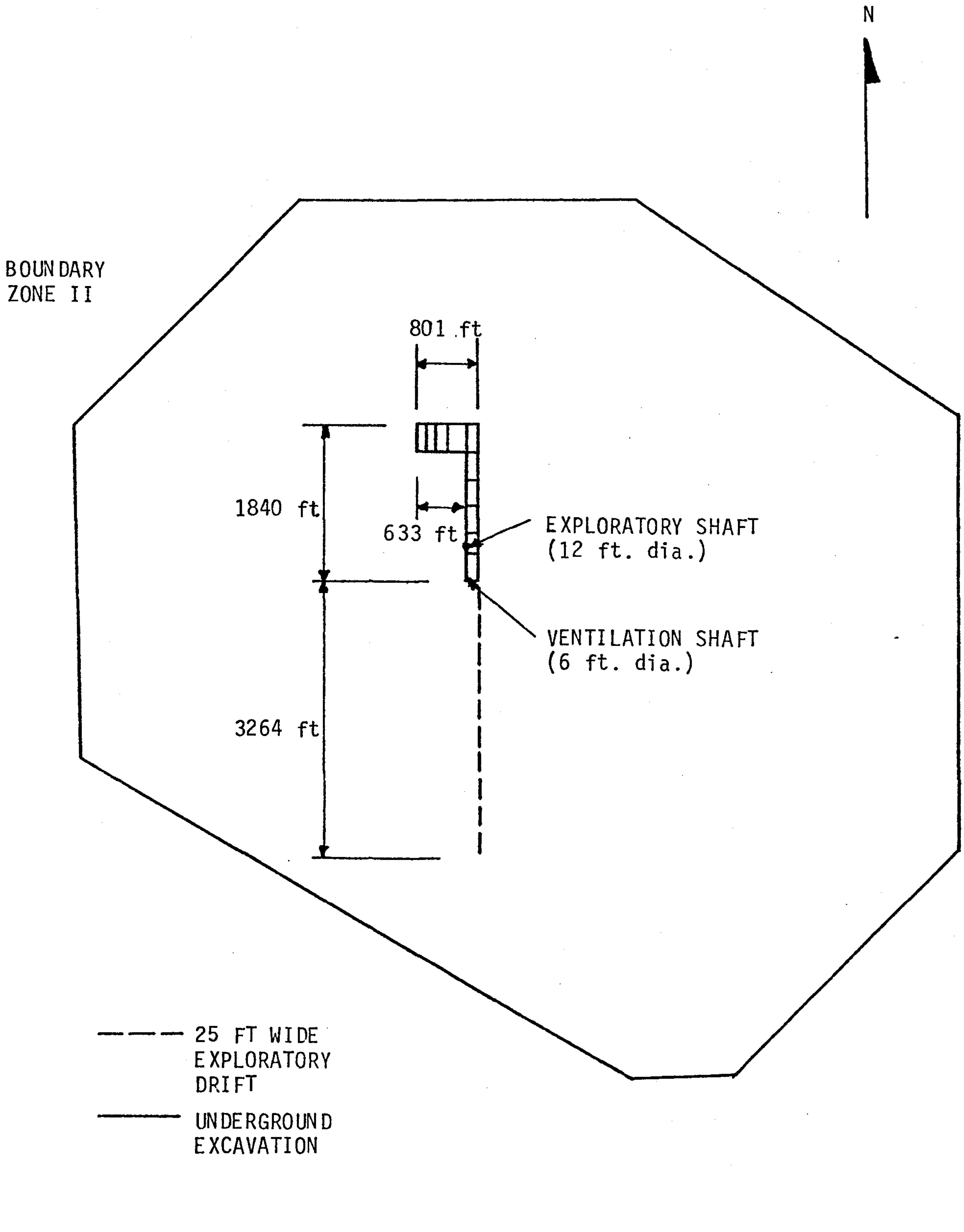


Figure 27. The SPDV layout.

main access to the underground and to bring the mined salt to the surface . The exploratory shaft has three testing areas: the upper part, which has a grouted steel liner from the surface down to the Salado formation (247-m, 850 ft.) is instrumented with piezometers for gathering hydrological data from the Rustlerformation, and with strain gages for gathering data on liner deformation; the shaft liner key, which seals the liner bottom from seapage, is instrumented with piezometers for obtaining hydrological data and with strain gages for obtaining strain data; the unlined portion of the shaft is instrumented for obtaining data on shaft closure and salt deformation. Figure 28 shows the instrumentation locations in the exploratory shaft. The 1.83-m diameter ventilation shaft is unlined except for about 100 ft. of surface conductor. It provides an outlet for the ventilation system and an escape way. It will be transformed into the 20 ft-diameter waste shaft later. The two shafts also provided mappings of the strata from the surface down to the repository horizon.

The underground facility consists of a 995-m (3264 ft.) drift to the south and a network of drifts to a design validation test panel in the north. The drift to the south was excavated to obtain data on the salt and to map the geology in the area of the repository. The design validation test panel consists of four 10 x 3.96-m rooms separated by 30.48-m pillars. The drifts and the test panel are instrumented to obtain data on room stability and room closure. Figure 29 shows the instrumentation of the underground facility.

For completeness, Figure 30 shows the entire WIPP underground layout.

4.0 Results of Site Validation Program

The results of the Site Validation Program are summarized below.

The host rock interval exhibits acceptable thickness and lithologic characteristics as projected from surface-based studies. All principal marker beds and intervening strata are consistent in thickness within the host rock interval throughout the extent of potential underground workings. The average apparent dip of rock strata is less than one degree. These statements are based on geologic profiles from deep boreholes, in-drift coreholes, geologic

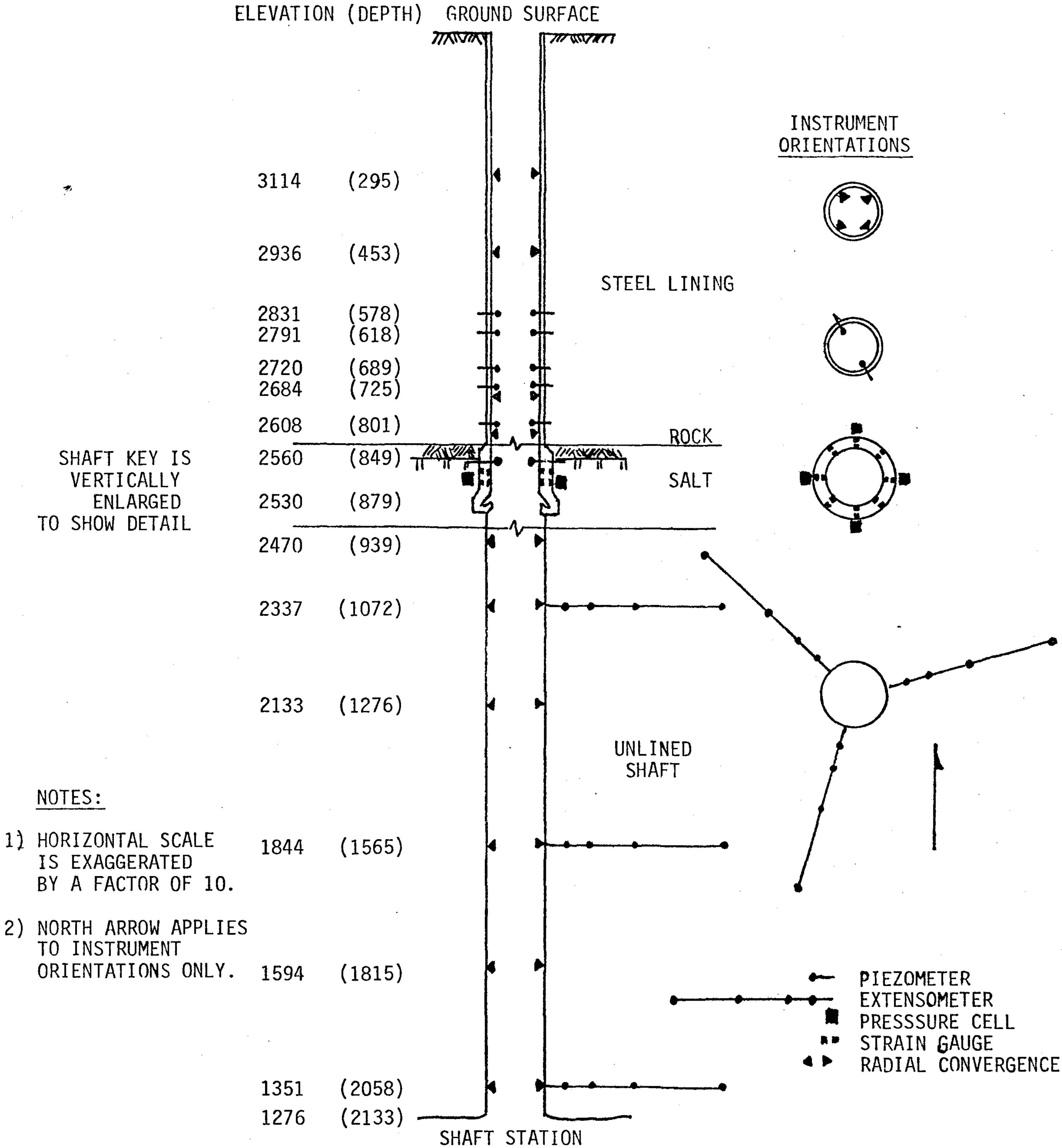


Figure 28. Instrumentation in the exploratory shaft.

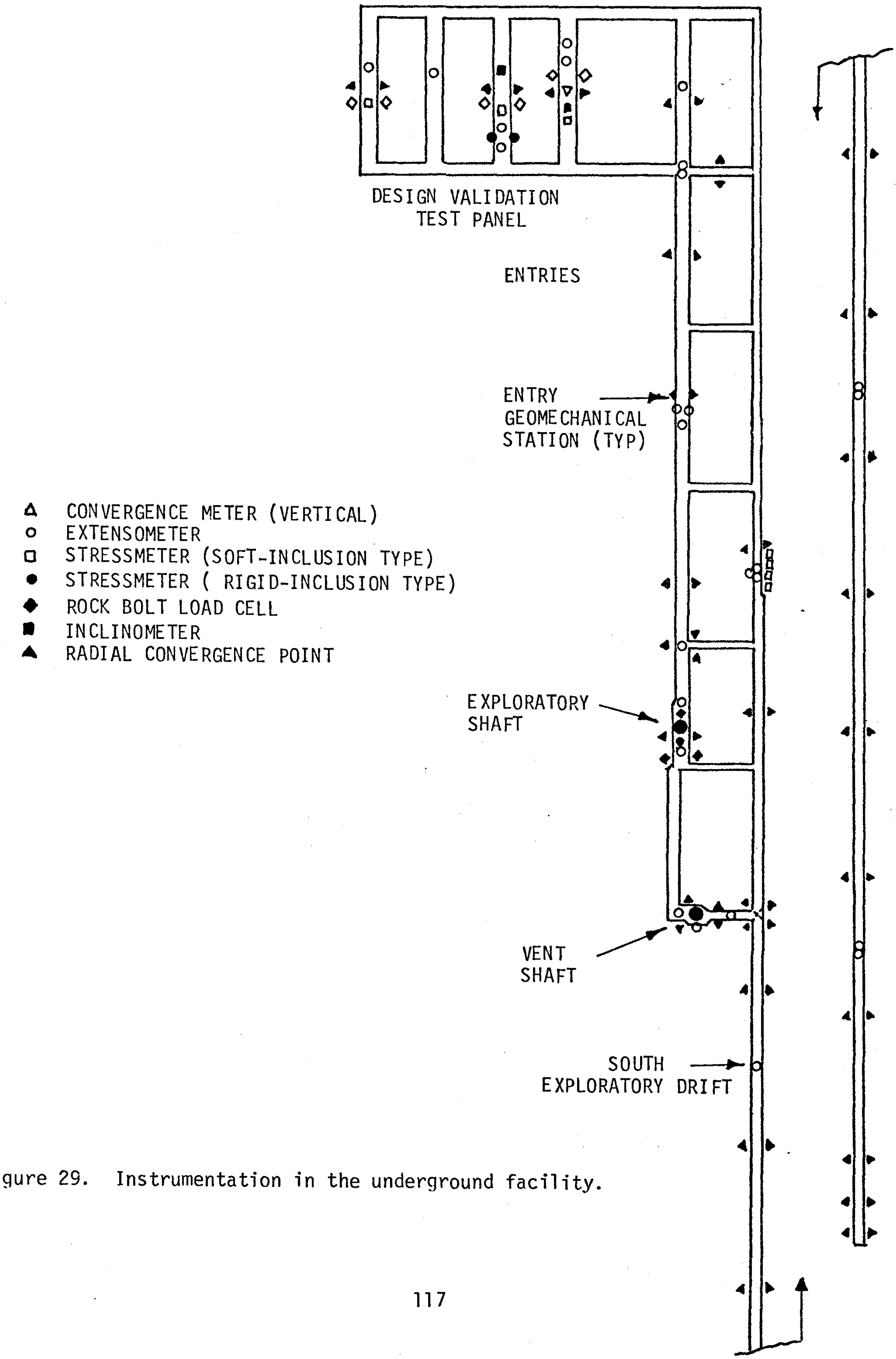


Figure 29. Instrumentation in the underground facility.

