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Environmental Assessment

Deaf Smith County Site, Texas

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FOREWORD

The Nuclear Waste Policy Act of 1982 (the Act) established a process for the selection of sites for the disposal of spent nuclear fuel and high-level radioactive waste in geologic repositories. The first steps in this process were the identification of potentially acceptable sites and the development of general guidelines for siting repositories. In February 1983, the DOE identified nine sites in six States as potentially acceptable for the first repository. The Deaf Smith County site in Deaf Smith County, Texas, was identified as one of those sites. The general guidelines were issued in November 1984 as Title 10 of the Code of Federal Regulations, Part 960. The DOE is now proceeding with the next step in the site-selection process for the first repository: the nomination of at least five of the nine potentially acceptable sites as suitable for site characterization, which is a program of detailed studies.

The Act requires that site nomination be accompanied by an environmental assessment (EA). The DOE has prepared EAs for the nominated sites through a process that provided opportunity for public input. Public hearings were held during March, April, and May 1983 to obtain recommendations on the issues to be addressed in an EA. All such recommendations were considered in preparing the EAs. The DOE issued draft EAs for public review and comment in December 1984 and conducted a series of public hearings in February and March 1985. The issues raised in the comment letters and hearings were considered in preparing the final EAs. These issues are addressed in a comment-response document appended to the final EAs (Appendix C).

The information presented in the EAs is derived from hundreds of technical reports containing more-detailed data and analyses. All of these reference documents are available to the public in various libraries and reading rooms; a listing of their locations is given in Appendix B.

After the nomination, the Secretary is required by the Act to recommend to the President not fewer than three of the nominated sites for characterization as candidate sites for the first repository. This recommendation will be submitted and documented in a separate report that is being issued separately from this environmental assessment. After submittal, the Act provides the President 60 days to approve or disapprove the candidate sites. The President may delay his decision for up to six months if he determines that the information supplied with the recommendation of the Secretary is insufficient to permit a decision within the 60-day period. If the President does not approve, disapprove, or delay the decision, the candidate sites shall be considered approved. After the President approves the candidate sites, the DOE will start site characterization.

ABSTRACT

In February 1983, the U.S. Department of Energy (DOE) identified a location in Deaf Smith County, Texas, as one of nine potentially acceptable sites for a mined geologic repository for spent nuclear fuel and high-level radioactive waste. The potentially acceptable site was subsequently narrowed to an area of 9 square miles. To determine their suitability, the Deaf Smith County site and the eight other potentially acceptable sites have been evaluated in accordance with the DOE's General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories. These evaluations were reported in draft environmental assessments (EAs), which were issued for public review and comment. After considering the comments received on the draft EAs, the DOE prepared the final EAs.

The Deaf Smith County site is in the Permian Basin, which is one of five distinct geohydrologic settings considered for the first repository. This setting contains one other potentially acceptable site--the Swisher County site. Although the Swisher County site is suitable for site characterization, the DOE has concluded that the Deaf Smith County site is the preferred site in the Permian Basin. On the basis of the evaluations reported in this EA, the DOE has found that the Deaf Smith County site is not disqualified under the guidelines.

Furthermore, the DOE has found that the site is suitable for site characterization because the evidence does not support a conclusion that the site will not be able to meet each of the qualifying conditions specified in the guidelines. On the basis of these findings, the DOE is nominating the Deaf Smith County site as one of five sites suitable for characterization.

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EXECUTIVE SUMMARY

1. INTRODUCTION

By the end of this century, the United States plans to begin operating the first geologic repository for the permanent disposal of commercial spent nuclear fuel and high-level radioactive waste. Public Law 97-425, the Nuclear Waste Policy Act of 1982 (the Act), specifies the process for selecting a repository site, and constructing, operating, closing, and decommissioning the repository. Congress approved geologic disposal by declaring that one of the key purposes of the Act is "to establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository" [Section 111(b)(1)].

A geologic repository can be viewed as a large underground mine with a complex of tunnels occupying roughly 2,000 acres at a depth between 1,000 and 4,000 feet. To handle the waste received for disposal, surface facilities will be developed which will occupy about 400 acres. The repository will be operational for about 25 to 30 years. After the repository is closed and sealed, waste isolation will be achieved by a system of multiple barriers, both natural and engineered, that will act together to contain and isolate the waste as required by regulations. The natural barriers include the geologic, hydrologic, and geochemical environment of the site. The engineered barriers consist of the waste package and the underground facility. The waste package includes the waste form, the waste disposal container, and materials placed over and around the containers. The underground facility consists of underground openings and backfill materials, not associated with the waste package, that are used to further limit ground-water circulation around the waste packages and to impede the subsequent transport of radionuclides into the environment.

In February 1983, the DOE carried out the first requirement of the Act by formally identifying nine sites in the following locations as potentially acceptable sites for the first repository (the host rock of each site is noted in parentheses):

1. Vacherie dome, Louisiana (domal salt)
2. Cypress Creek dome, Mississippi (domal salt)
3. Richton dome, Mississippi (domal salt)
4. Yucca Mountain, Nevada (welded tuff)
5. Deaf Smith County, Texas (bedded salt)
6. Swisher County, Texas (bedded salt)
7. Davis Canyon, Utah (bedded salt)
8. Lavender Canyon, Utah (bedded salt)
9. Reference repository location, Hanford Site, Washington (basalt flows).

The locations of these sites are shown in Figure 1.

Figure 1. Potentially acceptable sites for the first repository.

After identifying these potentially acceptable sites, the DOE published draft General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (the guidelines) in accordance with the Act. The draft guidelines were revised in response to extensive comments and received the concurrence of the Nuclear Regulatory Commission (NRC) in June 1984. Final guidelines were published in December 1984 as 10 CFR Part 960.

The Act requires the DOE to nominate at least five sites as suitable for site characterization--a formal information-gathering process that will include the sinking of one or more shafts at the site and a series of experiments and studies underground. The DOE must then recommend not fewer than three of those sites for characterization as candidate sites for the first repository. After site characterization is completed, one of the characterized sites will be recommended for development as a repository.

The Act also requires the DOE to prepare environmental assessments (EAs) to serve as the basis for site-nomination decisions. These EAs contain the following information and evaluations consistent with the requirements of Section 112 of the Act:

- A description of the decision process by which the site is being considered for nomination (EA chapters 1 and 2).
- A description of the site and its surroundings (EA Chapter 3).
- An evaluation of the effects of site characterization activities on public health and safety and the environment and a discussion of alternative activities that may be taken to avoid such effects (EA Chapter 4).
- An assessment of the regional and local effects of locating the proposed repository at the site (EA Chapter 5).
- An evaluation as to whether the site is suitable for site characterization (EA Chapter 6).
- An evaluation as to whether the site is suitable for development as a repository (EA Chapter 6).
- A reasonable comparative evaluation of the site with other sites that have been considered (EA Chapter 7).

This executive summary highlights the important information and evaluations found in the accompanying EA. Section 2 of this executive summary presents a summary of the decision process and findings leading to the nomination of the Deaf Smith County site. Sections 3 through 7 summarize the results of the evaluations contained in corresponding chapters in the EA.

2. DECISION PROCESS AND PRELIMINARY CONCLUSIONS

2.1 DECISION PROCESS

The guidelines require the DOE to implement the following seven-part evaluation and decision process for nominating and recommending sites for characterization:

1. Evaluate the potentially acceptable sites against the disqualifying conditions specified in the guidelines.

2. Group all potentially acceptable sites according to their geohydrologic settings.

3. For those geohydrologic settings that contain more than one potentially acceptable site, select the preferred site on the basis of a comparative evaluation of all potentially acceptable sites in that setting.

4. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for the development of a repository under the qualifying condition of each applicable guideline.

5. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for site characterization under the qualifying condition of each applicable guideline.

6. Perform a reasonable comparative evaluation under each guideline of the sites proposed for nomination.

7. Consider an order of preference of the nominated sites as recommended sites and, on the basis of this order of preference, recommend not fewer than three sites for characterization to the President.

The DOE prepared a draft EA for each of the nine potentially acceptable sites to give all interested parties an opportunity to review the full evaluation of all sites considered. In preparing the final EAs for the five nominated sites, the DOE has considered all comments that were received.

With the issuance of the final EAs, the DOE will formally nominate five sites as suitable for characterization. The Secretary of Energy will then recommend not fewer than three of these sites to the President as candidate sites for characterization. After the President approves the Secretary's recommendation, characterization activities will begin at those sites. After characterization is completed, the DOE will again evaluate each site against the guidelines and, after completing an environmental impact statement, will recommend one site to the President for the first repository. The President may then recommend the site to Congress. At this point, the host State may issue a notice of disapproval that can be overridden only by a joint resolution of both Houses of U.S. Congress. If the notice of disapproval is not overridden, the President must submit another repository site

recommendation within 12 months. If no notice of disapproval is submitted, or if Congress overrides the notice of disapproval, then the site designation is effective, and the DOE will file an application with the NRC to obtain a construction authorization for a repository at that site.

2.2 FINDINGS AND DETERMINATIONS

Summarized below are the DOE's findings and determinations that apply to the Deaf Smith County site.

2.2.1 EVALUATION AGAINST THE DISQUALIFYING CONDITIONS

The evidence does not support the disqualification of the Deaf Smith County site under the guidelines, nor are any of the other eight potentially acceptable sites found to be disqualified.

2.2.2 GROUPING OF SITES BY GEOHYDROLOGIC SETTING

The nine potentially acceptable sites are contained within five distinct geohydrologic settings as defined by the U.S. Geological Survey. The sites are grouped by the DOE's geohydrologic designations as follows:

Geohydrologic Setting	Site
Columbia Plateau	Reference repository location, Hanford Site, Washington
Great Basin	Yucca Mountain, Nevada
Permian Basin	Deaf Smith and Swisher Counties, Texas
Paradox Basin	Lavender Canyon and Davis Canyon, Utah
Gulf Interior Region of the Gulf Coastal Plain	Vacherie Dome, Louisiana; Cypress Creek Dome and Richton Dome, Mississippi

The distinctions among the geohydrologic settings and the host rocks are clear not only among basalt, salt, and tuff, but also among the three basins in salt. The bedded salt of the Permian and Paradox Basins are distinct from the dome salt of the Gulf Interior Region in terms of their structure, rock properties, and the relationship of the host rock to the aquifers in the

geohydrologic environment; the Permian Basin is also distinct from the bedded salt in the Paradox Basin in terms of stratigraphic sequence, regional hydrologic setting, history of deposition, and physiography.

2.2.3 SELECTION OF THE PREFERRED SITE IN THE PERMIAN BASIN

On the basis of the information and evaluations contained in the EA, and on a comparison of the Deaf Smith County site with the Swisher County site, the DOE has identified the Deaf Smith County site as the preferred site because (a) a downward or predominantly horizontal gradient (geohydrology guidelines) is present, and (b) it is farther from highly populated areas than the Swisher County site. The Deaf Smith County site is approximately 27 kilometers (17 miles) from Hereford (22 kilometers [14 miles] from the smaller community of Vega), whereas the Swisher County site is 8 kilometers (5 miles) from Tulia.

The only other conditions that distinguish between the Deaf Smith County and Swisher County sites relate to the relation of the sites to regional transportation routes that connect to the national network. The Swisher County site is 10 kilometers (6 miles) and 0 kilometers (0 miles) from the closest major highway and rail line, respectively, while the Deaf Smith County site is 6 kilometers (4 miles) from the nearest major highway and 30.5 kilometers (19 miles) from the nearest rail line. In addition, for the Swisher County site, the cost of building an access railroad is $3.5 million, while for the Deaf Smith County site, the cost is $21-44 million. Because the siting guidelines specify that conditions relative to radiological safety are of primary importance, the difference in distance to transportation routes and their costs is considered to be of lesser importance than the difference in distance to population centers.

2.2.4 SUITABILITY OF THE DEAF SMITH COUNTY SITE FOR DEVELOPMENT AS A REPOSITORY

Section 112(b) of the Act requires the DOE to evaluate the suitability of a site for development as a repository under each guideline that does not require site characterization as a prerequisite for the application of the guideline. The intent is to preclude the investment of money and effort in sites that could be disqualified under those guidelines for which substantial information is available for site evaluation. The guidelines that do not require characterization primarily relate to those characteristics of a site that are related to the effects of a repository on public health and safety, the quality of the environment, and socioeconomic conditions before the repository is closed and sealed.

For a site to be suitable for repository development under each of those guidelines that do not require site characterization, no disqualifying conditions can be present, and each of the qualifying conditions under those guidelines must be met. A final determination of suitability for repository development cannot be made until site characterization is complete. However at this stage, the evidence does not support a finding that the Deaf Smith County

site is disqualified. Furthermore, the evidence does not support a finding that the Deaf Smith County site is not likely to meet all the qualifying conditions under the guidelines that do not require site characterization.

2.2.5 SUITABLILTY OF THE DEAF SMITH COUNTY SITE FOR CHARACTERIZATION

To determine whether a site is suitable for characterization, the DOE must evaluate the site against all of the guidelines, including those that require site characterization. In order to judge that a site is suitable, the DOE must then conclude that the evidence does not support a finding that the site is not likely to meet all of the guidelines. As a result of the evaluations reported in Chapter 6, the DOE has found that the Deaf Smith County site is suitable for characterization.

2.2.6 DECISION ON NOMINATION

Having made the above findings, the DOE has decided to nominate the Deaf Smith County site as suitable for site characterization. The other potentially acceptable sites selected for nomination are Davis Canyon, Utah; the reference repository location at the Hanford Site, Washington; the Richton Dome, Mississippi, and Yucca Mountain, Nevada.

3. THE SITE

As shown in Figure 2, the Deaf Smith County site is in the north-central part of Deaf Smith County, in the Southern High Plains of the Texas Panhandle. The surface of the High Plains is nearly flat, sloping gently to the southeast. The terrain in the area of the site includes small internally drained lake basins (playas) and narrow stream valleys that carry water after rainstorms.

Most of the land in the county is fertile, irrigated cropland, although there is some rangeland at the site and its vicinity.

The site covers 23 square kilometers (9 square miles), or 2,331 hectares (5,760 acres). More than 85 percent of the site area contains soils classified as prime farmland by the Soil Conservation Service. Part of this area is irrigated by pivot sprinkler systems, supplementing furrow systems which have been the most common irrigation systems in the county. Nearly all of the land at the site and in its vicinity is privately owned. A Texas farm-to-market road (FM 2587) passes through the southern part of the site and connects with U.S. Interstate I-40 via U.S. Highway 385. The closest railroad passes within 30.5 kilometers (19 miles) of the site.

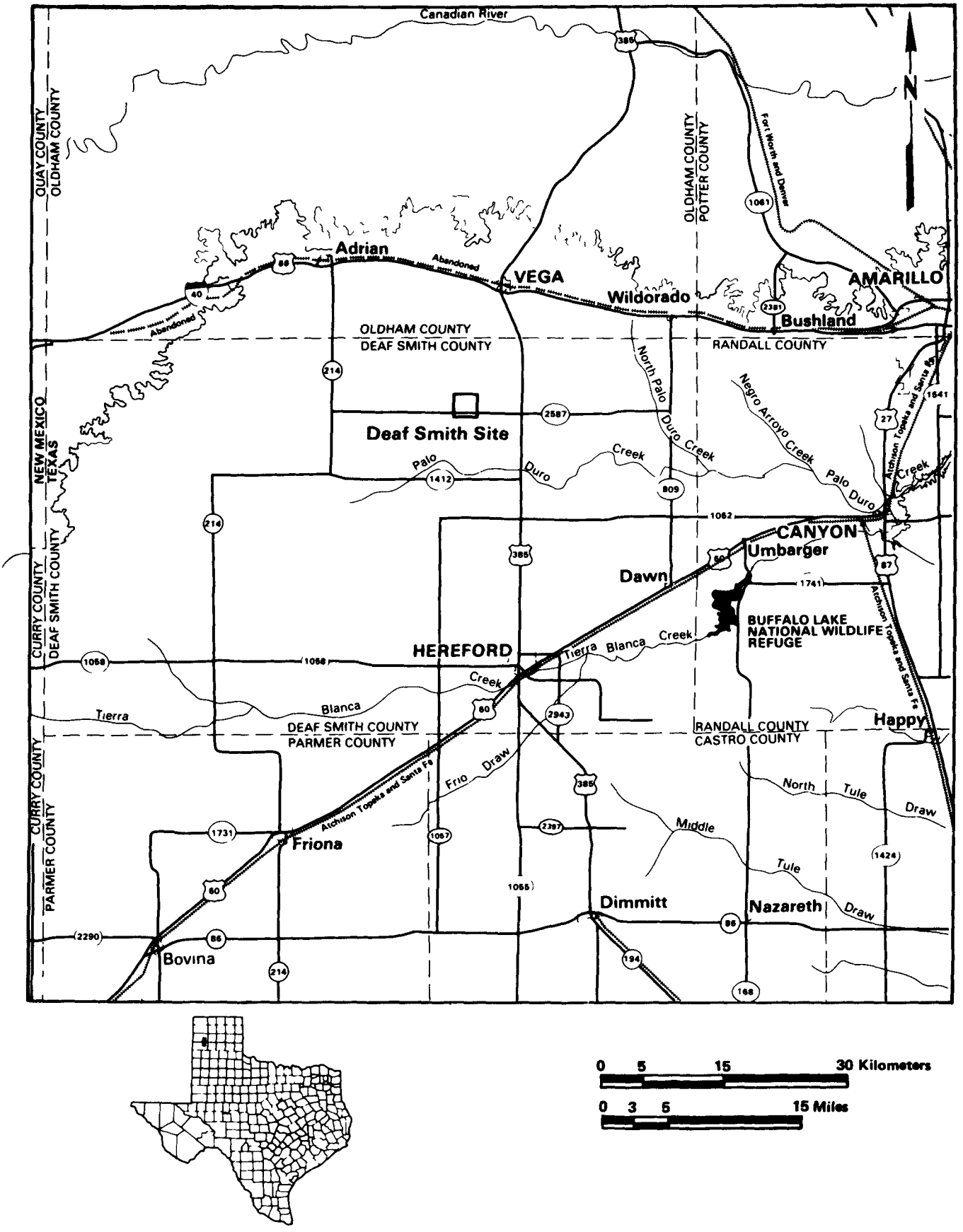


Figure 2. Deaf Smith site, Texas.

The site lies in the Palo Duro Basin, a structural basin within the larger Permian Basin. The basement rock in the Palo Duro Basin is igneous and metamorphic; it is overlain by a sequence of sedimentary rocks and evaporites, consisting mainly of sandstone, limestone, dolomite, shale, arkose, anhydrite, and salt.

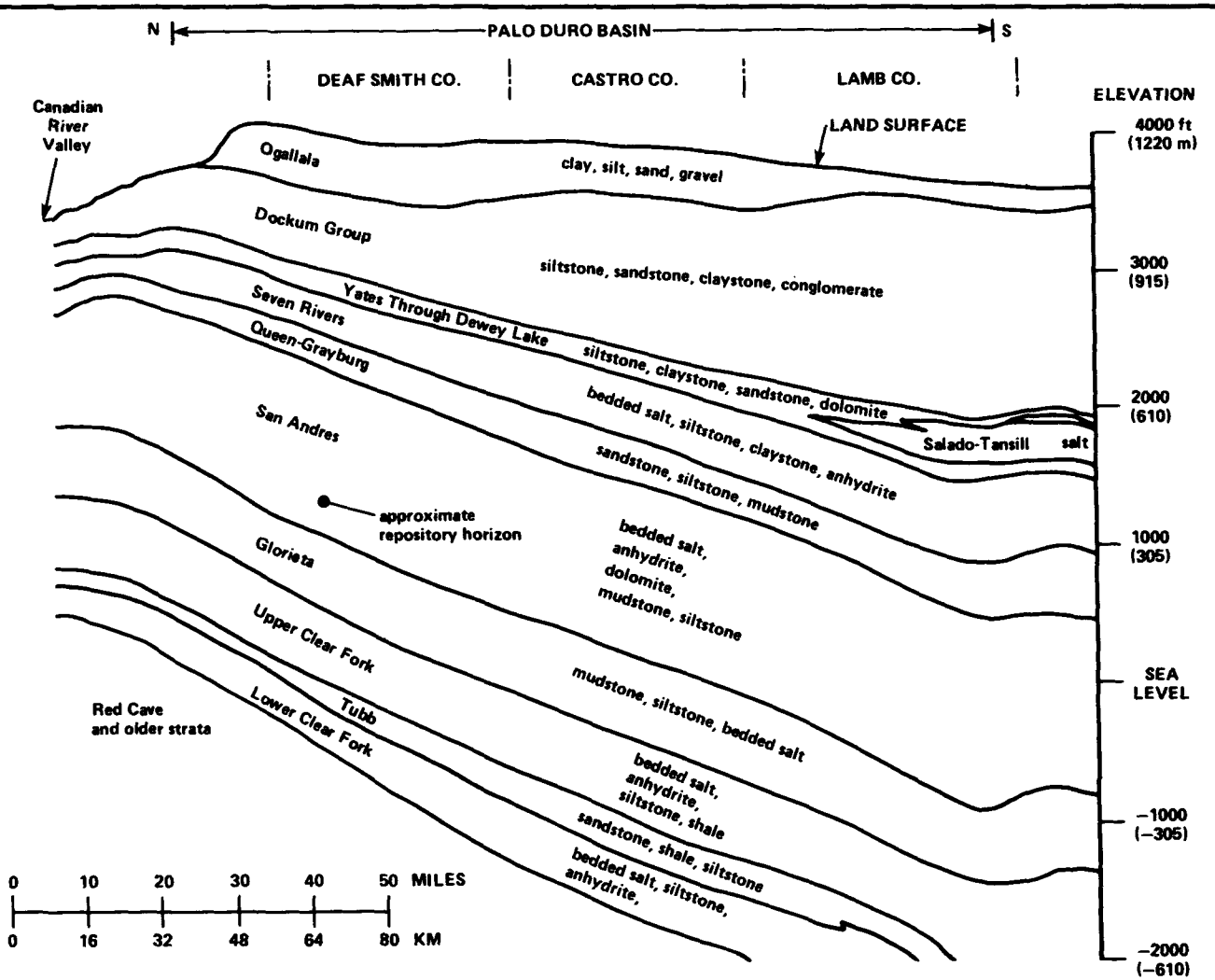
The host rock at repository depth is a sequence of bedded rock salt, about 48.8 meters (160 feet) thick, in the Lower San Andres Formation (see Figure 3). The top of the proposed repository level is about 2,400 to 2,500 feet below the surface. At the site and throughout the Palo Duro Basin, the host-rock bed does not consist of pure rock salt; it contains many impurities and interbeds.

Active fronts of salt dissolution have been identified along the western, northern, and eastern salt margins of the Palo Duro Basin. The site is about 100 kilometers (62 miles) from the eastern dissolution front of the Lower San Andres Formation, 29.8 kilometers (18.5 miles) from the northern front, and 174 kilometers (108 miles) from the western front. These fronts are advancing slowly toward the center of the basin, but, because the rate of their advance is low, no dissolution front is expected to reach a repository at the Deaf Smith County site for considerably longer than 10,000 years, which is the time required for waste isolation. There are no confirmed areas beneath the Southern High Plains where the uppermost salt has undergone interior dissolution during the past several hundred thousand years. While fractures have been identified in rock strata near the site, horizontal stresses at repository depth would make it unlikely that fractures would remain open.

In comparison with other regions of the United States, the Palo Duro Basin is stable tectonically. No active surface faults have been identified in the immediate vicinity of the Deaf Smith County site, but undetected faults may exist in the area. A fault striking northwest beneath the site has been inferred from oil exploration. The historical record, which covers less than 100 years, includes no reports of earthquakes closer than 48 kilometers (30 miles) from the site. However, a small earthquake was detected in April, 1985, in Oldham County approximately 24 kilometers (15 miles) northwest of the site, by a DOE microseismic network.

Economically important oil and gas resources are found in parts of the Palo Duro Basin, but neither oil nor gas is currently produced in Deaf Smith County. Oil and gas resources are not expected to be present in the immediate vicinity of the site, because the geologic conditions are not favorable for the accumulation of these resources. A variety of mineral resources are extracted from the Palo Duro Basin, but they are of marginal and mostly local value. Current and projected market conditions suggest that Deaf Smith County has little potential for the development of mineral resources in the future.

The Deaf Smith County site is nearly flat. There are no stream channels at the site, although there are playa wetlands. There are no water impoundments near the site except for small farm ponds. The Palo Duro Creek flows 3 to 5 kilometers (2 to 3 miles) south of the site, and there are two other creeks in the area: the North Palo Duro Creek to the east and an unnamed tributary of the North Palo Duro Creek to the north.



Geologic Cross Section of Deaf Smith Site Area

Figure 3

The ground-water regime beneath the Southern High Plains consists of three major hydrogeologic units. The uppermost unit is an unconfined aquifer that consists of the Ogallala Formation and the Dockum Group; it is often called "the High Plains aquifer." The middle unit is an aquitard consisting of some 1,524 to 1,828 meters (5,000 to 6,000 feet) of shales and evaporites that lie below the High Plains aquifer. The repository horizon is near the middle of this aquitard. The lower hydrogeologic unit, which lies below the aquitard, is a brine aquifer that consists of much older carbonate and clastic rocks. The High Plains aquifer is recharged to the west, in New Mexico. The most significant discharge of this aquifer occurs through pumping. The deep brine aquifer is believed to be recharged by lateral ground-water infiltration, possibly from units outcropping in New Mexico. No surface discharge from this aquifer has been identified.

The High Plains aquifer is the principal source of fresh water in the Southern High Plains. In 1980, 1.53 million acre-feet of ground water was used in the seven-county area surrounding and including the Deaf Smith County site. Most of this water was used for irrigation. Present and past pumping rates have exceeded the natural recharge rate, causing substantial declines in the water level and the removal of large volumes of water from the aquifer.

The natural plant cover in the region is a shortgrass prairie, but more than 85 percent of the area around the site is used as cropland, varying with the season. The long history of farming and grazing in the vicinity of the site has probably eliminated all traces of the prairie conditions that prevailed before the region was settled. Playa wetlands are ecologically important in the region, although many are plowed during dry years or modified for irrigation. The following eight animal species whose potential range may include the Deaf Smith County site are considered threatened or endangered by the Federal Government or the State of Texas: the Texas horned lizard, the Central Plains milk snake, the southern bald eagle, the American peregrine falcon, the arctic peregrine, the protected osprey, the woodstork, and the black-footed ferret. However, the site and its vicinity are not known to contain any critical or unique habitats. Because of the lack of preferred habitats, the variety and abundance of wildlife are expected to be low in the vicinity of the site.

The area that contains the Deaf Smith County site has a semiarid climate, which is characterized by sparse natural vegetation, warm temperatures, and periods of little precipitation. As measured in Amarillo, Texas, precipitation averages about 48 centimeters (19 inches) per year, and the average annual runoff is less than 2.5 centimeters (1.0 inch). Together with an average wind speed of 13.7 miles per hour, these semiarid conditions result in a relatively high potential for wind erosion of soil. However, they also favor the dispersion of pollutants in the atmosphere. The region meets or exceeds the applicable national standards for air quality. Severe weather includes tornadoes, thunderstorms, and heavy fog. On average, the area around the Deaf Smith County site experiences about eight tornadoes per year. Thunderstorms and heavy fog occur on about 50 and 20 days per year, respectively.

To date, no archaeological or historic sites have been recorded at the Deaf Smith County site or in the immediate vicinity. Areas with potential for containing unrecorded historic sites are located near water sources such as an

unnamed tributary immediately north of the site, Palo Duro Creek 5.6 kilometers (3.5 miles) south of the site, and nearby playa lakes. The landscape at the site shows little visual variety. The noise levels are characteristic of rural agricultural settings.

Seven counties in Texas and two counties in New Mexico are considered to be within a reasonable commuting distance of the site. These nine counties are the area that may experience socioeconomic effects from the repository. The 1980 population of this area was 281,060, and the average population density is 24 persons per square mile. The incorporated communities that are closest to the site (and their populations) are Hereford (15,853), Canyon (10,724), Vega (900), and Amarillo (149,230). These communities have an adequate base of community services, with Amarillo tending to have a slightly larger service base than the other three communities.

Much of the regional and local economy depends, either directly or indirectly, on agriculture. The region is a major producer of corn, sorghum, wheat, sugarbeets, vegetables, cotton, cattle, and seed for commercial farming. Irrigation is essential to the agricultural productivity of the region. Continuing depletion of the High Plains aquifer will reduce the amount of water available for irrigation and may change the character of the agricultural economy.

4. EFFECTS OF SITE CHARACTERIZATION

To obtain the information necessary for evaluating the suitability of the Deaf Smith County site for a repository, the DOE will conduct a site-characterization program of underground testing. To carry out this program, the DOE will construct two shafts down to the level of the repository (one shaft for removing rock and lowering construction materials into the facility and one for services and emergency egress), excavate drifts at the proposed repository depth, construct support structures on the surface, and improve the access roads to the site. In addition to the tests performed under the surface and in the exploratory shaft facility, geologic field studies will be conducted to characterize subsurface conditions.

At the same time, the DOE will study the environment of the site and its vicinity, including weather conditions, air quality, noise, plant and animal communities, and archaeological and cultural resources. Socioeconomic conditions will also be investigated in the nine-county area expected to be affected by the repository.

The site-characterization program will last several years. At the end of this period, if the Deaf Smith County site is found unsuitable for a repository, the shafts will be filled and sealed, and the site will be reclaimed.

Site characterization will entail some adverse effects. Current land uses in parts of the site will be disrupted. Approximately 25 hectares (61 acres) of land will be required for the construction of the Exploratory Shaft Facility (ESF), and an additional one-third acre will be needed for a new

access road. The DOE will obtain the needed surface and subsurface rights to this land through negotiation and purchase or, if necessary, condemnation. To conduct geotechnical field studies, the DOE will acquire rights to small parcels of land totaling 105 hectares (260 acres), of which approximately 93 hectares (230 acres) may be actually disturbed. Since field studies will be distributed over the entire site, the effects experienced by specific landowners will be small. On a county-wide basis, no more than a maximum of 350 acres of cropland and rangeland is expected to be disturbed for the shafts, the access roads, and geotechnical studies.

Since the DOE will not know precisely how much land would be needed for the repository until site characterization is completed, the DOE plans to protect an area of approximately 2,331 hectares (5,760 acres) by purchasing or leasing surface and subsurface rights. If this acreage is removed from agricultural use, the total reduction in cropland in the county will be almost 2 percent.

The excavation of salt from the subsurface test area will create a surface stockpile of approximately 118,000 cubic yards, covering an area of less than 5 acres. An impermeable liner will be placed beneath the pile and ponds will be used to control surface-water runoff in order to minimize the potential for surface- and ground-water contamination. During salt-handling operations, some windblown salt will be deposited on nearby ground. The DOE has managed salt excavation and stockpiling on a similar scale at two different sites. This experience has shown that salt emissions during excavation will not be significant. When stockpiled salt is wetted, after spreading and compacting, a hard surface crust forms in a few days. This crust prevents the spread of windblown particles. Waste salt and residues will be removed to an offsite licensed landfill.

Wildlife will be disturbed because of a loss of habitat and increased human activity. However, since the site and its immediate surroundings do not support any unique habitats and the area to be cleared is small in comparison with the surrounding undisturbed area, the effects on wildlife are expected to be minimal on a regional level.

Fugitive dust will be generated by road construction, site clearing and preparation, vehicle movement, drilling and trenching, development and wind erosion of spoils piles (including salt piles), and vehicle and machinery exhaust. The total concentration of suspended particles (TSP) will meet the 24-hour and annual NAAQ standards. Impacts from gaseous No_x emissions will not exceed the annual standards.

The construction of the exploratory shaft will produce noise levels that may exceed the sound-level guidelines of the U.S. Environmental Protection Agency (EPA) at the nearest residence. The noise of traffic on FM 2587 will also be increased during peak periods. A meteorological tower, drilling rigs, and the salt pile will be visible from outside the site. Previously undiscovered archaeological and historical resources may be disturbed by the development of access roads, the shafts, and field activities.

Site characterization is not expected to impose significant impacts on the quality of surface water. The water for exploratory-shaft activities will be obtained from the High Plains aquifer. The total expected fresh water demand of the exploratory shaft site will be 151 acre-feet (49.1 million gallons), including water for final disposition of shaft facilities after their use. The maximum drawdown on pumping wells within 2.4 kilometers (1.5 miles) of a water-supply well is estimated at about 0.6 meter (0.2 foot). The use of state-of-the-art mining techniques will ensure that the penetration of the High Plains acquifer during the excavation of the shafts will not significantly affect the quality of the ground water.

Site characterization is expected to create approximately 457 new jobs, drawing up to 893 new residents into the area. Most of these persons are expected to reside in Amarillo. The expected change in population for the affected communities is 0.3 percent for Amarillo, 1.3 percent for Hereford, 0.4 percent for Canyon, and 3.7 percent for Vega. The DOE expects that the increased demands for local services can be met with the existing service capacity. Deaf Smith County will be eligible for grants equal to taxes for the land used in site characterization.

Some transient effects are expected in the regional and local transportation network. Temporary congestion may result from the movement of equipment and personnel to the site. The greatest congestion will occur on FM 2587, which passes near the site.

5. REGIONAL AND LOCAL EFFECTS OF REPOSITORY DEVELOPMENT

To determine the effects of developing a repository at the site, three phases of repository development were examined: construction, operation, and closure and decommissioning. During the construction phase, which will last approximately 7 years, the DOE would construct surface and support structures, construct access shafts, excavate and prepare subsurface tunnels and waste-disposal rooms, and improve access roads and utility services. During the first few years of the operation phase, the repository would receive small amounts of waste -about 400 metric tons of radioactive waste per year - while the surface and underground facilities are completed. After construction is completed, the rate of waste receipt would increase to a maximum of 3,000 metric tons of radioactive waste per year. During the operation phase, underground development would continue concurrently with waste emplacement until the required area is excavated. This full-operation phase is estimated to last some 25 to 30 years; it would be followed by a "caretaker" period because the U.S. Nuclear Regulatory Commission requires the DOE to preserve the option of retrieving the waste for 50 years after the initial emplacement. During closure and decommissioning the underground repository would be backfilled, shafts and boreholes would be closed and sealed, land-use controls would be instituted, the surface facilities would be decontaminated and decommissioned, and permanent markers or monuments would be erected at the site to warn future generations about the presence of the underground repository.

Both adverse and beneficial effects may result from a repository at the Deaf Smith County site. About 162 hectares (400 acres) of land would be used for the surface facilities for the reference repository design. A total of 2,331 hectares (5,760 acres), including the 162 hectares (400 acres), would be withdrawn for a controlled area. Within this total there are approximately 2,091 hectares (5,168 acres) of active cropland. The removal of this land from agricultural use would represent less than 2 percent of the cropland in the county. The land inside the controlled area would be withdrawn from use for the period of repository operation, with the possible exception of dry-land farming and grazing. Landowners would be compensated at a fair market value for all land used for the repository.

Approximately 24 million tons of salt would be excavated for the reference repository design during the construction and operation of the underground facility. More than half of this salt would be returned underground for backfilling the repository, but about 11 million tons of salt would be removed from the site for disposal in an offsite mine or another salt disposal alternative. Although no salt disposal method has been selected, several mine sites have been tentatively identified for abandoned mine disposal within 100 miles of the Deaf Smith County site. A maximum of 3.7 million tons of salt would be stored at the site at any one time. The salt-storage pile would occupy an area of 22.4 hectares (55.5 acres) and reach a height of about 11.8 meters (39 feet). Although a hard crust would form over the salt pile, an insignificant amount of windblown salt is likely to be deposited in the immediate vicinity of the site. An impermeable liner would be used under the salt pile to minimize effects on ground water. To contain any water runoff from the salt pile, collection ponds would be constructed.

The ecological effects of a repository would be largely confined to the site. The construction of access roads and surface facilities would displace about 165 hectares (408 acres) of site and access-road soils. Increased noise and traffic levels would also disturb the local wildlife. On a regional level, the removal of cropland or rangeland for the repository would not be ecologically significant.

Air quality effects would be greatest during preparation of the site. However, during all phases of repository development, the 24-hour and annual NAAQ standards for suspended particulates (TSP) will be met at the boundary of the repository controlled area. The average annual NAAQ standards for gaseous NO_x emissions also will be met. The noise of repository construction may exceed the ambient sound level at the nearest residence, but during construction and operation all EPA noise-level guidelines would be met with the exception of short-term noises associated with building a railroad spur. Nonetheless, increased noise levels from passing vehicles may be a nuisance to people living close to FM 2587. The surface facilities, and the salt-storage pile may be visible from outside the site; their appearance would be in contrast with the visual character of the area.

A total of 559 acre-feet of water would be used during the 7 years of repository construction, of which 529 acre-feet would be used during the first year. During the period of full operations, the repository would use about 289 acre-feet per year, which is equivalent to the amount of water used to irrigate 170 acres of cropland. The water would be provided from onsite wells. The maximum drawdown due to ground-water withdrawal from an onsite

well is estimated to be 0.67 meter (2.2 feet) at 2.4 kilometers (1.5 miles) from the well. The maximum amount of municipal water needed for the in-migrants attracted by the repository would be approximately 50 to 60 acre-feet per year; this peak demand is expected to occur in the year 2005.

By the peak year of operation, the repository would generate about 1,150 direct and 1,150 indirect jobs in the region, with up to 2,520 persons expected to have migrated into the region. The maximum repository-related population increase in the year 2005 is estimated to be 1 percent for Amarillo, 2 percent for Hereford, 1 percent for Canyon, and 5 percent for Vega. The community of Vega is likely to experience more severe effects because its population is smaller.

Local business activity would increase. Local purchases for the construction of the repository are estimated at $16.9 million per year. The total repository-related purchases in the region during the operation period would be about $4.5 million per year.

Potentially adverse socioeconomic impacts would be mitigated by an increased tax base, grants equal to taxes, and financial assistance from the DOE. Such financial assistance has been mandated by Congress in the NWPA to mitigate repository-related impacts.

Two types of transportation effects would result from increased commuter traffic and the hauling of supplies, excess salt, and radioactive waste. They are radiological risks, which would result from the direct external radiation emitted by the radioactive waste as a shipment passes by, and nonradiological risks. The latter are traffic accidents and the health effects that result from the pollutants emitted by combustion engines; they would occur regardless of the cargo carried by the railcar or truck. In general, both types of risk will vary with the distance traveled and with the mode of transportation (road or rail). Since both the Deaf Smith and the Swisher County sites are closer to the sources of commercial waste from nuclear power plants than the other potentially acceptable sites, except for the three salt-dome sites, the nonradiological risks for these sites are likely to be relatively low. While the nonradiological risks would vary with the transportation mode, they are expected to be lower for rail transport.

The radiological risks for the Deaf Smith County site are expected to be much lower than the nonradiological risks. The actual radiological risks would vary with the number of shipments in each transportation mode; however, in any case, they are expected to be low. Texas has the capability to respond to waste-transportation accidents and has emergency response plans and procedures.

Road transportation of nuclear waste would reach the site from Interstate 40, going either east or west, via U.S. 385 from Vega to FM 2587 which would be improved for a short distance west to receive repository traffic. Rail shipments could come north on a special spur from Summerfield, a point on an Atcheson, Topeka, and Santa Fe (AT&SF) regional line. Estimated costs of transporting waste to the Deaf Smith County site are 1.13 billion dollars for road and 1.12 billion dollars for rail transport.

6. EVALUATIONS OF SITE SUITABILITY

The DOE has evaluated the Deaf Smith County site to determine its suitability as a candidate for site characterization. This evaluation was based mainly on the siting guidelines, but it was also based on the expected effects of site characterization and of repository development, as summarized in the preceding sections.

6.1 THE STRUCTURE OF THE GUIDELINES

The guidelines are divided into two sets: postclosure (the period after the repository is permanently closed) and preclosure (the period of repository siting, construction, operation, closure, and decommissioning). The postclosure and the preclosure guidelines contain both Technical and System Guidelines. The Technical Guidelines address the specific characteristics of the site that are considered to have a bearing on the preclosure and the postclosure performance of the repository. The System Guidelines address the expected performance of the total system, including its engineered components; their objective is to protect public health and safety and to preserve the quality of the environment.

The postclosure Technical Guidelines address the characteristics that could affect the long-term ability of the site to isolate the waste from the accessible environment. In particular, they cover geohydrologic conditions, geochemical conditions, rock characteristics, climatic changes, erosion, dissolution, tectonics, and human interference. The postclosure System Guideline requires the site to contain and isolate the waste from the accessible environment in accordance with the standards and the regulations specifically promulgated for repositories by the EPA and the NRC. In order to achieve the specified level of containment and isolation, both natural and engineered barriers may be used.

The set of preclosure guidelines is divided into three groups: (1) preclosure radiological safety; (2) the environment, socioeconomics, and transportation; (3) the ease and cost of siting, construction, operation, and closure. A preclosure System Guideline is specified for each of these groups. The associated Technical Guidelines address site suitability in terms of population density and distribution, site ownership and control, meteorology, offsite installations and operations, environmental quality, socioeconomics, transportation, surface characteristics, rock characteristics, hydrology, and tectonics.

6.2 SUMMARY OF SITE EVALUATIONS AGAINST THE POSTCLOSURE GUIDELINES

The features of bedded salt at the Deaf Smith County site that could contribute to its ability to isolate waste from the accessible environment include (1) the low permeability of the host rock (salt) and the long time predicted for ground-water travel to the accessible environment, (2) the presence of a downward ground-water gradient from the upper to the lower

aquifers, and (3) the favorable geomechanical and geochemical properties of the host unit. The candidate host rock at the Deaf Smith County site contains little water. Furthermore, estimates of the time of ground-water travel indicate that travel times to be accessible environment at a distance of 1 kilometer (0.62 mile) would be in excess of 10,000 years. In addition, the host rock has the ability to rapidly dissipate the heat generated by the emplaced waste, which reduces the potential for heat-induced fractures. Other favorable characteristics of bedded salt are its plasticity under confining pressure at depth and the resulting tendency of fractures and openings to close and seal. The favorable geochemical properties that would help retard the migration of radionuclides into the accessible environment are the presence of clays in the interbeds of the host rock and the overlying and the underlying evaporite sections, which would retard radionuclides by sorption, although such sorption would probably be mitigated by the presence of brines. There is also evidence of a potential for chemically reducing conditions, which would diminish the solubility of the waste and promote precipitation. Finally, since Texas is in a stable geologic region, there is little potential for earthquakes that are sufficiently large to disrupt the geohydrologic system.

A condition that could compromise the ability of the site to isolate the waste is the ongoing geologic process of salt dissolution. Although there is evidence of salt dissolution in the Palo Duro Basin, the predicted rates of dissolution are very low, and dissolution is not expected to adversely affect waste isolation. If dissolution continues at the rates estimated for the last 2 to 3 million years, the dissolution front would not reach the repository for considerably longer than 10,000 years, the time required by Federal standards for waste isolation.

With regard to the performance of engineered barriers at the site, the NRC standards specify that the waste package is to contain the waste for 300 to 1000 years and that the rate of radionuclide release beyond this period of containment is not to exceed 1 part in 100,000 per year. Current information on the corrosion of metals like those used for the waste canisters suggests that at the Deaf Smith County site the lifetime of the waste package is expected to exceed 10,000 years. The potential for corrosion will be addressed further during site characterization. The DOE estimates that the release rate beyond the period of containment will not only meet the regulatory limits--it may be much lower. Preliminary assessments of engineered-barrier performance under realistic but conservative assumptions indicate that the EPA's limit on the release rate to the accessible environment would be met at the Deaf Smith County site.

6.3 SUMMARY OF SITE EVALUATIONS AGAINST THE PRECLOSURE GUIDELINES

The evaluations of the Deaf Smith County site against the three groups of preclosure guidelines are summarized below.

6.3.1 RADIOLOGICAL SAFETY

Preliminary assessments of preclosure performance for the Deaf Smith County site do not indicate that any releases of radioactive material from the repository would exceed any applicable radiation standards during repository operation and closure. In addition, the site was evaluated against the following Technical Guidelines that are concerned with the radiological effects of repository operation on public health and safety: population density and distribution, site ownership and control, meteorology, and offsite installations and operations.

The Deaf Smith County site is far from highly populated areas. The closest highly populated area is Hereford, 27 kilometers (17 miles) away. The population density of the area within 80 kilometers (50 miles) is 31 persons per square mile, considerably below the national average of 64 persons per square mile. Furthermore, the weather conditions in the region, especially the high winds, would disperse any radioactive emissions. Severe weather, such as violent thunderstorms and tornadoes, does occur in the region, but the probability of operational accidents caused by such weather is very low because currently available construction practices can reduce any risk to surface facilities, and the subsurface facilities would not be affected. In order to establish a restricted zone of controlled access, the DOE intends to obtain ownership and control of the site.

The closest nuclear installation is the DOE's Pantex Plant; this plant is 77 kilometers (48 miles) from the site, and its radioactive emissions are negligible. No significant hazard is expected from any other installations or operations near the site.

6.3.2 ENVIRONMENT, SOCIOECONOMICS, AND TRANSPORTATION

Three Technical Guidelines address the environmental, socioeconomic, and transportation effects of a repository before closure. These effects, which would be both beneficial and adverse, are summarized in Sections 4 and 5. Preliminary analyses indicate that the expected adverse effects can be mitigated.

With respect to the System Guideline for the environment, socioeconomics, and transportation, the evidence does not support a finding that the Deaf Smith County site is not likely to meet the qualifying condition of protecting the public and the environment from the potential hazards associated with waste disposal.

6.3.3 EASE AND COST OF SITING, CONSTRUCTION, OPERATION, AND CLOSURE

Four Technical Guidelines address the ease and cost of repository siting, construction, operation, and closure; they are concerned with rock characteristics, hydrology, surface characteristics, and the tectonic stability of the site. With respect to rock characteristics, the tendency of salt to creep under confining pressure may necessitate some reexcavation of

some subsurface openings over time. However, it is expected that, with routine maintenance, the openings of the repository will remain stable enough to allow the retrieval of waste is necessary.

The presence of many interbeds limits vertical flexibility in locating the underground repository in the preferred salt horizon, Unit 4 of the Lower San Andres Formation; the lateral flexibility, on the other hand, is very great because the salt extends for many miles. Since the site is in a tectonically stable region, minimal disruption from earthquakes is expected. With proper site preparation and facility design, there is little potential for disruption from surface flooding or severe weather.

These evaluations suggest that the repository can be constructed and operated with reasonably available technology, and the costs would be comparable to those of a repository at the other potentially acceptable sites.

7. COMPARATIVE EVALUATION OF NOMINATED SITES

7.1 PURPOSE AND REQUIREMENTS

Chapter 7 presents a comparative evaluation of the five sites nominated as suitable for site characterization: Davis Canyon, Deaf Smith County, Hanford, Richton Dome, and Yucca Mountain. Each site is a preferred site within a geohydrologic setting: Davis Canyon is in the bedded salt of the Paradox Basin in Utah; Deaf Smith County is in the bedded salt of the Permian Basin in Texas; Hanford is in basalt in the Columbia Plateau in Washington; Richton is a salt dome in Mississippi; and Yucca Mountain is in tuff in the Southern Great Basin in Nevada.

The purpose of this chapter is to present a comparative evaluation of the nominated sites in order to satisfy the following:

1. Section 112(b)(1)(E)(iv) of the Nuclear Waste Policy Act of 1982, which requires that a "reasonable comparative evaluation" be included in the environmental assessments that accompany site nomination, and

2. Section 960.3-2-2-3 of the DOE's siting guidelines (10 CFR Part 960), which requires that a reasonable comparative evaluation be made and that a summary of evaluations with respect to the qualifying condition for each guideline be provided to "allow comparisons to be made among sites on the basis of each guideline."

This comparative evaluation is intended to allow the reader to compare the more detailed suitability evaluations of the individual sites that are presented in Chapter 6 of each environmental assessment. The comparison should assist the reader in understanding the basis for the nomination of five

sites as suitable for characterization [112(b)(1)(A)]; it is not intended to directly support the subsequent recommendation of three sites for characterization as candidate sites.

7.2 APPROACH AND ORGANIZATION

This comparative evaluation of the five nominated sites is based on the postclosure and preclosure guidelines (10 CFR Part 960, Subparts B and C, respectively). The evaluation presented in this chapter includes the system guidelines and the technical guidelines. The approach used to compare the sites with respect to each system and technical guideline in summarized below.

7.2.1 TECHNICAL GUIDELINES

Major considerations that could be used to compare the sites on the basis of the qualifying condition of each technical guideline were derived by identifying the favorable, potentially adverse, and disqualifying conditions that deal with the same general topic. Contributing factors that represent the characteristics of the site that are potentially important in evaluating the sites with respect to each major consideration were also identified. The relative importance of the major considerations was determined primarily by the degree to which they contribute to the qualifying condition; that is, the stronger the tie between the consideration and the qualifying condition, the greater the importance of the consideration.

The purpose of identifying major considerations for each guidelines is to combine closely related site conditions so that the balance of the favorable and potentially adverse conditions can be considered directly. Most guidelines that contain a disqualifying condition have one or more potentially adverse conditions that relate to the disqualifying condition. Since these potentially adverse conditions are considered in the formulation of a major consideration, the important aspects of the disqualifying conditions indirectly enter the comparative evaluation. Where a major consideration that is needed to evaluate the qualifying condition does not have a related favorable or potentially adverse condition, the consideration is derived directly from the qualifying or disqualifying condition.

The comparative evaluation of the sites with respect to each guideline, using the approach described above, is summarized in Sections 7.2 and 7.3 for the postclosure and preclosure guidelines, respectively.* These sections are organized in the following manner:

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*Since the comparative evaluations in Section 7.2 and 7.3 are already a summary of information in Chapter 6, this executive summary does not attempt to further abstract the substance of the comparative evaluation. The DOE believes that a further synopsis of Section 7.2 and 7.3 for the purpose of this executive summary would distort the information and possibly mislead the reader.

1. For each guideline, the major consideration(s) and associated contributing factors are identified.

2. The evaluation of each site on the basis of each major consideration is then summarized. The evaluation of each site with respect to each major consideration is presented in alphabetical order, by site.

3. The sites are then compared on the basis of the qualifying condition. This comparative evaluation describes the sites with the most favorable combination of characteristics first and those with a less favorable combination of characteristics last in order to allow easier comparison of the suitability evaluation of the site presented in Chapter 6 with sites having other combinations of characteristics.

7.2.2 SYSTEM GUIDELINES

The comparison of sites on the basis of the individual technical guidelines uses the major considerations to incorporate the favorable and potentially adverse conditions in an evaluation of a site's standing on the qualifying conditions for each technical guideline. It is not appropriate, however, to use this approach for a comparative evaluation of sites on the basis of the system guidelines. The qualifying conditions for the system guidelines do not lend themselves to the identification of major considerations in the way that the qualifying conditions for the technical guidelines do. The system guidelines for postclosure repository performance and preclosure radiological safety are stated in terms of regulatory requirements of the NRC and EPA. The evaluations of these two system guidelines are based on preliminary performance assessments that consider the associated technical guidelines as the elements of the system. These evaluations are summarized directly from Sections 6.3.2 and 6.2.2.1 of each environmental assessment.

The system guidelines for environment, socioeconomics, and transportation, and for ease and cost of repository construction, operation, and closure are not stated as regulatory standards, and they cannot be evaluated by a performance assessment as are the other two system guidelines. Instead, they are evaluated by considering the individual guidelines that make up these two system guidelines collectively to determine whether each site meets the qualifying condition of the relevant system guidelines. The evaluation of these system guidelines is summarized from Section 6.2.2.2 and 6.3.4, in each environmental assessment.

Chapter 1

PROCESS FOR SELECTING SITES FOR GEOLOGIC REPOSITORIES

1.1 INTRODUCTION

By the end of this century, the United States plans to begin the operation of a geologic repository for the permanent disposal of commercial spent nuclear fuel and high-level radioactive waste.* Public Law 97-425, the Nuclear Waste Policy Act of 1982 (the Act), specifies the process for selecting a repository site and assigns to the U.S. Department of Energy (DOE) the responsibility for siting, constructing, operating, closing, and decommissioning the repository.

A number of alternative methods for disposing of spent nuclear fuel and high-level radioactive waste have been studied during the past 10 years (DOE, 1980a; EPA, 1979; Interagency Review Group, 1979; Schneider and Platt, 1974). After an extensive evaluation of these alternatives, as documented in the final environmental impact statement on the management of commercially generated radioactive waste (DOE, 1980a), the DOE chose disposal in mined geologic repositories as the preferred method and documented this decision in a notice published in the Federal Register (Vol. 46, p. 2667, May 14, 1981). Congress endorsed this preference by declaring that one of the key purposes of the Act is "to establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository" (Section 111(b)(1)).

1.1.1 THE GEOLOGIC REPOSITORY CONCEPT

A geologic repository will be developed much like a large mine. Shafts will be constructed to allow for the removal of excavated material and to permit the construction of tunnels and disposal rooms at depths between 1,000 and 4,000 feet underground. Other shafts will be constructed to allow for the transfer of waste. Surface facilities will be provided for receiving and

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*High-level radioactive waste means (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations, and (2) other highly radioactive material that the U.S. Nuclear Regulatory Commission (NRC), consistent with existing law, determines by rule requires permanent isolation. The terms "radioactive waste" and "waste" are used for both spent fuel and high-level radioactive waste.

preparing the waste for emplacement underground. The surface and underground facilities will occupy about 400 and 2,000 acres of land, respectively. When the repository has been filled to capacity and its performance has been shown to be satisfactory, the surface facilities will be decommissioned and all shafts and boreholes will be backfilled and permanently sealed. A more detailed description of a conceptual design for a repository is presented in Section 5.1.

A repository can be viewed as a system of multiple barriers, both natural and engineered, that act together to contain and safely isolate the waste. The engineered barriers will include the waste package, the underground facility, and shaft and tunnel backfill materials. The waste package will consist of the waste form, either spent nuclear fuel or solidified high-level waste, a metal container, and specially designed backfill material to separate the waste container from the host rock. The waste package will contribute to long-term isolation by delaying eventual contact between the waste and the geologic environment. The underground facility will consist of underground openings and backfill materials not associated with the waste package. These barriers will further limit any ground-water circulation around the waste packages and impede the subsequent transport of radionuclides into the environment.

The geologic, hydrologic, and geochemical features of the site constitute natural barriers to the long-term movement of radionuclides to the accessible environment. These natural barriers will provide waste isolation by impeding radionuclide transport through the ground-water system to the accessible environment and will possess characteristics that will reduce the potential for human interference in the future.

Although the DOE plans to use engineered barriers--as required by both the Nuclear Regulatory Commission (NRC) in 10 CFR Part 60 and the Environmental Protection Agency (EPA) in 40 CFR Part 191--the DOE places primary reliance on the natural barriers for waste isolation. Therefore, in evaluating the suitability of sites, the use of an engineered-barrier system will be considered to the extent necessary to meet the performance requirements specified by the NRC and the EPA but will not be relied on to compensate for deficiencies in the natural barriers.

1.1.2 THE NUCLEAR WASTE POLICY ACT OF 1982

The search for suitable repository sites has been under way for about 10 years, although preliminary screening began in the mid-1950s. With the passage of the Act, a specific process for siting and licensing repositories was established. Through provisions for consultation and cooperation as well as financial assistance, the Act also established a prominent role in the siting process for potential host States, affected Indian Tribes, and the public. To pay the costs of geologic disposal, the Act provides for a Nuclear Waste Fund through which commercial electric utility companies are charged a fee that is based on the amount of electricity they produce in nuclear power plants. The DOE's strategy for implementing the Act is discussed in detail in the Mission Plan for the Civilian Radioactive Waste Management Program (DOE, 1985).

In February 1983, the DOE carried out the first requirement of the Act by formally identifying potentially acceptable sites in the following locations (the host rock of each site is shown in parentheses):

1. Vacherie Dome, Louisiana (salt dome)
2. Cypress Creek Dome, Mississippi (salt dome)
3. Richton Dome, Mississippi (salt dome)
4. Yucca Mountain, Nevada (welded tuff)
5. Deaf Smith County, Texas (bedded salt)
6. Swisher County, Texas (bedded salt)
7. Davis Canyon, Utah (bedded salt)
8. Lavender Canyon, Utah (bedded salt)
9. Reference repository location, Hanford Site, Washington (basalt flows)

The location of these sites in their host States is shown in Figure 1-1.*

The Act further requires the DOE to issue general guidelines to be used in determining the suitability of sites. In February 1983, the DOE published draft General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (DOE, 1983). The DOE revised the guidelines after receiving extensive comments from the NRC, the States, Indian Tribes, other Federal agencies, and the public. The NRC concurred with the revised guidelines in June 1984, and the final guidelines were promulgated in December 1984 (DOE, 1984a).

The Act requires that, after the guidelines are issued, the DOE nominate at least five sites as suitable for site characterization. The DOE must then recommend not fewer than three of those sites for characterization as candidate sites for the first repository. During site characterization, the DOE will construct exploratory shafts for underground testing to determine whether geologic conditions will allow the construction of a repository that will safely isolate radioactive waste. The Act requires the DOE to prepare site-characterization plans for review by the NRC, States, Indian Tribes, and the public. After site characterization and an environmental impact statement are completed, the DOE will recommend one of the characterized sites for development as the first repository.

1.1.3 THE ENVIRONMENTAL ASSESSMENT

The Act requires the DOE to prepare environmental assessments to serve as the basis for site nominations. Although not required by the Act, draft environmental assessments were prepared for each of the nine potentially acceptable sites and issued for comment by the NRC and other Federal agencies, the States, affected Indian Tribes, and the public. The DOE has considered the comments received on these drafts before making final decisions about

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*In Texas, the DOE first identified two locations that were up to 300 square miles in area. These were subsequently narrowed to 9 square miles. The other potentially acceptable sites identified in February 1983 were on the order of tens of square miles.

Figure 1-1. Potentially acceptable sites for the first repository.

nomination and recommendation. The issues raised by the comments and the DOE's responses are presented in Appendix C.

The final environmental assessments contain the following kinds of information and evaluations to meet the requirements of Section 112 of the Act:

- A description of the decision process by which the site being considered for nomination was selected (Chapter 2).
- A description of the site and its surroundings (Chapter 3).
- An evaluation of the effects of site characterization on the health and safety of the public and the environment as well as a discussion of alternative activities that may be taken to avoid such impacts (Chapter 4).
- An assessment of the regional and local impacts of locating the proposed repository at the site (Chapter 5).
- An evaluation as to whether the site is suitable for site characterization (Chapter 6).
- An evaluation as to whether the site is suitable for development as a repository (Chapter 6).
- A reasonable comparative evaluation of the five nominated sites (Chapter 7).

1.2 SUMMARY OF THE OVERALL DECISION PROCESS

In seeking sites for geologic repositories, the DOE divides the siting process into the following phases: (1) screening, (2) site nomination, (3) recommendation for characterization, (4) site characterization, and (5) site selection (recommendation for development as a repository). This section describes the site-screening process that led to the identification of the nine potentially acceptable sites listed in Section 1.1 and reviews how the process of site nomination is implemented under the guidelines.

1.2.1 SITE SCREENING

During the screening phase, the DOE identified potentially acceptable sites for characterization. This phase provided the information needed for judging which of these sites appear to justify the investment in characterizing them. Screening consisted of as many as four stages, each of which progressively narrowed the study area to a smaller land unit. These stages were as follows:

1. A survey of the nation or <u>geologic provinces</u>, narrowing to <u>regions</u>. Regions are generally smaller than provinces but may extend across several States and occupy tens of thousands of square miles.

2. A survey of the regions, narrowing to areas, which encompass hundreds to thousands of square miles. For the salt sites, the regional screening phase was completed with the publication of regional characterization reports and area-recommendation reports.

3. A survey of the areas, narrowing to locations, which usually occupy an area smaller than 100 square miles. This phase was completed with the publication of location-recommendation reports for bedded salt and site-recommendation reports for salt domes.

4. A survey of the locations, narrowing to sites, which are generally smaller than 10 square miles. Although a location may be large enough to contain several sites, only one or two potential sites were usually identified in a particular location.

During each screening phase for the first repository, the DOE identified as many potentially suitable land units as were judged to be necessary for an adequate sample to be studied in the next stage. Only the regions and areas believed most likely to contain suitable sites received further study; the evaluation of all others was deferred.

Data for comparing regions, areas, and locations became increasingly detailed as progressively smaller land units were considered and as exploration and testing were concentrated on them. National, province, and regional surveys were based on the distribution of potential host rocks, published geologic maps, maps of earthquake epicenters, land use, available geohydrologic information, and other information available in the open literature. Area and location surveys required more-thorough investigations that included field exploration and testing and drilling of boreholes to investigate subsurface hydrologic, stratigraphic, and geochemical conditions. The field studies were supported by laboratory studies that focused on the waste-isolation and the engineering characteristics of potential host rocks.

The bedded-salt sites under consideration in Texas and Utah were identified by the general siting process described above, beginning with national surveys and progressively narrowing to areas, locations, and sites. The salt domes were selected by a screening that began with more than 200 domes and ended with the one site being nominated.

The screening of sites in basalt and tuff was initiated when the DOE began to search for suitable repository sites on some Federal lands where radioactive materials were already present. This approach was recommended by the Comptroller General of the United States (1979). Although land use was the beginning basis for this screening of Federal lands, the subsequent progression to smaller land units was based primarily on evaluations of geologic and hydrologic suitability. These studies began at roughly the area stage.

The technical factors used to guide site-screening decisions have evolved throughout the screening phase and are specified in a number of published documents (Brunton and McClain, 1977; DOE, 1981; DOE, 1982a; International Atomic Energy Agency, 1977; NAS-NRC, 1978).

The sections that follow summarize how the DOE applied the screening process outlined above to determine that the nine sites listed in Section 1.1.2 are potentially acceptable. Section 2.2 of each environmental assessment discusses in detail how the DOE conducted site screening in specific geohydrologic settings.

1.2.2 SALT SITES

Salt was first recommended as a potentially suitable host rock for waste disposal in 1955, after the National Academy of Sciences-National Research Council evaluated many options (NAS-NRC, 1957). This recommendation was reaffirmed in subsequent reports (e.g., American Physical Society, 1978; NAS-NRC, 1970). Rock salt, which occurs both as bedded salt and in salt domes, has several characteristics that are favorable for isolating radioactive waste, including the following:

- Salt deposits that are sufficiently deep, thick, and laterally extensive to accommodate a repository are widespread in the United States and generally occur in areas of low seismic and tectonic activity.
- Many salt bodies have remained undisturbed and water-free in comparison with other rock types for tens of millions to several hundred million years.
- Because of its high thermal conductivity, rock salt can dissipate the heat that will be generated by the waste.
- Since salt is relatively plastic under high confining pressure, the fractures that might develop at repository depth would tend to close and seal themselves.
- Rock salt undergoes only minor, highly local change as a result of exposure to radiation.
- Rock salt has excellent radiation-shielding properties.

Screening of the entire United States in the 1960s and 1970s resulted in the identification of four large regions that are underlain by rock salt of sufficient depth and thickness to accommodate a repository and represent diverse geohydrologic conditions (Johnson and Gonzales, 1978; Pierce and Rich, 1962). The four regions are as follows:

- Bedded salt in the Michigan and the Appalachian Basins of southern Michigan, northeastern Ohio, western Pennsylvania, and western New York (also called the "Salina Basin").
- Salt domes within a large part of the Gulf Coastal Plain in Texas, Louisiana, and Mississippi.
- Bedded salt in the Permian Basin of southwestern Kansas, western Oklahoma, northwestern Texas, and eastern New Mexico.

- Bedded salt in the Paradox Basin of southeastern Utah, southwestern Colorado, and northernmost Arizona and New Mexico.

This screening at the national level served as the basis for all subsequent screening in salt. After proceeding to the area phase, further screening of the salt deposits in the Salina Basin was deferred. The studies of the Salina region were not specific enough to judge that any part of the region was suitable or unsuitable for a repository. They did reveal a number of unfavorable characteristics, including a high population density associated with the concentration of urban areas in Ohio, Michigan, and New York, and an abundance of natural resources, especially oil and gas. In view of these unfavorable conditions, the DOE decided to concentrate its siting efforts on more-promising areas in the remaining three regions.

1.2.2.1 Salt domes in the Gulf Coast salt-dome basin of Mississippi and Louisiana

There are more than 500 salt domes in the Gulf Coast salt-dome basin of Texas, Louisiana, Mississippi, and areas offshore from these States. An initial screening by the U.S. Geological Survey (USGS) eliminated all offshore domes because siting a repository under water would probably not be feasible. The application of this criterion eliminated about half the domes. The USGS also evaluated the remaining 263 onshore domes (i.e., Gulf interior domes) and identified 36 as being potentially acceptable for a repository and another 89 that were worthy of further study (Anderson et al., 1973). The USGS screening factors were the depth to the top of the dome and present use for gas storage or hydrocarbon production.

The DOE and its predecessor agencies conducted regional studies of the 125 salt domes identified in the above-mentioned USGS screening. All but 11 of the domes were eliminated on the basis of three screening factors: the depth to the salt, the lateral extent of the dome, and the history of use for hydrocarbon production or storage (NUS, 1978; BNI and LETCO, 1980). Three of the 11 domes were removed from consideration on the basis of environmental factors, and a fourth was eliminated because solution mining at the site contributed to a collapse of strata above the dome.

Area-characterization studies were completed for the seven remaining dome areas: Rayburn's and Vacherie Domes in Louisiana; Cypress Creek, Lampton, and Richton Domes in Mississippi; and Keechi and Oakwood Domes in Texas. The geologic field work conducted during this phase included the drilling of deep holes to collect rock cores from the aquifers and other strata for laboratory tests of their properties and geophysical surveys to determine the underlying rock structures. The area environmental studies included descriptions of the plant and animal communities, surface- and ground-water systems, weather conditions, land use, and socioeconomic characteristics. An evaluation of the seven domes on the basis of the DOE's criteria is summarized in a location-recommendation report (ONWI, 1982a).

In the area-characterization studies, the DOE chose a repository-size criterion that was more restrictive than the one used in earlier screening studies. The application of this stricter criterion resulted in the

elimination of Keechi, Rayburn's, and Lampton Domes (ONWI, 1982a). Thus, at the conclusion of area characterization, the Vacherie, Richton, Oakwood, and Cypress Creek Domes were recommended for further screening. After further review of the area-characterization studies, the Oakwood Dome was deferred from further consideration because of uncertainties raised by large-scale petroleum exploration.

In accordance with the Act, the DOE identified the Cypress Creek, Richton, and Vacherie Domes as potentially acceptable sites in February 1983.

1.2.2.2 Bedded salt in Davis Canyon and Lavender Canyon, Utah

Screening criteria were developed for the bedded salt of the Paradox Basin, which the USGS had identified as worthy of further investigation (Pierce and Rich, 1962). The following factors were applied to identify areas for further investigation (Brunton and McClain, 1977; DOE, 1981): the depth to, and the thickness of, the salt; mapped faults; surface igneous features; hydrocarbon and mineral resources, and potential for flooding. The results of this screening were integrated with the results of screening for environmental and socioeconomic factors, such as proximity to urban areas and the presence of certain dedicated lands. On the basis of this regional screening, four areas were recommended for further study: Gibson Dome, Elk Ridge, Lisbon Valley, and Salt Valley (ONWI, 1982b).

The primary screening factors used to identify potentially favorable locations within the four areas were the depth to the salt, the thickness of the salt, proximity to faults and boreholes, and proximity to the boundaries of dedicated lands (ONWI, 1982c). These screening factors were judged to have the strongest potential for differentiating possible locations within the areas.

Salt Valley and Lisbon Valley were both deferred from further consideration because all areas with an adequate depth to the salt were too close to zones of mapped surface faults and, for Lisbon Valley, existing boreholes (ONWI, 1982c).

Application of the screening factors to the Gibson Dome showed a location of 57 square miles near the center of the area that contained appropriately deep and thick salt deposits and was sufficiently far from faults or exploration boreholes that would make a site unsuitable. It was also outside the boundaries of the Canyonlands National Park. This location is referred to as the Gibson Dome location (ONWI, 1982c). The Elk Ridge area contained one location of about 6 square miles and several smaller ones, each less than 3 square miles, that met the screening criteria (ONWI, 1982c). The smaller locations were not large enough for a repository and were therefore excluded from further consideration. The larger location was designated the Elk Ridge location.

Further comparisons of the Gibson Dome and the Elk Ridge locations were made on the basis of more-refined criteria that discriminated between them. The thickness of the salt, the thickness of the shale above and below the depth of a repository, and the minimum distance to salt-dissolution features

were considered the most critical geologic discriminators. Archaeological sensitivity and site accessibility were considered the most important environmental factors. The Gibson Dome location was judged to be superior to the Elk Ridge location in terms of the number and relative importance of favorable factors and was selected as the preferred location (ONWI, 1982c).

During 1982 and 1983 three sites were identified for further evaluation: Davis Canyon, Lavender Canyon, and Harts Draw. Since much of the intrinsic value of southeastern Utah stems from its scenic and aesthetic character, a study of visual aesthetics was performed to evaluate the three sites (Bechtel Group Inc., 1984). Harts Draw was found to be less desirable than the sites at Davis Canyon and Lavender Canyon because it affords a greater total area of visibility, and it was eliminated from further consideration. In February 1983, Davis Canyon and Lavender Canyon were identified as potentially acceptable sites.

1.2.2.3 Bedded salt in Deaf Smith and Swisher Counties, Texas

In 1976, the Permian bedded-salt deposits in the Texas Panhandle and western Oklahoma that had been identified in the USGS study (Pierce and Rich, 1962) were evaluated to determine whether they contained any areas that might be suitable for waste disposal (Johnson, 1976). This screening focused on five subbasins: the Anadarko, Palo Duro, Dalhart, Midland, and Delaware Basins. The primary screening factors were the depth to, and the thickness of, the salt; faults; seismic activity; salt dissolution; boreholes; underground mines; proximity to aquifers; mineral resources; and conflicting land uses, such as historical sites and State or national parks. All the subbasins contain salt beds of adequate thickness and depth. The Palo Duro and the Dalhart Basins had far less potential for oil and gas production and have not been penetrated as extensively by drilling as have the Anadarko, the Delaware, and the Midland Basins. Therefore, the Palo Duro and the Dalhart Basins were judged to be preferable to the other three and were recommended for further studies at the area stage (ONWI, 1983a). These two basins rated higher on six major screening factors: the depth to, and the thickness of, the salt; seismicity; known oil and gas deposits; the presence of exploratory boreholes; and evidence of salt dissolution.

More-detailed geologic and environmental studies of the Palo Duro and the Dalhart Basins began in 1977, and screening criteria were developed to define locations with favorable characteristics. The screening criteria that were most useful in the area-to-location screening were the following: salt depth and thickness, salt purity, existing and abandoned oil and gas fields, flooding, urban areas, and conflicting land use. Six locations in parts of Deaf Smith, Swisher, Oldham, Briscoe, Armstrong, Randall, and Potter Counties, Texas, met the screening criteria. A second set of criteria was then applied to further differentiate among the six locations: distance from the margins of the Southern High Plains, distance from known oil and gas fields, more than one potential repository horizon, depth of salt, number of boreholes that penetrate the repository horizon, a large geographic area, low population densities, and potential land-use conflicts. After applying these criteria, the DOE decided to focus on the two locations that had the greatest likelihood of containing a suitable site, one in northeastern Deaf Smith and southeastern

Oldham Counties and one in northcentral Swisher County. All other locations in the Palo Duro Basin were deferred from further consideration (ONWI, 1983b). In February 1983, the DOE identified parts of Deaf Smith County and Swisher County as potentially acceptable sites and subsequently narrowed the size of the two sites to be considered at each location to 9 square miles each (DOE, 1984b).

1.2.3 SITES IN BASALT AND TUFF

In 1977, the waste-disposal program was expanded to consider previous land use as an alternative basis for site screening. This approach considered the advantages of locating a repository on land already withdrawn from public use and committed to long-term institutional control. Because both the Hanford Site and the Nevada Test Site are dedicated to nuclear operations, will remain under Federal control, have a large geographic area, and are underlain by potentially suitable rocks, screening was initiated in these two areas.

1.2.3.1 Basalt lava in the Pasco Basin, Washington

The DOE and its predecessor agencies have investigated the geologic and hydrologic characteristics of the Pasco Basin since 1977 as a continuation of studies conducted for the defense-waste management program between 1968 and 1972 (Gephart et al., 1979; Myers et al., 1979). These investigations showed that the thick formations of basalt lava in the Pasco Basin are suitable for further investigation as a geologic repository for the following reasons:

- Several basalt flows more than 2,100 feet below ground apparently are thick enough to accommodate a geologic repository.
- The slow rate of deformation of the basalt ensures the long-term integrity of a repository at the Hanford Site. Also, there are synclines where structural deformation appears to be limited.
- The potential for renewed volcanism at the Hanford Site is very low.
- The likely geochemical reactions between the basalt rock, ground water, and the materials that would be emplaced in the repository are favorable for long-term isolation.

The Pasco Basin was selected for screening to provide a broader scope from which to study processes that might affect the Hanford Site and to determine whether there are any obviously superior sites in the natural region outside, but contiguous with, the Hanford Site (Woodward-Clyde Consultants, 1980, 1981).

The first step in screening was to define the candidate area. The screening factors used at this step were fault rupture, ground motion, aircraft traffic, ground transportation, operational radiation releases from nuclear facilities at the Hanford Site, protected ecological areas, culturally

important areas, and site-preparation costs. The DOE identified a candidate area that included the central part of the Hanford Site and adjacent land east of the Hanford Site.

The second step in the screening was to define subareas (locations). The siting factors used in this step were fault rupture, flooding, ground failure, erosion, the presence of hazardous facilities, induced seismicity, and site-preparation costs. This step eliminated approximately half the candidate area.

Locations were identified through an evaluation of the subareas inside and adjacent to the Hanford Site. On the basis of land use, hydrologic conditions, and bedrock dip, subareas outside the Hanford Site were eliminated because they were not obviously superior to those found within the Hanford Site. After these subareas were eliminated, five locations were identified within the boundaries of the Hanford Site.

The identification of sites from among the five locations was based on an evaluation of 23 parameters (Rockwell, 1980). Nine sites were identified, seven of which lay in the Cold Creek Syncline, a major structural feature of the Pasco Basin. This syncline was selected partly because it is not as extensively deformed as nearby anticlines and is underlain by relatively horizontal strata. Since the other two sites were not technically superior to those in the Cold Creek Syncline and were closer to the Columbia River, they were removed from further study. To avoid some geophysical anomalies of uncertain source, the DOE identified three other sites that were largely superimposed on parts of the original seven sites in the Cold Creek Syncline (Myers and Price, 1981).

Since preliminary evaluations of the resulting 10 partly overlapping sites indicated that the sites were too closely matched to be differentiated by routine ranking, a formal decision analysis was used to identify the best site (Rockwell, 1980). Decision criteria were derived from the following siting factors: bedrock fractures and faults, lineaments, potential earthquake sources, ground-water travel times, contaminated soil, surface facilities, the thickness of the proposed repository horizon, the repetitive occurrence of columnar-jointed zones (colonnades) within the host flow, natural vegetative communities, unique microhabitats, and special species. The analysis showed that two approximately coincident sites rated higher than the other sites. These two sites were combined and designated the reference repository location. In February 1983, the DOE identified the reference repository location as a potentially acceptable site.

1.2.3.2 Tuff in the southern Great Basin, Nevada

At the same time that the DOE was considering the Nevada Test Site (NTS) on the basis of land use, the USGS proposed that the NTS be considered for investigation as a potential repository site for a variety of geotechnical reasons, including the following:

- Southern Nevada is characterized by closed hydrologic basins. This means that ground water does not discharge into rivers that flow to major bodies of surface water.

- Long flow paths occur between potential repository locations and ground-water discharge points.

- Many of the rocks occurring at the NTS have geochemical characteristics that are favorable for waste isolation.

- The NTS is located in an arid region (6 to 8 inches per year of rainfall). With the very low rate of recharge, the amount of moving ground water is also low, especially in the unsaturated zone.

In 1977, the geologic medium of prime interest at the NTS was argillite (a clay-rich rock), which occurs under the Syncline Ridge, near the center of the NTS. Geologic investigations and exploratory drilling there revealed a complex geologic structure in the center of the area being considered (Hoover and Morrison, 1980; Ponce and Hanna, 1982). It was decided in July 1978 that the geologic complexity of the area would make characterization prohibitively difficult, and further evaluation was deferred.

A question then arose concerning the compatibility of a repository with the testing of nuclear weapons--the primary purpose of the NTS. A task group formed to evaluate this issue determined in 1978 that a repository located in other than the southwest portion of the NTS might be incompatible with weapons testing. At that time the program refocused on the area in and around the southwestern corner of the NTS, which subsequently was named the Nevada Research and Development Area (NRDA). The entire area then being evaluated included land controlled by the Bureau of Land Management west and south of the NRDA and a portion of the Nellis Air Force Range west of the NRDA.

In August 1978, a preliminary list of potential sites in and near the southwestern part of the NTS was compiled. The areas initially considered were Calico Hills, Skull Mountain, Wahmonie, Yucca Mountain, and Jackass Flats. Of these five areas, Calico Hills, Wahmonie, and Yucca Mountain were considered the most attractive locations for preliminary borings and geophysical testing.

The Calico Hills location was known to contain argillite. It was of particular interest because a geophysical survey showed that granite might occur approximately 1,600 feet below the surface. The first exploratory hole for waste-disposal studies at the NRDA was drilled in 1978 in an attempt to confirm the existence of granite beneath the Calico Hills. Drilling was discontinued at a depth of 3,000 feet without reaching granite (Maldonado et al., 1979). Additional geophysical surveys indicated that the argillite at Calico Hills is probably very complex structurally, comparable with that at Syncline Ridge (Hoover et al., 1982). Because the granite was considered too deep and the argillite appeared too complex, further consideration of the Calico Hills was suspended in the spring of 1979.

Concurrent with drilling at Calico Hills, geophysical studies and surface mapping conducted at Wahmonie indicated that the granite there may not be large enough for a repository, that any granite within reasonable depths may contain deposits of precious metals, and that faults in the rock may allow vertical movement of ground water (Hoover et al., 1982; Smith et al., 1981). For these reasons, Wahmonie was eliminated from consideration in the spring of 1979.

Surface mapping of Yucca Mountain indicated the existence of a generally undisturbed structural block large enough for a repository. In 1978, the first exploratory hole drilled at Yucca Mountain confirmed the presence of thick, highly sorptive units of tuff (Spengler et al., 1979). Because tuff previously had not been considered as a potential host rock for a repository, a presentation was made to the National Academy of Sciences (NAS) Committee for Radioactive Waste Management in September 1978 to solicit its views on the potential advantages and disadvantages of tuff as a repository host rock. The NAS committee supported the concept of investigating tuff as a potential host rock, and the USGS subsequently pointed out the considerable advantages of locating a repository in the unsaturated zone. After comparing the results of preliminary exploration at Calico Hills, Wahmonie, and Yucca Mountain, the USGS recommended that attention be focused on Yucca Mountain. A technical peer-review group supported the DOE's decision to concentrate exploration efforts on the tuffs of Yucca Mountain (DOE, 1980b).

Because the foregoing process of selecting Yucca Mountain for early exploration was not highly structured, a more thorough, formal analysis was begun in 1980 to evaluate whether Yucca Mountain was indeed appropriate for further exploration. This analysis was conducted in a manner compatible with the area-to-location phase of site screening described in the national siting plan (DOE, 1982b), which was used by the DOE before the passage of the Act and the formulation of the guidelines. Details of the formal analysis are presented by Sinnock and Fernandez (1984). In brief, this formal decision analysis evaluated 15 potential locations and concluded that Yucca Mountain was indeed the preferred location. Several potentially suitable horizons were identified in the saturated and unsaturated zones. Therefore, the DOE identified Yucca Mountain as a potentially acceptable site in February 1983.

1.2.4 NOMINATION OF SITES FOR CHARACTERIZATION

The guidelines, in 10 CFR Part 960.3, require the DOE to implement the following six-part decision process in selecting sites for nomination from among the potentially acceptable sites:

1. Evaluate the potentially acceptable sites in terms of the disqualifying conditions specified in the guidelines.

2. Group all potentially acceptable sites according to their geohydrologic settings.

3. For those geohydrologic settings that contain more than one potentially acceptable site, select the preferred site on the basis of a comparative evaluation of all potentially acceptable sites in that setting.

4. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for the development of a repository under the qualifying condition of each applicable guideline.

5. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for site characterization under the qualifying condition of each applicable guideline.

6. Perform a reasonable comparative evaluation under each guideline of the sites proposed for nomination.

Section 1.3 presents the results of evaluating the nine potentially acceptable sites against the disqualifying conditions of the guidelines (step 1) and explains how the DOE has grouped the potentially acceptable sites by geohydrologic setting (step 2). Chapter 2 begins with a detailed description of the geohydrologic setting in which the Deaf Smith site is located and provides the basis for the identification of a preferred site in that geohydrologic setting (step 3). Chapter 6 evaluates the site against the guidelines and presents the findings required in steps 4 and 5. Chapter 7 provides a comparative evaluation of the sites proposed for nomination (step 6).

Having issued the final EAs, the DOE will formally nominate five sites as suitable for characterization. The Secretary of Energy will then recommend three of these sites to the President as candidate sites for characterization. The Secretary's recommendation is presented and documented in a separate report that is being issued simultaneously with this environmental assessment.

1.2.5 FINAL STEPS IN THE SITE-SELECTION PROCESS

After the President approves the sites recommended by the Secretary, characterization activities will begin at those sites. If site characterization reveals new information that shows that a site is unsuitable for development as a repository under the guidelines, the DOE will eliminate that site from further consideration and take steps to reclaim the site and to mitigate any significant adverse impacts caused by site characterization. In the event that a site is eliminated from further consideration during characterization, the DOE does not expect to substitute another site for characterization.

After characterization is completed, the DOE will again evaluate each site against the guidelines, prepare an environmental impact statement, and recommend one site to the President for the first repository. The President may then recommend the site to the Congress. At this point, the Governor or the legislature of the host State may submit to the Congress a notice of disapproval that can be overridden only by a joint resolution of both Houses of the Congress. If the notice of disapproval is not overridden, the President must submit another repository-site recommendation within 12 months. If no notice of disapproval is submitted, or if the notice of disapproval is overridden, then, as prescribed by the Act, the site designation is effective, and the DOE will proceed to file an application with the NRC to obtain a construction authorization for a repository at that site.

1.3 EVALUATION OF POTENTIALLY ACCEPTABLE SITES AGAINST THE DISQUALIFYING CONDITIONS OF THE GUIDELINES AND GROUPING INTO GEOHYDROLOGIC SETTINGS

1.3.1 EVALUATION AGAINST THE DISQUALIFYING CONDITIONS

Having evaluated the nine potentially acceptable sites against the disqualifying conditions in the guidelines, the DOE has found no evidence to support a finding that any site is disqualified. Details of this analysis are contained in Chapter 6, and a summary of findings for each disqualifying condition is presented in Section 2.3.

1.3.2 DIVERSITY OF GEOHYDROLOGIC SETTINGS AND TYPES OF HOST ROCK

Sections 960.3-1-1 and 960.3-1-2 specify that, to the extent practicable, sites recommended as candidate sites for characterization shall be located in different geohydrologic settings and shall have different types of host rock. This guideline-mandated diversity of geohydrologic settings and host rocks is consistent with similar requirements in the NRC's rule governing the disposal of high-level radioactive waste, 10 CFR Part 60. This requirement will protect against the possibility that future investigations might reveal a generic deficiency in a given rock type or within a given regional geohydrologic environment. Such deficiencies might lead to the disqualification of sites in that setting or rock type. If one rock type or geohydrologic environment were viewed initially as the most favorable for a repository, site nomination and recommendation might be dominated by sites in that type of host rock or geohydrologic environment. If later analyses revealed an unacceptable weakness in either the host rock or in the characteristics of the geohydrologic environment, all candidate sites might have to be eliminated. This could leave the program with no viable alternatives available without lengthy additional site exploration.

The guidelines (Part 960.2) define "geohydrologic setting" as a system of geohydrologic units located within a geologic setting. They further define "geohydrologic unit" as an aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system. A "geologic setting" encompasses thousands to hundreds of thousands of square miles and is characterized by general similarities in physiography, stratigraphy, structural style, and ground-water flow.

For the intents and purposes of the analyses contained in this environmental assessment, the term "geohydrologic setting" refers to a large and relatively distinct major geohydrologic province of the United States commonly identified and accepted in the technical literature. Such a geohydrologic province has recognizable distinct geologic, hydrologic, and geochemical characteristics and boundaries that distinguish it from other geohydrologic settings.

1.3.2.1 Geohydrologic classification system

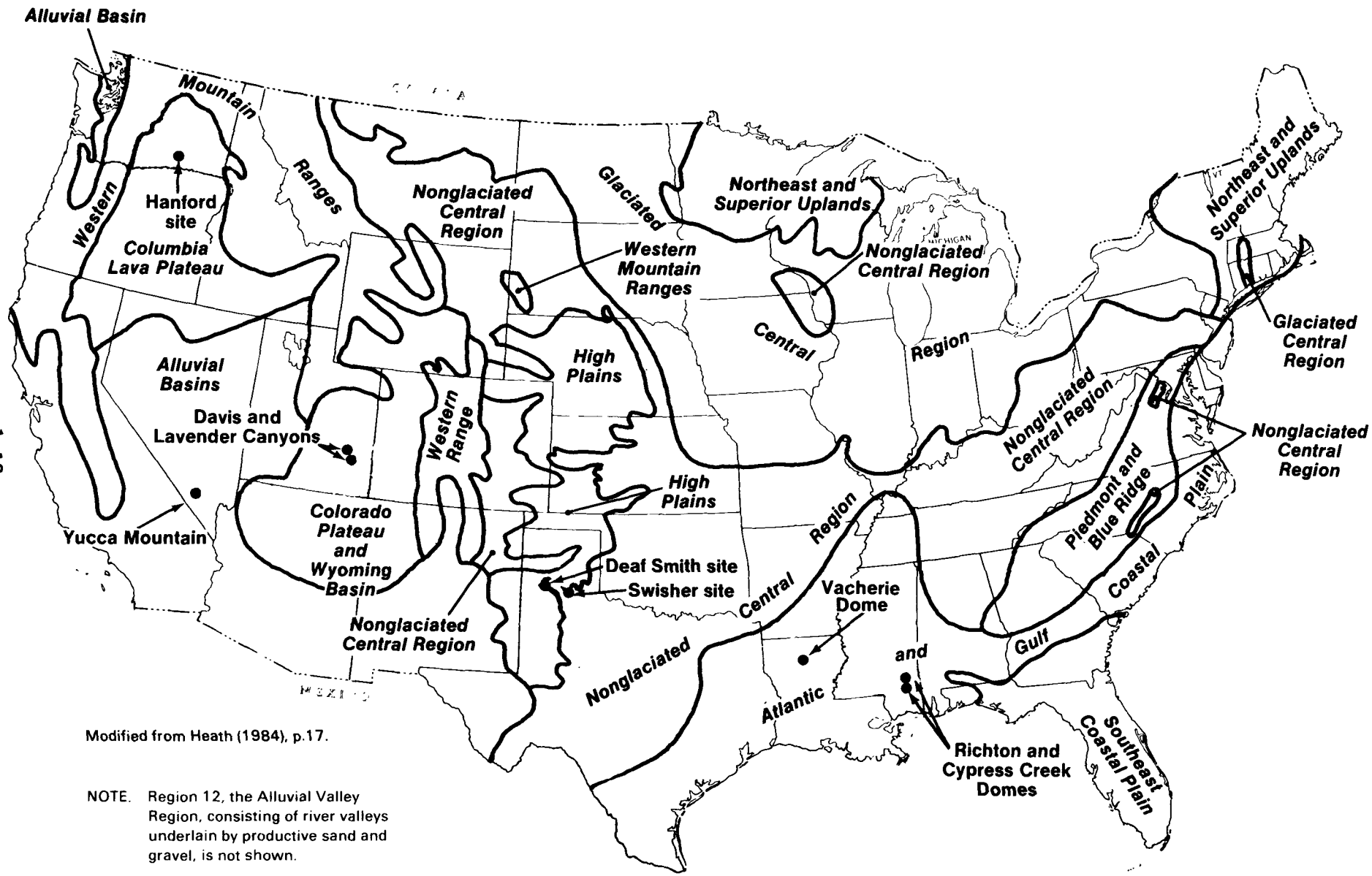
In a report entitled "Ground-Water Regions of the United States" (Heath, 1984), the USGS presents a classification that meets these broad criteria for geohydrologic settings. The USGS applied a logical set of criteria for classifying major geohydrologic regions that considers aquifers and confining units of the system, the nature of water-bearing openings in the rocks, the composition of the rocks, the water-transmitting and water-storage properties of the rocks, and the nature and location of recharge and discharge areas. These characteristics are also those that relate to repository performance (ground-water pathways, rates of radionuclide migration, and other factors important to waste isolation). Therefore, these general criteria appear suitable for application to this guideline requirement.

The USGS classification resulted in the delineation of 12 geohydrologic regions in the contiguous United States (see Figure 1-2). The specific rationale for the delineation and characteristics of each region is described in Heath's report.

It is within the framework of the USGS geohydrologic regions that the nine potentially acceptable sites were examined and classified as to their particular geohydrologic setting. In addition to the general criteria used in the USGS classification, other considerations were used to further subdivide the regions on the basis of tectonic activity, geologic structure, subbasins within the regions, and so on. Accordingly, the DOE has determined that the nine sites fall within the following five distinct geohydrologic settings (the name of the region within which each geohydrologic setting is located is listed in parentheses):

Geohydrologic setting	Site
Columbia Plateau (Columbia Lava Plateau)	Reference repository location as on the Hanford Site, Washington
Great Basin (Alluvial Basins)	Yucca Mountain, Nevada
Permian Basin (High Plains)	Deaf Smith County and Swisher County, Texas
Paradox Basin (Colorado Plateau and Wyoming Basin)	Lavender and Davis Canyons, Utah
Gulf Coastal Plain (Atlantic and Gulf Coastal Plain)	Vacherie Dome, Louisiana; Cypress Creek Dome and Richton Dome, Mississippi

The fundamental distinguishing characteristics associated with these settings as they relate to waste isolation are briefly described below. More-specific details on the characteristics of each of the geohydrologic settings are presented in Section 2.1.



Modified from Heath (1984), p.17.

NOTE. Region 12, the Alluvial Valley Region, consisting of river valleys underlain by productive sand and gravel, is not shown.

Figure 1-2. Geohydrologic regions of the contiguous United States.

1.3.2.2 Distinct differences among the geohydrologic settings and host rocks

The major distinguishing differences among the five geohydrologic settings of the nine potential repository sites are summarized below.

The Hanford and the Yucca Mountain sites are clearly unique in terms of the host rock, the geologic conditions, and the hydrologic conditions that make up the geohydrologic setting. The Hanford site is located within the Pasco Basin, which is a subunit of the Columbia Lava Plateau geohydrologic setting as defined by Heath (1984). It is underlain by a thick, extensive sequence of rocks composed entirely of basalt lava flows in the lower part and of increasing amounts of interbedded, sedimentary deposits in the upper part. Aquifers generally are in the upper parts of the lava flows and in the interbeds. Ground-water drainage is to the Columbia River or its tributaries.

The Yucca Mountain site is located in a region composed of alternating sequences of block-faulted mountains and alluvium-filled valleys of the Alluvial Basins geohydrologic setting as defined by Heath. Yucca Mountain is a typical small fault-block mountain in this region and is composed entirely of volcanic rocks called tuff. The site is in the relatively dry unsaturated welded zone, well above the water table. This is a unique geohydrologic setting in comparison with the other sites, which are all situated well below the water table. The Hanford site will rely principally on the interaction of the low permeability of the dense basalts, the ion-exchange characteristics of the host rock, and a long ground-water flow path for waste isolation. The Yucca Mountain site will rely principally on a very low water flux through unsaturated rocks in a very arid environment, the natural ability of this type of system to exclude flowing or standing water from the repository, and the sorption characteristics of the minerals in the host rock.

The salt-site settings are also clearly distinguishable from one another, but perhaps not as obviously as the nonsalt sites. The first distinction among the salt settings is between salt domes and bedded salt. Although both bedded and dome salt have salt as a host rock, the properties of the two types of salt are quite different, and the hydrologic framework of salt differs greatly from setting to setting. Bedded salt occurs as sedimentary layers of salt and impurities and is typically bounded by aquifers above or below the salt units or both. The domes are anomalous piercements of the thick unconsolidated to semiconsolidated sedimentary clays, silts, and sands that make up the Atlantic and Gulf Coastal Plain, as defined by Heath. The domes are surrounded by aquifers at different depths. Thus, the geohydrologic conditions around the domes are distinctly different from that of bedded salt.

The pathways and mechanisms by which radionuclides might reach the accessible environment are also quite different for bedded and dome salt because of their fundamental structural and stratigraphic differences. Salt domes originated from thick beds of deeply buried salt. When sediments were deposited on these salt beds, the salt was forced upward, forming a dome. Some domes have risen as much as 20,000 feet above their source rock. The salt rock was intensely deformed and "kneaded" during this intrusive rise of the salt dome; as a result, nearly all of the water originally contained in the salt was squeezed out. Consequently, salt domes contain less water than

salt beds. In addition, and largely because of the different mode of formation, the following differences between the two types of salt rock are noteworthy:

- Because of its higher water content, bedded salt has a lower strength than dome salt.
- At equal depths of burial, bedded salt has lower geothermal temperatures than dome salt.
- Bedded salt tends to have a faster rate of creep than dome salt.
- Bedded salt has a more variable chemical composition than dome salt.
- Bedded salt has a simpler structure than salt domes.

Some of the most important of the above factors affecting waste isolation at salt sites are related to the chemical composition and configuration of the host rock. All salt sites would rely primarily on the extremely low permeability of the salt and the isolation of the host rock from surrounding aquifers. One significant potential failure mechanism in salt that can affect ground-water flow is the dissolution of the salt in ground water, whether initiated by inadvertent human intrusion or by unexpected salt deformation. The nature and the relative importance of this failure mechanism differ significantly for bedded and dome salt in their respective geohydrologic environments. For example, at salt domes dissolution would occur along the flanks by ground water from surrounding sedimentary strata. The dissolution of bedded salt could be induced by laterally migrating dissolution fronts, inter-salt-bed sedimentary aquifers, or vertically circulating water in fault zones.

Finally, although the Paradox Basin in Utah and the Permian Basin in Texas are both bedded-salt settings, they also have significant differences that warrant considering them as separate and distinct geohydrologic settings. The bedded-salt sites in Swisher and Deaf Smith counties, Texas, are located in the High Plains setting as defined by the USGS. This setting is underlain by relatively horizontal bedded sedimentary rocks that are capped by the partially unconsolidated sands, gravels, and clays of the Ogallala Formation. The geohydrologic system is dominated by the High Plains aquifer (the Ogallala Formation). Other aquifers, such as the Triassic Dockum Group, occur in deeper strata, but they produce poor-quality water in comparison with the Ogallala.

The bedded-salt sites of Davis Canyon and Lavender Canyon, Utah, on the other hand, are located in the Paradox Basin, which is a subsetting of the Colorado Plateau and the Wyoming Basin and is characterized by a broad uplifted plateau consisting of gently folded sedimentary sandstones, shales, carbonates, and evaporites. The stratigraphic sequence includes a few low-yield aquifers that generally contain poor-quality water. Ground water generally flows toward drainage systems in deeply dissected canyons of the region. Other specific differences include the following:

- Because of overburden and tectonic stresses, the Paradox Basin salt deposits have been structurally deformed into anticlines and synclines

(thickened and thinned zones) much more than the Permian Basin salt deposits have.

- The recharge and discharge patterns of ground water in the two settings are expected to be significantly different.

- The age, stratigraphic sequence, depositional history, and mineral composition of the salts and interbeds in two settings are different.

- The elevation, climate, and physiography of the two settings are significantly different.

- The ground-water system of the Paradox Basin sites is dominated by a deep aquifer well below the repository level, of low yield and poor water quality, whereas the ground-water system at the Permian Basin sites is dominated by a shallow productive aquifer well above the repository level.

On the basis of the criteria and known site characteristics presented above, the DOE has concluded that the nine potentially acceptable sites lie within five distinctly different geohydrologic settings, as indicated, and four distinctly different types of host rock (basalt, welded tuff, bedded salt, and dome salt).

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Chapter 2

SITE SELECTION - PERMIAN BASIN

As discussed in Section 1.2.2.3, site screening activities have identified the Deaf Smith County and Swisher County bedded salt sites within the Permian Basin as acceptable salt sites for further study as potential nuclear waste repository sites.

The Deaf Smith County site is located approximately 56 kilometers (35 miles) west of Amarillo, Texas (Figure 2-1). The geologic repository operations area of the Deaf Smith County site would be located within a 23.3-square-kilometer (9-square-mile) area centered at 35° 07' N latitude and 102° 29' W longitude. The Swisher County site is located approximately 64 kilometers (40 miles) south of Amarillo, Texas (Figure 2-1). The geologic repository operations area of the Swisher site would be located within a 23.3-square-kilometer (9-square-mile) area centered at 34° 38' N latitude and 101° 42' W longitude.

This chapter describes the process and analysis used to identify and select a preferred site within the Permian Basin (Figure 2-2). Section 2.1 describes the geohydrologic setting of the region; Section 2.2 details how potentially acceptable sites were identified; Section 2.3 summarizes an evaluation of the identified sites against explicit disqualifying conditions set forth in U.S. Department of Energy (DOE) guidelines for siting repositories (10 CFR Part 960); and Section 2.4 is a comparative evaluation of the Deaf Smith County and Swisher County sites that identifies the Permian site being nominated for site characterization.

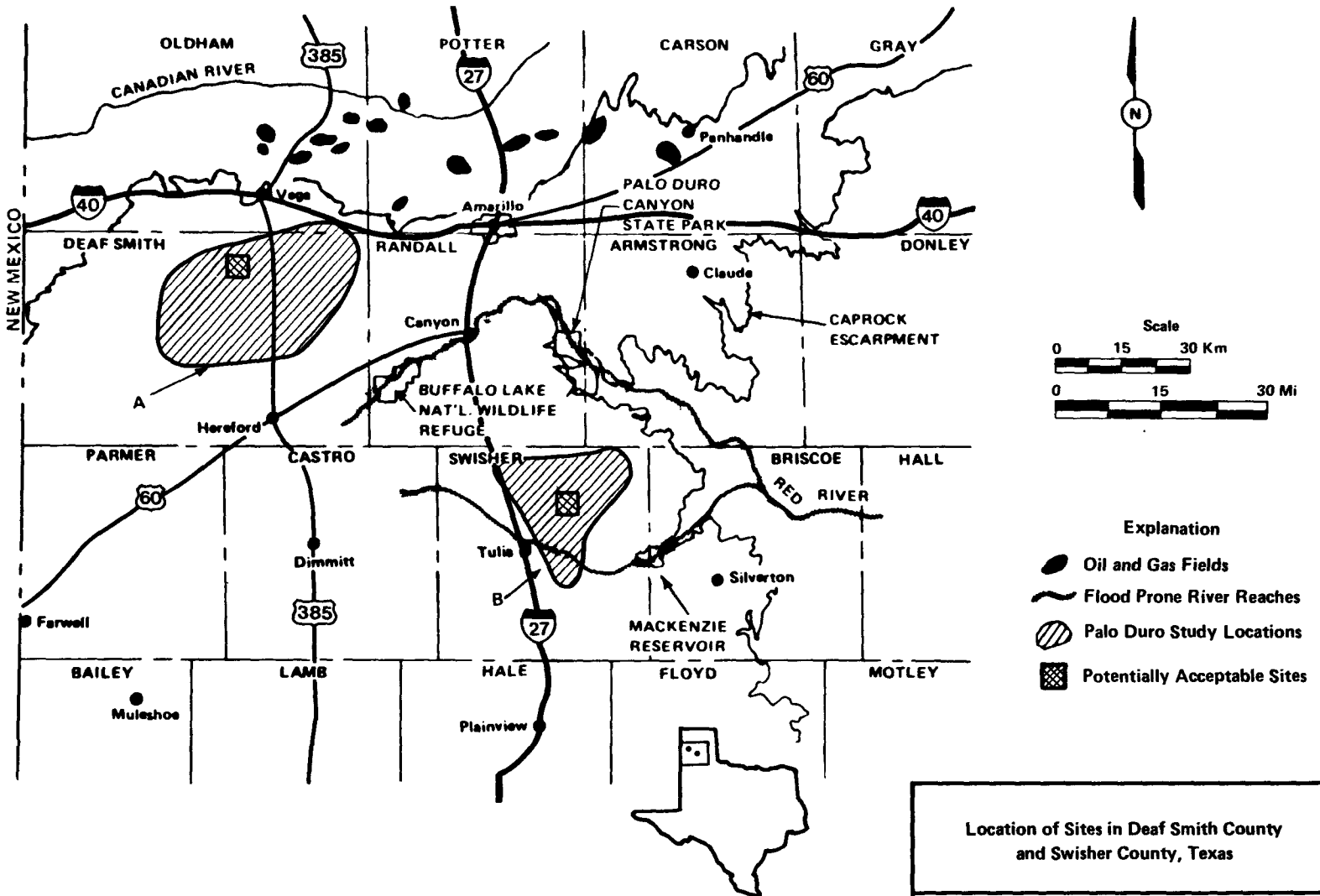
2.1 GEOHYDROLOGIC SETTING

As discussed in Section 1.3.2.1, the Deaf Smith County and Swisher County bedded salt sites are located in the same regional geohydrologic setting, the Permian Basin. "Geohydrologic setting" is defined in 10 CFR 960.2 as a system of geohydrologic units located within a geologic setting. "Geohydrologic unit" is further defined as an aquifer, a confining unit, or a combination of aquifers and confining units making up a framework for a reasonably distinct geohydrologic system. "Geologic setting" refers to the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

This summary description of the Permian Basin geohydrologic setting centers on the Palo Duro Basin, a subbasin within the Permian Basin in which the Deaf Smith County and Swisher County sites are located. This description provides a general overview of the regional characteristics on which the site identification and screening process was conducted.

The Permian Basin (Figure 2-3) is a large region of the southwestern United States in which Permian-age salts and other evaporites were deposited along with thick sequences of reddish-brown shales, sandstones, and carbonates. This region, located within the tectonically stable interior of North America, lies in the southern portions of the Central Lowland and the Great Plains Physiographic Provinces and includes the western parts of Kansas, Oklahoma, and Texas and the eastern parts of Colorado and New Mexico (Johnson and Gonzales, 1978; NUS, 1983, ONWI-28). The five principal structural basins of the Permian Basin are the Delaware, Midland, Palo Duro, Anadarko, and Dalhart Basins (Figure 2-3).

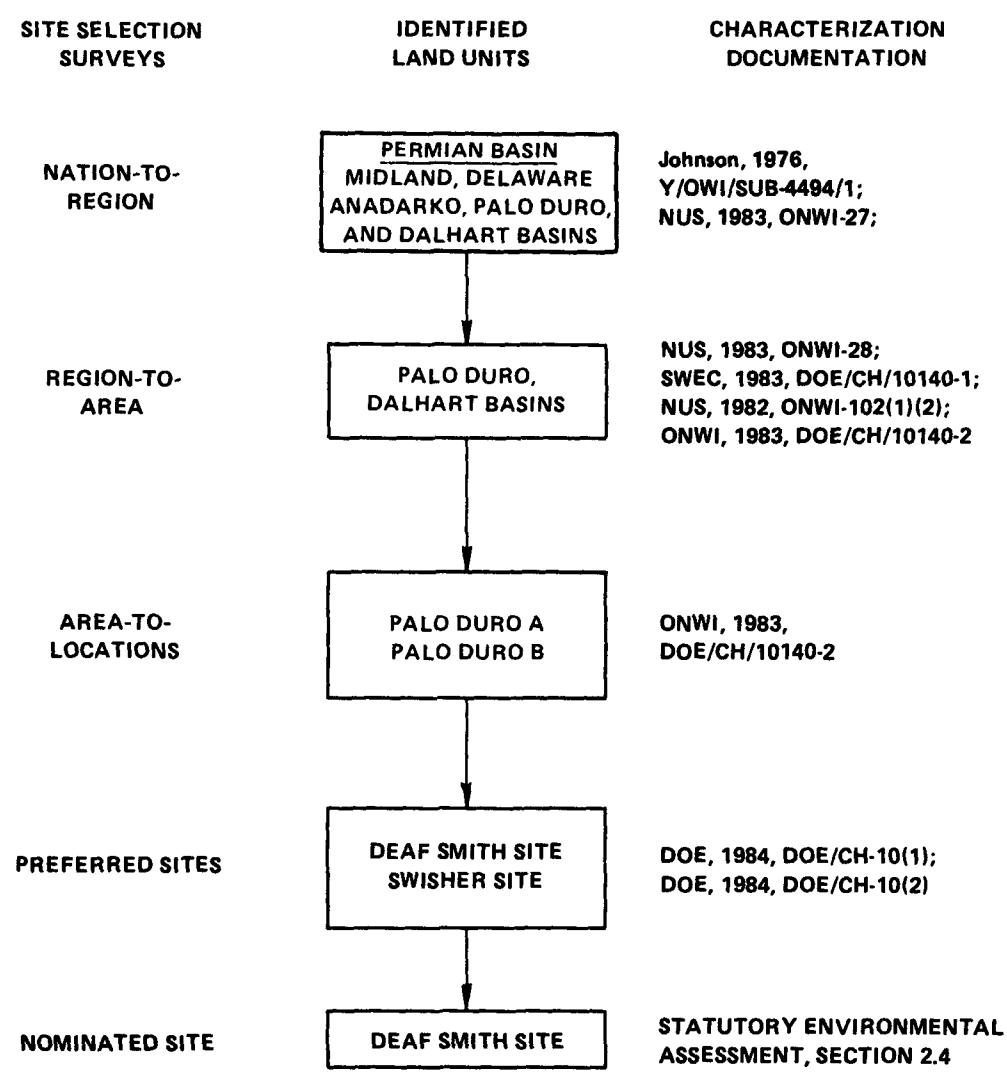
The Deaf Smith County and Swisher County sites within the Permian Basin are in the nearly flat, relatively undissected Southern High Plains of the Texas Panhandle. Surface drainage consists mainly of east-flowing streams and rivers whose headwaters are either in eastern New Mexico or in the west Texas Panhandle area. These rivers are mostly supplied by precipitation and runoff, but some are locally fed by springs emerging from the Tertiary Ogallala Formation and from Triassic and Permian sandstone, gypsum, and dolomite aquifers. Surface water resources of the region are generally limited. Smaller streams are dry for part of the year and provide mostly seasonal water habitats. Average annual precipitation ranges from about 40 to 60 centimeters (16 to 24 inches) in the west part to about 60 to 75 centimeters (24 to 30 inches) in the east part of the basin.



Source: Modified from ONWI, 1983, DOE/CH/10140-2, Figure 6-3.

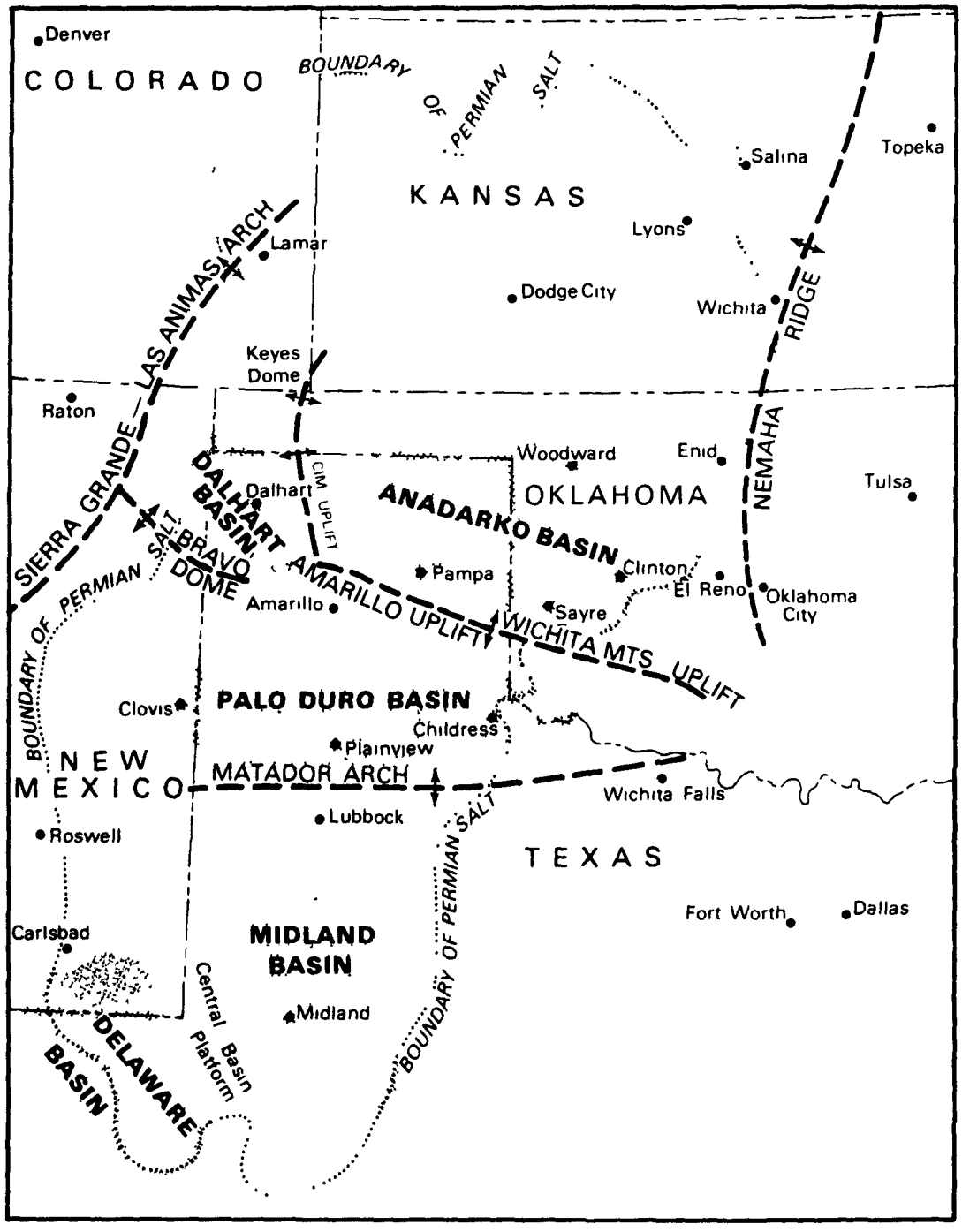
Location of Sites in Deaf Smith County and Swisher County, Texas

Figure 2-1



Permian Basin Screening Process

Figure 2-2



Map of Permian Basin Salt Area in Southwestern United States Showing Principal Tectonic Provinces

Source Johnson and Gonzales, 1978.

Figure 2-3

The Palo Duro Basin is about 240 kilometers (150 miles) long and 130 kilometers (80 miles) wide (Figure 2-3). Compared to basins to the north and south within the Permian Basin, the Palo Duro Basin is relatively shallow. Depth to the Precambrian basement within the Palo Duro Basin ranges from 1,500 to more than 3,000 meters (5,000 to more than 10,000 feet).

The igneous and metamorphic basement rock in the Palo Duro Basin is overlain by a sedimentary sequence consisting of Cambrian sandstones, Ordovician dolomites, Mississippian carbonates, Pennsylvanian granite wash (coarse detrital material), carbonates, sandstone, and shale. These are overlain by a thick Permian sequence consisting of limestone, shale, dolomite, some granite wash, and thick evaporites, the thickest salt portion of which is considered potentially suitable for a nuclear waste repository. Shale, sandstone, and conglomerate of the Triassic Dockum Group overlie Permian strata and are in turn overlain by clastics of the Tertiary Ogallala Formation and Pleistocene and Holocene deposits (Figure 2-4).

All the salt (sodium chloride) deposits in the region are of Permian age. Salt beds typically have interbeds of shale, anhydrite, limestone, or dolomite and also commonly grade laterally into one or several of these rock types away from the area of salt deposition. Salt-bearing units are commonly 60 to more than 300 meters (197 to more than 985 feet) thick, and there are many parts of the Permian Basin with thick salts 300 to 900 meters (985 to 2,955 feet) below the surface.

Dissolution of salt beds is occurring at shallow depths across most of the Permian Basin, although at some places the dissolution occurs as deep as 300 meters (985 feet) and at other places salt is still present as shallow as 10 meters (33 feet) below the surface (Johnson and Gonzales, 1978). Because of dissolution, salt beds do not crop out in the Permian Basin. Peripheral dissolution is also currently active along the western, northern, and eastern salt margins of the Palo Duro Basin.

The geohydrologic units in the Palo Duro Basin consist of an upper potable water aquifer (the Ogallala Formation and the Dockum Group, referred to jointly as the High Plains aquifer), a middle aquitard unit (the Permian evaporite sequence) and a lower nonpotable aquifer (the lower Permian and Pennsylvanian carbonates, sandstone, and granite wash; the Mississippian and Ordovician carbonates; and, locally, the Cambrian sandstones [Handford, 1980, p. 47]). (See Figure 2-4.)

Recharge to the High Plains aquifer is principally from precipitation collected in playa lakes. Recharge to the deep aquifers occurs in limited updip outcrop areas of these units to the west in New Mexico. Discharge from the lower aquifer units is primarily to the east (Bentley, 1981, p. 95).

With the exception of the Ogallala Formation and parts of the Triassic Dockum Group, rocks in the Palo Duro Basin contain strongly saline water, except locally at and near the outcrop where they may be flushed by meteoric recharge. The High Plains aquifer is at fairly shallow depth and is stratigraphically above the Permian salt deposits that might be used for waste storage.

2.2 IDENTIFICATION OF POTENTIALLY ACCEPTABLE SITES

The process for identifying sites consisted of a systematic screening, accomplished by a stepwise succession of surveys. In each phase, studies were conducted to evaluate land units against established criteria (DOE, 1981, DOE/NWTS-33[2]), which included geologic, hydrologic, geochemical, demographic, environmental, and socioeconomic factors. The decision as to which successively smaller land unit represented the most promising area for further study was made using those criteria that best provided a means of differentiation at each screening step. Not all performance criteria were used at each step of the screening process because either the criteria were not useful for screening large land units, or the data were insufficient to discriminate between smaller land units.

ERA	SYSTEM	SERIES	GROUP	FORMATION
CENOZOIC	QUATERNARY			RECENT FLUVIAL AEOLIAN AND LACUSTRINE DEPOSITS
	TERTIARY			OGALLALA AND LACUSTRINE DEPOSITS
	CRETACEOUS	COMANCHE	WASHITA	
			FREDRICKSBURG	
MESOZOIC			TRINITY	
	TRIASSIC		DOCKUM	TRUJILLO (Santa Rosa)
				TECOVAS
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE (Quartermaster)
				ALIBATES
		GUADALUPE	ARTESIA (WHITEHORSE)	SALADO-TANSILL
				YATES
				SEVEN RIVERS
				QUEEN-GRAYBURG
			PEASE RIVER	SAN ANDRES (BLAINE)
		LEONARD		GLORIETA
			CLEAR FORK	UPPER CLEAR FORK
				TUBB
				LOWER CLEAR FORK
				RED CAVE
			WICHITA	
		WOLFCAMP		
	PENNSYLVANIAN	VIRGIL	CISCO	
		MISSOURI	CANYON	
		DES MOINES	STRAWN	
		ATOKA	BEND	
		MORROW		
	MISSISSIPPIAN	CHESTER		
		MERAMEC		
		OSAGE		
	ORDOVICIAN	CANADIAN	ELLENBURGER	
	CAMBRIAN		UNNAMED SANDSTONE	
	PRECAMBRIAN			

Explanation

~~~~~ Unconformable Boundary

·— — — Boundary in Dispute

( ) Formation Name in Outcrop

Note: See Table 3-2 for expanded column of Cenozoic formations.

Sources: Handford and Dutton, 1980; Dutton et al., 1982; Barnes, 1967, 1968, 1969, 1983; Brand, 1953; Fink, 1963.

Stratigraphic Column of the Palo Duro Basin

Figure 2-4
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2.2.1 Region-to-Area Screening

In 1976, a geologic study of the Permian-age salt deposits in the Texas Panhandle and western Oklahoma was conducted to determine whether they contained areas that might be suitable for waste storage (Johnson, 1976). This study focused on the Anadarko, Palo Duro, Dalhart, Midland, and Delaware Basins within the Permian Basin (Figure 2-3). All of these basins contained salt-bearing units which are located at reasonable depths and are thick enough to make them eligible for further study. Additional regional geologic and environmental characterization studies were performed from 1976 to 1979 (NUS, 1983, ONWI-27).

For each of the DOE/NWTS-33(2) (DOE, 1981) criteria, technical screening factors were developed to help determine which land units were suitable for further characterization. The factors consisted of thickness and depth of salt-bearing units, faults, seismic activity, salt dissolution, boreholes, underground mines, proximity to aquifers, mineral resources, and conflicting land use. The environmental and socioeconomic criteria factors included exclusionary areas such as historic sites and national and state parks. (Only those areas in excess of 405 hectares [1,000 acres] that are protected by legislation were considered exclusionary.) The following paragraphs summarize the technical factors for each basin.

Permian-age (220 to 280 million years) and younger rocks are almost entirely free of tectonic deformation. The entire region lies within Seismic Risk Zone 1, which indicates a region of relatively low seismic potential. Some salt dissolution has occurred in deposits within approximately 180 to 425 meters (600 to 1,400 feet) (NUS, 1983, ONWI-28, p. 5) of the surface in the Palo Duro, Dalhart, and Anadarko Basins.

In the Midland, Delaware, and Anadarko Basins, three of the major oil-producing areas of the United States, many boreholes have been drilled through the salt units in search of oil and gas. In contrast, oil and natural gas occur only in small fields in the Dalhart and Palo Duro Basins, and few boreholes have been drilled through the salt units there.

The Ogallala aquifer, which underlies a large part of the region of the study, is absent in parts of the Delaware Basin, in the northeastern part of the Midland Basin, in the southern part of the Dalhart Basin, between the Dalhart and Palo Duro Basins, and in part of the south-central Anadarko Basin.

Substantial portions of the Midland Basin are included in restricted, alert, or military operations areas. Part of the Delaware Basin is also within such areas. In contrast, the Palo Duro and Anadarko Basins contain only small portions of these areas, and the Dalhart Basin contains none.

Based on the results of the regional evaluations, the Palo Duro and Dalhart Basins were considered preferable to the Midland, Delaware, and Anadarko Basins and were recommended for area characterization (NUS, 1983, ONWI-28, p. 50). The basis for these recommendations included the following:

- Numerous salt-bearing formations greater than 61 meters (200 feet) thick between depths of 305 and 914 meters (1,000 and 3,000 feet)
- Low levels of historic seismicity
- Absence of major, known petroleum deposits
- Relatively few exploratory boreholes that penetrate through all of the salt units
- No known significant economic mineral deposits
- No evidence of ongoing salt dissolution at depths greater than 425 meters (1,400 feet)

- No recognized geologic, hydrologic, environmental, or socioeconomic factors that preclude further study.

2.2.2 Area-to-Location Screening

Geologic and environmental factors were evaluated in greater detail for the Palo Duro and Dalhart Basin area-to-location screening studies. Existing sources of information were used and additional field studies were conducted at each area as needed.

Geologic field studies were begun in 1977 by the Texas Bureau of Economic Geology (Bureau of Economic Geology, 1977) to investigate the geologic and hydrologic aspects of the areas. During the area-to-location survey, 10 boreholes had been or were being drilled, selectively cored, and tested. The core samples, geophysical logs, and hydrologic test data were analyzed to determine the lithologic and hydrologic properties of the rocks in the stratigraphic section. Environmental studies of the Palo Duro and Dalhart Basins began in 1977 and were completed in 1980, and after a Texas State review, the study results were published in 1982 (NUS, 1982, ONWI-102[1][2]). Area characterization reports (NUS, 1982, ONWI-102[1][2]; SWEC, 1983, DOE/CH/10140-1) present technical results of environmental and geologic studies. A detailed discussion of the location selection process can be found in the Permian Basin Location Recommendation Report (ONWI, 1983, DOE/CH/10140-2). Screening specifications were developed for each criterion. Those found useful in the area-to-location screening, shown in Table 2-1, consisted of salt depth and thickness, salt purity, existing and abandoned oil and gas fields, flooding, urban areas, and conflicting land use.

The locations that warranted further consideration are shown in Figure 2-5; all are in the Palo Duro Basin and all met the depth, thickness, and salt purity screening criteria. Examination of the salt-bearing units within the Dalhart Basin showed that none of the salt units met the thickness specification of Criterion I (38 meters [125 feet]); this basin was deferred from further study. Subsequent application of the remaining specifications in the Palo Duro Basin for Criteria VII, VIII, and IX (Table 2-1) did not change those configurations. As a result, the locations labeled A through F in Figure 2-5 were identified as having favorable characteristics.

To further differentiate among Palo Duro Basin Locations A through F, the following set of factors was applied:

- Distance from the margins of the Southern High Plains, where topography is irregular, erosion rates are high, and salt dissolution may occur in the potential repository horizon
- Distance from known oil and gas fields
- More than one potential repository horizon
- Salt occurrence at depths as shallow as possible while maintaining a thick rock section between the potential repository horizon and the surface
- Relatively few boreholes that penetrate the potential repository horizon
- A large continuous geographic area to provide flexibility in siting
- Low population densities
- No unique land-use conflicts.

Each of the locations was examined with respect to these factors. Locations A and B were found to possess most of these favorable characteristics and no highly unfavorable characteristics; Locations C, D, E, and F were found to possess several unfavorable characteristics (ONWI, 1983, DOE/CH/10140-2), such as proximity to urban areas and to known oil and gas fields.

Table 2-1. Permian Basin Area-to-Location Screening Criteria

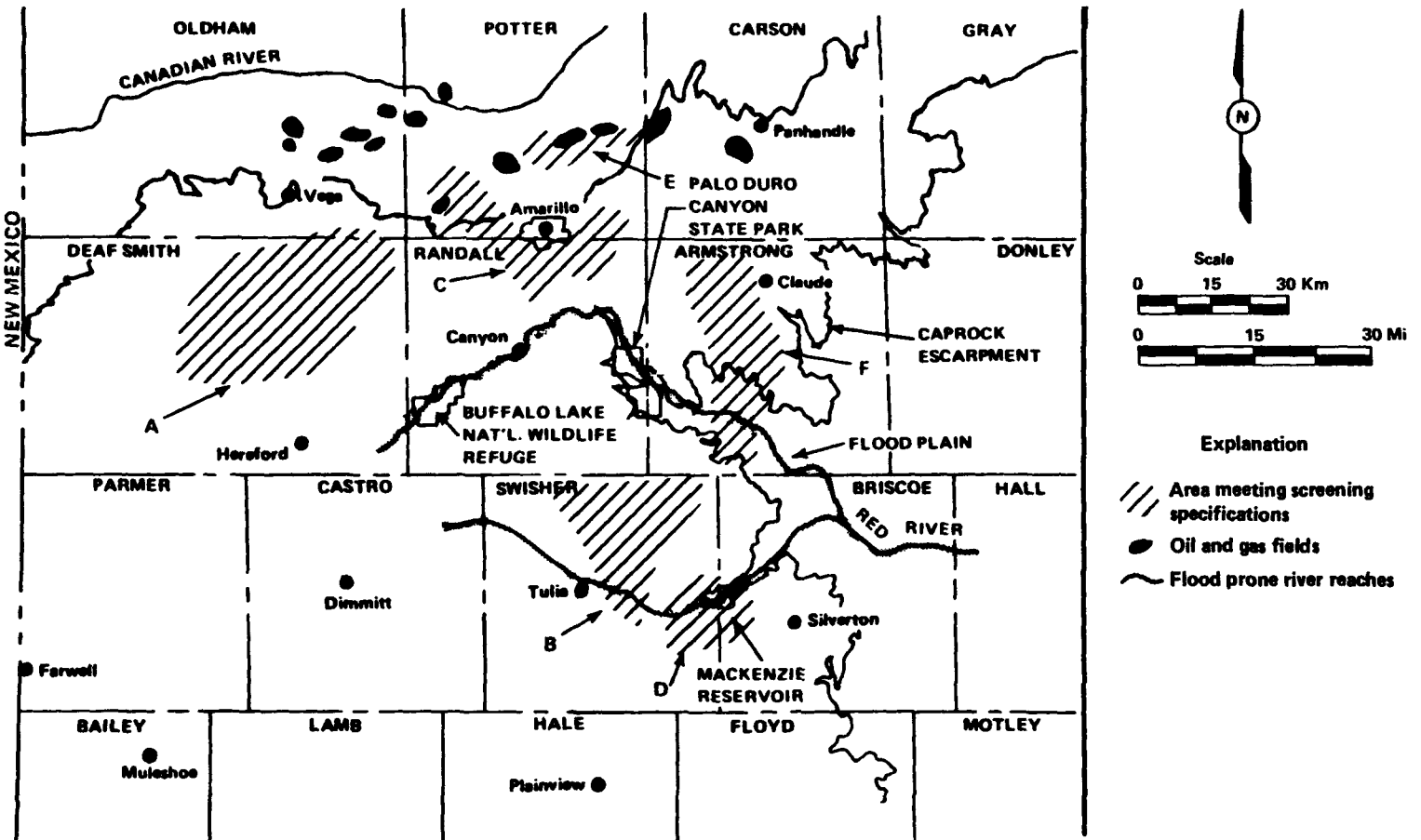
Criteria[a]		Technical Factors	Specification[b]
I.	Site Geometry	1. Minimum depth 2. Maximum depth 3. Minimum thickness	305 m (1,000 ft) 915 m (3,000 ft) 38 m (125 ft)[c]
IV.	Geologic Characteristics	Host-rock characteristics	Gamma-ray geophysical log response of 15 API[d] units or less (indicative of "massive salt")
VI.	Human Intrusion	Oil or gas resources	Avoid existing/abandoned fields
VII.	Surface Characteristics	Flooding	Defer 1.6 km (1 mile) on either side of perennial streams
VIII.	Demography	Urban areas	Exclude standard metropolitan statistical areas (SMSA)
IX.	Environmental Protection	Conflicting land use	Avoid wildlife refuges, reservoirs

(a) DOE, 1981, DOE/NWTS-33(2).

(b) ONWI, 1983, DOE/CH/10140-2, p. 70.

(c) Several salt thicknesses between 21 and 61 meters (70 and 200 feet) have been suggested for use in screening potential bedded-salt host rocks. While a salt thickness of 61 meters (200 feet) was used for screening in the Region-to-Area phase, the salt thickness specification for screening in the Area-to-Location phase was lowered to 38 meters (125 feet). This was determined to be require appropriate thickness to accommodate repository workings (emplacement, ventilation, and access drifts), with upper and lower salt "buffer" zones, and to allow additional thickness for local rock variations in the salt unit. The salt thickness for a final repository design may require less than 38 meters (125 feet), and will depend upon site specific stratigraphy and rock properties that will be evaluated in site characterization (ONWI, 1983, DOE/CH/10140-2 p. 52).

(d) API = American Petroleum Institute.



Identified Locations in Palo Duro Basin

Source: ONWI, 1983, DOE/CH/10140-2, Figure 6-2.

Figure 2-5

As a result of the area-to-location screening activities, it was determined that future repository siting and characterization efforts would focus on Palo Duro Location A (northeastern Deaf Smith and southeastern Oldham Counties) and Palo Duro Location B (northcentral Swisher County) because these locations had the greatest likelihood of containing suitable sites with the fewest licensing issues or concerns.

2.2.3 Preferred Site Identification Screening

The two locations in Deaf Smith and Swisher Counties were more than 500 square kilometers (200 square miles) in area. In accordance with Section 116(a) of the Nuclear Waste Policy Act (NWPA) (42 USC Sections 10101-10226), the DOE sent letters to the governor and legislature of Texas in February 1983 to formally notify the State that the DOE considered that Texas contained potentially acceptable sites.

Additional environmental and geologic characterization studies were performed, and the information relating to each discriminator was mapped. Results of environmental characterization studies are documented in a series of topical and technical reports (NUS, 1984, ONWI-461, BMI/ONWI-508-510, BMI/ONWI-526-528, BMI/ONWI-558-560; NUS, 1985, BMI/ONWI-557, 574, 575; NUS, 1985a, b, c, d). Results of geologic characterization studies are documented in several technical reports (SWEC, 1983, DOE/CH/10140-1; INTERA, 1984, ONWI-504; ONWI, 1983, DOE/CH/10140-2; DOE, 1984, DOE/CH-10[1][2][3]).

The focusing to small sites within Palo Duro Locations A and B was accomplished by a stepwise screening process (DOE, 1984, DOE/CH-10[1][2][3]). As in prior screening phases, the DOE/NWTS-33(2) criteria were used as the foundation upon which the process was constructed. A set of descriptors was developed for each criterion. Those characteristics or parameters useful in discriminating sites are listed in Table 2-2.

In the Palo Duro Basin, the required site area was tentatively selected as approximately 23.3 square kilometers (9 square miles) in a square configuration (DOE, 1984, DOE/CH-10[1], p. 101). In addition to approximating the required controlled area (area required for underground repository operations and buffer strip), this size and configuration permit flexibility and minimization of impacts during repository construction.

The discriminators were grouped and prioritized according to whether they could, in descending order of importance, affect (1) long-term performance, (2) operational performance, or (3) environmental and constructibility impacts (see Table 2-3).

Composite maps of the discriminators within each grouping were prepared and applied in order of priority to accomplish a stepwise screening of the locations. In many cases, a discrete boundary between more-preferred and less-preferred areas did not exist. In such instances, a boundary was chosen which would put no more than one-half of the location in the preferred area for any one discriminator. Screening through all of the priority groups was not required because the preferred size of 23.3 square kilometers (9 square miles) within each location was identified before the lower group of discriminators was used.

The two sites identified by this screening process are referred to as the Deaf Smith County and Swisher County sites.

2.3 DISQUALIFICATION EVALUATION OF THE PERMIAN BASIN SITES

The DOE is required to nominate at least five as suitable for further site characterization (NWPA, Section 112[b]). The first step in the nominating process, as required by 10 CFR 960.3-2-2, is to evaluate each site against the disqualifying conditions specified in the technical siting guidelines of 10 CFR 960.4-2 and 10 CFR 960.5-2.

A disqualifying condition is defined in 10 CFR 960.2 as a condition that, if present at a site, would eliminate that site from further consideration. A site may be disqualified at any time during the siting process if the evidence supports a finding by the DOE that a disqualifying condition exists or the qualifying condition of any system or technical guideline cannot be met (10 CFR 960.3-1-5).

Table 2-2. Permian Basin Location to Potentially Acceptable Site Discriminators

I.	Site Geometry	
		Thickness of Host Rock (a)
II.	Geohydrology	
		Recent Saturated Thickness of the Ogallala
		Depth to Base of Dockum
IV.	Geologic Characteristics	
		Depth to Host Rock
VI.	Human Intrusion	
		Location of Boreholes Reaching Host Rock
		Hydrocarbon Resource Potential
VII.	Surface Characteristics	
		Proximate Streams and Floodplains (probable maximum flood areas)
		Proximate Water Bodies (playas)
		Proximate Impoundments[a]
		Proximate Transportation Installations (paved roads, pipelines, and electrical transmission facilities)
VIII.	Demography	
		Population Density[b]
		Population Risk-Operations
IX.	Environmental Protection	
		Cultural Resources
		Aesthetics
		Ecological Habitat
		Prime Farmland
		Industrial or Commercial Installations
		Proximity to Road Access (major highways)
		Proximity to Rail Rights-of-Way
		Projected Saturated Thickness of Ogallala Aquifer in the Year 2030[c]

(a) Not a discriminator at Palo Duro Location A.

(b) Not used as a discriminator since the city of Tulia was excluded from consideration per NWPA Section 112(a). (See DOE, 1984, DOE/CH-10[2], pp. 78-81, 106).

(c) Not a discriminator at Palo Duro Location B.

Source: DOE, 1984, DOE/CH-10(1), p. vii; DOE, 1984, DOE/CH-10(2), p. vii.

Table 2-3. Discriminator Groupings for Site Selection

Category	Discriminator
Long-Term Performance	Thickness of Host Rock[a] Location of Boreholes Reaching Host Rock Hydrocarbon Resource Potential
Operational Performance	Population Risk-Operations
Environmental/Constructibility Impacts	
Priority 1	Ecological Habitat Projected Saturated Thickness of the Ogallala in the Year 2030[b]
Priority 2	Recent Saturated Thickness of the Ogallala Depth to Host Rock
Priority 3	Proximity to Rail Rights-of-Way Proximity to Road Access
Priority 4	Proximate Streams and Floodplains (probable maximum flood (PMF) areas) Proximate Water Bodies (playas) Depth to Base of Dockum
Priority 5	Cultural Resources Prime Farmland Aesthetics
Priority 6	Proximate Transportation Installations (paved roads, pipelines, and electrical transmission facilities) Proximate Impoundments[a] Industrial or Commercial Installations

(a) Not a discriminator in Palo Duro Location A.
(b) Not a discriminator in Palo Duro Location B.

Source: DOE, 1984, DOE/CH-10(1), p. viii; DOE, 1984, DOE/CH-10(2), p. viii.

The evaluation of site information against the explicit disqualifying conditions set forth in the technical guidelines of 10 CFR 960.4 and 10 CFR 960.5 is summarized in Table 2-4. This table summarizes the present rationale for not disqualifying either of these sites. Based on the data and analyses, no evidence was found to disqualify either of the identified Palo Duro sites as possible repository sites. On that basis, the Deaf Smith County and Swisher County sites were determined to be suitable candidates for possible subsequent nomination for further site characterization studies.

2.4 COMPARATIVE EVALUATION OF SITES WITHIN THE PERMIAN BASIN GEOHYDROLOGIC SETTING, AND SELECTION OF THE PREFERRED PERMIAN BASIN SITE

This section compares the two sites in the Permian Basin and concludes that, by a small margin, the site in Deaf Smith County is the preferred site. A review of the siting guideline findings indicates that there are six guideline conditions (one postclosure and five preclosure) which discriminate between the Deaf Smith and Swisher County sites. On the basis of this information and additional analysis, the Deaf Smith County site is found to be slightly preferred over the Swisher County site.

One favorable condition under the postclosure geohydrology Technical Guideline (found only at the Deaf Smith County site) concerned the presence of a downward or predominantly horizontal hydraulic gradient. One favorable condition under the preclosure radiological safety guidelines (found only for the Deaf Smith County site) concerned the remoteness of the site from highly populated areas. This conclusion is drawn because the town of Hereford is 27.2 kilometers (17 miles) from the Deaf Smith site; the town of Tulia is only 8 kilometers (5 miles) from the Swisher County site. Two favorable conditions under the preclosure environment, socioeconomic, and transportation guidelines (found only for the Swisher County site) concerned access routes that are relatively short and economical to construct, and access routes for which cuts, fills, tunnels or bridges are not required. Another favorable condition concerned the proximity to regional highways, mainline railroads, or inland waterways that provide access to the national transportation system. This conclusion is drawn because the Swisher County site is within 10.9 kilometers (6.8 miles) of a regional highway and 10.9 kilometers (6.8 miles) of a railroad that provides access to a national transportation system; the Deaf Smith County site is 6 kilometers (4 miles) from a regional highway and 40 to 56 kilometers (25 to 35 miles) from a railroad that provides access to the national transportation system. The related potentially adverse condition under this same Technical Guideline (found only for the Deaf Smith County site) concerned access routes that are expensive to construct relative to comparable siting options. In application of this guideline condition, a cost of truck or rail access routes greater than $10 million is considered expensive. At the Deaf Smith County site, the rail access route may cost between $21 million and $44 million.

The similarity of the sites, indicated by the guideline condition findings of Chapter 6, is attributable to the nearness (approximately 90 kilometers [56 miles]) of the two sites to each other, the flat terrain, the environmental settings, the comparable bedded salt stratigraphy over very large areas, and the limited site-specific data that are presently available for use in the comparative evaluation of sites.

Of the three discriminating guidelines, the postclosure geohydrology guideline grouping, concerning flow paths, and the preclosure radiological safety grouping concerning the proximity of the sites to population centers were judged by the DOE to be more important than the differences in the preclosure environment, socioeconomic, and transportation grouping concerning the proximity of sites to adequate highways and railroads. Therefore the Deaf Smith County site is preferred.

Section 960.3-2-2-2 of the DOE General Guidelines for Recommendation of Sites for Nuclear Waste Repositories (10 CFR Part 960), requires for those geohydrologic settings that contain more than one potentially acceptable site, that "the preferred site shall be selected on the basis of a comparative evaluation of all potentially acceptable sites in that setting." This

Table 2-4. Summary of Rationale for Not Disqualifying the Permian Basin Sites[a]

Disqualifying Condition			Present Rationale for Not Disqualifying	
Guideline	Statement Synopsis	EA Section Reference	Deaf Smith County, Texas	Swisher County, Texas
Geohydrology 960.4-2-1(d)	Pre-waste-emplacement ground-water travel time less than 1,000 years	6.3.1.1	Expected travel times along any path of likely radionuclide travel are expected to exceed 10,000 years.	
Erosion 960.4-2-5(d)	Any portion of subsurface facility less than 200 meters deep	6.3.1.5	Salt horizon of Unit 4 of Lower San Andres Formation proposed host rock is at a depth ranging from 700 to 760 meters.	
Dissolution 960.4-2-6(d)	Active dissolution likely to result in a loss of waste isolation within first 10,000 years after closure	6.3.1.6	Estimated rates of interior dissolution and of peripheral dissolution and front advancement rates will not result in a hydraulic interconnection of the underground facility to the geohydrologic system in 10,000 years.	
Tectonics 960.4-2-7(d)	Based on geologic records, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur	6.3.1.7	Geologic record for the Quaternary Period shows little evidence of active tectonism in the Palo Duro Basin. If present, low levels of ground motion are unlikely to be disruptive and lead to loss of waste isolation.	
Human Interface 960.4-2-8-1(d)(1)	Previous subsurface activities have created significant pathways between the projected underground facility and the accessible environment	6.3.1.8	Activities for exploration, mining, or extraction of resources have not occurred at either site.	
960.4-2-8-1(d)(2)	Ongoing or future recovery of mineral resources outside the controlled area would lead to an inadvertent loss of waste isolation		No known or anticipated valuable natural mineral resources exist at or near either site.	
Population Density and Distribution 960.5-2-1(d)(1)	Repository surface facility located in a highly populated area	6.2.1.2	Hereford, TX, the nearest highly populated area, is located 27.2 kilometers from the site.	Tulia, TX, the nearest highly populated area, is located 8 kilometers from the site.
960.5-2-1(d)(2)	Repository surface facility located adjacent to a 1 mile by 1 mile area having a population of 1,000 or more individuals		No such populations are located adjacent to the repository surface facility.	
960.5-2-1(d)(3)	Inability of the DOE to develop an emergency preparedness plan that meets DOE and NRC regulatory requirements		Compliance anticipated: NRC has not issued 10 CFR Part 60, Subpart 1, "Emergency Planning Criteria;" DOE has developed emergency preparedness programs for its other similar rural facilities per DOE Order 5500.3 (DOE, 1981).	
Offsite Installations 960.5-2-4(d)	Atomic energy defense activities in proximity and which are expected to conflict irreconcilably with a repository	6.2.1.5	Pantex, the closest atomic energy defense activity, is approximately 50 miles from either site and the operations of Pantex will not conflict irreconcilably with the repository operations.	
Environmental Quality 960.5-2-5(d)(1)	Environmental quality of affected area could not be adequately protected, or projected environmental impact that could not be mitigated to an acceptable degree	6.2.1.6	Quality of the environment can be protected in the affected area, and all projected environmental impacts can be mitigated to an acceptable degree.	
960.5-2-5(d)(2)	Location of a restricted area or its support facilities within the boundaries of a national park, wildlife refuge, wilderness preservation area, or wild and scenic river		No part of the repository support facilities or restricted areas is located within specified disqualifying areas.	
960.5-2-5(d)(3)	Presence of a restricted area or its support facilities would conflict irreconcilably with previous designated resource-preservation use of a national park, wildlife refuge, wilderness preservation area, wild and scenic river or forest, or any comparable significant State-protected resource area		No irreconcilable conflicts with dedicated resource preservation use of any Federal-or State-protected areas are expected; the nearest area is the Buffalo Lake Natural Wildlife Refuge, located 35 and 47 kilometers, respectively, from Deaf Smith County and Swisher County sites.	
Socioeconomic Impacts 960.5-2-6(d)	Repository would significantly degrade the quality or reduce the quantity of water from major sources of offsite supplies, and such impacts cannot be compensated or mitigated by reasonable measures	6.2.1.7	Repository related water requirements represent less than 1 percent of the projected water withdrawals for Deaf Smith County or Swisher County; thus the site activities are not expected to significantly reduce the quantity or quality of water from major sources of offsite supplies suitable for human consumption or crop irrigation.	
Rock Characteristics 960.5-2-9(d)	Repository activities are predicted to cause significant risk to health and safety of personnel	6.3.3.2	Potential hazards to personnel during repository construction, operation, and closure relate to gas pockets, excavation instability, large brine pockets, water inflow, and dust; such potential hazards are unlikely at either site and can readily be mitigated by proven mine safety and engineering practices.	

Table 2-4. Summary of Rationale for Not Disqualifying the Permian Basin Sites[a]
(Page 2 of 2)

Disqualifying Condition			Present Rationale for Not Disqualifying	
Guideline	Statement Synopsis	EA Section Reference	Deaf Smith County, Texas	Swisher County, Texas
Hydrology 960.5-2-10(d)	Based upon expected ground-water conditions, engineering measures beyond reasonably available technology will be required for exploratory shaft or repository	6.3.3.3	Ground-water conditions do not require engineering measures beyond reasonably available technology.	
Tectonics 960.5-2-11(d)	Based on expected nature and rates of fault movement or ground motion, engineering measures beyond reasonably available technology will be required for exploratory shaft or repository	6.3.3.4	Region has little or no active tectonisms, with no identified large-scale active faulting and low earthquake risk.	

(a) Based on the U.S. Department of Energy Final General Guidelines for Recommendation of Sites for Nuclear Waste Repositories.

evaluation must consider the distinguishing characteristics displayed by the potentially acceptable sites within the setting and the related postclosure and preclosure guidelines, placing primary significance on the postclosure guidelines.

Since two sites (Deaf Smith County and Swisher County) were identified in the Permian Basin geohydrologic setting (Section 2.2) and are not presently disqualified on the basis of specific 10 CFR Part 960 disqualifying conditions (Section 2.3), the present section describes the comparative evaluation procedure leading to the selection of one of these as the preferred Permian Basin site to be subsequently nominated for site characterization by the Secretary of Energy. An evaluation of the preferred Permian Basin site for all 10 CFR Part 960 guidelines, irrespective of whether they do or do not require site characterization as a prerequisite, is presented in Chapter 6. As finally required of the nomination decisional process, a comparative evaluation of the Deaf Smith County site with the other nominated candidates is conducted subsequently.

As specified in 10 CFR 960.3-2-2-2, the basis for this comparative evaluation of the two Permian Basin sites is the qualifying conditions, considering, on balance, the favorable and potentially adverse conditions for all postclosure and preclosure Technical Guidelines for which the kinds of evidence show significant distinguishing characteristics between the two sites. A comparison of the findings for the favorable and potentially adverse guideline conditions for both the Deaf Smith County and Swisher County sites results in six conditions, one postclosure and five preclosure, where the findings differed from one another.

2.4.1 Evaluation of Permian Basin Postclosure Discriminating Technical Guidelines

Postclosure repository guidelines specified in 10 CFR Part 960, Subpart C, which form one of the four guideline groups, include one System Guideline and eight Technical Guidelines. This subpart of the guidelines specifies the characteristics, processes, and events that may affect the long-term performance of the repository after waste emplacement and repository closure and which must be considered in evaluating and comparing potential sites. The objective of the postclosure waste containment and isolation System Guideline (10 CFR 960.4-1) is to ensure that, by means of natural and engineered barriers, the health and safety of the public will be protected until the radioactivity in the nuclear wastes has diminished to safe levels. These are the considerations most important for ensuring the long-term protection of the health and safety of the public. The eight Technical Guidelines included under this postclosure System Guideline have numerous qualifying, favorable, potentially adverse, and disqualifying conditions related to Geohydrology (10 CFR 960.4-2-1), Geochemistry (10 CFR 960.4-2-2), Rock Characteristics (10 CFR 960.4-2-3), Climatic Changes (10 CFR 960.4-2-4), Erosion (10 CFR 960.4-2-5), Dissolution (10 CFR 960.4-2-6), Tectonics (10 CFR 960.4-2-7), Human Interference (Natural Resources, 10 CFR 960.4-2-8-1), and Site Ownership and Control (10 CFR 960.4-2-8-2).

As summarized in Table 2-5 and discussed below, one difference has been identified which discriminates between the two sites for the postclosure guidelines. The qualifying condition for the geohydrology Technical Guideline (10 CFR 960.4-2-1) requires that the present and expected geohydrologic setting of a site shall be compatible with waste containment and isolation. A specific favorable condition 10 CFR 960.4-2-1(b)(4)(ii) under this guideline is "a downward or predominantly horizontal hydraulic gradient in the host rock and in the immediately surrounding geohydrologic units." This condition is satisfied at the Deaf Smith County site. At the Swisher County site, upward flow paths exist from the host rock to the Dockum aquifer. Thus, the Deaf Smith County site meets the favorable condition of 10 CFR 960.4-2-1(b)(4)(ii) and the Swisher County site does not; the Deaf Smith County site is preferred.

2.4.1.1 Postclosure Guidelines - Permian Basin Site Preference

The geohydrology guideline discriminates between the two sites. As discussed above and in Section 6.3.1.1, a favorable condition 10 CFR 960.4-2-1(b)(4)(ii) "a downward or predominantly horizontal hydraulic gradient..." is present for the Deaf Smith County site

Table 2-5. Summary of Findings Based on Discriminating Guidelines Between the Permian Basin Sites

		Finding	
		Less Favorable	More Favorable
	Postclosure Discriminating Guideline Conditions		
Geohydrology 10 CFR 960.4-2-1	A downward or predominantly horizontal hydraulic gradient	Swisher	Deaf Smith
Overall Postclosure		Swisher	Deaf Smith
	Preclosure Radiological Safety Discriminating Guideline Conditions		
Population Density and Distribution 10 CFR 960.5-2-1	Remoteness of the site from highly populated areas	Swisher	Deaf Smith
Overall Preclosure Radiological Safety		Swisher	Deaf Smith
	Preclosure Environment, Socioeconomic, and Transportation Discriminating Guideline Conditions		
Transportation 10 CFR 960.5-2-7	Proximity to local highways and railroads that are adequate to serve the repository without significant upgrading or construction.	Deaf Smith	Swisher
	Access routes to existing local highways and railroads that are expensive to construct relative to comparable siting options.	Deaf Smith	Swisher
	Availability of access routes that are relatively short and easy to construct.	Deaf Smith	Swisher
	Availability of access routes for which cuts, fills, tunnels, or bridges are not required.	Deaf Smith	Swisher
Overall Preclosure Environment, Socioeconomic and Transportation		Deaf Smith	Swisher
	Preclosure Ease and Cost of Siting, Construction, Operation, and Closure Discriminating Guidelines		
	No discriminating guidelines		

only. Evidence for the remaining postclosure Technical Guideline conditions does not distinguish between the two sites; therefore, the Deaf Smith County is preferred for this guideline group.

2.4.2 Evaluation of Permian Basin Preclosure Discriminating Technical Guidelines

The preclosure repository guidelines specified in 10 CFR Part 960, Subpart D, include three System Guidelines and eleven Technical Guidelines. Subpart D of the guidelines specifies the factors to be considered in evaluating and comparing sites on the basis of expected repository performance before closure. The Technical Guidelines in Subpart D set forth qualifying, favorable, potentially adverse, and, in seven guidelines, disqualifying conditions on which to base the suitability of a site relative to the three preclosure System Guidelines.

2.4.2.1 Preclosure Radiological Safety Guideline Group

This guideline group focuses on compliance with applicable safety requirements specified in various U.S. Department of Energy (DOE), Nuclear Regulatory Commission (NRC), and Environmental Protection Agency (EPA) regulations relating to any projected radiological exposures of the general public and releases of radioactive materials to restricted and unrestricted areas during repository operation and closure. The preclosure Radiological Safety Guideline group includes Population Density and Distribution (10 CFR 960.5-2-1), Site Ownership and Control (10 CFR 960.5-2-2), Meteorology (10 CFR 960.5-2-3), and Offsite Installations and Operations (10 CFR 960.5-2-4).

As summarized in Table 2-5 and discussed below, population distribution differences have been identified which discriminate between the two sites for the preclosure radiological safety guideline group. The qualifying condition for the Population Density and Distribution Technical Guideline (10 CFR 960.5-2-1) requires that the repository site be located so that, during repository operation and closure, (1) the expected average radiation dose to members of the public within any highly populated area will not be likely to exceed a small fraction of the allowable limits, and (2) the expected radiation dose to any member of the public in an unrestricted area will not be likely to exceed allowable limits. A specific favorable condition (10 CFR 960.5-2-1(b)(2)) under this guideline is "Remoteness of the site from highly populated areas." An evaluation of this favorable condition requires a precise definition of "remoteness," not specifically provided in the Definitions of 10 CFR 960.2. For the present analysis, "remoteness" is here defined to mean a distance of more than 8 kilometers (5 miles) to the nearest boundary of a repository controlled area. This distance criterion is principally based on analogy with the nuclear power reactor regulation precedent established by the U.S. Nuclear Regulatory Commission in Regulatory Guide 4.7 (1975). The available demographic data for the Permian Basin sites indicate that the southern edge of the Deaf Smith County site controlled area boundary is located approximately 27.2 kilometers (17 miles) from Hereford, Texas (1980 population of 15,853) and that the southern boundary of the Swisher County site is located 8 kilometers (5 miles) from Tulia, Texas (1980 population of 5,033). Since remoteness is defined as a distance of more than 8 kilometers (5 miles), the town of Hereford is remote from the Deaf Smith County site, but the town of Tulia is not remote from the Swisher County site. This difference is not great in terms of average radiological exposure to the public since the radiological 1-year dose from a 1-year exposure is fifty times less than allowed by 40 CFR Part 191. The Deaf Smith County site meets the favorable condition of 10 CFR 960.5-2-1(b)(2), and the Swisher County site does not. The two sites are discriminated on the basis of this condition, and the Deaf Smith County site is preferred.

2.4.2.1.1 Preclosure Radiological Safety Guidelines - Permian Basin Site Preference. The preclosure Guideline for Population Density and Distribution discriminates between the two sites. As discussed above and in Section 6.2.1.2, a favorable condition 10 CFR 960.5-2-1(b)(2), "remoteness of the site from highly populated areas," is present for the Deaf Smith County site only. The evidence for the remaining preclosure radiological safety Technical Guideline conditions does not distinguish between the two sites; therefore, the Deaf Smith County site is preferred for this guideline group.

2.4.2.2 Environmental, Socioeconomic, and Transportation Guideline Group

The second preclosure guideline group--environment, socioeconomics, and transportation--includes conditions related to Environmental Quality (10 CFR 960.5-2-5) and Socioeconomic Impacts (10 CFR 960.5-2-6) in areas potentially affected by a repository, and the Transportation (10 CFR 960.5-2-7) of waste to a repository site. This guideline group focuses on adequately protecting the public and the environment from the hazards posed by the disposal of radioactive waste during repository siting, construction, operation, closure, and decommissioning.

As summarized in Table 2-5 and discussed below, data differences have been identified which discriminate between the two sites for the transportation guidelines. The qualifying condition for the Transportation Technical Guideline (10 CFR 960.5-2-7) requires, in part, that a repository be located so that the access routes, to be constructed from existing local highways and railroads to the site, can be designed and constructed using reasonably available technology.

One favorable subcondition specified under the transportation guideline 10 CFR 960.5-2-7(b)(1)(i) is the availability of access routes that are relatively short and economical to construct. In application of this guideline, short and economical means less than 16 kilometers (10 miles) and less than $10 million. At the Deaf Smith County site, the access railroad required is 40 to 56 kilometers (25 to 35 miles) at a cost of $21 to $44 million. For the Swisher County site, the access railroad and highway routes are each 10.9 kilometers (6.8 miles) at a cost of $3.5 and $2.8 million, respectively. Thus, the Swisher County site meets the favorable condition 10 CFR 960.5-2-7(b)(1)(i), and the Deaf Smith County site does not.

Another favorable condition, 10 CFR 960.5-2-7(b)(1)(iii), is the availability of access routes for which cuts, fills, tunnels, or bridges are not required. The need for significant cuts and fills is minimal for both sites, but several bridges may be required for access to the Deaf Smith County site, whereas none are required for access to the Swisher County site. Thus, the Swisher County site meets the subfavorable condition 10 CFR 960.5-2-7(b)(1)(iii), and the Deaf Smith County site does not.

A third favorable subcondition specified under the Transportation Guideline (10 CFR 960.5-2-7[b][2]) is the "proximity to local highways and railroads that provide access to regional highways and railroads and are adequate to serve the repository without significant upgrading or reconstruction." In application of this guideline condition, the distance from the outer end of each newly constructed access route to the nearest highway or railroad which does not need significant upgrading must be less than 16 kilometers (10 miles) for the favorable condition to be present. As discussed in Section 6.2.1.8, the distances from the new access road and railroad to the nearest adequate highway or mainline railroad for the Deaf Smith County site are 6 kilometers (4 miles) and 21 kilometers (13 miles), respectively; in contrast, these distances for the Swisher County site are only 10 kilometers (8 miles) to a highway and 0 kilometers (0 miles) to a railroad. For this reason, the favorable subcondition was found for the Swisher County site, but not the Deaf Smith County site.

A related potentially adverse condition 10 CFR 960.5-2-7(c)(1) is "access routes to existing local highways and railroads that are expensive to construct relative to comparable siting options." In application of this guideline condition, a cost of highway or rail access routes greater than $10 million is considered expensive. At the Deaf Smith County site, the rail access route may cost up to $44 million. At the Swisher County site, both are less than $10 million. Thus, the potentially adverse condition is present for the Deaf Smith County site and not for the Swisher County site.

2.4.2.2.1 Environment, Socioeconomics, and Transportation Guidelines--Permian Basin Site Preference. As discussed above, the transportation preclosure guidelines 10 CFR 960.5-2-7(b)(1)(i), 10 CFR 960.5-2-7(b)(1)(iii), 10 CFR 960.5-2-7(b)(2), and 10 CFR 960.5-2-7(c)(1) which discriminate between the two sites, indicate that the Swisher County site is a more favorable Permian Basin site than the Deaf Smith County site. The

evidence indicates that the remaining preclosure environment, socioeconomics, and transportation guideline conditions do not distinguish between the two Permian Basin sites; therefore, based on its proximity to adequate highways and railroads, the Swisher County site is preferred for this guideline group.

2.4.2.3 Ease and Cost of Siting, Construction, Operation, and Closure Guideline Group

The third preclosure guideline group, ease and cost of siting, construction, operation, and closure, includes conditions related to the Surface Characteristics of the site (10 CFR 960.5-2-8), the Rock Characteristics of the host rock and surrounding strata (10 CFR 960.5-2-9), Hydrology (10 CFR 960.5-2-10), and Tectonics (10 CFR 960.5-2-11). These guidelines serve to demonstrate that repository siting, construction, operation, and closure are technically feasible on the basis of reasonable available technology, and that associated costs are reasonable relative to other available and comparable siting options. As summarized in Table 2-5, there are no Deaf Smith County and Swisher County site differences which discriminate on the basis of the preclosure ease and cost of siting, construction, operation, and closure guidelines.

2.4.3 Preferred Permian Basin Site

As summarized above, there are six guideline conditions which discriminate between the two Permian Basin sites. Because not all of the guideline conditions favor one site, additional analysis was performed to assist in the determination of the more favorable site. Such analysis is presented below.

The Deaf Smith County site is preferred for the postclosure guideline group and for the preclosure radiological safety guideline group, while the Swisher County site is preferred for the preclosure environment, socioeconomic, and transportation guideline group. Neither site is preferred on the basis of the ease and cost of siting, construction, operation, and closure guideline group.

If all guideline groups were considered to be of equal importance, a clearly preferable site would be identifiable, since the postclosure attribute and the radiological safety attribute of the Deaf Smith County site would outweigh the transportation attributes of the Swisher County site. In addition, a hierarchical ordering of the guideline groups is specified under 10 CFR 960.3-1-5, which indicates that some groups are more important than others. The order of importance specified includes the following:

1. Site comparison must be based on both the preclosure and postclosure guidelines.

2. Primary significance shall be placed on the postclosure guidelines.

3. Secondary significance shall be placed on the preclosure guidelines.

4. Preclosure guidelines are separated into the following groups in decreasing order of importance: (1) preclosure radiological safety; (b) environment, socioeconomics, and transportation; and (c) ease and cost of siting, construction, operation, and closure.

Further analysis which considers the order of importance specified under Item 4 of 10 CFR 960.3-1-5, above, indicates that the Deaf Smith County site is preferred over the Swisher County site for the preclosure guideline group. The Deaf Smith County site is more favorable for the preclosure radiological safety guideline which is specified to be of the greatest importance of the three preclosure guideline groups listed; although the Swisher site is more favorable for the preclosure environment, socioeconomics, and transportation group, this group is specified to be of lesser importance than the preclosure radiological safety group. Thus, the Deaf Smith County site is more favorable for both preclosure and postclosure guideline groupings.

In summary, based on the discriminating guideline data specified above for both of the Permian Basin sites, and pursuant to the comparative evaluation process specified by the 10 CFR Part 960 General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, the Deaf Smith County site is preferred for subsequent site characterization studies in the Permian Basin geohydrologic setting.

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2.5.2 Federal Regulations and Statutes

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40 CFR Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule, September 19, 1985.

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Chapter 3

THE SITE

This chapter is a summary of the present information base for the Deaf Smith County site. It is intended to provide the foundation for the evaluations and assessments in the other chapters of this Environmental Assessment, as mandated by the "Nuclear Waste Policy Act of 1982" (NWPA), 42 USC Sections 10101 et seq. Data and information presented here have been developed from literature review and preliminary field surveys conducted in support of the site-selection process described in Chapter 2. Details pertaining to the data base for the site can be found in the references cited in the text.

The physical, biological, and sociocultural environments of the Deaf Smith County site are described in this section. Included in the topic areas are site location, general appearance and terrain, and present uses; geologic conditions; hydrologic conditions; environmental setting; transportation and utilities; and socioeconomic conditions. Descriptions are focused on data most applicable to the site, which are intended to provide the data base for assessing the suitability of the site for nomination as a candidate for site characterization (Chapter 6) and for projecting the potential environmental effects of site characterization (Chapter 4) and repository development (Chapter 5).

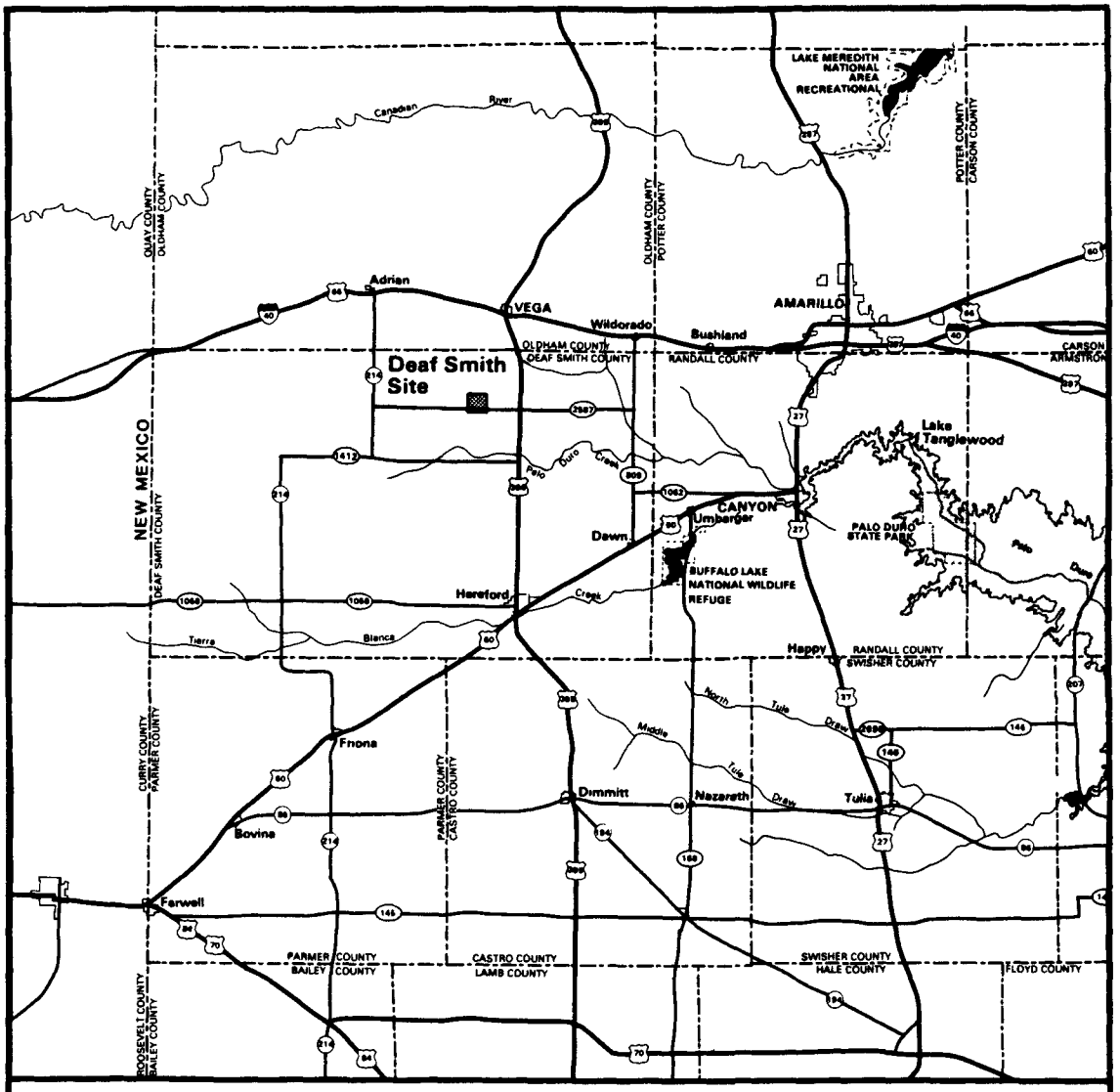
3.1 LOCATION, GENERAL APPEARANCE AND TERRAIN, AND PRESENT USES

The Deaf Smith County site is located in the north-central part of Deaf Smith County, in the Southern High Plains of the Texas Panhandle (Figure 3-1). The High Plains is nearly flat, relatively undissected table land. Surface drainage is poorly integrated and is controlled by small, shallow lake basins (playas) and some sharply defined ephemeral streams (draws). In the vicinity of the site, the land surface slopes gently to the east. The site is bordered on the north by a tributary of North Palo Duro Creek. Elevations on the site range from 1,215 to 1,239 meters (3,985 to 4,065 feet) above sea level (Figure 3-2). The site is a square, 4.8 kilometers (3 miles) on a side, centered at 35° 07' N latitude and 102° 29' W longitude. From the geographical center of the site, a site vicinity with a radius of 10 kilometers (6.2 miles) has also been designated. The configuration of this outer area provides a study area that conforms with standard procedure for other nuclear facilities licensed by the Nuclear Regulatory Commission (NRC, 1979, NUREG-0555, pp. 2.1-2 and 2.2.1-2). The site vicinity is similar in character to the site.

The site is located in a rural setting where the population density averages about four persons per square mile. The nearest cities and towns include Hereford in Deaf Smith County; Vega, Adrian, and Wildorado in Oldham County; Canyon in Randall County; and Amarillo in Randall and Potter Counties. The majority of the population in Deaf Smith County and surrounding counties is concentrated in the cities and towns. Amarillo is the regional population center.

Major highways near the site include I-40 between Amarillo and Adrian; U.S. 60, which connects Canyon and Hereford; and U.S. 385 between Vega and Hereford. Paved roads in the county include Routes 214, 1062, and 2587. Route 2587 runs through the southern portion of the site. The nearest rail line is the Atchison, Topeka and Santa Fe, which parallels U.S. 60. Commercial air traffic is accommodated at the Amarillo Regional Airport; there are small county or community airports near most of the larger towns of the region.

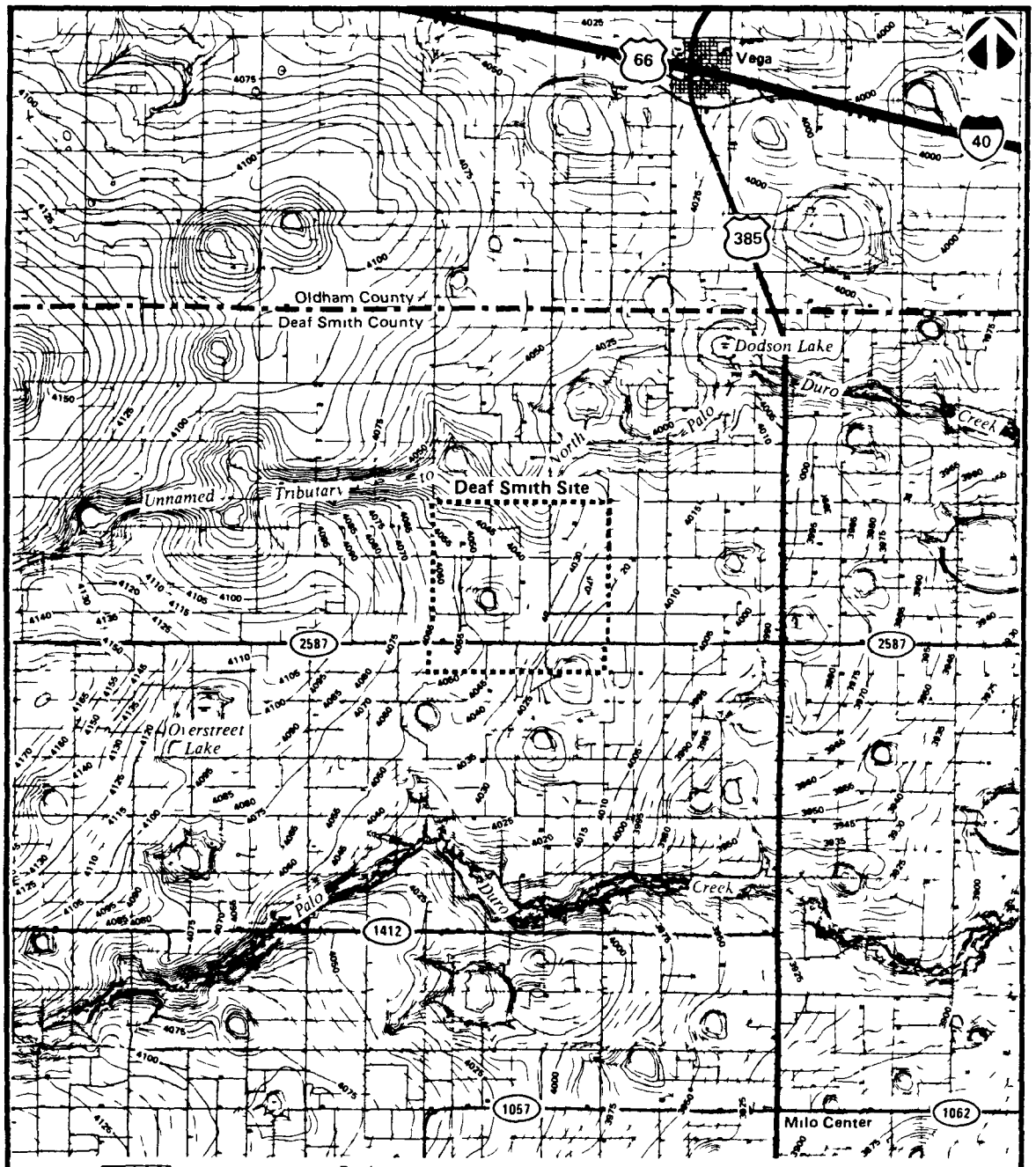
Most of the land in Deaf Smith County is cropland. However, there are expanses of rangeland within the site and site vicinity. The farmland is generally classified as "prime," with fertile soils, flat to gentle slopes, and sufficient precipitation or irrigation water. Water for irrigation comes from the High Plains aquifer, which consists primarily of the Ogallala Formation, and partly of the Dockum Group. There are relatively few surface-water resources because the climate is semiarid to subhumid, with warm summers, cold winters, and relatively high average winds. The rate of evapotranspiration exceeds precipitation. Palo Duro Creek and the numerous playas, with the exception of playas that receive irrigation tail water, are dry most of the year.



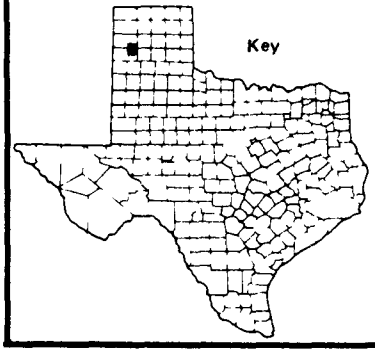
Source: USGS, 1973, 1974, 1975, 1977; Compiled from 1:250,000 maps.

Deaf Smith County Site and Vicinity Regional Locator

Figure 3-1



Explanation
Contour interval 5 feet



Source Compiled from USGS 1965 1971 1 24,000 quadrangle maps of Adrian, Allison Ranch, Everett, Ford Jay Taylor, Landergin Milo Center, Overstreet Lake Simms, Simms NE, Simms NW, Vega North, Vega South, Westway NE and Westway NW, Texas

0 1 2 3 4 5 6 7 8 Kilometers
0 1 2 3 4 5 Miles

Topography Near the Deaf Smith County Site

Figure 3-2

Cultural resources in the Texas Panhandle include both archaeological and historical sites. These resources are primarily associated with surface-water features such as streams (draws) and playas. There are no known cultural resources within the site or site vicinity, but the presence of surface-water features increases the likelihood of cultural resources being present.

Ecologically, the Southern High Plains is characterized as shortgrass prairie, but little of the original prairie ecosystem remains due to agricultural development. There are no known unique ecosystems within the site or site vicinity, although playa wetlands, the edges of cultivated fields, and relatively ungrazed rangeland can be ecologically important. Several federally or State-protected species may be present at various times of the year; however, there is no federally designated critical habitat for any of these species in the region.

3.2 GEOLOGIC CONDITIONS

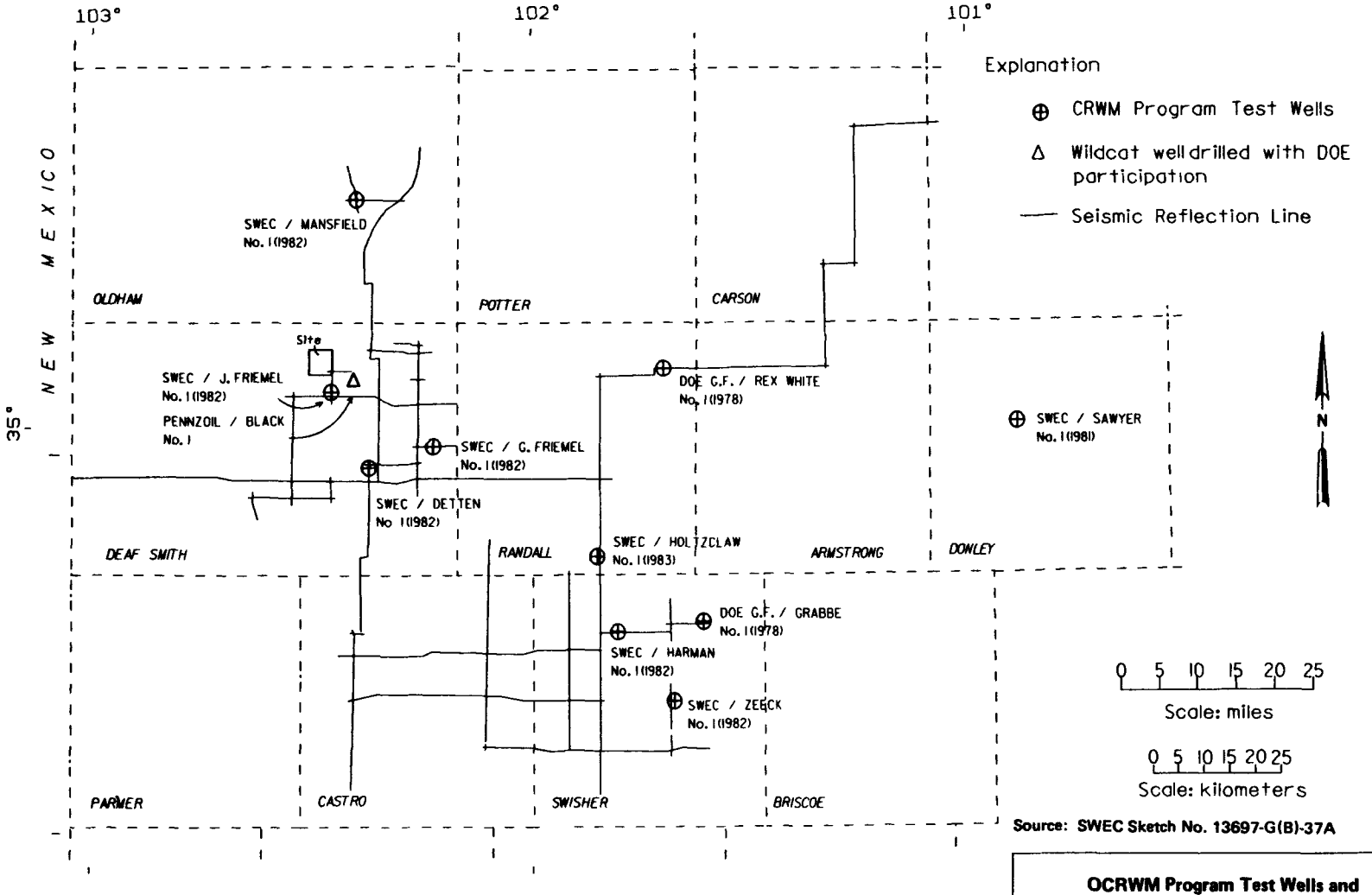
This section describes the geologic setting of the Deaf Smith County site. Some aspects of the site geology are meaningful only in a broad regional or areal context. These aspects have already been described in the Area Geological Characterization Report (AGCR) (SWEC, 1983, DOE/CH/10140-1). Only the salient points from this work are summarized here. Since the AGCR was prepared, new geologic studies have been undertaken for the Office of Civilian Radioactive Waste Management (OCRWM) program. None of these studies was conducted at the site; however, some of the new data have been acquired near the Deaf Smith County site (site stratigraphy, structure, and rock characteristics). Relevant new material is summarized in this section. The new data have been obtained principally from analysis of wildcat petroleum exploration wells in the Texas Panhandle, from test wells drilled specifically for the OCRWM program, and from seismic-reflection surveys. Figure 3-3 shows the location of the wells and seismic-reflection data acquired for the OCRWM program.

3.2.1 Regional Geology

The Permian Basin comprises several smaller basins underlain by Upper Permian bedded salts (Johnson and Gonzales, 1978). Interbasinal uplifts began to form in the Late Mississippian and achieved maximum structural development in the Early Permian (Wolfcampian). From Late Mississippian to Early Permian, the basins and uplifts controlled deposition, and carbonates and clastic rocks accumulated in the basins. Basinal subsidence did not keep pace with deposition during the remainder of Permian time. The uplifts were buried and their influence on deposition diminished. During the Late Permian, fluctuating ocean-margin environments produced sedimentary sequences dominated by evaporites. Minor uplift and subsidence alternated through the Mesozoic. Terrestrial clastic rocks of the Dockum Group (Triassic) are the principal Mesozoic units in the central Panhandle. These are unconformably overlain by the alluvial gravels and sands of the Ogallala Formation (Neogene).

The Palo Duro Basin (Figure 3-4) is one of the Permian subbasins. It is asymmetrical and has, as its deepest portion, an elongate trough adjacent and subparallel to the Matador Uplift, where 3,000 meters to 3,300 meters (10,000 feet to 11,000 feet) of sediment accumulated. The trough extends northwestward into Deaf Smith County. The 600-meter (2,000-foot) pre-Permian section consists of basal Cambrian marine sandstone, Cambro-Ordovician shallow-shelf carbonates, Mississippian carbonates, and Pennsylvanian clastic rocks and carbonates. The Permian-age rocks are clastics, evaporites, and carbonates totaling 2,000 meters (7,000 feet) in thickness. The Dockum and Ogallala sediments range in combined thickness from 300 to 600 meters (1,000 to 2,000 feet). Quaternary sediments, up to about 30 meters (100 feet) thick, occur locally.

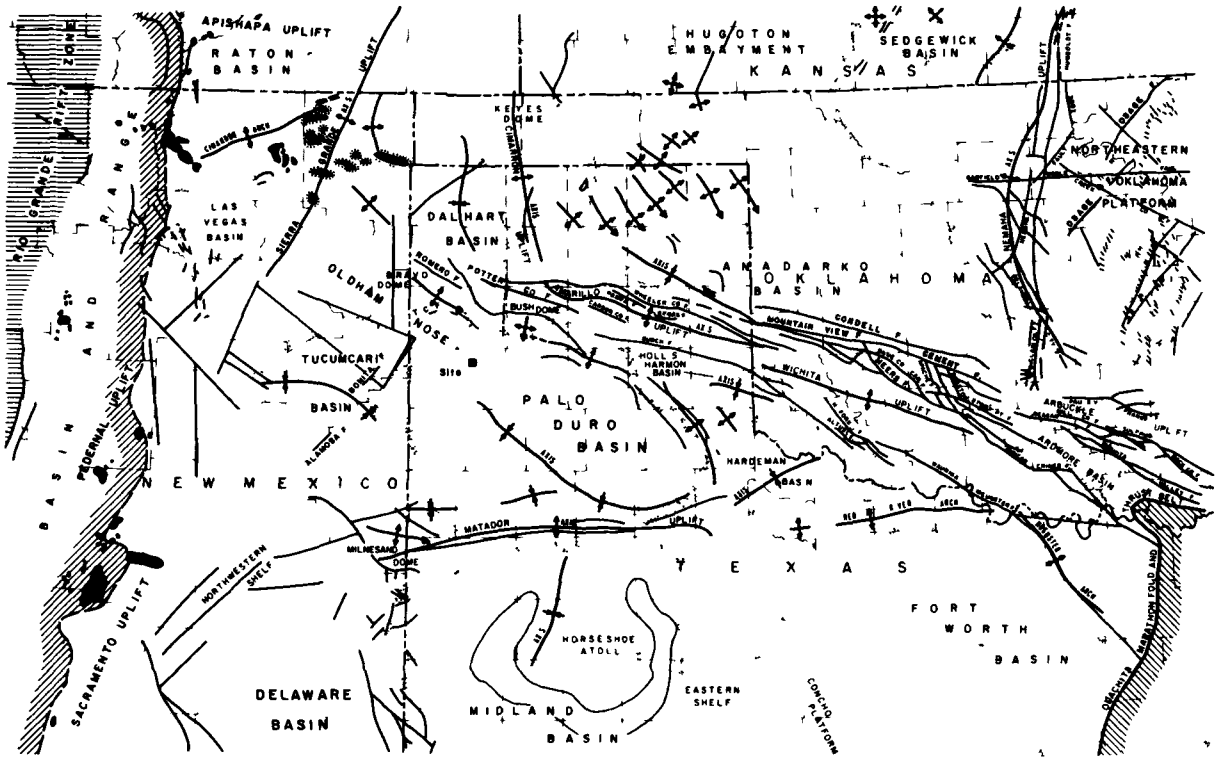
The Amarillo Uplift structurally separates the Palo Duro Basin from the much deeper Anadarko Basin to the northeast. The uplift is the most prominent tectonic feature in the region. By middle Wolfcampian (Early Permian) time, the Amarillo Uplift was entirely buried, but fault movements continued (Section 3.2.5.1). The eastern and western structural boundaries of the Palo Duro Basin are much less prominent features and were essentially inactive by Late Pennsylvanian time. The Matador Uplift separates Pennsylvanian and Wolfcamp shallow-shelf facies of the Palo Duro Basin from deep-basin facies of the Midland Basin to the south. It continued as a minor depositional boundary throughout Permian time.



Source: SWEC Sketch No. 13697-G(B)-37A

OCRWM Program Test Wells and Seismic Coverage of the Central Palo Duro Basin

Figure 3-3



Explanation

- Axis of Dome
- Anticline and Arch Axes
- Basin Axes
- Eastern Edge of Rocky Mountains
- Ouachita Marathon Fold and Thrust Belt
- Exposure of Late Cretaceous Tertiary Intrusions
- Faults (Undifferentiated)
- Late Tertiary Holocene Volcanics
- Rio Grande Rift Zone
- Site
- Outline of Basins

Note

Fault locations are based on various horizons

Sources:

Adams, 1962; Baldwin and Muehlberger, 1959; Barnes, 1977, 1983; Bayley and Muehlberger, 1968; Cole, 1962; Colner and Crum, 1933; Dane and Bachman 1965; Dutton 1979; Flawn 1956; Forgotson et al 1966; Foster et al 1972; Gould and Lewis, 1926; Hem et al 1964; Hem and McKinley, 1954; Harlton, 1963, 1972; Hills, 1970; Huffman, 1959; Jacobsen, 1949; Johnson, 1979; Luza and Lawson, 1982; Meholin, 1960; Merriam 1963; Miser, 1954; Myers et al 1966; Nicholson 1956, 1960; Pitt, 1973; Rogatz 1939; Sellards and Baker, 1934; Stearns, 1972; Steeples et al. 1979; Tobin, 1956; Woodward and Snyder, 1978.

0 25 50
Scale Miles
0 50 100
Scale Kilometers

Regional Tectonic Map

Figure 3-4

The rock strata within the basins are nearly flat-lying with some folding along basin margins. Tectonic faulting within the Palo Duro Basin is generally widely spaced with a predominant northwest trend. The youngest structurally offset unit is the Upper San Andres Formation of Leonardian age. Seismicity in the region is low. Many of the reported earthquakes are thought to be related to the Amarillo Uplift.

The region is a noted producer of natural gas, and also yields important quantities of oil. Production is mostly from the western Anadarko Basin, the Panhandle-Hugoton gas field (associated with the Amarillo Uplift), and the Midland Basin. The Palo Duro Basin has produced very little oil and gas. Production in the Palo Duro Basin is mostly from Pennsylvanian and Wolfcamp carbonates and clastics, in small fields located generally at the margins of the basin.

3.2.2 Geomorphology

3.2.2.1 Physiography

The site is located in the Southern High Plains section of the Great Plains Physiographic Province (Fenneman, 1931a, b, p. 1). The Southern High Plains is higher than the immediately surrounding physiographic elements and is separated from the Northern High Plains by the Canadian Breaks (the valley of the Canadian River) (Figure 3-5). To the west, the Southern High Plains terminates at the Western Caprock Escarpment above the Pecos Valley. The eastern margin is the prominent Eastern Caprock Escarpment developed by the headwater tributaries of the Colorado, Brazos, and Red Rivers, which flow southeastward across the Rolling Plains.

The Southern High Plains is underlain by the Neogene Ogallala Formation (see Section 3.2.3), an alluvial deposit that once extended continuously across the area from its source in the Rocky Mountains. The present surface of the plains is nearly flat and slopes southeastward at about 1.8 meters per kilometer (10 feet per mile). Topographic features include small, internally drained lake basins (playas) and occasional narrow stream valleys (draws) that carry surface water after rainstorms.

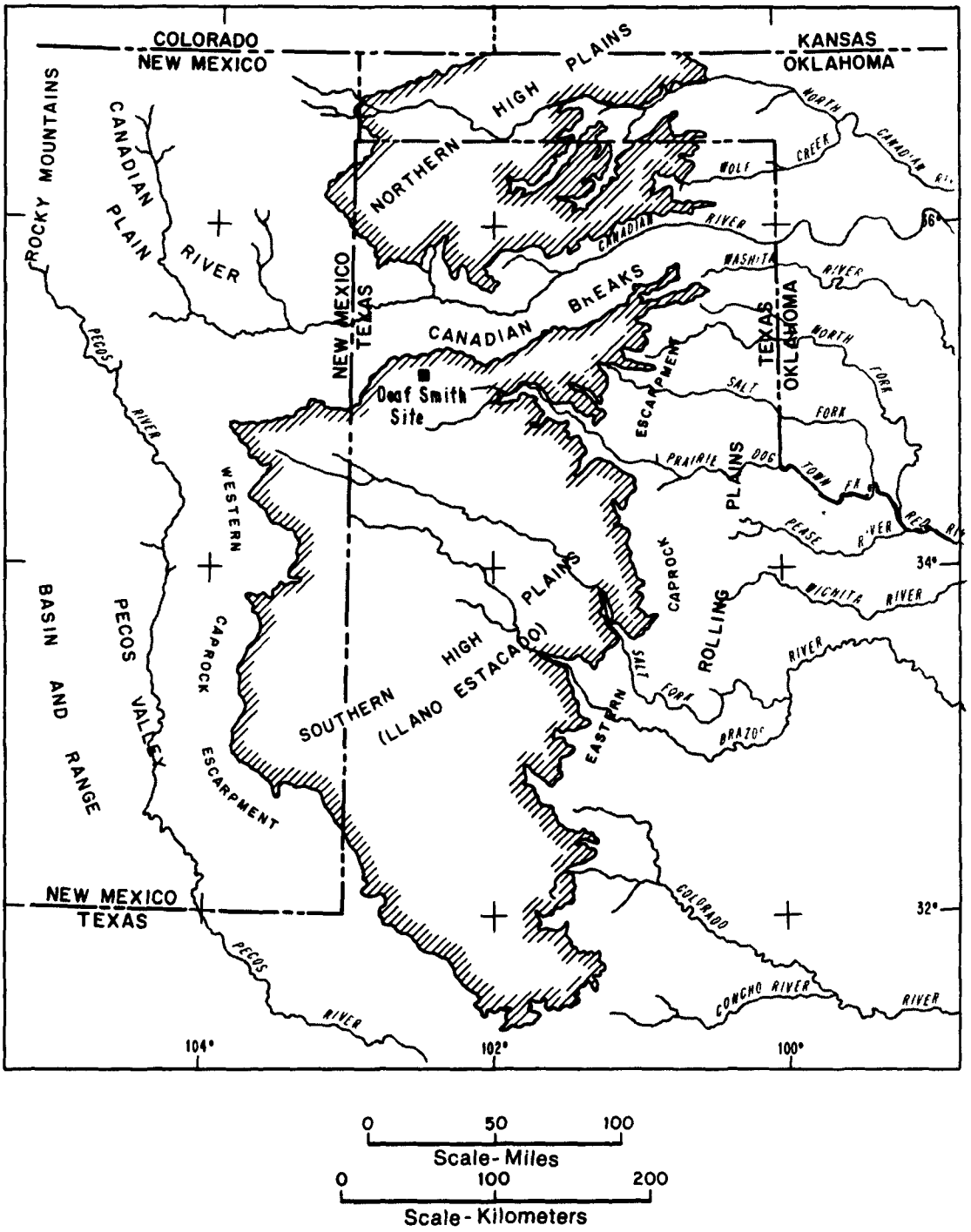
Development of the Pecos and Canadian River Valleys during the Pleistocene has isolated the Southern High Plains streams from the mountains to the west and from the remainder of the High Plains to the north. That isolation, the gently sloping surface, and the general lack of drainage integration have kept erosion by runoff on the Southern High Plains at a negligible level. Wind erosion (deflation) may have contributed to playa development (Evans and Meade, 1945, p. 487). A continuous sheet of windblown silt blankets the site (Barnes, 1983).

At the Deaf Smith County site, the ground surface ranges in elevation from 1,239 meters (4,065 feet) on the west to 1,215 meters (3,985 feet) on the east (Figure 3-2). It is bordered on the north by an unnamed tributary to North Palo Duro Creek. The main branch of Palo Duro Creek is 4.8 kilometers (3.0 miles) south of the site.

There is a playa about 1 kilometer (0.6 mile) in diameter and 7 meters (20 feet) deep in the west-central part of the site. A second playa, about 2.1 kilometers (1.3 miles) in diameter and 12 meters (40 feet) deep, straddles the site boundary in the southeast. Surface drainage is generally eastward across the site. However, most runoff is diverted into the playas. Runoff in the northern part of the site drains into the unnamed tributary to North Palo Duro Creek (Figure 3-2).

Playas. The origin of the so-called "playa lakes" on the High Plains is unresolved. Gilbert (1895, p. 49) attributed the basins to erosion by wind. Johnson (1901, pp. 702, 705) considered the smaller basins to be caused by differential compaction or subsidence within the Ogallala and the larger basins to be due to solution of salt or gypsum in the rocks below the Ogallala followed by collapse of the overlying material. Baker (1915) also believed the larger basins to be the result of solution of underlying strata.

Gould (1907, pp. 2, 36, and 37) subdivided the basins as buffalo wallows and larger playa lakes. The buffalo wallows are those basins which are very shallow and a few feet to a few



Explanation

Boundary of High Plains Surface

Major Physiographic Elements of the Texas Panhandle Region

Source: SWEC, 1983, DOE/CH/10140-1.

Figure 3-5

tens of feet across. No origin for the larger playa lakes was given. Patton (1935, p. 451) attributed the lakes to solution of underlying material and to surface erosion, possibly including deflation. Price (1940, p. 1939) concluded that playa lakes are manifestations of caliche karst; that is, dissolution of caliche in the Ogallala due to percolating ground water and subsequent subsidence of the surface to form a depression.

Evans and Meade (1945, pp. 487-490) described evidence for a subsidence origin of a few lake basins on the High Plains in Texas. However, for most of the playa lake basins they concluded that field evidence indicates that deflation during arid stages is the origin. Judson (1950, pp. 271-272; 1953) considered the origin of playa lakes on the Southern High Plains of New Mexico to be due to a combination of leaching of calcareous cement (caliche) from Ogallala sands and silts during moist periods and subsequent wind erosion of the loosened material during dryer periods. He found no evidence of collapse or subsidence beneath the playas, although a definitive collapse origin for a depression (Cuneva sink) on the High Plains to the northwest was noted.

Field studies by Reeves (1966, 1972) and Reeves and Parry (1969) conclude that playa lakes have various origins depending on their location, underlying structure, and previous geologic history. Most are probably the result of wind deflation and unequal eolian deposition (Reeves, 1972, p. 113; Reeves and Parry, 1969, p. 349). Aligned playas may be due to subsidence or solution along subsurface fractures (Reeves, 1972, p. 113). Larger basins may be due to solution or subsidence at the intersection of major buried fractures shown by lineament trends.

Havens (1961, p. B123) drilled a playa in New Mexico and found no evidence of solution of deeply buried salt or gypsum or of collapse of the Ogallala. He did find evidence of leaching of caliche caprock beneath the playa and of deflation followed by infilling of fine sediments. Lotspeich et al. (1971, p. 6, Figure 7, pp. 7, 10) did an intensive study of a playa lake near the northern edge of the Southern High Plains. They concluded that the lake originated in a natural low on the caliche caprock surface and has migrated through time toward the north, being maintained as a basin by deflation during dry periods and by wave erosion during wetter periods. Their studies showed no evidence of slumping or dissolution of underlying deep formations. Caliche caprock is absent in a small area beneath the playa. This is interpreted to be the result of leaching by ground water from the lake, rather than as a condition present before the lake formed.

Walker (1978, pp. 21, 22) considered the origin of playa lakes to be unresolved, but favored a caliche-solution and subsidence mechanism. Gustavson et al. (1980a, pp. 12-14) describe two large playa basins in Gray County, Texas, and state that solution of underlying salt was a contributing factor in their formation. These playas are within the zone of active salt dissolution along the Amarillo Uplift. The distribution of large playa basins is thought to be related to the zone of active salt dissolution (pp. 14 and 15). On the other hand, Lotspeich et al. (1971, pp. 3-5) believe that the distribution of large playas is controlled by the soil mantle; larger and shallower basins in clayey to silty soils, and smaller deeper basins in sandy soils.

Studies by Wood and Osterkamp (1984) and Osterkamp and Wood (1984) indicate an origin for playa lakes which differs from past interpretations. They consider gentle subsidence caused by downward piping of fines, eluviation, and caliche dissolution to be the dominant mechanism. Eolian processes may modify the shape of many basins, but piping of clays by recharging water is the primary cause of deepening and basin expansion. The process is enhanced along zones of fractures.

Preliminary studies by Simpkins (1984) indicate that wind deflation and deposition and slope wash are continuing processes at large playas studied in Bailey County, Texas.

The largest playas seldom exceed 15 meters (50 feet) in depth. Playas are notable because they are numerous and because they are practically the only landforms on an extensive and otherwise featureless plain. They remain scientific curiosities because their origins have never been satisfactorily determined, but, despite the uncertainties, it is clear that playas do not represent significant erosion or salt dissolution.

3.2.2.2 Erosion Processes

Using relationships established by Langbein and Schumm (1958) between sediment yield and precipitation, temperature, and vegetative cover, Gustavson et al. (1981) established that given the annual average temperature of the Rolling Plains (15.6 C to 17.2 C [60 F to 63 F]):

1. There will be an increase in sediment yield as precipitation increases towards a yearly average of 50 centimeters (19.7 inches).

2. There will be an increase in vegetation with increasing precipitation (with a transition from desert shrub to grass at about 50 centimeters per year (19.7 inches per year). Additional rainfall will promote additional grass cover and result in diminished sediment yield.

3. Maximum sediment yields for the Rolling Plains are reached at annual precipitation levels of 46 to 51 centimeters (18.1 to 20.1 inches).

Gustavson et al. (1981) conclude that with an annual precipitation of 50 to 56 centimeters (19.7 to 22.0 inches), the Rolling Plains and Adjacent Eastern Caprock Escarpment can be expected to have near maximum sediment yields.

Denudation is a measure of the average net thickness of land removed from a specified drainage area during a specified time interval. Denudation rates are useful for interbasinal comparisons, but fail to distinguish differing forms of erosion and localized extreme conditions within a drainage area (SWEC, 1983, DOE/CH/10140-1 pp. 177-179). For the purposes of this study, erosion is better evaluated in terms of escarpment retreat and stream incision.

The most significant erosional activity in the Palo Duro Basin area, now and during the history of the Quaternary, has been the retreat of the High Plains margin, particularly along the Eastern Caprock Escarpment, which is 73 kilometers (45 miles) east of the site at Palo Duro Canyon (an embayment in the escarpment). The High Plains are being reduced to the level and form of the Rolling Plains by the headwaters of rivers that flow across the Rolling Plains. Gustavson et al. (1981, p. 418) estimated average historical rates of retreat of the Eastern Caprock Escarpment at between 0.11 meter per year (0.35 foot per year) and 0.18 meter per year (0.60 foot per year) for periods ranging from 10,000 to 3,000,000 years. For the High Plains margin along the Canadian River Valley, Gustavson et al. (1980b, p. 78) estimated historical rates of retreat at between 0.031 meter per year (0.10 foot per year) and 0.042 meter per year (0.14 foot per year) for periods up to 600,000 years. The Canadian River rates are based on valley widening accompanying river incision.

According to Bloom (1969, p. 67), rivers that flow in alluvium-lined channels on continuous floodplains have achieved graded conditions. Although they continue to erode the land over which they flow, the rate of downcutting is substantially lower than that of actively incising streams. The Canadian River is graded along much of its course through the Canadian Breaks. Evans and Meade (1945, p. 500) measured more than 30 meters (100 feet) of sand fill at Tascosa (Oldham County), at the Santa Fe Railroad crossing north of Amarillo (Potter County), and at Canadian (Hemphill County); the extent and continuity of these deposits are shown by Barnes (1969 and 1983). Broad alluvial channels also line the valleys of the Prairie Dog Town Fork of the Red River and the Pease River, east of the Southern High Plains (Barnes, 1968; Gustavson et al., 1980b, Figure 30). Much farther south, the Brazos River appears ungraded. These observations indicate that the rivers of principal importance closest to the site are not actively incising their channels.

One late Pleistocene and two Holocene terraces are observed along rivers throughout the region (Evans and Meade, 1945, p. 500). The older terrace identified by Evans and Meade (1945) was dated by Gustavson et al. (1980b, p. 78) as Kansan (600,000 years old) or slightly younger. They estimated that the Canadian River has incised 62 meters (200 feet) since that time, at an average incision rate of 10^{-4} meter per year (3.3×10^{-4} foot per year). East of the Eastern Caprock Escarpment, Simpkins and Baumgardner (1982, p. 161) estimated the maximum average rate of incision during the past 600,000 years as 9.1×10^{-5} meter per year

(3.0×10^{-4} foot per year). At Holmes Creek, near the Eastern Caprock Escarpment, Gustavson et al., (1980b, p. 77) indicated 12.5 meters (41 feet) of incision in the last 7,900 to 9,500 years, which is an average incision rate of 1.3×10^{-3} to 1.6×10^{-3} meter per year (4.3×10^{-3} to 5.4×10^{-3} foot per year). Four kilometers (2.5 miles) to the north of Holmes Creek, near the head of Little Red River, Baumgardner (1983) estimated the rate of incision during the past 1,600 years as approximately 6.3×10^{-3} meter per year (2.1×10^{-2} foot per year). Along a small canyon on the High Plains near Buffalo Lake, Finley (1981) estimated the maximum average incision rate over the past 910 years at 2.3×10^{-3} meters per year (7.5×10^{-3} foot per year).

The short-term incision rates (those that are measured for periods of 10^3 to 10^4 years) are not representative of long-term mean conditions, either regionally or at the point of measurement. For example, if Little Red River had been incising its channel throughout the past 600,000 years, at the average rate determined by Baumgardner (1983) for the past 1,600 years, then the stream bed would now be 3,780 meters (12,600 feet) below the projection of the High Plains surface, whereas, in fact, it is only about 180 meters (600 feet) below. Average rates of erosion are meaningful only for the periods of time for which they are determined. Furthermore, extrapolations of high rates of incision along headwater streams fail to account for the exponential decrease in erosion rates as slopes are erosionally reduced. Unrestricted projections of tributary incision would lead to a conceptual situation in which the tributary streams erode to a lower elevation than the more slowly incising trunk river downstream.

3.2.2.3 Paleoclimate

Major fluctuations in the climate of the area have occurred during the past 1.8 million years (the Pleistocene Epoch). Four glacial stages are recognized, the most recent of which ended about 10,000 years ago (Table 3-1). Glaciers extended only as far south as Nebraska. Farther south, the climate was probably cooler and wetter than at present (pluvial).

The present climate of the Southern High Plains and vicinity is characterized as semiarid to subhumid. The area is located between the dry desert climate to the west and wet humid climate to the east and southeast. The Rolling Plains receives more precipitation on average than the High Plains. Much of the rainfall occurs as brief but intense local showers (refer to Section 3.4.3).

Based on observed orbital-climate relationships, Hays et al. (1976, p. 1131) predict that the trend during the next several thousand years will be toward extensive glaciation in the Northern Hemisphere. By analogy with Pleistocene glacial history, Bloom (1983, p. 528) suggests that in the next 10,000 years, continental glaciers could extend as far south as the Great Lakes. However, Imbrie and Imbrie (1979, p. 187) suggest that continental glaciation could be delayed as much as 23,000 years from the present by the CO_2-induced "superglacial" period.

In the shorter term (during the next century or two), the burning of fossil fuels will double the natural atmospheric concentration of CO_2, cause excess capture of infrared radiation, and increase the mean global temperature by 2 to 18 C (4 to 64 C) (Broecker, 1977, pp. 8, 12). Because of inadequate knowledge of cloud physics, modelers have assumed that the current average cloud cover will continue. However, if rising CO_2 levels enhance the extent of cloud cover, more incoming sunlight will be reflected back and the planet will not warm as much as predicted. Conversely, if average cloud cover decreases, the global warming will be greater (Broecker, 1977, p. 12). An average temperature of 18 C (64 F) would exceed the range of natural variability experienced during the last one million years of Quaternary history. The predicted rise in temperature would be only about half as great as the change that occurred during the last deglaciation, but it would be more abrupt (Broecker, 1977, p. 18). This so-called superinterglacial is expected to last about 1,000 years (Broecker, 1977, p. 8) or perhaps 2,000 years (Imbrie and Imbrie, 1979, p. 186). The effect of this brief global warming on geologic processes cannot be determined without reliable estimates of regional variations in temperature and rainfall. These estimates exceed the capability of existing climatic models (Broecker, 1977, p. 12). In the absence of reliable regional models, it may be reasonable to assume that the post-Wisconsinan trend to warmer and drier conditions will

Table 3-1. Pleistocene Stages

Glacial	Interglacial
	Holocene
Wisconsinan	
	Sangamonian
Illinoian	
	Yarmouthian
Kansan	
	Aftonian
Nebraskan	

Source: Seyfert & Sirkin, 1973, p. 437.

continue. As the natural cooling trend resumes after the superinterglacial, pluvial conditions are expected to return in the Texas Panhandle.

Langbien and Schumm (1958, pp. 1076-1077) found that soil erosion by runoff is greatest where the climate supports a natural vegetative cover transitional between grassland and desert shrub (similar to today's climate in the Texas Panhandle). When effective precipitation decreases, erosion decreases because of a deficiency of runoff. When effective precipitation increases, erosion decreases because of increased density of the protective vegetative cover. Gustavson et al. (1981, p. 415) conclude that present rates of erosion are near maximum. A change to pluvial conditions would tend to reduce the present rates of erosion.

Caran (1985, p. 13) points out that precipitation may not be the principal factor limiting vegetative ground cover in those areas near escarpments where soils are thin or saline. In that case, erosion could be expected to increase locally in response to increased precipitation.

A change to a wetter climate, with less evaporation, would increase ground-water flow and could increase dissolution along salt margins. Increased dissolution would increase erosion inasmuch as rock dissolution is a form of erosion. Furthermore, ground subsidence over areas of salt dissolution would temporarily lower erosional base levels and increase the rate of erosion upstream. The increased sediment load would settle out in the area of subsidence, and the stream channel would aggrade until it approximated its presubsidence profile.

3.2.3 Stratigraphy

3.2.3.1 Regional Stratigraphy

The succession of stratigraphic units recognized in the Palo Duro Basin is illustrated in Figure 3-6, and a geologic time scale is presented in Figure 3-7. Regional stratigraphic and structural relationships are illustrated in a series of cross sections (Figures 3-9 through 3-14), whose locations are mapped in Figure 3-8. For each of the two cross-section lines, the stratigraphic section is broken into three intervals: Precambrian through Wolfcamp, Wichita through Upper San Andres, and Queen and Grayburg through Ogallala. Constructing a separate cross section for each of these intervals allows moderate detail without excessive scale distortion, and using a mean-sea-level datum preserves a reasonable structural geometry. Cross sections are located to take advantage of wells that penetrate basement, and key geophysical logs from the wells are reproduced on the cross sections. Department of Energy (DOE) wells are not generally included because they do not reach basement. However, all wells near the cross sections were evaluated in deriving the regional correlations.

3.2.3.1.1 Precambrian Through Mississippian Systems. Precambrian rocks are not exposed in the immediate site region. Major basement rock units which have been identified in deep exploratory wells in the Panhandle region include the Sierra Grande Granite (1.27 billion years), the Amarillo Granite (1.0 to 1.19 billion years), the Panhandle Volcanics (1.1 to 1.18 billion years), and the Swisher Diabase (1.14 billion years; Figure 3-15). Precambrian igneous activity was followed by a period of erosion which extended from the late Precambrian into the Ordovician throughout most of the Panhandle area.

In southwestern Oklahoma, igneous activity continued into the Cambrian with intrusion of the Wichita Granite and Carlton Rhyolite (525 million years), both presently exposed in the Wichita Mountains.

Discontinuous Cambrian marine sandstone is reported in the Palo Duro Basin (Nicholson, 1960, p. 56), but none was penetrated in the wells shown on the cross sections. The Ordovician Ellenburger Group is present in the eastern and western parts of the basin but is absent along a northwest-southwest-trending belt through the basin center (Figures 3-9 and 3-10). It is predominantly dolomite (Dutton et al., 1982, p. 10; Totten, 1956, p. 1951). Silurian and Devonian rocks are not found in the Palo Duro Basin (Totten, 1956, p. 1953). Mississippian rocks are present through most of the Palo Duro Basin; they are absent locally over structure and along the northern margins of the basin (Figures 3-9 and 3-10).

ERA	SYSTEM	SERIES	GROUP	FORMATION
CENOZOIC	QUATERNARY			RECENT FLUVIAL AEOLIAN AND LACUSTRINE DEPOSITS
	TERTIARY			OGALLALA AND LACUSTRINE DEPOSITS
MESOZOIC	CRETACEOUS	COMANCHE	WASHITA	
			FREDRICKSBURG	
			TRINITY	
	TRIASSIC		DOCKUM	TRUJILLO (Santa Rosa)
				TECOVAS
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE (Quartermaster)
				ALIBATES
		GUADALUPE	ARTESIA (WHITEHORSE)	SALADO-TANSILL
				YATES
				SEVEN RIVERS
				QUEEN-GRAYBURG
			PEASE RIVER	SAN ANDRES (BLAINE)
		LEONARD		GLORIETA
			CLEAR FORK	UPPER CLEAR FORK
				TUBB
				LOWER CLEAR FORK
				RED CAVE
			WICHITA	
		WOLFCAMP		
	PENNSYLVANIAN	VIRGIL	CISCO	
		MISSOURI	CANYON	
		DES MOINES	STRAWN	
		ATOKA	BEND	
		MORROW		
	MISSISSIPPIAN	CHESTER		
		MERAMEC		
		OSAGE		
	ORDOVICIAN	CANADIAN	ELLENBURGER	
	CAMBRIAN		UNNAMED SANDSTONE	
	PRECAMBRIAN			

Explanation