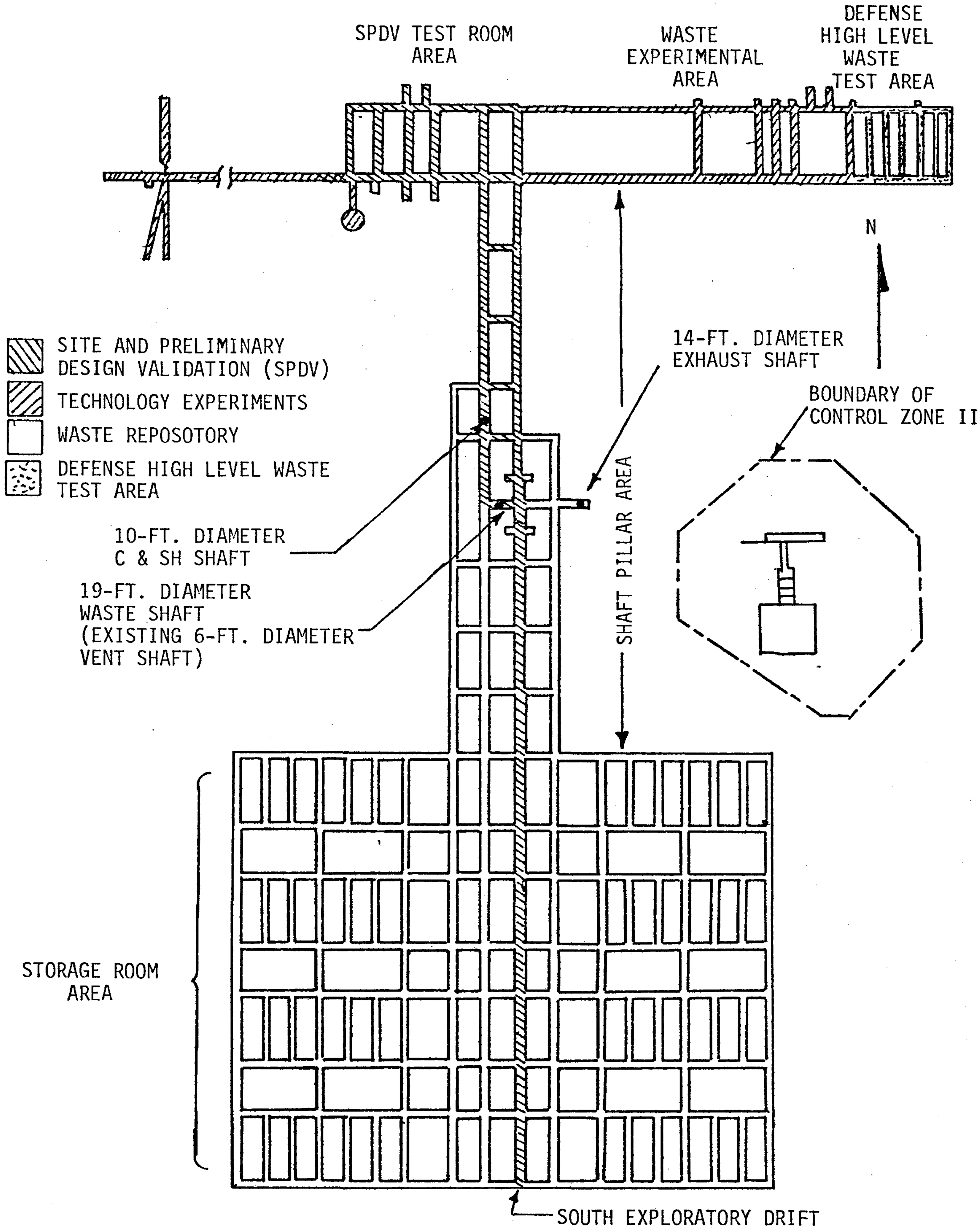


Figure 30. Layout of WIPP underground facility.

mapping of the shafts and of the drifts. Figures 31 and 32 summarize the geologic profile of the WIPP site.

The mean fluid content of the facility interval strata is 0.59% by weight. The principal mineral of the facility interval is halite with minor impurities consisting of polyhalite, quartz, magnesite, clay, anhydrite and gypsum. This statement is based on the analysis of 20 grab samples and 6 core samples. The locations from where the samples were obtained are shown in Figure 33.

The interbeds of the host rock interval are anhydrite and thin clay seams. Their physical properties do not pose an unmanageable problem on stability of the excavation. Based on laboratory testing, permeabilities of the interbeds measured under approximate lithostatic pressure were less than seven microdarcies. Test included Atterberg limits, direct shear, indirect tension, x-ray diffraction, and permeability. The sampling locations of interbedded materials is shown in Figure 34.

The observed inflow from the Rustler was approximately 1.5 gpm in the exploratory shaft and approximately 1 gpm in the ventilation shaft. The actual inflow may be larger, since all the water could not be collected during the inflow tests (ref. 14, p. 5-3).

No water inflows were encountered during excavations of the facility interval.

Permeability of facility interval samples tested under confining pressures approximating in situ conditions was less than 0.01 microdarcy. This statement is based on laboratory tests of 6 samples.

5.0 Results of Preliminary Design Validation Program

5.1 Preliminary Analysis

Sandia National Laboratory has performed calculations to predict the mechanical response of the shafts, the passageways, and the TRU demonstration rooms.

Figure 35 shows nominal calculated closures in the unlined shaft at three depths(ref. 15). These calculations are subject to considerable uncertainty and will have to be refined as more data are accumulated.

TME 3179

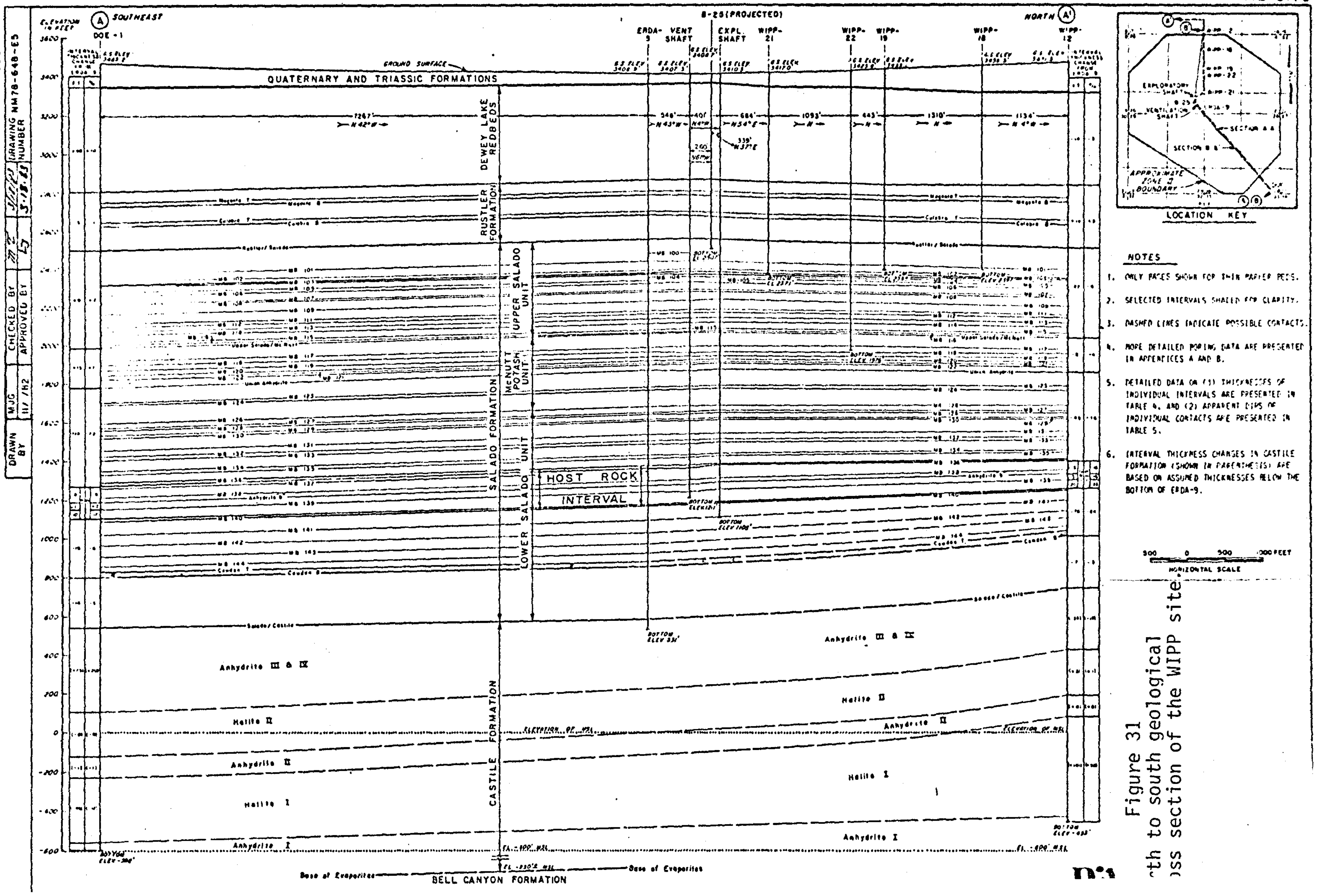
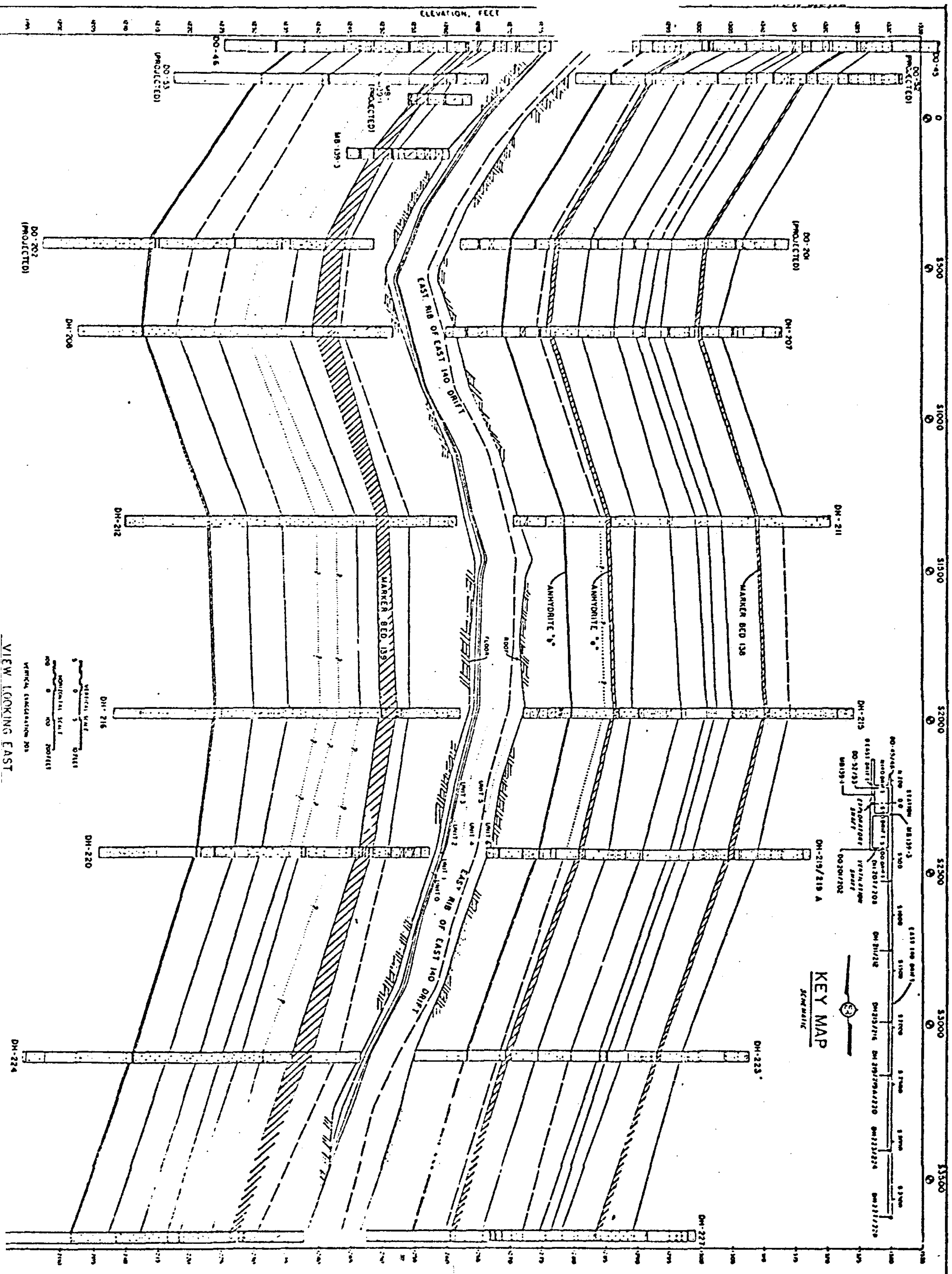


Figure 31
th to south geological
ss section of the WIPP site.



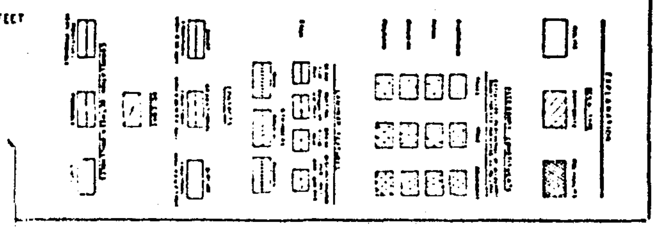


Figure 32. Correlation of vertical boreholes in the exploratory drift to the south

TME 3177

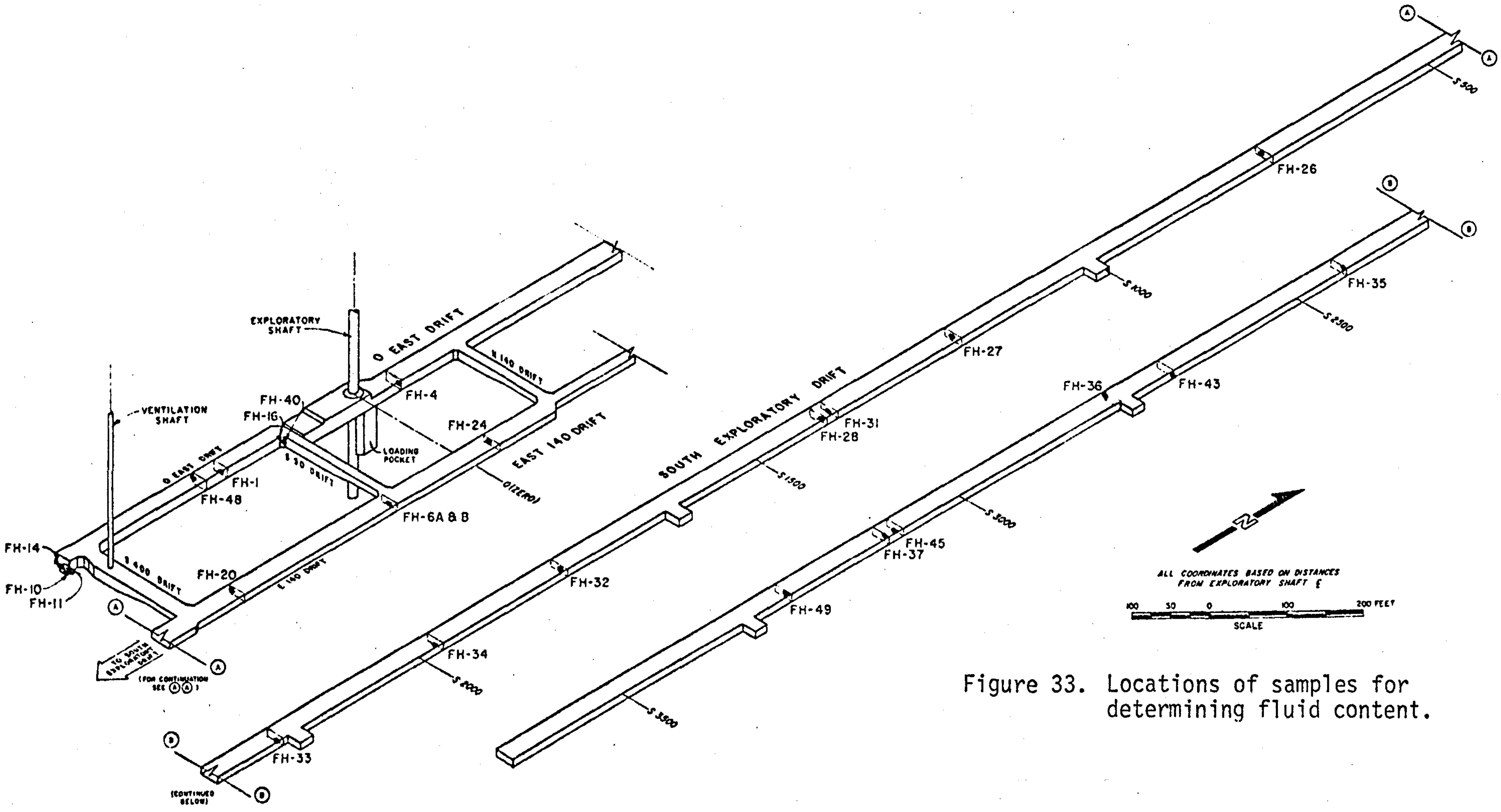


Figure 33. Locations of samples for determining fluid content.

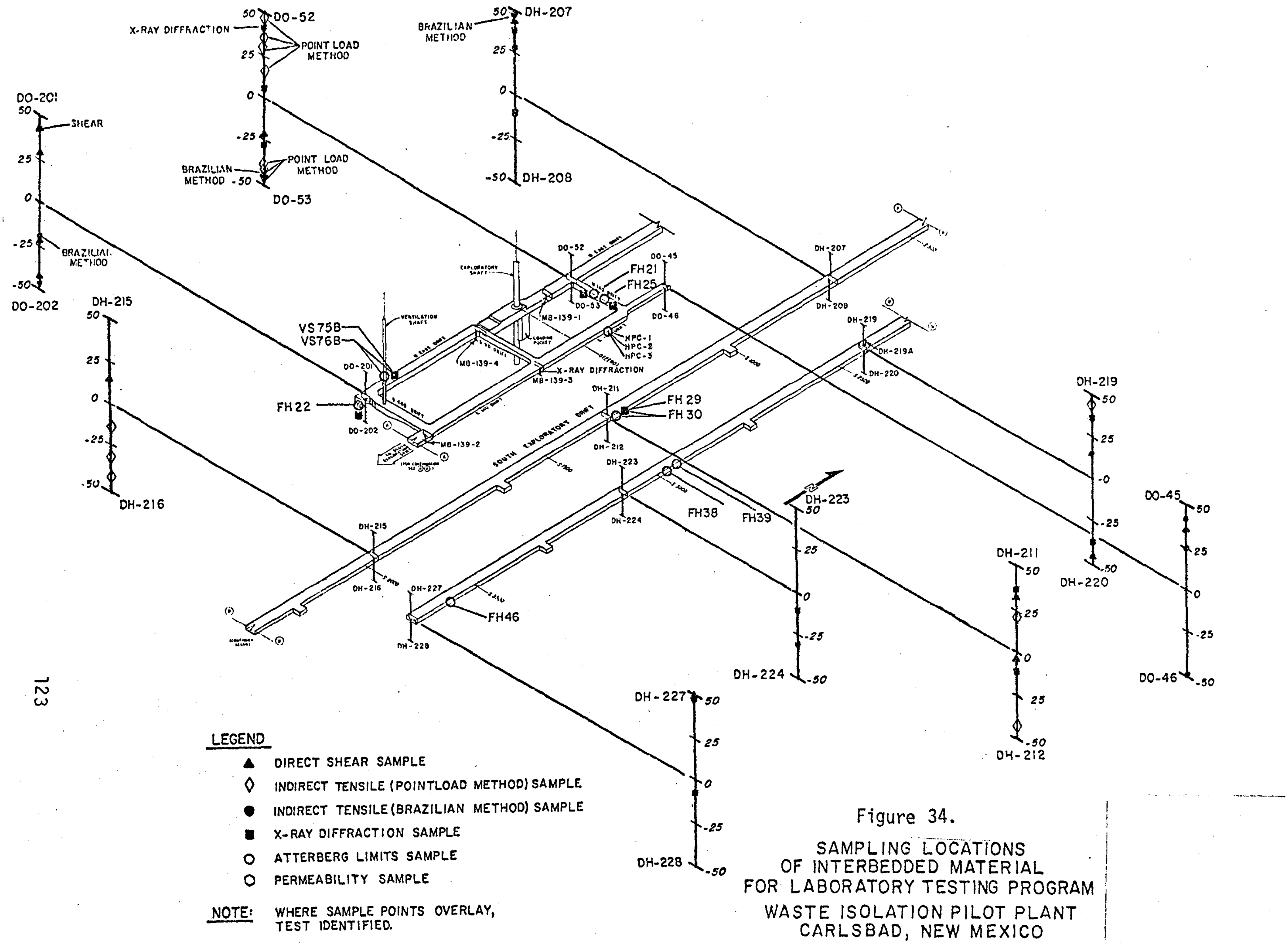


Figure 34.