~~~~~ Unconformable Boundary

-— — — Boundary in Dispute

( ) Formation Name in Outcrop

Note: See Table 3-2 for expanded column of Cenozoic formations.

Sources: Handford and Dutton, 1980; Dutton et al., 1982; Barnes, 1967, 1968, 1969, 1983; Brand, 1953; Fink, 1963.

Stratigraphic Column of the Palo Duro Basin

Figure 3-6
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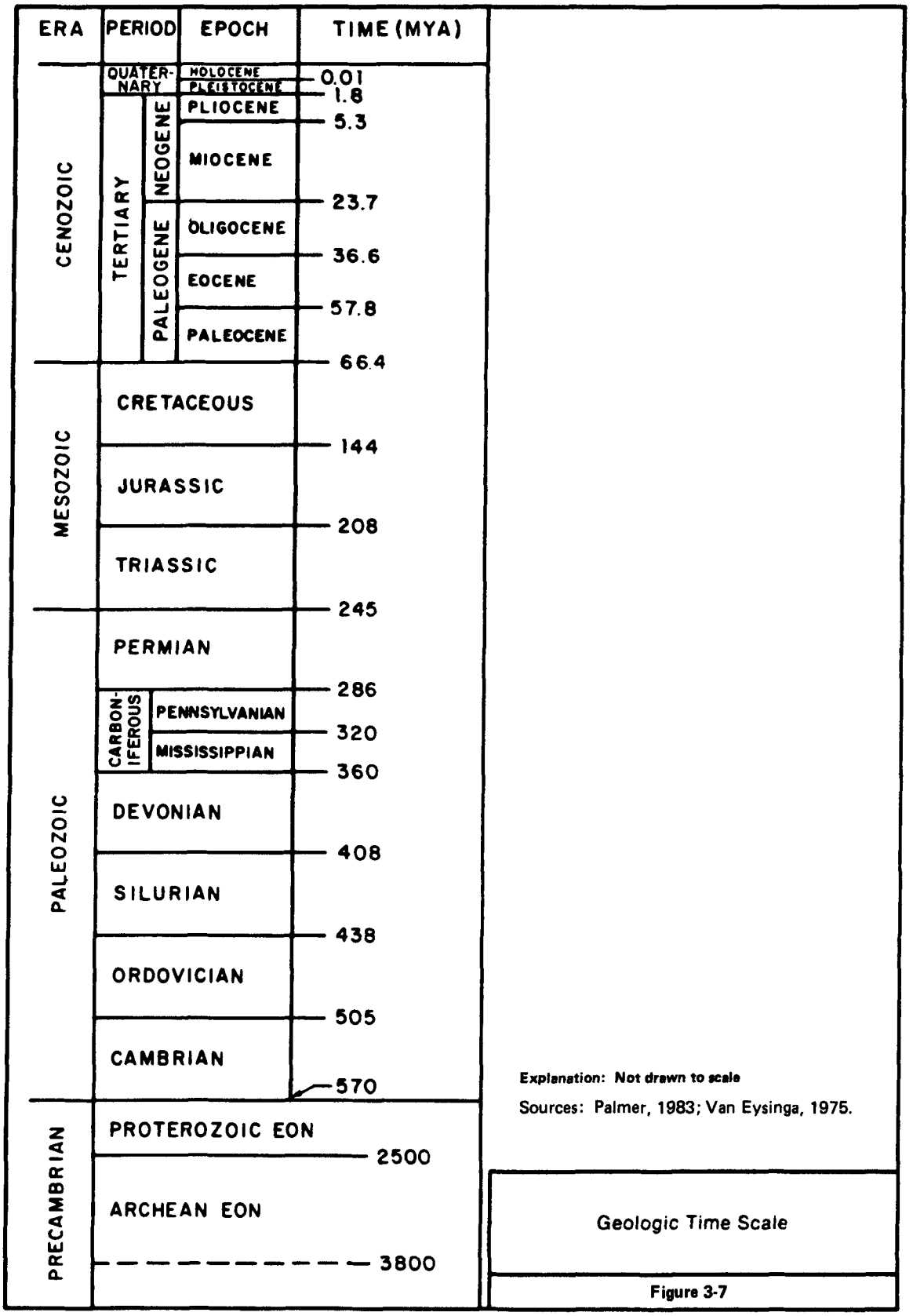
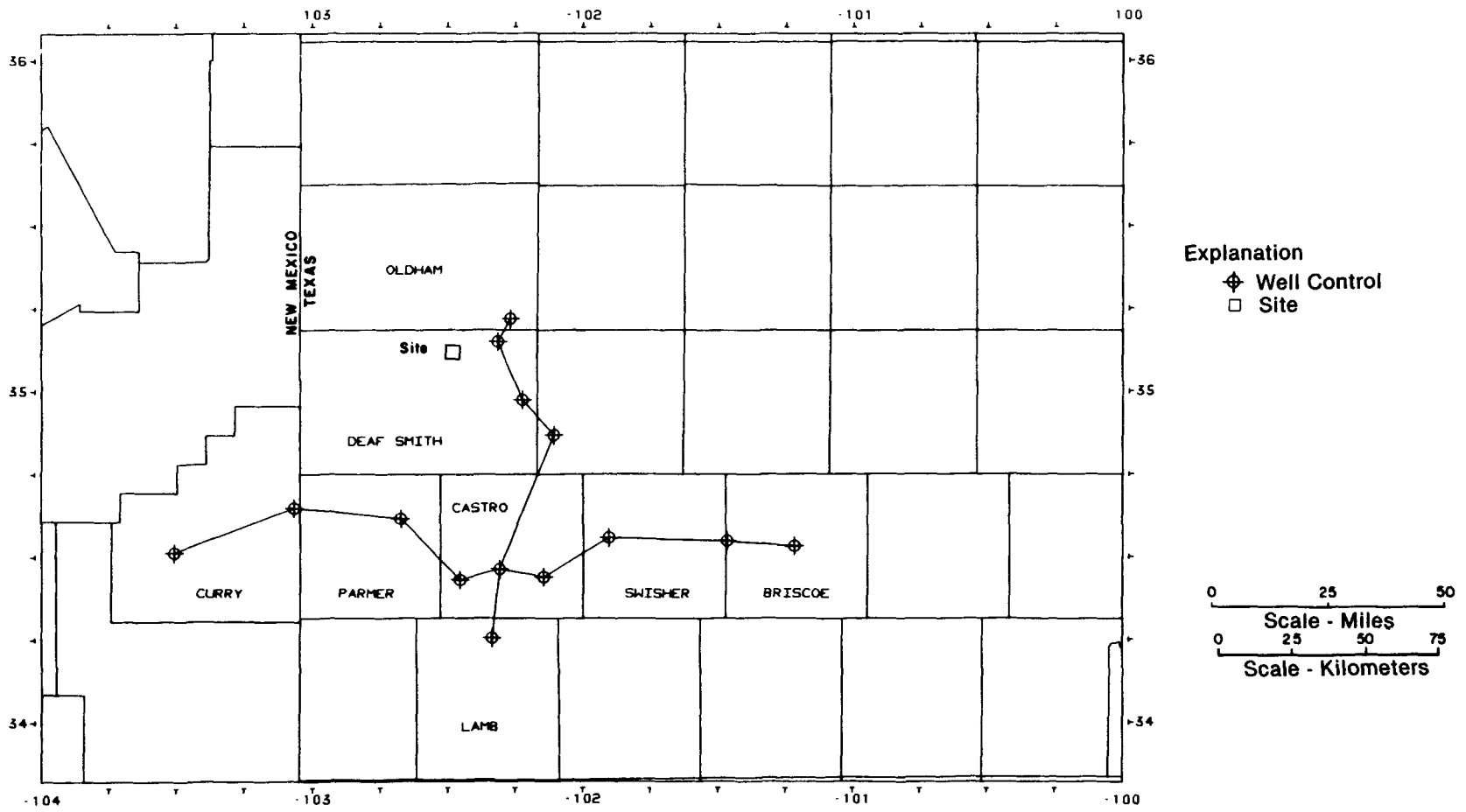


Explanation: Not drawn to scale

Sources: Palmer, 1983; Van Eysinga, 1975.

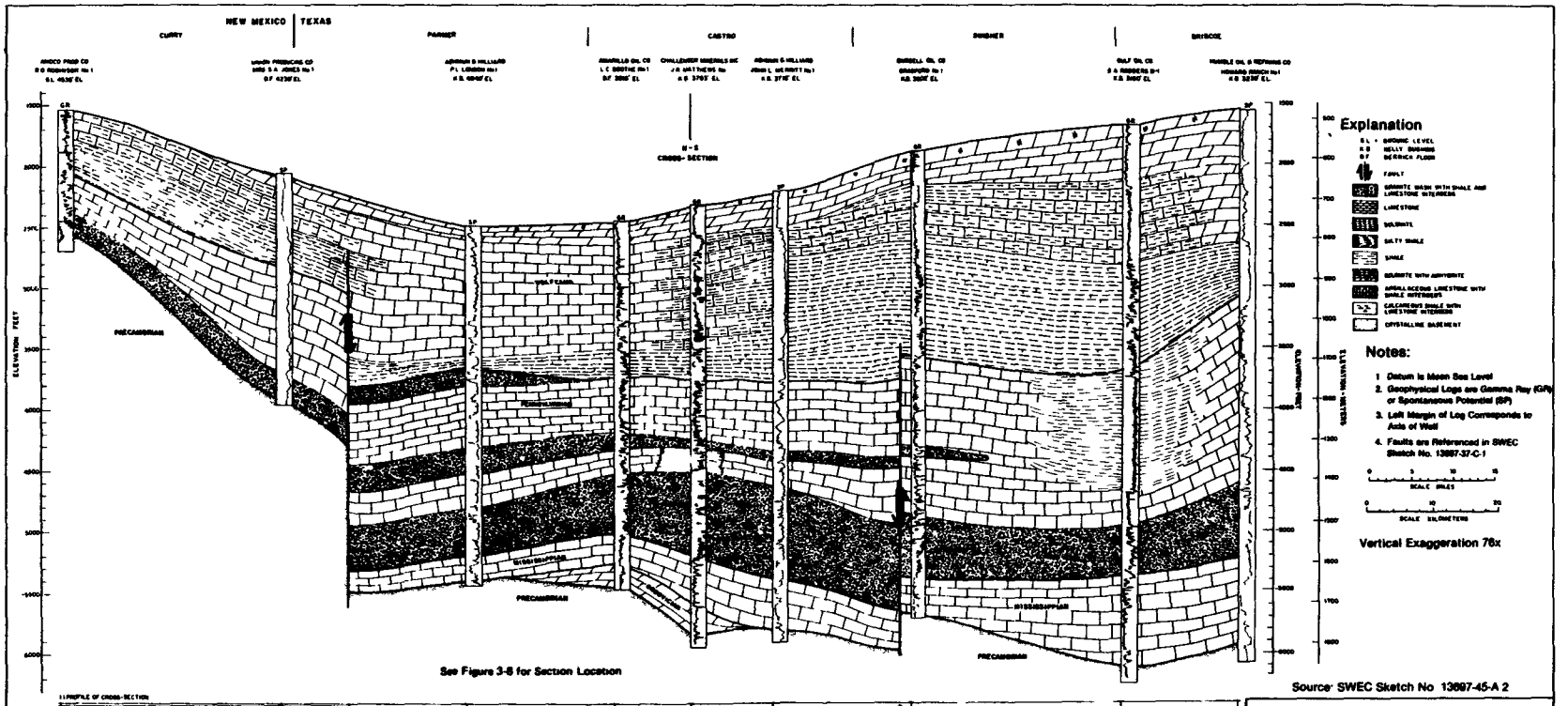
Geologic Time Scale

Figure 3-7



Cross Section Locations

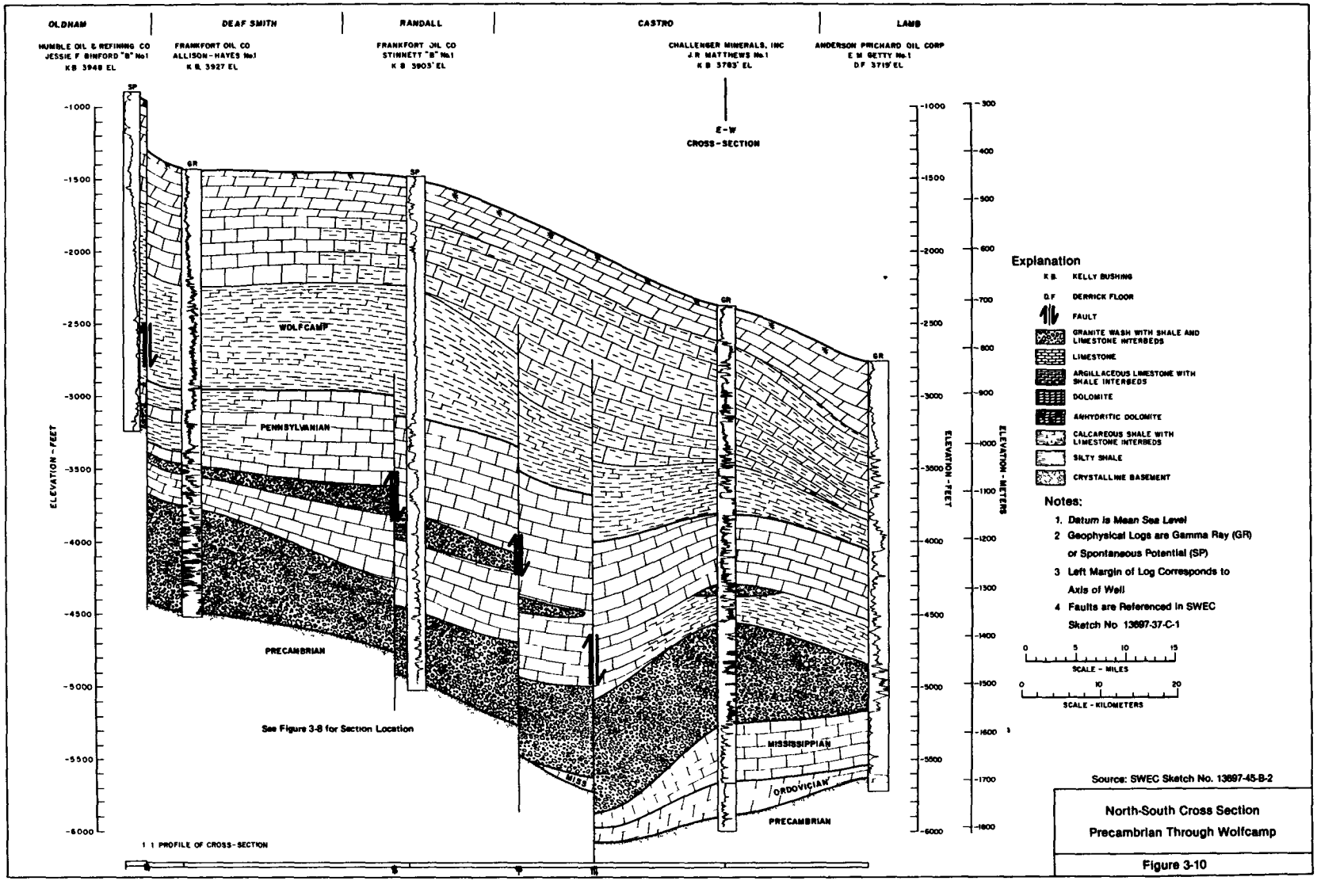
Figure 3-8



East-West Cross Section
Precambrian Through Wolfcamp

Figure 3-9

A larger reproduction of this figure appears at the back of this volume.



North-South Cross Section
Precambrian Through Wolfcamp

Figure 3-10

A larger reproduction of this figure appears at the back of this volume.

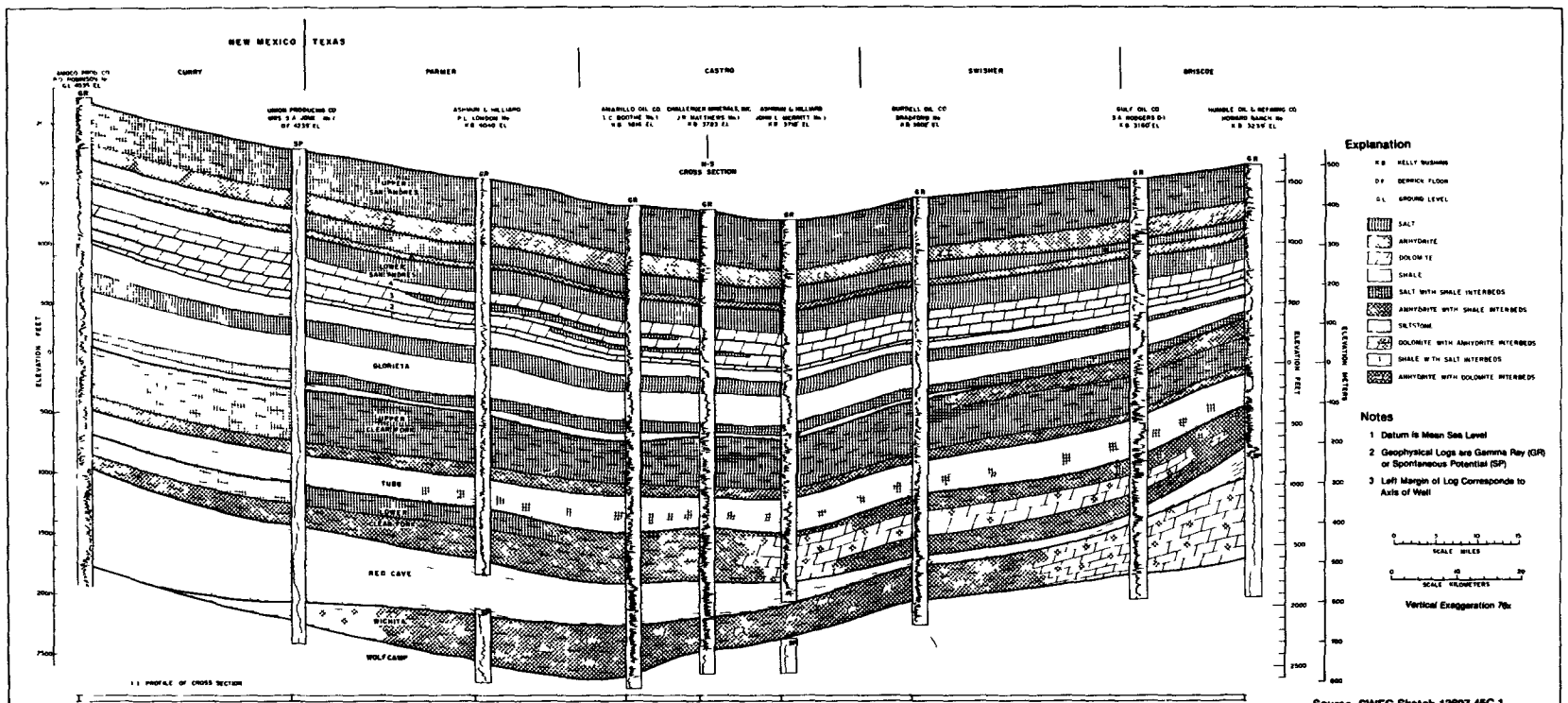
3.2.3.1.2 Pennsylvanian System. The Pennsylvanian rocks were deposited during the period of maximum subsidence of the Palo Duro Basin, which began in the Late Mississippian. Lower Pennsylvanian rocks consist primarily of thick intervals of arkose (granite wash) derived from erosion of basement highlands and deposited in extensive fan deltas. Continued subsidence resulted in a marine transgression (Dutton et al., 1982, p. 33), and Upper Pennsylvanian limestone and shale accumulated regionally (Figures 3-9 and 3-10).

3.2.3.1.3 Lower Permian System. The Lower Permian Wolfcamp Series records the transition of the area from a relatively deep basin to a restricted carbonate platform (Dutton et al., 1982, p. 19). It is a complex accumulation of shales, limestones, and argillaceous limestones; arkose is present locally near the uplifts (Figures 3-9 and 3-10). The top of the Wolfcamp consists of a persistent brown dolomite that is traceable throughout the Texas Panhandle. The brown dolomite is porous and is pumped extensively for hydrocarbons in the Amarillo Uplift area.

3.2.3.1.4 Upper Permian System. Topography at the beginning of evaporite deposition was subdued. The Wolfcamp Brown dolomite was deposited over all basement uplifts, and other Wolfcamp sediments filled basinal areas. Evaporite strata therefore show great lateral continuity (Figures 3-12 through 3-15). Handford (1979), based on studies of regional facies relationships in the Clear Fork Group, developed a model for evaporite deposition in a sabkha setting. However, Fracasso and Hovorka (1984) and Hovorka et al., (1985), working with core and geophysical logs of the San Andres Formation, emphasize the extensive shallow-water shelf setting in which the evaporites were deposited. Facies changes within the evaporite environment reflect a northward increasing salinity gradient and the effect of subtle differences in the rate of subsidence over structural features. The Amarillo Uplift in particular had a strong influence on the distribution of carbonates and evaporites in some intervals (Fracasso and Hovorka, 1984). The Wichita Group represents the continued transition from the fan delta, marine shelf, and deep-basin environments of the Pennsylvanian Period to the sabkhas, brine pans, and shallow marine conditions that prevailed during the Late Permian (Budnik and Smith, 1982, p. 45). The Red Cave Formation of the Clear Fork Group is composed of sandstone in the northwest part of Palo Duro Basin, and grades to finer-grained clastics interbedded with evaporites towards the center of the basin (Handford, 1981). It is conformably overlain by successively younger formations of the Clear Fork Group: the Lower Clear Fork Formation (predominantly carbonates and evaporites), the Tubb Formation (alternating clastic rocks and evaporites), and the Upper Clear Fork Formation (mostly carbonates and evaporites) (SWEC, 1983, DOE-CH-10140-1). The Wichita rocks consist of a belt of massive anhydrite and dolomite and lesser amounts of fine-grained clastics (Figures 3-11 and 3-12). The overlying Glorieta Formation consists of red mudstones and siltstones, with thick interbeds of salt (Figures 3-11 and 3-12) (Presley and McGillis, 1982, p. 4).

The San Andres Formation is an evaporite sequence containing minor amounts of carbonates and clastic rocks. San Andres regressive cycles generally consist, from bottom to top, of limestone, dolomite, nodular anhydrite, laminated anhydrite, bedded halite, and chaotic mixtures of halite and mudstone (Hovorka, 1983, p. 1). These cycles are generally separated by transgressive shales. Lower and upper divisions of the San Andres Formation have been established by the Texas Bureau of Economic Geology (Presley, 1980), with five subdivisions of the Lower San Andres based on depositional cycles (Figures 3-11 and 3-12).

Unit 1 is the basal Lower San Andres unit. It consists of a thin dolomite with interbeds of shale, anhydrite, and salt. Unit 1 was originally identified by Presley (1979). Regan and Murphy (1984, Figure 12) traced Unit 1 as far north as Oldham and Potter Counties. Fracasso and Hovorka (1984) were unable to differentiate the Unit 1 carbonate from the clastics of the Glorieta Formation in the northern Palo Duro Basin. Units 2 and 3 are thin cycles composed of carbonate, anhydrite, and halite. The Unit 2 carbonate pinches out against the Oldham Nose and Amarillo Uplift. Unit 3 pinches out against the Amarillo Uplift. The base of Unit 4 is microcrystalline dolomite, dolomitic limestone, and limestone. Above the carbonate is a sequence of the cleanest and thickest San Andres salt recognized in the basin (SWEC, 1984, BMI/SRP-5004). This part of Unit 4 is the proposed repository host rock. Like the other salt beds, its regional extent is controlled by facies change and dissolution (Section 3.2.3.3; Fracasso and Hovorka, 1984; Hovorka et al., 1985). In the central basin, Unit 5 consists of a

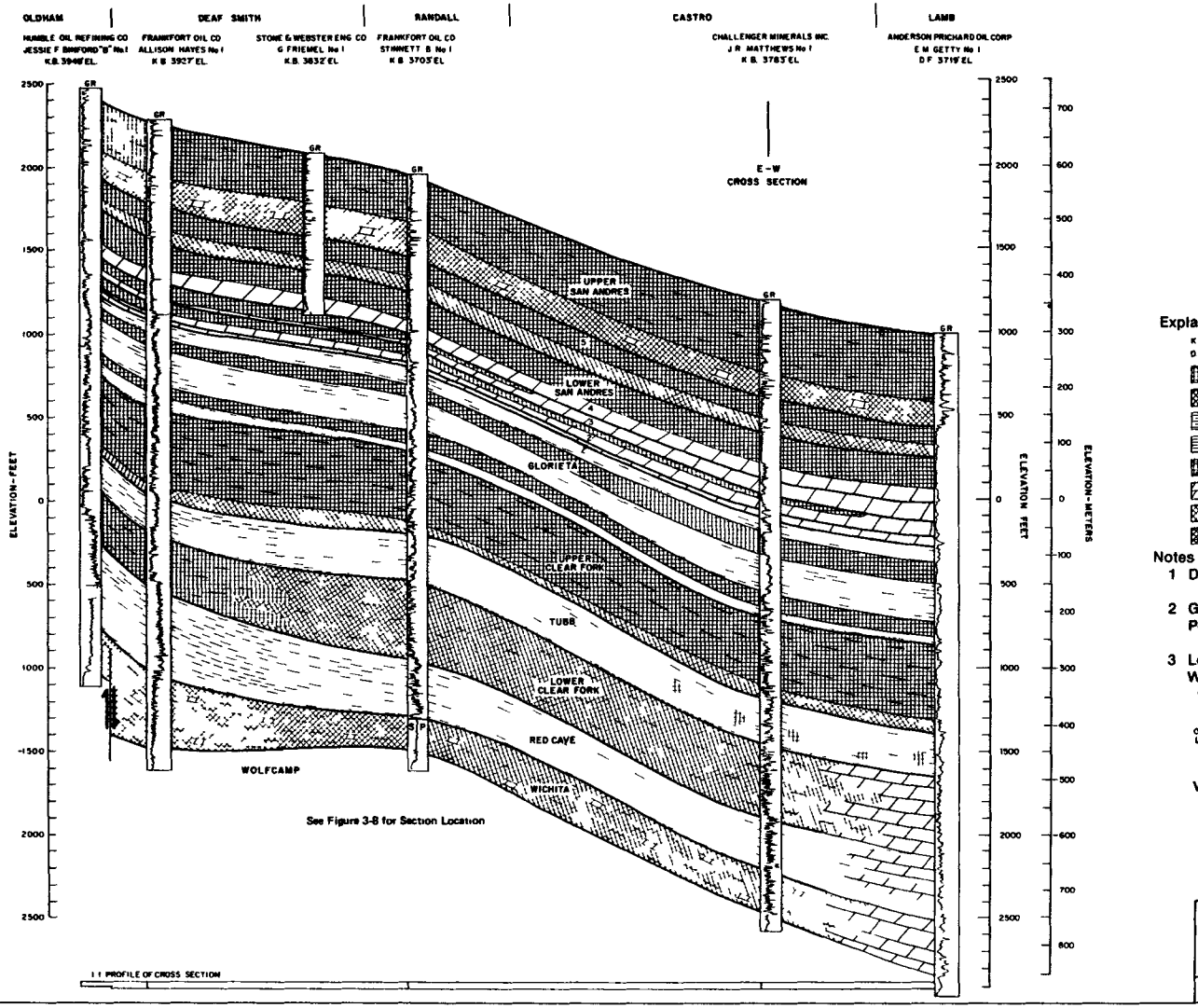


Source SWEC Sketch 13697-45C-1

East-West Cross Section
Wichita Through Upper San Andres

Figure 3-11

A larger reproduction of this figure appears at the back of this volume.



Explanation

K B KELLY BUSHING
D F DERRICK FLOOR

SALT
ANHYDRITE
SHALE
SILTSTONE
SALT W TH SHALE INTERBEDS
DOLOMITE
ANHYDRITE WITH DOLOMITE INTERBEDS
ANHYDR TE WITH SHALE INTERBEDS

Notes

1 Datum is Mean Sea Level

2 Geophysical Logs are Spontaneous Potential (SP) or Gamma Ray (GR)

3 Left Margin of Log is the Axis of the Well

0 5 10 15
SCALE – MILES

0 10 20
SCALE KILOMETERS

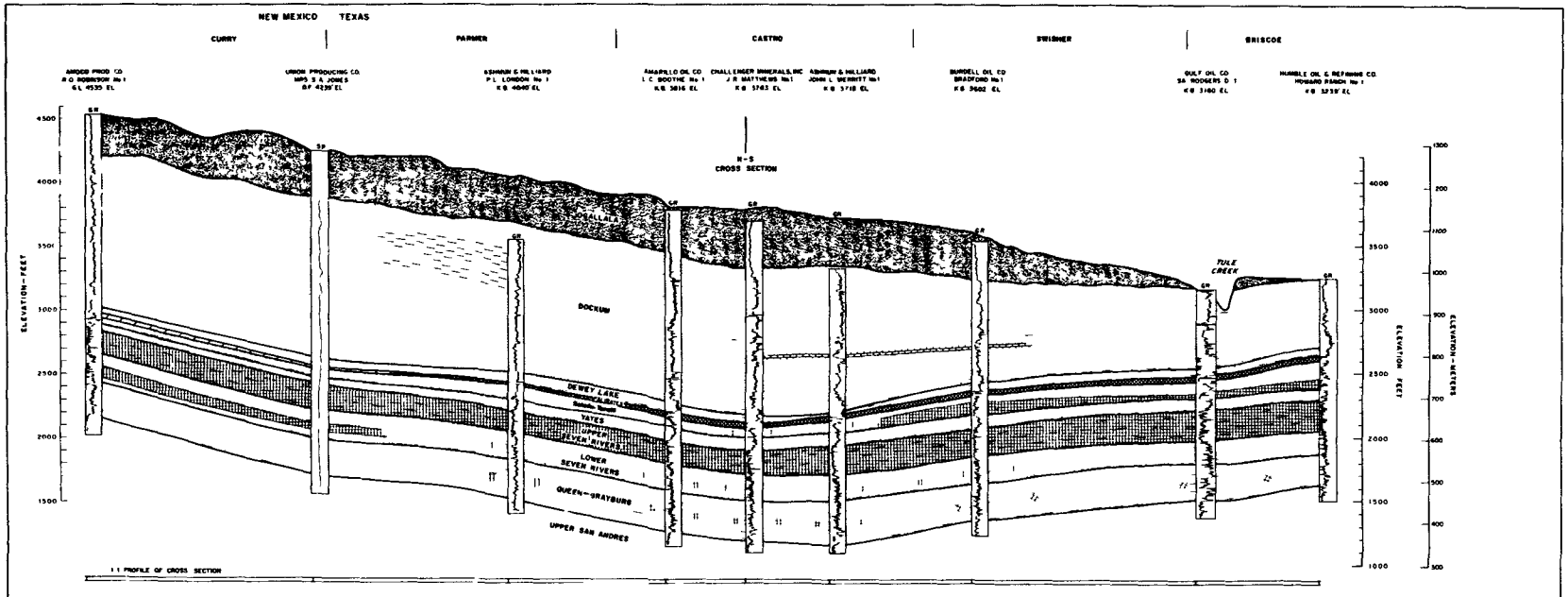
Vertical Exaggeration 76 x

Source SWEC Sketch 13697-45D-1

North-South Cross Section
Wichita Through Upper San Andres

Figure 3-12

A larger reproduction of this figure appears at the back of this volume.



Explanation

- UNCONSOLIDATED SAND AND GRAVEL
- LIMESTONE
- DOLOMITE
- SALT
- SALT WITH SHALE INTERBEDS
- ANHYDRITE
- SANDSTONE
- SANDY SILTSTONE
- SILTSTONE
- SILTSTONE WITH SALT INTERBEDS
- KB KELLY BUSHING
- DF DERRICK FLOOR
- GL GROUND LEVEL

Notes:

1. Datum is Mean Sea Level
2. Geophysical Logs are Gamma Ray (GR) or Spontaneous Potential (SP)
3. Left Margin of Log Corresponds to Axis of Well
4. Ogallala Thicknesses from "Ogallala Aquifer Mapping Program" SWEC 1983
5. Surface Topography from U S G S. Clovis (1983) and Plainview (1974) Texas 2° Sheets

SCALE MILES 0 5 10 15

SCALE KILOMETERS 0 10 20

Vertical Exaggeration 76x

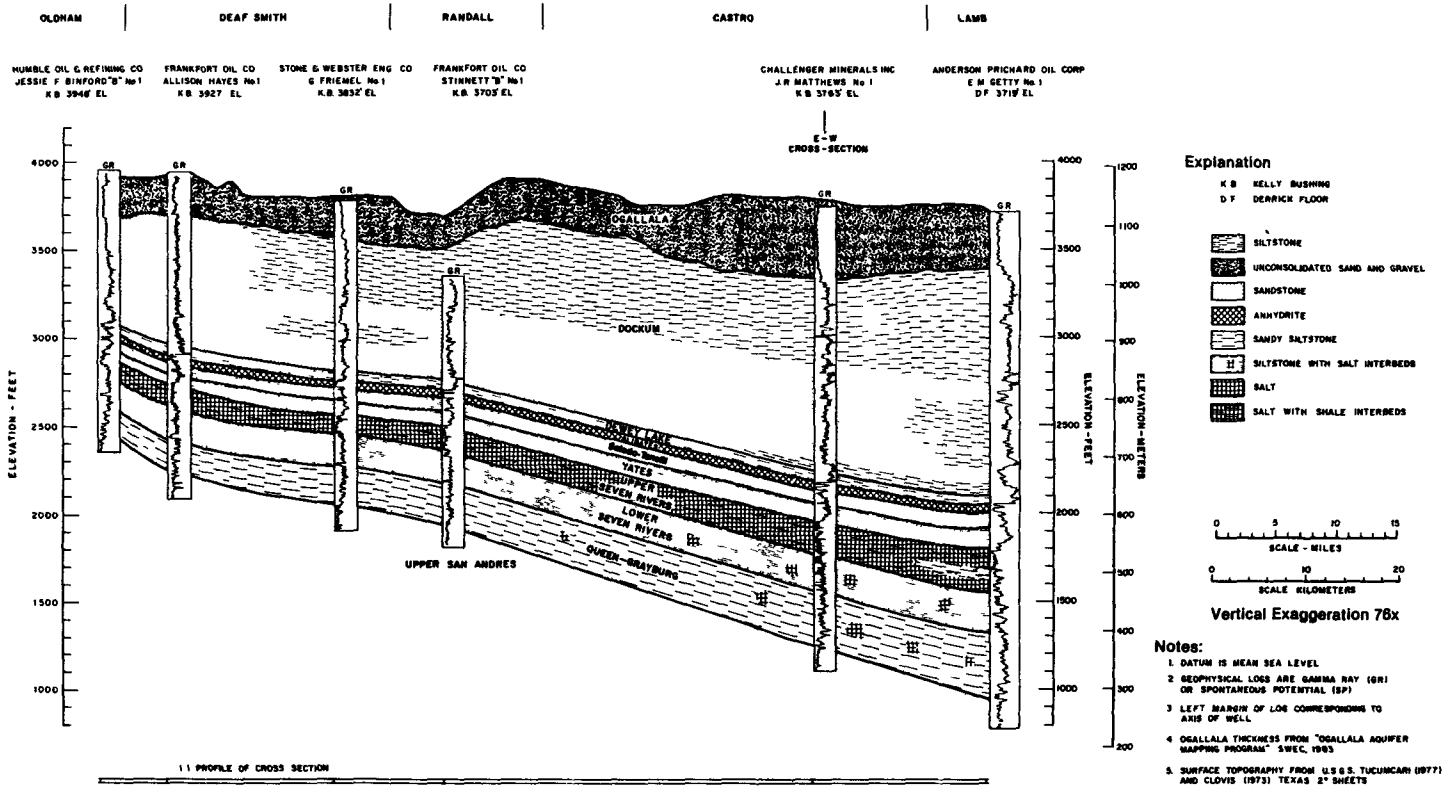
Source SWEC Sketch No 13697-45-E 1

East-West Cross Section

Queen-Grayburg Through Ogallala

Figure 3-13

A larger reproduction of this figure appears at the back of this volume.



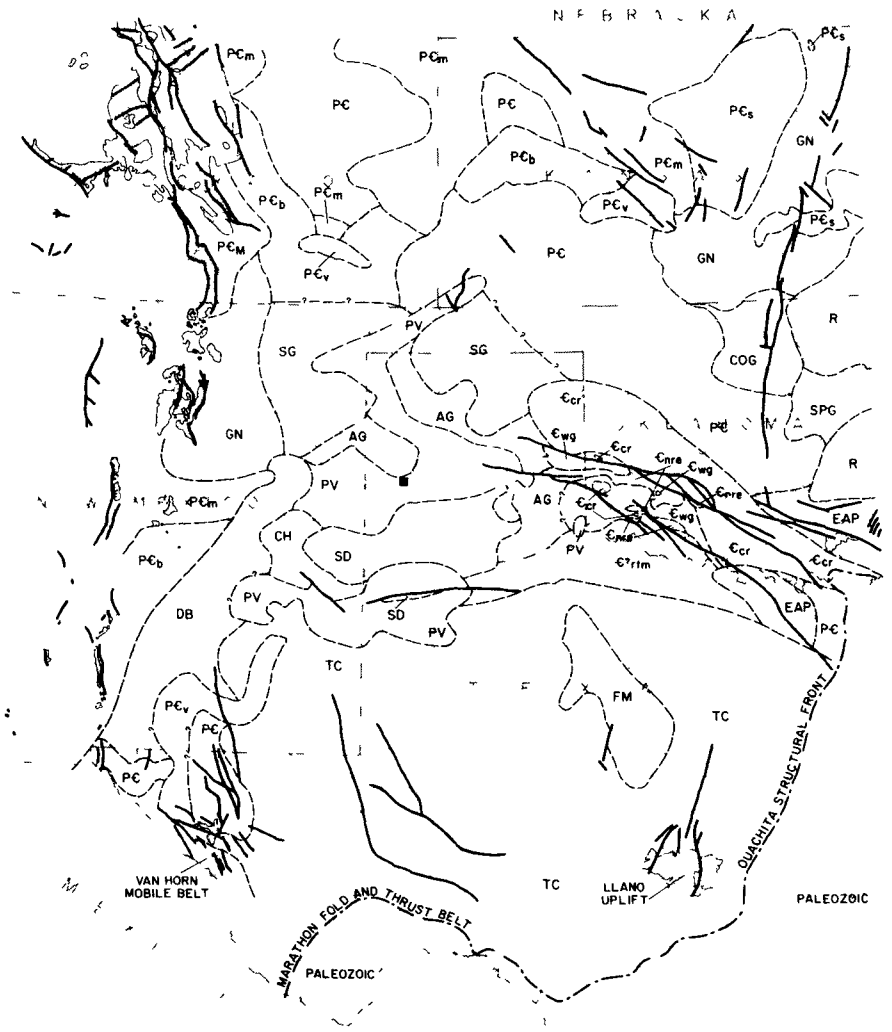
See Figure 3-8 for Section Location

Source: SWEC Sketch No 13697-45F 1

North-South Cross Section
Queen-Grayburg Through Ogallala

Figure 3-14

A larger reproduction of this figure appears at the back of this volume.



Explanation

- Outcrop of Precambrian Rocks
- Site
- Faults (Undifferentiated)

MIDDLE CAMBRIAN	ϵ_{cr}	– CARLTON RHYOLITE (525 M Y)
	ϵ_{wg}	– WICHITA GRANITE (525 M Y)
EARLY CAMBRIAN	ϵ_{nre}	– NAVAJO-RAGGEDY MT IGNEOUS EVENT (535 M Y)
	$\epsilon?_{rtm}$	– RED RIVER-TILLMAN METASEDIMENTS (>550 M Y)
PRECAMBRIAN	DB	– DE BACA SEDIMENTS AND INTRUSIONS (>900 M Y)
	FM	– FISHER METASEDIMENTS (1000 M Y)
	TC	– TEXAS CRATON, UNDIFFERENTIATED IGNEOUS AND METAMORPHIC ROCKS (1100 M Y)
	PV	– PANHANDLE VOLCANICS (1140 M Y)
	SD	– SWISHER DIABASE (1140 M Y)
	AG	– AMARILLO GRANITES (1140 M Y)
	SPG	– SPAVINAW GRANITE (1200 M Y)
	COG	– CENTRAL OKLAHOMA GRANITE (1200 M Y)
	EAP	– EASTERN ARBUCKLE GRANITE (1200 M Y)
	R	– RHYOLITE INTRUDED BY SPG (>1200 M Y)
	SG	– SIERRA GRANDE GRANITE (1270 M Y)
	CH	– CHAVES GRANITE (1350 M Y)
	GN	– GNEISS AND GRANITE, UNDIFFERENTIATED (1660 M Y)
PRECAMBR AN (AGE UNDIFFERENTIATED)	$P\epsilon_s$	– UNMETAMORPHOSED SEDIMENTARY ROCKS
	$P\epsilon_v$	– RHYOLITE AND PYROCLASTICS
	$P\epsilon$	– UNDETERMINED COMPOSITION
	$P\epsilon_b$	– ORTHOGNEISS AND FELSITE BATHOLITHS
	$P\epsilon_m$	– METASEDIMENTS AND METAVOLCANICS

Sources: Flawn, 1954, 1956; Ham et al., 1964; Muehlberger et al., 1967; Bayley and Muehlberger, 1968.

0 50 100 150
SCALE-MILES
0 100 200 300
SCALE-KILOMETERS

Basement Rock Map of the Texas Area

Figure 3-15

lower interval of anhydrite with minor dolomite and shale overlain by relatively clean salt, interbedded shale, and anhydrite.

The basal Upper San Andres is dominated by anhydrite, with interbeds of dolomite that are fairly persistent throughout the Palo Duro Basin (Figures 3-11 and 3-12). The upper portion is a thick salt that is extensively interbedded with shales, anhydrites, and dolomites of variable thicknesses.

The Queen-Grayburg Formation is primarily reddish-brown fine sandstone, siltstone, and mudstone, with thinly bedded layers of salt and anhydrite throughout (Figures 3-13 and 3-14). The Upper Seven Rivers Formation consists of a lower section of siltstone with interbeds of anhydrite and salt and an upper section of predominantly massive salt with interbeds of mudstone and anhydrite. Across much of the northern Palo Duro Basin, the Seven Rivers Formation contains the uppermost Permian salt bed. The Yates Formation is a thin interval of siltstone and claystone with thinly interbedded anhydrite and salt to the south. The Salado (Salado-Tansill) Formation consists, in the north, of interbedded anhydrite and silty shale. It thickens southward, where it includes massive beds of salt (McGillis and Presley, 1981, p. 6). The Alibates Formation is a thin and persistent marker bed across the basin, composed of a lower anhydrite and dolomite unit, a middle siltstone unit, and an upper anhydrite and dolomite unit. Its lithology grades southeastward generally from dolomite to anhydrite to gypsum (McGillis and Presley, 1981, p. 17). In the J. Friemel well, dolomite is the dominant lithology. The youngest Permian unit is the Dewey Lake Formation (Figures 3-13 and 3-14), which represents the transition from generally marginal marine Late Permian conditions to terrestrial conditions of the Triassic. The Dewey Lake is a relatively thin interval of fluvial siltstones and claystones.

3.2.3.1.5 Mesozoic Era

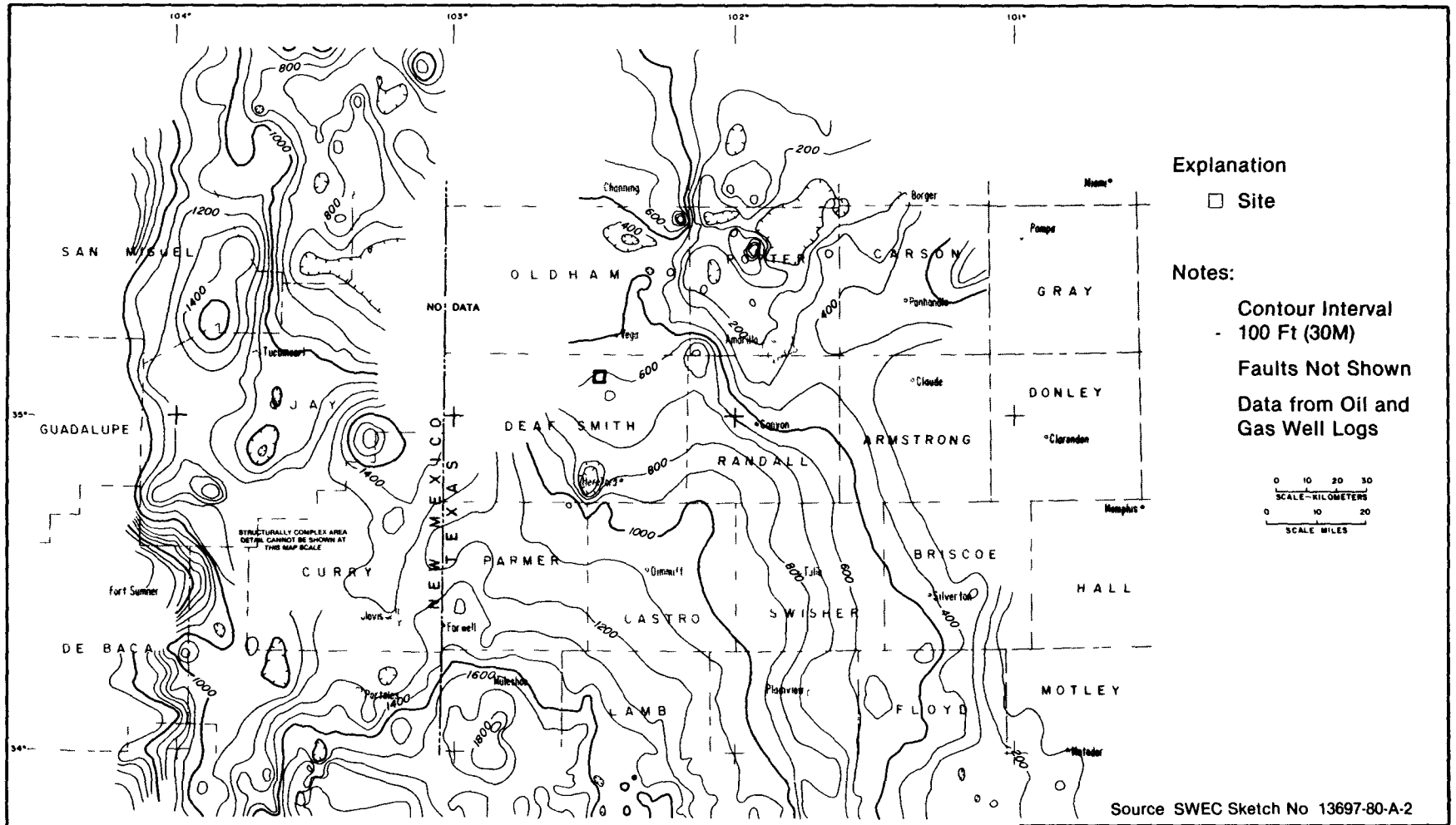
Triassic System. The Upper Triassic Dockum Group consists mainly of terrigenous clastics deposited in a complex fluvial-lacustrine basin. The basin was defined, in part, by Paleozoic structural elements such as the Amarillo Uplift (McGowen et al., 1979, p. 2). The Dockum siltstones, sandstones, conglomerates, and claystones represent a major climatic change from the arid, evaporating salt-pan conditions of the Permian to an alternating humid and arid environment, but the relationship between the Dewey Lake and the Dockum is obscure. The climate change and development of the basin may have been related to the episode of Mesozoic rifting which opened the Gulf of Mexico and Atlantic Ocean (McGowen et al., 1979, p. 3). Deposition appears to have been continuous in some areas from the Permian to Triassic but is marked by an obvious unconformity in others. Complex interfingering of conglomeritic sandstone with finer-grained sediments complicate stratigraphic correlation in the Dockum Group. Some intervals of the Dockum are unconsolidated. Figure 3-16 indicates the thickness of the Dockum Group in the Palo Duro Basin area.

Fink (1963) correlates the permeable sandstones of the Santa Rosa Formation in New Mexico with the Trujillo Formation in the Palo Duro basin (Figure 3-16). In some areas of the Palo Duro basin, these sandstones produce water suitable for livestock and irrigation.

Jurassic System. Jurassic strata occur in the subsurface of the Dalhart Basin (Budnik and Smith, 1982) and do not occur in the Palo Duro Basin.

Cretaceous System. Strata of the Cretaceous System occur only in isolated remnants in the Dalhart and Palo Duro Basins east of the main Cretaceous deposits in New Mexico. The Cretaceous of the Palo Duro Basin consists of basal sandstone (Trinity Group), interbedded shale and limestone (Fredericksburg Group), and shale and thin-bedded limestone (Washita Group) (Brand, 1953).

Tertiary System. Triassic Dockum Group deposits in the site area are unconformably overlain by the Ogallala Formation of Neogene age. The Ogallala consists of mostly fine-to-coarse sand, gravel, and silt with some clay. It is unconsolidated except where caliche has been deposited in 1- to 2-meter (3- to 6-foot)-thick layers near the top of the formation.



Source SWEC Sketch No 13697-80-A-2

Thickness of Dockum Group

Figure 3-16

In localized areas of the Panhandle, sediments of probable lacustrine origin, such as the Blanco and Rita Blanca Formations, overlie the Ogallala (Barnes, 1983; Barnes, 1967). Previously, the Blanco and Rita Blanca were considered to be Quaternary in age. Based on further analyses of fossil fauna, they are now attributed to the Pliocene (Schultz, 1977).

The Ogallala was derived from erosion of rapidly emerging uplift areas in the vicinity of the southern Rocky Mountains by east- and southeast-flowing streams. The formation is a wedge-shaped apron on the Great Plains formed by coalescence of several alluvial fans along the mountain front (Reeves, 1984, p. 129). Some portions of the Ogallala may be eolian in origin (Reeves, 1984, p. 139). Thicknesses between 60 and 120 meters (200 and 400 feet) are common in the Palo Duro Basin area with maximum thicknesses of 250 meters (800 feet) occurring in the vicinity of pre-Ogallala surface valleys and basins. Figure 3-17 shows the thickness and extent of the Ogallala Formation. The Ogallala is the major aquifer for the region; the hydrology is discussed in greater detail in Section 3.3.2.

3.2.3.1.7 Quaternary System. Quaternary deposits in the site vicinity are shown on Figure 3-18. At the surface, they consist mainly of windblown silt or loess deposits which directly overlie the Ogallala Formation. To the south, the Blackwater Draw Formation of Illinoian age, which consists of windblown sand and silt, intervenes between the Ogallala and the loess deposits. Further south, in southern Parmer and Bailey Counties, it crops out in a wide band north and south of the Sand Hills (Barnes, 1967; 1977; 1983). Playa lake deposits occur sporadically throughout the site region but generally increase to the south and east of the site. They are developed in shallow, roughly circular depressions within the loess and Ogallala deposits, and consist mainly of clay and silt. Soil classifications and uses in the site vicinity are described in Section 3.2.9.

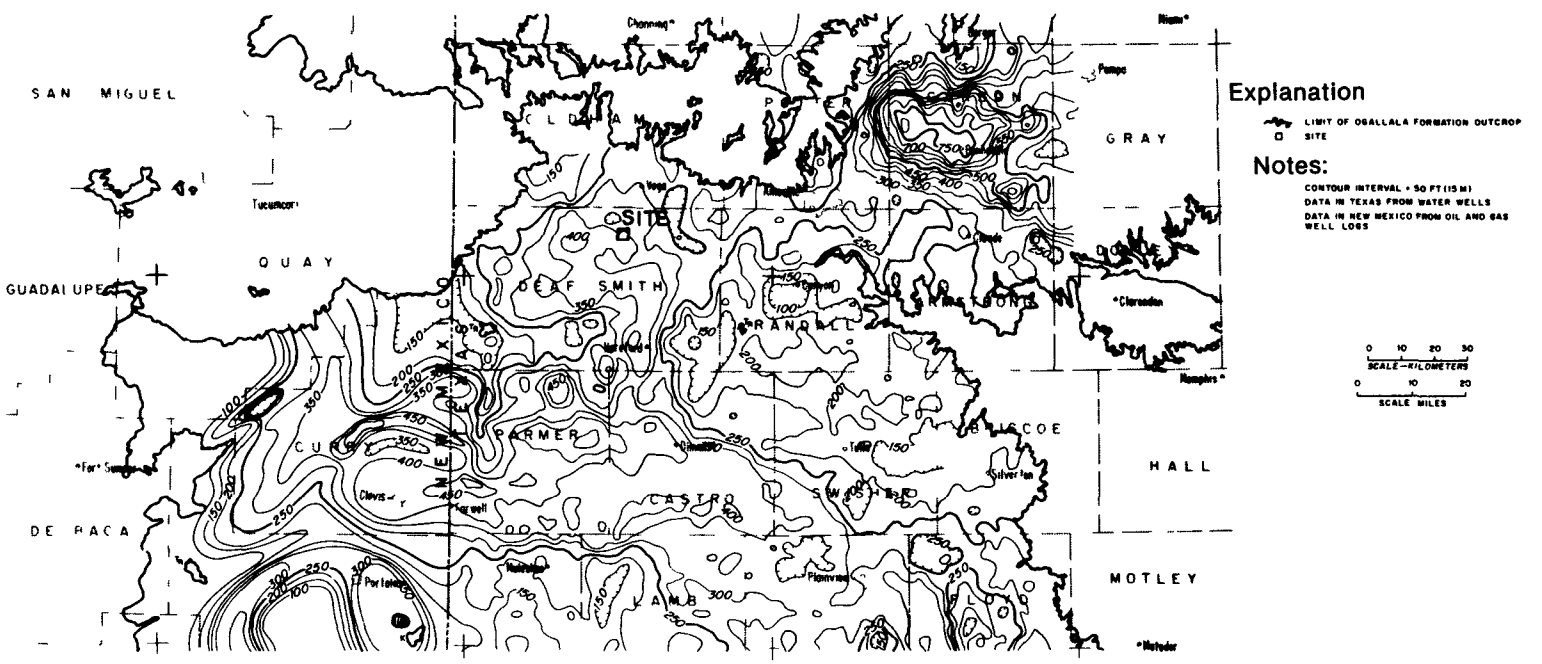
Other Quaternary formations that occur in the Palo Duro Basin area, but south of the area shown on Figure 3-18, include the Tahoka, Double Lakes, and Tule Formations (Table 3-2) (Barnes, 1967; 1968; 1977). The early Wisconsinan Double Lakes Formation consists of interbedded fluvial sands and gravel. The predominantly lacustrine Tahoka Formation, of Wisconsinan age, consists of clay, silt, sand, and gravel; locally, it contains dolomites in the upper clay zones as well. The Tule Formation, which is Kansan, contains lacustrine and fluvial sands, silts, and clays, with a discontinuous basal gravel.

3.2.3.2 Site Stratigraphy

The stratigraphy at the Deaf Smith County site is not known precisely, because no exploratory wells have been drilled within the nine-square-mile site. The nearest deep stratigraphic test is the Stone & Webster J. Friemel No. 1 well located approximately 4.8 kilometers (3.0 miles) south of the site (Figure 3-3). Based on the regional relationships described in Section 3.2.3.1, the formation lithologies and thicknesses in the J. Friemel No. 1 well are thought to be a good representation of actual site conditions. The well was drilled and selectively cored to a depth of 2,524 meters (8,283 feet) and terminates in the Pennsylvanian. Figures 3-19, 3-20 and 3-21 are a graphic summary of the stratigraphic section in the J. Friemel No. 1 well. This summary was prepared using core descriptions and geophysical logs reported by SWEC (1984, BMI/SRP-5011). A generalized stratigraphic column representative of site stratigraphy is presented in Table 3-3.

The wildcat wells closest to the site are the recently completed Hudson Taylor No. 1 and the Pennzoil Black No. 1 which are, respectively, 1 mile east and 3 miles southeast of the site. Geophysical logs obtained from these wells confirm the stratigraphic sequence and the continuity of thicknesses of the Upper Permian Formations identified in J. Friemel No. 1. The DOE participated in the Black No. 1 well (Figure 3-3) and the formation elevations and thicknesses interpreted from the logs are reported by Pierce (1985).

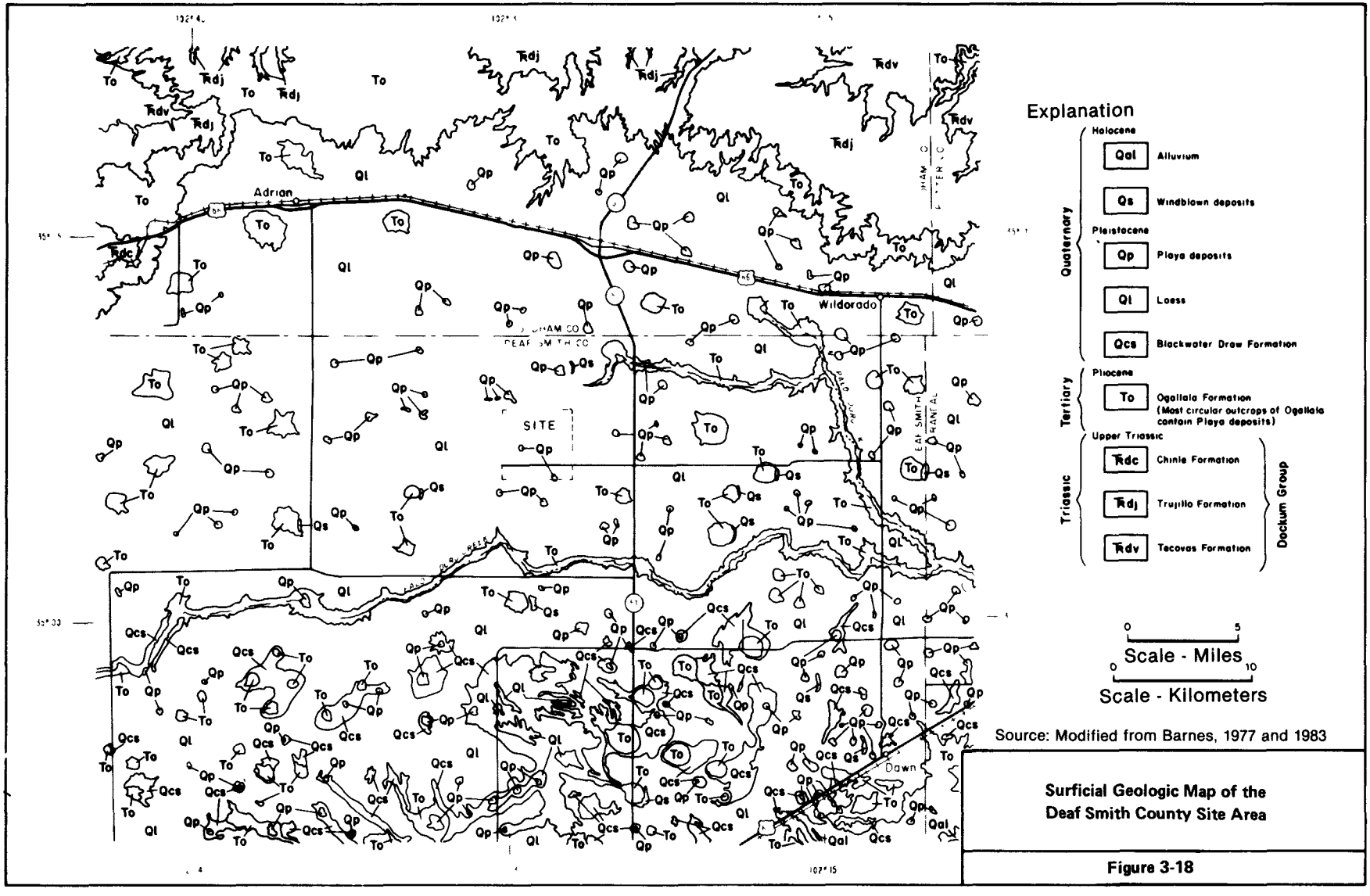
The repository host rock is a thick sequence of bedded salt within Unit 4 of the Lower San Andres Formation. The depth to the top of this unit ranges from about 700 meters (2,400 feet) to 760 meters (2,500 feet) near the Deaf Smith County site (Figure 3-22). The host salt sequence is about 48 meters (160 feet) thick near the site (Figure 3-23).



Source: SWEC Sketch No 13697-80-B-1

Thickness and Extent of Ogallala Formation

Figure 3-17



Source: Modified from Barnes, 1977 and 1983

Surficial Geologic Map of the Deaf Smith County Site Area

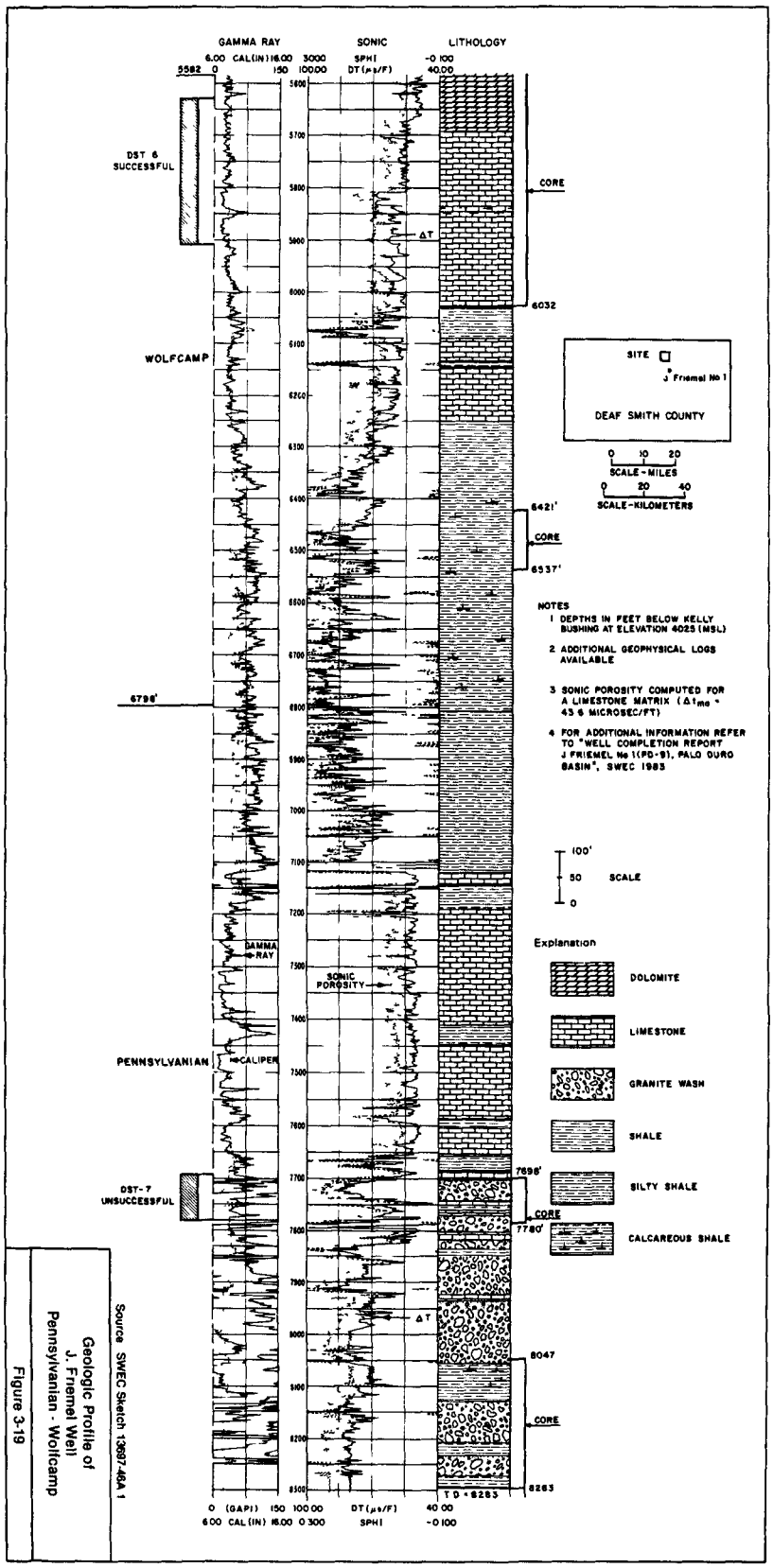
Figure 3-18

Table 3-2. Cenozoic Stratigraphy of the Texas Panhandle

System	Epoch	Formation
Quaternary	Holocene	Alluvium, windblown deposits, colluvium
	Pleistocene	Tahoka Double Lakes Blackwater Draw Tule
Tertiary	Pliocene	Blanco Rita Blanca Ogallala

Sources: Barnes, 1967; 1968; 1977; Schultz, 1977.

A larger reproduction of this figure appears at the back of this volume.

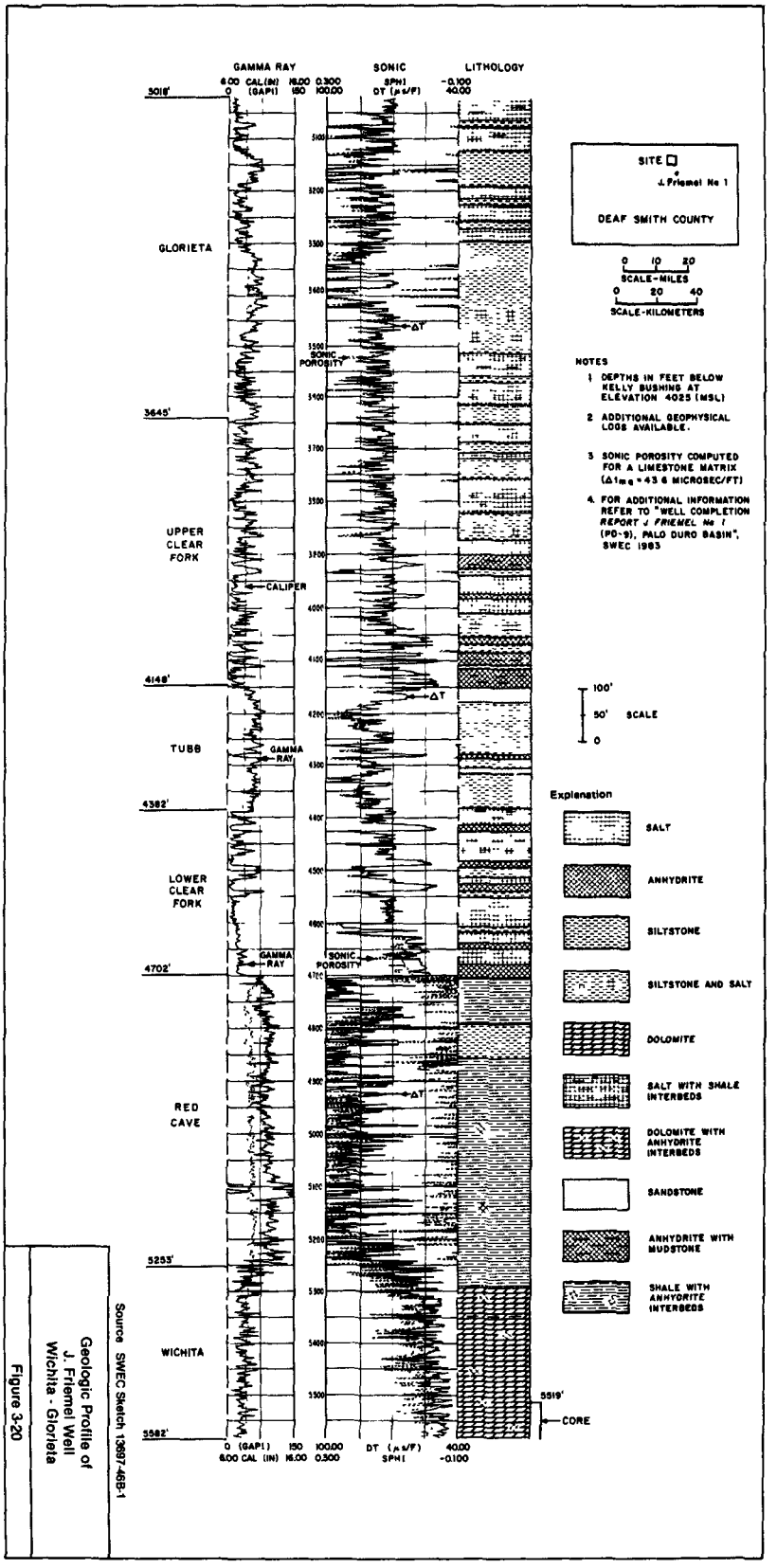


Source SWEC Sketch 13687-46A 1

Geologic Profile of J. Friemel Well Pennsylvanian - Wolfcamp

Figure 3-19

A larger reproduction of this figure appears at the back of this volume.