SAMPLING LOCATIONS
OF INTERBEDDED MATERIAL
FOR LABORATORY TESTING PROGRAM
WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO

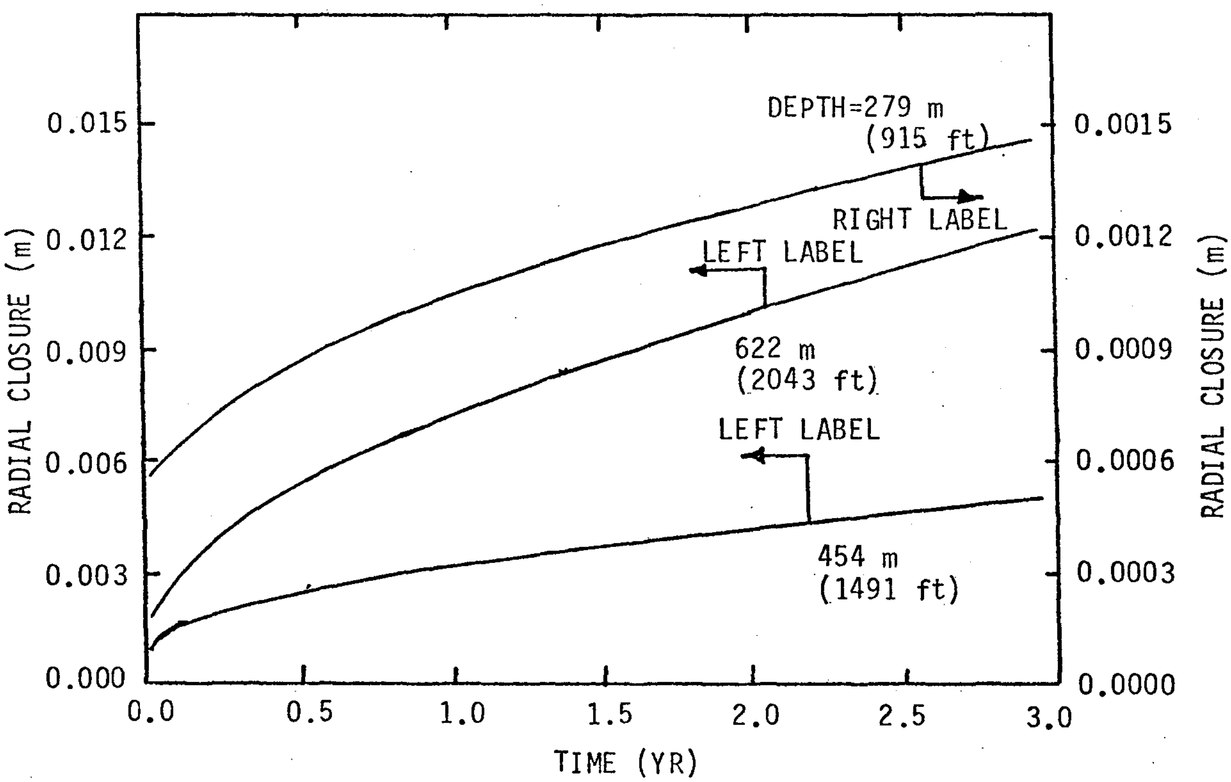


Figure 35. Calculated shaft radial closure at three extensometer locations for the SPDV (ref. 15).

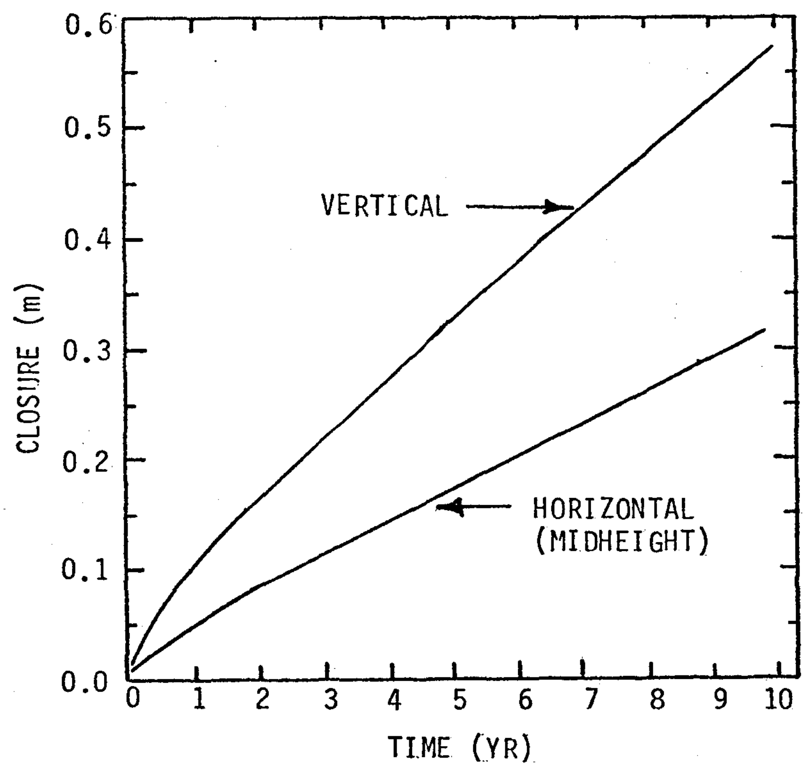


Figure 36. Preliminary calculations of storage room closure for design validation test panel of SPDV. (ref. 15).

Figure 36 shows typical calculation results for vertical and horizontal room closures. Figure 37 shows a two dimensional closure pattern. The calculations were made using sophisticated rock mechanics codes, the reference WIPP stratigraphy, and current steady-state constitutive models (ref. 16, 17). Again, the calculations will have to be refined as data are accumulated.

5.2 Early Design Validation Data

Most of the instrumentation, in particular that in the drift and in the test panel, has been only recently installed. A data gathering period of one year will probably be required before attempting any correlation between measurements and prediction. This is especially true of room and drift convergence. Hence only the sampling data is presented below and no attempt is made to correlate the observations with the calculated predictions.

Figure 38 shows the stabilized readings from the piezometers installed behind the steel lining in the exploratory shaft. Also shown is the design hydrostatic pressure. There is no correlation of pressure with depth; hence, more data will be necessary before drawing any conclusions on these pressure readings.

The piezometers installed in the salt formation behind the shaft key so far have shown a nominal reading of 6 psi. This indicates that there is no water pressure buildup behind the key.

Four earth pressure cells installed behind the shaft key do not indicate any pressure buildup between the salt formation and the concrete key. This confirms the prediction that the initial shrinkage rate of concrete is greater than the radial creep rate of the salt. An interactive pressure is not expected for two years. The strain gages in the concrete do not indicate significant strains.

Limited water leakage observed through telltales in the shaft key indicate that the chemical seal ring placed near the top of the shaft key is fairly effective in preventing the migration of water from the upper aquifers down to the shaft key and the salt formation.

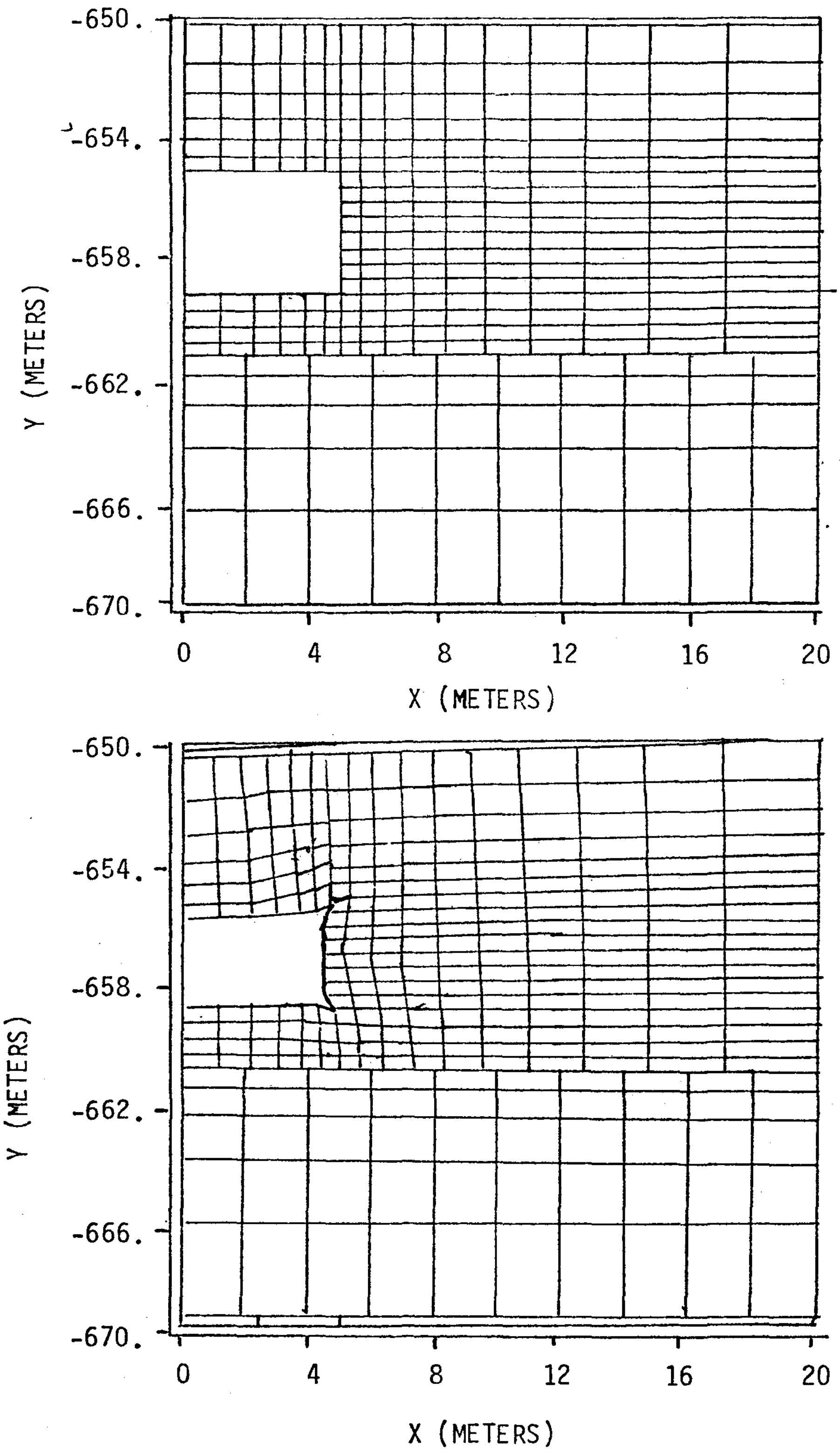


Figure 37. Two dimensional room closure calculations. Comparison of undeformed room and deformed room after 10 years (ref. 16).

PIEZOMETER READING ON
FEBRUARY 21, 1983

LEVEL	PIEZOMETER	PSI	FT
578	PE-00201, 00202	95	219
618	PE-00203, 00204	94	217
689	PE-00205, 00206	85	196
725	PE-00208	108	249
801	PE-00209, 00210	144	332

△ PIEZOMETER READING

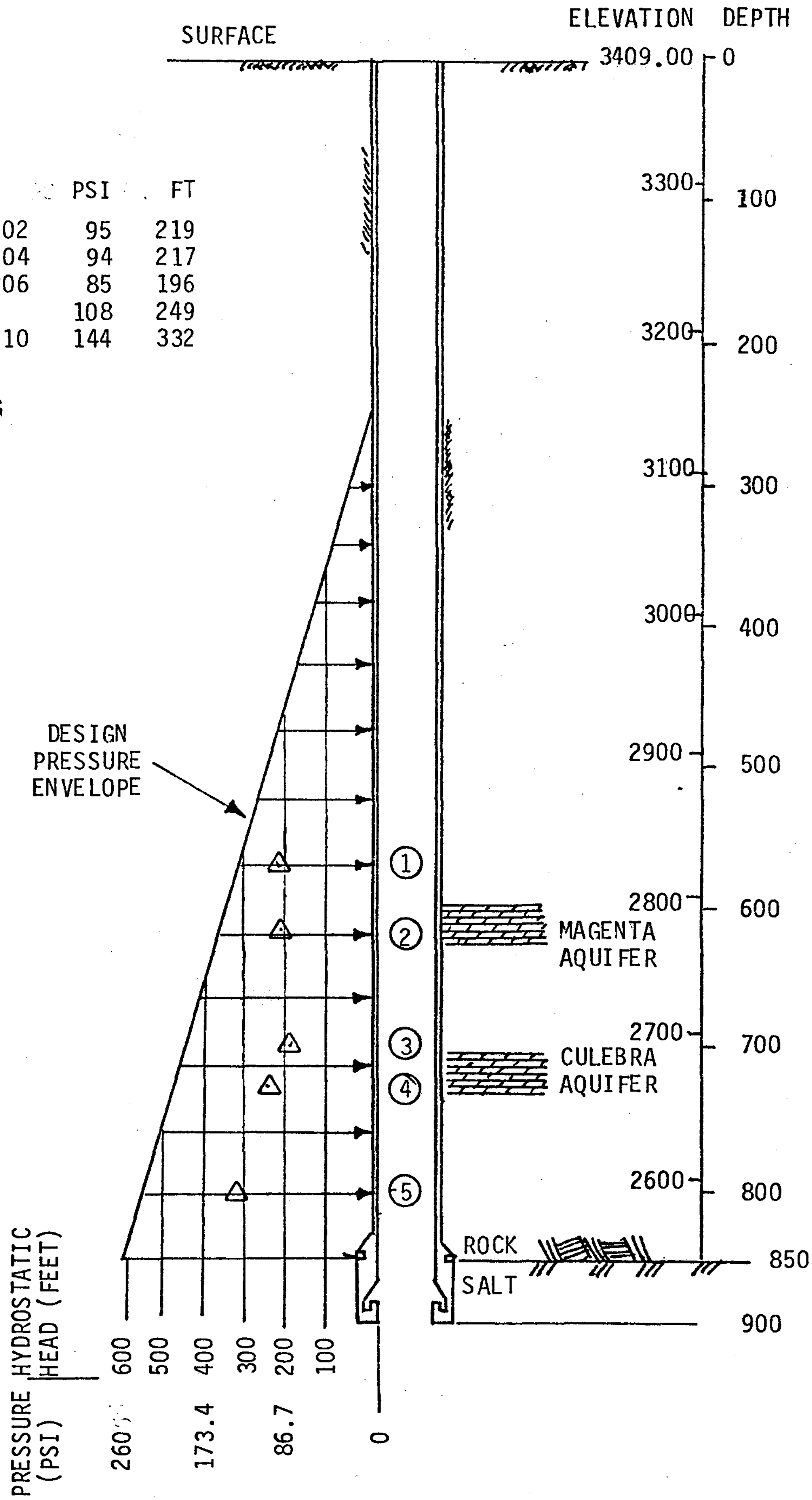


Figure 38. Stabilized piezometer readings and design pressure envelope of liner for exploratory shaft. (ref. 2).

Radial convergence of the unlined shaft has been monitored since July 1982. For the three extensometers at the level of 2057 ft., the seven month average radial convergence is 0.081 in. The calculated value is 0.087 in. For the three extensometers at the level of 1564 ft., the average radial convergence is 0.030 in. The calculated value is 0.027 in. For the three extensometers at the level of 1073 ft., the average reading is 0.002 in. The calculated value is 0.008 in.

The extensometer data thus indicate shaft closure rates ranging from 0.001 in./year at the top of the Salado formation to 0.10 in./year at the level of the repository horizon.

Six rock bolt load cells were installed in the exploratory shaft station in May 1982. Some showed a large increase in rock bolt load in the months following their installation. However, two cells indicate a significant decrease in rock bolt load since January 1983. Based on seven extensometers in the exploratory shaft station that were installed in July, September, and October, the total roof movement has been estimated at 1 1/2 to 2 1/2 in. up to the end of February. The roof movement appears to be decreasing. Figures 39 and 40 are samples of data obtained by extensometers in the exploratory shaft station. The figures suggest that the extensometers will provide data necessary to verify two dimensional room closure calculations.

Three extensometers installed since mid November in the ventilation shaft indicate that roof and wall movement is occurring at a decreasing rate.

Accumulated roof movement shown by the extensometers is less than 2 in.

Only minimal measurements are available for the 3256 ft. drift south, the instrumentation having been installed after January 1, 1983. However, all the room closure rate data show a gradual decrease.

6.0 Assessment of SPDV Program

General criteria for nuclear waste emplacement in geological repositories are in the process of being finalized. The Environmental Protection Agency (EPA) has published standards for comments under 40 CFR 191 (ref. 19) and the DOE has published general guidelines for comments under 10 CFR 960 (ref. 20). These criteria are similar to those published in NWTS-33 (ref. 9). For WIPP, criteria were first published in the GCR (ref. 8) and later in documents entitled Site Validation Program (refs. 7, 10, 2). In the site validation documents, the WIPP site criteria are cross-referenced with the NWTS-33 criteria. EEG also gave consideration to site criteria in its first report (ref. 21).

EEG concludes that the detailed geologic mapping at the repository horizons and a limited number of rock mechanics experiments conducted in the drifts and the shafts show no adverse conditions at the proposed repository level. However, the marker bed 139 (MB 139), which lies less than 10 feet below the repository horizon and consists of "mounds caused by growth of gypsum crystal clusters which were later slightly crushed by overburden pressure" (p. 6-4, ref. 22) may not satisfy DOE Criterion 13.2 (p. 12, ref. 22). EEG has recommended a detailed study of this layer to DOE.

No comprehensive set of criteria pertaining to the verification of design validation exists at present since an NRC licensed mined geological repository will not be built before 1990.

The excavations to date, the shaft and the underground facilities, clearly verify the first objective in Table 10. The piezometer readings in the Rustler formation (Fig. 38) show high hydrostatic pressures away from the Magenta and Culebra aquifers. Assuming that the Piezometers are functioning properly, this raises questions concerning the Rustler hydrology, which are raised in the Regional Hydrology section. Several years of data gathering will be necessary to verify the remaining objectives. EEG will evaluate this data as it becomes available and will make appropriate recommendations applicable to the design of the facility.

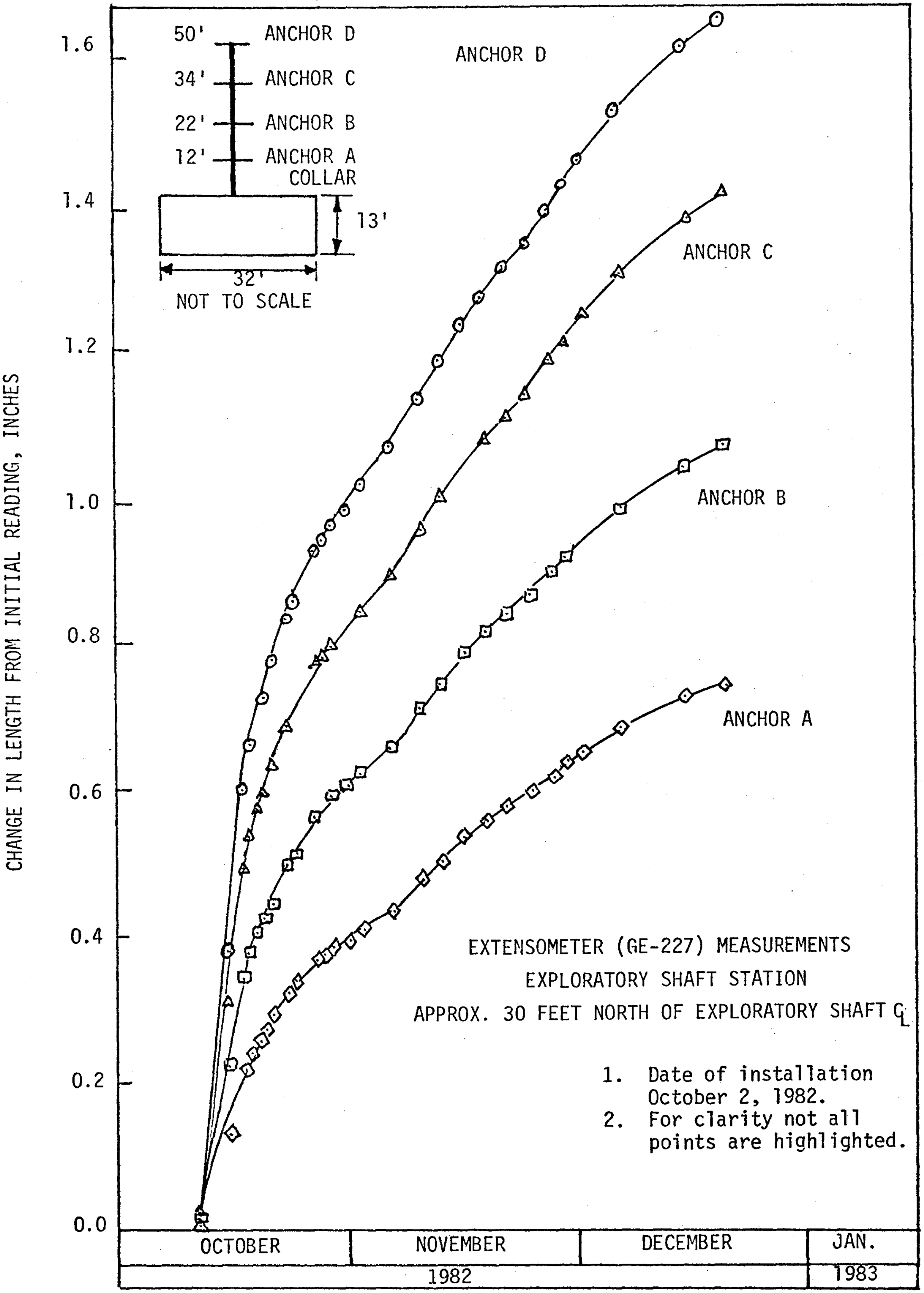


Figure 39. Closure data from an extensometer in the exploratory shaft station (ref. 18).

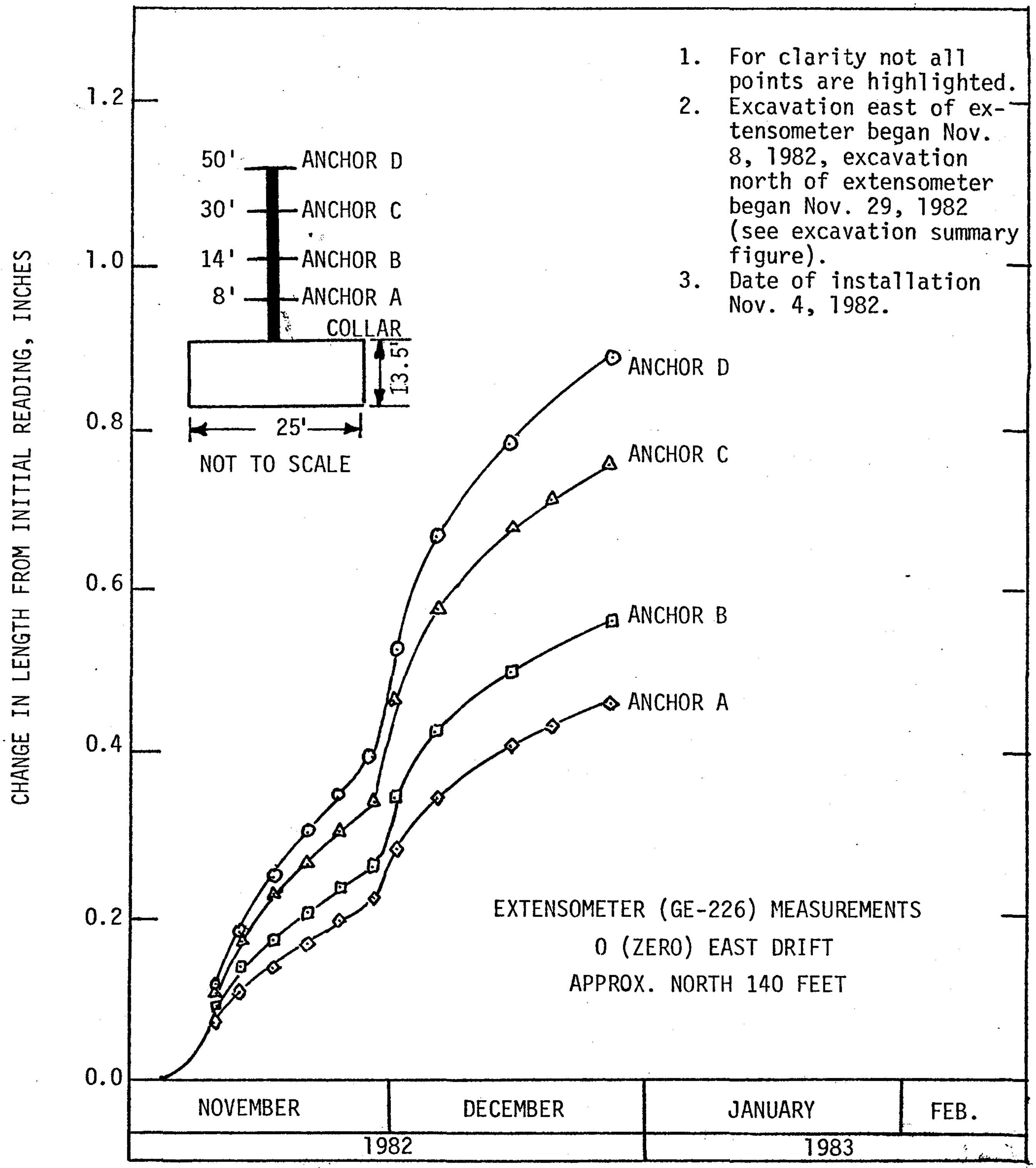


Figure 40. Closure data from an extensometer in the 0 drift 140 feet north of exploratory shaft.(ref. 18).