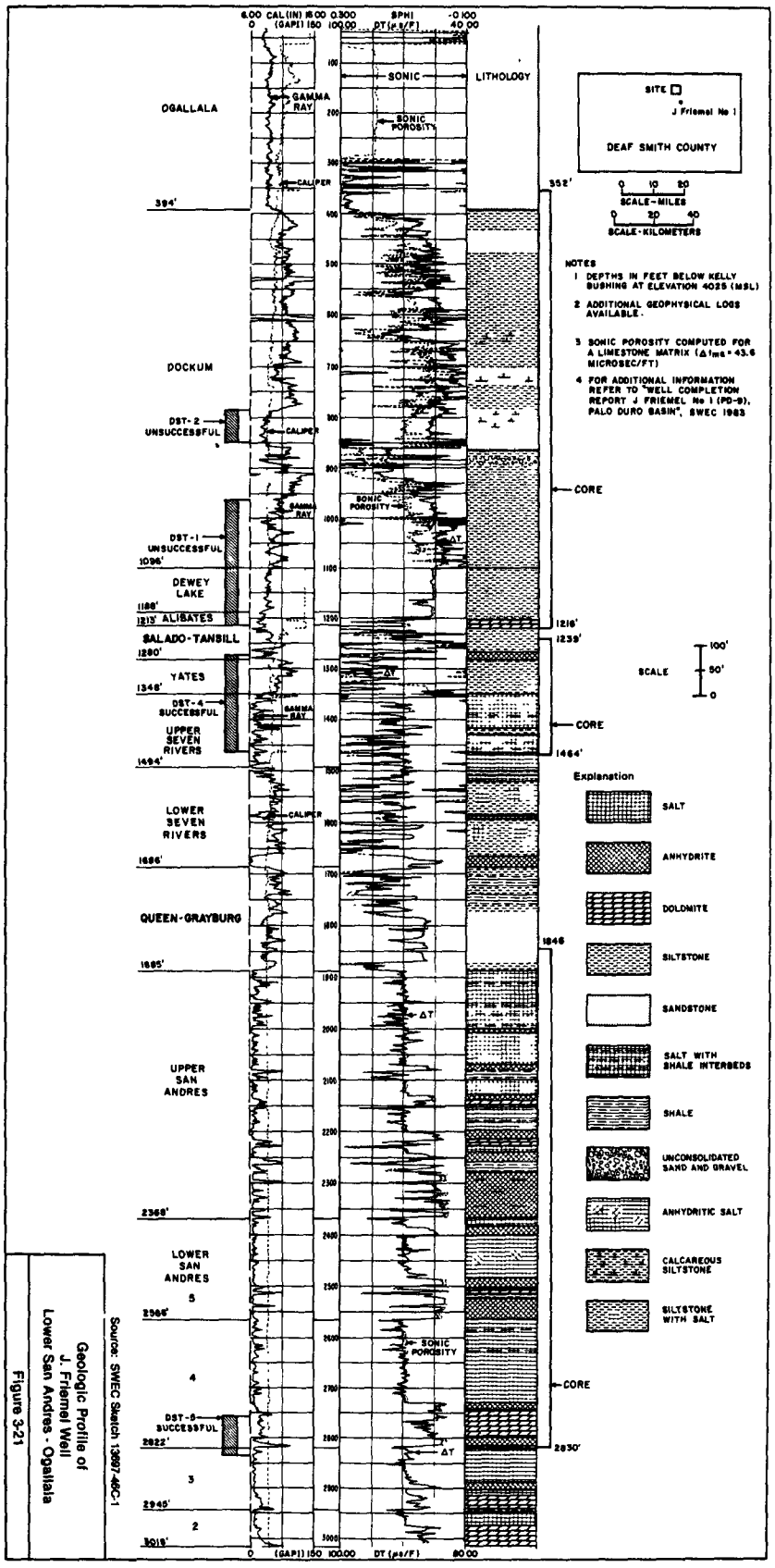


Source SWEC Sketch 13697-46B-1

Geologic Profile of J. Friemel Well Wichita - Glorieta

Figure 3-20

A larger reproduction of this figure appears at the back of this volume.



Source: SWEC Sketch 13697-46C-1

Geologic Profile of J. Friemel Well Lower San Andres - Ogallala

Figure 3-21

Table 3-3. Estimated Stratigraphy at the Deaf Smith County Site[a,b]

Geologic Unit	Elevation of Top[c] from MSL (ft)	Depth to Top from Ground Surface (ft)	Thickness (ft)	Lithology[d]
Ogallala Formation	4,033 ± 2	0	340 ± 25	Reddish-tan claystone and sandstone unconsolidated to soft; fine subrounded to round grains.
Dockum Group	3,693 ± 25	340 ± 25	621 ± 50	Red-brown sandy siltstone with layers of claystone and sandstone, grading to conglomerate.
Dewey Lake Formation	3,072 ± 75	961 ± 75	74 ± 20	Red-brown siltstone and claystone.
Alibates Formation	2,998 ± 150	1,035 ± 150	32 ± 5	Light green to white dolomite with siltstone.
Salado-Tansill Formation	2,966 ± 150	1,067 ± 150	67 ± 5	Red-brown siltstone with some gypsum and anhydrite.
Yates Formation	2,899 ± 150	1,134 ± 150	65 ± 5	Red-brown siltstone and very fine sandstone.
Upper Seven Rivers Formation	2,834 ± 150	1,199 ± 150	130 ± 15	Interbedded gray anhydrite and red-brown claystone/siltstone, salt with some siltstone/ claystone and anhydrite.
Lower Seven Rivers Formation	2,704 ± 150	1,329 ± 150	194 ± 5	Red-brown siltstone with minor anhydrite.
Queen-Grayburg Formation	2,510 ± 150	1,523 ± 150	180 ± 10	Red-brown siltstone and sandstone.

Table 3-3. Estimated Stratigraphy at the Deaf Smith County Site[a,b]
(Page 2 of 4)

Geologic Unit	Elevation of Top[c] from MSL (ft)	Depth to Top from Ground Surface (ft)	Thickness (ft)	Lithology[d]
Upper San Andres Formation	2,330 ± 150	1,703 ± 150	474 ± 10	Salt with varying amounts of red-brown mudstone impurities, occasional anhydrite and dolomite layers. Mostly anhydrite with interbeds of dolomite and siltstone at the base.
Lower San Andres Unit 5	1,856 ± 150	2,177 ± 150	194 ± 10	Upper section alternating beds of salt with some red-brown mudstone impurities and bluish gray anhydrite; lower section alternating beds of bluish gray anhydrite and grayish brown dolomite.
Lower San Andres Unit 4	1,662 ± 150	2,371 ± 150	250 ± 5	Salt with varying amounts of red-brown mudstone. Mainly dolomite and limestone with anhydrite beds at the base (see Table 3-5).
Lower San Andres Unit 3	1,412 ± 150	2,621 ± 150	120 ± 5	Clear to white salt with a 30-foot-thick layer of gray-brown anhydritic dolomite and limestone at the base.
Lower San Andres Unit 2	1,292 ± 150	2,741 ± 150	71 ± 5	Upper section salt with red-brown siltstone impurities; lower section light to medium gray dolomite with occasional interbeds of salt.
Lower San Andres Unit 1	Absent	Absent	Absent	
Glorieta Formation	1,221 ± 150	2,812 ± 150	610 ± 10	Thick salt sequence with varying quantities of red-brown siltstone impurities, occasional sandstone.

Table 3-3. Estimated Stratigraphy at the Deaf Smith County Site[a,b]
(Page 3 of 4)

Geologic Unit	Elevation of Top[c] from MSL (ft)	Depth to Top from Ground Surface (ft)	Thickness (ft)	Lithology[d]
Upper Clear Fork Formation	611 ± 150	3,422 ± 150	495 ± 10	Mainly salt with some beds of red-brown siltstone, light tan dolomite and white anhydrite; sequence of white anhydrite, red-brown siltstone and light tan dolomite at the base.
Tubb Formation	116 ± 200	3,917 ± 200	212 ± 25	Red-brown siltstone and fine sandstone with some anhydrite and salt.
Lower Clear Fork Formation	-96 ± 200	4,129 ± 200	294 ± 25	Alternating beds of red-brown siltstone, clear to white salt, and white anhydrite.
Red Cave Formation	-390 ± 200	4,423 ± 200	543 ± 20	Red shale with some siltstone and anhydrite.
Wichita Group	-933 ± 250	4,966 ± 250	330 ± 20	Upper section interbedded anhydrite and red shale with some medium olive-gray dolomite; lower section olive gray argillaceous dolomite with anhydrite.
Wolfcamp Series	-1,263 ± 250	5,296 ± 250	1,245 ± 50	Upper section thick sequence of olive-gray dolomite (210 ft); middle section limestone varying in color from olive gray-tan to dark gray (310 ft); lower section dark gray to black argillite (725 ft).
Pennsylvanian System, Upper Section	-2,508 ± 350	6,541 ± 350	309 ± 50	Alternating shale and tan limestone grading downward into a thick sequence of medium-gray shale.

Table 3-3. Estimated Stratigraphy at the Deaf Smith County Site[a,b]
(Page 4 of 4)

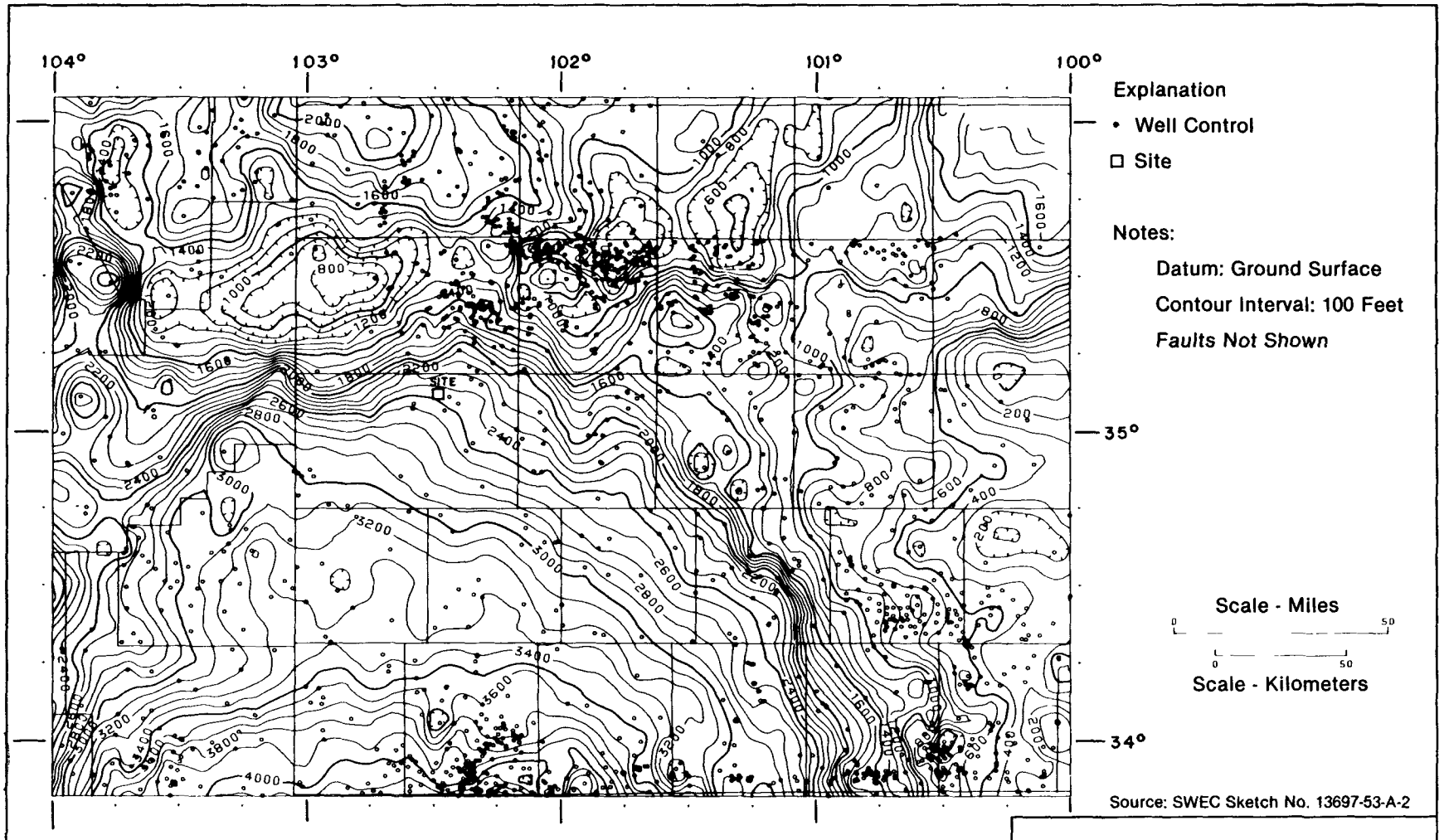
Geologic Unit	Elevation of Top[c] from MSL (ft)	Depth to Top from Ground Surface (ft)	Thickness (ft)	Lithology[d]
Pennsylvanian System, Carbonate Section	-2,817 ± 400	6,850 ± 400	550 ± 75	Limestone and black shale.
Pennsylvanian System, Granite Wash Section	-3,367 ± 450	7,400 ± 450	683 ± 100	Arkose with thin interbeds of shale and limestone.
Precambrian Basement	-4,050 ± 500	8,083 ± 500	--	Rhyolite

(a) The location is assumed to be N 411, 161, E 1,710,436 (Texas coordinate system, north zone) which is the location of a proposed engineering design borehole (EDBH).

(b) All tabulated thicknesses, depths, and elevations are estimates. Actual conditions are not known. It would constitute a misuse of this information to proceed with the expectation that conditions at this site location are exactly as estimated; however, it is likely that actual conditions are within the ranges given.

(c) Ground-surface elevation at the site location specified in Note 1 is 4,033 ± 2 ft above mean sea level (USGS 7.5-Minute Topographic Series, Vega South Quadrangle, Texas, 1966).

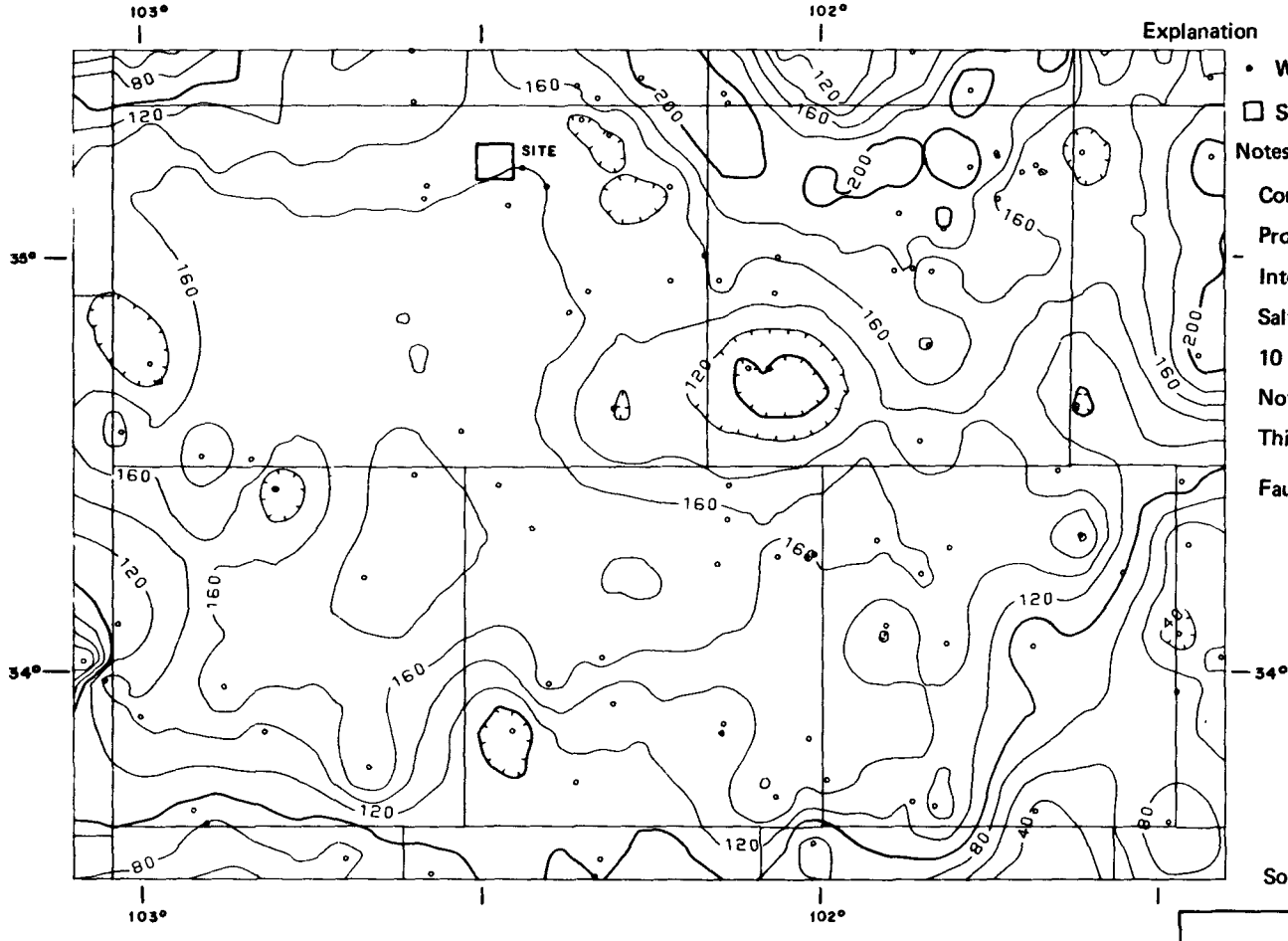
(d) Lithologic descriptions are based on SWEC (1984, BMI/SRP-5011, Table 1 and Appendix E) and Flawn (1956).



Source: SWEC Sketch No. 13697-53-A-2

Depth to the
Lower San Andres Unit 4

Figure 3-22



Explanation

- Well Control
- Site

Notes:

Contour Units in Feet

Proposed Salt Horizon: A Salt Bed With Interbeds of Nonsalt and Poor Quality Salt Individually Not Exceeding 10 Feet Thick and Cumulatively Not Exceeding 15% of Total Bed Thickness

Faults Not Shown

0 — 25 Scale - Miles

0 — 40 Scale - Kilometers

Source: SWEC Sketch No. 13697-36-A-3

Thickness of Proposed Salt Horizon in Lower San Andres Unit 4

Figure 3-23

At the Deaf Smith County Site, the Lower San Andres Unit 4 is expected to be approximately 76 meters (250 feet) thick (Table 3-5). It consists of 2 meters (6 feet) of gray anhydritic mudstone and 25 meters (83 feet) of interbedded dolomite, anhydrite, and limestone overlain by approximately 49 meters (161 feet) of bedded salt (Table 3-5), the latter comprising the repository host horizon. The host horizon is composed predominantly of halite, andyrite, and mudstone, with trace amounts of several other constituents such as dolomite and celestite, which are usually identifiable only in thin section or by chemical analysis (Section 3.2.7.1). Halite is the dominant component of the Unit 4 host horizon at 87 to 89 percent by volume; anhydrite is 4 to 5 volume percent, and mudstone and trace constituents constitute the remaining 7 to 9 percent (Table 3-4).

Mudstone, as defined by Folk (1968, p. 141), is a clastic material composed by subequal amounts of silt- and clay-sized material. At Deaf Smith County about half of the material is silt-sized, consisting of quartz, small amounts of feldspar, some heavy minerals, and other detrital grains. The clay-sized half of the material consists of clay minerals and other detrital material such as fine quartz grains. The mudstone occurs principally in two modes: in disseminated centimeter- to millimeter-sized masses embedded in halite (referred to as chaotic mudstone/salt mixtures) and in recognizable bands, which are called mudstone beds. Minor amounts of mudstone also occur in isolated masses disseminated through relatively pure halite.

The mudstone beds are composed of halite and anhydrite, along with mudstone (Table 3-4). Within the mudstone beds, the halite occurs as coarse to euhedral crystals, as cement, and as fracture fillings; at J. Friemel No. 1 in Deaf Smith County the amount of halite in the mudstone beds is approximately 20 volume percent. The anhydrite in the mudstone beds occurs as nodules, blebs, and cement and, at J. Friemel No. 1, amounts to 15 volume percent. Within the mudstone beds, mudstone itself comprises the remaining 65 percent at J. Friemel No. 1 and slightly more or less in other nearby coreholes (Table 3-4).

About 8 volume percent of the 49-meter (161-foot) thick Unit 4 host horizon is composed of mudstone, as calculated from visual estimates of the composition of core by Hovorka et al. (1985). About half of this mudstone is in discrete mudstone beds, and half is disseminated in salt as chaotic mudstone/salt mixtures. From 91 to 116 discrete mudstone beds were identified in the J. Friemel No. 1, G. Friemel No. 1, and Detten No. 1 cores (Table 3-4). Average mudstone bed thickness ranged from 1.5 to 3 centimeters (0.6 to 1.2 inches), and maximum bed thicknesses observed were 31 to 64 centimeters (12 to 25.2 inches). Chaotic mudstone/salt mixtures typically contain 10 to 15 volume percent mudstone, which occurs as irregular masses in the salt. The chaotic mudstone/salt mixtures generally occur in fairly discrete intervals, which comprise approximately 17 volume percent of the Unit 4 host horizon. The remaining, minor amount of mudstone is disseminated through relatively clean halite intervals, which contain an average of 1 to 2 volume percent mudstone, occurring as isolated masses.

Anhydrite makes up from 4 to 5 volume percent of the Unit 4 host horizon in the three wells closest to the Deaf Smith County site (Table 3-4). Eight-six (86) anhydrite beds, most occurring as thin partings, were logged by Hovorka et al. (1985) at J. Friemel No. 1. Anhydrite is also abundant along halite grain boundaries and occasionally occurs as irregular masses within the halite.

Halite makes up 87 to 89 volume percent of the Unit 4 host horizon and exhibits a variety of primary and diagenetic fabrics (Table 3-4). A detailed stratigraphic column representative of the Unit 4 host horizon at the site is presented in Table 3-5. Further mineralogical, textural, and petrographic descriptions of the host rock and other lithostratigraphic units near the site are provided in Sections 3.2.6.1.4 and 3.2.7.1.

3.2.3.3 Salt Dissolution

If salt is absent from a salt-bearing formation, it could have been dissolved post depositionally, dissolved in the depositional environment, or never deposited due to facies change. It is often difficult from the evidence to determine which circumstance is the correct one. In addition, the locations of peripheral dissolution margins, and the extent,

Table 3-4. Lower San Andres Unit 4 Host Horizon Compositional Data

	J. Friemel No. 1	G. Friemel No. 1	Detten No. 1
Composition (vol. %)			
Halite	87	89	87
Anhydrite	4	4	5
Mudstone	9	7	8
Composition (vol. %)			
Halite	20		
Anhydrite	15		
Silt and Clay	65	63	75
Thickness of interval (total ft.)	165.5	152.5	172.7
Anhydrite beds (number)	86		
Mudstone beds			
Number	91	116	112
Maximum thickness (mm)	470	310	640
Average thickness (mm)	30	15	19

Source: Hovorka et al., 1985.

Table 3-5. Assumed Stratigraphy of Lower San Andres Unit 4 at the Deaf Smith County Site[a,b]

Zone	Elevation of Top[c,d] from MSL (ft)	Depth to Top[d] from Ground Surface (ft)	Thickness (ft)[d]	Halite[e] Type	Lithology[f]
28	1,662 ± 150	2,371 ± 150	1 ± 1	B	Banded B type halite with well developed disseminated bands of mudstone and minor anhydrite.
27	1,661 ± 150	2,372 ± 150	10 ± 1	B, D	Type D halite interbed (<1 ft) at the top of the zone. Middle section contains banded B type with well developed bands of mudstone and anhydrite. Basal 3 ft consists of D type halite marked at the top by a 3" mudstone band.
26	Absent	Absent	0	N/A	N/A
25	1,651 ± 150	2,382 ± 150	5 ± 1	F, H	F type halite at the top containing anhydrite stringers. The basal H-type halite is free of interbeds.
24	1,646 ± 150	2,387 ± 150	4 ± 1	B	B type halite containing several mudstone and anhydrite laminations and stringers. 10" to 12" basal mudstone (50% halite).
23	1,642 ± 150	2,391 ± 150	11 ± 1	A, B, D E, F, H	Interbedded halite types with thin (<2") to discontinuous anhydrite and mudstone laminations.
22	1,631 ± 150	2,402 ± 150	4 ± 1	D	D type halite with contorted and disturbed siltstone and mudstone.

Table 3-5. Assumed Stratigraphy of Lower San Andres Unit 4 at the Deaf Smith County Site[a,b]
(Page 2 of 6)

Zone	Elevation of Top[c,d] from MSL (ft)	Depth to Top[d] from Ground Surface (ft)	Thickness (ft)[d]	Halite[e] Type	Lithology[f]
21	1,627 ± 150	2,406 ± 150	10 ± 1	A, B, D, F	Primarily bedded and banded B type halite interbedded with other halite types. Bedding marked by disseminated bands anhydrite and mudstone.
20	1,617 ± 150	2,416 ± 150	5 ± 1	B, D	Complex interval of primarily F type halite with interstitial anhydrite marked by a D type halite unit, 1 ft thick at the top.
19	1,612 ± 150	2,421 ± 150	5 ± 1	A, E	1 ft red-brown silt/mudstone at the top underlain by a poorly developed A type halite with interstitial chaotic mudsalt.
18	1,607 ± 150	2,426 ± 150	5 ± 1	B, D, E	Top marked by a 1 ft section of D type halite and interstitial mudstone underlain by 6" to 8" of banded B, D and E types with several mudstone laminae. Basal 18" consists of red-brown mudstone.
17	1,602 ± 150	2,431 ± 150	8 ± 1	A, D	Top 2 feet consists of A, and D types intermixed. Primary constituent is D type halite with numerous discontinuous mudstone interbeds.
16	Absent	Absent	0	N/A	N/A
15	1,594 ± 150	2,439 ± 150	10 ± 1	A, B	Predominantly banded B type halite with several 1/4" to 6" mudstone and anhydrite partings and drapes.

Table 3-5. Assumed Stratigraphy of Lower San Andres Unit 4 at the Deaf Smith County Site[a,b]
(Page 3 of 6)

Zone	Elevation of Top[c,d] from MSL (ft)	Depth to Top[d] from Ground Surface (ft)	Thickness (ft)[d]	Halite[e] Type	Lithology[f]
14	1,584 ± 150	2,449 ± 150	2 ± 1	A, E	A and E type halites with thin (1/4") to discontinuous interstitial laminations of anhydrite.
13	1,582 ± 150	2,451 ± 150	8 ± 1	B, E	E type halite underlain by B type halite relatively free of interbeds.
12	1,574 ± 150	2,459 ± 150	1 ± 1	D	D type halite with interstitial bodies of mudstone.
11	1,573 ± 150	2,460 ± 150	6 ± 1	B, D	Banded B type halite and dark disseminated mudstone.
10	1,567 ± 150	2,466 ± 150	1 ± 1	D	D type halite with thin mudstone at top.
9	1,566 ± 150	2,467 ± 150	7 ± 1	B, D, E	Primarily banded and bedded B type halite intermixed with D and E types. Bedding marked by disseminated bands of mudstone and anhydrite.
8	1,559 ± 150	2,474 ± 150	2 ± 1	B	B type halite with interbeds of mudstone and anhydrite drapes.
7	1,557 ± 150	2,476 ± 150	4 ± 1	A, B	Yellow-orange halite with anhydrite partings and drapes.
6	1,553 ± 150	2,480 ± 150	5 ± 1	A, B	Bedded B type halite with disseminated anhydrite bands. Contains a 1" section of A type halite.

Table 3-5. Assumed Stratigraphy of Lower San Andres Unit 4 at the Deaf Smith County Site[a,b] (Page 4 of 6)

Zone	Elevation of Top[c,d] from MSL (ft)	Depth to Top[d] from Ground Surface (ft)	Thickness (ft)[d]	Halite[e] Type	Lithology[f]
5	1,548 ± 150	2,485 ± 150	7 ± 1	A, B, E, F	Bedded A and B types with interstitial and/or laminated anhydrite and mudstone.
4	1,541 ± 150	2,492 ± 150	10 ± 1	A, B, D, E	Top 4" contains D type halite marked by mudstone layer. Bedded B type halite with interstitial anhydrite. 3 foot section of D type halite with mudstone underlain by A and B types with several mudstone and anhydrite interbeds.
3	1,531 ± 150	2,502 ± 150	3 ± 1	A	Milky white bedded A type halite with bedding marked by anhydrite drapes.
2	1,528 ± 150	2,505 ± 150	17 ± 1	A, B, D	Top marked by a 4 foot section of D type halite with interstitial mudstone underlain by a 7 foot section of banded and bedded B type halite intermixed with A type halite with anhydrite and mudstone stringers. A two foot section of D type halite with interstitial and laminar anhydrite and mudstone. Bedded basal B type halite with mudstone and anhydrite bands.
1	1,511 ± 150	2,522 ± 150	10 ± 1	B, D, E, F	Interbedded layers of halite types (primarily B type) containing interstitial and disseminated anhydrite drapes and bands.

Table 3-5. Assumed Stratigraphy of Lower San Andres Unit 4 at the Deaf Smith County Site[a,b]
(Page 5 of 6)

Zone	Elevation of Top[c,d] from MSL (ft)	Depth to Top[d] from Ground Surface (ft)	Thickness (ft)[d]	Halite[e] Type	Lithology[f]
N/A	1,501 ± 150	2,532 ± 150	29 ± 2	N/A	Medium to dark gray anhydrite interlaminated with olive gray dolomite and wackestone.
N/A	1,472 ± 150	2,561 ± 150	42 ± 2	N/A	Light olive-gray to yellow gray limey to dolomitized fossiliferous mudstone and wackestone.
N/A	1,430 ± 150	2,603 ± 150	12 ± 2	N/A	Medium gray anhydrite with interstitial yellow-gray dolomite and mudstone.
N/A	1,418 ± 150	2,615 ± 150	6 ± 2	N/A	Poorly indurated grayish-black claystone with siltstone layers and anhydrite stringers.

(a) The location is assumed to be N 411,161, E 1,710,436 (Texas coordinate system, north zone) which is the location of a proposed engineering design borehole (EDBH).

(b) The stratigraphy of the lower San Andres Unit 4 is based on Hovorka et al. (1985). Stratigraphy of the salt-bearing section is assumed herein to be the same as described by Hovorka et al. (1985, Plate 2) for the nearest control well (the Stone & Webster/J. Friemel No. 1 well, located approximately 4.25 miles to the south); stratigraphy of the basal section is assumed herein to be the same as described in SWEC (1983, DOE/CH/10140-1, Appendix E).

(c) Ground-surface elevation at the site location specified in Note 1 is 4,033 ± 2 feet above mean sea level (USGS, Vega South Quadrangle, Texas, 1966).

Table 3-5. Assumed Stratigraphy of Lower San Andres Unit 4 at the Deaf Smith County Site[a,b]
(Page 6 of 6)

(d) Assumed thicknesses, depths, and elevations have been proportionally adjusted from those reported for the J. Friemel well (Hovorka et al., 1985; SWEC, 1983, DOE/CH/10140-1) to account for an estimated 6-foot thinning of Unit 4 at the site location specified in Note a (see Table 3-3). Variations between thicknesses presented in this table and those found at the site are expected to be similar to variations observed between program wells.

(e) Halite types are described as follows by Hovorka et al. (1985, Figure 6 [key to Column 4: Halite types]):

Halite Type	Description
A	Bedded halite with chevron fluid inclusions
B	Bedded halite with vertically oriented crystals
C	Not described
D	Chaotic mudstone-halite
E	Recrystallized muddy halite
F	Recrystallized halite with interstitial anhdyrite
G	Displacive halite in sediments
H	Coarse recrystallized cavity - fill halite
I	Fibrous fracture fill

(f) Lithologic descriptions are based on Hovorka et al. (1985, Plate 2 and Figure 6) and Hovorka (1984). For more conventional core descriptions, refer to SWEC (1983, DOE/CH/1-140-1, Appendix E) (core depths 2,562.5 ft to 2,821.0 ft). Variations between lithologies presented in this table and those found at the site are expected to be similar to variations observed between program wells.

timing, and modes of interior dissolution are not well defined. Sources of evidence for salt dissolution are (1) core observations, (2) geophysical well logs, (3) stratigraphic thickness variations, and (4) surface features.

Core provides the opportunity for a wealth of direct observation. In core, a zone consisting of mottled clay and siltstone often containing discordant beds or nodules of soft and friable gypsum often occurs just above a salt bed. This association of knobby, marbled rock, often slickensided, with gypsum is suggestive of the dissolution of halite, the accumulation of insoluble residues, and the reversion of diagnetic anyhydrite to gypsum due to interaction with low-salinity waters.

On geophysical logs, the presence of gypsum in association with an increase in porosity can be observed. Such observations can be interpreted to be due to salt dissolution. However, the geophysical logs do not themselves provide sufficient detail to distinguish the origin of deposited clastics or precipitated carbonates from insoluble residues. In addition, neither core nor geophysical logs provide much information on the magnitude of the dissolution since original salt thickness and salt purity are unknown. The recognition of depositional and diagnetic characteristics of salt-bearing evaporite sequences in core is described in detail by Hovorka et al. (1985). Boyd and Murphy (1984) describe criteria for identifying salt dissolution, and SWEC (1983, DOE/CH/10140-1, Appendix A) summarizes the procedures for distinguishing salt in geophysical logs.

Thickness variations and the areal distribution of facies are obtained by correlation of stratigraphic units from both core observations and geophysical log interpretations. Thickness or elevation variations can sometimes be attributed to dissolution; for example, when specific well data are contrary to that expected from regional trends.

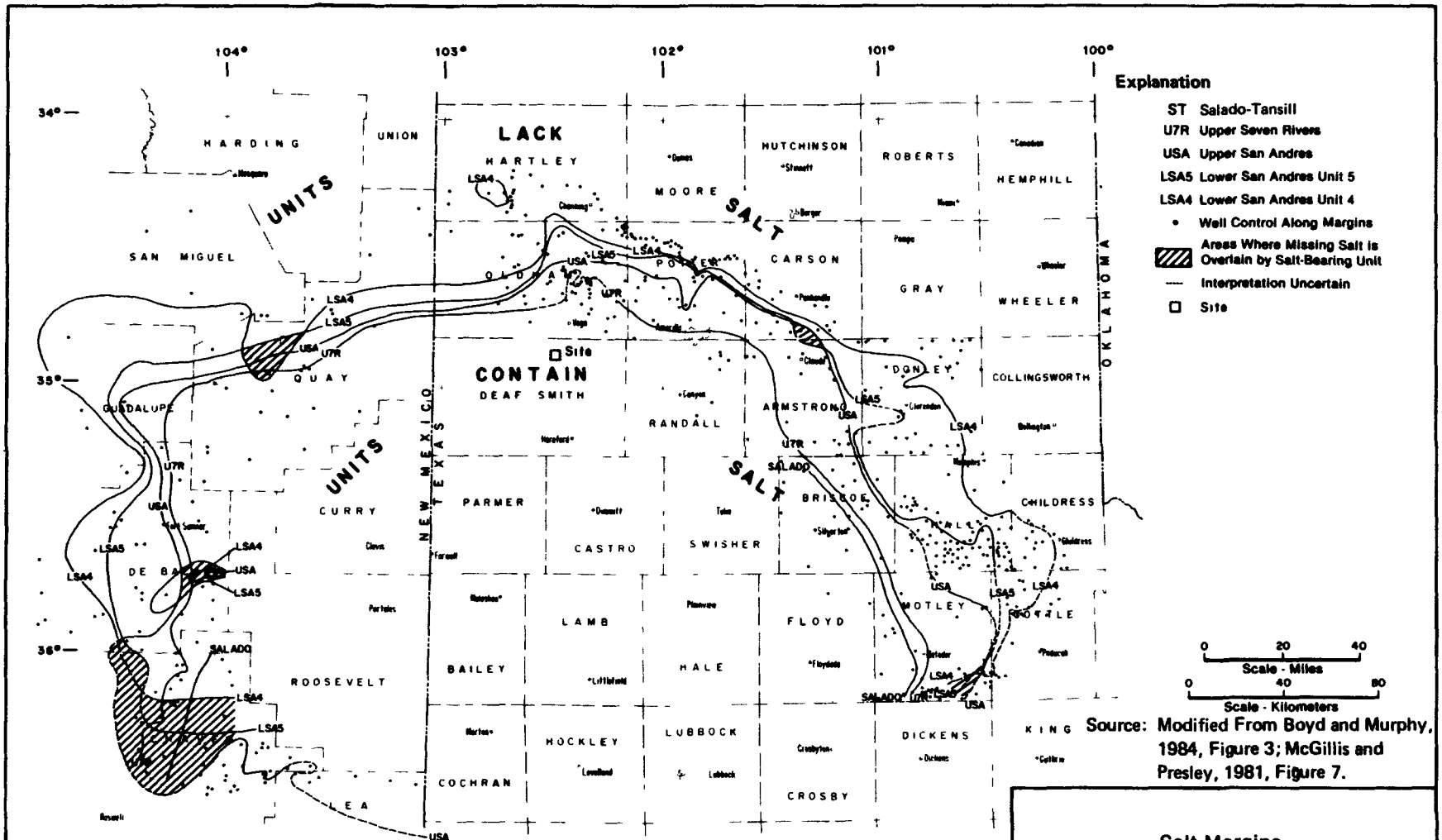
Surface features such as collapse sinkholes, closed depressions, linear drainage elements and fractures (Gustavson et al., 1981; Gustavson and Finley, 1984) are easily identified expressions of on-going or recent dissolution. The origin of playas is problematic, although they may be related to dissolution.

The timing of dissolution events is difficult to establish firmly, but is sometimes inferred by assigning a relative age to the uppermost strata that appear to be affected. Fracasso and Hovorka (1984) and Boyd and Murphy (1984) describe criteria for specifically identifying dissolution which occurred within the Permian depositional environment.

3.2.3.3.1 Peripheral Dissolution. The present boundaries of the San Andres, Seven Rivers, and Salado-Tansill bedded salts are defined along the periphery of the Permian Basin in New Mexico and Texas (Figure 3-24) (Gustavson et al., 1980a; Boyd and Murphy, 1984). The salt margins and the salt-bearing formations are controlled by postdepositional and syndepositional dissolution and by nondeposition (facies change). It is difficult to distinguish depositional margins from salt dissolution boundaries because the same structural highs that define a basin margin, and therefore control depositional pinchouts, also are characterized by faulting and fracturing that could enhance salt dissolution (Boyd and Murphy, 1984).

San Andres nonsalt evaporites pinch out near the Pedernal and Sierra Grande Uplifts, indicating an ancient western depositional salt margin (Boyd and Murphy, 1984, pp. 17 and 34; Kelley, 1972a, Figure 1). Unit 2 and 3 carbonates and halite pinch out near the Amarillo Uplift. Continued Guadalupian structural activity may have locally exposed Upper San Andres evaporites to syndepositional erosion and the Lower San Andres salt to concurrent paleodissolution, interrupting the continuity of the San Andres salts across the Amarillo Uplift (Boyd and Murphy, 1984, pp. 14 and 16); however, Permian dissolution has been obscured by post-Permian dissolution in this area. Thickness variations in the Queen-Grayburg Formation may be related to local uplift activity and dissolution collapse of the Upper San Andres (Boyd and Murphy, 1984, p. 19; Figure 24).

Post-Permian dissolution began in the Triassic. Local unconformities, which incise as deeply as the Queen/Grayburg Formation, indicate fluvial erosion of Upper Permian strata during the Triassic that brought unsaturated ground water into contact with shallow salts along



Source: Modified From Boyd and Murphy, 1984, Figure 3; McGillis and Presley, 1981, Figure 7.

Salt Margins

Figure 3-24

the western, northern, and northeastern basin margins (Boyd and Murphy, 1984). A lack of significant Jurassic and Cretaceous sediments prevents detailed evaluation of paleodissolution from Triassic through Tertiary time. The outer margins of the San Andres, Seven Rivers, and Salado salts migrated basinward in response to Tertiary dissolution. The southern edge of a depression in the Alibates Formation in west-central Carson County (Figure 3-25) resulted from Tertiary solution subsidence. This date is determined by the Ogallala fill it contains. In New Mexico, the basinward migration of the outer margins of the salt throughout the Pliocene-Pleistocene is marked by subsidence of valley fill west of the Pecos River (Boyd and Murphy, 1984). Detailed structure sections illustrate displacement of Ogallala sediments due to salt dissolution along the west, north, and east escarpments of the High Plains (Gustavson, 1982, pp. 178-181).

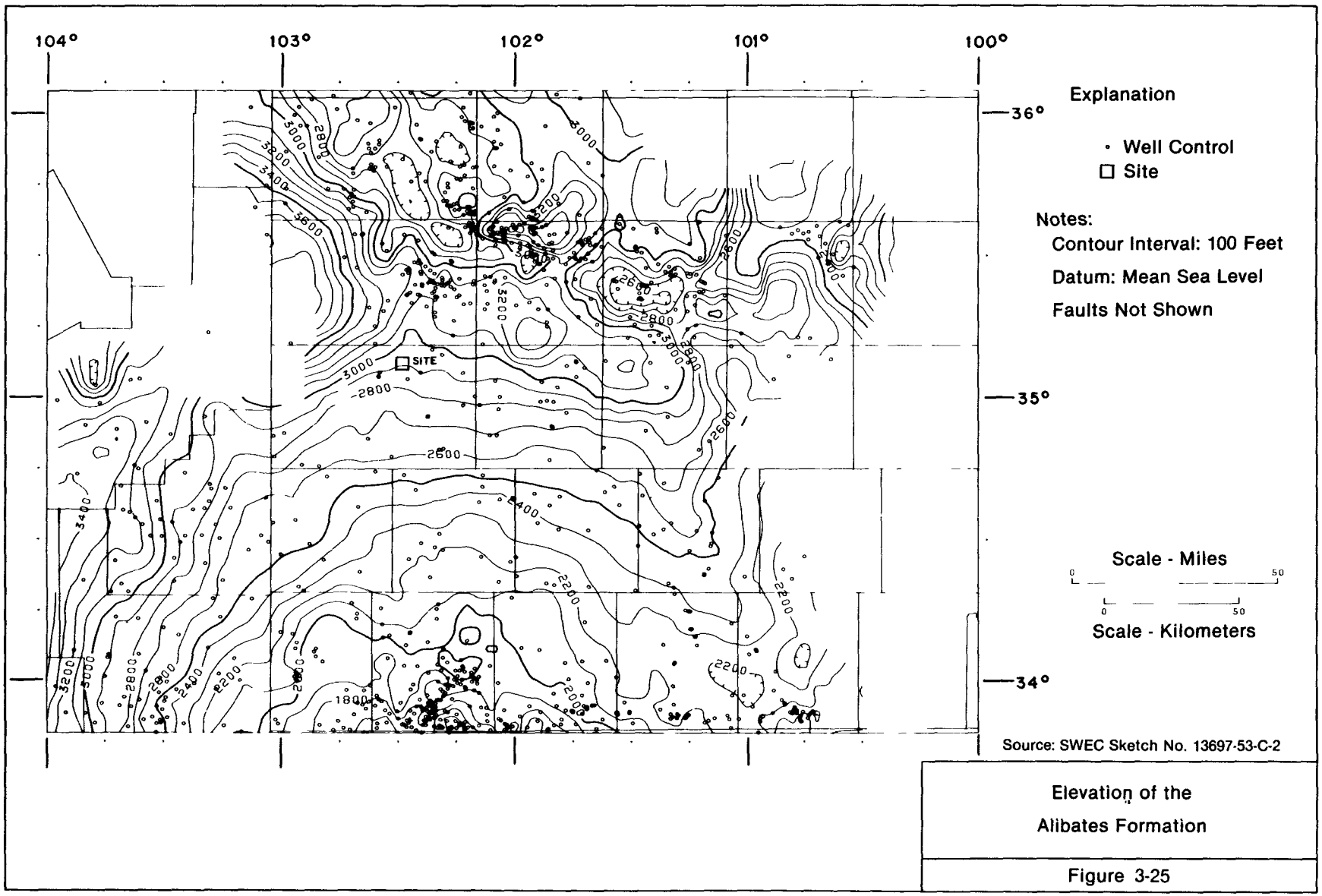
Active dissolution is recognized along the western, northern, and eastern salt margins. There are areas of high brine discharge in the streams of the Rolling Plains east of the Caprock Escarpment, as well as along the Pecos and Canadian Rivers. Analyses performed on water pumped from the Sawyer and Mansfield wells (Figure 3-3) in Donley and Oldham Counties indicate that these brines are derived from the dissolution of Permian salt rather than originating from deep saline aquifers (Dutton and Orr, 1985). Comparison of black and white low-level aerial photographs of Hall and Briscoe Counties reveals that at least 36 collapse sinkholes and 2 closed depressions have formed along the eastern dissolution front since 1940 (Gustavson et al., 1982, p. 545). Kelley (1972b, p. 31) identified similar collapse features along the western salt margin in New Mexico.

Along the eastern salt margins, the structure contours on the Alibates turn back north-northeast along a southeast-trending axis from Armstrong through Briscoe to Motley County (Figure 3-25 and 3-26), whereas the Lower Permian Tubb Formation (Figure 3-27 and 3-28) horizon is essentially featureless throughout the same region. The dip of the Alibates Formation away from the basin center in this region is a result of collapse of Upper Permian strata due to salt dissolution rather than to post-Permian tectonic faulting (Boyd and Murphy, 1984 p. 22). Along the northern margin, in Hartley County, both the Alibates and Ogallala Formations lie 120 to 180 meters (400 to 600 feet) lower on the north side of the Canadian River than on the south, suggesting Quaternary collapse (Gustavson et al., 1980b, p. 9). Displacement across the river is not seen in the Tubb Formation. The collapse of Upper Permian strata in Hartley County illustrates a greater amount of Quaternary dissolution north of the Canadian River.

In order for present-day salt dissolution to occur, ground water unsaturated with chlorides must flow along the surface of the salts. Highly faulted areas such as the Amarillo Uplift contain ground-water conduits (fractures), and the escarpment provides the hydraulic gradient necessary for ground-water circulation. The escarpment becomes more pronounced where fault frequency and displacement increase near the Amarillo Uplift. The depth to active dissolution also apparently increases along the eastern margin as the uplift is approached (Boyd and Murphy, 1984). In Chaves County, New Mexico, areas lacking major faulting and topographic relief have salts as shallow as 60 meters (200 feet).

Horizontal dissolution rates were calculated for salts beneath 16 drainage basins on the Rolling Plains by estimating the cross-sectional area of the salt being dissolved and dividing that area into the volume of salt discharged as solute from each drainage basin (Gustavson et al., 1980a, Table 1). Calculated dissolution rates vary among basins by four orders of magnitude, from 5.5×10^{-5} meter per year (1.8×10^{-4} foot per year) to 0.98 meter per year (3.2 feet per year). The largest drainage basin (Prairie Dog Town Fork of the Red River) has a dissolution rate of approximately 0.07 meter per year (2.73 inches per year), which probably approximates an average rate of horizontal dissolution for salts beneath the Rolling Plains.

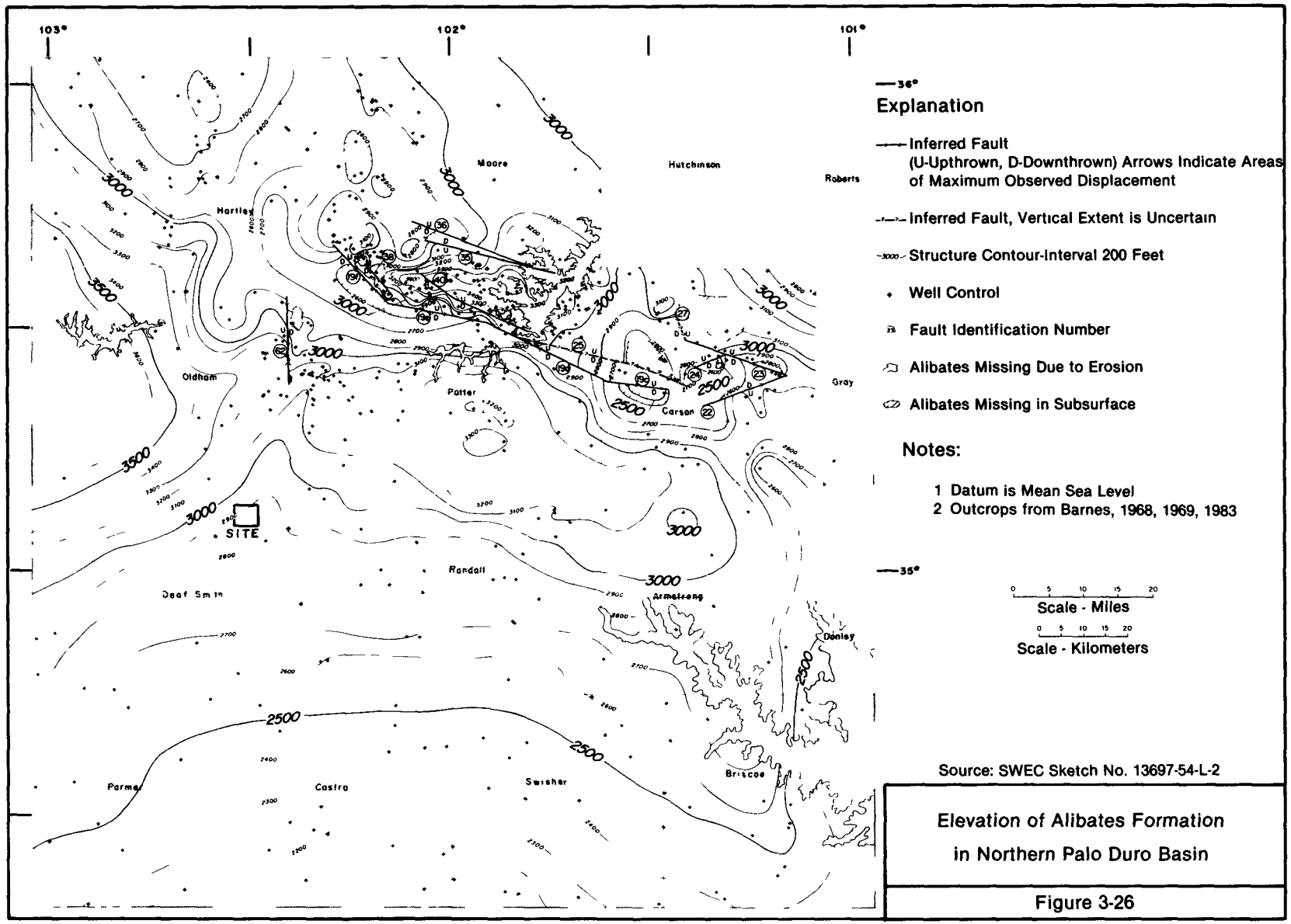
In contrast to the estimates for dissolution rates, estimates for the rate of escarpment retreat by erosion were determined for time periods ranging from 7,900 to 3,000,000 years and vary by less than one order of magnitude (Gustavson et al., 1981, p. 413). Because the Caprock Escarpment controls the shallow hydraulic gradient, its retreat to the west influences the rate of horizontal dissolution and basinward migration of the outer margins of the salt.



Source: SWEC Sketch No. 13697-53-C-2

Elevation of the Alibates Formation

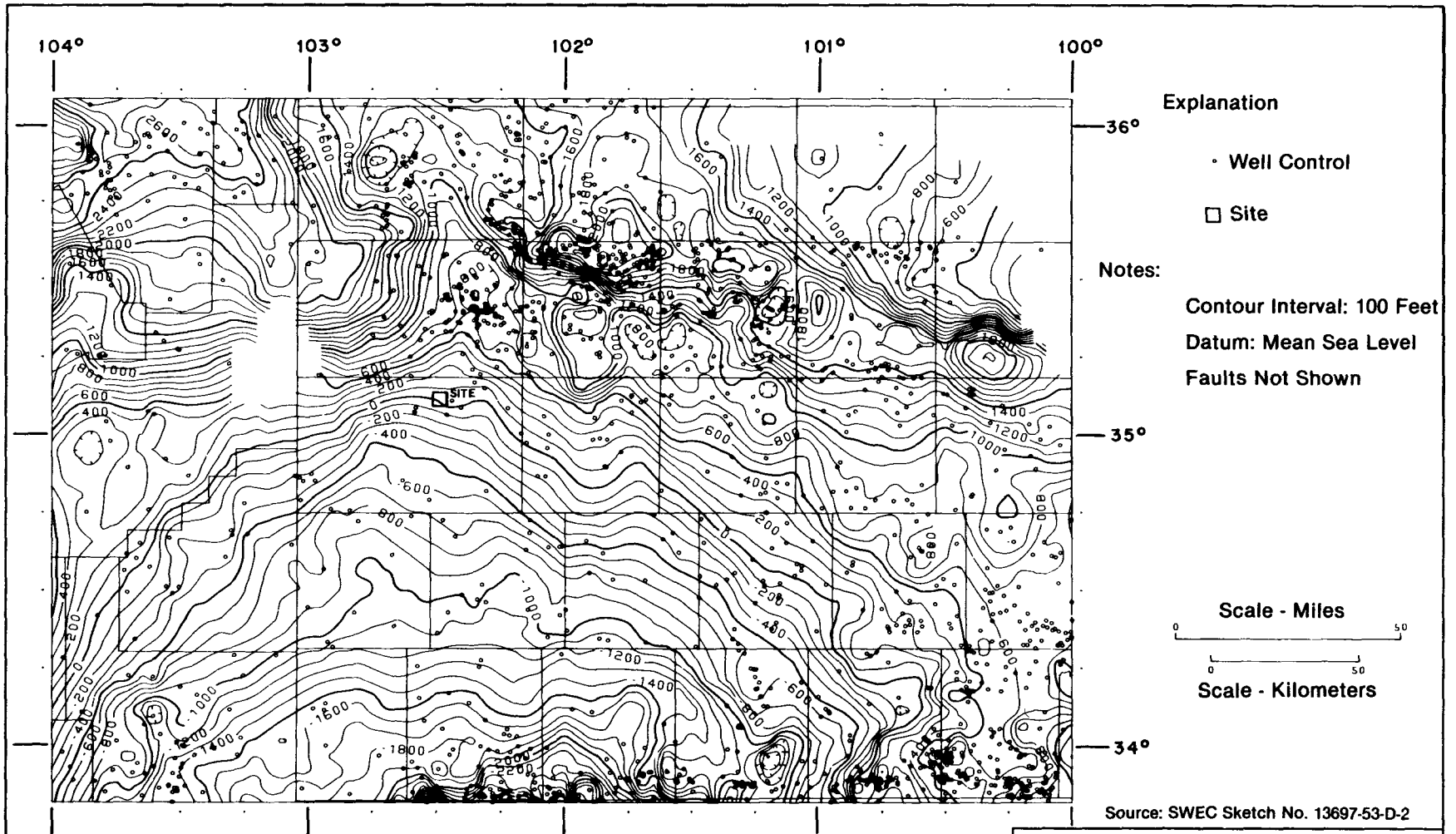
Figure 3-25



Source: SWEC Sketch No. 13697-54-L-2

Elevation of Alibates Formation in Northern Palo Duro Basin

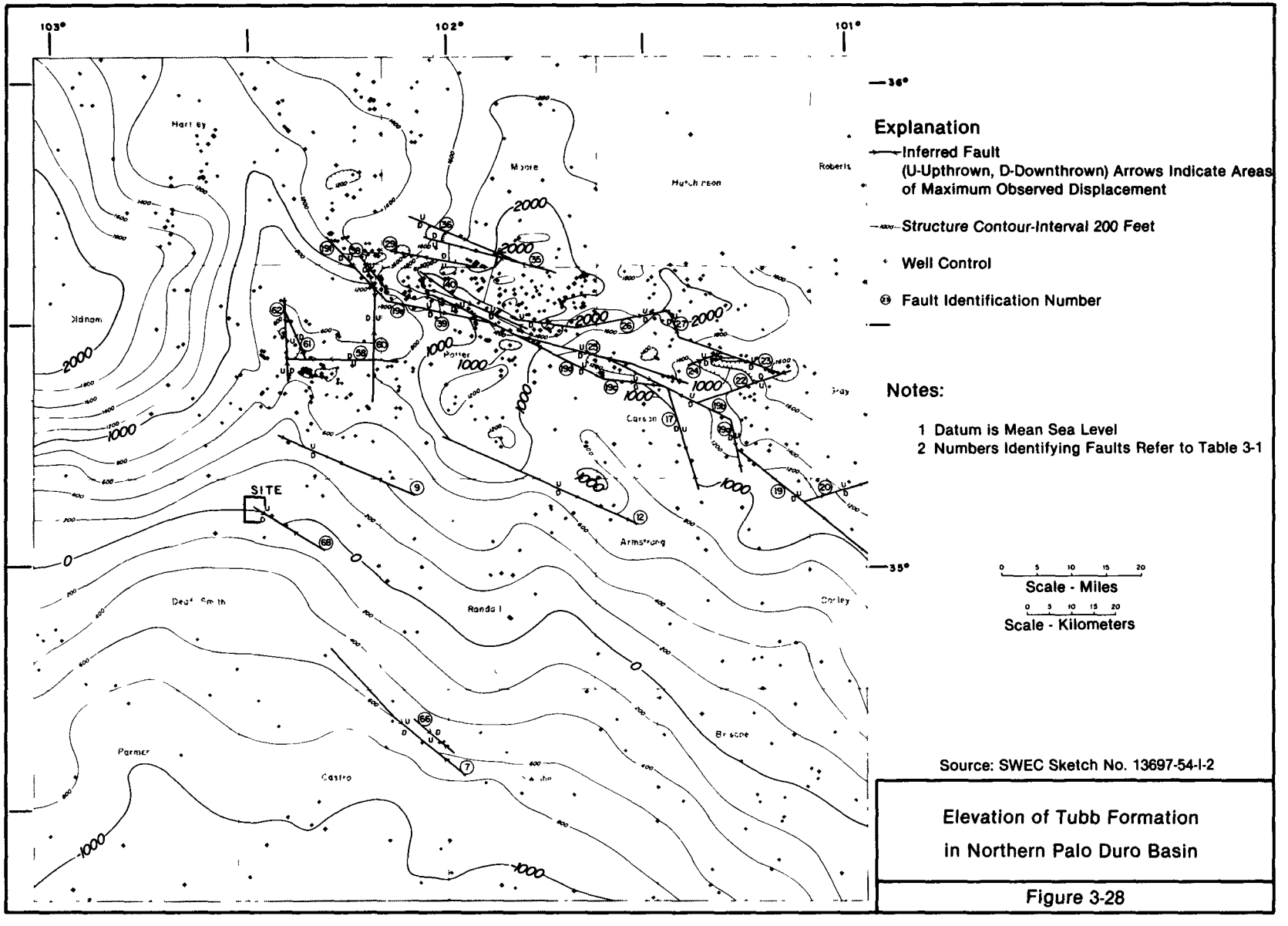
Figure 3-26



Source: SWEC Sketch No. 13697-53-D-2

Elevation of
the Tubb Formation

Figure 3-27



Source: SWEC Sketch No. 13697-54-I-2

Elevation of Tubb Formation in Northern Palo Duro Basin

Figure 3-28

The present salt margins, as well as the Southern High Plains escarpment, are roughly parallel, suggesting that, over geologic time, regional dissolution and scarp retreat have proceeded at similar rates. The average rate of dissolution (0.07 meter per year [2.73 inches per year]) is similar to the retreat rates (0.11 to 0.18 meter per year [4.29 to 7.02 inches per year]) of the eastern Caprock Escarpment (Gustavson et al., 1981). The maximum calculated rate of horizontal dissolution (North Fork of the Wichita River drainage basin) is 0.98 meter per year (3.21 feet per year) and is probably an order of magnitude higher than the average dissolution rate.

In this context, as a conservative approach, the maximum calculated short-term rates of dissolution beneath the Rolling Plains (0.98 meter per year [3.21 feet per year]) and Canadian River Valley (8.0×10^{-4} meter per year [0.03 inch per year]) are assumed to approximate the maximum possible sustained rates of dissolution in these areas (Gustavson et al., 1980a). The greater of these rates exceeds the rate of escarpment retreat by more than five times.

These estimates of present dissolution rates may be used to project basinward migration of the dissolution front into the geologic future. This approach is conservative because it ignores factors that impede dissolution:

1. The Permian strata, including the bedded salts, deepen basinward (Figures 3-30, 3-31, and 3-32).

2. The Southern High Plains Escarpment, which apparently controls dissolution, is retreating five times more slowly than the dissolution front.

The distance from the site to the dissolution front of the Lower San Andres Unit 4 salt is 100 kilometers (62 miles) to the eastern front, 29.8 kilometers (18.5 miles) to the northern front, and 174 kilometers (108) miles) to the western front (Figure 3-29). These distances were determined by measuring from the site boundary to the closest approach of the inside boundry of the zone of dissolution of the Lower San Andres Unit 4 salt as presented on Figure 3-29. For the purposes of this measurement, the boundary of the northern and western dissolution fronts is defined as being at the eastern edge of the bend in the dissolution zone trend in Guadalupe County and San Miguel County in New Mexico. The boundary of the northern and eastern dissolution fronts is defined as being in south-central Carson County where the zone of dissolution widens abruptly to the south.

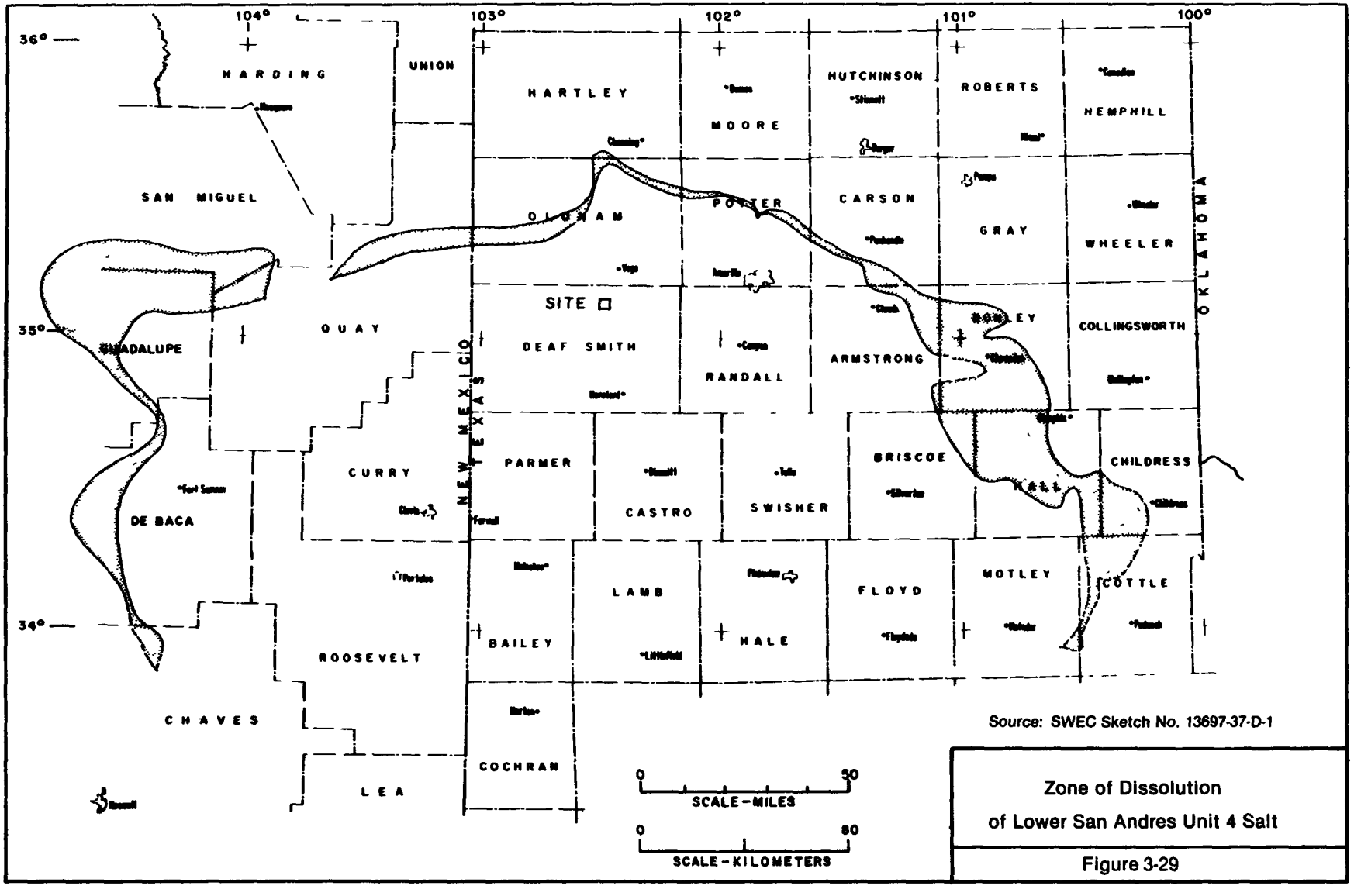
3.2.3.3.2 Interior Dissolution. The Southern High Plains lack most of the easily identified surface expressions of on-going or recent dissolution, such as collapse sinkholes, closed depressions, linear drainage elements and fractures (Gustavson et al., 1981; Gustavson and Finley, 1984). In contrast to the Rolling Plains, there are no confirmed areas beneath the Southern High Plains where the uppermost salt has undergone post-Pleistocene interior dissolution. There appears to be some stratigraphic evidence that there has been more interior dissolution in the northern part of the Palo Duro Basin than in the southern part.

In the Southern Palo Duro Basin, thick Salado-Tansill salts with interbedded mudstone, siltstone, and minor amounts of anhydrite grade northward into redbeds (McGillis and Presley, 1981, p. 6; Figure 3; Figure 7). Since the salt thinning to the north is counter to the northwest trend of clastics in the same formation, the salt boundaries are assumed to be dissolution controlled (McGillis and Presley, 1981, p. 11).

Core taken from DOE wells in the interior of the Palo Duro Basin (i.e., all DOE wells except Sawyer No. 1 and Mansfield No. 1) exhibit evidence of dissolution of the uppermost salt. Comparison between the cores in Swisher County and Deaf Smith County suggests that the following features formed as a result of salt dissolution from the upper part of the Seven Rivers Formation and the lower part of the Salado-Tansill Formation:

- Thinning of these intervals

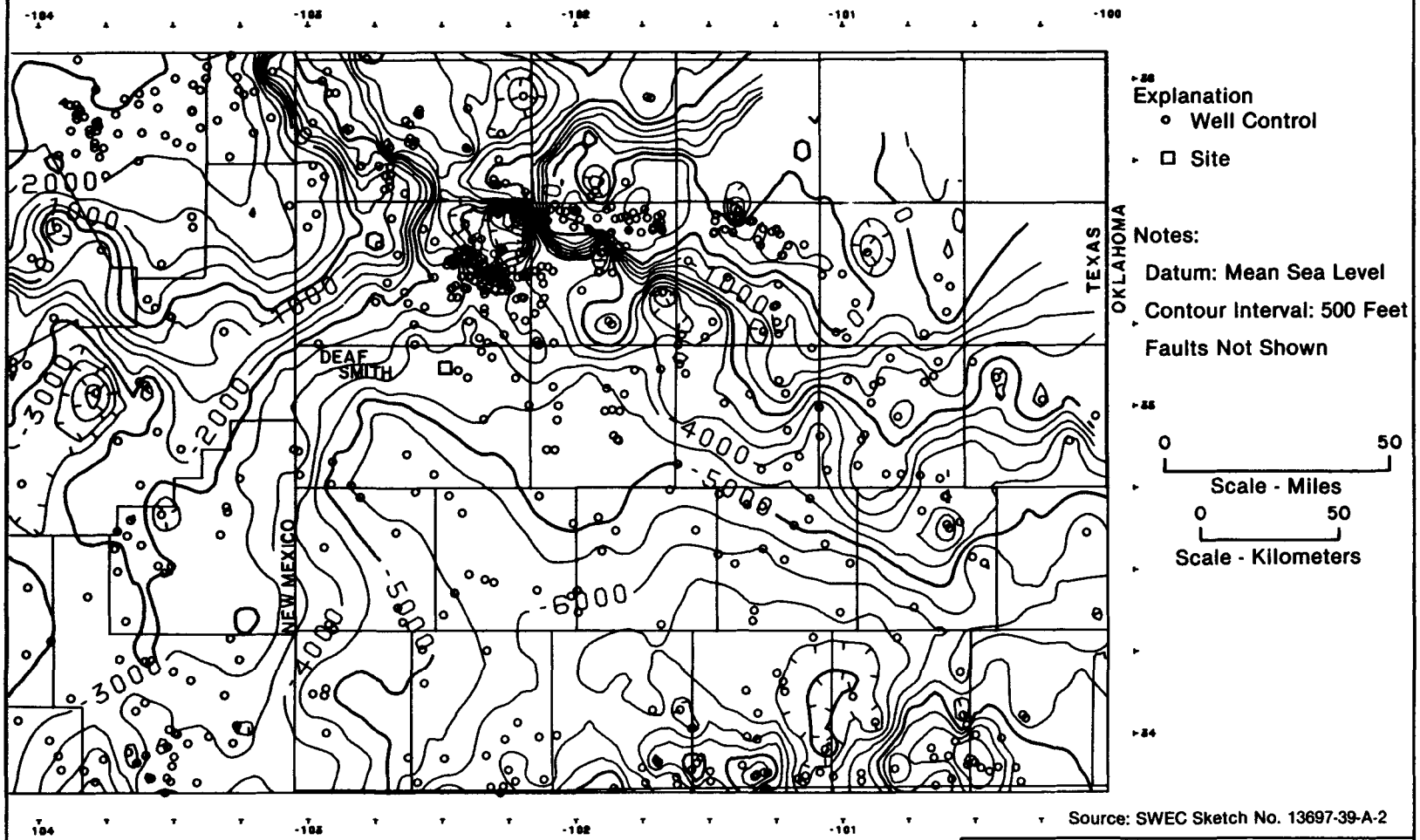
- Formation of fractures



Source: SWEC Sketch No. 13697-37-D-1

Zone of Dissolution
of Lower San Andres Unit 4 Salt

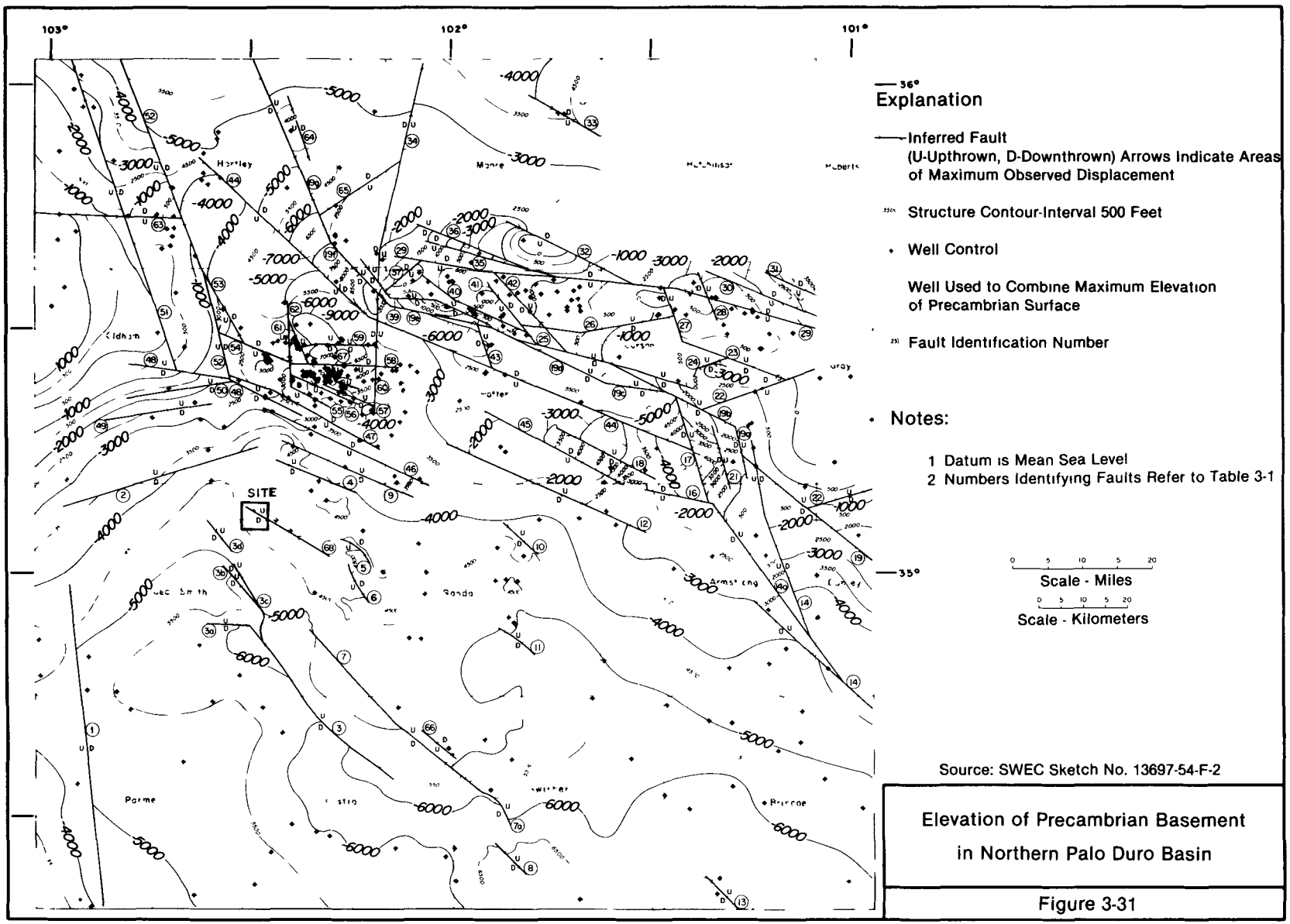
Figure 3-29



Source: SWEC Sketch No. 13697-39-A-2

Elevation of
the Precambrian Basement

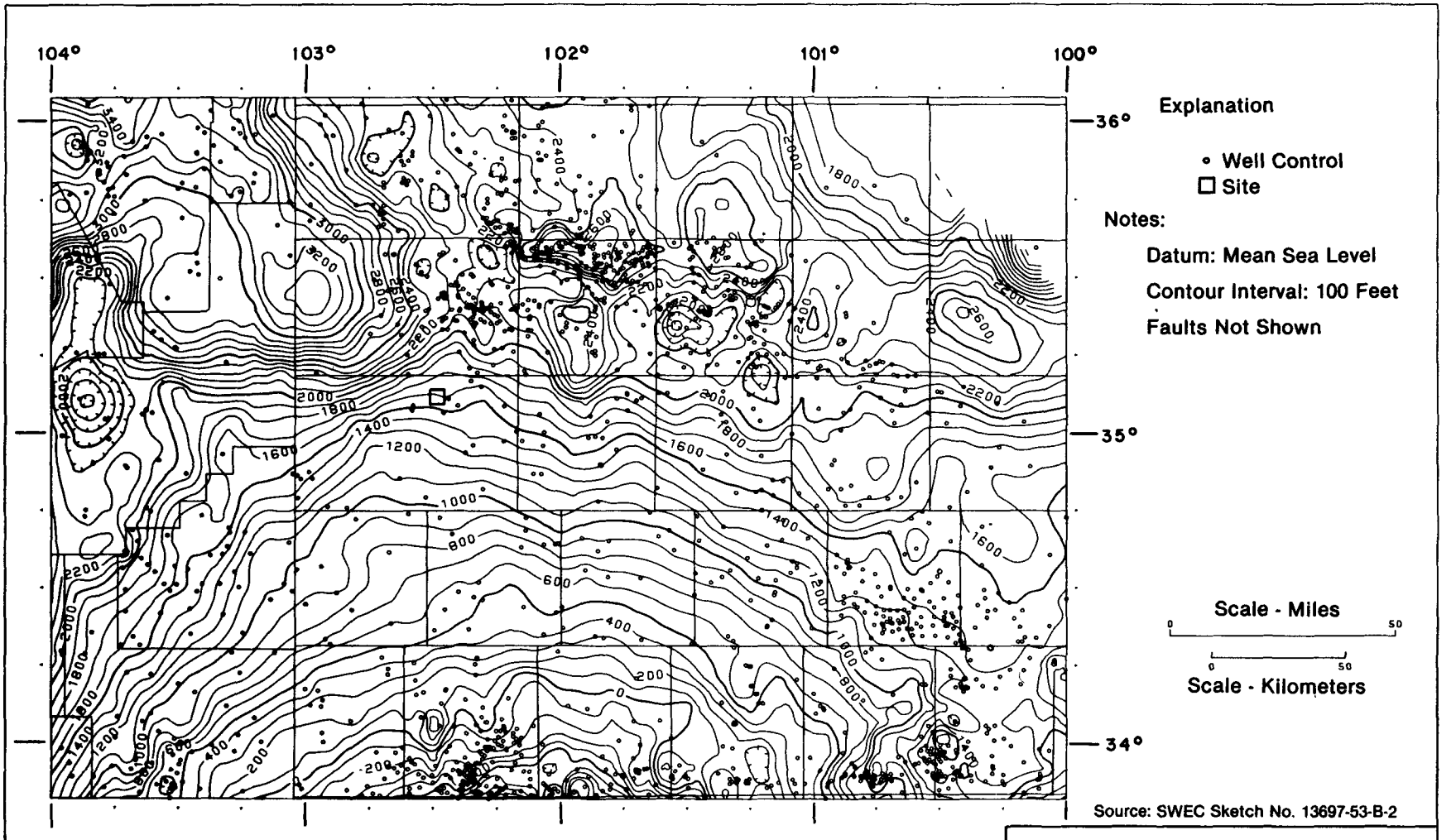
Figure 3-30



Source: SWEC Sketch No. 13697-54-F-2

Elevation of Precambrian Basement in Northern Palo Duro Basin

Figure 3-31



Source: SWEC Sketch No. 13697-53-B-2

Elevation of the
Lower San Andres Unit 4

Figure 3-32

- Hydration of anhydrite to gypsum
- Formation of breccia
- Accumulation of the insoluble components in the salt (mudstone, claystone, anhydrite, and dolomite) as residue mixtures (Hovorka et al., 1985).

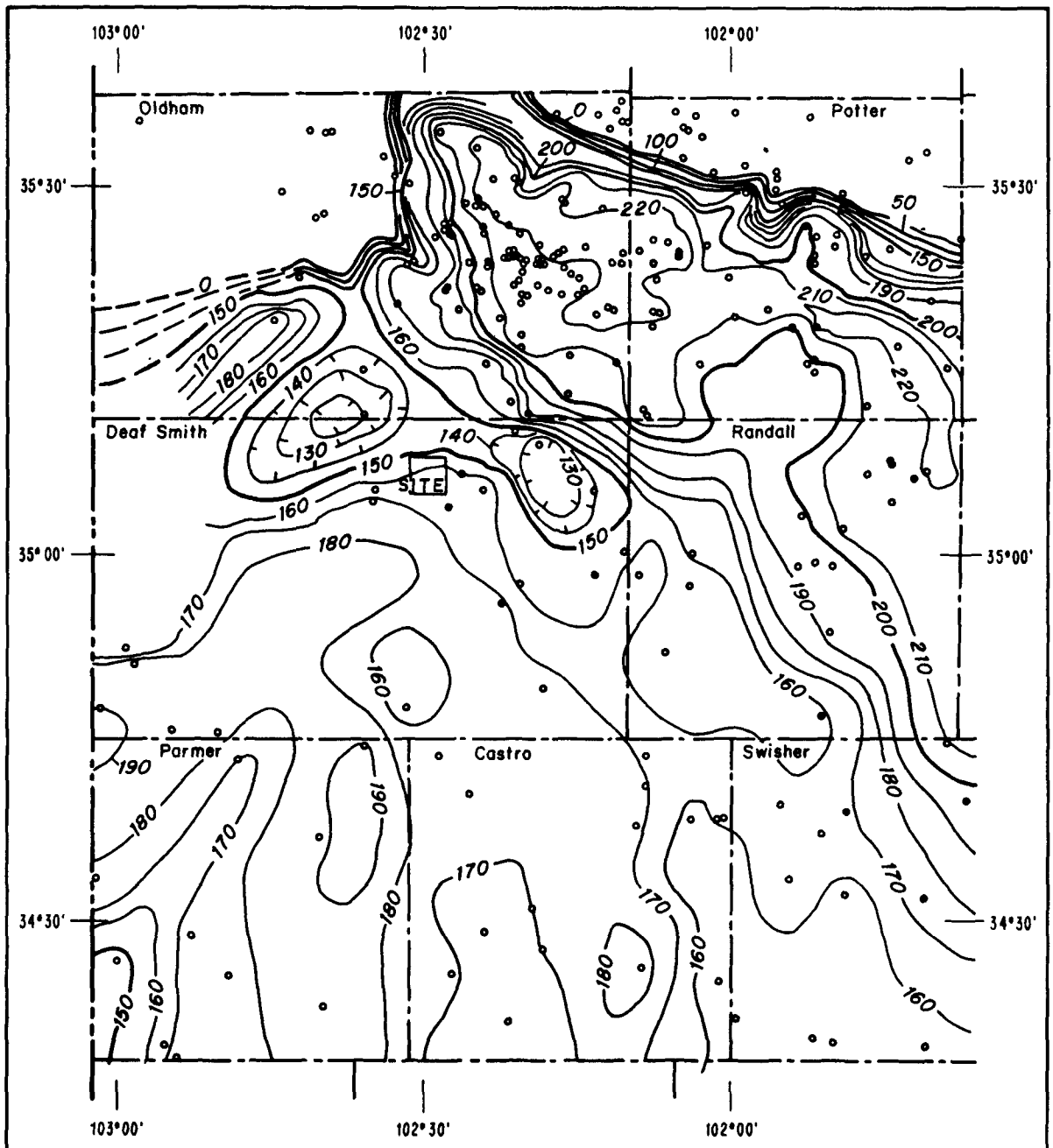
In Swisher County, the uppermost salt unit is present in the Seven Rivers Formation. Salt also occurs as cement and as isolated crystals of halite in the overlying Yates Formation (Hovorka, 1984). Salt is present at or near the base of the Salado-Tansill Formation in the Gruye No. 1 and Zeeck No. 1, but is missing from this horizon in the Harman No. 1 (McGillis and Presley, 1981; SWEC, 1984, BMI/SRP-5004; BMI/SRP-5009). The uppermost salt in the Harman No. 1 well, and in the rest of the wells in the interior of the basin, is in the Upper Seven Rivers Formation (Figure 3-24).

In Deaf Smith County, the Seven Rivers Formation above the top of salt is composed of thinly interbedded red-brown mudstone and claystone, anhydrite, and brecciated mixtures of mudstone claystone, gypsum, anhydrite, and dolomite. Slickensided fractures filled with gypsum or anhydrite are abundant (Hovorka, 1984) The overlying Yates Formation is composed of muddy sandstone and muddy siltstone, and contains several porous intervals. Above that lies the Salado-Tansill Formation, which is composed of red-brown claystone, mudstone, siltstone, and sandy mudstone, with interbeds of anhydrite and gypsum. Horizontal fractures filled with vertical fibrous gypsum and high angle fractures are abundant. Brecciated textures and mixtures of mudstone, claystone, anhydrite, gypsum, and dolomite are also present.

A similar suite of features has been described in core from the Sawyer No. 1 well in Donley County, which is in an area of documented dissolution.

Gustavson and Budnik (1985) propose that northeast-striking basement faults in eastern Deaf Smith County influence or control a number of geologic processes, including dissolution of Upper Seven Rivers and possibly Salado-Tansill salt. Several references cited by Gustavson and Budnik (1985) indicate northeast facies trends in Pennsylvanian and Permian rocks, and 8 meters (25 feet) of thickening of the Alibates Formation along a northeast trend was mapped by them. Further supporting evidence includes northeast and northwest fracture trends interpreted by logs from the Detten No. 1 and G. Friemel No. 1 wells; principal horizontal stresses oriented northeast and northwest (as measured in the Holtzclaw No. 1 well), which are compressional, with the maximum horizontal stress oriented northeast. Gustavson and Budnik (1985, p. 175) conclude that northeast-trending fractures would remain relatively open. The authors also mapped structurally closed depressions on the basal Ogallala surface and attributed them to preferential dissolution and to erosion. Structural control was inferred for northeast-flowing streams, such as Tierra Blanca Creek. According to this interpretation, preferential dissolution in southeastern Deaf Smith County occurred during or possibly after the Miocene-Pliocene.

The interpretation of northeast basement faults is possible because of the sparseness and limitations of the data. Most basement maps show no northeast faults in this area (Figures 3-31 and 3-36; Nicholson, 1960, Figures 42 and 43; Budnik and Smith, 1982, Figure 31; McGookey and Budnik, 1983, Figure 6; and Regan and Murphy, 1984, Figure 4). Persistent structural control of deposition would also be shown by trends in formation thicknesses; isopach maps of formations throughout the Pennsylvanian-Permian section show no northeast structural trends in eastern Deaf Smith County (Dutton, 1980, Figure 8; Budnik and Smith, 1982, Figure 36; Dutton et al., 1982, Figure 16; Presley and McGillis, 1982, Figure 36; and Regan and Murphy, 1984, Figure 15). Fracture plots from the comparatively shallow Detten No. 1 and J. Friemel No. 1 wells (Gustavson and Budnik, 1984, Figure 4) indicate about 10 northeast-trending fractures in each well, all of which are restricted to the rock section above the Glorieta. An east-west fracture trend in the Wolfcamp Series in the nearby J. Friemel No. 1 well indicates that the northeast trend may not be stratigraphically pervasive.



Explanation

- ○ Well Control
- ● Program Wells

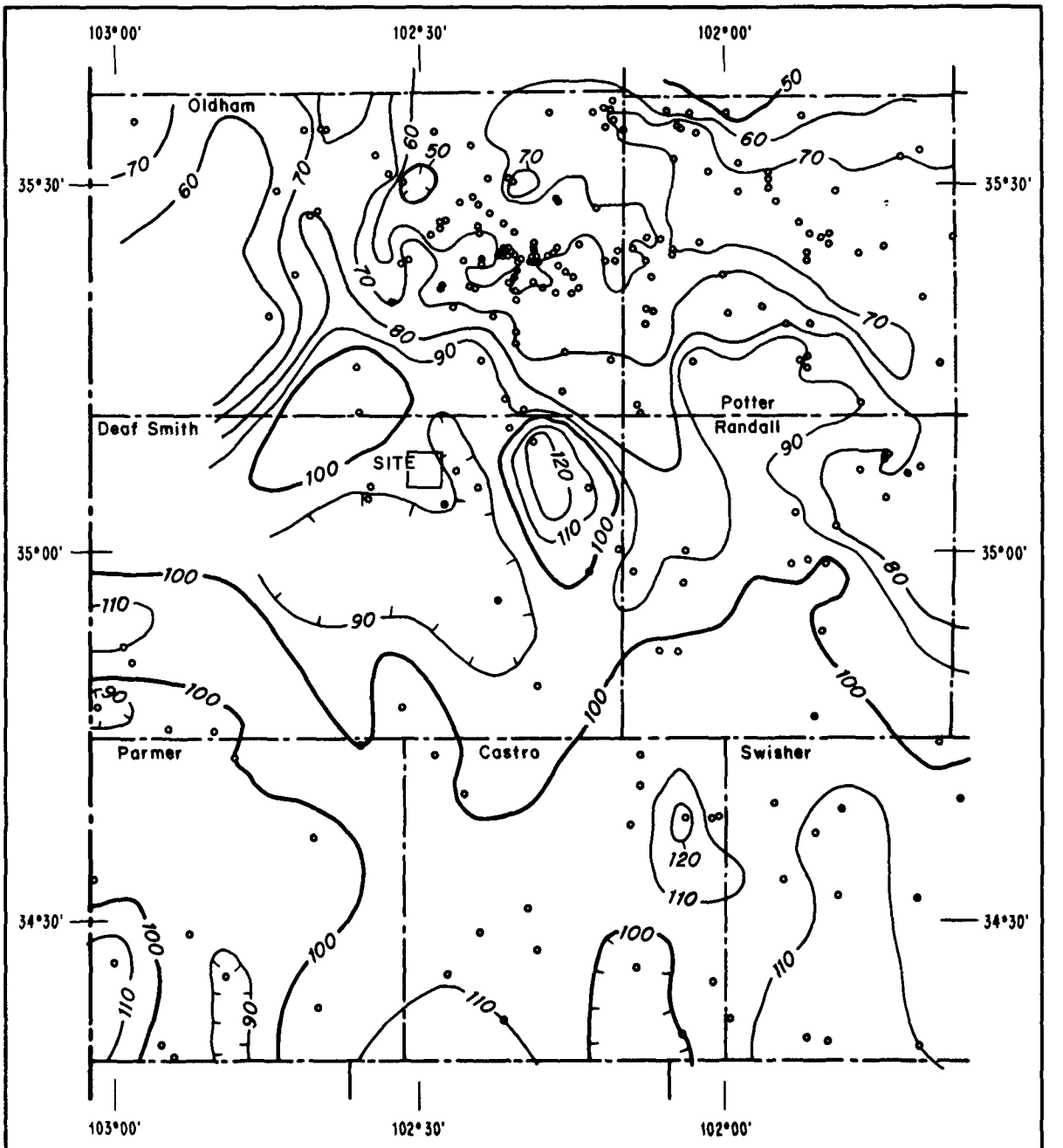
Contour Interval 50 Ft. (0-150 Ft.)
10 Ft. (120-220 Ft.)