Additionally, EEG must also keep abreast of the WIPP R and D program because many of the experiments, notably the plugging and sealing of boreholes and shafts, and demonstration of waste emplacement, will provide important data applicable to design and operation of the facility.

7.0 References Cited

U.S. Department of Energy, Results of Site Validation Experiments Waste Isolation Pilot Plant (WIPP) Project Southeastern New Mexico, 2 Volume, TME 3177, March 1983.

U.S. Department of Energy, Site Validation Program, WIPP-DOE-116, Rev. 1. October 1982.

U.S. Department of Energy, Waste Isolation Pilot Plant. Preliminary Design Validation Report, Job 12484 performed by Bechtel National, Inc., March 30, 1983.

U.S. Department of Energy, SPDV (Site Preliminary Design Verification) Project Plan Summary, WIPP-DOE-49, November 1979.

U.S. Department of Energy, Technical and Environmental Analyses Development of the Site and Preliminary Design Validation Program Los Medanos Site, Southeastern New Mexico, Report TME-3058, October 1980.

U.S. Department of Energy, A Description of the Site and Preliminary Design Validation Program for the WIPP Site, Report TME-3063, October 1980.

U.S. Department of Energy, Site Validation Program, April 1981, Report TME-2975, April 1981.

Powers, D.W., Lambert, S.J., Shaffer, S.E., Hill, L.R., Weart, D.W., Geological Characterization Report Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, Volume I, SAND 78-1596, August 1978.

NWTS Program Office U.S. Department of Energy, NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste, DOE/NWTS-33(2), February 1981.

U.S. Department of Energy, Site Validation Program, Report WIPP-DOE-116, January 1982.

Golder Associates, Final Report. Review of Site Preliminary Design Verification Project Plan, August 1980.

Matalucci, R. V., Christensen, C.L., Hunter, T.O., Molecke, M. A., Munson, D. E., Waste Isolation Pilot Plant (WIPP) Research and Development Program: In Situ Testing Plan, Draft Report SAND 81-2628, March 1982.

U.S. Department of Energy, Design Validation Plan, WIPP-DOE-160, January 1983.

WIPP-SPDV, Geotechnical Field Data Report No. 4, Geologic Mapping and Water Inflow Testing on the SPDV Ventilation Shaft, 1983.

Matalucci, R.V., Christensen, C.L., Hunter, T.O., Molecke, M.A., and Munson, D.E., Waste Isolation Pilot Plant (WIPP) Research and Development Program: In Situ Testing Plan, March 1982, SAND 81-2628 (December 1982)

Brandstetter, L.J., Stone, C.M., and Krieg, R.D., WIPP Benchmark II results Using SANCHO, SAND 81-0853 (Albuquerque, NM, November 1981).

Morgan, H.S., Krieg, R.D., and Matalucci, R.V., Comparative Analysis of Nine Structural Codes Used In the Second WIPP Benchmark Problem, SAND 81-1389 (November 1981).

WIPP-SPDV, Geotechnical Field Data Report No. 6, Underground Excavation Field Instrumentation Data, January 17, 1983.

40 CFR Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Radioactive Wastes, Federal Register, Vol. 47, No 250, December 29, 1982, Proposed Rule, p. 58196.

10 CFR 960 - General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, Federal Register, Vol. 48, No 26, February 7, 1983, Proposed Rules, p. 5676.

Goad, D., A Compilation of Site Selection Criteria, Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, Report EEG-1, June 1979.

U. S. DOE, Correlation of Drill hole and Shaft Logs, WIPP, S. E. New Mexico, TME-3179, March 1983.

CONCLUSIONS AND RECOMMENDATIONS

The Environmental Evaluation Group (EEG) has concluded that the Los Medanos site for the WIPP project has been characterized in sufficient detail to warrant confidence in the safety of the site for the permanent emplacement of approximately 6 million cubic feet of defense transuranic waste. This conclusion is based on the assumption that the maximum surface dose rate for the unshielded remote-handled transuranic waste (RH-TRU) canisters will be 100 rem per hour with a maximum radionuclide concentration of 23 curies per liter as indicated in Table E-3 of the Final Environmental Impact Statement for WIPP. The Site and Preliminary Design Validation (SPDV) program, through the drilling of two shafts to the selected repository level at 2160 feet below the surface and excavation of about 9000 feet of tunnels, has confirmed the interpretations made about the subsurface geological conditions at the center of the site.

For an assessment of the potential radiation effects of the nuclear waste repository on the public health and safety, it is necessary to understand the regional geological and hydrological setting. A large amount of work has been done to understand these conditions and to address several specific issues which have arisen as a result of such studies. However, in an assessment effort of this magnitude, it is almost inevitable that some questions remain unanswered at a given time in the decision-making process. EEG has identified work which still needs to be done at the Los Medanos site in order to improve confidence in the worst case scenario models of possible breaches of the repository. Also, it is anticipated that some of the additional information will be necessary to assure compliance with the EPA standard when it is promulgated.

The following is a summary of EEG conclusions on each of the major issues of suitability of the WIPP site and a list of recommendations for additional work for further characterization of the site.

CONCLUSIONS

Dissolution

There is no doubt that a large amount of salt has been removed from the Rustler and Salado formations in the Delaware Basin through the process of shallow blanket dissolution. This process has removed the salt from these two formations in the western part of the basin and only the collapsed insoluble residue of the Rustler and Salado remain in that area. The two dolomite aquifers in the Rustler formation provide the unsaturated water necessary for this shallow dissolution. The exit point for the brines produced by such dissolution near the WIPP site at the present time is the Pecos River at Malaga Bend and several points downstream. Piper (1973) calculated that the salts discharged into the Pecos River at Malaga Bend amount to 310,000 tons of NaCl and 170 tons of $CaSo_4$ each year. On the basis of an estimate of 955 tons per square mile per year of salt discharged by the springs and streams into the Pecos River, Bachman and Johnson (1973) calculated a present vertical-dissolution rate of about 500 feet of salt per million years. Using two different approaches for calculating the rate of advance of the "shallow" dissolution front towards the WIPP site, it has been shown that it would take at least 2 to 3 million years for such dissolution to be a threat to the repository.

The question of deep-seated dissolution, which has been postulated to be responsible for removing up to 70% of the lower Salado salt (Anderson, 1981) is of more concern to EEG. This concern arises from the fact that the stratigraphic level from which the salt is postulated to have been removed is that of the proposed repository. EEG has examined the evidence for and against "deep dissolution" and concludes that there is sufficient evidence to accept the existence of deep-seated dissolution as a strong hypotheses to explain the missing salt from the lower Salado and Castile formations. The mechanism for such a dissolution process, i.e., the source and the sink for the unsaturated water and the saturated brine respectively, still remains unexplained.

Anderson (1983) has argued that the lack of understanding of the mechanics of deep dissolution throws suspicion on the integrity of the Delaware Basin as a whole. However, a detailed examination of hundreds of logs in the Basin has resulted in the drawing of "dissolution edges" by Anderson (1981). These dissolution edges are at least 15 miles to the south and farther to the east of the WIPP site. Therefore, EEG views the WIPP site to be situated in an area which is safe from the effects of any deep-seated dissolution process, now or during the isolation time of the proposed repository. This conclusion is strengthened by the study of cores from deep boreholes at and around the WIPP site and the results of the excavation at the repository level under the SPDV program.

There is one area, two miles north of the center of the site, where the lower Salado marker beds show a depression. EEG recommends that the logs of boreholes in this area be reexamined and a modeling of the anomaly be conducted. After this work, a decision can be made whether to drill a new borehole to test the possibility of this anomaly having been caused by the process of point source deep dissolution.

Breccia Pipes

A chimney of brecciated rock represents collapse of the overlying rock into a cavity formed at some location at depth. Vine (1960) identified several domal structures in the Delaware Basin which have been explored during the investigations for WIPP, as possible breccia pipes. Anderson and Kirkland (1980) proposed the mechanism of brine density flow for the formation of breccia pipes. This mechanism requires an active participation of the DMG aquifer in supplying the unsaturated water and in removing the saturated brine. The characteristics of the DMG aquifer (Wood et al., 1982) do not appear to support this role.

Detailed investigations and analyses of the breccia pipes in the Delaware Basin have shown that the breccia pipes appear to form only over the buried Capitan Reef which borders the Delaware Basin. The domes in the basin show characteristics which identify them as having resulted from near surface phenomena. The "Castile" domes which are commonly found in the west-central part of the basin may have resulted from an interconnection between the DMG aquifer (which is at a shallow depth in the western part of the Basin) and the overlying evaporites. However, these are not "active" features. On the basis of a drill hole core, Anderson (personal communication) has identified a breccia pipe in the Basin, about 60 miles south of the WIPP site. Several miles of mining activity for potash in the upper Salado formation has not found a breccia pipe near the WIPP site. EEG, therefore, concludes that breccia pipes are not present at the WIPP site, and therefore do not pose a threat to the WIPP.

Spiegler, 1982 calculated the effect of a hypothetical breccia pipe developing under the repository and concluded that the radiological impact of such a feature returning radioactive materials to the biosphere would be insignificant.

Brine Reservoirs

Pressurized brine, at pressures between hydrostatic and lithostatic, have been encountered in the upper anhydrite layer of the Castile formation. Thirteen such encounters have been reported within eight miles of the proposed repository site. All except two of these were encounters in commercial oil and gas exploratory holes. ERDA-6 and WIPP-12 were WIPP project boreholes. WIPP-12 is situated at the northern edge of Zone II of WIPP. In addition to the pressurized encounters, brines at sub-artesian heads have also been found in the Castile formation, mainly along the Pecos River (Snyder, 1983, Personal Communication).

It should be realized that only the encounters at WIPP-12 and ERDA-6 were studied in detail. Varying degrees of detail are available on the other encounters.

Based on a study of all the data available, EEG has reached the following tentative conclusions.

- The Castile brine is not confined to a zone bordering the Capitan Reef. If one wishes to draw a zone, it would include the entire WIPP site.

- Each encounter of brine may not represent a distinct brine reservoir.

- Most of the brine encounters appear to be related to a structure in the Castile.

- Hydrologic testing and geochemical analyses of WIPP-12 and ERDA-6 brines indicate that the two are not connected.

- Geochemical data indicate that the brines may have been produced from water trapped in the rock at the time of deposition and later squeezed out at the time of structural deformation. However, the Capitan aquifer cannot be ruled out as a source.

- The brine, at least in WIPP-12 and ERDA-6, is not connected to any active aquifer at present.

- The presence of brine in the Castile formation underlying the WIPP site cannot be ruled out.

To provide an estimate of risk associated with a possible presence of brine under the repository, EEG modeled the case of a man-made future drilling intrusion 125 years hence. The results of EEG's two analyses (Channell, 1982; Bard, 1982) produce a maximum radiation dose to the bone of a nearby resident of 3.4 rem, less than the 5 rem permitted for a low probability accident. The man-made intrusion has been assumed to be a limiting case since a plausible scenario in which natural causes will allow brine to be brought to the biosphere more rapidly has not been identified. A recent EEG consultant's report (Logan, 1983) concludes that an unexpected communication between the brine reservoir in the Castile and the repository level, during excavation, will have serious consequences. DOE takes precautions for such a possibility although the chances of this occurrence are remote. To provide additional assurance and knowledge, EEG recommends further evaluation and field testing of geophysical methods such as CSAMT to identify possible occurrence of brine under the repository level.

Regional Hydrology

- The only perennial surface water in the vicinity of the WIPP is located at least 10 miles from the center of the site. The surface water bodies are discharge points for local groundwaters beneath the site. There is no direct threat to the repository from these surface water bodies.

- The groundwater in the Bell Canyon aquifer does not appear to pose a significant threat to the repository based on previous EEG scenario consequence calculations. Some recent data indicates that some parameters in the previous calculations were not conservative. Evaluation of the previous calculations is under way, but the results are not expected to yield significantly different consequences than the previous calculations.

- The Castile formation contains pressurized brines near the WIPP site. These brines are discussed in detail in the section on Brine Reservoirs.

- The Capitan Reef Aquifer is at its nearest point about 10 miles from the site. Since the basinward dissolution from the north has not progressed towards the site, the Capitan Reef Aquifer does not pose a threat to the repository.

- The characteristics of the Rustler aquifers are discussed in a separate section.

Disturbed Zone

The Disturbed Zone was initially defined (e.g. in Powers, et al., 1978) as the area where seismic reflection signals were uninterpretable. The cause for this was later determined to be the structural complexity within the Castile formation (Borns et al., 1983). Since the Castile formation shows extensive thinning and thickening of the salt layers, even within the WIPP site boundary, a conservative approach would be to assume that the so-called "Disturbed Zone" extends underneath the WIPP site.

The gravity foundering hypothesis provides a reasonable explanation for the deformation present in the Castile formation in the northern Delaware Basin. By using this hypothesis, DOE has calculated that if the deformation is progressing towards the WIPP repository area, it would take 4.6 m.y. for the deformation front to reach the area directly under the WIPP repository. EEG's calculations show that this may happen in 125,000 to 375,000 years. The progression of a structure such as that located at WIPP-12, however, requires conditions which facilitate the gravity foundering mechanism and these conditions (e.g., more trapped fluid in rock, low yield strength, etc.) may not exist under the southern part of Zone II of the WIPP site. The borehole DOE-1 drilled just outside the Zone II, to the southeast, certainly does not exhibit the Castile deformation structures except some minor lateral flow textures in the Castile halites. Further, with the reorientation of the WIPP repository to the south within Zone II, EEG concludes that the new location of the WIPP repository is in a relatively undeformed area.

Hydrologic Transport Characteristics of the Rustler Aquifers

There are three discreet zones in the Rustler formation through which the water moves. The quality and flow characteristics of these aquifers vary significantly but at the WIPP site, the waters are of poor quality and the flow rates are low. These aquifers are (a) the Rustler-Salado Interface Residuum (b) the Culebra dolomite, and (c) the Magenta dolomite. The water exists primarily in interconnected fractures in all three zones. In addition, there is some evidence that a very small quantity of water may exist in zones other than these three distinct aquifers. There is a possibility that features of karst hydrology may exist in the Rustler formation. However, all the information available at this time suggest that, if present, the karst solution channels would be very small in aperture.

The aquifers at the Rustler-Salado interface and the Magenta appear to carry a very limited volume of water at a very low velocity. The Culebra is the primary aquifer at the site and in case of a breach of the WIPP repository, it would be the most rapid pathway for radionuclides to reach the accessible environment. At the present time, the Culebra aquifer is not sufficiently characterized to model the hydrologic transport through it with confidence. Additional study of the Culebra aquifer is therefore recommended by EEG. These recommendations are outlined in the section of this title as well as at the end of this chapter.

Natural Resources

Extensive potash (sylvite, KCl and langbeinite $K_2Mg_2(SO_4)_3$) mining has occurred several miles to the north (in the McNutt Potash Zone) at a horizon 500 feet above the repository horizon. There are 38 million tons of sylvite and 122 million tons of langbeinite of varying economic grades in Zones I, II and III and DOE has banned any potash mining in these zones during the next 25 years - the operational lifetime of the repository. Seven percent of the known langbeinite resources in the U. S. are in these zones. To minimize possible future risk to the repository, we believe that mining of these potassium salts should be banned indefinitely.

If hydrocarbon resources exist at depths greater than 10,000' below the site, it is not clear their extraction is economically feasible via off-set slant drilling outside Zone III. The removal of natural gas does not present any radiological problems.

The presence of such resources appears to violate the provisions of the EPA proposed standard 40 CFR 191, Section 191.14(f).

SPDV Results

DOE has provided two reports entitled "Results of SPDV Site Validation Experiments" and "Results of SPDV Design Validation Experiments." Concerning site validation experiments, EEG concludes that the detailed mapping at the repository horizons and a limited number of rock mechanics experiments conducted to date in the drifts and the shafts, show no adverse conditions at the proposed repository level. However, in order to satisfy Section 13.2 of the DOE's Site Criteria and Qualification Factors, EEG recommends further stud on a bed (MB 139) underlying the repository level.

With respect to the design validation experiments, EEG concludes that several years of data gathering will be necessary to predict the closure and stability of the facility over its project lifetime of 25 years. EEG has not identified any additional experiments for design validation that should be conducted prio to the decision to construct.

RECOMMENDATIONS

The following is a list of certain investigations currently in progress or planned by DOE and additional work which EEG recommends that the State should demand if the construction is allowed to proceed.

Continuing or Planned DOE Studies

1. Evaluate and field test non-invasive geophysical methods to identify possible occurrence of brine under the repository.

2. Analyze the drawdown data in test holes H-1, H-2 and H-3 caused by the excavation of WIPP shafts.

3. Publish the results of solute transport modeling in the Rustler aquifers.

4. Analyze the Rustler aquifer waters for environmental isotopes (Carbon-14, Chlorine-36, Uranium-234, Uranium-238) to aid in understanding the groundwater flow direction and relative velocity.

5. Drill the planned additional wells for hydrologic testing, viz. H-11 and H-12. Obtain the cores while drilling these wells to determine the extent of fracturing and solution residues throughout the Rustler formation.

6. Conduct a water balance study for the WIPP site.

7. Study the mechanics of removal of salt from the Rustler formation at and near the site.

8. Drill a shallow auger-hole in the depression in the SW corner of Sec. 30, T225, R 31E in Zone III to address the suspicion of this depression being a doline.

9. Further study marker bed 139 (MB139) underlying the repository horizon to determine its origin and its effect on the repository and to confirm that it does not violate Section 13.2 of the DOE's site criteria and qualification factors.

Studies Recommended by EEG

1. Investigate the depression of the marker beds in the lower part of the Salado formation, centered two miles north of the WIPP shafts.

2. Perform computer modeling of groundwater flow in the Rustler aquifers.

3. Conduct the following hydrology tests:
   a) A long duration pumping test at the well H-3.
   b) Measure the anisotropy of the hydraulic conductivity at test pads H-1, H-2 and H-3.
   c) Perform convergence tracer tests at wells H-1, H-3 and H-4.
   d) Perform convergence tracer tests at well H-6 using sorbing tracers.

APPENDIX

SUMMARY OF EEG INVOLVEMENT WITH SITE SUITABILITY DETERMINATION FOR WIPP

SUMMARY OF EEG INVOLVEMENT WITH SITE SUITABILITY DETERMINATION FOR WIPP

APPENDIX

1.0 Review of GCR and DEIS (1979)

After an exhaustive review of available criteria for site characterization and selection (EEG-1), one of the first documents that the Environmental Evaluation Group reviewed upon its formation in 1978 was the Geological Characterization Report (GCR) by Powers, et al (1978). EEG's comments on this detailed compilation of up-to-date knowledge on the geologic and hydrologic characteristics were published in a report (EEG-2), which was included as Appendix III in EEG-3. The principal concerns expressed in that review were as follows:

What is the origin, evolution and occurrence of the high-pressure brine-reservoirs which were encountered in the upper part of the Castile formation in ERDA No. 6 and in at least 6 wells within 9 miles of the site?

What is the origin, evolution and occurrence of the "breccia pipes" which have been encountered in the area? They may be localized deep dissolution features which originate in the lower portion of the evaporites and migrate upward. Such localized dissolution features could now exist or develop later beneath the proposed site.

What are the processes and rates of deep dissolution of salt near the site? There may be a preferential removal of the salt horizon which is proposed for the repository.

What are the regional and site hydrologic conditions for the aquifers above and below the evaporites? The hydrologic information is necessary to assess any possible long-term release of radioactive material from the repository.

The Draft Environmental Impact Statement (DEIS) on WIPP was issued in April, 1979. This document contained very little additional information in the areas of geology and hydrology. In its review of the DEIS, EEG repeated the concerns expressed in EEG-2 and made additional recommendations as follows in EEG-3:

- The values of hydrologic parameters for WIPP site aquifers vary over a wide range. This data base should be improved and the subsurface hydrology should be better understood.

- The effect of impurities in salt at the proposed repository horizon should be taken into account in evaluating the physical, hydrological, thermal and strength characteristics of rock salt from the repository horizons.

- More information is needed on the regional hydrology of the WIPP site. Items such as surface runoff, existing and planned water resource development in the area, water use downstream of Malaga Bend and the present and potential well water use from aquifers in the area, need to be better understood.

- The long range modeling for potential breach of the site should take into account plausible future climatic changes in the hydrologic regime.

The correspondence between DOE and EEG following these comments reflects a consideration of most of these concerns and recommendations by DOE. In general, DOE conveyed to EEG that the continuing studies for site characterization would answer most of these concerns.

2.0 Geotechnical Meeting - January, 1980

EEG organized a two-day meeting of experts representing a wide spectrum of earth sciences, on January 17 and 18, 1980, to address the geotechnical questions concerning the WIPP site. The meeting, titled "Geotechnical Considerations for Radiological Hazard Assessment of WIPP", was attended by 66 persons, 35 of whom were geological scientists. The participants included members of State and Federal agencies, the National Academy of Sciences WIPP panel, the Governor's Advisory Committee on WIPP, several universities in the State, the mining industry and the state and national environmental groups.

The report of this meeting (EEG-6), published in April, 1980, contained the following recommendations in various geotechnical areas:

2.1 Geohydrology

- Better define the regional geohydrology through more field tests.
- Provide a clearer definition of recharge areas for the Rustler and DMG aquifers.
- Further refine Hiss' map of potentiometric surfaces in the Bell Canyon aquifer and its connection with the Capitan and/or San Andres aquifers.
- Evaluate the hydrologic transit times from the WIPP site to man from existing or potential water well development in all aquifers near the site.

2.2 Deep Dissolution

- Provide the arguments against active deep dissolution in a reviewable scientific paper format.
- Thoroughly investigate several anomalous features near the WIPP site, which have been pointed out by proponents of the deep dissolution idea. The results of such investigation should be presented to the scientific community in a reviewable paper.
- Assess potential consequences of deep dissolution and make the calculations available.

2.3 Brine Reservoirs

At the time of the meeting in early January, 1980, EEG was performing the hazard analyses described below and recommended that DOE do the same. EEG further recommended that DOE provide detailed documentation.

2.3.1 Salado Brine: The likelihood and potential extent of water movement into a waste-filled portion of the repository, both during and after the operating lifetime of the repository should be evaluated. If it is determined that a sealed repository might contain large amounts of brine, then hydrologic breach and drilling scenarios should be evaluated under the assumption that some waste is mixed or dissolved in brine at the time of the breach. In the hydrologic breach scenarios, the waste/salt dissolution rate is an important determinant of nuclide concentrations in the Rustler aquifer and in the Pecos River. The assumption that a portion of the waste is already in solution at the time of the breach might alter the scenario consequences significantly.