Source: SWEC Sketch No. 13697-53-J-1

Note:
Salt Section is defined by the top of first salt to base of last salt.

Thickness of the Salt Section of the Lower San Andres Unit 4

Figure 3-33



Explanation

- ∘ Well Control
- • Program Wells

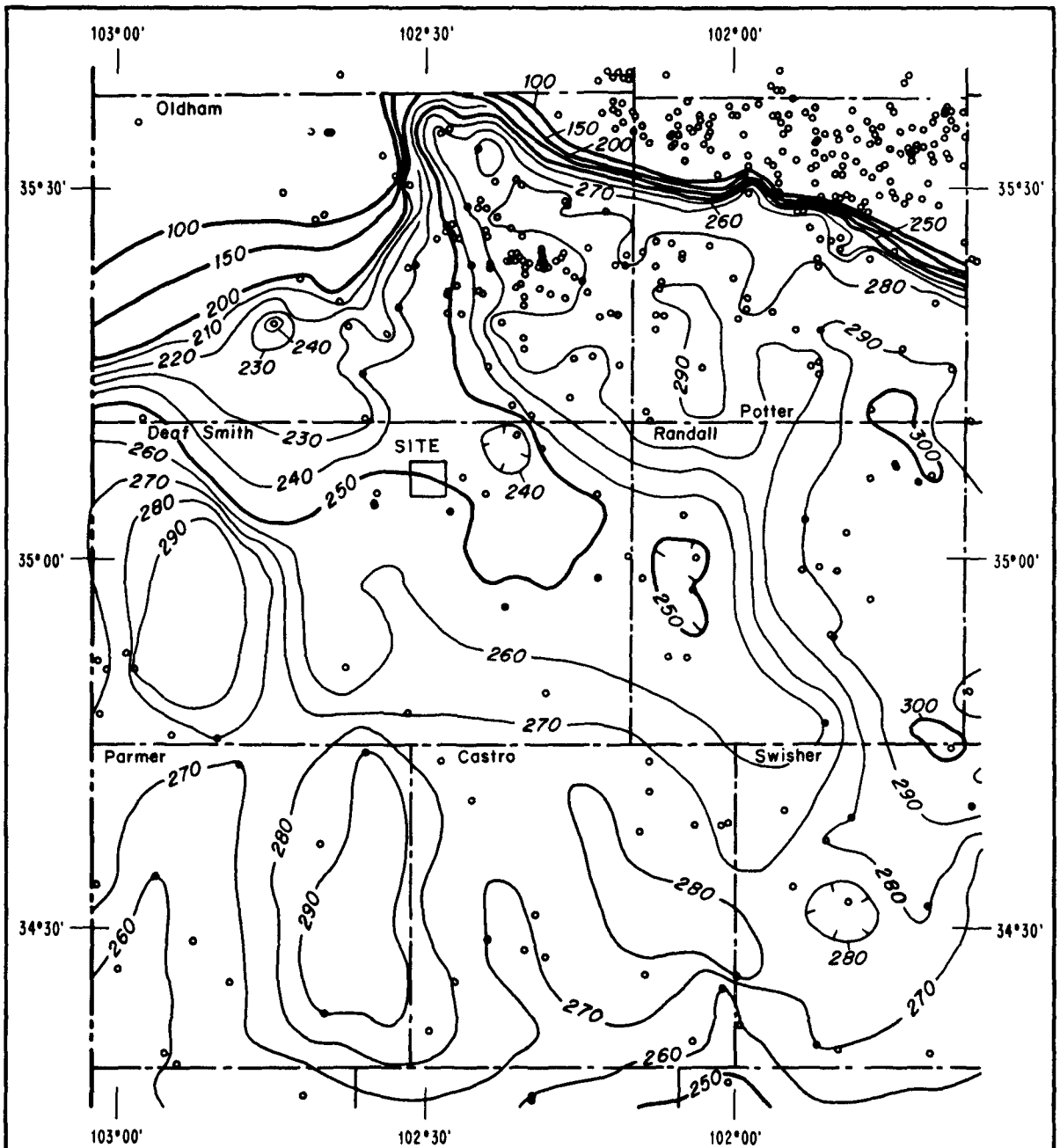
Contour Interval 10 Ft.

Source: SWEC Sketch No. 13697-53-K-1

Note:
Nonsalt Section is defined by the base of last salt to the top of Unit 3.

Thickness of the Nonsalt Section of the Lower San Andres Unit 4

Figure 3-34



Explanation

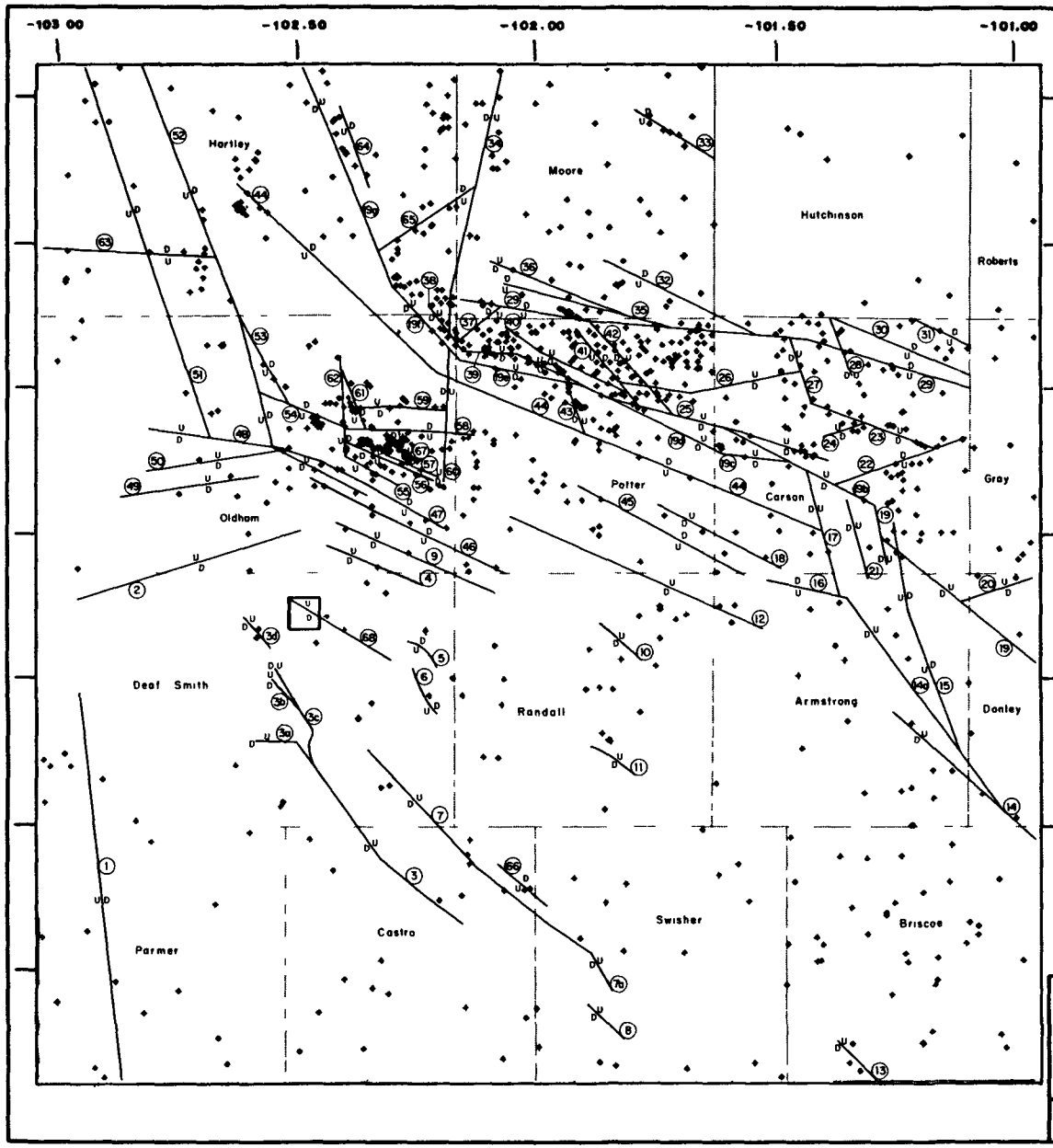
- ○ Well Control
- ● Program Wells

Contour Interval 50 Ft. (100-200 Ft.)
10 Ft. (200-300 Ft.)

Source: SWEC Sketch No. 13697-53-I-1

Thickness of the
Lower San Andres Unit 4

Figure 3-35



Explanation

- Well Control
- Inferred Fault Interpreted from Geophysical Well Log Data
- Fault Identification Number

Note: Numbers Identifying Faults Refer to Table 3-6.

0 5 10 15 20
Scale - Miles

0 5 10 15 20
Scale - Kilometers

Source: Modified from Regan and Murphy, 1984, Figure 3.

Inferred Faults in the Northern Palo Duro Basin

Figure 3-36

The horizontal-stress ratio measured in the Queen-Grayburg Formation from a hydrofracture test performed in the Holtzclaw #1 well is 1.14. Theoretical considerations and field observations (Carter et al., 1982; Baar, 1977, p. 72) suggest the differential between stresses is small. Based on the above, no fractures at depth would be likely to remain open. A detailed study of San Andres core by Hovorka et al. (1985) revealed that all fractures are healed. Closure on the basal Ogallala surface exceeds 46 meters (150 feet). A dissolution/subsidence origin for these features would require at least 46 meters (150 feet) of differential post-Permian dissolution. Gustavson and Budnik (1985, Figure 5) mapped 18 meters (60 feet) of differential thinning of Seven Rivers salt, 8 meters (25 feet) of which is accounted for by Alibates (Upper Permian) thickening (Figure 4). No Salado-Tansill salt remains in the area. The basal Ogallala depressions correspond to equivalent overthickening of the Ogallala. Thus, whatever the mechanism, the depressions formed before or during the Ogallala deposition (Miocene-Pliocene).

Budnik and Smith (1982, Figures 51 and 53) present a map of net salt in the Seven Rivers and Salado-Tansill Formations in the Palo Duro Basin. A maximum rate for interior dissolution can be calculated by assuming that the Seven Rivers and Salado-Tansill salts both extended across the site and that the original thickness of salt at the site is equal to their greatest combined thickness anywhere in the Palo Duro Basin (210 meters [690 feet] Hale County). By attributing the difference between the original and the present thickness at the site (20.4 meters [67 feet]) entirely to dissolution of the uppermost salt, a maximum amount of local interior dissolution may be calculated (190 meters [623 feet]). This value neglects depositional thinning of the salts. (The Lower Seven Rivers salt pinches out south of the site [Budnik and Smith, 1982, Figure 51].) By further assuming that all interior dissolution occurred after deposition of the Ogallala, a rate of 6.4×10^{-5} meter per year (2.1×10^{-4} foot per year) is estimated. This rate neglects paleodissolution of the Salado-Tansill salts (Budnik and Smith, 1982, Figure 53).

There is a prominent pattern of thinning of the upper (salt-bearing) section of Lower San Andres Unit 4 along a northwest trend in northeastern Deaf Smith County (Figure 3-33), which coincides with thickening of the basal (nonsalt) section of Unit 4 (Figure 3-34). Although these are partly offsetting, there remains a pattern of net thinning of Unit 4 along this trend (Figure 3-35). Hovorka et al. (1985, p. 46, Figures 73 and 79) conducted a detailed examination and correlation of core from seven DOE-sponsored wells in the northern Palo Duro Basin. They observed updip pinching out of anhydrite beds from the middle of the upper section of Unit 4 in this area. They also observed low-salinity facies at the base of Unit 5, separated from missing and thin halite zones at the top of Unit 4 by anhydritic mudstone (interpreted as an insoluble residue). From this, Hovorka et al. (1985, p. 51) concluded that the transgression which initiated the deposition of Unit 5 was responsible for dissolution of salt from the top of Unit 4 in this area.

In a study of the Hutchinson Salt Member of the Wellington Formation (Permian) in central Kansas, Walters (1976, pp. 1-2) found that dissolution of salt during modern rotary drilling, using fresh-water-based muds, results in borehole enlargement to about three times the diameter of the drilled hole, and that cable-tool drilling during the 1930s typically caused enlargement to about five times. In wells with shallow aquifers properly isolated from the salt by casing and/or plugging, no dissolution ordinarily occurs after drilling is completed. In wells in which the shallow aquifiers were not isolated (such as very old wells with no surface casing), dissolution can continue after abandonment. However, even in these cases Walters (1976, p. 126) found that salt dissolution tends to be self-limiting due to packing of voids by caving shale. The DOE has obtained relevant information for all oil and gas wells of record in the vicinity of the site. All of these were drilled in the 1950s and later. There remains a low probability that there may be unrecorded wildcat wells near the site that have resulted in increased dissolution of salt locally.

3.2.4 Paleontology

Although time-stratigraphic formation boundaries are often defined based on fossil evidence in the type locality, the interpretations used in the OCRWM program's study of the Palo Duro Basin are based on geophysical log signatures. Cenozoic vertebrate fauna occur in some lake beds on the High Plains. The site is distant from known localities of vertebrate fauna.

3.2.5 Structure and Tectonics

The early tectonic history of the site region is not well understood because Precambrian rocks are not exposed. In addition, the configuration, distribution, and relative motion of the continental plates during the Precambrian are not well known. Igneous intrusion and orogenic activity are presented by some investigators as the development of a shield area known as the Texas Craton (Flawn, 1956, p. 7) dating back to a period between 1.8 and 1.1 billion years ago (Condie, 1982, pp. 37-38). Another hypothesis proposes the development of a Precambrian rift system, one arm of which encompasses the Wichita Uplift System and its adjoining basins in the Panhandle of Texas and southern Oklahoma (Figure 3-4; Ham et al., 1964; Burke and Dewey, 1973; Hoffman et al., 1974; and Wickham, 1978). This structure is believed to greatly influence the trend and character of later Paleozoic tectonic activity in this area (Brewer et al., 1983, pp. 113-114).

Proposed early Paleozoic events include intrusion in the Wichita Mountains area, widespread marine transgression and intermittent broad uplift of the region, and early subsidence of the Anadarko Basin. Major tectonic activity, which occurred mainly during the Late Mississippian to Late Pennsylvanian or Early Permian, includes subsidence and filling of the Palo Duro and Anadarko Basins as well as development and erosion of the bounding uplift areas. This activity coincided, in part, with the Ouachita orogeny which in turn is the presumed result of collision between the North American and South American or African lithospheric plates. The Ouachita orogeny is believed to be concurrent with the Appalachian orogeny, which occurred from Middle Mississippian to Early Permian time.

Uplift during the geologic interval mentioned above was accompanied by rapid erosion of the granitic highlands which supplied a great deal of clastic material, including the "granite wash" arkose, to the Anadarko and Palo Duro Basins. The history and sequence of movements on individual blocks or areas have not been determined. Granite wash deposits are found in rocks of Wolfcampian age, indicating uplift was still active in earliest Permian. Deposition of the Wolfcamp "brown dolomite" over all the uplift areas indicates that a period of tectonic stability existed at the end of the Early Permian.

Later Permian history was markedly different from Mississippian and Pennsylvanian time. Tectonic movements appear to have been limited to eperiogenic uplift over a broad region of the continent combined with continuing subsidence in the basinal areas. Widespread shallow water and evaporitic conditions resulted in thick accumulations of salt, gypsum, shale, and carbonate in the Palo Duro and adjacent basins. Carbonate shelf development took place at the basin margins concurrently with interior deposition in the basins. By Late Permian time, the basins had been filled and redbed deposition predominated.

Effects of major Mesozoic and Cenozoic events, such as the Laramide orogeny, are only suggested in the area except to the west in New Mexico. The principal effect on the Palo Duro and Dalhart Basins was uplift and tilting which reinforced regional surficial gradients to the southeast and resulted in widespread deposition of alluvial materials.

Quaternary tectonic events include volcanic activity as young as Holocene age in northeastern New Mexico, possible activity of the Meers Fault in southwestern Oklahoma, and recently identified microseismic activity in Oldham County, Texas, which is north of the site. These events are discussed in greater detail in following sections.

The Deaf Smith County site is located in the northwestern part of the Palo Duro Basin, which is one of several subbasins within the larger Permian Basin (Figure 3-4). The subbasins are separated by northwestward and westward-trending basement uplifts evident mainly in the subsurface. The Palo Duro Basin was the site of deposition for up to 3,350 meters (11,000 feet) of sediment, primarily during the Pennsylvanian and Early Permian (Dutton, 1979, p. 10). The structure of the basin is asymmetrical, the deepest part occurring adjacent and parallel to the Matador Uplift. The basinal axis trends to the northwest from this area through Deaf Smith County (Figure 3-30).

The structural features which bound the Palo Duro Basin exhibit greater relief on the north and south than on the east and west boundaries. Figure 3-4 shows the basin margins and Figure 3-30 illustrates the structural contours of the Precambrian basement within the Palo Duro Basin.

A minor arch exhibiting faulting at the north end separates the western boundary of the Palo Duro Basin from the Tucumcari Basin. Because the basins were formed at the same time, the Tucumcari Basin is generally considered to be an extension of the Palo Duro Basin.

The Matador Uplift forms the southern boundary of the Palo Duro Basin and separates it from the Midland Basin. The uplift trends approximately east-west and is believed to consist of a series of fault-bounded blocks which are offset by cross faults. The Midland Basin, which is south of the Matador Uplift, was formed during the Early Pennsylvanian and was a site of relatively shallow marine carbonate deposition throughout most of its history.

To the east, an unnamed minor faulted uplift separates the Hardeman and Hollis-Harmon Basins from the Palo Duro Basin. The faults are believed to have developed during Late Mississippian to Early Pennsylvanian time. By the Late Pennsylvanian, all three basins were stratigraphically continuous.

The Amarillo-Wichita Uplift System is the most prominent tectonic feature in the region, and forms the northern boundary of the Palo Duro Basin. It is composed of several structural elements. The westernmost element is the Amarillo Uplift, which separates the Palo Duro Basin from the larger and deeper Anadarko Basin.

Considerable drilling has shown the Amarillo Uplift to be fault-controlled with a steep northern flank. Structural relief from the uplift to the deepest part of the Anadarko Basin may exceed 12,000 meters (40,000 feet) (Brewer et al., 1983, p. 11). Combined vertical displacement of faults on the southern flank of the uplift, adjacent to the Palo Duro Basin, is approximately 2,000 meters (6,000 feet). There is also considerable relief within the uplift itself. Major development of the uplift is believed to have occurred during the Late Mississippian and Early Pennsylvanian; it was entirely buried by the Lower Permian Wolfcamp Formation.

The western end of the Amarillo Uplift is in the vicinity of Hartley and Oldham Counties in an area of geologically complex structures. The Dalhart Basin lies north of the uplift in this area and has a history similar to the Palo Duro Basin. Stratigraphic evidence indicates the two basins were connected through most of the Pennsylvanian and Permian, and that the seaway probably was fault controlled (Dobervich and Taylor, 1967, p. 1688). The Dalhart Basin contains about 2,750 meters (9,000 feet) of sedimentary rock including over 120 meters (400 feet) of bedded salt.

The western border of the Dalhart Basin is formed in part by the Sierra Grande Uplift (Figure 3-4). The uplift developed during the Pennsylvanian as a broad, low northeast-trending basement flexure but was buried by mid-Permian time when sediments overflowed the Dalhart Basin. The Oldham Nose, a southeastward extension of the Sierra Grande Uplift, partially separates the Tucumcari and Palo Duro Basins from the Dalhart Basin. Well data indicate several northwest-trending normal faults in this area with displacements generally less than 100 meters (300 feet) (Figure 3-31). The Bravo Dome formed in this area at the same time as the Amarillo Uplift although it is offset from the Uplift by about 32 kilometres (20 miles). The dome overlies the Oldham Nose and is the result of sediments being draped over the basement ridge. The saddle between the dome and the Amarillo Uplift may be the result of Early Pennsylvanian faulting.

The confluence of structures in the Oldham-Hartley County area results in a level of geologic complexity unique in the Panhandle area. Numerous small oil and gas fields, marked irregularity of the basement surface, and the recent identification of microseismic activity indicate faulting may be extensive and that some faults are probably active in this area. Further studies are required to provide information on the interrelationships among these structures and delineate the type and extent of seismic activity.

The Wichita Uplift is the southeastern continuation of the Amarillo Uplift and forms the major central portion of the Amarillo-Wichita Uplift System, trending southeast across southwestern Oklahoma and the Texas Panhandle. This portion of the uplift has outcrops of granite and gabbro of Early to Middle Cambrian ages. Recent seismic evidence suggests that the Wichita Uplift has been thrust to the northeast 10 to 20 kilometers (6 to 12 miles) over the sedimentary rocks of the Anadarko Basin (Brewer et al., 1983, p. 113). This event is believed to be associated with a period of major crustal shortening that occurred during the Early Pennsylvanian. Strike-slip movement during the Late Pennsylvanian is also possible along the Early Pennsylvanian faults (Brewer et al., 1983, p. 114).

3.2.5.1 Faulting

Faulting within the site region has been identified primarily as a result of petroleum exploration activities. The faults shown on Figure 3-4 have been identified in the published geologic literature. Most faults shown on Figure 3-4 are related to the basement uplifts and subsidence of the adjacent basins and are believed to be high-angle normal faults that form a complex series of fault blocks stepping downward into the basins. Many faults have Paleozoic movement histories; a few are known to be early to middle Cenozoic.

The Potter County fault is exposed at the surface and offsets strata of Precambrian to Triassic age (Barnes, 1969). Younger deposits are not present to indicate the age of more recent movement. The Deaf Smith County site is approximately 64 kilometers (40 miles) southwest of this fault.

The Meers Fault is located along the Amarillo-Wichita Uplift in southwestern Oklahoma (Figure 3-4), approximately 320 kilometers (200 miles) east of the Deaf Smith County site. It is the southernmost fault of the Wichita frontal fault zone (Harlton, 1963), and displays surface offsets of probable Holocene age (Donovan et al., 1983). Similar faults with Holocene movement may exist elsewhere along the Amarillo-Wichita Uplift. Thus there is the possibility of surface rupture and associated seismicity along the uplift.

The Meers Fault was originally interpreted as a normal fault downthrown to the Anadarko Basin on northern side of the Wichita Uplift. Displacement of several kilometers occurred in Pennsylvanian to Early Permian time (Harlton, 1963). Brewer et al. (1983) present evidence indicating that the Meers Fault and other faults of the frontal fault zone originated as high-angle reverse faults, with the Wichita Mountains thrust northward over the Anadarko Basin. The vertical motion reversed in the Permian with lesser movements up to the north.

Recent investigations have confirmed a 26-kilometer (16-mile) surface trace and a 3- to 5-meter (10- to 16-foot) fault scarp for the Meers Fault (Donovan et al., 1983, p. 126). Investigators do not agree on the predominant attitude of most recent movement. Ramelli and Slemmons (1985) report dominantly left-lateral strike-slip. Tilford and Westen (1985) report dominantly normal slip. Geomorphological evidence and preliminary radiometric data indicate that there were at least three episodes of movement between 4000 years and 5000 years before present (Tilford and Westen, 1985, p. 1; Madole and Rubin, 1985, p. 1).

The Oklahoma earthquake catalog, which describes discernable earthquake activities in the area since the establishment of Fort Sill in 1869, was examined for possible correlations of seismic activity with the Meers Fault. It is unlikely that, near the fault, earthquakes exceeding magnitude 4 have occurred in the last 116 years, or that earthquakes exceeding magnitude 3 have occurred in the last 23 years (establishment of seismic recording station in Tulsa). In the 7 years of operation of the Oklahoma microseismic network, only one earthquake (a magnitude 1.8 event in 1981) could have been associated with the fault (Lawson, 1985). Although the Meers Fault is geologically young, seismic evidence does not indicate current activity on this fault.

In addition, an 8-month microearthquake monitoring program failed to detect any seismic activity near the fault (Lawson, 1985).

The Bonita fault (Stearns, 1972) in the adjacent Tucumcari Basin is exposed along the edge of the Western Caprock Escarpment in Quay County, New Mexico, and offsets Cretaceous strata but not the overlying Ogallala (Barnes, 1977). Clemons et al. (1982) interpret the Bonita fault as the result of deep-seated geologic processes. Gustavson et al. (1980b, p. 30) believe the fault is related to dissolution of Artesia Group evaporites and subsequent collapse of overlying sediments. The Alamosa Fault in northern Roosevelt County, New Mexico, displaces the Triassic Dockum Group and the Tertiary Ogallala Formation (Barnes, 1977). Gustavson et al. (1980b, p. 30) believe the Alamosa Fault is also related to evaporite dissolution and collapse. They propose that the Bonita and Alamosa Faults were initially tectonic in origin, with later dissolution and subsidence along the faults accounting for most of the observed offset. These faults are at least 80 kilometers (50 miles) west of the Deaf Smith County site.

Seismic reflection data (Figure 3-3) have been used to identify additional faults within the Palo Duro Basin (G. J. Long, 1983; Budnik, 1984). Most of the faults trend to the northwest; however, Birsa (1977) and Dutton et al. (1982) present maps showing north-eastward-trending faults in Palo Duro Basin. Budnik (1984) and Gustavson and Budnik (1985) report a secondary trend of several northeast striking faults and suggest that depositional trends in the Upper Paleozoic were influenced by these basement faults. These concepts are discussed in Section 3.2.3.3.2.

Figure 3-36 and Table 3-6 show the integration of seismic reflection data with borehole depth information, and with geophysical log data from exploratory wells. The faults shown offset the Precambrian basement by as much as 300 meters (1,000 feet). The magnitude of the displacements decreases upward from the basement and most offsets die out within the Permian strata. As indicated on Table 3-6, the youngest faults offset units above the Alibates, and occur along the northern boundary of the Palo Duro Basin within the Amarillo Uplift.

Within the interior of the Palo Duro Basin, only fault No. 7 (Figure 3-36, Table 3-6) appears to offset the Upper San Andres Formation (mid-Permian). No other faults within the basin are known to be younger than the Upper Clear Fork Formation.

Stratigraphic data from two recent wildcat wells east and southeast of the Deaf Smith County site suggest that there may be a fault striking northwest and possibly extending beneath the site (Figure 3-36; Table 3-6; Pierce, 1984, 1985). The wells were probably drilled on strike because the formation elevations are approximately equal. However, elevations for basement and the Tubb Formation are shallower in the wildcat wells than anticipated from recent interpretations of regional trends (Regan and Murphy, 1984, Figures 4 and 7). Specifically, basement is approximately 140 meters (450 feet) and the Tubb Formation is about 30 meters (100 feet) shallower than anticipated.

J. Friemel No. 1 Well was drilled approximately 3 miles (5 kilometers) southwest of the wildcat wells. Data from the three wells indicate a change in dip relative to the regional dip reported by Regan and Murphy (1984), and suggest faulting or folding between the wildcat wells and the J. Friemel well. Faulting is consistent with possible thickening of the Pennsylvanian section. However, the thickening cannot be verified because the J. Friemel No. 1 Well bottomed out in the Pennsylvanian Granite Wash rather than basement.

Two alternative interpretations are postulated for the observed conditions, either faulting or folding. In the first case, the wildcat wells were probably drilled on strike and may have been targeted at an inferred fault which can be postulated to exist near them. The Tubb Formation is the youngest horizon with recognizable offset indicating that the last movement was before San Andres deposition. An inferred northwest-striking fault, upthrown to the northeast, would be consistent with the regional tectonic framework (Nicholson, 1960) and with previously mapped structures in the Palo Duro Basin (Budnik and Smith, 1982, Figure 3-1; McGookey and Budnik, 1983, Figure 6; Regan and Murphy, 1984, Figures 4, 5, and 7).

As shown on Figure 3-3, seismic reflection data have been recorded in the region, as part of area characterization work. Some of the lines have recently been reprocessed to enhance reflections from basement and lower Paleozoic formations in an attempt to confirm the presence

Table 3-6. Summary of Fault Data

Fault No.	Strike	Dip Direction	Youngest Unit Displaced	Max. Observed Displacement (ft)	Remarks
1	N8°W	NE	Red Cave	1,825	Fault dies out in Wolfcamp to the south
2	N74°E	SE	Wolfcamp	925	
3	N55°W	SW	Pennsylvanian (?)	165	From seismic[a] data
3a	N90°W	S	Wolfcamp (?)	535	From seismic data
3b	N38°W	SW	Pennsylvanian (?)	430	3b, 3c, and 3d may be a a series of en echelon faults rather than branching as shown. All three are from seismic data and are shown as interpreted by Long, 1983.
3c	N32°W	SW	Pennsylvanian (?)	355	
3d	N49°W	SW	Pennsylvanian (?)	205	
4	N68°W	SW	Pennsylvanian (?)	425	From seismic data
5	N67°W	NE	Pennsylvanian (?)	255	From seismic data
6	N27°W	NE	Pennsylvanian (?)	620	From seismic data
7	Variable	SW	Upper San Andres (?)	440+	Displacement of Wolfcamp top. Wolfcamp shows more displacement than Pennsylvanian (330 feet) and Precambrian (385 feet on seismic map) due to Wolfcampian reef.
7a	Variable	SW	Wichita	250	From seismic data, continuation of Fault No. 7
8	N46°W	SW	Pennsylvanian (?)	250	From seismic data
9	N67°W	SW	Upper Clear Fork	1,450	

Table 3-6. Summary of Fault Data
(Page 2 of 6)

Fault No.	Strike	Dip Direction	Youngest Unit Displaced	Max. Observed Displacement (ft)	Remarks
10	N52:W	SW	Pennsylvanian (?)	110	From seismic data
11	N66:W	SW	Pennsylvanian (?)	155	From seismic data
12	N65:W	SW	Lower San Andres (?)	835	NW extent of fault and amount of displacement questionable due to lack of well log and seismic data
13	N46:W	SW	Pennsylvanian	235	
14	N48:W	SW	Red Cave	1,115	
14a	N38:W	SW	Wolfcamp	1,350	
15	Variable	NE	Red Cave	2,330	
16	N78:W	NE	Wolfcamp	655+	Displacement of Pennsylvanian top
17	N18:W	SW	Upper Clear Fork	5,006	Displacement of Pennsylvanian top
18	N61:W	SW	Wichita	1,580	
19	N51:W	SW	Lower San Andres	1,525	Faults 19 through 19g may represent one variable striking fault or a series of NW trending en echelon faults related to the Amarrillo uplift
19a	N13:W	SW	Glorieta	2,280	
19b	N65:W	SW	Upper Clear Fork	700+	Displacement of Pennsylvanian top
19c	N79:W	SW	Post-Alibates	500+	Displacement of Pennsylvanian top

Table 3-6. Summary of Fault Data
(Page 3 of 6)

Fault No.	Strike	Dip Direction	Youngest Unit Displaced	Max. Observed Displacement (ft)	Remarks
19d	N63:W	SW	Post-Alibates	725+	Displacement of Pennsylvanian top
19e	N80:W	SW	Post-Alibates	6,290	
19f	N45:W	SW	Post-Alibates	1,990+	Displacement of Pennsylvanian top. Precambrian is at -9,405 feet on SW side of this fault (deepest observed Precambrian top in basin)
19g	N27:W	SW	Red Cave	2,675+	Displacement of Mississippian top
20	N73:W	SE	Glorieta	1,540	
21	N18:W	SW	Wolfcamp	115+	Displacement of Pennsylvanian top
22	N71:E	NW	Post-Alibates	650+	Displacementof Pennsylvanian top
23	N70:W	SW	Post-Alibates	840+	Displacement of Wolfcamp top
24	N70:E	SE	Post-Alibates	740+	Displacement of Wolfcamp top
25	Variable	SW	Post-Queen/ Grayburg	945+	Displacement of Pennsylvanian top. No well log data above Queen/Grayburg Formation to north of fault.
26	Variable	SE	Glorieta	390+	Displacement of Wolfcamp top

Table 3-6. Summary of Fault Data
(Page 4 of 6)

Fault No.	Strike	Dip Direction	Youngest Unit Displaced	Max. Observed Displacement (ft)	Remarks
27	N20:W	SW	Post-Lower Seven Rivers	360	No well log data above Lower Seven Rivers Formation to east of fault
28	N24:W	SW	Wolfcamp	2,930	
29	Variable	V?[c]	Glorieta	3,455	
30	N68:W	NE	Wichita	305+	Displacement of Wolfcamp top
31	N64:W	NE	Red Cave	1,095+	Displacement of Pennsylvanian top
32	N62:W	V?[c]	Wolfcamp	1,600+	Displacement of Ellenburger top
33	N59:W	V?[c]	Pennsylvanian	1,370+	Displacement of Ellenburger top
34	Variable	NW	Pennsylvanian	835+	Displacement of Mississippian top. Southern extent of fault uncertain due to a lack of deep well log data
35	N74:W	V?[c]	Post-Alibates	3,170	
36	N68:W	V?[c]	Post-Alibates	3,240	
37	N48:E	NW	Wolfcamp	1,540	
38	N43:W	SW	Post-Alibates	440+	Displacement of Wolfcamp Top
39	Variable	SW	Upper Clear Fork	480	

Table 3-6. Summary of Fault Data
(Page 5 of 6)

Fault No.	Strike	Dip Direction	Youngest Unit Displaced	Max. Observed Displacement (ft)	Remarks
40	Variable	SW	Post-Alibates	690	Fault is exposed on the surface approximately 3/4 mile NE of Colorado Interstate Gas Co., Masterson A No. 25 (Barnes, 1969)
41	N38:W	NE	Wolfcamp	750	Faults 41 and 42 form a graben with a thick accumulation of granite wash at its base
42	N41:W	SW	Wolfcamp	880	
43	N21:W	SW	Wichita	700+	Displacement of Pennsylvanian top
44	Variable	NE	Wolfcamp	3,615	
45	N64:W	NE	Lower Clear Fork	2,900	
46	N66:W	NE	Pennsylvanian	460	
47	N62:W	NE	Pennsylvanian	595	
48	Variable	SW	Wichita	1,125	
49	N81:E	SE	Red Cave	670	
50	N80:E	SE	Wolfcamp	790	
51	N18:W	NE	Wolfcamp	1,480	
52	Variable	NE	Red Cave	2,960	
53	N29:W	NE	Wolfcamp	1,115	
54	N67:W	NE	Wichita	1,190	
55	N60:W	NE	Wolfcamp	485	

Table 3-6. Summary of Fault Data
(Page 6 of 6)

Fault No.	Strike	Dip Direction	Youngest Unit Displaced	Max. Observed Displacement (ft)	Remarks
56	N66:W	NE	Pennsylvanian	570	
57	N66:W	SW	Pennsylvanian	475	
58	Variable	N	Upper San Andres	2,760	
59	Variable	SW	Wolfcamp	1,020	
60	N2:E	NW	Post-Lower San Andres	1,215	
61	N19:W	NE	Upper Clear Fork	1,390	
62	N2:W	NE	Post-Alibates	1,035	
63	N87:W	NE	Wolfcamp	2,900	
64	N19:W	NE	Pennsylvanian	680	
65	N55:E	NW	Wolfcamp	2,035	
66	N42:W	NE	Glorieta	240+	Displacement of Wichita top. Precambrian displacement (210 ft) from G. J. Long, 1983.
67	Variable	SW	Pennsylvanian	420	
68	N42:W	SW	Upper Clear Fork	300	

(a) Seismic data reduction was done on four horizons: Precambrian, Wolfcamp, Glorieta, and Upper San Andres. The youngest unit displaced is questionable due to a lack of information between each of these four horizons.

(b) Maximum displacement observed on a horizon younger than Precambrian.

(c) Faults are given a vertical dip direction because it is uncertain whether they are normal or reverse faults.

or absence of the inferred fault. Turner (1985) describes the reprocessing sequence and discusses the results. Generally, the conclusion is that, although the reprocessing enhanced basement reflections, there is no conclusive proof of the existence of the fault. Additional subsurface data are necessary to resolve the uncertainties.

Alternatively, observed conditions can be explained by folding, a series of northwest-striking faults having individually small offsets, or a combination of faulting and folding.

3.2.5.2 Lineaments and Joints

Data on joint orientations for the Southern High Plains are from caliche layers in the Ogallala, locations near the Caprock Escarpment where Triassic and Permian age rocks outcrop, and Fracture Identification Logs from DOE wells. Joint orientations at selected locations in the Texas Panhandle are reported by several authors (Finley and Gustavson, 1981; Collins and Luneau, 1985; Goldstein and Collins, 1984; Collins, 1984; and Gustavson and Budnik, 1985). Orientations appear to vary considerably, even within a single study area and single rock unit although Collins and Luneau (1983) indicate that joints in the Ogallala Formation have a different trend from joints in the Permian and Triassic rocks, suggesting different stress fields. Formations in which jointing has been measured in outcrop are limited to the Upper Permian Whitehorse Group and Quartermaster Formation, the Triassic Dockum Group, and rarely, caliche units of the Tertiary Ogallala Formation. Joint data are summarized in Table 3-7. A dominant trend is northwest-southeast with a secondary trend at northeast-southwest.

Hovorka et al. (1985) examined several thousand feet of core from the DOE wells, across Lower San Andres Units 4 and 5. That study is unable to document open joints or fractures.

Lineament trends are more consistent over the Panhandle region than joint trends (Finley and Gustavson, 1981; Finch and Wright, 1970; Baumgardner, 1983; and Cooley, 1984). Lineaments, which are straight or slightly curved segments of escarpments, ridges, valleys, and streams, natural vegetation patterns, alignment of playas and sinks, and lithologic boundaries, can be grouped into two general orientations. The more dominant trend is a northwest trend which includes those between north-northwest and west-northwest. The other trend is a northeast trend including those between north-northeast and east-northeast. North-south and east-west trends appear subordinate, which may be due to effects of rectangular north-south patterns of cultivated fields and roads along section lines. In addition, major highways and railroads, being generally east-west, mask lineaments of that orientation.

Many lineaments appear to be controlled by joints. However, the extent to which joints occurring in subsurface formations influence the development of joints or lineaments in overlying, unconsolidated, or poorly consolidated materials is a matter of speculation. The existence of several unconformities in the stratigraphic record further complicates any attempt at correlation.

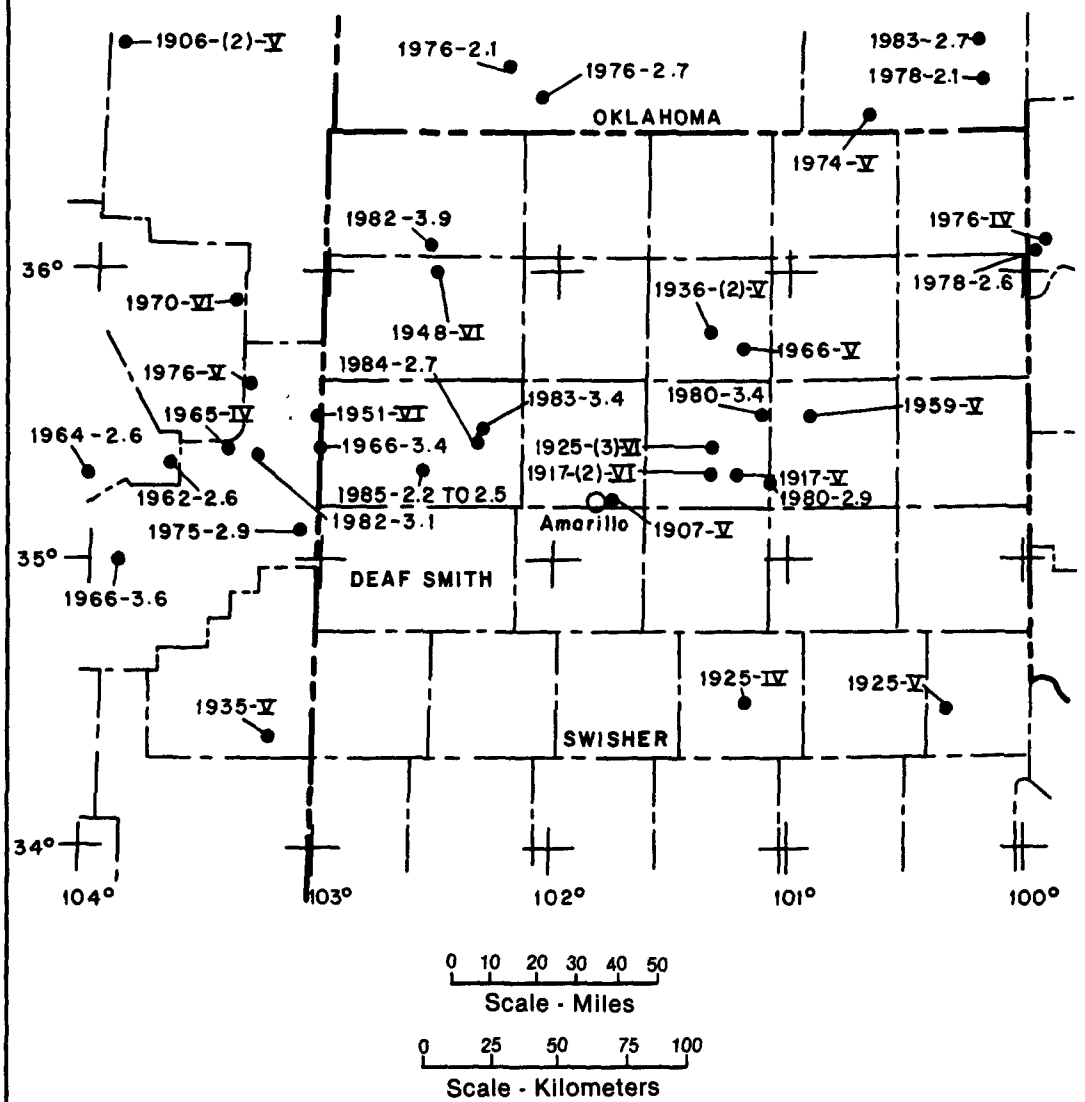
The subsurface state of stress is addressed in Section 3.2.6.1.1. Correlation between hydrofracturing results from the Palo Duro Basin and basinal joint trends is speculative at this time. The age of the jointing and its relation to tectonic stresses are not known yet. Finley and Gustavson (1981), Gustavson and Budnik (1985), and Finch and Wright (1970) suggest lineaments and joints may be related to faults in the Precambrian basement.

3.2.5.3 Seismicity

The historical seismicity of the region surrounding the Palo Duro Basin has been compiled by Acharya (1985a) and Pennington and Davis (1984). Figure 3-37 is an epicenter map for historical earthquakes in the Texas Panhandle. Most locations shown for events are based on felt reports; the remaining locations are determined from instrumental data. In some instances, two events have been assigned the same location. Figure 3-37 shows the dates and sizes (magnitude or intensities) of events that occurred at a given location; Table 3-8 lists the parameters (time, location, size) for all earthquakes that are reported to have occurred in the Texas Panhandle and vicinity.

Table 3-7. Joint and Lineament Trends

Type of Data	Orientation			Data Source	Location of Formation	Reference
	Dominant	Other	Other			
Joints	70°-90°	30°-50°		Caprock Escarpment, So. High Plains, Quay Co., N.M.	Dockum (?)	Finley and Gustavson, 1981
Joints	350°-10°	270°-290°		Buffalo Lake, So. High Plains, Randall Co., Tx.	Ogallala	Finley and Gustavson, 1981
Joints	350°-10°	330°-350°		Palo Duro State Pk., Randall Co., Tx.	Ogallala, Dockum	Finley and Gustavson, 1981
Joints	290°-310°	310°-330°		Palo Duro State Pk. Randall Co., Tx.	Upper Permian, Dockum, Ogallala	Finley and Gustavson, 1981
Joints	270°-290°	350°-10°		Eastern Caprock Escarpment	Ogallala, Dockum	Finley and Gustavson, 1981
Joints	270°-290°	010°-030°	070°-090°	Rolling Plains, Lake Theo Area, Briscoe Co., Tx.	Upper Permian	Finley and Gustavson, 1981
Alignment of Sinks	300°			Chaves and Lea Co., S.E.N.M.	Ogallala	Reeves, 1970
Alignment of Drainage	NW-SE	NE-SW		Curry Co., N.M. to Crosby Co., Tx.	Ogallala	Finch & Wright, 1970
Drainage Patterns	285°-295°	48°-55°	355°-0°	So. High Plains, Tx., and N.M.		Reeves, 1970
LANDSAT Lineaments	101°-020°	030°-040°	060°-070°	Rolling Plains, Canadian Breaks, Pecos Plains		Finley and Gustavson, 1981
LANDSAT Lineaments	300°-320°	030°-050°		So. High Plains		Finley and Gustavson, 1981



Sources: Acharya, 1984, 1985b; Coffman and von Hake, 1975; Docekal, 1970; Lawson et al., 1979; Northrop and Sanford, 1972; Nuttli, 1979; Reagor et al., 1982; Stover et al., 1981, 1983.

Explanation

- Seismic Event

Yr - (No. of Events) - Maximum Intensity or Magnitude

(Refer to Table 3-3)

Epicenters of Historical Earthquakes in the Texas Panhandle Area

Figure 3-37

Table 3-8. Earthquake Catalog for the Texas Panhandle and Vicinity

Date (mo.dy.yr)	Time (GMT) (hr, mn)	Lat.	Long.	Inten. (Modified Mercalli)	Mag.	Location	Felt Area (sq. km)	Ref.
4.20.06	AM	36.8	103.9	V	-	Folsom, NM		3
4.21.06	AM	36.8	103.9	V	-	Folsom, NM		3
4. .07		35.2	101.8	V	3.0	TX, North		5
3.24.17	1930	35.3	101.2	V	4.2	TX, North		6
3.27.17	1956	35.3	101.3	VI	4.7	TX, North	5,000	6
3.28.17	2338	35.3	101.3		3.0	TX, North		6, 7
7.29.25	1130	34.5	101.2	IV	3.8	TX		6
7.30.25	0800	34.5	100.3	V	4.2	TX		6
7.30.25	1217	35.4	101.3	VI	4.8	TX, North	500,000	6
7.30.25	1222	35.4	101.3	IV				7
7.30.25	1227	35.4	101.3	IV				7
12.20.35	0530	34.4	103.2	V		Clovis, NM		9
6.20.36	0318	35.8	101.3	III	3.0	Borger, TX		6, 7
6.20.36	0324	35.8	101.3	V	4.7	Borger, TX		6, 7
3.12.48	0429	36.0	102.5	VI	4.7	Dalhart, TX	80,000	5
6.20.51	1837	35.5	103.0	VI	4.7	TX, North	103,600	2
2.10.59	2005	35.5	100.9	V	4.5	TX, North	120,000	6
1.03.62	2329	35.32	103.64		2.6	Tucumcari, NM		8
3.03.64	0126	35.3	104.0		2.6	Tucumcari, NM		5
2.03.65	1132	35.4	103.4	IV	2.9	Logan, NM	13,700	9

Table 3-8. Earthquake Catalog for the Texas Panhandle and Vicinity
(Page 2 of 2)

Date (mo.dy.yr)	Time (GMT) (hr, mn)	Lat.	Long.	Inten. (Modified Mercalli)	Mag.	Location	Felt Area (sq. km)	Ref.
4.21.66	1414	35.4	103.0		3.4	Logan, NM		5
7.20.66	0904	35.7	101.2	V	3.9	TX, North	60,000	7
9.17.66	2130	35.0	103.9		3.6	Tucumcari, NM		5
1.12.70	1121	35.89	103.4	VI	3.5	Amistad, NM	9,600	9
2.15.74	1333	36.5	100.69	V	4.5	OK-TX Border		7
2.02.75	2039	35.10	103.10		2.9	NM		9
3.30.76	0653	36.68	102.25	V	2.1 MBLG			8
3.30.76	0927	36.61	102.08	V	2.7 MBLG			8
4.19.76	0442	36.13	99.84	IV	3.5	OK, West		8
6.24.76	1527	35.62	103.28	V	3.5	NM, Eastern		9
8.03.78	0035	36.69	100.16		2.1 MBLG	Beaver Co., OK		4
8.06.78	0428	36.07	99.94		2.6	Ellis Co., OK		4
2.21.80	2042	35.281	101.076	Felt	2.9 MBLG	Carson Co., TX		10
6.09.80	2237	35.513	101.082	V	3.4 MBLG	Carson Co., TX		10
3.16.82	1103	35.357	103.268	III	3.1 MBLG	Logan, NM		11
10.14.82	1252	36.102	102.571		3.9 MBLG	Dalhart, TX		11
3.11.83	1650	36.791	100.196		2.7 MBLG	TX-OK Border		11
4.3.83	0455	35.448	102.321		3.4 MBLG	Oldham Co., TX		11
5.21.84	1330	35.416	102.330		2.7 MBLG	Oldham Co., TX		1
4.18.85	1839	35.298	102.597		2.5	Oldham Co., TX		12

Sources:

1. Acharya, 1984.
2. Coffman and von Hake, 1975.
3. Docekal, 1970.
4. Lawson et al., 1979.
5. Northrop and Sanford, 1972.
6. Nuttli, 1979.
7. Reagor et al., 1982.
8. Stover et al., 1981.
9. Stover et al., 1983.
10. Stover and von Hake, 1982.
11. USGS, 1982, 1983, Preliminary Determination of Epicenters.
12. Acharya, 1985b.

Because the Texas Panhandle was not settled until near the end of the 19th Century, less than 100 years of seismicity data are available. The sparse settlement of the area, particularly in earlier years, implies incomplete reporting of the effects from events smaller than about Modified Mercalli Intensity VI; the Modified Mercalli Intensity scale is described by Coffman and von Hake (1973, pp. 3-4).

The seismographic coverage of the area has been limited. Acharya (1985a) shows the seismograph stations in the south-central United States; Poppe (1979) and Lawson et al. (1979) describe the equipment used at these stations. The nearest regional stations are located at Trinidad, Colorado, Albuquerque, New Mexico, and Lubbock, Texas; seismographic data from these and other more distant stations have yielded the location of only a few earthquakes in the Texas Panhandle. Because the seismicity data base is incomplete and there are uncertainties in the earthquake locations, the seismicity record must be combined with geologic data for earthquake hazard studies.

The available data suggest that the level of seismic activity is very low in the Palo Duro Basin. As shown on Table 3-8, the largest events reported in the Texas Panhandle correspond to Modified Mercalli Intensity VI, or about magnitude 4.7 to 4.8. In the mid-continent region of the United States, peak ground acceleration for such events is estimated to be 0.06 gravity, using an equation by Murphy and O'Brien (1977 p. 877) which relates intensity to peak acceleration, or 0.09 gravity using an equation by Nuttli and Herrmann (1981) which relates magnitude to peak acceleration. Both equations provide mean-value estimates and the difference between the two estimates is probably not statistically significant because of the uncertainty for each estimate.

Many earthquakes that have occurred in the Texas Panhandle appear to be spatially related to the Amarillo Uplift on the Anadarko Basin (compare Figures 3-4 and 3-36). Epicenters are not determined with sufficient accuracy to permit confident association with specific faults. Uncertaintites in epicenters also do not permit confident correlation of other earthquakes with features such as faults in Oldham Nose, or faults in the Palo Duro Basin. A recently-installed sixteen-station microearthquake network is in operation in the Texas Panhandle to detect smaller earthquakes and locate all local earthquakes with better accuracy. The result will lead to a clearer understanding of the causes of local, low-level seismicity for the region. The network has already detected a number of very small earthquakes; those closest to the site have occurred in Oldham County. Additional stations and site improvements are being planned to expand the network and provide better coverage.

Historically, there are no reports of earthquakes having originated in Deaf Smith County, although some seismic events have been reported nearby in New Mexico. The microearthquake network has not detected any earthquake activity in Deaf Smith County since its installation, but a few small earthquakes have been detected in Oldham County. The earthquake nearest the site occurred April 18, 1985 and was located approximately 25 kilometers (15 miles) north-northwest of the Deaf Smith County site; the magnitude was approximately MbLg 2.2 to 2.5 (Acharya, 1985b). MbLg is a magnitude scale widely used for the United States, east of the Rocky Mountains.

A study of maximum earthquake potential for the central United States designates a "Wichita-Ouachita" zone, which includes the Amarillo Uplift, and a "Residual Events" zone, which includes all areas in the central United States not otherwise included in specific zones (Nuttli and Herrmann, 1978, pp. 14, 78). For these two zones, the study estimates the magnitudes of the maximum earthquakes as MbLg 6.3 and MbLg 5.3, respectively. The Palo Duro Basin is judged to lie within the zone of "Residual Events;" the maximum earthquake magnitude is estimated at MbLg 5.3 and, for this site analysis, the event is postulated to occur anywhere within the basin. Using the Nuttli and Herrman (1981) equation, the mean-value for peak acceleration in the epicentral area from a MbLg 5.3 event is 0.14 gravity.

For the site analysis, the magnitude 6.3 earthquake is postulated to occur about 55 kilometers (35 miles) from the Deaf Smith County site at the closest approach of the larger faults along the south flank of the Amarillo Uplift, according to the Nuttli and Herrmann (1981) equation; such an earthquake would cause a mean-value peak acceleration of approximately 0.14 gravity at the site.

The maximum earthquakes estimated by Nuttli and Herrmann (1978) are based on seismicity studies in the central United States, including consideration of the tectonic character of the different seismic zones. Their estimates are larger than any earthquakes in the historical record for the Texas Panhandle. According to Nuttli and Herrmann (1978, p. 77) the maximum earthquake is considered to be an infrequent event, having an annual probability of occurrence on the order of 10^{-3} to 10^{-4}. Other potential earthquake sources which could affect the Deaf Smith County site have distances and magnitudes such that accelerations smaller than 0.14 gravity would occur at the site. A peak ground acceleration value of 0.14 gravity is taken as the mean-value estimate for maximum ground motion at the Deaf Smith County site. Because of uncertainties in the data, acceleration values used for design will be more conservative (higher) than the mean-value estimate.

Additional studies and analyses may result in modification to the value for the closest approach distance for an earthquake along the Amarillo Uplift as well as estimates of maximum magnitudes and accelerations. Present analyses, however, indicate that moderate effects from potential earthquakes can be expected and that available engineering practice will mitigate any potential hazard.

3.2.5.4 Igneous Activity

The only area in the region that has experienced volcanic activity since Early Paleozoic time is 160 kilometers (100 miles) northwest of the Deaf Smith County site in northeastern New Mexico (Figure 3-4). Baldwin and Muehlberger (1959) document a history of extrusion of basaltic lavas including the Raton, Clayton, and Capulin flows. The Raton and Clayton flows are of probable Pliocene age, whereas the Capulin flow has been dated as between 10,000 and 4,400 years old (Baldwin and Muehlberger, 1959, p. 77). The distribution of vents suggests intrusion along a fracture system that trends northwest to west-northwest. A northeastward fracture trend is also recognized, with many of the centers of activity occurring at the intersection of the two fracture systems (Baldwin and Muehlberger, 1959, p. 83). Suppe et al. (1975) hypothesize that the Quaternary volcanism is the latest manifestation of plate migration over a mantle hot spot. Volcanic activity is believed to have occurred progressively in a northeastward direction from at least the area of the White Mountains in eastern Arizona to its present location in Union County (Suppe et al., 1975, p. 412). Volcanic activity, if it recurred, would most likely be farther to the northeast, along the same trend.

3.2.5.5 Uplift, Subsidence, and Folding

Tectonic folding is not readily apparent in the Palo Duro Basin. Nicholson (1960, p. 54) postulates a series of gentle northwest-southwest trending folds near the Amarillo Uplift and attributes them to shear movement along faults that bound the uplift. No folding is apparent in the vicinity of the Deaf Smith County site (Figures 3-25, 3-27, and 3-32).

The post-Permian tectonic history of the Palo Duro Basin indicates intermittent periods of gentle uplift and subsidence during the Mesozoic. The Laramide episode that produced the North American Cordilleran chain began in Late Cretaceous time. Hills (1963, pp. 1720-1721) suggests that the Paleozoic uplift areas acted as buttresses, protecting the basinal areas from Laramide deformation. The principal effect on the Palo Duro Basin was one of regional uplift and tilting to the southeast.

Direct evidence of Neogene uplift or tilting in the site region has not been identified to date. Reilinger and Oliver (1976, Figure 4) presented the results of first-order leveling surveys in 1911 and 1958 at benchmarks located between Belen, New Mexico, and Amarillo, Texas. Although they provided no analysis of the data in the Texas Panhandle area, their profile shows an absence of regional tilting. Gable and Hatton (1983) include the area in their Central Lowlands and Great Plains Provinces, characterized since the Pliocene by broad regional uplift that begins in the central United States and increases to about 1,500 meters (5,000 feet) at the Rocky Mountain front. Integrated streams on the Southern High Plains appear to be well graded and local incision of streams in the Rolling Plains and along the Eastern Caprock Escarpment appears to be related to differential resistance of the rocks.

These observations suggest an absence of significant recent or active uplift. Subsidence and collapse are active processes in areas of peripheral salt dissolution beyond the High Plains margin (Section 3.2.3.3).

3.2.5.6 Diapir Development

The bedded salts within the Palo Duro Basin show no evidence of diapir development (Figure 3-32).

Salt diapirs develop through a characteristic sequence of stages as the original salt bed deforms by horizontal and vertical flow of salt (Trusheim, 1960, pp. 1519-1540). Salt flow leading to diapir development is believed to be the result of differential sediment loading, underlying structure, compressive forces, or a combination of these factors. Initial salt movement is a slow, horizontal flow toward locally thickened zones within the bedded salt. With time, the thickened zones bulge upward, forming salt pillows which are commonly elongate (salt anticline). Plastic flow of salt continues to feed these pillows, leaving behind areas depleted in salt. Subsidence occurs at an increased rate over the evacuated area (rim syncline), causing thickening of the contemporaneously deposited sediments. The record of domal growth is preserved in the differential thicknesses of contemporaneous sediments: thin or absent over the dome (but this record is commonly removed by later erosion) and thick in the rim syncline. Continued lateral flow under an increasing temperature and pressure regime induced by sedimentation and contemporaneous basin subsidence further enlarges the salt pillow until the buoyant force is sufficient to cause vertical domal growth and piercement through overlying sediments (diapirism). Diapirism continues with further deposition until the forces causing vertical flow (sedimentation and subsidence) cease. Salt flow may continue (postdiapiric growth) at lower rates until equilibrium is reached.

3.2.5.7 Dissolution

Salt dissolution has caused faulting and subsidence in areas beyond the High Plains margins and has been postulated to occur beneath the Southern High Plains (Gustavson and Budnik, 1984). Refer to Section 3.2.3.3 for a description of the salt dissolution process and the areas in which it occurs.

3.2.6 Rock Characteristics

Physical, mechanical, and thermal properties of rocks in Deaf Smith County have been investigated by analysis of geophysical logs, hydrologic and geotechnical testing in wells, and laboratory tests on core. No site-specific data are available at the present time. Therefore, data obtained from nearby wells are presented in this section.

Four OCRWM program wells provided the major sources of data for the Deaf Smith County site (Figure 3-3). These are the Mansfield No. 1 well approximately 35.4 kilometers (22 miles) north of the site in Oldham County (SWEC, 1984, BMI/SRP-5005), the G. Friemel No. 1 well approximately 25.7 kilometers (16 miles) southeast of the site in Deaf Smith County (SWEC, 1984, BMI/SRP-5003), the Detten No. 1 well approximately 22.5 kilometers (14 miles) southeast of the site in Deaf Smith County (SWEC, 1984, BMI/SRP-5008), and the J. Friemel No. 1 well approximately 6.4 kilometers (4 miles) south of the site in Deaf Smith County (SWEC, 1984, BMI/SRP-5011). Full suites of geophysical logs and mud logs are available for these wells.

Analysis of geophysical logs and laboratory testing on core has confirmed the variability of lithology and associated physical and mechanical properties in the vertical direction and their general similarity in the lateral direction. The presence and persistent nature of interbeds and zones containing relatively great amounts of impurities in the salt sections has been documented. Testing on the major lithologies encountered provides a general impression of the physical and mechanical properties of the intact rock, but additional work is needed to document the effects of temperature on these properties. Further, the properties of mixed lithologies and of the transition or contact zones between lithologies are not well understood

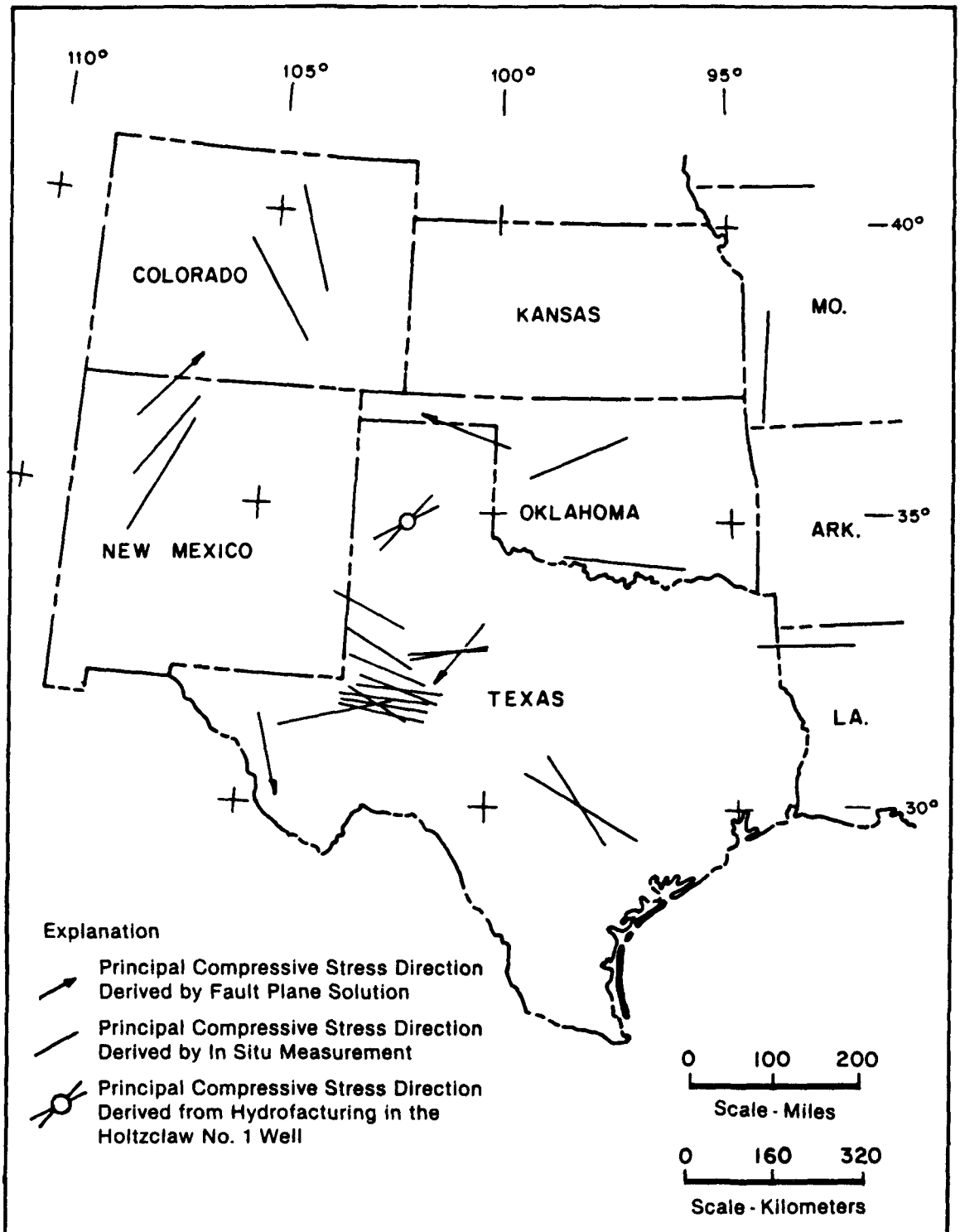
at the present time. Some data are available on the effects of impurities on intact-rock physical and mechanical properties, but the effect of interbeds on these properties and the properties of the interbeds themselves are largely unknown. Since there are no mines in the basin which could provide access for in situ testing, rock mass properties have not been measured directly, but must be inferred from laboratory tests and geophysical logs obtained in nearby wells. This lack of data, together with the vertical variability of the rock, introduces uncertainty into any estimates of rock mass properties.

General conclusions regarding the response of interbedded salt units in the Palo Duro Basin to mining can be drawn from the Waste Isolation Pilot Plant (WIPP) project which is in bedded salt of similar age and stratigraphy as that in the Palo Duro Basin, and is located at roughly comparable depth. Even though hydrologic conditions and stratigraphic details at the WIPP are different, experience at the WIPP demonstrates that stable openings can be constructed in bedded salts, provided interbeds in the immediate roof are avoided. Detailed response of rooms cannot be predicted because of the differences in stratigraphic details.

Continuous core was drilled in the Mansfield No. 1 well from 14 meters (46 feet) to 1,073 meters (3,540 feet). An additional 212.5 meters (701 feet) of core was obtained from selected zones below the Red Cave Formation. A total of 1,560 meters (5,149 feet) of core was drilled from selected zones in the Detten No. 1, G. Friemel No. 1, and J. Friemel No. 1 wells. Point-load strength index testing was completed on core recovered from the upper 790 meters (2,600 feet) of the J. Friemel No. 1 well. Open-hole hydrologic tests to measure in situ permeability and formation fluid pressures include 9 successful drill-stem tests and 19 successful repeat formation tests. Pump testing in the Wolfcamp Formation was conducted in the Mansfield No. 1 well (SWEC, 1984, BMI/SRP-5020) and in the J. Friemel No. 1 well (SWEC, 1985a). Hydrofracture tests were conducted to measure in situ stresses in the Holtzclaw No. 1 well in Randall County (Borjeson and Lamb, 1984). Related mining experience in these types of rocks is not available within the basin. However, the experience developed during excavation within similar bedded salt at the Waste Isolation Pilot Plant (WIPP) site near Carlsbad, New Mexico, is relevant. Published rock mechanics test results are currently generic in scope (e.g., Tammemagi et al., 1985, ONWI-364; Pfeifle et al., 1983, ONWI-450) and are not location specific, although some test data are available from wells in Deaf Smith County. Thermal and thermomechanical analyses, generic in scope, are described by Svalstad (1983), Svalstad and Wagner (1982), McNulty (1984), Wagner et al. (1985, BMI/ONWI-512), and RRCIWG (1983). Thermal property data in the Palo Duro Basin itself are quite limited, as discussed in Section 3.2.6.2. Detailed mineralogical data are available for Lower San Andres Unit 4 and Unit 5 salt in the Detten No. 1 and G. Friemel No. 1 wells (Fukui, 1984, BMI/ONWI-540). Detailed logging of DOE cores by Hovorka (1984) and Hovorka et al. (1985) documents lithologic variations that, in part, form the basis of sampling for rock mechanics testing. Clay-mineral analyses are available from wells in Deaf Smith and Oldham Counties (SWEC, 1984, BMI/SRP-5018). Geochemical data have been obtained from DOE program wells in Deaf Smith and Swisher Counties and are discussed in Section 3.2.7.

3.2.6.1 Geomechanical Properties

3.2.6.1.1 Rock Mechanics Testing. In situ stresses in the San Andres and Queen/Grayburg Formations were measured by the hydraulic fracturing technique in the Holtzclaw No. 1 well (Figure 3-3). The maximum and minimum horizontal stresses, in pounds per square inch, were determined to be 0.68 to 0.95 and 0.60 to 0.69 times the depth in feet, respectively, for non-salt units. In the Unit 4 and Unit 5 salt, the minimum horizontal stress and the vertical stress (in pounds per square inch) are approximately equal to each other and to 1.14 times the depth in feet, although recent experimental work suggests that hydraulic fracturing consistently overestimates the minimum stress in salt (Boyce et al., 1984). The magnitude of difference between maximum and minimum horizontal stresses in salt could not be determined (Borjeson and Lamb, 1984). Theoretical considerations and field observations (Carter et al., 1982; Baar, 1977, p. 72) suggest the difference is small. The maximum horizontal compressive stress is oriented N30E to N60E, which regionally correlates to data in Oklahoma and New Mexico, but is different from data obtained in west-central Texas (Figure 3-38). However, the



Sources: SWEC, 1983, DOE/CH/10140-1, Figure 5-10
Zoback and Zoback, 1980
Voss and Herrmann, 1980
Herrmann, 1979
Hooker and Johnson, 1969
Raleigh, 1974
Haimson, 1977
Borjeson and Lamb, 1984

Principal Compressive Stress Directions Determined by In Situ Measurements and Fault Plane Solutions

Figure 3-38

data are consistent with the stress provinces developed by Zoback and Zoback (1980) as discussed in Borjeson and Lamb (1985). Although the stress measurements were performed a considerable distance from the site, the results from different formations are consistent with each other and with the geologic and tectonic history of the area, suggesting that similar stress conditions exist at the site. Confirmation by additional measurements closer to the site is needed. However, it can be tentatively concluded that horizontal stresses higher than the vertical stress are not present in the nonsalt rocks. For the salt units, the data would seem to confirm the lithostatic stress state generally assumed for salt, even though considerable uncertainty exists in the value of the maximum horizontal stress, which cannot be measured directly with current techniques.

Index tests (hardness, slake durability, density, porosity, and water content) have been performed on core from the Mansfield No. 1, Detten No. 1, G. Friemel No. 1, and J. Friemel No. 1 wells (SWEC, 1984, BMI/SRP-5022; BMI/SRP-5030; BMI/SRP-5025; 1985, BMI/SRP-5034). Results of unconfined compression and indirect tensile tests from the Mansfield No. 1, J. Friemel No. 1, Detten No. 1, and G. Friemel wells are presented in Tables 3-9 through 3-12. Point-load tests were performed at approximately 2-meter (6-foot) intervals on core from the J. Friemel No. 1 well (Figure 3-39) (SWEC, 1984, BMI/SRP-5011). In the subsequent discussion, the following strength classifications (Deere and Miller, 1966) are referred to:

Qualitative Descriptor	Uniaxial Compressive Strength Metric	Uniaxial Compressive Strength English	Point Load Strength Index
Extremely Strong	>220 MPa	>32,000 psi	>9.0
Very Strong	110 - 220	16,000 - 32,000	4.5 - 9
Strong	55 - 110	8,000 - 16,000	2.3 -4.5
Medium Strong	24 - 55	3,500 - 8,000	1.0 -2.3
Weak	7 - 24	1,000 - 3,500	0.3 -1.0
Very Weak	1.7 - 7	250 - 1,000	0.07 -0.3
Extremely Weak	<1.7	<250	<0.07

These categories are based on generally accepted strength classifications now in use in the United States and Great Britain.

Triaxial compression tests at various confining pressures, including tests at elevated temperatures, have been performed on both salt and nonsalt rocks. Creep tests have also been performed on core from wells in Deaf Smith County (Pfeifle et al., 1983, ONWI-450; SWEC, 1984, BMI/SRP-5015; Senseny et al., 1985, BMI/ONWI-549). Additional test results are available from other program wells outside Deaf Smith County.

Triaxial and unconfined compression test results available to date indicate that dolomite, limestone, and anhydrite interbeds are strong to very strong, while clastic materials (shale, siltstone, and mudstone) vary from very weak to strong but generally become more competent below the Dockum. Point-load test data from the J. Friemel No. 1 well (Figure 3-39) confirm this and give a semiquantitative indication of the variations in strength that may be expected in the various formations. Salt specimens exhibited nonlinear behavior, as expected. Specimens tested in triaxial compression, in particular, showed significant amounts of plastic strain during the test. These results confirm that elastic parameters have limited value for ductile rocks such as salt. Nevertheless, they are useful for comparative and index purposes. Impurities within the salt appear to have an effect on strength and modulus. Dynamic properties were measured during many of the unconfined and triaxial tests.

Laboratory creep tests indicate that Palo Duro Basin salt has a relatively high ductility (high creep rate) compared to other salts. Typical results are presented in Figure 3-40. Although using laboratory creep tests to predict in situ behavior has been questioned (Baar, 1977, p. 76), laboratory results are useful for comparison and for preliminary analysis. Field tests are planned during site characterization to develop creep data for design.

Table 3-9. Unconfined Compression and Indirect Tensile Test Results, Mansfield No. 1 Well, Oldham County, Texas

Formation	Rock Type	Depth (m)	Depth (ft)	Density[a] (gm/cc)	E (GPa)	Poisson's Ratio	Compressive Strength (MPa)	Tensile Strength (MPa)
Alibates	Siltstone[1]	168.6	553.1	2.42	24.6	0.37	34.0	-
Alibates	Siltstone[2]	168.9	554.1	2.34	-	-	-	2.22
Yates	Siltstone[1]	190.7	625.5	2.45	10.8	0.20	45.8	-
Lower 7 Rivers	Siltstone[1]	224.0	735.0	2.40	4.3	0.14	16.8	-
Lower 7 Rivers	Siltstone[2]	224.5	736.6	2.28	-	-	-	1.30
Queen-Grayburg	Salty Siltstone[1]	285.3	936.0	2.52	21.3	0.23	56.1	-
Queen-Grayburg	Siltstone[2]	286.1	938.7	2.42	-	-	-	2.01
Upper San Andres	Salt[1]	323.9	1062.8	2.18	15.0	0.34	16.9	-
Upper San Andres	Dolomitic Siltstone[1]	349.0	1146.0	2.62	30.5	0.20	84.8	-
Upper San Andres	Anhydrite[2]	371.6	1219.3	2.69	-	-	-	7.75
Lower San Andres Unit 5	Salt[3]	445.9	1463	-	-	-	-	1.50
Lower San Andres Unit 5	Salt[3]	446.2	1464	-	-	-	-	1.30
Lower San Andres Unit 5	Salt[3]	449.3	1474	-	24.2	-	24.2	2.00
Lower San Andres Unit 5	Dolomite[3]	457.7	1500.4	2.43	22.7	0.15	51.6	-
Lower San Andres Unit 3	Salty Siltstone[1]	573.7	1882.2	2.46	34.5	0.30	60.3	-
Lower San Andres Unit 2	Salt[1]	596.7	1957.7	2.19	34.0	0.26	21.9	-
Glorieta	Silty Sandstone[1]	709.2	2326.6	2.49	46.7	0.22	36.1	-

(a) Densities are "as tested," and are not corrected for water content.
Sources: (1) SWEC, 1984, BMI/SRP-5015.
(2) SWEC, 1984, BMI/SRP-5019.
(3) Pfeifle et al., 1983, ONWI-450.

Table 3-10. Unconfined Compression and Indirect Tensile Test Results, J. Friemel No. 1 Well, Deaf Smith County, Texas

Formation	Rock Type	Depth (m)	Depth (ft)	Density (gm/cc)	E (GPa)	Poisson's Ratio	Compressive Strength (MPa)	Tensile Strength (MPa)	Reference
Lower San Andres Unit 4	Salt	793.7	2604[a]	-	21.4	-	26.3	-	Senseny et al., 1985
Lower San Andres Unit 4	Salt	794.3	2606[b]	-	24.7	-	29.0	-	Senseny et al., 1985
Lower San Andres Unit 4	Salt	801.6	2630[a]	-	24.8	-	27.1	-	Senseny et al., 1985
Lower San Andres Unit 4	Salt	802.2	2632[b]	-	23.3	-	25.9	-	Senseny et al., 1985
Lower San Andres Unit 4	Salt	811.4	2662[b]	-	26.0	-	30.7	-	Senseny et al., 1985
Lower San Andres Unit 4	Salt	812.3	2665[a]	-	24.9	-	27.9	-	Senseny et al., 1985
Lower San Andres Unit 4	Salt	818.4	2685[a]	-	27.0	-	34.2	-	Senseny et al., 1985
Lower San Andres Unit 4	Salt	819.3	2688[b]	-	23.0	-	26.5	-	Senseny et al., 1985

(a) Test at 24 C (75 F).
(b) Test at 50 C (122 F).

Table 3-11. Unconfined Compression and Indirect Tensile Test Results, Detten No. 1 Well, Deaf Smith County, Texas

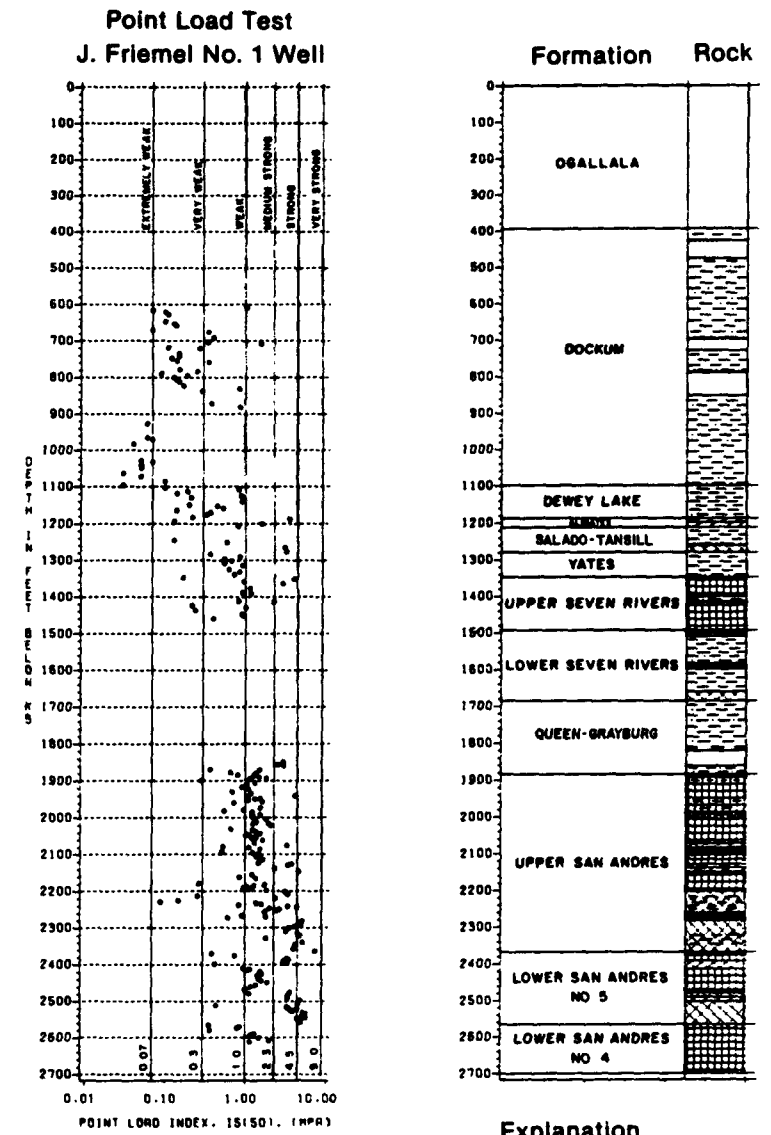
Formation	Rock Type	Depth (m)	Depth (ft)	Density[a] (gm/cc)	E (GPa)	Poisson's Ratio	Compressive Strength (MPa)	Tensile Strength (MPa)
Alibates	Siltstone/Gypsum[b]	345.6	1133.8	2.49	4.8	0.25	20.2	-
Alibates	Sandstone[c]	346.9	1138.0	2.42	-	-	-	1.28
Salado-Tansill	Siltstone[c]	357.1	1171.5	2.38	-	-	-	0.60
Yates	Silty Sandstone[b]	385.4	1264.5	2.34	1.4	0.07	17.9	-
Yates	Sandstone[c]	385.7	1265.5	2.33	-	-	-	0.92
Yates	Sandstone[c]	385.8	1265.7	2.32	-	-	-	1.06
Upper 7 Rivers	Siltstone[b]	406.8	1334.8	2.44	4.0	0.19	13.9	-
Upper 7 Rivers	Claystone & Salt[c]	428.3	1405.2	2.09	-	-	-	1.00
Upper 7 Rivers	Chaotic Salt/Salt[b]	428.4	1405.6	2.07	8.4	0.29	5.1	-
Upper 7 Rivers	Salt[c]	429.6	1409.5	2.14	-	-	-	1.67
Upper 7 Rivers	Chaotic Salt/Salt[b]	431.9	1416.9	2.29	7.1	0.09	11.6	-
Upper San Andres	Salt[d]	578.5	1898	-	22.5	-	19.5	-
Upper San Andres	Salt[d]	579.7	1902	-	28.3	-	33.6	-
Upper San Andres	Salt[d]	579.7	1902	-	28.5	-	29.6	1.7
Upper San Andres	Salt[d]	580.9	1906	-	-	-	-	1.8
Upper San Andres	Salt[d]	580.9	1906	-	-	-	-	1.3
Upper San Andres	Anhydrite[c]	663.9	2178.3	2.93	-	-	-	6.44
Upper San Andres	Anhydrite[b]	664.1	2178.9	2.95	51.1	0.31	87.5	-
Upper San Andres	Salt[d]	670	2200	-	21.7	-	16.5	-
Upper San Andres	Salt[d]	670	2200	-	19.5	-	15.0	-
Upper San Andres	Salt[d]	672	2206	-	-	-	-	1.2
Upper San Andres	Salt[d]	672	2206	-	-	-	-	1.8
Upper San Andres	Salt[d]	672	2206	-	-	-	-	1.5
Upper San Andres	Salt[d]	684.0	2244	-	19.6	-	18.2	1.8
Upper San Andres	Salt[d]	684.3	2245	-	23.3	-	25.4	1.8
Upper San Andres	Salt[d]	684.6	2246	-	20.5	-	28.3	-
Upper San Andres	Salt[d]	685.8	2250	-	-	-	-	1.6
Upper San Andres	Anhydrite[c]	718.0	2355.6	2.88	-	-	-	6.93
Lower San Andres Unit 5	Salt[d]	735.8	2414	-	-	-	-	1.9
Lower San Andres Unit 5	Salt[d]	745.5	2446	-	27.3	-	33.5	-
Lower San Andres Unit 5	Salt[d]	745.5	2446	-	28.4	-	36.8	-
Lower San Andres Unit 5	Salt[d]	746.8	2450	-	-	-	-	1.8
Lower San Andres Unit 5	Salt[d]	747.1	2451	-	-	-	-	1.0
Lower San Andres Unit 5	Salt[d]	751.6	2466	-	-	-	-	1.5
Lower San Andres Unit 5	Salt[d]	751.6	2466	-	-	-	-	1.8
Lower San Andres Unit 4	Salt[b]	812.0	2664.2	2.18	20.5	0.28	17.8	-
Lower San Andres Unit 4	Argillaceous Salt[c]	812.3	2665.0	2.13	-	-	-	1.53
Lower San Andres Unit 4	Argillaceous Salt[c]	813.3	2668.4	2.14	-	-	-	1.44
Lower San Andres Unit 4	Limestone[c]	839.7	2755.0	2.53	-	-	-	6.27
Lower San Andres Unit 4	Arg Limestone[c]	849.2	2786.0	2.60	-	-	-	11.2
Lower San Andres Unit 4	Limestone[b]	849.7	2787.7	2.66	64.7	0.28	129.8	-

(a) Densities are "as tested," and are not corrected for water content.
(b) Source: SWEC, 1984, BMI/SRP-5015.
(c) Source: SWEC, 1984, BMI/SRP-5023.
(d) Source: Pfeifle et al., 1983, ONWI-450.

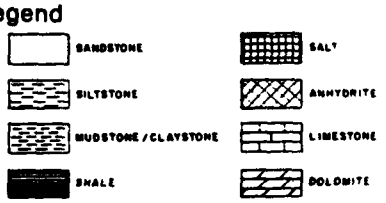
Table 3-12. Unconfined Compression and Indirect Tensile Test Results, G. Friemel No. 1 Well, Deaf Smith County, Texas

Formation	Rock Type	Depth (m)	Depth (ft)	Density[c] (gm/cc)	E (GPa)	Poisson's Ratio	Compressive Strength (MPa)	Tensile Strength (MPa)
Yates	Siltstone[a]	366.3	1201.9	2.35	5.0	0.35	23.2	-
Yates	Siltstone[a]	377.2	1237.6	2.47	11.5	0.25	26.5	-
Queen/Grayburg	Siltstone[a]	528.5	1734.0	2.50	19.1	0.31	37.0	-
Upper San Andres	Salt[a]	532.1	1745.8	2.22	33.4	0.20	29.0	-
Upper San Andres	Salt[a]	538.1	1765.3	2.21	12.2	0.20	18.2	-
Upper San andres	Dolomite[b]	616.2	2021.6	2.51	-	-	-	2.79
Upper San Andres	Anhydrite[a]	670.5	2199.7	2.94	91.4	0.33	120.7	-
Upper San Andres	Anhydrite[b]	671.4	2220.9	2.94	-	-	-	6.67
Lower San Andres Unit 5	Dolomite[b]	719.9	2361.7	2.42	-	-	-	3.36
Lower San Andres Unit 5	Dolomite[a]	720.9	2362.7	2.43	27.9	0.37	69.2	-
Lower San Andres Unit 5	Dolomite[b]	721.1	2365.7	2.32	-	-	-	2.37
Lower San Andres Unit 4	Salt[a]	770.6	2528.3	2.19	17.7	0.43	29.1	-
Lower San Andres Unit 4	Dolo/Anhy[b]	790.9	2594.9	2.95	-	-	-	7.80
Lower San Andres Unit 4	Dolomite[a]	800.7	2627.1	2.47	40.2	0.30	132.7	-
Lower San Andres Unit 4	Dolomite[b]	802.3	2632.3	2.39	-	-	-	5.19
Lower San Andres Unit 4	Dolomite[a]	810.3	2658.6	2.60	40.5	0.24	74.6	-

(a) Source: SWEC, 1984, BMI/SRP-5015.
(b) Source: SWEC, 1984, BMI/SRP-5025.
(c) Densities are "as tested," and are not corrected for water content.



Legend



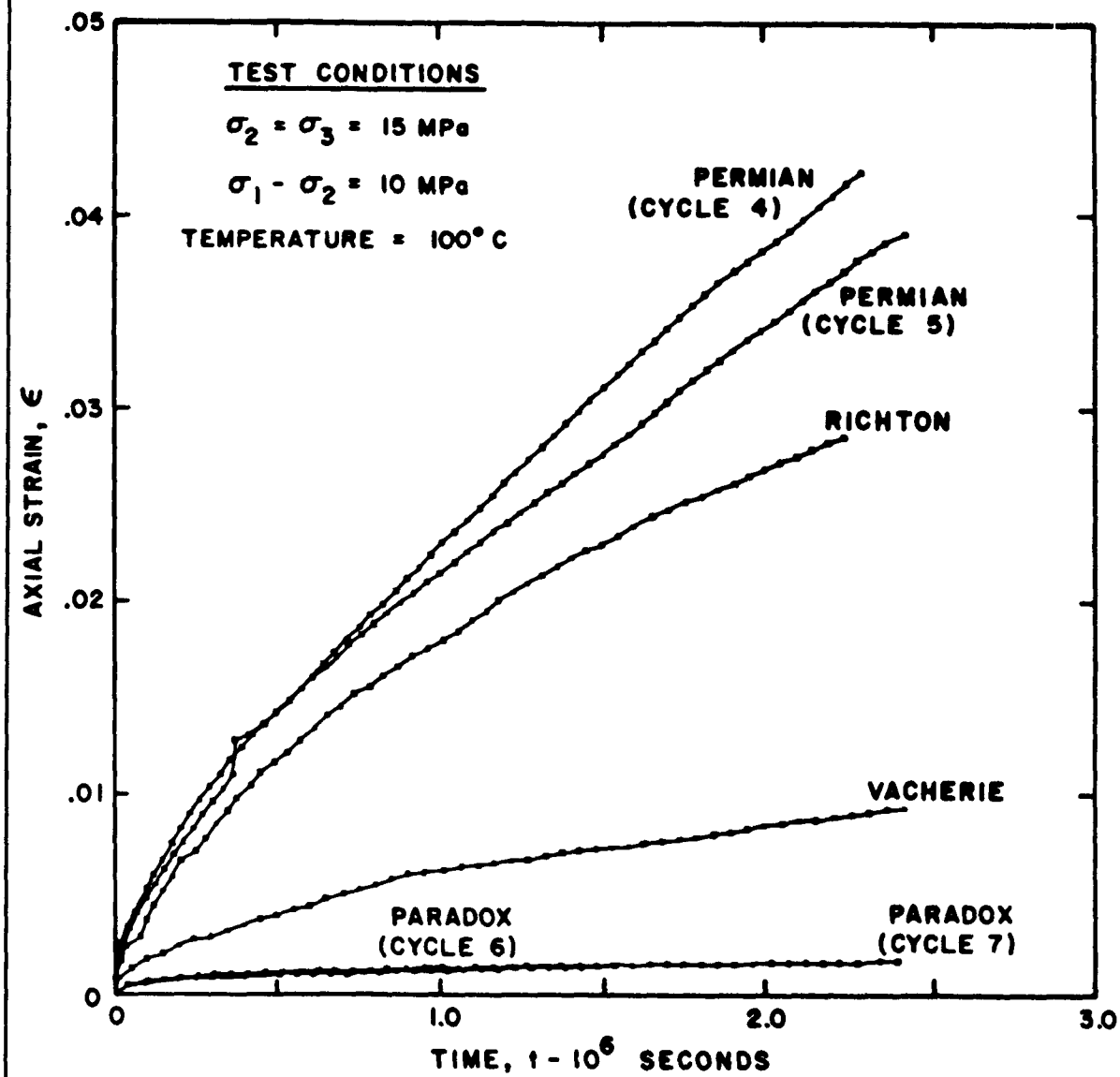
Explanation

Point Load Test Depths are Related to Final Core Depths and Have Not Been Depth-Correlated to Geophysical Log Depths

Source: SWEC Sketch 13697-51A-1

Point Load Test Results and Graphic Log for the J. Friemel No. 1 Well

Figure 3-39



Axial Creep Strain as a Function of Time for Salt Core Samples from Four Potential Repository Sites

Source: Pfeifle et al., 1983, ONWI-450, Figure 4-6.

Figure 3-40

3.2.6.1.2 Salt Material Model. A material model for the thermomechanical behavior of the repository horizon salt is required for design and performance assessment calculations. The material model gives the relationship between load quantities, such as stress and stress rate, and deformation quantities, such as strain and strain rate. The thermomechanical behavior of salt deviates from the linear elastic model that is often used to describe the deformational behavior of many brittle rocks. This deviation increases as the temperature increases. Since elevated temperatures are associated with disposal of high-level nuclear waste, understanding the thermomechanical behavior of salt is important.