2.3.2 Castile Brine: Possible consequences of a connection between a brine reservoir, the repository, and the surface should be assessed and the plausibility of different sequences of events which might lead to such a connection should be evaluated. Consequences of a connection between a brine reservoir and the repository extending only as far as the Rustler aquifers are discussed in a draft of the final WIPP Environmental Impact Statement. At the time, EEG was reviewing this analysis.

2.4 Human Intrusion

- The DOE should publish detailed plans and restrictions on drilling for hydrocarbon resources at the site. The description should include:

  a) plans for regulating drilling and production outside of Zone IV;
  b) permissible drilling and production practices in and under Zone IV.
  c) whether secondary and tertiary recovery methods are being considered for Zone IV;
  d) possible use of slant drilling to recover natural gas or oil from beneath Zones I, II and III;
  e) the length of time over which drilling controls would be imposed.

The DOE should publish detailed plans and restrictions on mining of potash at the site. This description should include:

a) whether solution mining would ever be permitted;
b) whether any recovery inside of Zone IV would be permitted;
c) whether shafts will be sealed when potash mines are decommissioned;
d) the length of time over which mining controls would be imposed;
e) whether any controls are to be imposed on mining outside of Zone IV.

- Scenarios need to be evaluated for the following situations:

a) a repository breach involving an abandoned potash mine in Zone IV, either as a source of water into the repository or as a pathway for migration away from it;
b) drilling into a repository containing highly pressurized gas that has developed from decomposition of organic material in the wastes;
c) an exploratory well striking a brine pocket below the repository. The brine ascends to the surface (being under pressure) and brings contaminants with it.
d) appropriate breach scenarios for any additional exploration or mining activity that may be proposed (e.g., solution mining, secondary and tertiary air recovery methods, and exploitation of Zones I, II and III).

2.5 Additional Scenarios

The following scenarios had been proposed by EEG, its consultants, or other groups commenting on the WIPP DEIS. EEG suggested that DOE analyze the hydrologic or geologic events described in these scenarios, determine their plausibility, and whether other events should be considered in designing meaningful radiological hazard scenarios.

2.5.1 <u>Event</u>: Breaching of the excavation workings by pressurized brine after installation of substantial quantities of waste.

Note: This scenario is a variation on DEIS scenario 1, where water flows vertically from the Delaware Mountain Group to the Rustler horizon before moving laterally to Malaga Bend.

2.5.4 Event: Communication between the repository, a source of water, and reserves of potash, oil or natural gas.

Causes:
a) Communications between aquifers and repository, as in items 2, 3.
b) Communication between brine reservoir and repository, as in item 1.
c) Solution mining for potash after site control is lost.
d) Injection of water for secondary oil recovery.

Result: Dissolution of a fraction of the waste and contamination of retrievable resources.

3.0 Geological Field Trip, June, 1980

A consensus which emerged from the geotechnical meeting of January, 1980 was that a geological field trip to the site and vicinity would further clarify the different views on the geological processes active at the site. A three-day field conference to the site was organized by EEG on June 16 to 18, 1980 for this purpose. Twenty-three participants in this field conference included seventeen geoscientists from State and Federal agencies, universities and the private sector. There were extensive discussions on many aspects of the geology of the site at each field stop. In addition, there was a 1-2 hour post-field trip meeting each day and a 1/2 day discussion session on the third day. Participants were also requested to send written comments on the geological issues debated during this field conference.

Based on the discussions and the written comments, EEG formulated and submitted to DOE the following recommendations for further work by DOE (EEG-7, pp. 105-106):

3.1 Review Papers. Prepare detailed review papers on the following topics:

a) Deep dissolution - Specifically addressing Roger Anderson's hypothesis about extensive deep dissolution in the lower part of the Ochoan evaporite deposits in the Delaware Basin.

b) Structural anomalies at and near the WIPP site - This should include the anomalies interpreted from geophysical data and from drill cores. The discussion should include the details of geological interpretation of the anomalies and the work being planned or conducted to resolve the seismic data discrepancies, as stated in the Safety Analysis Report, pp. 1.7-65 and 1.7-66.

c) Occurrence of brine reservoirs/pockets in the evaporite beds of Delaware Basin - This should include available information on location, quantity, pressures, quality, ideas on origin, methods of handling it in mines, etc.

d) Details of DOE plans to allow recovery of potash and hydrocarbon resources without disturbing the sealed repository.

e) Basic data and interpretations of boreholes WIPP-31 and WIPP-16 - drilled at hills A and C respectively to obtain more information on the origin of these breccia pipes.

3.2 Exploratory Program. DOE should perform and submit detailed reports on the following explorations:

a) Run a seismic reflection profile across the San Simon Swale to pass over WIPP-15 (sink) from the Antelope Ridge to San Simon Ridge. This should answer the question regarding the postulated fault between the sink and the ridge.

b) Drill 4 or 5 shallow holes across Bell Lake Sink or Slick Sink to reach the Red Soil horizon and drill one deep exploratory hole to the evaporites, if Red Soil is not missing. Even though it is far from the WIPP site, this testing program will answer an important question about the presence of deep dissolution in the Basin itself.

c) Drill one core-hole to the lower Castile in Section 9, northern part of the WIPP site.

d) Reopen one of the brine reservoir wells: AEC-7, Pogo or ERDA-6; allow it to flow for 10 days; measure the depletion of pressure and levels in all three and test the brine at regular intervals.

4.0 Scenario Modeling by EEG

In 1979, EEG published a "Simple Model for Estimating Maximum Radionuclide Concentrations in the Pecos River, and Associated Ingestion Doses, due to the Release of Radioactivity from the WIPP Repository" by Moses A. Greenfield in EEG-2. The results generally agreed within a factor of 2 with the calculated doses shown in the DEIS.

During the latter part of 1980 and the first part of 1981, EEG published two reports (EEG-8 & 9) on a sensitivity analysis and a well scenario and their impact on the hazard assessment for WIPP. This effort of radiological hazard assessments is continuing with the publication of 9 more reports (EEG-11, 12, 13, 15, 17, 18, 19, 20 and 21) to date.

5.0 Stipulated Agreement

As a result of a Stipulated Agreement between DOE and the State signed in July 1981 after the State filed a lawsuit against DOE, the DOE agreed to produce a number of reports addressing specific geologic issues and also agreed to perform additional experiments and field work at the site. The list of these reports and experiments is contained in Appendices B and C of the Stipulated Agreement. These appendices are reproduced below.

5.1 "Appendix B: Comprehensive Topical Reports to be Made Available to Environmental Evaluation Group Before the Decision to Construct the Permanent Repository

1. Deep Dissolution: Including all available pertinent up-to-date data and arguments for and against the hypothesis of deep dissolution in the Delaware Basin and its potential effect on WIPP.

2. Disturbed Zone: Including all available pertinent up-to-date data and analyses of the nature, extent and potential significance to the repository.

Breccia Pipes: Including all available pertinent up-to-date data and analyses concerning the existence of breccia pipes in the basin and the reef, potential for future breccia pipe development, and their significance to WIPP.

4. DMG Hydrology: Including all available pertinent up-to-date data and analyses of the hydrologic characteristic, geochemistry, potential and rates for salt removal, and directions of flow and possible communication with other aquifers e.g., reef aquifer, San Andres Limestone aquifer and shallow aquifers.

5. Regional Hydrology: Including all available pertinent up-to-date data and analyses of the recharge and discharge area, flow times and interconnections of aquifers near the site.

6. Natural Resources: Including detailed plans to control recovery of potash and hydrocarbons without disturbing the repository, and the evaluation of potential consequences of these plans.

7. Results of SPDV Site Validation Experiments: Including all pertinent results and analyses of experiments as listed in WIPP-TME-2975, pp. 15-16.

8. Plans for SPDV Design Validation: Updated, detailed plans and rationale for the proposed design validation experiments as outlined in TME-3058 and TME-3063.

9. Results of SPDV Design Validation Experiments: Including all pertinent results and analyses of experiments as agreed by DOE and EEG. (Further results to be later provided per *note below.

10. Plans for Stimulated Wastes Experiments: Updated, detailed plans and rationale for the proposed experiments.

11. Results of Simulated Waste Experiments: Including all pertinent results and analyses of experiments as agreed by DOE and EEG.*

5.2 Appendix C: Additional Investigations, the Results of Which to be Made Available to Environmental Evaluation Group Before the Decision to construct the Permanent Repository.

1. Test Brine Reservoir in Deformation Zone: Reopen ERDA-6 and allow it to flow for at least 10 days to measure the depletion of pressure at regular intervals in this well, and if access can be obtained, in Pogo #1 federal well. Perform other necessasry tests to determine the size, age, origin, and possfible association with aquifers or other brine pockets.

2. Report on Brine Reservoirs: Provide a comprehensive topical report on available information concerning brine reservoirs in evaporite beds found in the Delawre Basin including the results of tests on ERDA-6. This should include available information on the location, sizes, quantity, pressures, quality, ideas on origin and methods of handling in mines.

3. Horizontal Exploration of the Disturbed Zone: At the earliest possible stage of facility construction and before emplacement of any waste at the WIPP repository, provide for an additional 3000 feet of drift north of presently planned station #2, which is approximately 2500 feet North of ERDA #9, and drill 3000 feet horizontal cores to the north from this new location.

4. Fracture Flow in Rustler Aquifers: Evaluate the extent of fracture flow in the Rustler aquifers and provide a report on the effect of fracture flow on the resultant release pathways considered in the FEIS.

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*Note: To be completed prior to the 45 day review period and prior to the decision to proceed as set forth in Paragraph 5 of the Order.

5. Study of Aquifer Characteristics: Using in-situ methods, assess quantitatively and qualitiatively the lithology, porosity, permeability, bulk density and distribution coefficients of the Rustler aquifers."

6.0 Costs and Merits Evaluation for Stipulated Agreement Activities

As required in the Stipulated Agreement, the DOE provided a document titled, "Report Assessing the Merits and Costs of Experiments and Studies Set Forth in Appendix B and Appendix C of the Stipulated Agreement Between the State of New Mexico and the U. S. Department of Energy and Others," August 31, 1981. This report provided a detailed review of the items to be covered in the reports and experiments to be conducted by DOE. There was further correspondence between the State and the DOE to clarify some of these items.

After a careful study of all the reports received under the Stipulated Agreement, the EEG finds that the following items which are contained in the "Costs and Merits Evaluation" or in subsequent clarifying letters, are not contained in the reports and have not been transmitted separately.

6.1 Fracture Flow in the Rustler Formation

The proposed work for this report is contained on p. 37 of the "Costs and Merits" report. The following items have not been completed do date.

- Tracer tests in Well number H-5 has not been conducted. The H-4 test is in process, but no useful data has been generated to date.
- A model to represent the flow path and aquifer characteristics in the Rustler has not been released.

It is recommended that this work be completed.

6.2 Study of Aquifer Characteristics

The proposed work under this item is outlined on p. 39 of the "Costs and Merits" report. The following proposed work has not been completed.

- The water inflow tests in the shafts were not conducted for each aquifer. The total inflow down the shaft was measured but not very accurately. EEG concurs with the evaluation by D'Appolonia Consulting Engineers that it is extremely difficult to do this work.

6.3 Marker Bed 124 Depression at the Northern Edge of Zone III

In a letter (Goldstein toSchueler, 10/5/81) following the submission of the "Costs and Merits" proposal, the State suggested that the DOE should reexamine all available data on the MB 124 depression centered at well # F-92 and should determine if the evidence warrants a new borehole at that location. DOE agreed to evaluate this feature in the Disturbed Zone report. However, this report (SAND 82-1069) does not contain such an evaluation. It is recommended that this work be done.

7.0 Review of Stipulated Agreement Reports

During the period from November 1981 to April 1983, EEG received the Appendix B Stipulated Agreement reports as well as the certified data from the Appendix C experiments from DOE. Generally, the reports were first sent to EEG in draft forms, upon which EEG made detailed comments to DOE. Meetings of EEG and DOE technical personnel were then held to resolve any differences concerning the content and scope of the reports. The DOE subsequently issued each report with modifications that they deemed fit to make. EEG-22 contains the EEG comments and DOE replies for all the reports which had been received by EEG through March 1, 1983.