The total deformation of salt can be divided into three components: elastic deformation, thermal expansion, and inelastic deformation. The elastic deformation and thermal expansion are described by the generalized Duhamel-Neumann form of Hooke's Law (Sokolnikoff, 1956). The elastic constants (e.g., Young's Modulus, E; and Poisson's ratio, ν) are determined from unload-reload cycles performed on specimens that are deformed in triaxial compression (Pfeifle et al., 1983, ONWI-450). The coefficient of linear thermal expansion, α_L, is determined by measuring the change in specimen dimensions that corresponds to a specific change in specimen temperature (Yang, 1981). Following are the values and standard deviations for Young's modulus, Poisson's ratio, and the coefficient of thermal expansion of Unit 4 rock salt at the Permian Basin:

Young's modulus, $E = 27.1 \pm 2.8$ GPa

Poisson's ratio, $\nu = 0.32 \pm 0.02$

Coefficient of linear thermal expansion, $\alpha_L = (42 \pm 3) \times 10^{-6}\ K^{-1}$

The elastic and thermal expansion contributions to salt deformation, although important for calculating thermal stresses produced by waste emplacement, are often insignificant when compared to the large inelastic deformation that is produced by the stress, temperature, and time duration which are of interest for nuclear waste isolation. The inelastic deformation is primarily viscoplastic; that is, ductile behavior in which the stress is a function of not only the strain, strain history, and temperature, but also the strain rate. Over the range of temperature of interest, the viscoplastic behavior is strongly temperature dependent. The inelastic deformation has been modeled using an exponential-time model (Senseny et al., 1985, BMI/ONWI-549). This is a semi-empirical model based on first-order kinetics that incorporates both transient and steady-state deformation. It utilizes a functional form that assumes that deformation results from a diffusion-controlled micromechanism (e.g., dislocation climb) which is expected to be operable at the stresses and temperatures expected for a nuclear waste repository. Stress and temperature dependence of the deformation are incorporated in this function. Values for the inelastic parameters of this model have been determined for the Palo Duro Unit 4 salt by Senseny et al. (1985, BMI/ONWI-549).

Although this model poorly reproduces the short-term laboratory data from which it was derived, it does predict strain rates approaching steady state conditions fairly well, and can be used for preliminary repository design and performance assessment calculations, since long-term behavior can be modeled with some confidence. Short-term behavior cannot be accurately modeled, based on comparisons of predicted and measured strains. The transient part of the exponential-time model requires revision. Additionally, more tests need to be performed so that the uncertainty associated with the parameter values can be reduced. Studies investigating the development of an improved model are in progress and predictive capabilities of a model are expected to improve. The uncertainty in the model results from both salt variability and lack of fit of the model.

3.2.6.1.3 Failure Criterion. Failure of salt over the ranges of stress and temperature of interest can be either brittle or ductile. Failure under either mode is defined to occur when peak stress is reached. At low mean stress and low temperature, brittle failure is observed; whereas at higher mean stress and temperature, brittle failure is suppressed and the salt undergoes very large deformations without fracturing. For example, triaxial compression

tests using Unit 4 salt performed at 24 C and at a constant stress rate of 2.5×10^{-2} megapascals show that brittle failure is suppressed at confining pressures greater than about 5 megapascals, and the test is stopped at about 12-percent specimen shortening when the limits of the apparatus are reached (Pfeifle et al., 1983, ONWI-450). This shortening corresponds to a true strain of about 14 percent, and there is no evidence of fracture. The hardening modulus, however, is very low so that the stress when the test is stopped is close to the peak stress.

The envelope of Mohr's circles at the end of the tests is characterized by a nonlinear Mises-Schleicher law that empirically assumes an exponential decay in the mean stress dependence of the shear strength:

$$J_2' = K + \alpha \quad 1 - \exp(-\beta J_1)$$

where

J_2' = the second invariant of the deviator stress

J_1 = the first invariant of stress

K, α, β = fitting parameters.

This Mises-Schleicher model was chosen instead of a similar Mohr-Coulomb model because the manner in which the Mises-Schleicher model incorporates the influence of the intermediate principal stress is thought to be more appropriate for ductile behavior.

Following are values of the Mises-Schleicher parameters for Unit 4 salt as well as the uncertainty in the parameter values.

$$K = 1.0 \pm 3.49 \text{ MPa}$$

$$\alpha = 38.8 \pm 9.3 \text{ MPa}$$

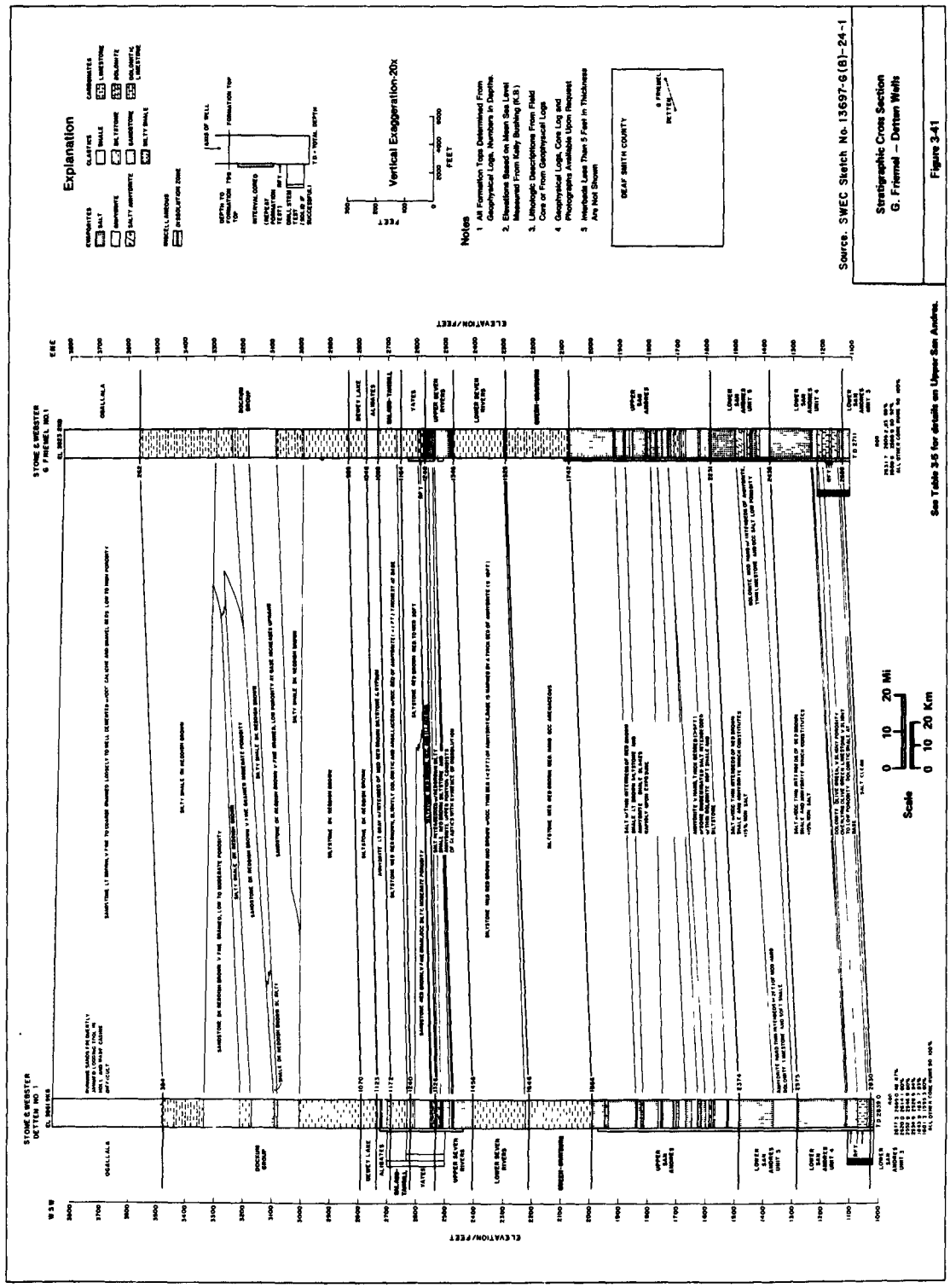
$$\beta = 0.017 + 0.011 \text{ MPa}^{-1}$$

The uncertainty results from both variability of the salt and lack of fit of the model.

3.2.6.1.4 Lithostratigraphic Characterization. The stratigraphy and lithology of the rocks in Deaf Smith County are discussed in Section 3.2.3. The rocks in the Palo Duro Basin below the Dockum consist of interbedded evaporates, clastics, and carbonates whose composition and properties vary rather abruptly in the vertical direction but are very consistent in the lateral direction. Major lithologic units can be traced for miles between wells (Figure 3-41; Presley, 1980). Work by Hovorka (1984), Fracasso and Hovorka (1984), and Hovorka et al. (1985) indicates that individual lithologic units, and in some cases individual interbeds within the Lower San Andres units, can be traced across large portions of the basin. Preliminary results from the study of geophysical logs (SWEC, 1982, p. 1) indicate that the variability of mechanical properties moduli values between wells is comparable to the variability within a rock unit in a single well. A detailed statistical analysis of sonic logs in the Zeeck No. 1 well in Swisher County and the J. Friemel No. 1 well in Deaf Smith County (Gokce, 1985) showed that the variation in sonic velocity or modulus between similar lithologic units type in different formations in a single well was generally greater than that between the same lithologic units of the same formation in the two wells. Many lithologic units within a formation were found to have the same modulus in the two wells (92 kilometers [57 miles]) apart at the 95 percent confidence level. These studies confirm the lateral persistence of lithologic units and their associated engineering properties and increase the confidence with which data from nearby wells can be extrapolated to the site.

Vertical variations in rock characteristics also appear to be predictable, at least in a general way. Hovorka et al. (1985) recognized very consistent sequences of rock units and

A larger reproduction of this figure appears at the back of this volume.



developed a depositional model for the Lower San Andres characterized by a broad, uninterrupted shelf subjected to approximately simultaneous depositional events, rather than the migration of depositional fronts. This interpretation considerably increases the confidence with which the sequence of rock units can be extrapolated from nearby wells to the site.

Geologic anomalies such as gas or brine pockets, collapse zones, faulted or fractured zones, or abrupt lateral facies changes are not anticipated at the site. The broad, uninterrupted depositional environment and the uneventual tectonic history subsequent to deposition argue against the presence of such anomalies, and none have been encountered in the near-site wells drilled to date.

The discussion of rock characteristics that follows is organized by formation from the ground surface downward. Figure 3-21 summarizes the geologic data derived from study of core and geophysical logs in the J. Friemel No. 1 well. Figure 3-41 is a stratigraphic profile between the Detten No. 1 and G. Friemel No. 1 wells, summarizing the formation depths and thicknesses, rock type groupings, and open-hole hydrologic tests. Elastic properties and porosity estimates derived from geophysical logs run in the J. Friemel No. 1 well (closest to the site) and the lower part of the Mansfield No. 1 well are presented in Tables 3-13 through 3-16. Several assumptions are necessary to perform these calculations, so the values are considered range-of-value estimates and are subject to revision as additional information becomes available. Porosity estimates have been derived from neutron logs and reflect total water (hydrogen index), which is not the same as effective porosity.

Permeabilities in the Palo Duro Basin are classified as follows:

Qualitative Descriptor	Permeability Range
Tight	<0.1 millidarcy
Low Permeability	0.1 to 1.0 millidarcy
Medium Permeability	1.0 to 10 millidarcies
High Permeability	>10 millidarcies

This classification system is used for convenience in the following section (SWEC, 1985, BMI/SRP-5034). The use of a standard permeability classification, such as that given by Terzaghi and Peck (1967, p. 55), is of little value to classify permeability of rocks since nearly all rocks encountered are classified as "practically impervious." Permeabilities are estimated from open-hole hydrologic tests, pump tests, and laboratory permeability tests, as discussed in Section 3.3.2.

Near-Surface Units (Ogallala, Dockum, and Dewey Lake). The Ogallala consists of interbedded gravels, sands, silts, and clays, some of which are cemented into caliche layers of variable thickness. The Ogallala is otherwise unconsolidated. Porosities and permeabilities are generally high, but the Ogallala thickness is variable across the location. Well yields are highly variable (Section 3.3.2). Below the Ogallala, the Dockum Group and Dewey Lake Formation consist of lithified sands, silts, and clays. The Dockum contains zones that are poorly lithified. The Santa Rosa sand within the Dockum Group is a potentially significant source of water that may have to be dealt with during shaft construction. High-angle joints have been measured in the Dockum where it crops out, although few joints were encountered in the wells drilled to date.

Petrophysical parameters have been computed from geophysical logs run in the J. Friemel No. 1 well (see Table 3-13). Mechanical properties tests have been performed on core from the same well. Point-load test results at the J. Friemel No. 1 well (Figure 3-39) suggest that rocks in this interval are extremely weak to weak, generally being very weak except for some sandstones that are medium strong. Because the variability of these units, especially the Ogallala and Dockum, is great, site-specific testing will be required to characterize these materials, in order to assess shaft design and aquifer potential. Drill-stem tests at the J. Friemel No. 1 well were unsuccessful because of mechanical problems, but repeat formation tests in Swisher County suggest variably tight to medium permeable sections in the Dockum.

Table 3-13. Average Formation Petrophysical Parameters, for Shallow Formations - J. Friemel No. 1 Well, Deaf Smith County; for Deep Formations - Mansfield No. 1 Well, Oldham County

Formation	P-Wave Velocity (ft/sec)	P-Wave Velocity (km/sec)	Young's Modulus (10^6psi)	Young's Modulus (GPa)	Bulk Density (gm/cc)	Bulk Density (lb/cu ft)	Neutron Porosity (percent)
Shallow Formations							
Ogallala	6,600	2.0	0.58	4.0	2.10	131	31.4
Dockum Group	8,600	2.6	1.16	8.0	2.26	141	33.9
Dewey Lake	10,200	3.1	1.98	13.6	2.38	149	29.5
Alibates	12,000	3.7	3.12	21.5	2.35	147	21.9
Salado-Tansill	10,600	3.2	2.34	16.2	2.32	145	37.0
Yates	11,000	3.4	2.47	17.0	2.34	146	29.0
Upper 7 Rivers	13,300	4.1	3.48	24.0	2.14	134	7.8
Lower 7 Rivers	13,200	4.0	3.89	26.8	2.34	146	12.8
Queen-Grayburg	14,300	4.4	4.99	34.4	2.40	150	11.0
Upper San Andres	15,400	4.7	5.27	36.3	2.36	147	3.6
Lower San Andres 5	16,300	5.0	6.26	43.2	2.45	153	2.4
Lower San Andres 4	15,600	4.7	5.40	37.3	2.30	143	4.9
Lower San Andres 3	15,200	4.6	5.10	35.2	2.30	144	4.0
Lower San Andres 2	15,500	4.7	5.66	39.0	2.38	149	5.8
Glorieta	12,700	3.9	3.32	22.9	2.23	139	12.2
Upper Clear Fork	13,900	4.2	4.07	28.1	2.30	144	7.8
Tubb	12,900	3.9	3.96	27.3	2.39	149	16.6
Deep Formations							
Lower Clear Fork	8,100	2.5	0.41	2.8	2.00	125	3.0
Red Cave	9,500	2.9	0.69	4.8	2.19	137	24.8
Wichita	17,200	5.2	7.55	52.1	2.74	171	7.1
Upper Wolfcamp	17,200	5.2	7.35	50.7	2.58	161	9.5

Source: SWEC, 1984, Calculations 13697.62-G(B)-28 and 13697.62-G(B)-34.

Table 3-14. Elastic Properties and Parameters Estimated From Geophysical Logs, J. Friemel No. 1 Well, San Andres Section Above the Proposed Host Rock

Formation Average

Minimum Depth, ft (m)	Maximum Depth, ft (m)	Thickness, ft (m)	Bulk Density, gm/cc (lb/cu ft)	P-Wave Velocity, ft/sec (m/sec)	Poisson's Ratio	S-Wave Velocity, ft/sec (m/sec)	Young's Modulus (10^6 psi) (GPa)	Shear Modulus (10^6 psi) (GPa)	Neutron Porosity (%)
1885.0 (574.5)	2566.0 (782.1)	681.0 (207.6)	2.38 (149)	15600 (4756)	0.33	7900 (2409)	5.56 (38.3)	2.09 (14.4)	2.0

Cumulative Lithologic Averages

Lithology	Cumulative Thickness (ft)	Cumulative Thickness (%)	Bulk Density (gm/cc)	P-Wave Velocity (ft/sec)	Poisson's Ratio	S-Wave Velocity (ft/sec)	Young's Modulus (10^6 psi)	Shear Modulus (10^6 psi)	Neutron Porosity (%)
Siltstone	2.0	0.3	2.35	14800	0.29	8000	5.47	2.12	13.8
Salty Clastics	5.0	0.7	2.33	15600	0.30	8300	5.64	2.17	2.2
CMT Mudstone	8.5	1.2	2.40	13800	0.34	6800	4.07	1.52	16.8
Calc. Shale	3.5	0.5	2.44	11800	0.34	5800	2.99	1.12	28.0
Anh. Mudstone-Sh.	4.5	0.7	2.49	14200	0.34	7000	4.65	1.74	15.0
Salty Mudstone	43.0	6.3	2.20	13400	0.37	6100	3.03	1.11	5.3
Muddy Salt	28.5	4.2	2.13	13700	0.35	6600	3.35	1.24	2.6
Clean Salt	155.5	22.8	2.08	14600	0.31	7600	4.28	1.63	0.6
Dirty Salt	128.0	18.8	2.10	14100	0.33	7100	3.83	1.44	1.6
Anhydritic Salt	27.0	4.0	2.36	15400	0.32	7900	5.32	2.02	0.9
Shaley Dolomite	24.5	3.6	2.62	15100	0.32	7700	5.76	2.18	14.9
Dolomite	37.0	5.4	2.55	15600	0.31	8200	6.08	2.32	18.6
Anhydrite Dolomite	5.5	0.8	2.70	17600	0.32	9000	7.89	2.99	2.0
Shaley Anhydrite	12.0	1.8	2.77	16000	0.35	7700	6.01	2.23	11.3
Salty Anhydrite	91.5	13.4	2.65	17400	0.33	8800	7.39	2.78	0.3
Anhydrite	88.0	12.9	2.93	19000	0.34	9400	9.33	3.48	0.4
Dolo-Anhydrite	15.0	2.2	2.85	17200	0.33	8700	7.74	2.91	2.8
Argillite	2.0	0.3	2.36	13600	0.33	6900	3.99	1.50	14.0

Note: Moduli calculated from velocity measurements.

Source: SWEC, 1984, Calculation 13697.62-G(B)-34.

Table 3-15. Elastic Properties and Parameters Estimated From Geophysical Logs, J. Friemel No. 1 Well, Deaf Smith County, Proposed Host Rock Section, Lower San Andres Unit 4 Salt

Formation Average

Minimum Depth, ft (m)	Maximum Depth, ft (m)	Thickness, ft (m)	Bulk Density, gm/cc (lb/cu ft)	P-Wave Velocity, ft/sec (m/sec)	Poisson's Ratio	S-Wave Velocity, ft/sec (m/sec)	Young's Modulus (10^6 psi) (GPa)	Shear Modulus (10^6 psi) (GPa)	Neutron Porosity (%)
2566.0 (782.1)	2730.5 (832.2)	164.5 (50.1)	2.09 (130)	14400 (4375)	0.32	7400 (2260)	4.08 (28.2)	1.55 (10.7)	1.1

Cumulative Lithologic Averages

Lithology	Cumulative Thickness (ft)	Cumulative Thickness (%)	Bulk Density (gm/cc)	P-Wave Velocity (ft/sec)	Poisson's Ratio	S-Wave Velocity (ft/sec)	Young's Modulus (10^6 psi)	Shear Modulus (10^6 psi)	Neutron Porosity (%)
Muddy Salt	8.5	5.2	2.15	13400	0.35	6400	3.24	1.200	5.1
Clean Salt	102.5	62.3	2.07	14500	0.31	7600	4.26	1.63	0.6
Dirty Salt	51.5	31.3	2.11	14100	0.33	7100	3.80	1.43	1.6
Anhydritic Salt	2.0	1.2	2.28	14800	0.32	7600	4.72	1.79	0.8

Note: Moduli calculated from velocity measurements.

Source: SWEC, 1984, Calculation 13697.62-G(B)-34.

Table 3-16. Elastic Properties and Parameters Estimated From Geophysical Logs, J. Friemel No. 1 Well, Deaf Smith County, Lower San Andres Section Below the Proposed Host Rock

Formation Average

Minimum Depth, ft (m)	Maximum Depth, ft (m)	Thickness, ft (m)	Bulk Density, gm/cc (lb/cu ft)	P-Wave Velocity, ft/sec (m/sec)	Poisson's Ratio	S-Wave Velocity, ft/sec (m/sec)	Young's Modulus (10^6 psi) (GPa)	Shear Modulus (10^6 psi) (GPa)	Neutron Porosity (%)
2730.5 (832.2)	3017.5 (919.7)	287.0 (87.5)	2.44 (152)	16100 (4909)	0.32	8300 (2530)	6.08 (41.9)	2.30 (15.9)	6.9

Cumulative Lithologic Averages

Lithology	Cumulative Thickness (ft)	Cumulative Thickness (%)	Bulk Density (gm/cc)	P-Wave Velocity (ft/sec)	Poisson's Ratio	S-Wave Velocity (ft/sec)	Young's Modulus (10^6 psi)	Shear Modulus (10^6 psi)	Neutron Porosity (%)
Salty Clastics	12.0	4.2	2.39	14900	0.30	8000	5.35	2.06	2.0
Anh Mudstone-Sh	6.0	2.1	2.58	14400	0.34	7100	4.730	1.77	17.1
Salty Mudstone	3.0	1.0	2.28	13900	0.37	6300	3.333	1.22	4.5
Clean Salt	60.0	20.9	2.09	14600	0.31	7700	4.324	1.65	0.7
Dirty Salt	11.0	3.8	2.14	14400	0.33	7300	4.04	1.52	1.4
Anhydritic Salt	26.0	9.1	2.21	14900	0.32	7700	4.603	1.74	0.6
Shaley Dolomite	10.0	3.5	2.51	13800	0.32	7100	4.602	1.74	14.7
Dolomite	55.0	19.2	2.592	17100	0.31	9000	7.50	2.86	9.1
Anhy Dolomite	20.0	7.0	2.62	18200	0.32	9400	8.17	3.09	11.5
Salty Anhydrite	22.0	7.7	2.612	16700	0.33	8400	6.70	2.52	1.0
Anhydrite	9.5	3.3	2.932	19100	0.34	9400	9.36	3.49	1.1
Dolo-Anyhdrite	9.0	3.1	2.90	19400	0.33	9800	9.93	3.73	0.3
Dolo-Limestone	43.5	15.2	2.59	17200	0.33	8700	7.01	2.64	15.6

Note: Moduli calculated from velocity measurements.

Source: SWEC, 1984, Calculation 13697-G(B)-34.

Evaporite Section Above the San Andres. The Alibates is the zone between the upper aquifers and salt-bearing horizons (Figure 3-39). The unit is quite complex and variable in Deaf Smith County and appears to be gypsiferous in the upper portion. Results of strength tests to date are noted in Tables 3-9 and 3-11. Point load tests from J. Friemel No. 1 Well (Figure 3-39) suggest that dolomites are moderately strong, whereas siltstones are weak. The rocks from the base of the Alibates to the top of the Queen-Grayburg may be generally characterized as interbedded evaporite and salty clastic rocks. Paleodissolution and collapse have resulted in several highly fractured zones, especially in the upper portions of the Salado-Tansill, which are variously filled with salt, anhydrite, or gypsum. Siltstone, where present, is weak to medium strong and has an elastic modulus varying from approximately 1 to 20 gigapascals (0.1 to 3.0 x 10^6 pounds per square inch) (Tables 3-9, 3-11, and 3-12); chaotic mudstone/salt, on the other hand, is weak and has an elastic modulus of approximately 7 to 8 gigapascals (1.0 to 1.2 x 10^6 pounds per square inch) (Table 3-6), whereas anhydrite is strong. The Queen-Grayburg is predominantly clastic rock that is tight, and weak to strong. Sandstone units in the Queen-Grayburg are somewhat porous and contain brine. One test at the G. Friemel No. 1 well indicates a 19 gigapascals (2.8 x 10^6 pounds per square inch) modulus and a 37 megapascals (5,400 pounds per square inch) strength for the siltstone (Table 3-12). Petrophysical parameters computed from the J. Friemel No. 1 well geophysical logs are shown in Table 3-13.

San Andres Section Above Proposed Host Rock. The San Andres section above the potential host rock includes both the Upper San Andres and the Lower San Andres Unit 5. This section contains appreciable salt including "major salt beds" as defined by SWEC (1983, BMI/ONWI-518) in the Lower San Andres Unit 5. Both salt and nonsalt rocks are present. There is a reasonably good rock mechanics data base (see Tables 3-9 through 3-12). Anhydrite, where present, is the most competent rock type, having a strong to very strong classification depending on the percentage of salt impurities; porosities are typically less than 1 percent. Dolomite, on the other hand, is classified as strong and may have porosities ranging from 2.5 to 15 percent. Primary porosity is frequently occluded with salt, anhydrite, or infrequently calcite. Fractures are commonly filled with salt, or to a lesser degree, anhydrite. Salt rocks are classified as weak to medium strong and are essentially nonporous. An evaluation of geophysical logs from the J. Friemel No. 1 well allows a petrophysical analysis for each rock type within the section. These results are summarized in Tables 3-13 and 3-14. Petrologic data are available from Fukui (1984, BMI/ONWI-540) on mineral abundances and whole-rock chemical analyses. Clay minerals identified in the nonsalt portions of this sequence include illite, random illite-smectite, chlorite, random chlorite-smectite, and kaolinite in decreasing frequencies (Fukui, 1984, BMI/ONWI-540; SWEC, 1984, BMI/SRP-5018). Detailed logs of the Unit 5 salt are presented by Hovorka et al. (1985).

Proposed Host Rock (Lower San Andres Unit 4 Salt). Considerable rock mechanics testing has been completed on core from the Mansfield No. 1, J. Friemel No. 1, Detten No. 1, and G. Friemel No. 1 wells (Tables 3-9 through 3-12) (Pfeifle et al., 1983, ONWI-450; Senseny et al., 1985, BMI/ONWI-549; SWEC, 1984, BMI/SRP-5022; BMI/SRP-5030; BMI/SRP-5025; BMI/SRP-5015). The salt is generally medium strong. Considerable petrologic data are available (Fukui, 1983, BMI/ONWI-5001; 1984, BMI/ONWI-540; 1984a; Bassett and Palmer, 1981); an insoluble residue analysis is also available (Fukui, 1983, BMI/ONWI-5001) for Unit 4 salt.

The Unit 4 major salt bed at the Deaf Smith County site, and throughout the Palo Duro Basin, is not pure, homogeneous halite. Impurities are present both as persistent interbeds, ranging in thickness from a few inches to several feet, and as dispersed material within the salt or along grain boundaries. Impurity content in the salt itself ranges from almost none (clear salt) through a few percent (dark or banded salt) to more than 50 percent (chaotic mixtures of salt and anhydrite or mudstone) (SWEC, 1984, BMI/SRP-5011; BMI/SRP-5005; BMI/SRP-5003; BMI/SRP-5008).

From a geomechanical point of view, the mudstone beds represent one form of discontinuity. In general, these discontinuities are scattered throughout salt in Unit 4 and appear to be distributed in a weakly cyclic fashion of increasing and decreasing frequency. Though not always the case, in many instances such discontinuities represent planes of weakness.

Fractures have been noted in cores obtained from the host rock, particularly in the mudstone interbeds. These fractures are typically filled with salt; no open fractures have been observed. While the filled fractures will have some influence on rock mass properties, the effects will be much less than the effect of open fractures.

Analysis of geophysical logs from the J. Friemel No. 1 well allows the petrophysical characterization shown in Tables 3-13 and 3-15. Figure 3-39 shows point-load test results and indicates the variability in strength. Other mineralogical, petrological, and geochemical aspects of the host rock are discussed in Section 3.2.7.1.

San Andres Section Below the Proposed Host Rock. This unit includes the basal dolomitic/calcitic portion of the Lower San Andres Unit 4 and the underlying Lower San Andres Units 1, 2, and 3. Although predominantly evaporitic, this section does not contain major salt beds and is similar to the Upper San Andres section above the host rock in that it contains anhydrite, dolomite, and shaley or salty clastic rocks as interbeds. Most significant is the Unit 4 dolomite (or limestone), referred to as the Yellowhouse dolomite by Ramondetta (1982). Bein and Land (1982) present detailed lithofacies analyses and a diagenetic history of these carbonates, as well as basic geochemical data. These carbonates are classified as strong to very strong (Tables 3-11 and 3-12), and test results from the Detten No. 1 and G. Friemel No. 1 wells show effective porosities of 5 to 20 percent (SWEC, 1984, BMI/SRP-5030; 1984, BMI/SRP-5025). Inspection of core recovered from program wells indicates that the porosity is often occluded by salt, anhydrite, or calcite (SWEC, 1984, BMI/SRP-5011, BMI/SRP-5005; BMI/SRP-5003; BMI/SRP-5008).

Evaporite Section Below San Andres. The rocks below the Lower San Andres section are predominantly interbedded evaporites and salty clastics to depths greater than 760 meters (2,500 feet) below the proposed repository level. Fracture fillings are variously composed of salt and clay. Rock mechanics testing and core are very limited at these depths; however, one sandstone specimen from the Mansfield No. 1 well is classified as medium strong (Table 3-9). Average petrophysical properties are shown in Table 3-13.

3.2.6.2 Thermal Properties

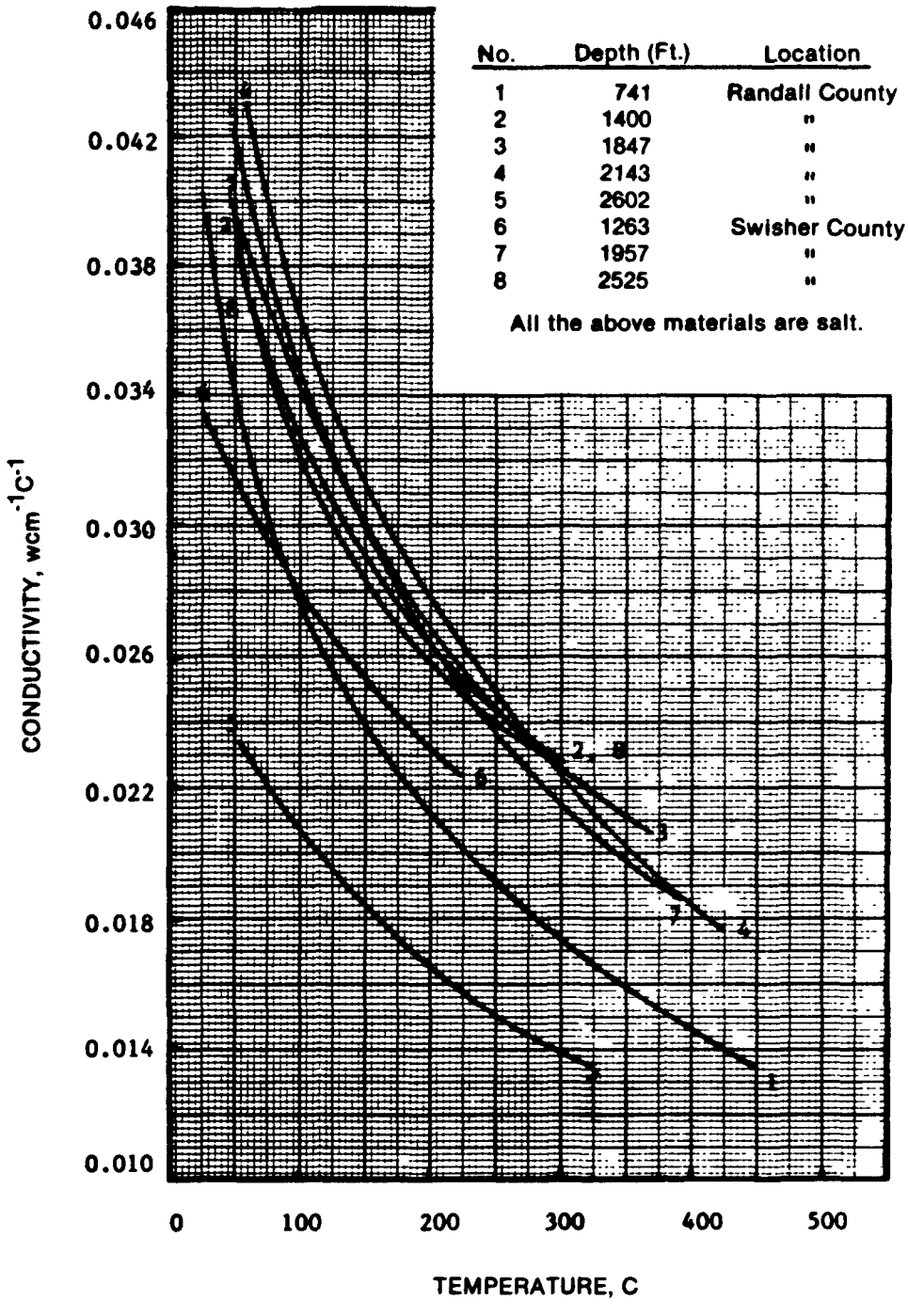
No thermal property data are available from Deaf Smith County. Thermal properties have been determined on prisms cut from core specimens from wells in the Palo Duro Basin (Lagedrost and Capps, 1983, BMI/ONWI-522). Typical thermal conductivity measurements (on core specimens from wells outside Deaf Smith County) are shown in Figure 3-42. Specimens of Permian Cycle 5 salt were observed to disaggregate at about 350 C (662 F) (Senseny, 1982, ONWI-9[82-4], p. 155). Thermal expansion and specific heat data are also available (Lagedrost and Capps, 1983, BMI/ONWI-522). Thermal fracture was noted for some specimens between 316 C and 422 C (600 and 800 F) (Lagedrost and Capps, 1983, BMI/ONWI-522 p. 31). The thermal properties measured on Palo Duro Basin salt specimens show some variations, but, in general, they are comparable to values obtained in the laboratory by other investigations (Lagedrost and Capps, 1983, BMI/ONWI-522, pp. 80-87). Table 3-17 summarizes the thermal data obtained for the Palo Duro Basin together with generic values obtained from the literature. Field tests will be performed during site characterization to evaluate in situ thermal properties.

3.2.6.3 Natural Radiation

The salt contains traces (a few parts per million) of uranium and thorium (Livingston et al., 1984), and their daughter products are presumed to be present at unit activities relative to uranium-238, uranium-235, and thorium-232. Additional gamma radiation comes from potassium-40, which is present in illite among the clays and as trace amounts in the water-soluble minerals of the salt (Fukui, 1984, BMI/ONWI-540).

3.2.6.4 Temperature and Geothermal Gradient

The geothermal gradient in the vicinity of the site is 0.4 to 0.6 C per 30 meters (0.8 to 1.0 F per 100 feet) of depth (SWEC, 1983, DOE/CH/10140-1, Figure 5-13). Formation-fluid



Source: Lagedrost and Capps, 1983, BMI/ONWI-522, Figure 9.

Axial Thermal Conductivity of Salt Specimens, Rex White No. 1 (Randall County) and Grabbe No. 1 (Swisher County) Wells

Figure 3-42

Table 3-17. Measured Thermal Properties of Permian Basin Salt Core Samples

Borehole County	Depth, m (ft)	Formation	Density at 20 C,[a] g/cm^{-3}	Thermal Conductivity at 100 C,[a] $w\ m^{-1}\ C^{-1}$	Total Expansion at 200 C,[a] %	Temperature of Thermal Fracture, C (f)	Coefficient of Linear Thermal Expansion,[f] $x10^{-6}C^{-1}$	Specific Heat Capacity,[a] $J\ Kg^{-1}C^{-1}$
Rex White No. 1/ Randall Co.	227 (741)	Upper Seven Rivers	2.14	2.85	0.78	305	46.2	908.7
Rex White No. 1/ Randall Co.	428 (1400)	Upper Seven Rivers	2.16	3.30	0.76	252	45.6	904.5
Rex White No. 1/ Randall Co.	565 (1847)	Lower San Andres Unit 4	2.17	3.60	0.78	310	47.3	904.5
Rex White No. 1/ Randall Co.	655 (2143)	Lower San Andres Unit 2	2.16	3.67	0.75	305	45.3	896.1
Rex White No. 1/ Randall Co.	796 (2603)	Upper Clear Fork	2.33	2.05	0.65	325	43.4	908.7
D. M. Grabbe No. 1/ Swisher Co.	387 (1266)	Upper Seven Rivers	2.18	2.86	0.75	310	46.3	900.3
D. M. Grabbe No. 1/ Swisher Co.	598 (1957)	Upper San Andres	2.21	3.48	0.80	310	49.1	896.1
D. M. Grabbe No. 1/ Swisher Co.	772 (2526)	Lower San Andres Unit 4	2.15	3.48	0.64	320	37.3	904.5
Average Value (Std. Deviation)			2.19 (0.06)	3.15 (0.54)	0.74 (0.06)	305 (22)	45.1 (3.5)	902.9 (5.0)
Typical Values			2.165[d]	5.28[b]	0.78[c]	-	-	908.7[e]

(a) Source: Raines, 1980, p. 17, Table 2.
(b) Source: Gevantman, 1981, p. 211, Table 4.1.
(c) Source: Gevantman, 1981, p. 214, Table 4.3.
(d) Source: Weast, 1984, p. B-142.
(e) Source: Hodgman et al., 1959-1960, p. 2272.
(f) Calculated from data in Lagedrost and Capps, 1983, BMI/ONWI-522, Figures 1 through 8.

temperatures measured during long-term pumping tests in the basal dolomite of the Lower San Andres Unit 4 in the J. Friemel well indicate that the host rock temperature is approximately 27 C (81 F) (Lamb, 1984).

3.2.7 Geochemistry

Specific information on the composition of the Unit 4 host horizon at the Deaf Smith County site is not available; thus, chemical, mineralogical, and petrographic data for the proposed host rock as sampled by drill holes near the site must be used. Available cores have been logged for lithology and textures. The information presented below supplements lithological and stratigraphic data presented in Section 3.2.3.2.

3.2.7.1 Mineralogy and Petrology

The predominant mineralogy (halite, mudstone, and anhydrite) is essentially the same for all cores; however, the mineral percentages vary. Table 3-4 shows the total amount of halite, mudstone, and anhydrite in the Lower San Andres Unit 4 host horizon, as sampled in three different wells in the vicinity of the Deaf Smith County site.

Unit 4 halite has variable grain size and is anhedral to subhedral in habit. Anhydrite is generally very fine-grained, and occurs primarily at halite and halite grain boundaries. Fine-grained anhydrite is frequently intermixed with goethite-stained clay minerals. Aggregates of anhydrite also form discrete discontinuous lenses and clasts intergranular to halite (Hovorka et al., 1985).

The mudstone is predominantly present as both discrete interbeds as well as in chaotic mixtures with halite and anhydrite. Clay-size grains comprise approximately 27 to 44 percent of the mudstone (Hovorka et al., 1985). Some clay minerals are interstitial to halite, frequently goethite-stained and associated with anhydrite. Clays are also occasionally found in halite fracture fillings. However, most Unit 4 host horizon clay minerals occur in discrete mudstone interbeds or as chaotic mudstone/halite mixtures, associated with detrital minerals such as quartz and feldspar (Hovorka et al., 1985). Logging and correlation show many of the mudstone zones to be continuous within much of the basin. Individual beds may or may not be continuous. Detailed logs have been prepared for the Unit 4 host horizon salt for all program wells drilled to date (Hovorka et al., 1985). From Table 3-4, mudstone and anhydrite contents in Unit 4 salt average 7 to 9 and 4 to 5 volume percent (which is roughly equivalent to weight percent), respectively. Halite constitutes the remaining 87 to 89 percent (Hovorka et al., 1985). Assuming that clay minerals comprise approximately one-half of Unit 4 mudstone, then clay mineral contents are approximately 3.5 to 4.5 percent in the Unit 4 host horizon salt.

The clay minerals in the Unit 4 host horizon are disseminated in and among the halite crystals (Fukui, 1984a, BMI/ONWI-540) and also occur as bands, beds, and zones where clay or anhydrite predominate (Hubbard et al., 1984). The clay mineral suite in the Deaf Smith County cores includes illite, chlorite, kaolinite, and saponite, in addition to interlayered illite/smectite, illite/chlorite, chlorite/smectite, and chlorite/vermiculite (Fukui, 1984, BMI/ONWI-540; Fukui, 1984a; Fukui and Hopping, 1985; Hovorka et al., 1985; Hall et al., 1985). A similar suite was identified in Lower San Andres Unit 4 in the Rex White well in Randall County (Bassett and Palmer, 1981). Reynolds (SWEC, 1984, BMI/SRP-5018) identified illite/smectite and corrensite in cores from four different Palo Duro Basin drill holes. Discrete illite and chlorite are also present and are considered detrital (Bassett and Palmer, 1981).

Unit 4 host horizon trace minerals include dolomite, quartz, goethite, gypsum, and to a lesser extent, rutile, pyrite, muscovite, feldspar, anatase, epidote, tourmaline, and possibly polyhalite (Fukui, 1984 a, b; Fukui and Hopping, 1985; Hovorka et al., 1985). Dolomite is frequently euhedral to anhedral interstitial to anhydrite aggregates. Euhedral dolomite also occurs at halite/halite and halite/anhydrite grain boundaries. Quartz is commonly fine-grained to medium-grained associated with goethite-stained clay, anhydrite, and halite. Euhedral quartz is found within anhydrite aggregates. Some anhedral quartz occurring at

halite/halite and halite/anhydrite grain boundaries may be authigenic rather than detrital. Goethite occurs chiefly with clay minerals as an iron stain. Gypsum was observed associated with anhydrite in a few samples. Also, muscovite was rarely identified associated with clay and detrital quartz. Hematite rather than goethite was also observed in a few samples.

3.2.7.2 Brine Content and Geochemistry

The Lower San Andres Unit 4 host horizon contains small amounts of brine as fluid inclusions and intergranular water in halite and as hydration and pore water in the mudstone layers and chaotic salt/mudstone mixtures. The maximum amount of brine available is calculated from data on the water content of halite and mudstone in the Lower San Andres Unit 4 host horizon. The calculations, which are based on overestimations and approximations, are presented below and summarized as Case A in Table 3-19.

1. Water in Halite: Based on the analysis of over 150 samples from various Lower San Andres Unit 4 cores, fluid inclusions and integranular water contribute from 0.1 to 0.8 weight percent water to the host halite and average 0.4 weight percent (Fisher, 1984). A conservative assumption is made of 0.5 weight percent water in clay-free halite (Fisher, 1984). Halite comprises approximately 88 percent of Unit 4 host horizon strata (Tables 3-4 and 3-19). Hence, 0.44 weight percent water can be derived from halite.

2. Water in Mudstone: The maximum water content of host horizon mudstone is estimated to be 15.0 weight percent, but the actual value is likely closer to 7.5 weight percent (Fisher, 1984). This includes both pore water in the mudstone and water in hydrous minerals such as clays. The average mudstone content of Unit 4 host horizon is 8 percent (Tables 3-4 and 3-19). Therefore, 1.20 weight percent water can be derived from Unit 4 mudstone.

3. Sum of Water from Halite and Mudstone: 0.44 weight percent water from halite plus 1.20 weight percent water from mudstone equals 1.64 total weight percent water.

4. Conversion from Weight Percent Water to Volume Percent Water: Assuming a density of water of 1.00 gram per cubic centimeter and average density of Unit 4 salt (mostly halite) of 2.16 grams per cubic centimeter (Weast, 1984), then 1.64 weight percent water converts to 3.48 volume percent water (Table 3-19).

5. Conversion from Volume Percent Water to Volume Percent Brine: The volumetric expansion of water upon saturation with halite at 90 C is readily calculated from density and halite solubility data given in Seidell (1919) and equals 18.6 percent. This accounts for both the thermal expansion of water from 25 to 90 C as well as the volumetric expansion of water upon saturation with halite. Assuming 19 percent expansion, then 3.48 volume percent water converts to 4.14 volume percent brine.

Therefore, the maximum amount of brine expected to be available for migration toward, and for corrosion of, waste packages at the Deaf Smith County site is 4.14 volume percent, which is lower than the 5.0 volume percent brine value assumed for the waste package corrosion calculations in Section 6.4.2.3.2. The above calculations are based on overapproximations of the total amount of water available from the halite and mudstone sources. Water availability calculations that reflect realistic as opposed to conservatively overestimated water contents yield a value of 2.42 volume percent brine (Case B in Table 3-19), which is approximately one-half of the value used in the waste performance assessment calculations (Section 6.4.2.3.2).

It is unlikely that all of the fluid inclusion and intergranular water will migrate to the waste package at repository temperatures. The migration of intergranular water may be obstructed, and molecular water may remain trapped in halite even at high temperatures, despite long periods of heating (Roedder and Bassett, 1981). Furthermore, clays will release only adsorbed and interlayer water at tempertures less than 300 C. Loss of lattice hydroxyl groups generally occurs at temperatures exceeding 400 C (Grim, 1968). If the above water

Table 3-18. Palo Duro Brine Compositions Compared with WIPP Brine Compositions (mg/l)

	Estimated Average Palo Duro Fluid Inclusion Composition[a]			Palo Duro Dissolution Brine[c]	Recommended Palo Duro Fluid Inclusion Brine[d]	Dessication Brine[e] ($MgCl_2$ Brine)	WIPP Brines[c]			
							WIPP Dissolution Brine[c]	WIPP Brine A	WIPP Fluid Inclusion Compositions (Preliminary)	
	#1A	#1B	#2[b]							
Ca^{++}	---	---	12,630	1,560	1,336	---	900	600	210	150
Mg^{++}	50,000	50,500	18,810	134	50,000	138,720	10	35,000	23,000	40,000
Na^{++}	49,000	55,200	78,840	123,460	25,290	---	115,000	42,000	63,000	32,000
K^{+}	15,690	15,800	5,030	39	15,690	---	15	30,000	8,700	6,800
SO_4^{--}	61,450	76,200	470	3,197	3,200	---	3,500	3,500	13,200	13,200
Cl^{-}	191,000	187,900	200,900	191,380	200,000	406,260	175,000	190,000	160,000	160,000

(a) Brine 1A has the centroid magnesium concentration (Hubbard et al., 1984b, Figure 5) with the concentrations of other ions estimated from simple evaporation of seawater.
Brine 1B is an observed composition reported in Carpenter (1978) for simple evaporation of seawater.

(b) This is an observed brine in a modern carbonate sabkha, Trucial Coast, Persian Gulf (Kinsman, 1965). This brine has extensively participated in dolomitization. Similar compositions are also expected for Palo Duro.

(c) Data from Molecke, 1983.

(d) This has the centroid magnesium concentration (Hubbard et al., 1984b, Figure 5) with the Ca^{++} and $SO_4^{=}$ values taken to be the saturation values at molar $Ca^{++}/SO_4^{=}$ is equal to 1.00. Molar $Ca^{++}/SO_4^{=}$ ratios different from one is perhaps more likely but not important because of the effectively unlimited supply of anhydrite to saturate the brine.

(e) This is an extreme brine composition that could result from extensive dessication of a high-Mg brine. The Mg^{++} and Cl^{-} concentrations given are for a saturated solution of $MgCl_2$. See Jenks (1972, ORNL/TM-3717) for a detailed explanation of how such brines could form.

Table 3-19. Lower San Andres Unit 4 Water Content Calculations (Conservatively Overestimated and Reference Cases)

Data and Calculations	Case A Conservatively Overestimated	Case B Reference
1. Water in Halite		
a. Weight percent water in clay-free halite	0.5[a]	0.4[a]
b. Percent halite in Unit 4 strata	88[b]	88[b]
c. Weight percent water from halite (1a x 1b x 0.01)	0.44	0.35
2. Water in Mudstone		
a. Weight percent water in mudstone	15.0[a]	7.5[a]
b. Percent mudstone in Unit 4 strata	8[b]	8[b]
c. Weight percent water from mudstone (2a x 2b x .01)	1.20	0.60
3. Total Weight Percent Water from Halite and Mudstone (1c+2c)	1.64	0.95
4. Conversion to Volume Percent Water		
a. Weight water (grams) per 100 grams Unit 4 strata (3)	1.64	0.95
b. Density water	1.00[c]	1.00[c]
c. Volume water (cubic centimeters) per 100 grams Unit 4 strata (4a ÷ 4b)	1.64	0.95
d. Weight rock (grams) per 100 grams Unit 4 strata (100-4a)	98.36	99.05
e. Density rock[d]	2.16[c]	2.16[c]
f. Volume rock (cubic centimeters) per 100 grams Unit 4 strata (4d ÷ 4e)	45.537	45.857
g. Volume water plus rock (cubic centimeters) per 100 grams Unit 4 strata (4c+4f)	47.177	46.807
h. Volume percent water (4c ÷ 4g)	3.48	2.03
5. Conversion to Volume Percent Brine		
a. Volumetric expansion of water upon saturation with halite at 90 C (percent)	19[b]	19[d]
b. Total volume percent brine (4h + [.01 x 5a x 4h])	4.14	2.42

Sources:
(a) Fisher, 1984.
(b) Hovorka et al., 1985.
(c) Weast, 1984.
(c) Seidell, 1919.

availability calculations accounted for processes that limit brine migration to the waste package, then the total amount of brine available for waste package corrosion would likely be less than 2.0 volume percent.

Roedder (1982, 1984) has observed three different types of fluid inclusions in the Palo Duro salt units: (1) primary inclusions (originally formed at the time of precipitation of salt), (2) secondary recrystallized inclusions and, (3) intragranular inclusions (i.e., fluid inclusions at grain boundaries), which would represent the last fluids present in salt. The fluid inclusions in Lower San Andres Unit 4 salt vary considerably in size and have the following textures: (1) irregularly distributed within halite grains, (2) aggregates of inclusions aligned along chevron (growth) zones, (3) inclusions at grain boundaries, and (4) inclusions along planes that represent healed fractures in the salt. Most fluid inclusions found in Unit 4 salt are single-phase, i.e., contain only fluid. However, many of the larger fluid inclusions have a small vapor bubble (generally about 1 percent volume). The liquid/vapor ratio in these inclusions is sufficiently high that their behavior in a thermal gradient would be almost identical to that of all-liquid inclusions. Sometimes closely associated with the fluid inclusions is cryptomelane (Roedder, 1984; Belkin and Libelo, 1985), where some fibers penetrate into halite host crystal.

The fluid inclusions in the Lower San Andres Unit 4 halite contain a high-magnesium brine (total dissolved solids ranging from 98,600 to 390,000 parts per million by weight), with magnesium concentration ranging from about 11,500 to 146,000 parts per million (Moody, 1985, Table 2). The mean magnesium concentration in fluid inclusions has been reported to be 39,700 parts per million in Unit 5 salt and 49,400 parts per million in Unit 4 salt, based on the analysis of over 50 samples from various wells (Moody, 1985, Table 2). These values are in good agreement with the expected magnesium concentration of 50,000 milligrams per liter, based on a sea water evaporation model (Hubbard et al., 1984b). The best current estimate of the average chemical composition of Palo Duro fluid inclusions in halite is given in Table 3-18 under "Recommended Palo Duro Fluid Inclusion Brine." Brine compositions from the Waste Isolation Pilot Plant (WIPP) project are shown for comparison. The composition of the Recommended Palo Duro Fluid Inclusion Brine is reasonably close to that of WIPP Brine A (Table 3-18), which is used as the basis of waste package corrosion rate estimates in Section 6.4.2.3. However, fluid inclusions are expected to be only a minor source of brine that may migrate to the waste package environment in a Deaf Smith County repository. The principal source is hydration and pore water present in the mudstone interbeds and chaotic mudstone and salt mixtures (Table 3-18), and the composition of brine from this source is not known at present.

Brines could also form by dissolving salt in the unlikely event that the repository is flooded by external water. The composition of these types of brines is relatively well known. They represent the water-soluble fraction of the salt. Such intrusive brines are expected to be of low-magnesium and low-potassium types, with compositions similar to that of the Palo Duro Dissolution Brine in Table 3-18. The composition of the Palo Duro Dissolution Brine in Table 3-18 agrees well with that of an experimentally-produced composite Palo Duro dissolution brine, reported by Pederson et al., (1984).

The geochemistry of deep basin brine aquifers above and below the Lower San Andres Unit 4 is presented in Section 3.3.2.1.3, which includes a discussion of radionuclide transport issues.

3.2.7.3 Isolation Characteristics

Petrographic and isotopic signatures of the salts and fluid inclusions indicate that, for the most part, the salt beds of the Lower San Andres Unit 4 have been unaltered since their deposition (Knauth and Beeunas, 1985, BMI/ONWI-569; Hubbard et al., 1984a). Some of the Palo Duro Basin data were obtained from inclusions in "chevron" crystals (Knauth and Beeunas, 1985, BMI/ONWI-569) that are considered to have formed directly from highly evaporated brines and to have preserved their original features (Handford, 1981). Oxygen-18/16 and deuterium to hydrogen ratios of water extracted from such beds are dissimilar to those of meteoric and formation waters above and below the lower San Andres Unit 4 but are similar to values

obtained from San Felipe, California evaporite pan brines (Figure 3-43). Based on stable isotopic evidence, fluid inclusions in the Lower San Andres Unit 4 represent neither modern meteoric water, connate sea water, connate marine evaporite brines, gypsum dehydration water, nor contamination fluids from drilling, sawing, storage, or sample preparation (Knauth and Beeunas, 1985, BMI/ONWI-569). The simplest explanation for the isotopic data is that the fluid inclusions are droplets of Permian-aged water trapped in halite during the primary deposition and diagenesis of the evaporites. Parent fluids were evaporated marine and meteoric waters that mixed in various proportions during intermittent periods of marine flooding and meteoric water runoff in restricted coastal marine environments (Knauth and Beeunas, 1985, BMI/ONWI-569). The variability in the inorganic composition of the fluid inclusions observed by Roedder (1984) can be explained if the parent fluids were Permian-aged brines that mixed with meteoric waters prior to burial, as suggested by Knauth and Beeunas (1985, BMI/ONWI-569). The existence of primary textures (i.e., chevron crystals) also supports the isotopic analyses because those textures strongly suggest that halite has persisted unaltered since Permian time.

The evolution and diagenetic histories of brines can also sometimes be reconstructed on the basis of chloride to bromide ratios. Brines with high chloride to bromide ratios (2,000 to 3,000 grams/gram) are typically associated with the dissolution of halite by meteoric waters, whereas lower chloride to bromide ratios (100 to 200) are expected in relict evaporation brines that were preserved in salt from its time of deposition (Kreitler et al., 1985). Edwin Roedder of the U.S. Geological Survey analyzed the chloride and bromide contents of fluid inclusions from 7 different salt samples from the Lower San Andres Unit 4 and lower section of the Lower San Andres Unit 5 (Moody, 1985, Table 1). Chloride to bromide ratios calculated from these data ranged from 137.9 in abnormal "chevron" inclusions in a chevron-type halite crystal to `.7 to 87.8 in halite cavity filling cements and 35.0 to 41.2 in chaotic mudstone and halite samples. These low chloride to bromide ratio values suggest fluids that reflect depositional and diagenetic processes, but not post-depositional dissolution and reprecipitation. Furthermore, bromide and chloride concentrations in approximately 50 to 60 fluid inclusions from Lower San Andres Units 3, 4, and 5 are similar to those expected for highly evaporated seawater, again suggesting that the inclusions, and hence the salt in which they are contained, have been largely unaltered since Permian time (Roedder et al., 1985, Figure 6A).

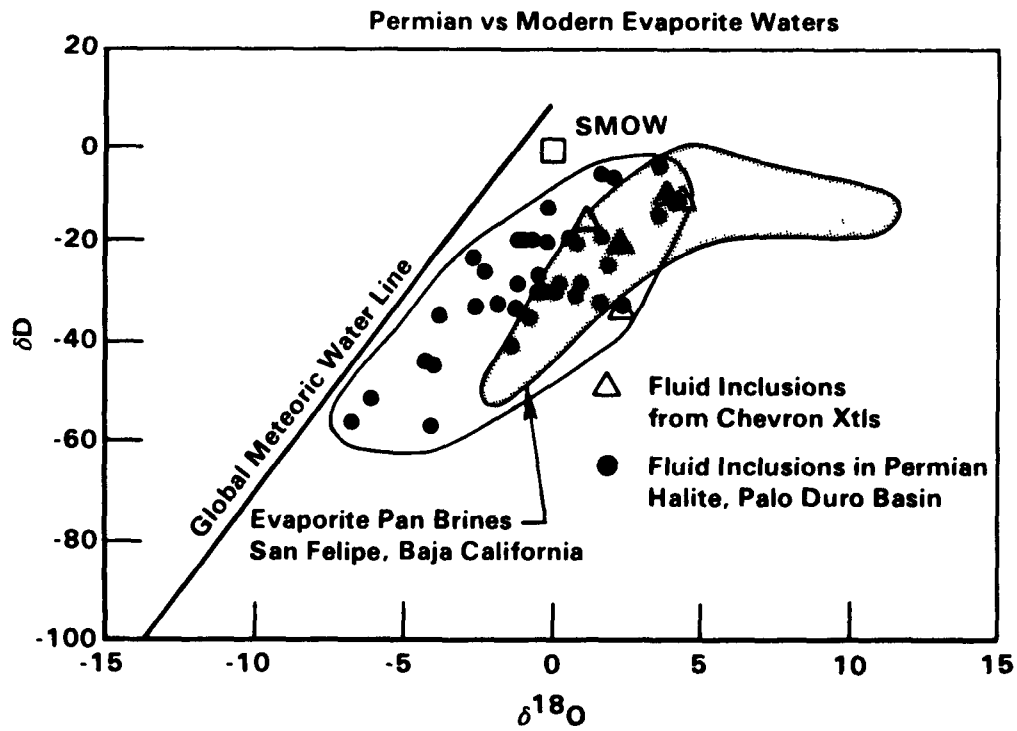
The primary minerals of Lower San Andres Unit 4 host horizon are expected to be stable in the repository environment. Neither halite nor anhydrite melts at maximum repository temperatures at about 250 C (Section 6.3.1.2.2). Lower-melting evaporite minerals such as carnallite and kieserite have not been identified in Lower San Andres Unit 4 strata. Halite and hydrous minerals such as clays may undergo thermal dehydration, and resulting brines are assumed to migrate up the thermal gradient toward the waste packages. The maximum volume of brine available for migration toward the waste package environment (calculated in Section 3.2.7.2), is not expected to lead to early waste package failure (Section 6.4.2). Changes in the physical properties of the host rock resulting from thermal dehydration of the mudstone-rich layers and chaotic mudstone and salt mixtures or from radiolysis of the halite are expected to be small and are discussed further in Section 6.3.1.2.3.

3.2.8 Mineral Resources

Mineral resources known within, and in the vicinity of, the Palo Duro Basin include hydrocarbons (oil and gas), sand, gravel, limestone, caliche, clay, salt (brine), diatomaceous earth, volcanic ash, gypsum, halite, uranium, oil, gas, and helium (Figure 3-44). Tentative classification of these mineral resources in the Palo Duro Basin is general and limited to resource categories defined by the U.S. Geological Survey and U.S. Bureau of Mines (1980) (Figure 3-45).

3.2.8.1 Hydrocarbon Resources

Identified hydrocarbon resources occur in the northern, southern, and southeastern portions of the Palo Duro Basin (Figures 3-46 and 3-47). However, prolific production in these



Explanation:

Comparison of Delta Deuterium and Delta 18 Oxygen Data for Waters from Fluid Inclusions in Palo Duro Halite with Data from Seawater/ Rainwater Mixtures Undergoing Evaporation in a Sabkha-like Environment: San Felipe, Baja California

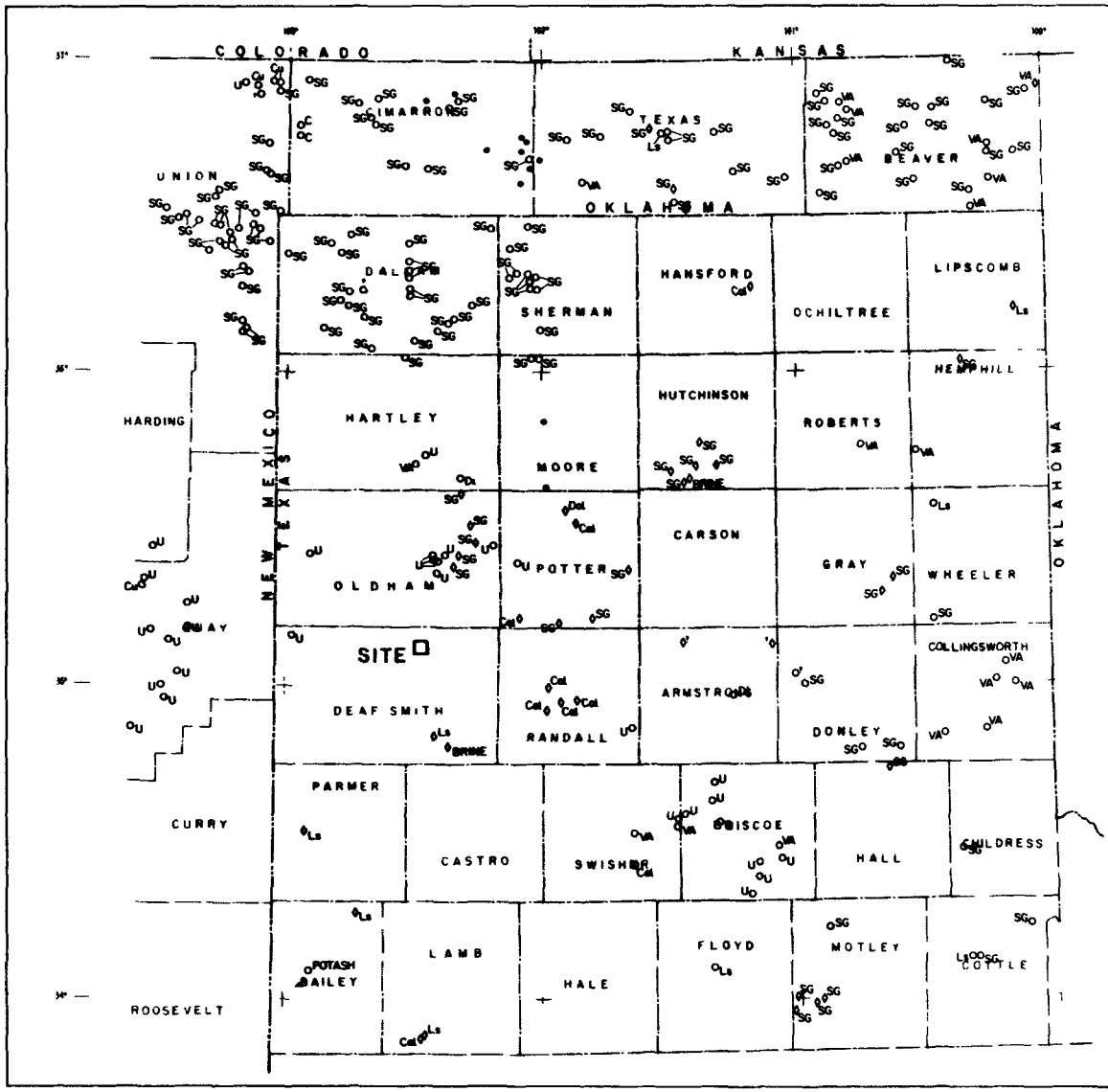
SMOW = Standard Mean Ocean Water

Data for Fluid Inclusions in Permian Halite are from Knauth and Beeunas, 1985, BMI/ONWI-569.

Data for San Felipe Brine Pans are from Kreitler et al., 1984.

Comparison of Permian vs. Modern Evaporite Waters

Figure 3-43



Explanation

- ○ INACTIVE MINE OR PIT, OCCURENCE, PROSPECT
- ◊ ACTIVE MINE, PIT OR QUARRY
- ♠ HELIUM WELLS
- ' SEVERAL INACTIVE AND ACTIVE OPERATIONS SHOWN FOR WHICH COMMODITY NOT KNOWN

MINERAL OR COMMODITY INDICATED BY LETTER SYMBOL

Cu - COPPER	VA - VOLCANIC ASH
U - URANIUM*	Di - DIATOMITE
C - COAL/LIGNITE	Dol - DOLOMITE
SG - SAND & GRAVEL	Cal - CALICHE
Ls - LIMESTONE	

Notes:

STATUS OF ACTIVITY MAY BE INACCURATE BECAUSE DATA ARE NOT AVAILABLE

*RADIOACTIVITY ANOMALY OR RADIOACTIVE MINERAL OCCURRENCE IN TEXAS, ANOMALY, OCCURRENCE, A FEW PROSPECTS IN NEW MEXICO

Sources: DeCicco et al., 1980; Garner et al., 1979, 1980; Johnson, 1969; Harley, 1940.

0 10 20 30 40
SCALE - MILES
0 20 40 60 80
SCALE - KILOMETERS

Known Mineral Occurrences in the Palo Duro Basin

Figure 3-44

Resources Classification System

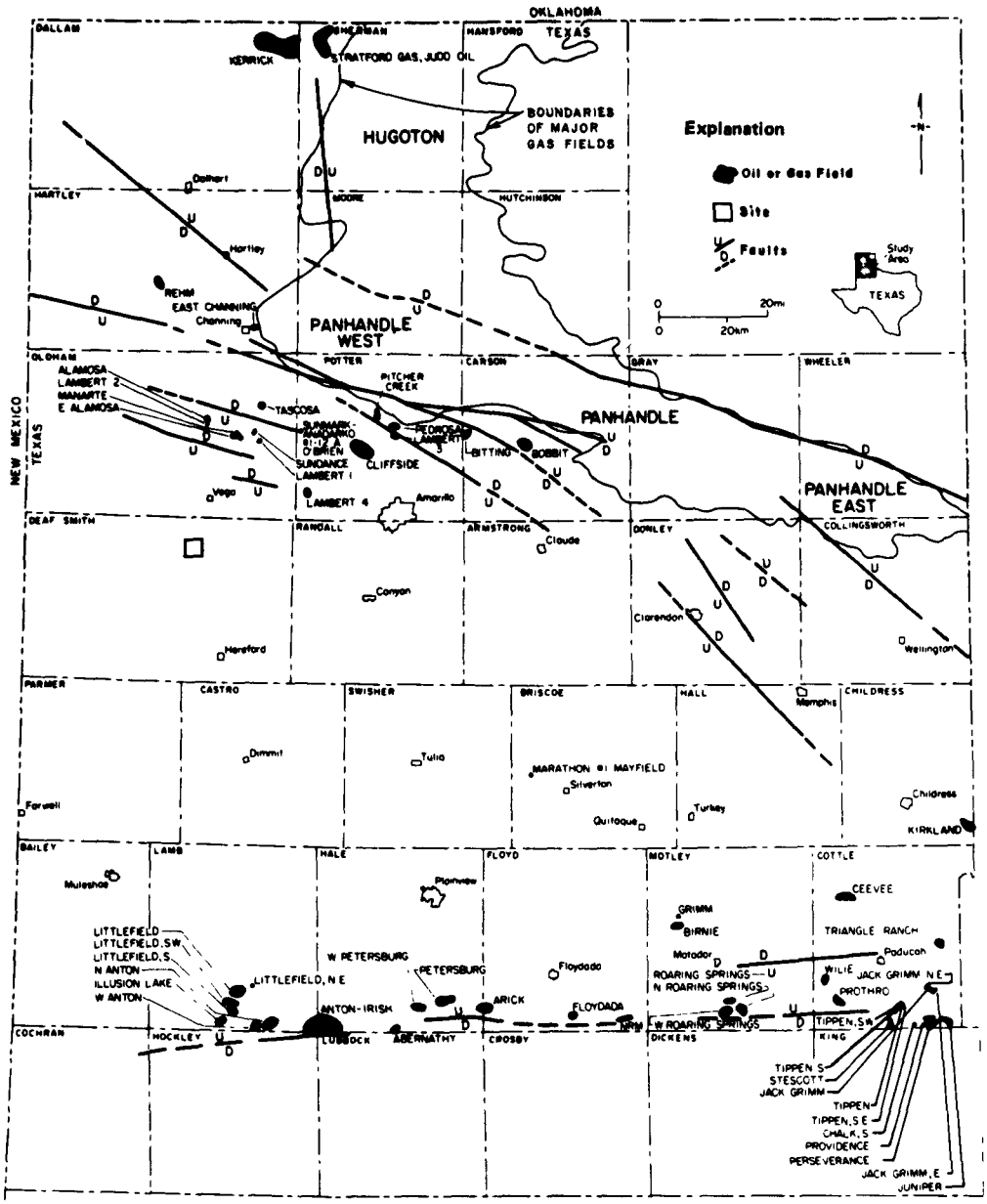
A Part of Reserves or any Resource Category may be Restricted from Extraction by Laws or Regulations

Cumulative Production	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		
Other Occurrences	Includes nonconventional and low-grade materials				

Source: USGS and USBM, 1980

Major Elements of Mineral Resource Classification

Figure 3-45

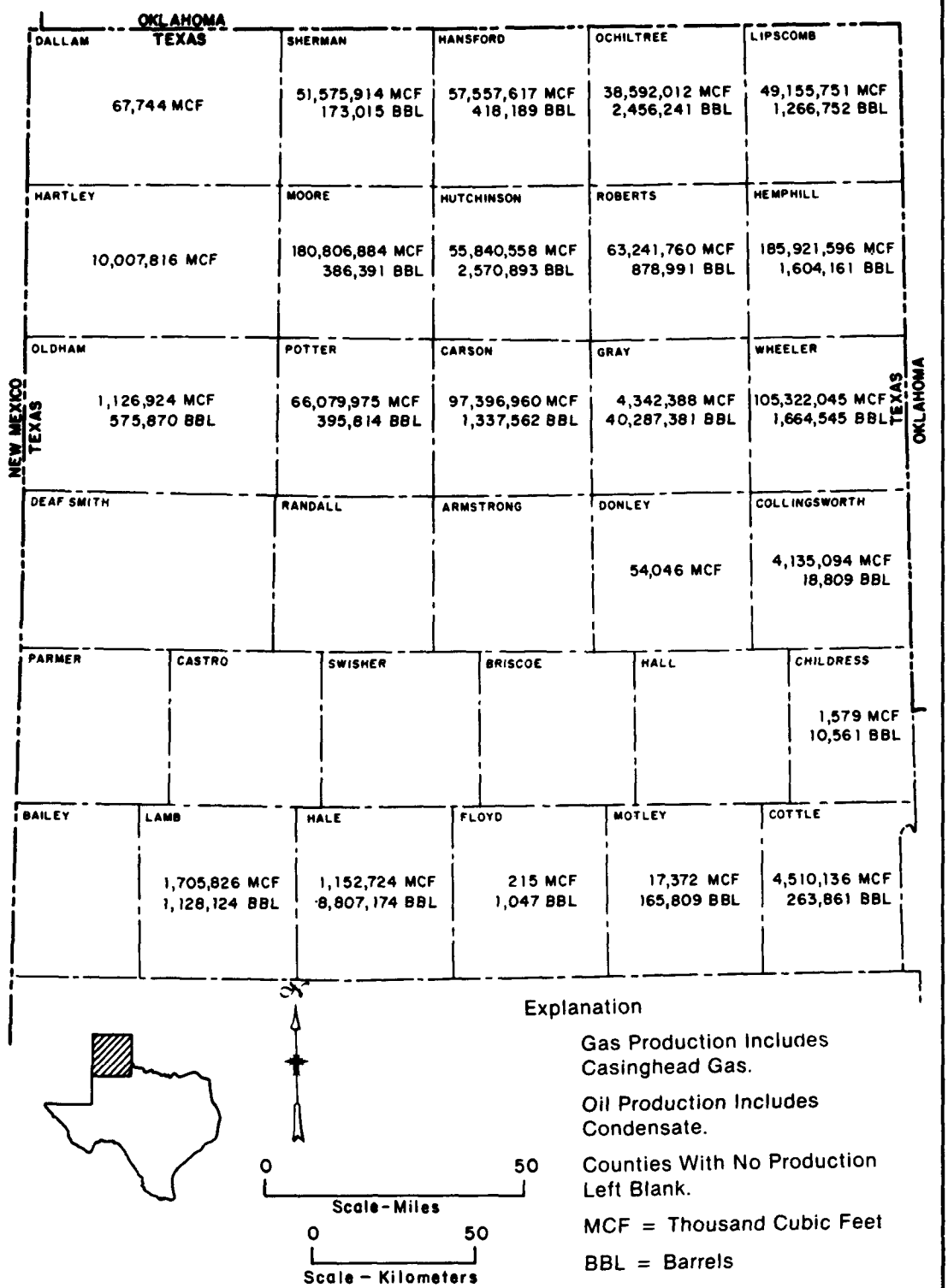


MARGIN OF PALO DURO BASIN IS SHOWN ON FIGURE 3-4

Location of Oil and Gas Fields in the Palo Duro Basin and Surrounding Areas

Source: Dutton et al., 1982.

Figure 3-46



Explanation

Gas Production Includes Casinghead Gas.

Oil Production Includes Condensate.

Counties With No Production Left Blank.

MCF = Thousand Cubic Feet

BBL = Barrels

1979 Oil and Gas Production of the Texas Panhandle

Source Texas Railroad Commission, 1980

Figure 3-47

areas does not accurately reflect the hydrocarbon potential of the Palo Duro Basin interior. Structural anomalies related to the Amarillo Uplift and Matador Arch trap most of the Palo Duro hydrocarbon production. In the southern producing fields, migrating Midland and Hardeman Basin oil accounts for most of the current production, whereas in the northern Palo Duro Basin, oil produced appears indigenous.

Production from Pennsylvanian granite wash sequences in the northern Palo Duro Basin is attributed to deep faults associated with the Amarillo Uplift. Movement along these faults was responsible for the anomalously deep burial of organic-rich Pennsylvanian shales (Dutton et al., 1982, Plate II), source rocks for the hydrocarbon accumulations.

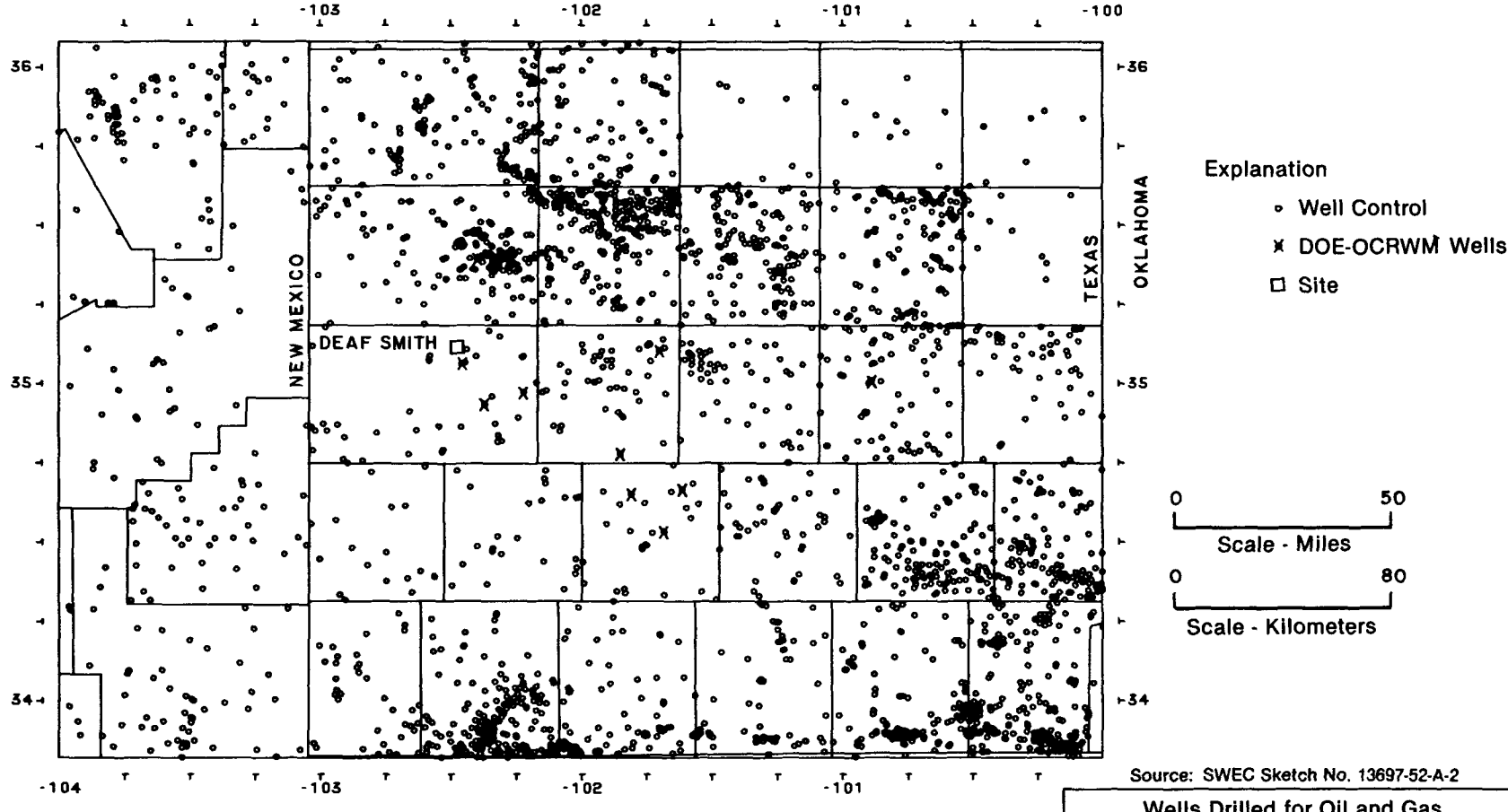
Small oil fields in east-central Oldham County are controlled by faults. There has been no oil or gas production in Deaf Smith County (Figure 3-47). However, petroleum exploration continues in southern Oldham and northeastern Deaf Smith Counties.

Similar geologic settings are not found in the Palo Duro Basin interior. Production in the southern and southwestern margins of the Palo Duro Basin is from Pennsylvanian and Permian carbonate reservoirs (Lower Clear Fork and San Andres Formations). Hydrocarbons generated in the Midland Basin migrated along the Matador Arch to the carbonate reservoirs in the Palo Duro Basin, where they were trapped by the impermeable evaporite rocks of the inner shelf system (Ramondetta, 1981, pp. 52, 58; Presley and Ramondetta, 1981, pp. 58-62). In the southeastern margin of the Palo Duro Basin, production from the Pennsylvanian granite wash and carbonate reservoirs is due to migrating hydrocarbons generated from the unusually organic-rich Mississippian shales in the Hardeman Basin. Hydrocarbon traps include structural barriers (faults) and, to a lesser extent, lithologic changes associated with distal fans of fan delta systems in the granite wash (Dutton et al., 1982, p. 32; SWEC, 1983, DOE/CH/10140-1, Figures 3-3 through 3-6).

The Mayfield No. 1 discovery in Briscoe County may be more characteristic of future production from the Palo Duro Basin interior than are fields along the margins of the Palo Duro Basin. Production from the Marathon Mayfield No. 1 well was from porous carbonate debris eroded from the Pennsylvanian shelf margin. The reservoir is small. Two wells drilled for field development were dry. Production from the Mayfield No. 1 well dropped from 126 barrels per day to 14 barrels per day in less than a year. Less than 20,000 barrels were produced, which is considered subeconomic. The well has been plugged and abandoned. Based on the presence of favorable geologic factors (Dutton et al., 1982), however marginal, the Mayfield No. 1 probably represents the "low end" of the production potential of the Palo Duro Basin interior.

In light of the relationship of rank wildcat drilling activity to discovery rates and the source rock geochemistry (Dutton et al., 1982, pp. 64 and 65; Dutton, 1980) in the Palo Duro Basin, it is concluded that the basin is "cold" or undercharged (i.e., potential source rocks have not been subject to sufficently high temperatures for sufficiently long periods of time to generate significant amounts of hydrocarbons). Exploratory basin drilling activity is in the intermediate to advanced stage (Figure 3-48); however, the Marathon Mayfield No. 1 well represents the only discovery in the Palo Duro Basin interior. The large volume of potential reservoir rock (Dutton et al., 1982, pp. 29, 35, 40, 41) compared to the apparently low volume of source rock also indicates an undercharged condition in the Palo Duro Basin. Because of the undercharged condition of the basin interior and the overall marginal source-bed geochemistry, the potential for undiscovered hydrocarbons and their development is low. However, local occurrences of favorable geologic conditions for hydrocarbon generation and accumulation may exist in the Palo Duro Basin interior (i.e., the juxtaposition of suitable source rock, reservoir rock, trapping mechanisms, and geothermal gradients persisting for an adequate time period). Prospective horizons are presumed to be Pennsylvanian shelf-margin carbonates and, to a lesser extent, the granite wash.

The relative petroleum potential of the Deaf Smith County site was evaluated by Means and Hubbard (1985). Nine different petroleum proximity indicators, including six source-rock



Source: SWEC Sketch No. 13697-52-A-2

Wells Drilled for Oil and Gas in the Palo Duro Basin and Surrounding Areas

Figure 3-48

indicators from Dutton et al. (1982) and three ground water indicators, including iodide, bromide, and short-chain aliphatic acid anion contents, were compared. These indicators suggested that the petroleum potential of the basin as a whole is relatively low.

The U.S. Geological Survey has estimated the undiscovered oil and gas resources in the Palo Duro Basin (Dolton et al., 1981, p. 77) by analyzing geologic, geochemical, production, and market data using statistical and subjective probability methodologies. Mean values are as follows:

- Crude oil: negligible (less than 0.05 billion barrels)
- Natural gas (associated): negligible (less than 0.05 trillion cubic feet)
- Natural gas (nonassociated): 0.1 trillion cubic feet.

The estimate includes Curry and Quay Counties in New Mexico and producing areas in Oldham, Potter, Lamb, Hale, Floyd, Motley, Cottle, and Childress Counties. Using the same geographic definition of the Palo Duro Basin that was used by U.S. Geological Survey, Zarnikau (1983a) has determined the gross present value (discounted) of oil and gas deposits in the Palo Duro Basin as follows:

- Crude oil: $0
- Natural gas: $193 million.

This estimate represents the value of known and undiscovered oil and gas produced over the next 20 years using exploration, production, and supply models. Because Zarnikau's study area coincides with that of the U.S. Geological Survey, his value of oil and gas is also heavily influenced by the producing areas peripheral to the Palo Duro Basin.

In a more detailed study of the Palo Duro Basin, Rose (1984a, b) also concludes that the Palo Duro Basin has an extremely low hydrocarbon occurrence and exploration potential. As part of the detailed basin analysis, Rose has evaluated the structural and stratigraphic trapping mechanisms, top-seals, reservoir rock, source rock geochemistry, hydrocarbon generation potential, and the migration mechanisms and pathways. This analysis shows that the least favorable interrelationships are in the large central or interior portion of the Palo Duro Basin within which lies the Deaf Smith County site.

Although suitable reservoir and cap rock are present at the site, the area is located more than 24.6 kilometers (15 miles) southwest of the petroleum source rocks comprising the western Upper Pennsylvanian shelf margin. The hydrocarbon-generating capacity of source rock at the site is low. "Less than critical" temperatures have been projected at the base of an estimated 2,591-meter (8,500-foot) sediment column with a "below average" temperature gradient (0.6 C per 30 meters [1 F per 100 feet] (Rose, 1984b) over a period of less than 300 million years.

The Deaf Smith County site is not located along any of the projected regional hydrocarbon migration pathways and is structurally poorly situated for suitable trapping characteristics. The site is located near the axis of a south-plunging syncline and lies south of the fault system responsible for the production along the Oldham Nose trend (Figure 3-4). Approximately 350 wildcats drilled in central Palo Duro Basin geologic anomalies have proved dry (except for the noncommercial discovery of the Mayfield No. 1 well).

Rose's resource volume estimates of undiscovered hydrocarbons for the central portion of the basin were calculated using a probabilistic approach and are as follows:

Confidence Level	Crude Oil (MBO)	Natural Gas (BCFG)
.95	14	12
.50	23	25
.05	182	109

Resource analyses by the U.S. Geological Survey (Dolton et al., 1981) and Rose (1984a, b) clearly indicate that, based on the basin size and sediment volume, the Palo Duro Basin is one of the leanest petroleum-bearing basins in the world.

On the basis of current oil prices ($26-28 per bbl. [The Wall Street Journal, 1985, p. 25]), drilling costs ($500,000 per well [Anderson and Funk, 1984 p. 158]), and lease acquisition costs (approximately $100,000), a recoverable reserve of more than 21,000 barrels of oil would be necessary to cover extraction costs alone. The probability is low for the occurrence of these reserve quantities.

In light of this discussion concerning the potential occurrence of hydrocarbons in the Palo Duro basin interior, the undiscovered oil and gas resources in the target areas are currently considered to be hypothetical (USGS and USBM, 1980, p. 3).

Helium gases are associated with hydrocarbon resources in the northern part of the Palo Duro Basin (Figure 3-44). Helium resources in the Panhandle result from radioactive decay of uranium-238, uranium-235, and thorium-232 within granitic rocks in basement highs or granite wash (Brobst and Pratt, 1973, pp. 286-288). Granitic basement highs are not present at the Deaf Smith County site and the lower Pennsylvanian granite wash is thinner at the site than it is farther north near the uplift. Helium accumulates in traps and is found only with hydrocarbons. Neither have been encountered in wells near the site. The potential for helium occurrence at the site is very low.

3.2.8.2 Other Resources

With the exception of uranium, other mineral resources in the Palo Duro Basin have been and are currently being extracted from surface or near-surface deposits of marginal and mostly local value. Because of variable market conditions, classification of known deposits has fluctuated between identified marginal economic reserves and identified subeconomic resources. Undiscovered resources are considered to be hypothetical and subeconomic. Based on the economic constraints on transportation and the marginal value of these nonhydrocarbon resources, both identified and undiscovered deposits have a low development potential at the Deaf Smith County site.

Sand and gravel occur as stream deposits and in the Ogallala Formation. Their distribution and use as construction materials are widespread throughout the Palo Duro Basin. Caliche occurs in the Ogallala Formation and is mined for aggregate and as a source of calcium for cement. The widespread distribution of sand, gravel, and caliche and a projected low level of future construction activities suggests a marginal value for most of these resources (Zarnikau, 1983b, p. 55). Zarnikau's model demonstrates that future demand can be met by supplies from known deposits (Zarnikau, 1983b, p. 14).

The extensive salt beds of the Permian evaporite sequence constitute a halite resource. However, the depth and extent of the resource have prohibited its development in the Palo Duro Basin. With the exception of a brine well abandoned in 1981 in Deaf Smith County near Hereford, there is no recorded production from bedded salts in the Palo Duro Basin.

Abundant potassium salts have not been observed in the DOE wells. Potash was reportedly found in wells drilled at Boden in Potter County and in Randall and Oldham Counties, Texas (Cunningham, 1934). Samples in the Boden well were taken at depths between 266 and 282 meters (875 and 925 feet) and were found to contain 9.2 percent potash (K_2O). In the Randall County well, some samples of red salt taken between 457 and 518 meters (1,500 and 1,700 feet) contained 6.1 percent potash (K_2O) (Mansfield and Lang, 1934). A test well for potash was drilled at Cliffside, Potter County, in 1915 on the basis of the earlier findings but failed to find any significant amounts of potash in 140 meters (460 feet) of salt beds penetrated. Despite these "shows," detailed subsurface correlation and mapping of the Permian evaporates have not proved the occurrence of crystalline-type potash deposits in the Palo Duro Basin (Handford, 1979). Potash from brine concentrate has not been reported in the Palo Duro Basin.

Brine type deposits are low-grade and are generally not commercially exploited unless co-produced with sulfate, borate, carbonate, or bromine compounds. The richer crystalline deposits are both more profitable and simpler to exploit (Smith et al., 1973, p. 203).

Current United States potash reserves are mainly located in southeastern New Mexico and northwestern and eastern Utah and are sufficient to last as least 100 years. One-half of the world reserves are located in Canada where they have been under diligent development for more than 15 years. Consideration of the potash reserve status in the United States and Canada, the cost of new deep mines, and the relatively inexpensive transportation costs of Canadian potash to U.S. markets renders the expensive exploration and exploitation of undiscovered potash deposits at the Deaf Smith County site a speculative activity.

The clay resources of the Palo Duro Basin have been extracted in western Briscoe County for filtering agents in petroleum refining (Evans, 1942), in Donley and Gray Counties for drilling clay, and in Hall and Potter Counties for refractory clay (Garner et al., 1979). Industrial clay is generally a high-bulk, low-value commodity. The widespread occurrence of Tertiary clay in the Palo Duro Basin permits processing plants and quarries to be located near industrial consumers of the commodity, thereby avoiding prohibitive transportation costs. All of the major consumption of clay products near the Deaf Smith County site is in petroleum drilling and refining and in ceramic and brick industries located in Amarillo, Borger, Phillips, White Deer, Sunray, Briscoe, and Lubbock, Texas. The clay mines have been located in Briscoe, Donley, Gray, Hall and Potter counties. Due to the widespread distribution of clay resources and the location of industrial users, clay, if present, would not be a unique resource at the Deaf Smith County site.

Gypsum occurrence is widespread in the Permian redbeds of the Texas Panhandle and southwest Oklahoma. Minable deposits occur in Permian exposures east of the Palo Duro Basin (Ward, 1982, p. 512). Economic occurrences of gypsum do not occur in the site vicinity.

Occurrence of diatomaceous earth and volcanic ash is common in Pliocene and Pleistocene lake deposits of the High Plains. Diatomite deposits occur in Armstrong, Crosby, and Hartley Counties (Garner et al., 1979), but no production is reported. Volcanic ash deposits occur in Swisher, Briscoe, and several other counties, but no significant production has been reported (Garner et al., 1979).

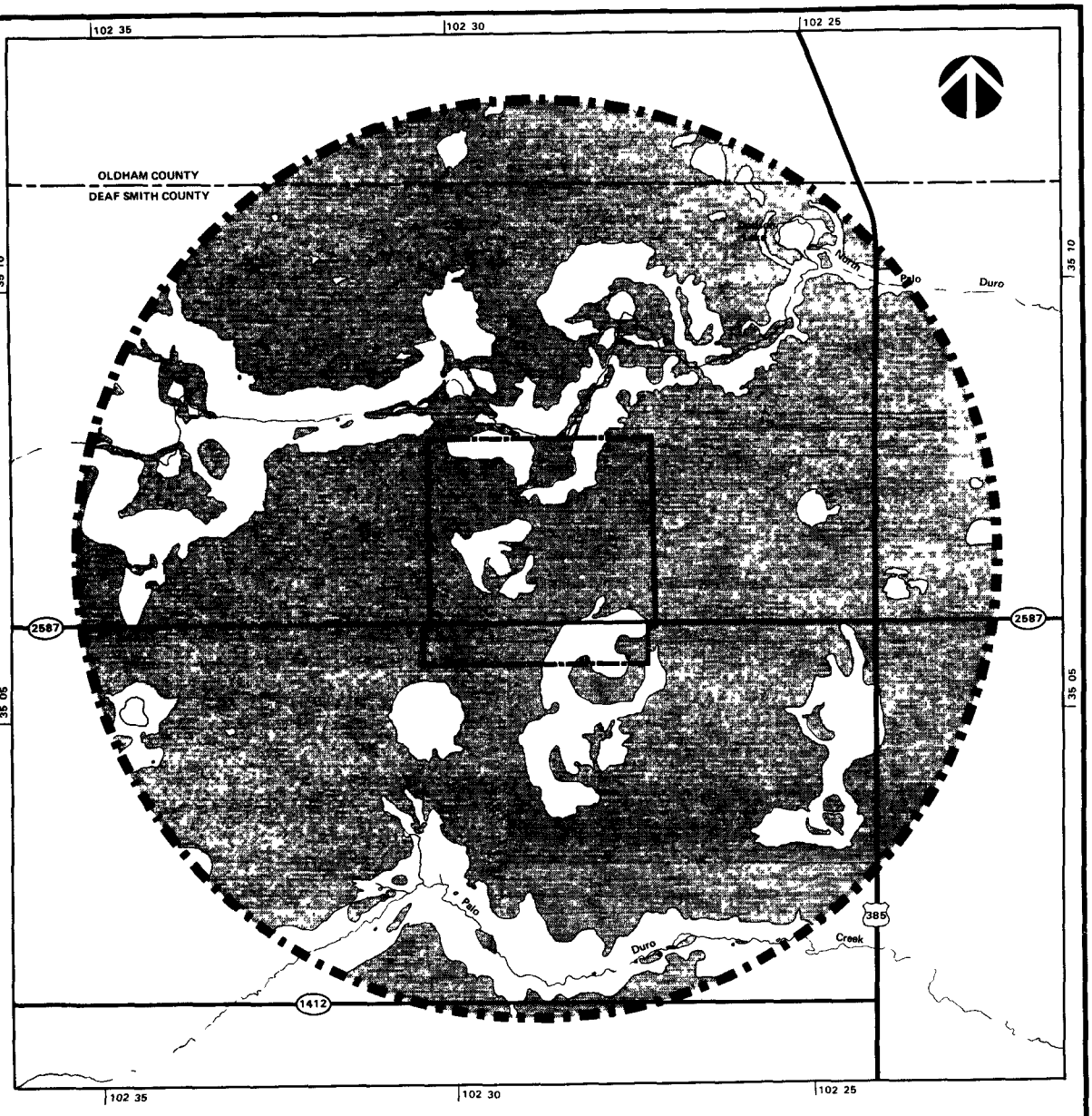
Uranium-bearing horizons have been postulated in Pennsylvanian and Permian strata (Kolker, 1983, p. 88). Undiscovered uranium resources within these zones are currently classified as speculative and subeconomic. Undiscovered uranium resources in the Dockum Group are considered hypothetical, subeconomic resources. Based on current and projected market conditions and the inadequate size of type deposits, undiscovered uranium resources have a low potential for development (Zarnikau, 1983c, pp. 65-66).

Copper deposits similar to those in north-central Texas and southwestern Oklahoma are speculative but may be postulated based on the similarity of geologic setting.

3.2.9 Soils at the Deaf Smith County Site

Most soils within the Deaf Smith County site and site vicinity are well suited for agricultural purposes and are used extensively for dryland farming, irrigated farming, and grazing. Seventy-eight percent of the soils on the site and site vicinity are categorized as Prime Native (Geiger et al., 1968) (Figure 3-49). The Prime Native category includes all soils which are highly suited for agricultural purposes without costly management requirements such as drainage or irrigation.

Soil associations on the site and within the site vicinity fall predominantly into two categories: the Pullman Association and the Mansker-Potter-Bippus Association. Most of the site and vicinity is composed of Pullman Association soils located on nearly level to gently sloping (0 to 3 percent) plains. The Mansker-Potter-Bippus Association is located on bottom lands and sloping areas in strips along the stream valleys of the Palo Duro and North Palo Duro Creeks (Figure 3-50).



Explanation

Prime Native Agricultural Soils

Other Soils

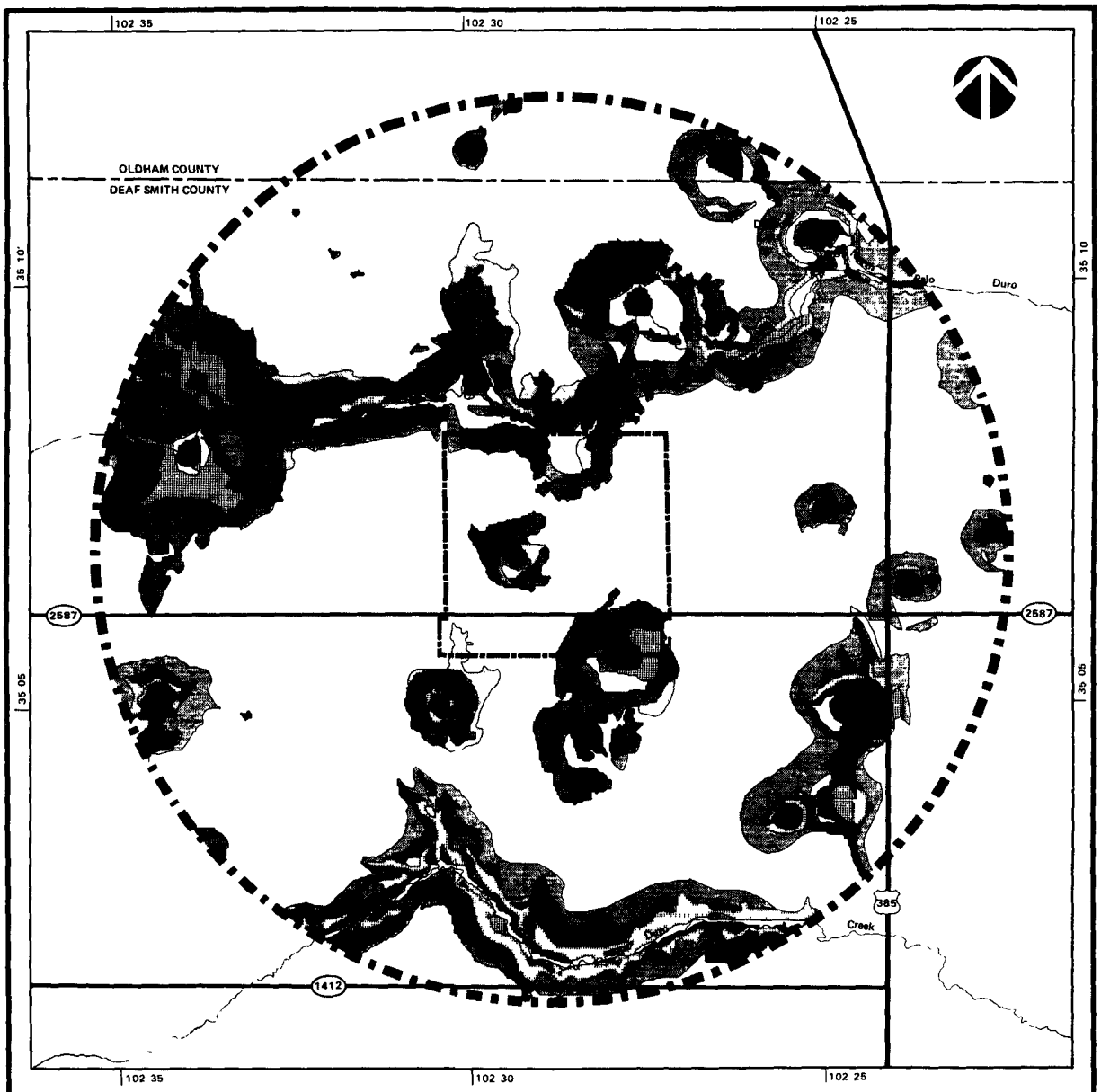
1 0 1 5 Kilometers

1 0 1 3 Miles

Source Geiger et al , 1968, Pringle, 1980

Deaf Smith County Site and Vicinity
Prime Native Agricultural Soils

Figure 3-49



Explanation

- Bippus Clay Loam
- Church Clay
- Mansker Clay Loam 3 to 5 Percent Slope
- Mansker Clay Loam 5 to 8 Percent Slope
- Olton Clay Loam 0 to 1 Percent Slope
- Olton Clay Loam 1 to 3 Percent Slope
- Pullman Clay Loam 0 to 1 Percent Slope
- Pullman Clay Loam 1 to 3 Percent Slope
- Pullman-Ulysses Complex 0 to 3 Percent Slope
- Randall Clay
- Spur and Bippus Soils
- Ulysses Clay Loam 0 to 1 Percent Slope
- Ulysses Clay Loam 1 to 3 Percent Slope
- Other Soils

1 0 1 5 Kilometers

1 0 1 3 Miles

Source. Geiger et al , 1968; Pringle, 1980.

Deaf Smith County Site and Vicinity Soils

Figure 3-50

The Pullman series, which covers about 90 percent of the Pullman Association, is probably the most intensively cultivated in the region (Geiger et al., 1968). It is Prime Native soil. The remaining 10 percent of the association comprises small areas of the Randall, Church, Ulysses, Mansker, Olton, and other soils. Only the Olton is considered a Prime Native soil. NUS (1984, BMI/ONWI-510) gives a more detailed description of those soils and all other soils found in the site vicinity.

The soils of the Mansker-Potter-Bippus Association occupy the balance of the site vicinity. The Mansker soils make up about 60 percent of this association. Most of the rest is made up of about equal acreages of Potter and Bippus soils, but there are small areas of Spur, Ulysses, and other soils. Only the Bippus soil in this association is considered Prime Native.

The physical and agricultural properties of the soils in the site vicinity are given in Table 3-20. Descriptions of the engineering properties of these soils are in Table 3-21.

3.3 HYDROLOGIC CONDITIONS AT THE DEAF SMITH COUNTY SITE

This section describes surface-water and ground-water resources and conditions near the Deaf Smith County site. It also provides an estimate of current and projected water use through the year 2030.

The Deaf Smith County site is located in the Palo Duro Creek drainage basin in the Upper Red River Basin on the Southern High Plains (Figure 3-51), which is the southernmost part of the High Plains section of the Great Plains physiographic province (Thornbury, 1965, pp. 287-309). The Southern High Plains is a plateau bounded on the north by the deep valley of the Canadian River, on the east by the Caprock Escarpment, and on the west by the Mescalero Ridge in New Mexico. On the south, it merges imperceptibly into the Edwards Plateau (Cronin, 1969, p. 1; Bureau of Reclamation, 1982, p. II-6).

The ground-water regime beneath the Southern High Plains consists of three major hydrogeologic units. The uppermost is an unconfined aquifer, comprising the Ogallala Formation and Dockum Group, often referred to as the High Plains aquifer. An aquitard consisting of 1,500 to 1,800 meters (5,000 to 6,000 feet) of Upper Permian shales and evaporites underlies the High Plains aquifer. The repository horizon is a thick salt bed in the Lower San Andres Unit 4, which occurs near the middle of the aquitard. Below the aquitard, the deepest hydrogeologic unit is a brine aquifer that includes primarily carbonate and clastic rocks of Permian and Pennsylvanian age.

The deep-basin brine aquifer is underpressured with respect to the High Plains aquifer, resulting in downward flow potential. Recharge to the deep basin system is in the highlands of eastern New Mexico. The discharge zone is not yet defined.

The High Plains aquifer is the principal source of fresh water on the Southern High Plains. It consists primarily of the Ogallala Formation, and includes all water-bearing units with which it is in hydraulic continuity. The Santa Rosa sand of the Dockum Group underlies the Ogallala in many areas and locally yields good-quality water (TDWR, 1984, pp. II-5 to II-9; Muller and Price, 1979, pp. 14-17,53,54).

Irrigation is the principal water use on the Southern High Plains, and the Ogallala Formation is the principal water source. Current and historical pumping rates have exceeded the natural recharge rate, causing substantial declines in water level and the removal of large volumes of water from storage (Knowles et al., 1984, pp. 98-100).

3.3.1 Surface Water

3.3.1.1 Hydrology

The surface of the Southern High Plains within the Red River Basin is nearly flat and slopes southeastward at a rate of about 1.5 to 1.9 meters per kilometer (8 to 10 feet per

Table 3-20. Deaf Smith and Oldham County Soils, Physical and Agricultural Properties and Interpretations

Soil Series and Map Unit	Physiographic Position	Slope (%)	Texture(s)	Depth to Bedrock or Hard Caliche (inches)	Prime Native	Land Capability Class (Dry Land)[a]	Erosion Hazard	
							Wind	Water
Bippus (Br)	Along Palo Duro Creek, in valley fills, and on high bottomlands that are seldom flooded	0-3	Clay loam	60	Yes	IIe	Slight	Moderate
Church (Lipan) (Ch)[b]	On broad, level benches of playa basins in the High Plains	0-1	Clay	60	No	IVes	Moderate	Slight
Drake (DrC)	On eastern slopes of larger playa basins in the High Plains (scattered throughout)	3-5	Clay loam Silty clay loam	60	No	VIe	Moderate	Severe
Drake (DrD)	On eastern slopes of larger playa basins in the High Plains (scattered throughout)	5-8	Clay loam Silty clay loam	60	No	VIe	Moderate	Severe
Kimbrough (Kl)	On low ridges in a nearly level landscape	5-10	Loam	9	No	VIIs	Moderate	Severe
Lea (Kl)	Low areas (swales) in rolling landscape	1-3	Loam Clay loam	20	No	IVe	Moderate	Moderate
Mansker (MkA)	In irregularly shaped areas in nearly level landscapes	0-1	Clay loam	45	No	IVe	Moderate	Slight
Mansker (MkB)	In areas around playas and along draws of the High Plains	1-3	Clay loam	45	No	IVe	Moderate	Moderate
Mansker (MkC)	In areas around playas and along streams	3-5	Clay loam	45	No	IVe	Moderate	Severe

Table 3-20. Deaf Smith and Oldham County Soils, Physical and Agricultural Properties and Interpretations
(Page 2 of 3)

Soil Series and Map Unit	Physiographic Position	Slope (%)	Texture(s)	Depth to Bedrock or Hard Caliche (inches)	Prime Native	Land Capability Class (Dry Land)[a]	Erosion Hazard	
							Wind	Water
Mansker (MkD)	Mostly along Palo Duro Creek; some narrow areas around playas	5-8	Clay loam	45	No	VIe	Moderate	Severe
Olton (OcA)	On the High Plains, mainly surrounded by large areas of the Pullman soils	0-1	Clay loam Silty clay loam	60	Yes	IIIe	Slight	Slight
Olton (OcB)	Areas adjoining draws and playas of the High Plains	1-3	Clay loam Silty clay loam	60	Yes	IIIe	Slight	Moderate
Potter (Pe)	On side slopes of streams and in sloping to steep areas that border escarpments	5-30	Gravelly loam	9	No	VIIs	Moderate	Severe
Pullman (PmA)	On nearly level landscapes	0-1	Clay loam Clay Clay loam Silty clay loam	74	Yes	IIIe	Slight	Slight
Pullman (PmB)	Borders draws and playa depressions in nearly level landscapes	1-3	Clay loam Clay Clay loam Silty clay loam	74	Yes	IIIe	Slight	Moderate
Pullman (PmB2)	Borders draws and playa depressions in a nearly level landscape	1-3	Clay loam Clay Clay loam Silty clay loam	74	No	IVe	Slight	Severe

Table 3-20. Deaf Smith and Oldham County Soils, Physical and Agricultural Properties and Interpretations
(Page 3 of 3)

Soil Series and Map Unit	Physiographic Position	Slope (%)	Texture(s)	Depth to Bedrock or Hard Caliche (inches)	Prime Native	Land Capability Class (Dry Land)[a]	Erosion Hazard	
							Wind	Water
Pullman-Ulysses Complex (PuA)	On nearly level areas on the High Plains	0-1	Clay loam	74	Yes	IIIe	Slight	Slight
Pullman-Ulysses Complex (PuB)	On gently sloping areas around playas and along draws and creeks of the High Plains	1-3	Clay loam	74	Yes	IIIe	Slight	Moderate
Randall (Ra)	In playas on the High Plains	0-1	Clay	70	No	VIw	Moderate	None
Spur (Sp)	On bottomlands along Palo Duro Creek	0-1	Clay loam	60	No	Vw	Slight	Slight
Ulysses (UsA)	On the nearly level High Plains and surrounded by large areas of Pullman soils	0-1	Clay loam	70	No	IIIe	Moderate	Slight
Ulysses (UsB)	Around playas and along draws and creeks of the High Plains	1-3	Clay loam	70	No	IIIe	Moderate	Moderate

(a) Capability class groups soils according to their suitability for farming without major alteration. The class (Roman numerals) indicates the risk of damage when soils are used for common field crops. Class I is best and means the soil has few limitations; Class VIII means the soil should not be used for crops or grazing at all. The subclass indicates the specific limitation. Letter e = erosion; w = water or wetness; s = shallow, droughty or stony; and c = climate is the chief limitation.

(b) Church series are no longer used in these counties. Interpretations are the same as Lipan series.

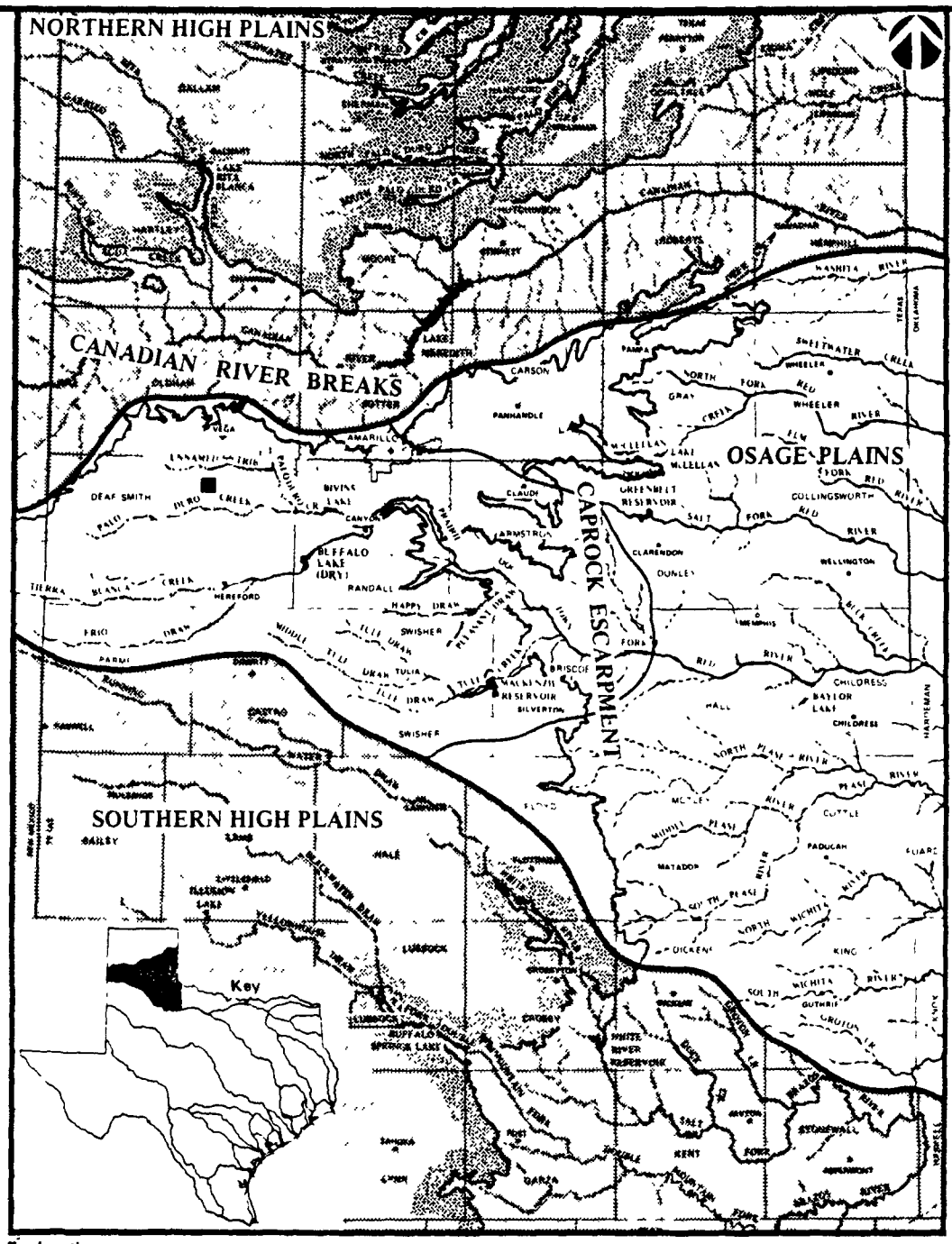
Source: Geiger et al., 1968, Williams, 1984.

Table 3-21. Deaf Smith and Oldham County Soils Engineering Properties

Map Unit	Soil Conservation Service Ratings[a] For: Low Building Foundations	Road Subgrade	Topsoil	Unlined Reservoirs
Bippus (Br)	Severe: floods	Severe: floods	Good	Moderate seepage losses
Church Lipan (Ch)	Severe: shrink-swell, ponding	Severe shrink-swell; low strength, ponding	Poor	Moderate: seepage
Drake (DrC), (DrD)	Slight to moderate: slope	Moderate: low strength	Fair	Moderate seepage and slope
Kimbrough (Ki)	Severe: cemented pan, slope	Severe: cemented pan	Poor	Severe: cemented pan, slope
Lea (Kl)	Moderate: shrink-swell; cemented pan	Moderate: shrink-swell, cemented pan	Fair	Moderate: seepage, cemented pan
Mansker (MkA), (MkB), MkC), (MkD)	0-4%: slight 4-8%: moderate: slope	Moderate: low strength	Fair	Moderate: seepage
Olton (OcA), (OcB)	Moderate: shrink-swell	Severe: low strength	Fair	Slight
Potter (Pe)	Moderate to severe: large stones; slope	Moderate: large stones; slope	Poor	Severe: seepage
Pullman (PmA), (PmB), (PuA), (PuB), (PuB2),	Severe: shrink-swell	Severe: shrink-swell; low strength	Poor	Slight
Randall (Ra)	Severe: ponding, shrink-swell	Severe: shrink-swell; ponding; low strength	Poor	Slight
Spur (Sp)	Severe: floods	Severe: low strength; floods	Fair	Moderate: seepage
Ulysses (UsA), UsB), (PuA), (PuB)	Slight	Severe: low strength	Fair	Moderate: seepage

(a) Ratings are extracted from both the Deaf Smith soil survey and SCS-5's for all Texas series.

Source: Geiger et al., 1968; Williams, 1984.



Explanation

Escarpment of High Plains

Deaf Smith County Site

Sources: Adapted from Texas Board of Water Engineers, 1960; Baker et al., 1963; Cronin et al., 1973.

0 10 20 30 40 50 Kilometers

0 10 20 30 Miles

The Upper Red River Basin and the Southern High Plains

Figure 3-51

mile). The principal features of relief are numerous saucer-like depressions or playas and small stream valleys or draws. Canyons have been cut into both the eastern and western escarpments, the larger ones along the eastern escarpment (Baker et al., 1963, p. 14; Cronin, 1969, pp. 1-2). Palo Duro Canyon, the most notable canyon in the area, is about 8 kilometers (5 miles) wide and 267 meters (875 feet) deep in Armstrong County.

Playas vary from a few hundred feet to several miles in diameter and range from a few feet to as much as 12 meters (40 feet) in depth below the land surface. During periods of heavy rainfall, runoff collects in the playas to form playa lakes. Playa basins, the areas contributing runoff to individual playas, range in size from a few square kilometers to as much as 129 square kilometers (50 square miles). It is estimated that about 90 percent of the Southern High Plains drains into playa basins, which act as closed basins and do not contribute runoff to the creeks (Bureau of Reclamation, 1982, pp. II-6, II-7).

Stream drainage is poorly developed on the Southern High Plains within the Red River Basin. Long, shallow valleys follow the general slope of the land surface at widely spaced intervals. The following valleys form the headwater streams of the Red River: Palo Duro, Tierra Blanca, and Tule Creeks. The area contributing runoff to the creeks is limited to the stream valleys and to narrow belts of sloping land adjacent to the valleys. The major portion of the interfluve area is occupied by the playa basins (Cronin, 1969, p. 2; Woodruff et al., 1979, pp. 219, 220).

Palo Duro Creek rises in eastern New Mexico and flows eastward across Deaf Smith County to Randall County, where it joins Tierra Blanca Creek near Canyon to form Prairie Dog Town Fork of the Red River (Figure 3-52). The Deaf Smith County site is in a nearly flat area bounded on the south by Palo Duro Creek, on the east by North Palo Duro Creek, and on the north by an unnamed tributary of North Palo Duro Creek. The site slopes eastward from an elevation of about 1,239 meters (4,065 feet) above mean sea level at its western boundary, to about 1,225 meters (4,020 feet) above mean sea level at its eastern boundary (Figure 3-2). There are no stream channels on the site. There are, however, two playas, one in the southwest quadrant and the other in the southeast quadrant. There are no impoundments near the site except small farm ponds (Figure 3-52 and Table 3-22).

The Southern High Plains within the Red River Basin has a steppe (semiarid) type of climate with a mean annual precipitation of about 457 millimeters (18 inches) (Haragan, 1976, pp. 1, 193) and an average annual runoff of less than 2.5 centimeters (1 inch) (Busby, 1966). Palo Duro, Tierra Blanca, and Tule Creeks are ephemeral and flow only during periods of heavy rainfall. The locations of stream-gaging stations are described in Table 3-23 and shown in Figure 3-52. The only stations currently being operated are on Tule Creek near Silverton and on Prairie Dog Town Fork of the Red River near Wayside. The average and extreme stream flows are shown in Table 3-23; the mean and extreme monthly stream flows are shown in Table 3-24. The data indicate that the average annual discharge is low, with most occurring from April through October; the creeks are often dry; and the annual yield varies over a wide range.

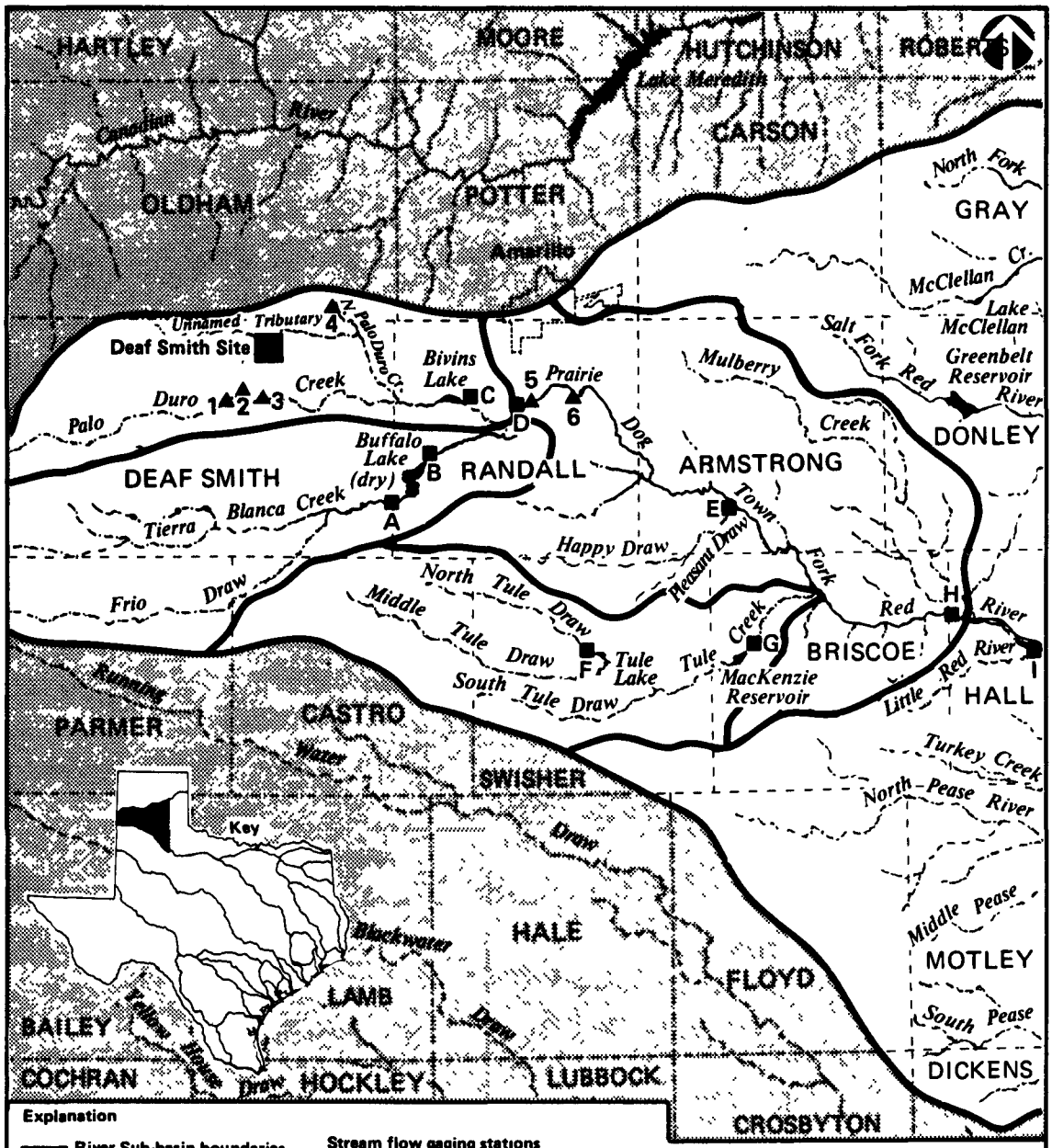
3.3.1.2 Surface-Water Quality

Tierra Blanca, Palo Duro, and Tule Creeks have water that is generally hard but otherwise of good quality (Leifeste et al., 1971, pp. 10-13, 71-75). The principal chemical constituents in surface waters are sodium, calcium, magnesium, and bicarbonate.

The playa basins on the Southern High Plains are isolated, natural retention basins that collect most of the area's runoff. Playa lake water was found to be of better quality than Ogallala ground water for many uses because the playa water had a lower pH and lower total dissolved solids (Lehman, 1972, pp. 25-26). However, agricultural runoff, industrial and municipal wastes, and feedlot runoff locally degrade the water in playa lakes.

3.3.1.3 Flooding

Major flooding occurs infrequently on the Southern High Plains. However, local intense thunderstorms can produce local flooding with rapidly rising and falling discharges (TDWR,



Source: Adapted from Hydrologic Unit Map of Texas, USGS, 1976.

Impoundments and Stream Flow Gaging Stations Near the Deaf Smith County Site

Figure 3-52

Table 3-22. Impoundments in Palo Duro Creek Drainage Basins and on Prairie Dog Town Fork of the Red River

Dam	River	Location	Impoundment, Acre-Feet Normal	Impoundment, Acre-Feet Maximum	Acres	Use[a]	Owner
Schulte Lake	Palo Duro Creek	Deaf Smith County Lat 35° 02.6' Long 102° 31.4'	32	64	10	NA	Bill Schulte
Grigsby Lake	Palo Duro Creek	Deaf Smith County Lat 35° 02.7' Long 102° 29.9'	64	128	10	I	Sam F. Grigsby
Harris and Thrush	Palo Duro Creek	Deaf Smith County Lat 35° 02.0' Long 102° 28.3'	55	75	7	I	Texas Agronomics Farming
Montgomery Lake	North Palo Duro Creek	Deaf Smith County Lat 35° 10.8' Long 102° 15.1'	26	52	5	I	Richard Montgomery
Bivins Lake	Palo Duro Creek	Randall County Lat 35° 02.2' Long 102° 01.6'	5,131	9,240	379	A	City of Amarillo
Palo Duro Club Lake	Prairie Dog Town Fork of the Red River	Randall County Lat 35° 01.2' Long 101° 52.5'	460	4,514	35	R	Palo Duro Club
Lake Tanglewood	Prairie Dog Town Fork of the Red River	Randall County Lat 35° 02.4' Long 101° 46.2'	4,897	13,275	148	R	Lake Tanglewood Inc.

(a) *NA = not specified; I = irrigation; A = aquifer recharge; R = recreation.*

Source: TNRIS, 1982b.

Table 3-23. Mean, Maximum, and Minimum Discharges for Streams in the Upper Red River Basin

Station Number	River	Drainage Area,[a] Square Miles	Period of Record	Discharge, cubic feet per second[c] Mean Annual	Peak	Minimum	Comments
07-2970-00	Palo Duro Creek (Near Canyon)	982 (920)	8/42 to 12/54 (discontinued)	3.76	(b)	(b)	200 feet upstream from Bivins Lake Dam; records represent flow into lake; lake provides recharge to Ogallala aquifer.
07-2955-00	Tierra Blanca Creek (Near Umbarger)	1,968 (1,430)	12/39 to 9/54, 3/57 to 9/73 (discontinued)	7.22	11,300 (6/6/41)	No flow at times	9 miles upstream from Buffalo Lake Dam. Creek is considered headwater of Red River.
07-2961-00	Tierra Blanca Creek (Near Umbarger)	2,075 (1,500)	3/67 to 9/73 (discontinued)	0.06	14	No flow at times	25 feet downstream from Buffalo Lake Dam; 20 miles upstream from Palo Duro Creek.
07-2980-00	North Tule Draw (Near Tulia)	189 (124)	11/40 to 9/73 (discontinued)	3.22	10,600 (6/20/65)	Water rarely released from Tule Lake Dam downstream from station	At upstream side of Tule Lake Dam; records represent flow into lake.
07-2982-00	Tule Creek (Near Silverton)	1,150 (960)	7/64 to 1983	9.24 2.44[d]	12,800 (5/20/77)	No flow at times for many days each year	1.0 mile downstream from MacKenzie Dam; flow regulated by MacKenzie Dam since 6.74.
07-2975-00	Prairie Dog Town Fork, Red River (Near Canyon)	3,369 (2,658)	1924 to 1926, 1938 to 1949, 1951 (discontinued)	11.2	15,200 (5/16/51)	(b)	1.2 miles downstream from confluence of Palo Duro and Tierra Blanca Creeks; 2 miles upstream from Palo Duro Club Dam; partly regulated by Bivins Lake and Buffalo Lake.
07-2979-10	Prairie Dog Town Fork, Red River (Near Wayside)	4,211 (3,281)	10/67 to 1983	26.5	58,000 (8/28/68)	No flow at times	Several small diversions above station.
07-2985-00	Prairie Dog Town Fork, Red River (Near Brice)	6,082 (4,501)	1/39 to 6/44, 9/49 to 7/51, 12/59 to 5/63 (discontinued)	85.0	49,000 (6/7/60)	No flow for many days each year	Several small diversions above stations.
07-2992-00	Prairie Dog Town Fork, Red River (Near Lakeview)	6,792 (4,769)	5/63 to 9/80 (discontinued)	76.1	95,000 (5/20/77)	No flow at times	

(a) Values in parentheses indicate drainage area probably not contributing.
(b) Not given in source.
(c) Before completion of MacKenzie Dam.
(d) After completion of MacKenzie Dam.

Sources: Hendricks, 1964; Patterson, 1964; USGS, 1972, 1979, 1984a, 1984b.

Table 3-24. Monthly Mean, Maximum, and Minimum Discharges for Streams in the Upper Red River Basin

Station Number	River		Mean Discharge, acre-feet[a]												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
07-2955-00	Tierra Blanca Creek	Max.	246	222	292	1,220	23,750	26,060	4,330	2,360	4,150	15,170	871	493	67,739
		Min.	0	0	.30	0	0	0	0	0	0	0	0	0	115
		Mean	81.1	72.5	79.5	165	2,462	1,847	409	274	380	1,314	103	94.5	7,282
07-2970-00	Palo Duro Creek	Max.	96.0	75.0	101	143	10,460	438	3,750	1,220	621	2,690	222	97.0	12,261
		Min.	6.10	11.0	18.0	18.0	12.0	0	0	0	0	0	6.0	6.10	314
		Mean	54.3	50.9	53.9	57.2	1,048	108	406	234	141	390	64.3	58.6	2,666
07-2975-00	Prairie Dog Town Fork, Red River	Max.	491	924	1,090	664	3,440	31,930	2,370	1,900	1,880	26,560	2,860	506	66,283
		Min.	0	0	0	0	0	0	0	0	0	0	0	0	206
		Mean	108	148	163	159	977	2,585	597	206	172	2,5665	324	78.9	8,083
07-2979-10	Prairie Dog Town Fork, Red River	Max.	639	203	1,380	5,800	29,020	7,620	4,780	86,720	6,550	5,900	3,090	439	100,526
		Min.	18.0	9.2	21.0	10.0	67.0	86.0	0.02	186	0	0	4.0	6.10	2,865
		Mean	134	91.0	304	775	4,560	2,924	1,391	8,938	1,541	1,088	443	112	22,301
07-2980-00	North Tule Draw	Max.	408	348	288	856	8,680	13,230	3,960	1,970	397	4,500	563	489	13,308
		Min.	0	0	0	0	0	0	0	0	0	0	0	0	18.9
		Mean	16.2	14.3	13.3	49.6	379	940	233	120	42.4	420	22.2	21.8	2,272
07-2982-00	Tule Creek	Max.	107	85.0	121	221	5,100	25,110	1,020	5,530	2,480	534	113	76.0	26,994
		Min.	1.70	1.90	1.00	0	2.40	20.0	0	0	0	0	0	0	352
		Mean	28.5	33.6	31.9	49.0	519	2,515	249	440	414	85.0	31.9	25.2	4,422
07-2985-00	Prairie Dog Town Fork, Red River	Max.	1,310	452	775	7,830	81,700	73,250	41,200	9,280	14,190	63,840	6,060	2,230	188,903
		Min.	0	0	0	0	25.0	2,470	0	0	0	0	0	0	20,152
		Mean	382	125	187	1,158	11,811	16,302	11,761	4,817	4,135	12,105	1,518	643	64,944

Source: TWRIS, 1982c

1984, p. III-2-1). Flash flooding is a local hazard, especially on the floors of canyons cut into the Caprock Escarpment (Finley and Gustavson, 1980, p. 10). The peak discharges recorded in the area are shown in Table 3-23.

The heavy precipitation that fell in the Palo Duro and Tierra Blanca Creek drainage basins on May 26, 1978 is typical of a local intense thunderstorm in the area. The storm produced a 24-hour precipitation of 129.5 millimeters (5.1 inches) at Canyon and 71.1 millimeters (2.8 inches) at Buffalo Lake, 16 kilometers (10 miles) southwest of Canyon. This heavy precipitation produced a flash flood along Prairie Dog Town Fork of the Red River, with an estimated peak discharge at the Wayside gaging station of 1,310 cubic meters per second (46,400 cubic feet per second) and at the Lakeview gaging station of 1,610 cubic meters per second (56,800 cubic feet per second). The peak flood elevation at water crossing No. 1 in Palo Duro Canyon State Park was estimated to be 4.2 meters (13.7 feet) as indicated by flood debris studies (Finley, 1979, pp. 69, 70; USGS, 1979, pp. 54, 64).

The extent of the floodplains for the 48-hour 100-year, 500-year, and probable maximum floods was determined for Palo Duro Creek near the site (NUS, 1985a). In order to provide a conservative estimate of flood levels in the creek, it was assumed that the entire drainage area, including playa basins, contributes flow to the creek channels. It was also assumed that there were no infiltration losses and that all rainfall appears as runoff. Basin and channel geometry were estimated from U.S. Geological Survey topographic maps.

The 25-, 50-, and 100-year rainfall depths were estimated from regional rainfall-frequency maps (Hershfield, 1961, pp. 12-56; Miller, 1964, pp. 9-11; Frederick et al., 1977, pp. 14-28). The 500-year rainfall depths were estimated by extrapolation using the Extreme Value Type 1 (Gumbel) distribution (NBS, 1953, pp. 2, 3, 17, 18). Regional probable maximum precipitation (PMP) maps were used to estimate the all-season PMP depths (Schreiner and Riedel, 1978, pp. 42, 43, 48-77). Flood hydrographs were determined using the rainfall-runoff model developed by the Soil Conservation Service for ungaged drainage basins (Bureau of Reclamation, 1977, pp. 64-81, 527-544). Computations were made with the HEC-1 Flood Hydrograph Package computer program developed by the U.S. Army Corps of Engineers (1981a, pp. 8-33). The rainfall depths and peak discharges for Palo Duro Creek are shown on Figure 3-53. The 100-year, 500-year, and probable maximum floods produce an estimated maximum discharge of 3,925, 4,848 and 16,067 cubic meters per second (138,600, 171,200, and 567,400 cubic feet per second).

The water-surface elevations for the floods in the creek channels were computed using the HEC-2 Water Surface profiles computer program developed by the U.S. Army Corps of Engineers (1981b, pp. 3-16). The floodplains for the 500-year and probable maximum floods are shown on Figures 3-54 and 3-55, respectively. The water elevation for the 100-year flood is about 0.3 to 0.6 meter (1 to 2 feet) below 500-year flood elevation. It was assumed that the playas will be filled with water for these extreme floods.

3.3.2 Ground Water

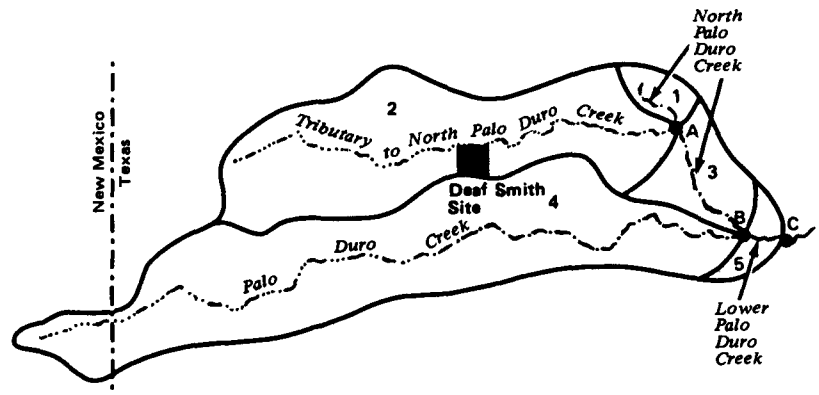
3.3.2.1 Hydrology and Modeling

Calculation of seepage velocities within the major hydrostratigraphic units is needed to characterize the basin and site flow regimes. This is done assuming Darcian flow:

$$V = -\frac{ki}{n_e}$$

where

V = seepage velocity
k = hydraulic conductivity
i = flow gradient
n_e = effective porosity.



Subbasin	Area (sq. mi.)	48-Hour Precipitation (inches)		
		100-Year	500-Year	PMP
1	27	6.99	8.60	35.43
2	256	6.67	8.21	28.21
3	50	6.89	8.48	33.60
4	434	6.66	8.20	26.07
5	16	7.05	8.67	37.19

Operation	100-Year Flood		500-Year Flood		PMF	
	Peak Flow (ft^3/s)	Time of Peak (hrs)	Peak Flow (ft^3/s)	Time of Peak (hrs)	Peak Flow (ft^3/s)	Time of Peak (hrs)
Hydrograph in 1	17,600	27.0	21,600	27.0	78,100	42.5
Hydrograph in 2	58,800	35.0	67,300	35.0	236,200	50.0
2 combined at A	56,600	35.0	69,500	35.0	243,400	49.5
Routed A to B	54,800	37.0	67,800	37.0	239,200	51.0
Hydrograph in 3	25,500	27.5	31,200	27.5	118,000	43.0
2 combined at B	58,200	36.5	72,300	36.5	279,900	44.0
Hydrograph in 4	80,500	37.5	98,900	37.5	318,800	52.0
2 combined at B	138,500	37.0	170,800	37.0	567,900	51.0
Routed B to C	138,071	38.0	170,400	37.5	567,100	51.5
Hydrograph in 5	14,400	26.0	17,600	26.0	58,100	41.5
2 combined at C	138,600	38.0	171,200	38.0	567,400	51.5

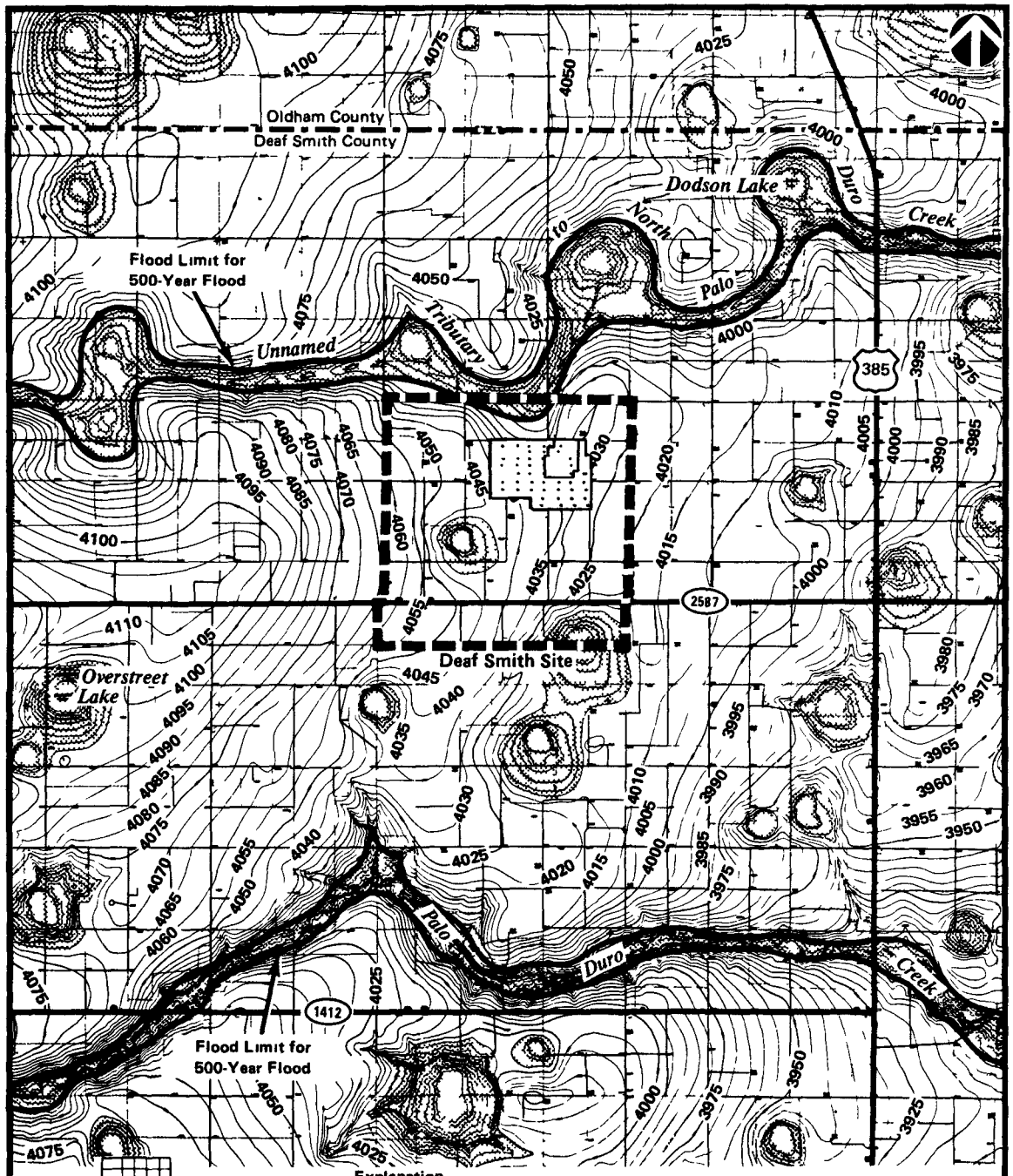
0 5 10 15 20 25 30 Kilometers

0 5 10 15 20 Miles

Source: NUS, 1985, BMI/ONWI-574.

HEC-1 Computer Program Inputs and Outputs for Palo Duro Creek Drainage Basin

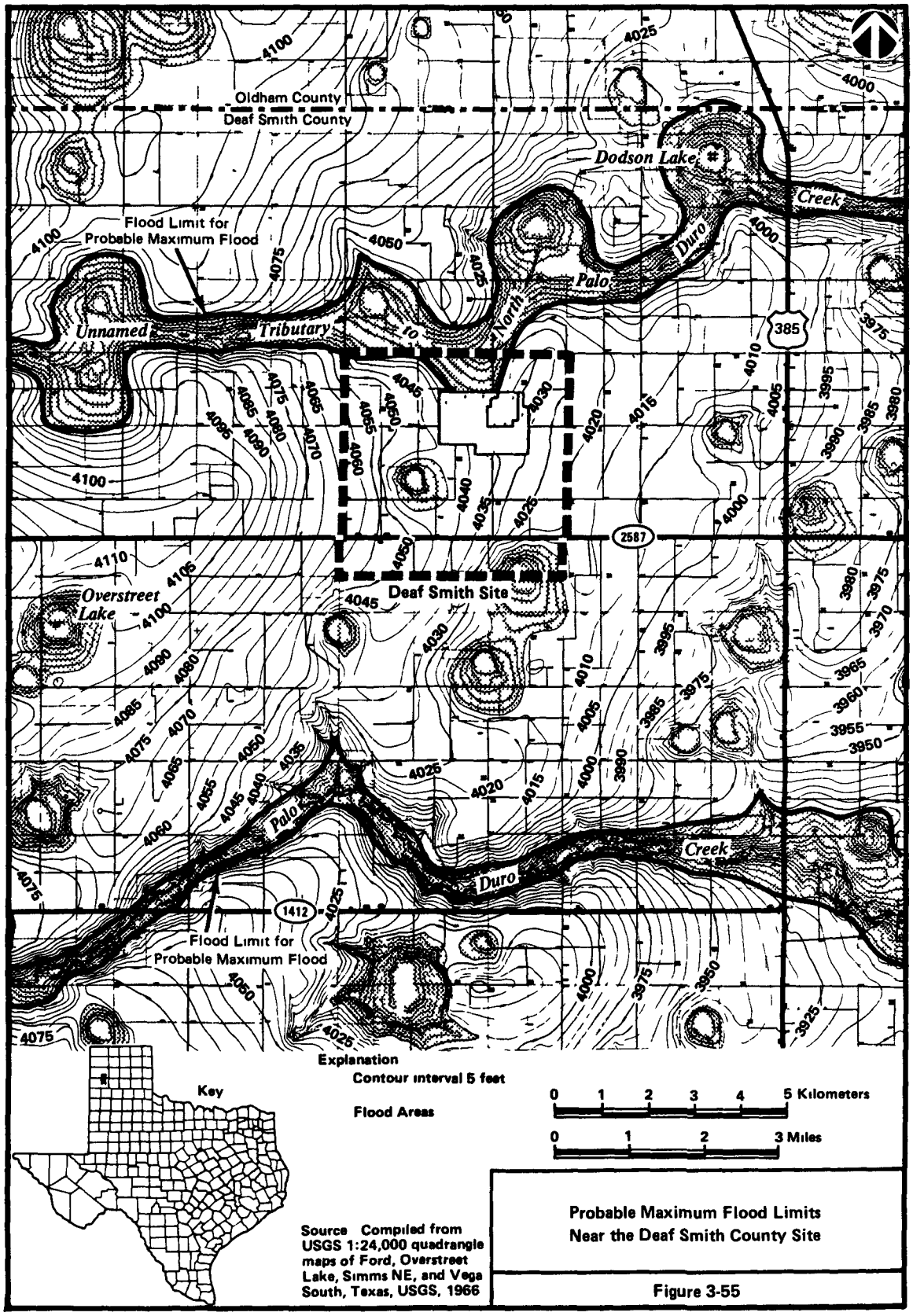
Figure 3-53



Source: Compiled from USGS 1:24,000 quadrangle maps of Ford, Overstreet Lake, Simms NE, and Vega South, Texas, USGS, 1966

500-Year Flood Limits
Near the Deaf Smith County Site

Figure 3-54



Probable Maximum Flood Limits
Near the Deaf Smith County Site

Figure 3-55

The following sections describe the hydrologic characteristics of the major geologic units in the Palo Duro Basin and at the Deaf Smith County site. Measured values of conductivity, gradient, and effective porosity are reported. Where basin-specific values for these parameters are not available, they are estimated.

3.3.2.1.1 Regional Hydrostratigraphic Units. In order to evaluate site hydrogeologic conditions in the context of repository integrity and performance, it is necessary to understand basinwide hydrogeologic conditions. Atwood et al., (1985) modeled basin flow using a profile consisting of 23 hydrogeologic units. The units were determined from geophysical well logs and drill-stem tests, and were defined entirely by lithology and hydrologic properties. Boundaries of the hydrogeologic units were not based on time-stratigraphic relationships and do not necessarily coincide with contacts of stratigraphic units. The resulting flow net tends to validate a gross breakdown of the basin into the three major hydrostratigraphic units shown in Figure 3-56. The grouping of the geologic units described in Section 3.2.3 into these regional hydrostratigraphic units is based on regional lateral continuity and similarity of permeability, lithology and recharge-discharge relationships. This grouping into three hydrostratigraphic units is for the purpose of explaining the major hydrogeologic features of the basin. Within each of these units are differences in flow characteristics that affect directions and rates of flow within individual hydrogeologic units. This hydrostratigraphic grouping was first described by Bassett et al. (1981) and in detail by Bair et al., (1985, BMI/ONWI-566). Sources of data include work for the Office of Civilian Radioactive Waste Management (OCRWM) program, previous studies by other researchers, and reduction of petroleum-exploration data.

Shallow Freshwater Flow System (HSU A). Hydrostratigraphic unit A (HSU A) comprises Triassic through Quaternary formations (Section 3.2.3; Figure 3-56). The principal aquifers of HSU A are the uppermost unconfined Ogallala and the Dockum. Thousands of irrigation, stock, and domestic wells tap these aquifers, the main source of potable water on the High Plains. The Texas Department of Water Resources (TDWR) and other Texas agencies keep detailed records of wells drilled in the Ogallala and Dockum and monitor water levels and water chemistry.

Hydraulic conductivity and permeability data summarized from Myers (1969) and Knowles et al. (1982) for the Ogallala are listed in Table 3-25. The Myers data are from single-well pump tests. TDWR data from lab analyses of core indicate that permeabilities range from 1.3 to 44 darcys. Dockum permeabilities cannot be summarized because of insufficient data. However, Duffin (1984) reports the results of one pumping test conducted in Deaf Smith County that indicated an average transmissivity of 22,000 gallons per day per foot and an average storage coefficient of 0.0001. These values may not represent the hydraulic characteristics of the Dockum at the site because of differences in thickness and character of the formation.

The effective porosity of an unconfined aquifer is equivalent to specific yield (Todd, 1959, p. 23). Cronin (1961, pp. 45-46) cites Ogallala porosity and permeability studies by several researchers. Based on these studies, Cronin accepts an average Ogallala specific yield of 15 percent. Core analyses by Knowles et al. (1982) report specific yields from 7.23 to 19.54 percent, with an average of 16.06 percent. Average neutron porosities for the Dockum from the Mansfield No. 1 and J. Friemel No. 1 wells are given in Table 3-13 (Section 3.2.6).

Knowles et al. (1982, p. 51) estimate an average velocity of ground-water flow of 65 meters (213 feet) per year in the Ogallala aquifer. Flow velocities in the Ogallala, computed from gradients estimated from Figure 3-57, as well as TDWR estimates of hydraulic conductivity and effective porosity, yield ranges of velocity from 23 to 52 meters (76 to 170 feet) per year. Flow gradients range from approximately 1.25×10^{-3} to 3×10^{-3}. Regional Ogallala ground-water flow is to the southeast (Figure 3-57).

The permeable sandstones and conglomerates in the Dockum Group are less continuous and thinner than those in the Ogallala. The Dockum Group has a terrestrial origin. Thus, it is difficult to trace specific permeable zones laterally because of their lenticular character and because similar beds commonly occur at different horizons (Bair, 1985; Fink, 1963; McGowen et al., 1979). Figure 3-58 represents an approximation of the regional Dockum potentiometric

ERA	SYSTEM	SERIES	GROUP	FORMATION	HYDROSTRATIGRAPHIC UNIT (HSU)
CENOZOIC	QUATERNARY			RECENT FLUVIAL AEOLIAN AND LACUSTRINE DEPOSITS	FRESHWATER FLOW SYSTEM *HSU A*
	TERTIARY			OGALLALA AND LACUSTRINE DEPOSITS	
MESOZOIC	CRETACEOUS	COMANCHE	WASHITA FREDRICKSBURG		
			TRINITY		
	TRIASSIC		DOCKUM	TRUJILLO (Santa Rosa)	
				TECOVAS	
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE (Quartermaster)	SHALE AND EVAPORITE AQUITARD *HSU B*
				ALIBATES	
		GUADALUPE	ARTESIA (WHITEHORSE)	SALADO - TANSILL	
				YATES	
				SEVEN RIVERS	
				QUEEN-GRAYBURG	
			PEASE RIVER	SAN ANDRES (BLAINE)	
		LEONARD		GLORIETA	
			CLEAR FORK	UPPER CLEAR FORK	
				TUBB	
				LOWER CLEAR FORK	
				RED CAVE	
			WICHITA		
		WOLFCAMP			DEEP-BASIN FLOW SYSTEM *HSU C*
	PENNSYLVANIAN	VIRGIL	CISCO		
		MISSOURI	CANYON		
		DES MOINES	STRAWN		
		ATOKA	BEND		
		MORROW			
	MISSISSIPPIAN	CHESTER			
		MERAMEC			
		OSAGE			
	ORDOVICIAN	CANADIAN	ELLENBURGER		
	CAMBRIAN		UNNAMED SANDSTONE		
	PRECAMBRIAN				

Explanation

~~~~~~~~ Unconformity

– – – – – Boundary in Dispute

Source: Bair et al., 1985, BMI/ONWI-566.

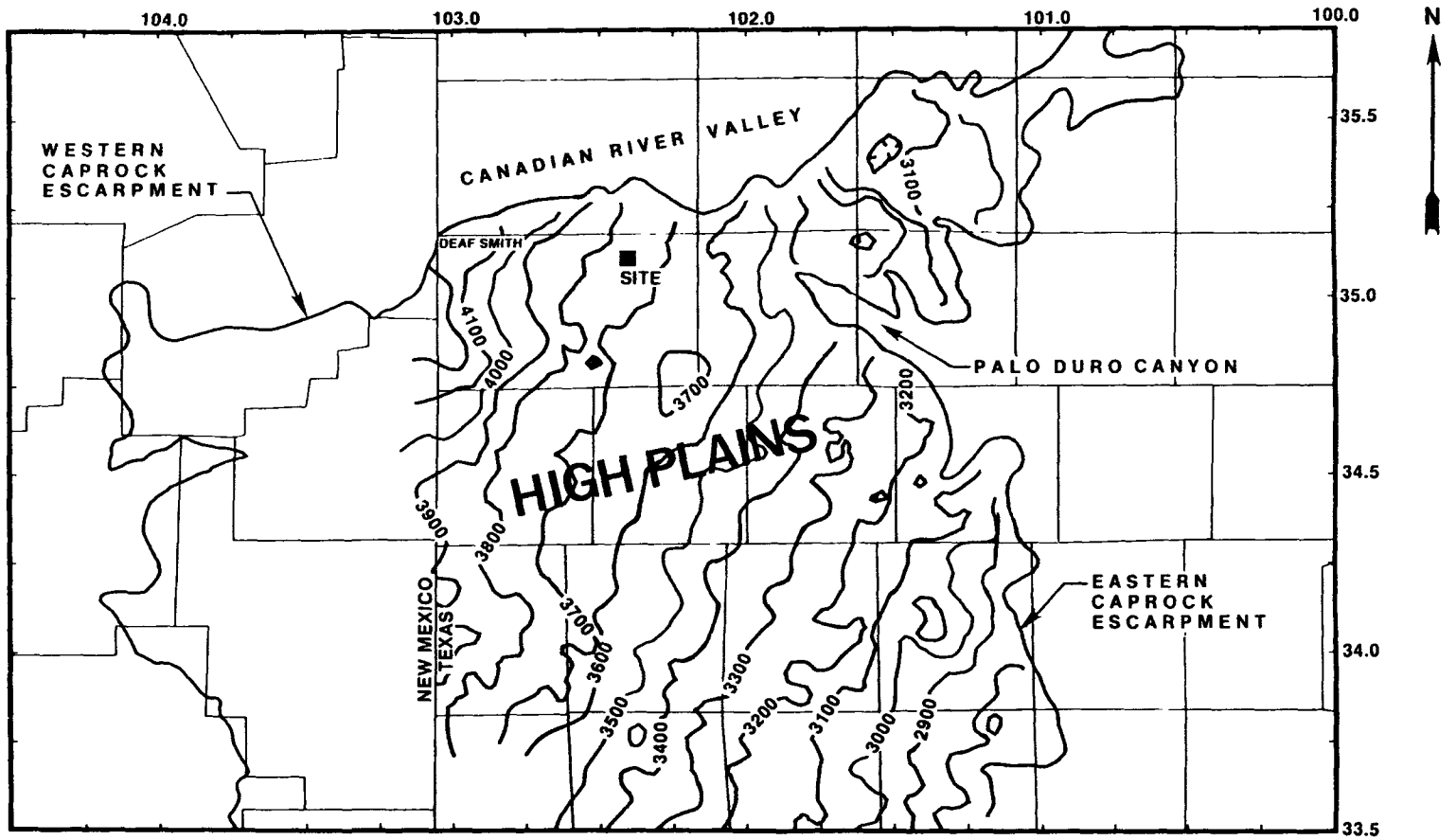
Generalized Hydrostratigraphic Column for the Palo Duro Basin

Figure 3-56
~~~~~~~~

Table 3-25. Permeability and Hydraulic Conductivity of the Ogallala Formation

County	Number of Wells	Conductivity[a] (GPD/ft^2) K_{min}	Avg. K	K_{max}	Permeability[a] (Darcys)[b] D_{min}	Avg. D	D_{max}	Conductivity[c] (GPD/ft^2)	Permeability[c] (Darcys)[b]
Armstrong	1	--	112	--	--	6.2	--	41.8	2.3
Bailey	39	33	369	1920	1.8	20.3	105.5	37.4	4.8
Briscoe	4	8	151	457	0.5	8.3	25.1	--	--
Castro	45	28	159	343	1.5	8.7	18.9	101.9	5.6
Crosby	10	14	52	107	0.8	2.9	5.9	193.8	7.9
Deaf Smith	43	34	224	619	1.9	12.3	34.0	103.7	5.7
Floyd	58	31	140	619	1.7	7.7	34.0	80.1	4.4
Hale	34	52	142	1935	2.4	7.8	106.3	273.0	15.0
Hockley	19	48	270	1263	2.6	14.8	64.4	23.7	1.3
Lamb	31	59	226	884	3.2	12.4	48.6	163.8	9.0
Lubbock	33	30	300	1200	1.7	16.5	65.9	800.8	44.0
Parmer	31	60	290	2219	3.3	15.9	121.9	143.8	7.9
Randell	14	94	316	1695	5.2	17.4	93.1	29.1	1.6
Swisher	34	81	269	537	4.5	19.8	29.5	36.4	2.0

(a) From Myers, 1969.
(b) Assumes ground water at 60 F.
(c) From Knowles et al., 1982.



CONTOUR INTERVAL: 100 FEET

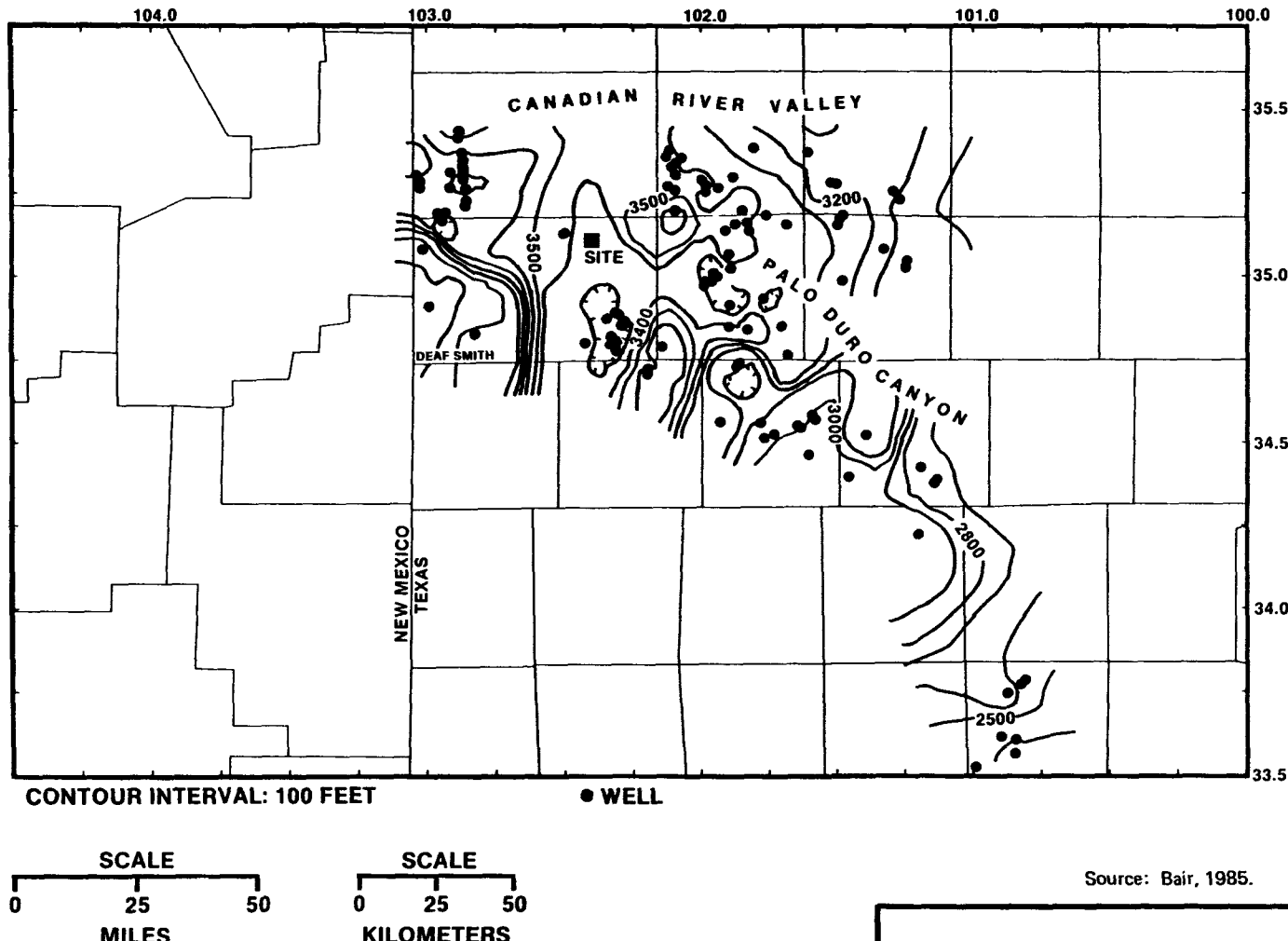
SCALE
0 25 50
MILES

SCALE
0 25 50
KILOMETERS

Source: Bair, 1985.

Ogallala Potentiometric Surface
1979 - 1981

Figure 3-57



Source: Bair, 1985.

Approximate Dockum Potentiometric Surface

Figure 3-58

surface, and shows that water generally moves in an east-southeast direction (Bair, 1985). The Dockum has not been as extensively pumped as the Ogallala. Historic water-level data show that although water levels in the Dockum have declined as much as 6.1 to 15.2 meters (20 to 50 feet) around local pumping centers, on a regional basis, water levels have not declined significantly. Flow velocities for the Dockum have not been computed but are presumed to be lower than those of the more permeable Ogallala.

In the Northern High Plains, north of the Canadian River, recharge to HSU A is by precipitation and underflow from New Mexico (Alexander, 1961, p. 15). Theis (1937) estimated Ogallala recharge to be 0.44 centimeter (0.175 inch) per year. Bell and Morrison (1980, p. 4) assume 1.27 centimeters (0.5 inch) per year due to natural recharge, plus 10 percent of this value for recirculation of irrigation water. On the Southern High Plains, south of the Canadian River, the Ogallala is isolated from recharge to the north by the river valley; recharge is solely from precipitation.

Recharge to the Dockum occurs predominantly from downward leakage from the Ogallala. Water levels in the Ogallala are as much as 122 meters (400 feet) higher than water levels in the Dockum, indicating the potential for downward flow into the Dockum (Bair, 1985).

The most significant source of discharge of HSU A is through pumping. Therefore, the saturated thickness of the Ogallala in the Texas Panhandle has shown a significant decline. The regional saturated thickness ranges from 0 to 100 meters (0 to 350 feet) in the Ogallala. Popkin (1973, p. 10) estimates that discharge of the Ogallala in Donley County is 3.8 times larger than recharge. Muller and Price (1979, Table 1) estimate that discharge from the entire Ogallala between 1980 and 1989 will be more than 15 times recharge.

The Dockum is fully saturated where it is overlain by saturated Ogallala, but partially saturated where it crops out along the Eastern Caprock Escarpment and the Canadian Breaks. In New Mexico, the partially saturated Dockum crops out at the Western Caprock Escarpment, in the Pecos River Valley, and in the Conchos River Valley. Dockum thicknesses range from 120 to 300 meters (400 to 1,000 feet).

Shale and Evaporite Aquitard (HSU B). HSU B consists of the Leonardian through Ochoan Series Permian rock (Section 3.2.3; Figure 3-56). It is composed of thick sequences of shale, siltstone, carbonates, and evaporites. HSU B is not a source of water for any use. The permeability of HSU B is extremely low and the unit is characterized by nearly vertical downward flow gradients (Smith, 1983; Bassett and Bentley, 1983). It is a regional aquitard separating the shallow freshwater flow system (HSU A) from the deep-basin brine flow system (HSU C).

Information regarding permeability, porosity, saturated thickness, and flow rates in HSU B is limited. Permeabilities have been derived from drill stem tests (DSTs), pump tests, repeat formation tests (RFTs), and core analyses. Porosities have been derived from geophysical logs and core analyses.

Horner plot analyses of DST data from the DOE wells provide seven permeabilities in HSU B (Table 3-26). Horner plot analysis involves plotting formation pressure versus time recorded during DSTs from a particular stratigraphic interval. RFTs also measure pressure versus time, but for a much smaller formation interval. Using test data in wildcat wells, 150 permeability analyses of the Lower San Andres Carbonate of HSU B have been performed (SWEC, 1984, BMI/SRP-5012). These tests are biased toward high permeabilities because tested rock was from the most permeable zones encountered during drilling.

Six of the seven Horner plot analyses in HSU B were from the Lower San Andres Unit 4 Carbonate and ranged from 0.01 to 0.3 millidarcy. The seventh analysis was from the Queen Grayburg formation and indicated 1.56 millidarcy (Table 3-26). Seven analyses of repeat formation tests in Lower San Andres Unit 4 range from 0.03 to 3.05 millidarcys, with a geometric mean of 0.14 millidarcy. An analysis of the 150 Lower San Andres limited DST data mentioned above indicates a median permeability of 0.25 millidarcy.

Figure 3-59 shows the lognormal distribution of these data. No permeability testing of the predominant shales and evaporites of HSU B has been done. However, generic permeability values for shale are reported to range from 10^{-5} to 10^{-1} millidarcy (Freeze and Cherry, 1979, Table 2-2). In situ permeabilities of Salado salt near Los Medaños, New Mexico, are reported to range from 0.03 to 0.0007 millidarcy (Isherwood, 1981, Table 3-9, p. 194).

Porosities for parts of HSU B have been determined from analyses of geophysical logs and core samples and are reported in Section 3.2.6. Reported porosities range from less than one percent to greater than 10 percent. Much of the porosity in HSU B is plugged with salt transported and reprecipitated by ground water (Dutton et al., 1982, p. 51).

If flow does exist in HSU B, it will be downward toward HSU C, due to the underpressured nature of HSU C. Formation pressures throughout HSU B are also lower than expected hydrostatic pressures, and hydrostatic heads in HSU B are lower than those in HSU A, with possible local exceptions. Bassett et al. (1981) and Bair (1985) conclude that the potential exists for downward flow at very low velocities through HSU B. Smith (1983), Senger and Fogg (1984), and Wirojanaqud et al. (1984) also demonstrated with two-dimensional, finite-element flow models that regional flow through HSU B would be downward.

Because HSU B lies below the water table established by HSU A, it can be assumed that HSU B is saturated. The amount of fluid in a saturated rock is directly related to the rock's pore space. Thus the evaporite sequence of HSU B, with extremely low porosity, contains very little fluid. A vertical gradient "i_z" across HSU B can be calculated, but must take into consideration the increased density of the ground water in this unit because of a high dissolved solids content. Figure 3-60 is a vertical gradient map from the base of the Dockum group to the top of the Wolfcamp formation. Calculation of the gradient is based on the concept of Environmental Water Head (Lusczynski, 1961) and assumes a specific gravity of 1.20 for HSU B ground water. The map indicates a downward gradient throughout the region. Using these gradient values, flow rates across HSU B can be estimated where localized values of hydraulic conductity and effective porosity can be ascertained.

Deep-Basin Flow System (HSU C). HSU C, the deep-basin flow system, comprises Permian Wolfcamp Series, Pennsylvanian, Mississippian, Ordovician, and Cambrian rock (Figure 3-56). It is bounded by HSU B above and by Precambrian crystalline rock below.

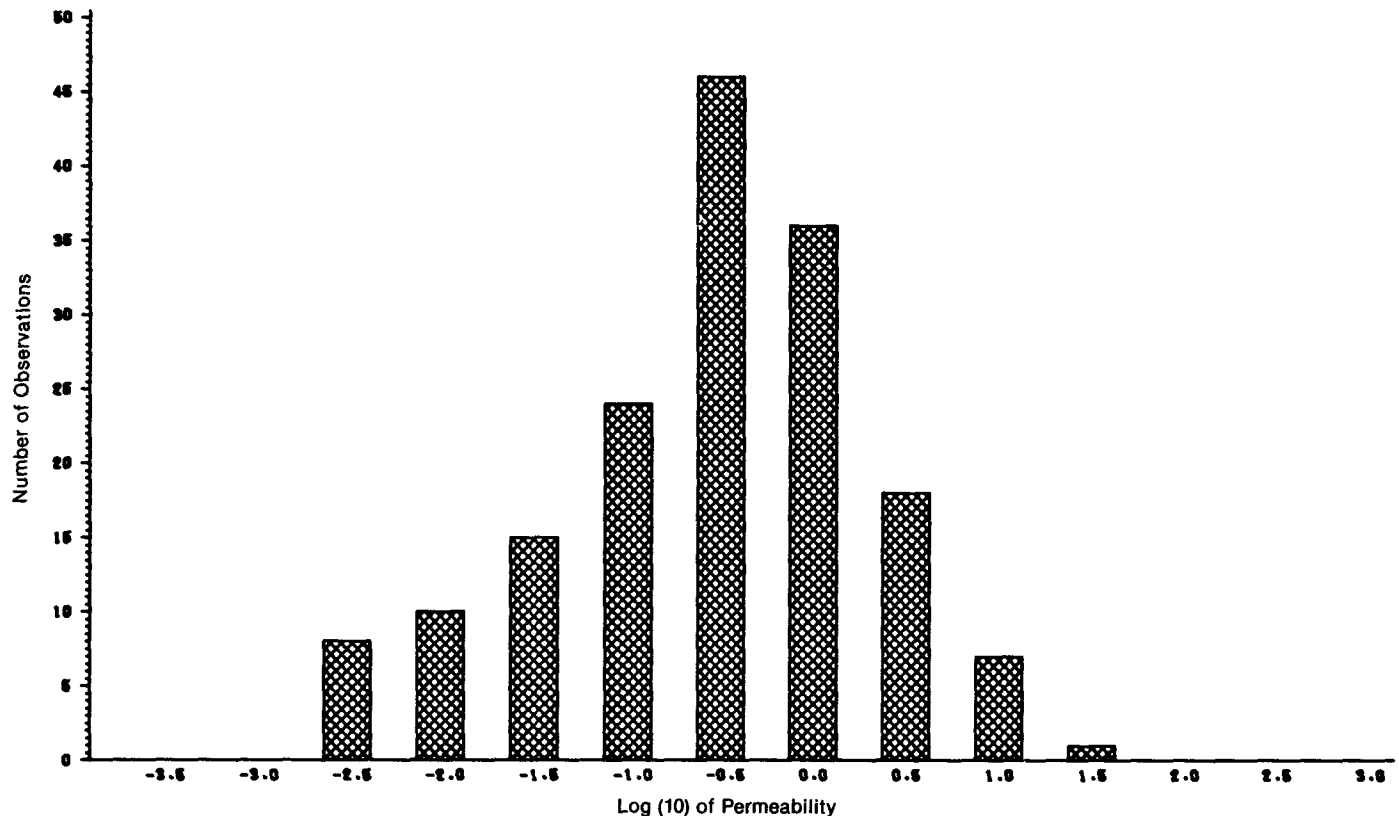
The transmissive units within HSU C are the Wolfcamp carbonates and "granite wash" and the Pennsylvanian marine-shelf carbonates and granite wash. Granite wash occurs along the flanks of the uplifts that border the study area and spread into the basin, interfingering with marine carbonates. Reef- and shelf-margin carbonates, particularly those which have been dolomitized, are often highly porous and permeable (Dutton et al., 1982, p. 17).

Flow within HSU C is predominantly northeastward. The Wolfcamp Series and Pennsylvanian rock have been studied separately, and potentiometric-surface maps have been constructed for each (Figures 3-61 and 3-62), because each unit is regionally continuous and contains rock of relatively consistent permeability. These potentiometric surfaces were constructed from formation pressure data obtained from drill-stem tests (DSTs). Results of transient, depressured DSTs from oil and gas production zones were culled from the data sets used to construct these pre-production steady-state surfaces (Bair et al., 1985, BMI/ONWI-566). The horizontal hydraulic gradient in the Wolfcamp and the Pennsylvanian potentiometric surfaces in the Deaf Smith County site area are not significantly altered by incorporation of these transient pressures because almost all of the depressured DSTs occur along the Amarillo and Matador uplifts (Figures 3-63 and 3-64). Consequently, the horizontal hydraulic gradient in these aquifers and the vertical hydraulic gradient across HSU B in the Deaf Smith County area are unaffected by transient affects of oil and gas production in the Palo Duro Basin area. HSU C is an underpressured hydrologic unit because in no area does its potentiometric surface rise to the level of the Ogallala water table. Hydrostatic heads in HSU C are also lower than those of HSU B.

Bair et al. (1985, BMI/ONWI-566) and INTERA (1984, ONWI-504) have separated HSU C into the Permian Wolfcamp Series and Pennsylvanian Systems. A limited amount of data is available

Table 3-26. Drill-Stem and Pump Test Permeability Data for OCRWM Program Wells

Well/County	Test Type	Depth (ft)	Formation/Lithology	Permeability (md)
Mansfield/Oldham	DST	4800-4996	Wolfcamp/limestone (HSU C)	26.6
	DST	4812-4840	Wolfcamp/limestone (HSU C)	11.6
	DST	6612-6640	Pennsylvanian/- (HSU C)	8.8
	Pump Test	4514-4638	Wolfcamp/limestone (HSU C)	0.5
	Pump Test	4818-4890	Wolfcamp/limestone (HSU C)	4.3
Sawyer/Donley	DST	2950-3123	Wolfcamp/dolomite (HSU C)	0.2
	Pump Test	3172-3189	Wolfcamp/- (HSU C)	6.1
	Pump Test	4250-4342	Pennsylvanian/granite wash (HSU C)	2.7
	Pump Test	4450-4535	Mississippian/limestone (HSU C)	5.4
	Pump Test	4604-4640	Ellenberger/- (HSU C)	0.3
J. Friemel/Deaf Smith	DST	5630-5909	Wolfcamp/dolomite (HSU C)	1.0
	Pump Test	5809-5926	Wolfcamp/carbonate (HSU C)	1.0
	Pump Test	7300-7329	Pennsylvanian/carbonate (HSU C)	100.0
	Pump Test	7707-7734	Pennsylvanian/granite wash (HSU C)	500.0
	Pump Test	7590-7904	Pennsylvanian/granite wash (HSU C)	10.0
	Pump Test	8040-8050	Pennsylvanian/granite wash (HSU C)	150.0
	Pump Test	8122-8137	Pennsylvanian/granite wash (HSU C)	150.0
	Pump Test	8168-8204	Pennsylvanian/granite wash (HSU C)	50.0
Zeeck/Swisher	DST	2927-2972	Lower San Andres 4/carbonate (HSU B)	0.3
	DST	5365-5542	Wolfcamp/carbonate (HSU C)	6.8
	DST	7146-7225	Pennsylvanian/limestone (HSU C)	2.8
	Pump Test	5470-5550	Wolfcamp/limestone (HSU C)	6.0
	Pump Test	5603-5640	Wolfcamp/limestone (HSU C)	0.1
	Pump Test	7140-7230	Pennsylvanian/carbonate (HSU C)	6.4
	Pump Test	2930-2970	Lower San Andres 4/carbonate (HSU B)	0.18
Detten/Deaf Smith	DST	2749-2839	Lower San Andres 4/carbonate (HSU B)	0.2
G. Friemel/Deaf Smith	DST	2600-2710	Lower San Andres 4/carbonate (HSU B)	0.1
Harmon/Swisher	DST	2840-2906	Lower San Andres 4/limestone (HSU B)	0.01
	DST	2830-3050	Lower San Andres 4/carbonate (HSU B)	0.2
Holtzclaw/Randall	DST	1718-1764	Queen-Grayburg/siltstone (HSU B)	1.56



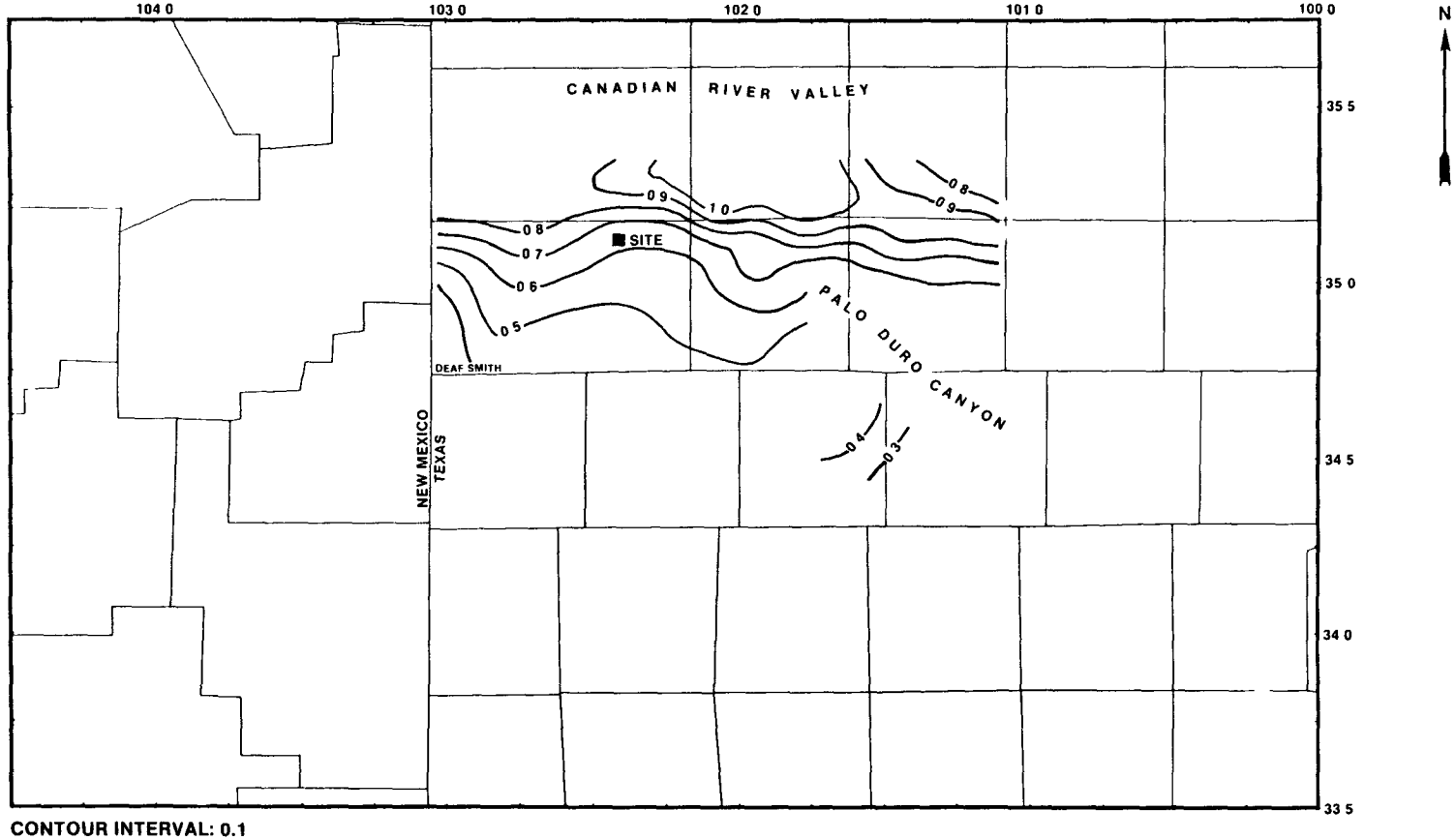
Explanation

Log (10) of Permeability Represents
Midpoints of Permeability Values
in 0.5 Log Increments

Source: SWEC, 1984, BMI/SRP-5012.

Formation Log Normal Permeability Distribution Lower San Andres Formation

Figure 3-59



CONTOUR INTERVAL: 0.1

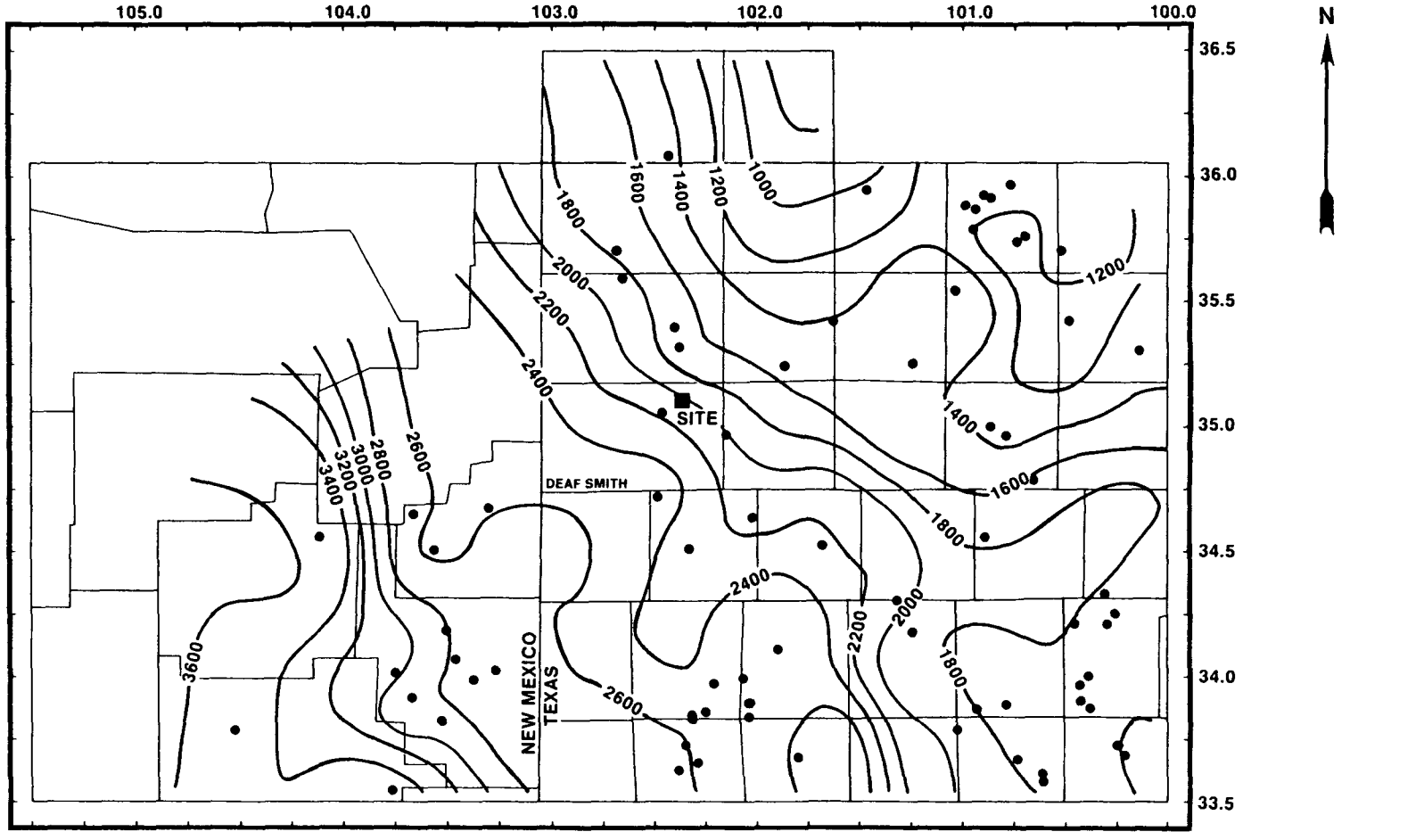
SCALE
0 25 50
MILES

SCALE
0 25 50
KILOMETERS

Source SWEC Sketch 13697-71-C-1

Dockum to Wolfcamp
Gradient Contours Based on
Environmental Heads

Figure 3-60



CONTOUR INTERVAL: 200 FEET

● DST WELL

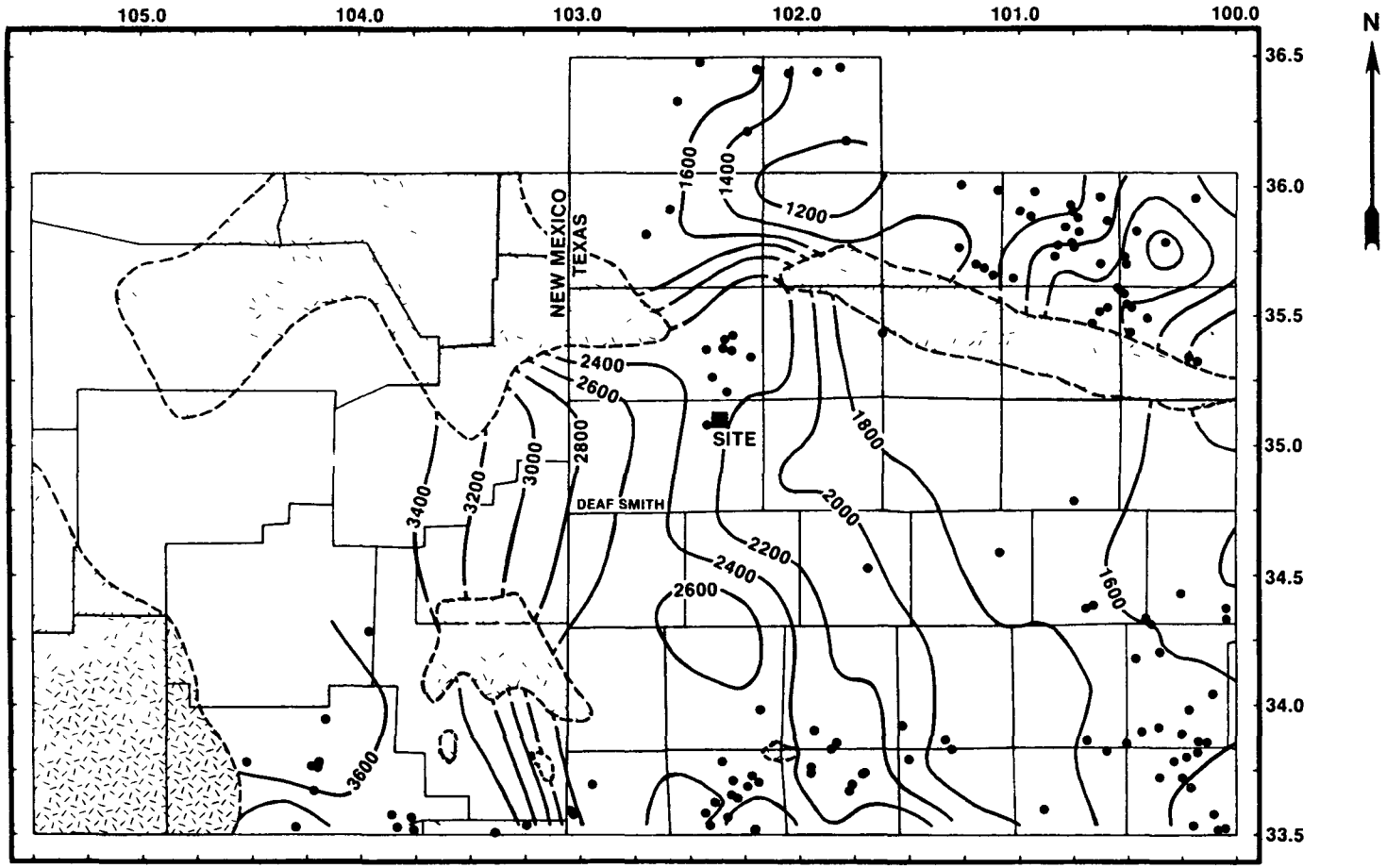
Source: Bair et al., 1985, BMI/ONWI-566.

SCALE
0 30 60
MILES

SCALE
0 30 60
KILOMETERS

Wolfcamp
Potentiometric Surface

Figure 3-61



CONTOUR INTERVAL: 200 FEET

● DST WELL

PENNSYLVANIAN ABSENT

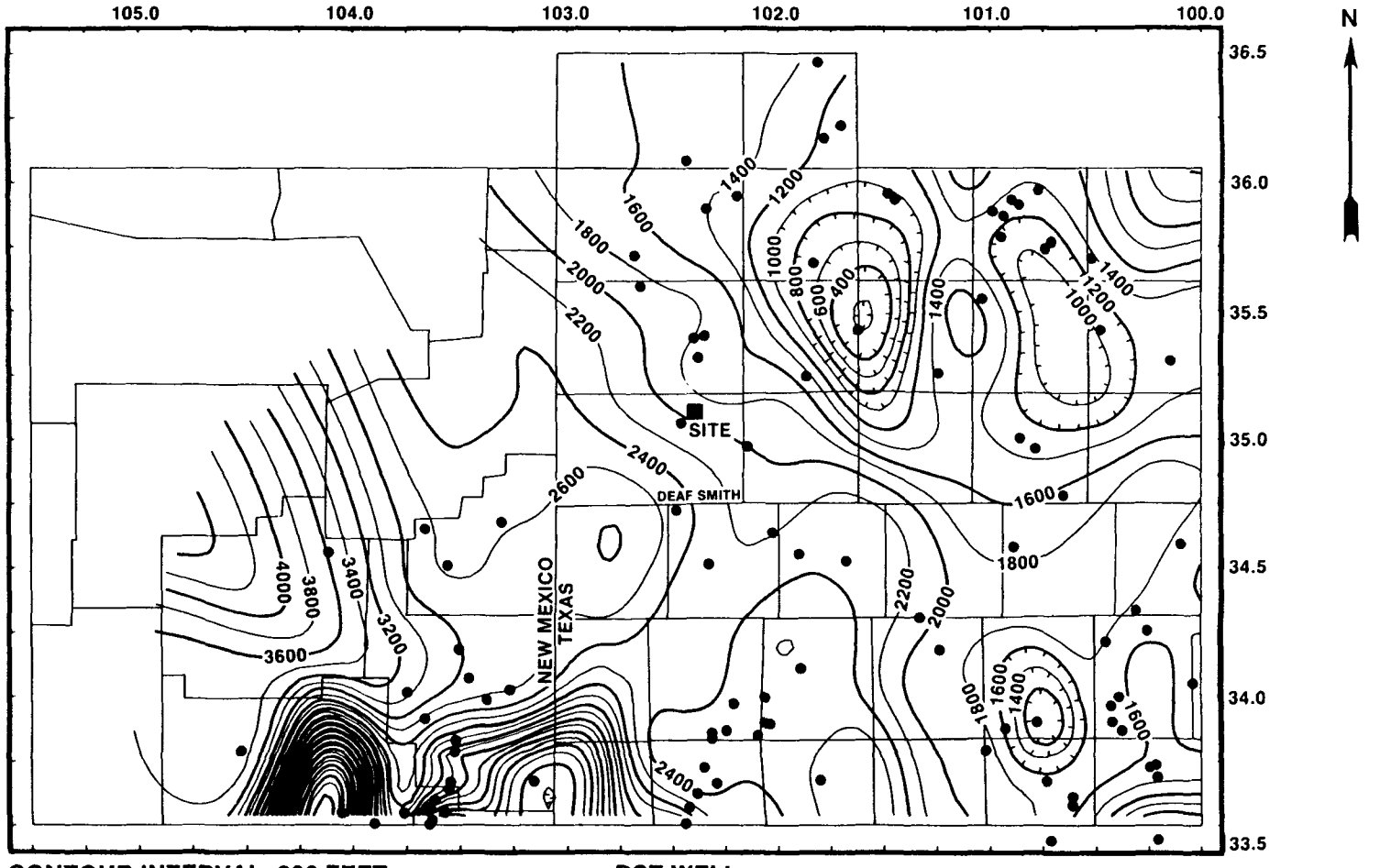
SCALE
0 30 60
MILES

SCALE
0 30 60
KILOMETERS

Source: Bair et al., 1985, BMI/ONWI-566.

Pennsylvanian
Potentiometric Surface

Figure 3-62



CONTOUR INTERVAL: 200 FEET

• DST WELL

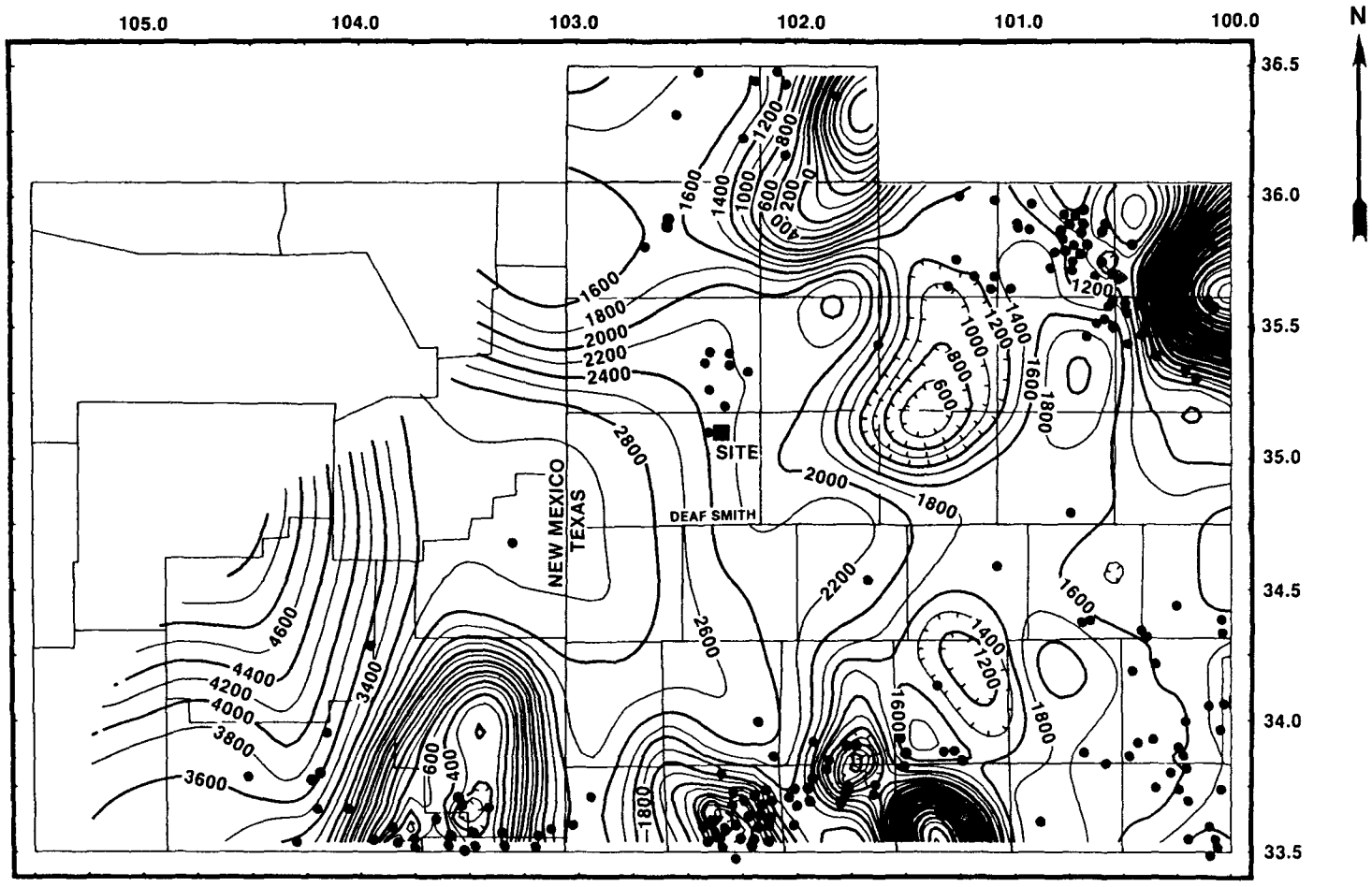
Source: SWEC Sketch 13697-71-D-1

SCALE
0 25 50
MILES

SCALE
0 25 50
KILOMETERS

Transient Wolfcamp
Potentiometric Surface

Figure 3-63



CONTOUR INTERVAL: 200 FEET

•DST WELL

Source: SWEC Sketch 13697-71-E-1

SCALE
0 25 50
MILES

SCALE
0 25 50
KILOMETERS

Transient Pennsylvanian Potentiometric Surface

Figure 3-64

for the Mississippian, Ordovician, and Cambrian Systems, which are laterally discontinuous. Over 5,000 wildcat DSTs have been analyzed for permeability and hydraulic head (SWEC, 1984, BMI/SRP-5012; Bair et al., 1985, BMI/ONWI-566). Numerical models have been constructed to determine flow within HSU C (Smith, 1983; INTERA, 1984, ONWI-504; Wirojanaqud et al., 1984).

Permeability values have been determined from the Horner plot analyses of DSTs performed at four DOE wells (SWEC, 1984, BMI/SRP-5004; 1984, BMI/SRP-5011; 1984, BMI/SRP-5005; 1984, BMI/SRP-5006) and at 19 wildcat wells (Bassett et al., 1982, Table 3, p. 128), from 16 pump test analyses at DOE wells (SWEC, 1984, BMI/SRP-5009; 1984, BMI/SRP-5011; 1984, BMI/SRP-5005; 1984, BMI/SRP-5006), and from nine RFTs at DOE wells (SWEC, 1984, BMI/SRP-5009; 1984, BMI/SRP-5004; 1984, BMI/SRP-5005; 1984, BMI/SRP-5008; 1984, BMI/SRP-5007). Pump-test and DST results are given in Table 3-26. Approximately 2,400 permeability values have been computed from DST data for wildcat wells throughout the study area (SWEC, 1984, BMI/SRP-5012). Bassett et al. (1982) list 288 permeabilities from core analyses in three wells.

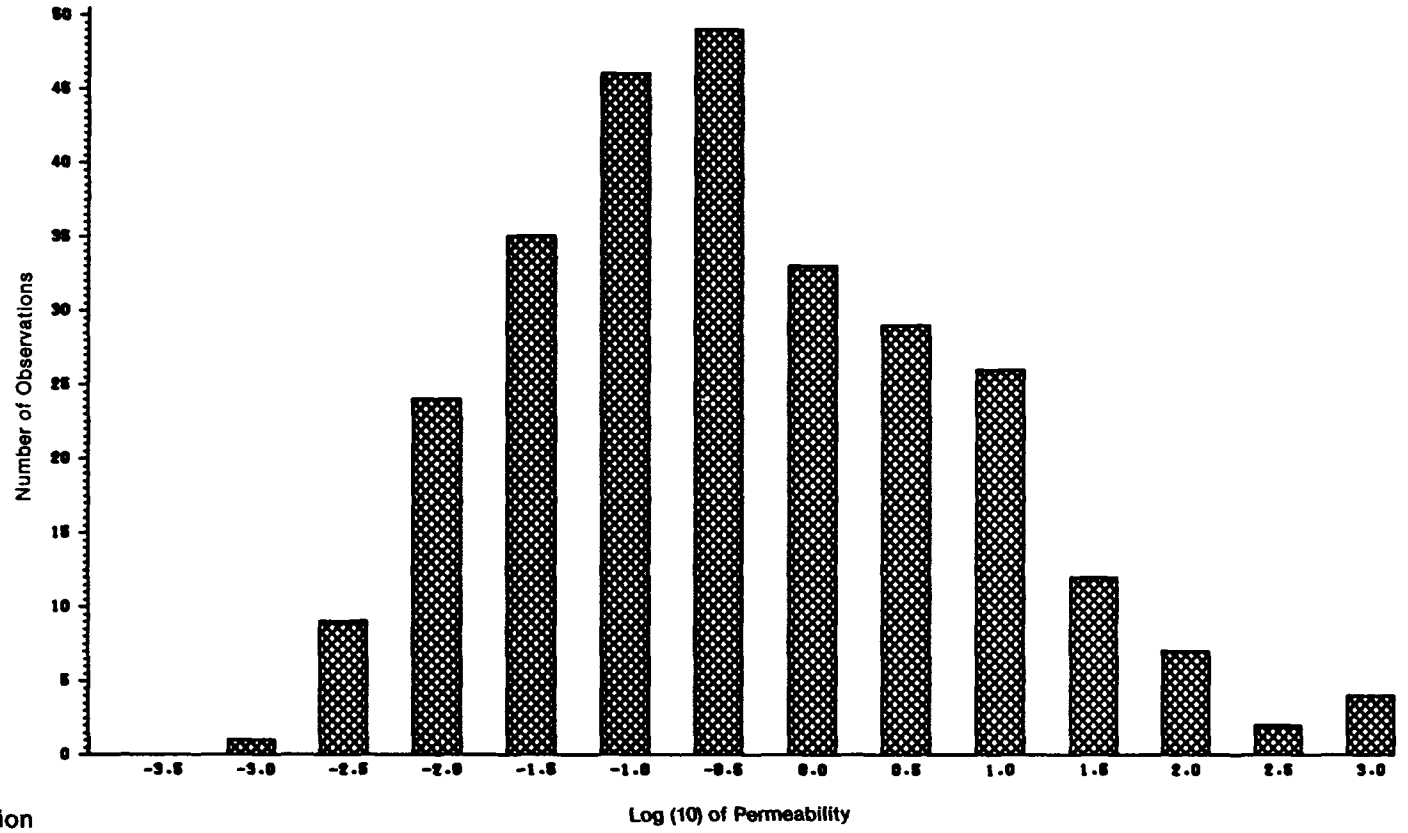
Stone and Webster Engineering Corporation calculated Pennsylvania (HSU C) permeability values of 8.8 to 500 millidarcys and Wolfcamp (HSU C) permeability values of 0.15 to 26.6 millidarcys from DST analyses (SWEC, 1984, BMI/SRP-5009; 1984, BMI/SRP-5011; 1984, BMI/SRP-5005; 1984, BMI/SRP-5006). RFT and pump test analyses (SWEC 1984, BMI/SRP-5009; 1984, BMI/SRP-5004; 1984, BMI/SRP-5011; 1984, BMI/SRP-5005; 1984, BMI/SRP-5006; 1984, BMI/SRP-5008; and 1984, BMI/SRP-5007) indicate Wolfcamp (HSU C) permeability values which range from 0.1 to 6.1 millidarcys and Pennsylvanian (HSU C) permeability values which range from 2.7 to 500 millidarcys. Texas Bureau of Economic Geology (TBEG) analyses of DST data in the Wolfcamp Series (HSU C) range from 0.03 to 262.0 millidarcys (Smith, 1983). Similarly, TBEG analyses of DST data in the Pennsylvanian carbonates and Pennsylvanian granite wash yield permeability values which range from 0.04 to 694.0 millidarcys and 0.06 to 138.0 millidarcys respectively. Analysis of historic DST data (Smith et al., 1984) yields Mississippian, Pennsylvanian, and Wolfcampian permeabilities. The mean of lognormal distribution (Figures 3-65, 3-66, and 3-67) of these values is 0.40 millidarcy (Mississippian), 0.45 millidarcy (Pennsylvanian), and 0.66 millidarcy (Wolfcampian).

Porosities for HSU C have been determined from core analysis and geophysical log analysis. Core analyses by SWEC of Wolfcamp and Pennsylvanian samples from the Zeeck No. 1 well in Swisher County yield effective porosities from 3.4 to 21.3 percent, with a mean value of 9.8 percent (SWEC, 1984, BMI/SRP-5029). Analyses of Wolfcamp core from the Mansfield No. 1 well in Oldham County yield effective porosities from 5.2 to 9.1 percent, with a mean value of 7.6 percent (SWEC, 1984, BMI/SRP-5029). Total porosities based on neutron porosity log analyses are given in Section 3.2.6.

Although the entire thickness of HSU C is saturated, most ground-water flow will be through the porous granite wash and carbonates of the Permian Wolfcamp and Pennsylvanian. Net thicknesses of granite wash range from 0 to 488 meters (0 to 1,600 feet), net porous Pennsylvanian carbonates range from 0 to 150 meters (0 to 500 feet), and net Wolfcamp shelf carbonates range from 0 to 427 meters (0 to 1,400 feet) (Dutton et al., 1982).

A study of two cross sections parallel to flow (Smith, 1983) indicates flow fluxes of between 1.3×10^{-2} meter per year and 4.9×10^{-3} meter per year (4.4×10^{-2} foot per year and 1.6×10^{-2} foot per year) for HSU C. INTERA (1984, ONWI-504) indicated Wolfcamp fluxes of 6.1×10^{-3} meter per year to 3.0×10^{-2} meter per year (2.0×10^{-2} to 1.0×10^{-1} foot per year) and Pennsylvanian granite wash fluxes of 0.46 to 0.82 meter per year (1.5 to 2.7 feet per year). In the vicinity of the Deaf Smith County site, Atwood et al. (1985) indicate a flux of 2.3×10^{-3} meter per year (7.5×10^{-3} foot per year) for both the porous brown dolomite portion of the Wolfcamp and for the Pennsylvanian granite wash.

Major faults are know to exist that offset the strata of HSU C (Section 3.2.5.1). Lineaments have been identified on the High Plains surface (Section 3.2.5.2). The effect, if any, that these features have on ground-water flow is unknown. Analysis of the pump-test data from HSU C in the Mansfield No. 1 and Sawyer No. 1 wells indicated numerous hydraulic boundaries, some of which may have resulted from faulting (Wilton and Picking, 1985).



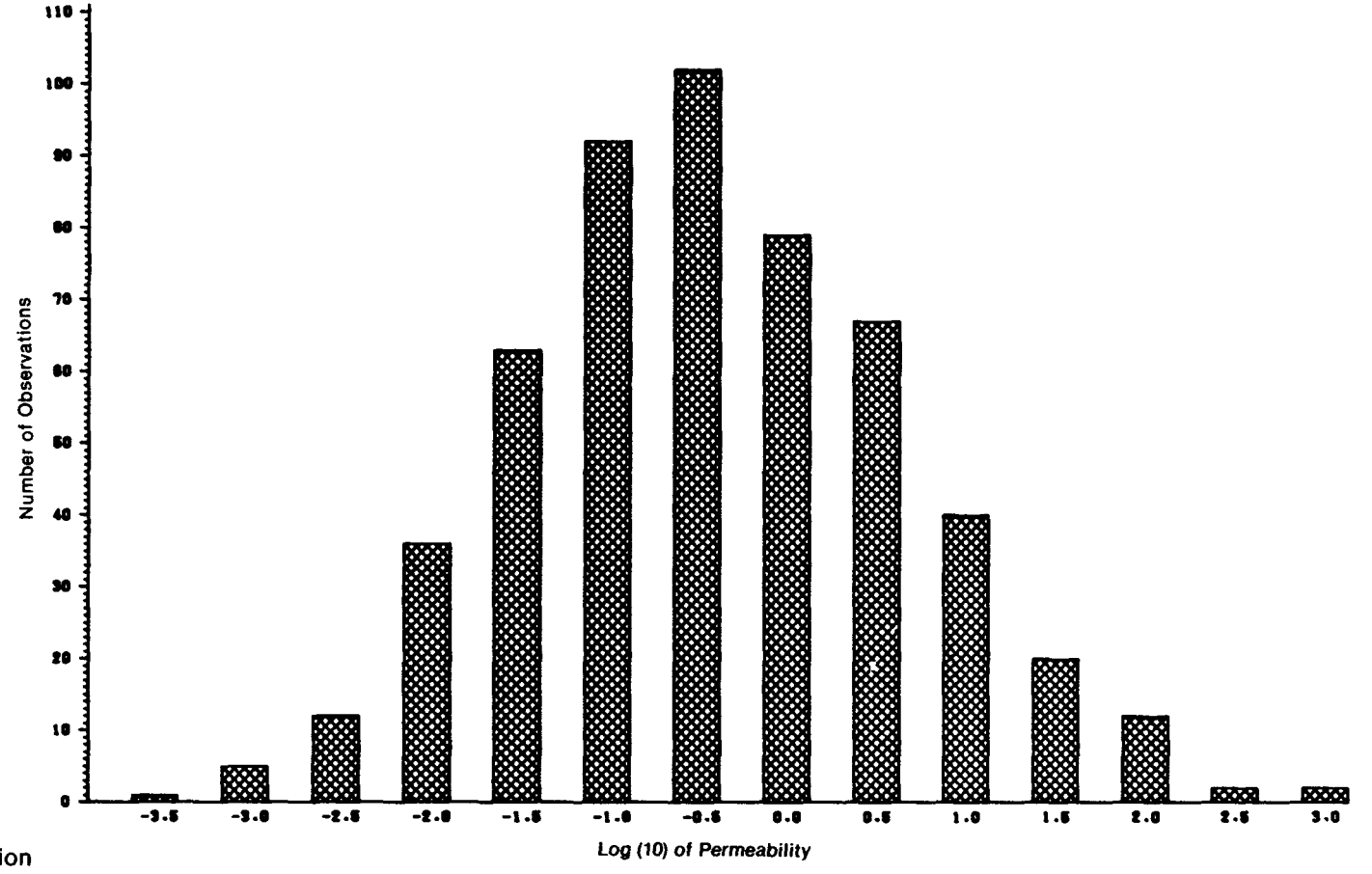
Explanation

Log (10) of Permeability Represents Midpoints of Permeability Values in 0.5 Log Increments

Source: SWEC, 1984, BMI/SRP-5012.

Formation Log Normal Permeability Distribution Mississippian System

Figure 3-65



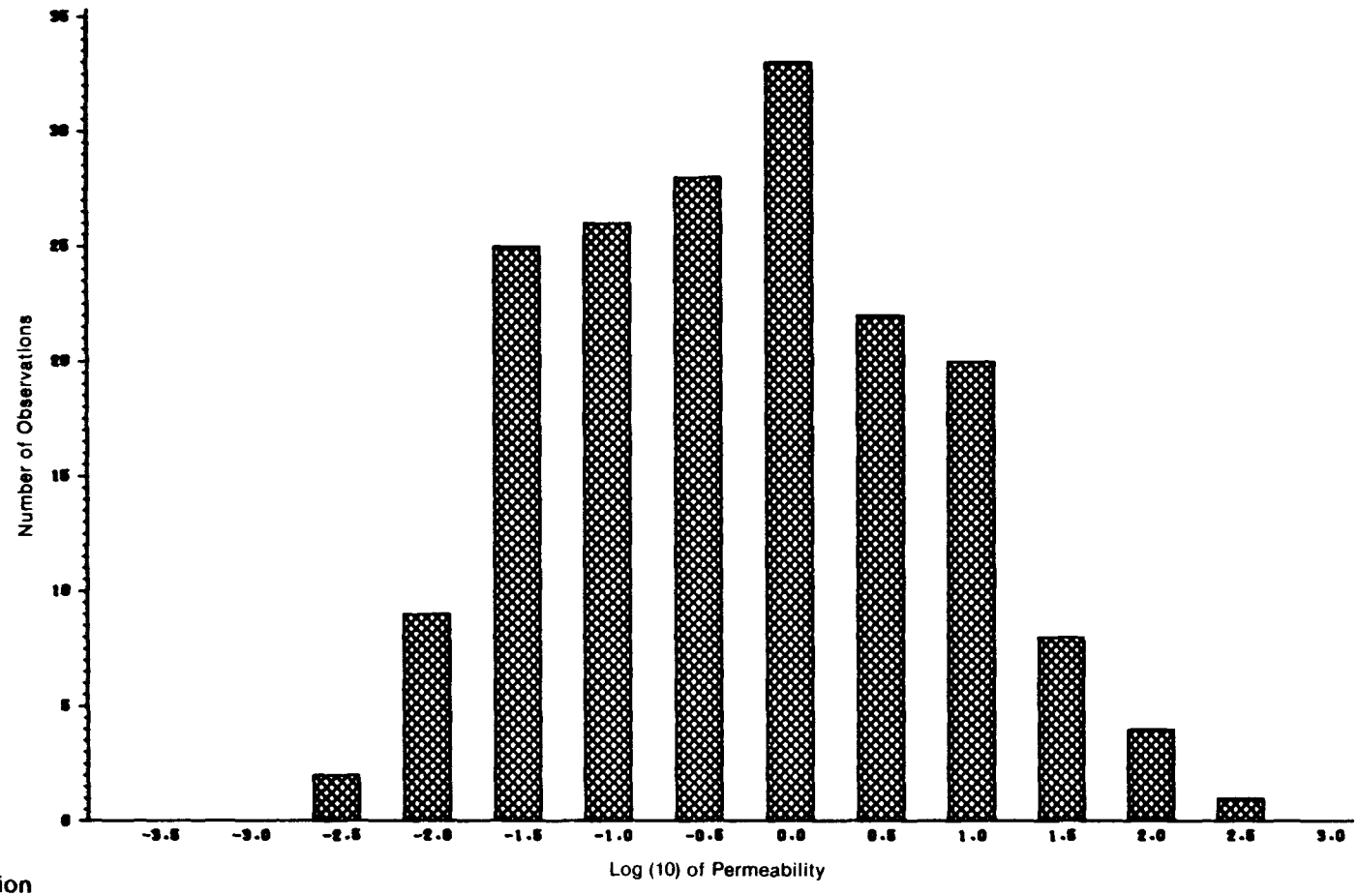
Explanation

Log (10) of Permeability Represents Midpoints of Permeability Values in 0.5 Log Increments

Source: SWEC, 1984, BMJ/SRP-5012.

Formation Log Normal Permeability Distribution Pennsylvanian System

Figure 3-66



Explanation

Log (10) of Permeability Represents
Midpoints of Permeability Values
in 0.5 Log Increments

Source: SWEC, 1984, BMI/SRP-5012.

Formation Log Normal Permeability Distribution Wolfcamp Series

Figure 3-67

Principal recharge to HSU C is assumed to be from lateral infiltration of ground water from the west, possibly from units cropping out in New Mexico near the Pedernal Uplift (Bair et al., 1984, BMI/ONWI-566; Bassett et al., 1982; Smith, 1983). No quantitative analysis of the entire basin has yet been made to establish ranges of recharge and discharge. Discharge is believed to be through the granite wash sequence which follows the Amarillo-Wichita Uplift. No surface discharge from HSU C has been identified.

3.3.2.1.2 Site Hydrogeologic Setting

HSU A. The Ogallala ranges from approximately 84 to 116 meters (275 to 380 feet) thick within the site area. Saturated thickness ranges from 15 to 35 meters (50 to 115 feet) (Figure 3-68), averaging approximately 23 meters (75 feet). Depth to water ranges from 81 to 87 meters (275 to 300 feet) (Figure 3-69). The water table at the site slopes southeastward (Figure 3-70).

The thickness of the Dockum Group at the site is estimated from the J. Friemel No. 1 well, where it is 214 meters (702 feet) thick (Figure 3-21). The permeable sandstones of the Dockum at the J. Friemel No. 1 well total 64 meters (210 feet). The average Ogallala and Dockum total porosities at the J. Friemel No. 1 well, based on neutron logs, are 31.4 and 33.9 percent (Table 3-13), respectively. These are probably much higher than formation effective porosities and a value of 15 percent is assumed.

HSU A hydraulic heads were not measured in the near-site hydrogeologic test wells. Based on the regional trends (Section 3.3.2.1.1), vertical gradients are expected to be downward from the Ogallala to the Dockum.

HSU B. The J. Friemel No. 1 well fully penetrated HSU B, encountering a total thickness of 1,368 meters (4,486 feet) (Figures 3-20 and 3-21). DSTs in the Lower San Andres Unit 4 carbonate were run at the G. Friemel No. 1 and Detten No. 1 wells, indicating permeabilities of 0.07 and 0.16 millidarcy, respectively. Repeat formation tests in the Unit 4 carbonate at the Detten No. 1 and G. Friemel No. 1 wells indicate permeabilities of 0.06, 0.05, 0.04 millidarcy (Detten No. 1) and 0.03 millidarcy (G. Friemel No. 1).

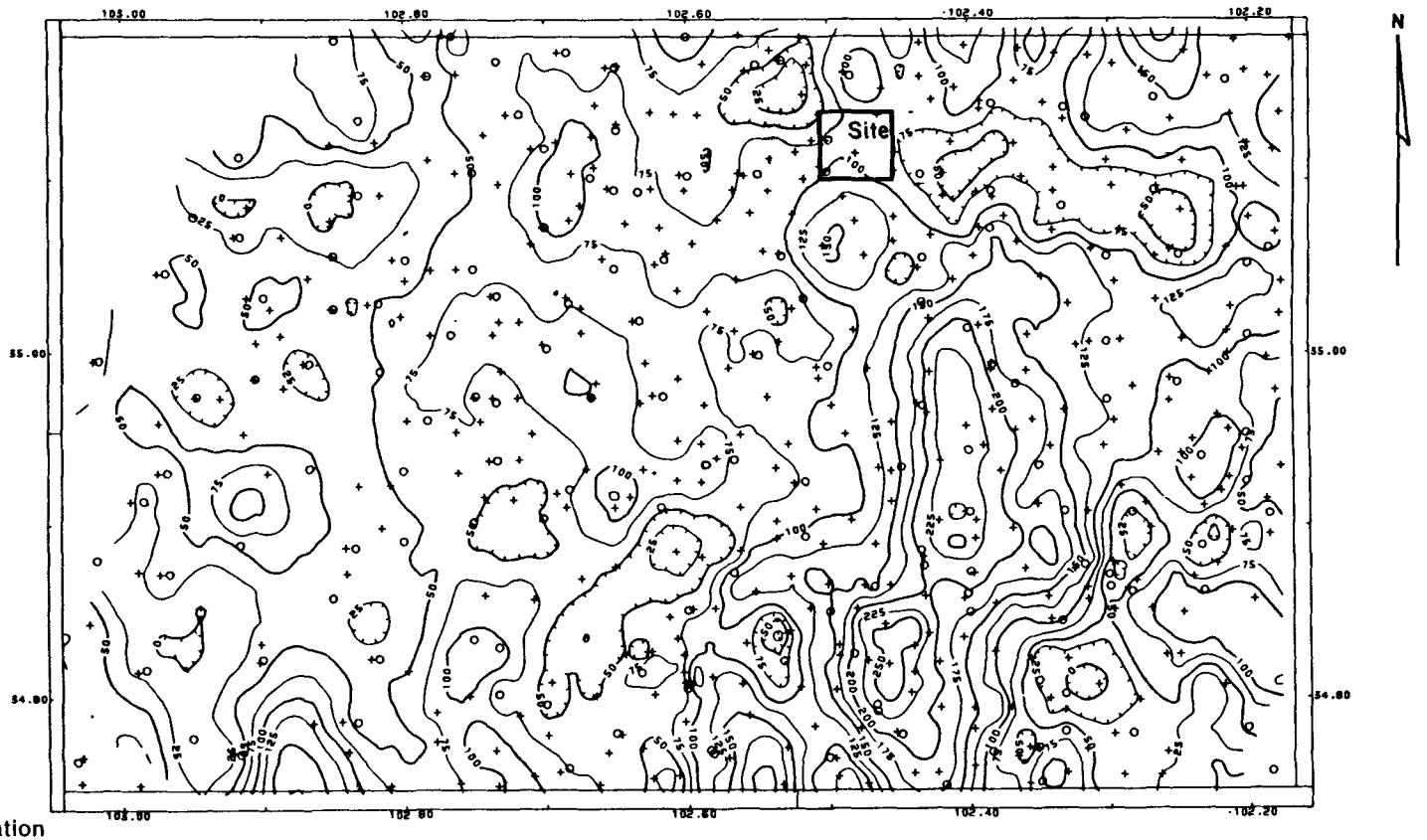
Effective porosities (by oven drying) have been measured in core by SWEC of HSU B from the Mansfield No. 1 well (SWEC, 1984, BMI/SRP-5022). These values are as follows: salt, 0.009; carbonate, 0.06; and shale, 0.28. Total neutron porosities computed for J. Friemel No. 1 are reported in Tables 3-13, 3-14, 3-15, and 3-16.

HSU C. No DOE well fully penetrates HSU C in Deaf Smith County. The J. Friemel No. 1 well penetrates 372 meters (1,216 feet) of Wolfcamp carbonates and mudstones and 453 meters (1,485 feet) of Pennsylvanian shale, carbonate, and granite wash (Figure 3-19). The Pennsylvanian is only partially penetrated. One DST was performed in the Wolfcamp dolomite at J. Friemel No. 1 and indicated a permeability of 1.03 millidarcy (SWEC, 1984, BMI/SRP-5029, p. I-69). Effective porosities (by oven drying) from Upper Wolfcamp core in the Mansfield No. 1 well have been reported (SWEC, 1984, BMI/SRP-5022), and average 0.08.

An analysis of ground-water flow paths and travel times is presented in Section 6.4.2.3.5.

3.3.2.1.3 Geochemistry of Deep Basin Brine Aquifers. The deep basin brine aquifers below the Permian evaporite section all contain $Na^+ - Cl^-$ brines with total dissolved solids (TDS) near or over 100,000 milligrams per liter (Bassett and Bentley, 1983). These brines have been sampled in four DOE wells. The Wolfcamp and Pennsylvanian aquifers contain brines with about 20 percent dissolved material, mostly sodium and chlorine (Table 3-27).

Flow Paths. Delta deuterium and delta 18 oxygen data for the Palo Duro Basin show two groups of deep basin brines (Knauth and Hubbard, 1984; Fisher and Kreitler, 1984). One group has isotopic signatures expected for isotopic equilibrium with carbonates at the measured subsurface temperatures. These brines are present in the eastern part of the Palo Duro Basin (Swisher and Donley Counties). The second group of brines has isotopic signatures that may



Explanation

Contour Interval: 25 Feet (7.6 Meters)

Well Control:

+ Base of Ogallala

o Recent Water Levels

Source: SWEC, 1984, BMI/ONWI-524.

0 5 10

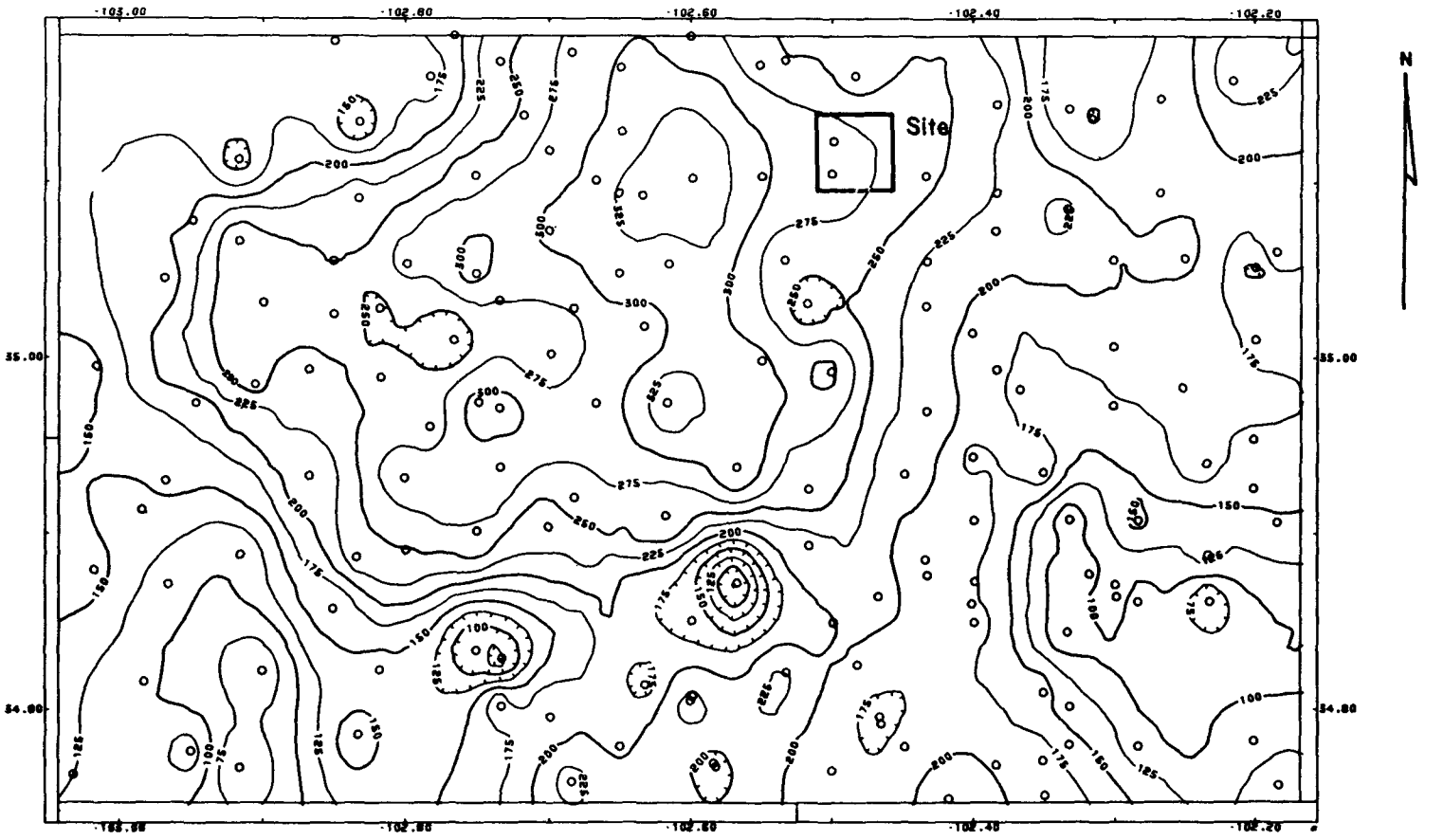
Scale - Miles

0 16

Scale - Kilometers

Ogallala Aquifer Saturated Thickness

Figure 3-68



Explanation

Contour Interval: 25 Feet (7.6 Meters)

Depth Datum: Ground Surface

Well Control:

- Recent Water Levels

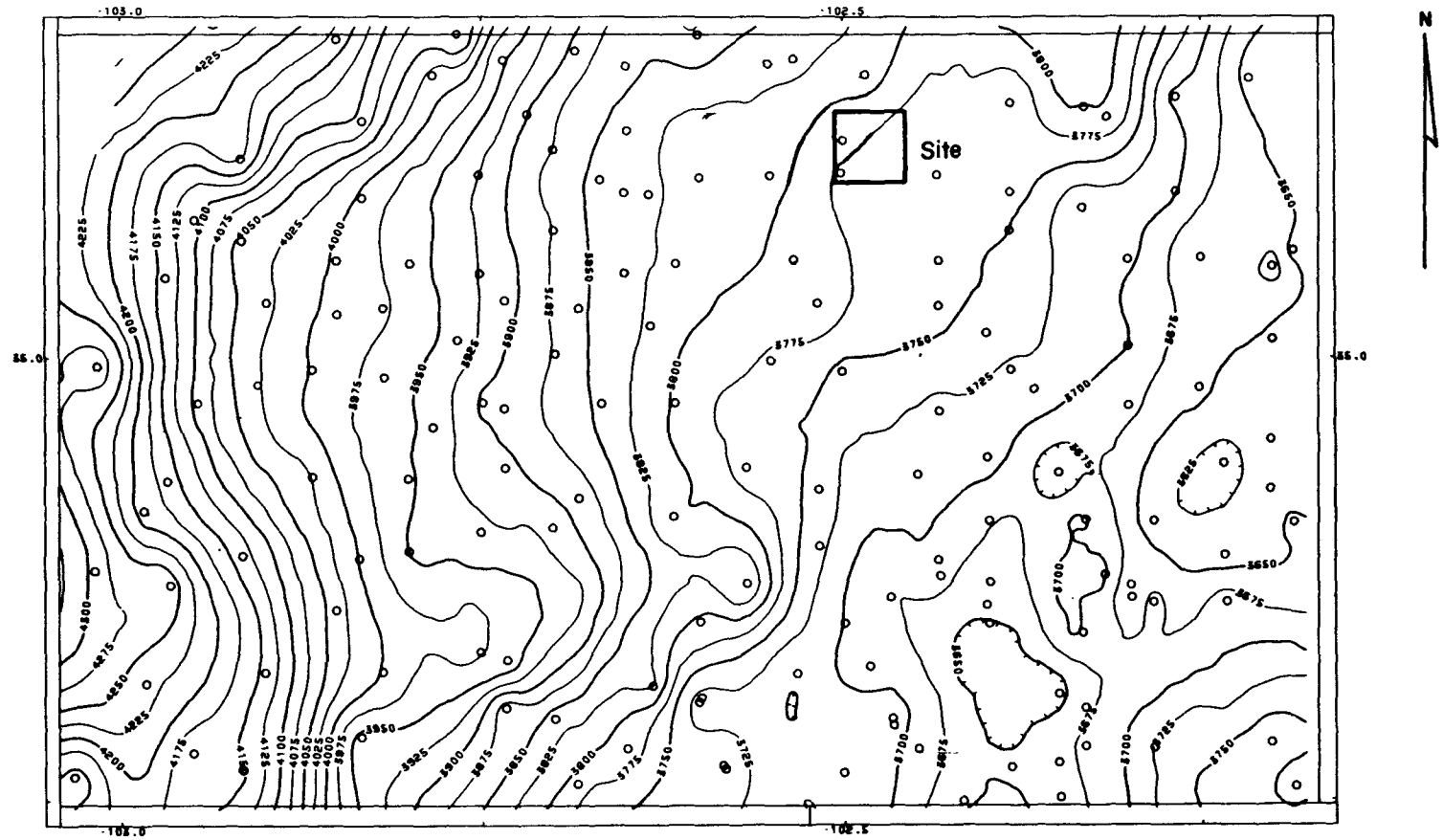
0 5 10
Scale - Miles

0 8 16
Scale - Kilometers

Source: SWEC, 1984, BMI/ONWI-524.

Depth to Water in Ogallala Aquifer

Figure 3-69



Explanation

Contour Interval: 25 Feet (7.6 Meters)

Elevation Datum: MSL

Well Control:

- Recent Water Levels

Source: SWEC, 1984, BMI/ONWI-524.

0 5 10
Scale-Miles

0 16
Scale-Kilometers

Elevation of 1981 Ogallala Water Levels

Figure 3-70

Table 3-27. Chemical Analyses of Palo Duro Deep Basin Brines

Well, Location, Aquifer	Concentrations of Ions in milligrams/liter					
	Ca^{++}	K^{+}	Mg^{++}	Na^{+}	Cl^{-}	SO_4^{--}
Sawyer No. 1, Donley Co., Granite Wash	19,200	360	2,560	57,200	140,000	400
Mansfield No. 1, Oldham Co., Wolfcamp	9,000	530	1,900	79,000	130,000	1,240
Zeeck No. 1, Swisher Co., Penna. Carbonate	12,500	207	2,100	74,900	155,000	200
Zeeck No. 1, Swisher Co., Wolfcamp	7,000	400	2,000	71,000	120,000	-
J. Friemel No. 1, Deaf Smith Co., Granite Wash	16,000	630	2,400	74,000	150,000	430
J. Friemel No. 1, Deaf Smith Co., Penna. Carbonate	12,000	590	2,300	77,000	150,000	560

Source: Sewell, 1984.

result from variable mixtures of meteoric waters with isotopically equilibrated brines. The mixed brines occur to the west of the isotopically equilibrated brines.

One hypothesis (Knauth and Hubbard, 1984) is that mixing of meteoric brines and carbonate-equilibrated brines occurs somewhere in the western part of the flow system. Presumably, the meteoric waters acquired their salinity by dissolving salt along the western edge of the Permian evaporite sequence in the Palo Duro Basin, as was earlier suggested by Bassett and Duncan (1982).

A second hypothesis is that the mixed brines represent a mixture of isotopically equilibrated brines and nonisotopically equilibrated waters leaking through the evaporite section (Fisher and Kreitler, 1984). This model is supported by the high sodium to chlorine ratios in the Wolfcamp, the high bromide to chloride ratios in the DOE wells in Deaf Smith and Oldham Counties, and numerical modeling of ground-water flow in the basin, which suggest that a component of flow in the deep basin brine aquifer may result from leakage through the evaporite section (Senger and Fogg, 1984).

Delta deuterium, delta 18 oxygen, and other chemical data have also been used to identify the origin of saline springs in a region along the eastern margin of the Caprock Escarpment. It was found, in the northern section of the region, that meteoric water is percolating downward, dissolving salt, and issuing as saline springs (Kreitler and Bassett, 1983). The hypothesis that the saline springs are discharging deep basin brines was refuted by the isotopic data. However, in the southern section of the saline spring region, saline springs and shallow saline ground waters may have a component of deep basin discharge (Richter and Kreitler, 1984).

Ground-Water Ages. The deep basin brines are expected to be too old to date by methods other than the uranium →thorium, helium-4, neon-21 and potassium-40 →argon-40 methods. Work is under way to radiometrically date the deep basin brines using these methods (Zaikowski et al., 1984). The carbonate-equilibrated brines in the eastern part of the Palo Duro Basin have preliminary radiometric ages of about 1.3 x 10^8 years (Zaikowski et al., 1984). The deep basin brines west of the carbonate-equilibrated brines are currently considered to be mixtures; therefore residence times (ages) cannot be determined (Zaikowski et al., 1984). In contrast, numerical modeling of ground-water flow in the deep-basin brine aquifer (Senger and Fogg, 1984; Smith, 1984) suggest transit times across the basin of 10 million years.

Radionuclide Transport. Various factors can reduce the rate of radionuclide transport in ground waters relative to the flow rate of the ground waters. A reduction in radionuclide transport rate would improve the isolation provided by slow ground-water flow rates.

Ground water in the deep basin aquifers below the host salt consists of brines containing methane and ethane (Sewell, 1984), and is considered to be chemically reducing (Sections 6.3.1.2.2 and 6.3.1.2.3). The brines also contain relatively low concentrations of short-chain aliphatic acid anions, such as acetate, which are anaerobic decomposition products of sedimentary organic matter, and not stable in aerobic environments containing microorganisms (Means and Hubbard, 1985). Redox conditions in the San Andres Formation and lower strata are thought to be buffered between oxidized and reduced forms of carbon, iron, and sulfur, and yield Eh estimates in the range of -100 millivolt or lower (Fisher, 1984). These estimates agree well with values calculated for formation waters from deep geopressurized geothermal regions (Kharaka et al., 1980). At these lower redox potentials, redox-sensitive radionuclides are expected to be present in their lower oxidation states. Uranium 234-to-thorium 230 ratio evidence suggests that naturally occurring uranium in Palo Duro deep basin brines is predominantly tetravalent rather than hexavalent (Hubbard et al., 1984b). The retention of radionuclides such as uranium, neptunium, plutonium, and technicium is greatly increased under reducing conditions because these elements form compounds having much lower solubilities than those formed under oxidizing conditions (Cleveland, 1979a, b; Cleveland et al., 1983; Bondietti and Francis, 1979; Langmuir, 1978; Pigford, 1983).

The organic geochemistry of lower Permian- and Pennsylvanian-age Palo Duro brines was evaluated by Means and Hubbard (1985). Four ground-water samples from J. Friemel No. 1 well

in Deaf Smith County were found to possess relatively low total organic carbon contents, ranging from 5.8 to 16.1 milligrams per liter. Short-chain aliphatic acid anions are the predominant organic species present, with acetate concentrations ranging from 18 to 42 milligrams per liter, and proprionate in concentrations of up to 3 milligrams per liter. Chemical-equilibrium calculations suggest that the short-chain aliphatic acid anions will not complex significantly with radionuclides (Means and Hubbard, 1985).

Inorganic ligands such as carbonate may complex significantly with certain radionuclides, even in their reduced states (Garrels and Christ, 1965, Figure 7.32b; Cleveland, 1979a, b). Certain radionuclide are expected to form relatively insoluble sulfates or carbonates (Langmuir et al., 1983; Stumm and Morgan, 1970, pp. 172-183; Bassett and Bentley, 1983).

Brines promote the conversion of stable, hydrophilic colloidal suspensions to unstable, hydrophobic particles (Stumm and Morgan, 1970, pp. 500-507). The conversion process is accompanied by colloid growth and charge reversal, resulting in large, relatively immobile particles that can be more effectively filtered by geological substrates. The applicability of this phenomenon to radiocolloid transport in site-specific Palo Duro salt-repository environments will be further investigated. Laul et al. (1985) examined particle sizes of natural radium, thorium, and uranium isotopes in a Palo Duro Wolfcampian brine and concluded that colloidal transport was not occurring.

Various sorption processes can retard the movement of radionuclides relative to ground-water flow. Clay minerals, both within the host rock and in clastic strata above, below, and adjacent to the host rock, are expected to promote radionuclide adsorption, should release occur from the engineered barriers. Current data are insufficient to quantify the expected extent of sorption, which will be addressed further during detailed site characterization.

3.3.2.2 Ground-Water Quality

The chemical composition of the Ogallala ground water (Table 3-28) is described by hundreds of standard water quality analyses from the Texas Water Resources Board and the National Uranium Resources Evaluation Program (Cagle and Baldwin, 1978).

The chemical composition of the Dockum ground water (Table 3-29) is not well known but appears to contain several hydrochemical facies. In the Deaf Smith County site area, the water is a Na-HCO_3 type that is potable and generally has less than 2,000 milligrams per liter total dissolved solids.

Usable ground waters in the Palo Duro Basin are drawn almost entirely from two aquifer systems, the new-surface Ogallala aquifer in the west and the dissolution-zone aquifer which is utilized in the region to the east of the High Plains Escarpment (SWEC, 1983, BMI/ONWI-518).

Salinity, measured as specific conductance (mhos per centimeter), of Ogallala ground waters is low and relatively uniform wherever measured. Median values are in the range of 700-1,100 µmhos/cm with small variations (Sewell, 1984; Langfeldt et al., 1981; Oak Ridge Gaseous Diffusion Plant, 1978, 1979 a, b; and Zinkl et al., 1982). In the dissolution-zone aquifer, specific conductance values are much higher and more variable. Median values are in the range of 700-4,000 µmhos per centimeter with extreme values ranging from less than 300 to over 10,000 µmhos per centimeter.

The alkalinity of both aquifer systems is similar. Median values for total alkalinity in Ogallala ground waters range from 210 to 300 parts per million, and from 110 to 340 parts per million in the dissolution-zone aquifers. Variance is comparatively large for both aquifers. At places in each aquifer, values for total alkalinity exceed 1,000 parts per million. For certain water-bearing formations in the dissolution-zone aquifer, (e.g. the Whitehorse Sandstone and Cloud Chief Gypsum), median values for alkalinity range as low as 110 to 190 parts per million (Oak Ridge Gaseous Diffusion Plant, 1978; 1979a, b).

Table 3-28. Average Chemical Composition of Ogallala Ground Waters

Component	Concentration (ppm)
Na^+	39
Ca^{++}	45
Mg^{++}	29
K^+	2
Cl^-	23
SO_4^{--}	41
HCO_3^-	294
pH	7.9
TDS	379
DO	8
SiO_2	46

Source: Cagle and Baldwin, 1978.

Table 3-29. Average Chemical Composition of Dockum Ground Waters in Deaf Smith County[a]

Component	Concentration (mg/l)
Na^+	373
Ca^{++}	7.6
Mg^{++}	3.4
Cl^-	111
SO_4^{--}	217
HCO_3^-	523
pH	8.5
TDS	987

(a) Information obtained from the general files, listing non-commingled wells, of the Texas Department of Water Resources, Austin, Texas.

Ogallala ground waters can be classified as bicarbonate-type ground waters due to their relatively high concentrations of bicarbonate and generally low values for specific conductance (Table 3-26). Compared to ground water from the dissolution-zone aquifer, Ogallala waters are relatively high in barium and silicon and low in sulfate. In contrast, dissolution-zone ground waters are characterized by high concentrations of calcium, sodium, strontium, magnesium and sulfate, and have high values for specific conductance. As a group, they can be classified as calcium-sulfate-type groundwaters.

3.3.3 Water Supply

The Texas Water Plan provides data on water requirements and supplies for the year 1980 and projections for each decade through the year 2030 for low- and high-population, industrial, and agricultural growth rates (TDWR, 1984, Vol. 2, pp. II-21 to II-40). In this section, (1) the rights to the use of surface and ground water are described, (2) ground- and surface-water users near the site are identified, (3) the current and projected water-use data are summarized for Deaf Smith and six nearby counties (Figure 3-71), and (4) potential water sources that might supply the repository are identified.

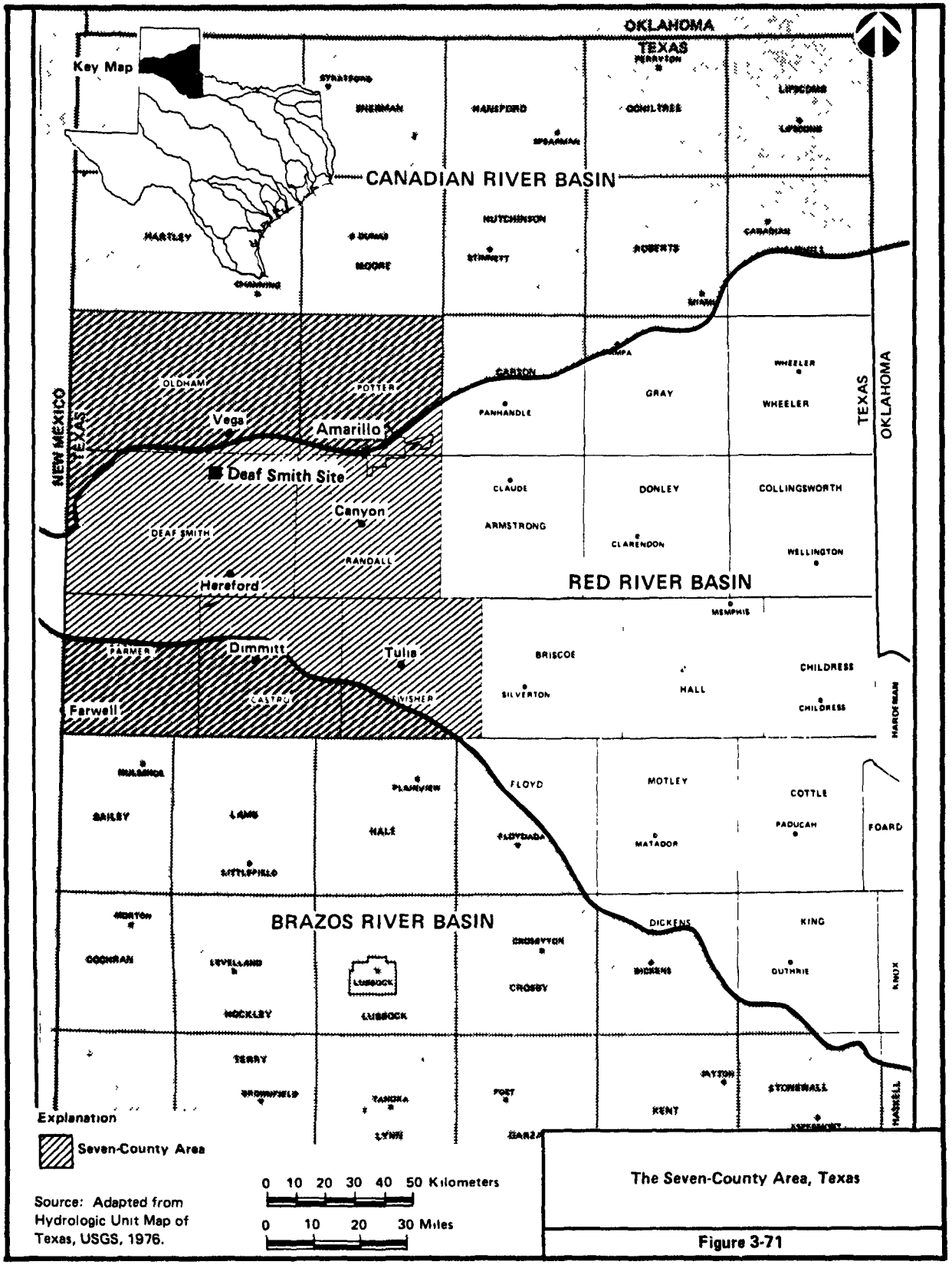
3.3.3.1 Water Rights

Surface-water law in the State of Texas reflects the distinction between diffused surface water and water within a defined watercourse. Diffused surface water, i.e., water that occurs naturally on the earth's surface though not in a watercourse, lake, or pond, is regarded as private water, subject to capture and use by the landowner before it enters the watercourse. Persons seeking to appropriate surface water from defined watercourses in Texas must apply in writing to the Texas Water Commission, a regulatory agency that is charged with the administration of rights to the surface-water resources of the State. If the application is approved, the applicant receives a permit to withdraw and use water to the extent specified (TDWR, 1984, Vol. 2 p. I-11 to I-16).

State law with respect to ground water is based on the presumption that all sources of such water are percolating waters, i.e., waters below the surface of the land that do not flow in known and defined channels but percolate, ooze, and filtrate through the earth. In both statute and case law, the State of Texas has recognized the right of the surface landowner to take for use or sale all water beneath his land. For their mutual protection, however, landowners may adopt voluntary well regulation through association in underground water conservation districts, the framework of which is provided in Section 52.001 of the Texas Water Code. To date, 12 such districts have been created, but only 9 are currently active. One of these, the High Plains Underground Water Conservation District No. 1, encompasses the site of the proposed repository in Deaf Smith County (TDWR, 1984, Vol. 2, p. I-16 to I-19).

3.3.3.2 Water Users

The High Plains aquifer is the principal source of fresh water on the Southern High Plains. It consists primarily of the Ogallala Formation, and includes those water-bearing units, mainly Cretaceous and Triassic sediments, with which it is in hydraulic continuity (TDWR, 1984, Vol. 2, p. II-5). The Triassic aquifer is composed of the Dockum Group. The Santa Rosa Sandstone is the major water-bearing unit of the Dockum near the Deaf Smith County site (Duffin, 1984, p. II-14). In small areas of Randall County, wells are completed in both the Ogallala and the Santa Rosa. Except for these areas, the base of the Ogallala is considered to be the base of the High Plains aquifer. Water wells are completed in Triassic rocks in Castro, Deaf Smith, Hale, Oldham, and Swisher Counties, but because of a lack of hydraulic continuity with the Ogallala or small lateral extent, the areas in which these wells are completed are not considered part of the High Plains aquifer (Knowles et al., 1984, Vol I, pp. 8-12.



The Seven-County Area, Texas

Figure 3-71

Knowles et al. (1984, Vol. 1, pp. 123-159) have compiled well data* for Deaf Smith County. The locations of water wells near the Deaf Smith County site are shown on Figure 3-72. Type of use and well ownership are listed in Table 3-30. Eight of the wells identified by Knowles et al. are on the site. Seventeen wells are within 4.8 kilometers (3.0 miles) of the center of the site, and 20 wells are located between 4.8 and 7.2 kilometers (3.0 and 4.5 miles).

The cities of Hereford, Vega, Canyon, and Tulia maintain municipal well fields (NUS, 1985, BMI/ONWI-557). Hereford's system includes 1 Santa Rosa and 29 Ogallala wells, all of which are in the city or within 152 meters (500 feet) of the city limits. A new Ogallala well field is planned for a 243-hectare (600-acre) site west of the city. Vega obtains all of its water from five Ogallala wells. Two of these wells make up the Strafuss Well Field. This field is located 6.4 kilometers (4 miles) south of Vega along U.S. 385, approximately 8 kilometers (5 miles) from the nearest site boundary. The field is connected to the town via a pipeline that runs north along U.S. 385. Vega has an option on one Santa Rosa well (Merriman and Barber Consulting Engineers, Inc., 1985, pp. V-1). The well is situated on land within the Deaf Smith County site (Committee on Environment and Public Works, 1985, pp. 23-24). Canyon obtains all of its water from 16 Ogallala wells, two within city limits and 14 in a well field west of town. Tulia has eight Ogallala and three Santa Rosa wells, which are used to supplement the city's surface-water supply from MacKenzie Reservoir.

The locations of impoundments in the Palo Duro Creek drainage basin and on Prairie Dog Town Fork of the Red River are shown on Figure 3-52. Their owners and uses are indicated in Table 3-22. There are no impoundments used for potable water. Several small farm ponds upstream from the site are used for irrigation. Bivins Lake, situated on Palo Duro Creek about 36.6 kilometers (24 miles) downstream from the site, is used for aquifer recharge. Palo Duro Club Lake and Lake Tanglewood, both situated on Prairie Dog Town Fork of the Red River, are about 57.9 kilometers (36 miles) and 69.2 kilometers (43 miles) downstream from the site, respectively; these lakes are used for recreation.

3.3.3.3 Current and Projected Water Use

The year 1980 was the base year for water requirement and supply projections in the Texas Water Plan. In that year, water use in the seven-county area totaled 1.92×10^9 cubic meters (1,560,000 acre-feet**), with 1.89×10^9 cubic meters (1,530,000 acre-feet), about 98 percent, supplied from ground-water sources. Irrigation represented 94 percent of the total water use (Table 3-31). Water use in Deaf Smith County totaled 3.97×10^8 cubic meters (322,163 acre-feet), with all except 3.24×10^5 cubic meters (263 acre-feet) supplied from ground-water sources (Table 3-32). Irrigation represented 96 percent of the total water use. Amarillo had the largest municipal water use near the Deaf Smith County site, with 4.07×10^7 cubic meters (33,000 acre-feet) (Table 3-33). Lake Meredith, on the Canadian River, supplied about 50 percent of Amarillo's municipal water requirements. Other nearby municipal users, all supplied from ground-water sources, include Hereford, Canyon, Tulia, and Vega (Table 3-33) (TNRIS, 1982a). The principal manufacturing water users near the site are meatpacking and sugar-beet-processing plants near Hereford. The irrigated farmland in the seven-county area is shown in Figure 3-73.

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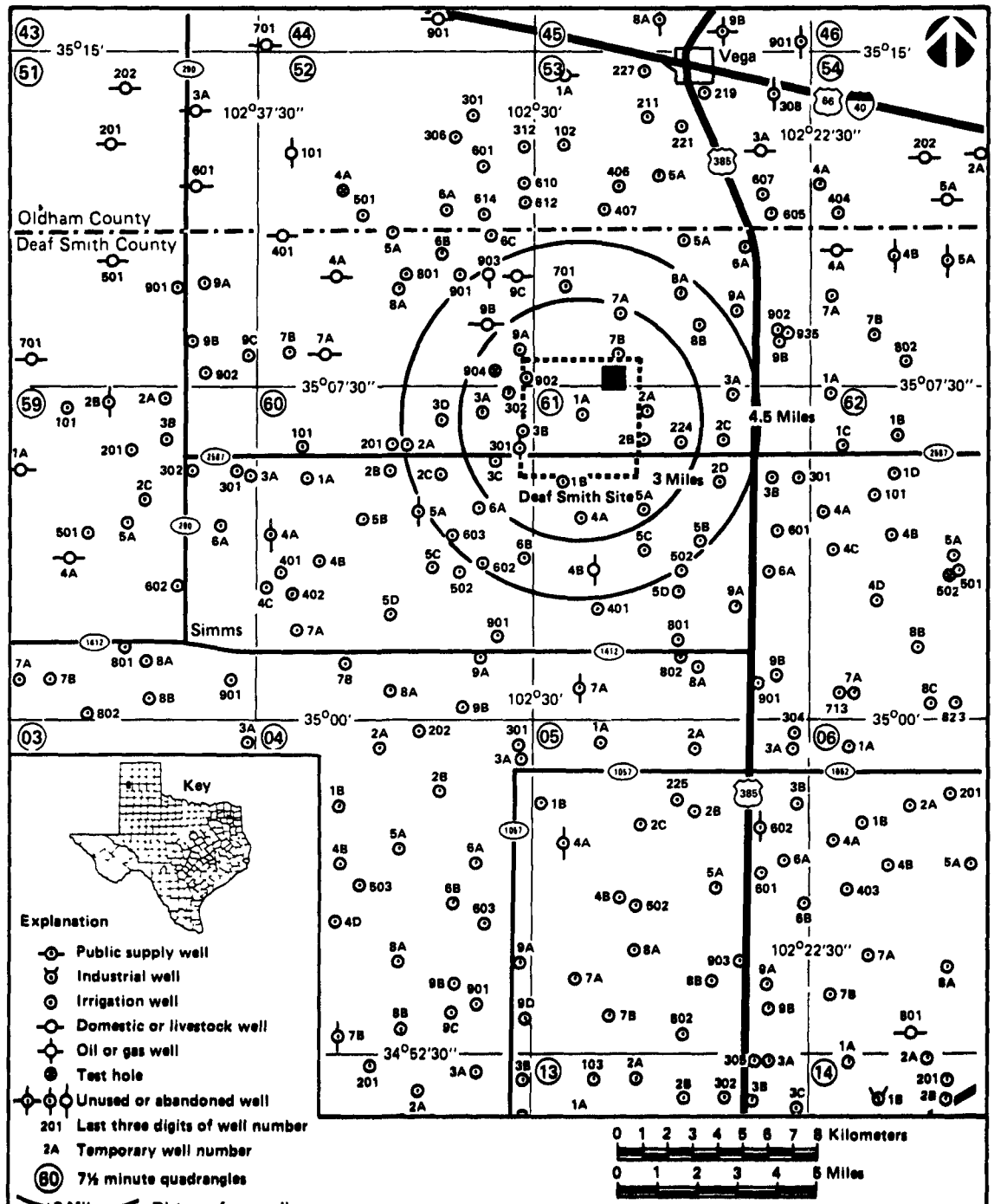
*The well data were collected from a network of observation wells maintained by the Texas Department of Water Resources (TDWR) and ground-water district cooperators (Knowles et al., 1984, Vol. 1, p. 47). Additional observation-well data obtained from Duffin (1984) and the Texas Natural Resources Information System (TNRIS, 1985) are included in Table 3-30 and Figure 3-72. The data do not include all of the water wells in the High Plains aquifer.

**Water use, water supply, and ground water in recoverable storage values in the text have been rounded to three significant figures. Values in the tables have not been rounded; they appear as provided by the cited source.



Note: Wells located near site boundary may be within site.

Sources: Duffin, 1984; Knowles et al., Vol. 3, 1984; TNRIS, 1985.

Wells Near the Deaf Smith County Site

Figure 3-72

Table 3-30. Wells Within 4.5 Miles of Center of the Deaf Smith County Site

State Well Number	Latitude	Longitude	Owner	Water-Bearing Unit[a]	Use[b]	Remarks
			Wells Within 3.0 Miles of Center of Site			
07-52-9A	35-08-17 N	102-30-22 W	Henry Kinsey	To	I	
07-52-902[c]	35-07-40 N	102-30-07 W	Richardson Seed Farms	Trdsr	I	Reported yield 900 gal/min
07-52-904	35-07-52 N	102-31-00 W	Richardson Seed Farms	To	D	Observation well (water quality)
07-53-7A[c]	35-09-10 N	102-27-43 W	John J. Gordon, Estate	To	I	
07-53-7B	35-08-16 N	102-27-52 W	W. A. Carter	To	I	
07-60-3A	35-06-58 N	102-31-23 W	Richardson Seed Farms	To	I	
07-60-3B[c]	35-06-2B N	102-30-21 W	Fred Paschel	To	I	
07-60-3C[c]	35-06-01 N	102-31-02 W	R. D. Hicks	To	I	
07-60-301[c]	35-06-18 N	102-30-21 W	J. H. Fangman	To	A	Observation well (water level)
07-60-302	35-07-23 N	102-30-41 W	Richardson Seed Farms	To	I	Observation well
07-61-1A[c]	35-06-56 N	102-28-49 W	Anthony Paschel	To	I	
07-61-1B[c]	35-05-24 N	102-29-21 W	W. M. Stewart	To	I	
07-61-2A[c]	35-06-58 N	102-27-09 W	Everett Wiseman	To	I	
07-61-2B[c]	35-06-20 N	102-27-12 W	James Fangman	To	I	
07-61-224	35-06-13 N	102-26-07 W	A. C. Brorman	To	I	Observation well
07-61-4A	35-04-34 N	102-28-51 W	Jerome Friemel	To	I	
07-61-5A	35-04-43 N	102-27-12 W	James Fangman	To	I	

Table 3-30. Wells Within 4.5 Miles of Center of the Deaf Smith County Site
(Page 2 of 3)

State Well Number	Latitude	Longitude	Owner	Water-Bearing Unit[a]	Use[b]	Remarks
			Wells Between 3.0 and 4.5 Miles from Center of Site			
07-52-9B	35-08-57 N	102-31-05 W	Forrester Brothers	To	L	
07-52-9C	35-09-59 N	102-30-53 W	Bob Thruett	To	D	
07-52-903	35-09-59 N	102-31-22 W	Bob Thruett	Trd	N	
07-53-701	35-09-44 N	102-29-18 W	Paul W. Metcalf	To	I	Observation well (water level)
07-53-8A	35-09-36 N	102-26-05 W	H. E. Owens	To	I	
07-53-8B	35-08-48 N	102-25-35 W	R. L. Thompson	To	I	
07-60-2A	35-06-08 N	102-33-34 W	Norman Gray	To	I	
07-60-2C	35-05-37 N	102-32-34 W	O.O. Cox Estate	To	I	
07-60-3D	35-06-45 N	102-32-29 W	High Plains Irrigation	To	I	
07-60-5A	35-04-50 N	102-33-18 W	S. M. Crain	To	A	
07-60-6A	35-04-48 N	102-31-31 W	Raymond L. Thompson and C. E. Winder	To	I	
07-60-6B	35-03-42 N	102-30-15 W	Raymond Thompson	To	I	
07-60-602	35-03-33 N	102-31-20 W	Tom Vestal	To-Trd	I	
07-60-603	35-01-10 N	102-32-06 W	Tom Vestal	To-Trd	I	
07-61-2C	35-06-15 N	102-25-04 W	O. D. Jackson	To	I	
07-61-2D	35-05-27 N	102-25-05 W	W. V. Swinburn	To	I	

Table 3-30. Wells Within 4.5 Miles of Center of the Deaf Smith County Site
(Page 3 of 3)

State Well Number	Latitude	Longitude	Owner	Water-Bearing Unit[a]	Use[b]	Remarks
07-61-3A	35-07-20 N	102-24-46 W	G. W. Simmons	To	I	
07-61-4B	35-03-22 N	102-28-29 W	Texas Agronomics	To	A	
07-61-5B	35-04-05 N	102-25-37 W	John A. & Raymond Smith	To	I	
07-61-502	35-03-22 N	102-26-13 W	C. D. Carnahan	To	I	Observation well (water level)

(a) To = Ogallala Formation; Trd = Dockum Group (Undifferentiated); To-Trd = Ogallala Formation - Dockum Group; Trdsr = Santa Rosa Sandstone.

(b) I = Irrigation; D = Domestic; L = Livestock; A = Abandoned; N = None.

(c) Within Deaf Smith County site as shown in Figure 3-72.

Source: Duffin, 1984
Knowles et al., 1984b
TNRIS, 1985.

Table 3-31. Projected Annual Water Requirements and Supply (Low Growth Rate) for the Seven-County Area, Texas, in Acre-Feet

Decade	Requirement/Supply	Demand Category						
		Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
1980	Requirement	47,944	10,082	9,599	535	1,474,093	20,286	1,562,539
	Supply							
	Ground Water	31,567	7,640	891	535	1,471,719	18,857	1,531,209
	Surface Water	16,377	2,442	8,708	0	2,374	1,429	31,330
	Total	47,944	10,082	9,599	535	1,474,093	20,286	1,562,539
	Surplus or (Shortage)	0	0	0	0	0	0	0
1990	Requirement	53,247	15,121	17,126	1,866	1,296,898	22,726	1,406,984
	Supply							
	Ground Water	25,473	6,532	0	1,866	1,108,338	19,325	1,161,534
	Surface Water	27,774	8,589	17,126	0	2,374	3,401	59,264
	Total	53,247	15,121	17,126	1,866	1,110,712	22,726	1,220,798
	Surplus or (Shortage)	0	0	0	0	(186,186)	0	(186,186)
2000	Requirement	58,385	18,883	17,126	2,205	1,309,625	26,340	1,432,564
	Supply							
	Ground Water	32,165	11,467	0	2,205	1,024,433	15,789	1,086,059
	Surface Water	26,220	7,416	17,126	0	2,374	10,551	63,687
	Total	58,385	18,883	17,126	2,205	1,026,807	26,340	1,149,746
	Surplus or (Shortage)	0	0	0	0	(282,818)	0	(282,818)

Table 3-31. Projected Annual Water Requirements and Supply (Low Growth Rate) for the Seven-County Area, Texas, in Acre-Feet (Page 2 of 2)

Decade	Requirement/Supply	Demand Category						
		Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
2010	Requirement	63,619	22,711	17,126	2,559	1,552,712	26,340	1,685,067
	Supply							
	Ground Water	38,613	13,689	0	2,559	1,011,853	15,526	1,082,240
	Surface Water	25,006	9,022	17,126	0	2,374	10,814	64,342
	Total	63,619	22,711	17,126	2,559	1,014,227	26,340	1,146,582
	Surplus or (Shortage)	0	0	0	0	(538,485)	0	(538,485)
2020	Requirement	70,250	27,533	17,126	2,914	1,508,168	26,340	1,652,331
	Supply							
	Ground Water	46,621	15,184	0	2,914	746,540	11,634	822,893
	Surface Water	23,629	12,349	17,126	0	2,374	14,706	70,184
	Total	70,250	27,533	17,126	2,914	748,914	26,340	893,077
	Surplus or (Shortage)	0	0	0	0	(759,254)	0	(759,254)
2030	Requirement	78,884	33,329	17,126	3,268	1,639,259	26,340	1,798,206
	Supply							
	Ground Water	52,976	18,498	0	3,268	573,416	9,198	657,356
	Surface Water	25,908	14,831	17,126	0	2,374	17,142	77,381
	Total	78,884	33,329	17,126	3,268	575,790	26,340	734,737
	Surplus or (Shortage)	0	0	0	0	(1,063,469)	0	(1,063,469)

Sources: TDWR, 1983c; TNRIS, 1982c.

Table 3-32. Projected Annual Water Requirements and Supply (Low Growth Rate) for Deaf Smith County, Texas, in Acre-Feet

Decade	Requirement/Supply	Demand Category						
		Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
1980	Requirement	4,686	4,012	0	0	309,193	6,113	322,163
	Supply							
	Ground Water	4,686	4,012	0	0	309,193	5,850	321,900
	Surface Water	0	0	0	0	0	263	263
	Total	4,686	4,012	0	0	309,193	6,113	322,163
	Surplus or (Shortage)	0	0	0	0	0	0	0
1990	Requirement	5,350	2,689	0	0	300,095	7,271	315,405
	Supply							
	Ground Water	5,350	2,689	0	0	239,302	6,221	253,562
	Surface Water	0	0	0	0	0	1,050	1,050
	Total	5,350	2,689	0	0	239,302	7,271	254,612
	Surplus or (Shortage)	0	0	0	0	(60,793)	0	(60,793)
2000	Requirement	6,153	3,424	0	0	303,040	8,429	321,046
	Supply							
	Ground Water	6,153	3,424	0	0	205,903	5,085	220,565
	Surface Water	0	0	0	0	0	3,344	3,344
	Total	6,153	3,424	0	0	205,903	8,429	223,909
	Surplus or (Shortage)	0	0	0	0	(97,137)	0	(97,137)

Table 3-32. Projected Annual Water Requirements and Supply (Low Growth Rate) for Deaf Smith County, Texas, in Acre-Feet
(Page 2 of 2)

Decade	Requirement/Supply	Demand Category						
		Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
2010	Requirement	6,838	4,193	0	0	359,290	8,429	378,750
	Supply							
	Ground Water	6,838	4,193	0	0	197,675	4,939	213,645
	Surface Water	0	0	0	0	0	3,490	3,490
	Total	6,838	4,193	0	0	197,675	8,429	217,135
	Surplus or (Shortage)	0	0	0	0	(161,615)	0	(161,615)
2020	Requirement	7,820	5,144	0	0	348,982	8,429	370,375
	Supply							
	Ground Water	7,820	5,144	0	0	154,391	3,930	171,285
	Surface Water	0	0	0	0	0	4,499	4,499
	Total	7,820	5,144	0	0	154,391	8,429	175,784
	Surplus or (Shortage)	0	0	0	0	(194,591)	0	(194,591)
2030	Requirement	9,283	6,280	0	0	379,316	8,429	403,308
	Supply							
	Ground Water	9,283	6,280	0	0	123,737	3,205	142,505
	Surface Water	0	0	0	0	0	5,224	5,224
	Total	9,283	6,280	0	0	123,737	8,429	147,729
	Surplus or (Shortage)	0	0	0	0	(255,579)	0	(255,579)

Sources: TDWR, 1985c; TNRIS, 1982c.

Table 3-33. Projected Annual Municipal Water Use (Low Growth Rate) for the Seven County Area, Texas, in Acre-Feet

County	City[a]	Requirement[b]	Decade 1980	1990	2000	2010	2020	2030
Castro	Dimmit	Ground Water	1,225	1,719	2,026	2,256	2,587	3,050
		Surface Water	0	0	0	0	0	0
		Total	1,225	1,719	2,026	2,256	2,587	3,050
	Hart	Ground Water	186	130	143	159	183	215
		Surface Water	0	0	0	0	0	0
		Total	186	130	143	159	183	215
	Other	Ground Water	532	587	591	659	755	890
		Surface Watter	0	0	0	0	0	0
		Total	532	587	591	659	755	890
Deaf Smith	Hereford	Ground Water	4,012	4,848	5,726	6,369	7,289	8,662
		Surface Water	0	0	0	0	0	0
		Total	4,012	4,848	5,726	6,369	7,289	8,662
	Other	Ground Water	674	502	427	469	531	621
		Surface Water	0	0	0	0	0	0
		Total	674	502	427	469	531	621
Oldham	Vega	Ground Water	280	288	363	441	528	634
		Surface Water	0	0	0	0	0	0
		Total	280	288	363	441	528	634
	Other	Ground Water	169	284	342	416	499	598
		Surface Water	0	0	0	0	0	0
		Total	169	284	342	416	499	598

Table 3-33. Projected Annual Municipal Water Use (Low Growth Rate) for the Seven County Area, Texas, in Acre-Feet
(Page 2 of 3)

County	City[a]	Requirement[b]	Decade 1980	1990	2000	2010	2020	2030
Parmer	Bovina	Ground Water	501	520	584	642	735	875
		Surface Water	0	0	0	0	0	0
		Total	501	520	584	642	735	875
	Farwell	Ground Water	351	380	419	461	527	627
		Surface Water	0	0	0	0	0	0
		Total	351	380	419	461	527	627
	Friona	Ground Water	837	1,088	1,261	1,386	1,587	1,889
		Surface Water	0	0	0	0	0	0
		Total	837	1,088	1,261	1,386	1,587	1,889
	Other	Ground Water	553	447	422	460	521	612
		Surface Water	0	0	0	0	0	0
		Total	553	447	422	460	521	612
Potter	Amarillo	Ground Water	10,405	6,104	10,293	11,482	16,070	15,481
		Surface Water	10,226	16,899	14,373	14,232	11,074	14,426
		Total	20,631	23,003	24,666	25,714	27,144	29,907
	Other	Ground Water	910	782	307	122	487	814
		Surface Water	0	0	0	0	0	0
		Total	910	782	307	122	487	814

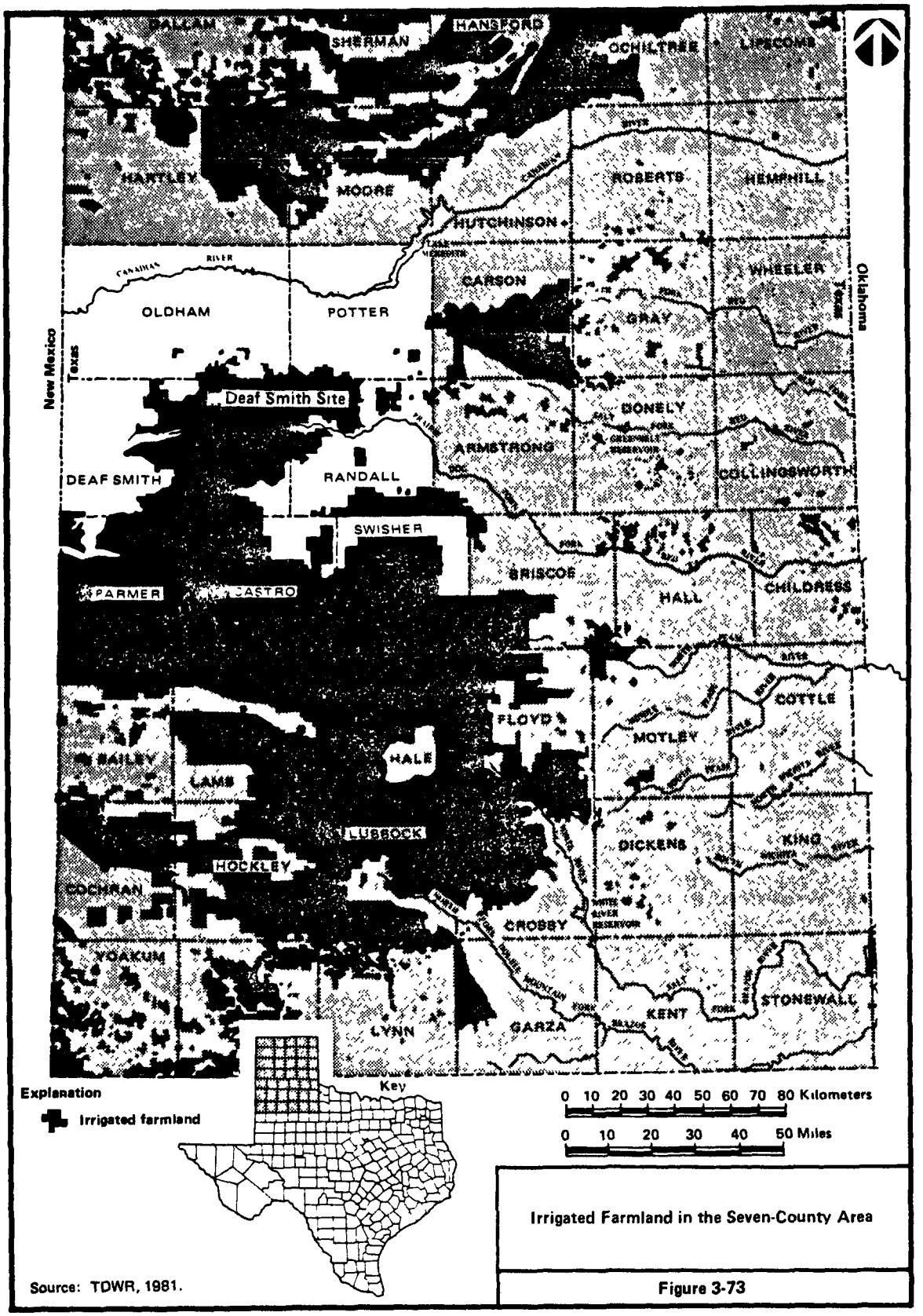
Table 3-33. Projected Annual Municipal Water Use (Low Growth Rate) for the Seven County Area, Texas, in Acre-Feet
(Page 3 of 3)

County	City[a]	Requirement[b]	Decade 1980	1990	2000	2010	2020	2030
Randall	Amarillo	Ground Water	6,251	2,500	2,633	5,673	6,500	9,607
		Surface Water	6,151	9,983	10,658	9,250	10,244	8,743
		Total	12,402	12,483	13,291	14,923	16,744	18,350
	Canyon	Ground Water	1,919	2,040	2,213	2,514	2,764	2,985
		Surface Water	0	0	0	0	0	0
		Total	1,919	2,040	2,213	2,514	2,764	2,985
	Other	Ground Water	1,079	2,179	3,262	3,791	3,961	4,117
		Surface Water	0	0	0	0	0	0
		Total	1,079	2,179	3,262	3,791	3,961	4,117
Swisher	Tulia	Ground Water	1,132	400	400	400	0	0
		Surface Water	0	892	1,189	1,524	2,311	2,739
		Total	1,132	1,292	1,589	1,924	2,311	2,739
	Other	Ground Water	551	675	753	913	1,097	1,299
		Surface Water	0	0	0	0	0	0
		Total	551	675	753	913	1,097	1,299

(a) Municipal water use for individual city covers use by households, commercial establishments, light manufacturing establishments, public facilities, fire protection services, public recreational areas, and munipcal facilities; the category "other" covers rural domestic use.

(b) The Texas Water Plan (TDWR, 1984) assumes that projected municipal water requirements are completely satisfied.

Sources: TDWR, 1985a; TNRIS, 1982c.



Irrigated Farmland in the Seven-County Area

Source: TDWR, 1981.

Figure 3-73

Total water requirements in the seven-county area are projected to increase from 1.93 x 10^9 cubic meters (1,560,000 acre-feet) in 1980 to 2.22 x 10^9 cubic meters (1,800,000 acre-feet) in the year 2030 for the low-growth rate and to 3.26 x 10^9 cubic meters (2,640,000 acre-feet) for the high growth rate (Tables 3-31 and 3-34). Total water requirements in Deaf Smith County are projected to increase over the same time period by 25 percent for the low growth rate and 90 percent for the high growth rate (Figures 3-74 and 3-75). Irrigation is projected to remain the principal water use and ground water the principal water source through the year 2030 (TDWR, 1983b; 1983c; 1985a; 1985b). The projected water requirements by category of use are shown in Tables 3-31, 3-32, 3-34, and 3-35. The projected municipal water requirements are shown in Tables 3-33 and 3-36.

The projected average annual supply available from the Ogallala Formation is estimated as the average annual recharge plus the annual quantity of water that would be withdrawn from recoverable storage to meet projected annual demands. This is the quantity of water that the Ogallala is hydrologically capable of supplying; it decreases as a result of aquifer depletion (TDWR, 1984, Vol. 2, p. II-10). Projected water requirements in the seven-county area are estimated to exceed available water supplies from 1990 through the year 2030. The estimated shortage in the year 2030 is 1.31 x 10^9 cubic meters (1,060,000 acre-feet) for the low growth rate and 2.33 x 10^9 cubic meters (1,890,000 acre-feet) for the high growth rate (Tables 3-31 and 3-34). The estimated shortage in Deaf Smith County in the year 2030 is 3.15 x 10^8 cubic meters (256,000 acre-feet) for the low growth rate and 5.67 x 10^8 cubic meters (460,000 acre-feet) for the high growth rate (Tables 3-32 and 3-35). The water shortages are projected to occur in irrigated agriculture (TDWR, 1983a, 1983b, 1983c, 1985a, 1985b).

Historical ground-water withdrawals from the Ogallala Formation in the seven-county area have exceeded the natural recharge rate. These overdrafts have caused substantial water-level declines and the removal of large volumes of ground water from recoverable storage. In 1980, ground-water withdrawals in the seven-county area totaled 1.89 x 10^9 cubic meters (1,530,000 acre-feet). This withdrawal rate is about 69 times greater than the estimated annual recharge rate of 2.75 x 10^7 cubic meters (22,300 acre-feet). Ground-water withdrawals in Deaf Smith County totaled 3.97 x 10^8 cubic meters (322,000 acre-feet). This withdrawal rate is about 71 times greater than the estimated annual recharge rate of 5.61 x 10^6 cubic meters (4,550 acre-feet) (TDWR, 1985c; TNRIS, 1982c).

The ground water in recoverable storage, the saturated thickness, and well yields in the Ogallala Formation are projected to decrease in the seven-county area as a consequence of the projected requirements. Ground water in recoverable storage in the seven-county area is projected to decrease from the 1980 volume of 5.42 x 10^{10} cubic meters (43,900,000 acre-feet) to 1.52 x 10^{10} cubic meters (12,300,000 acre-feet) by the year 2030 for the low growth rate and to 8.67 x 10^9 cubic meters (7,030,000 acre-feet) for the high growth rate (Table 3-37). Ground water in recoverable storage in Deaf Smith County is projected to decrease over the same time period from 1.2 x 10^{10} cubic meters (10,000,000 acre-feet) to 4.45 x 10^9 cubic meters (3,610,000 acre-feet) for the low growth rate and to 2.07 x 10^9 cubic meters (1,680,000 acre-feet) for the high growth rate (Figure 3-76, TDWR, 1985c, 1985d).

The saturated thickness of the Ogallala Formation at the Deaf Smith County site is estimated to range from 12.2 to 39.6 meters (50 to 115 feet) (Figure 3-68). Well yields in 1980 ranged from about 31.5 to more than 63.0 liters per second (500 to more than 1,000 gallons per minute). By the year 2030, the saturated thickness is projected to range from 6.1 meters to 30.5 meters (20 feet to 100 feet) with well yields ranging from 6.3 to more than 63.0 liters per second (100 to more than 1,000 gallons per minute) (Knowles et al., 1984, Vol. 1, p. 81; Wyatt et al., 1977, pp. 9, 23).

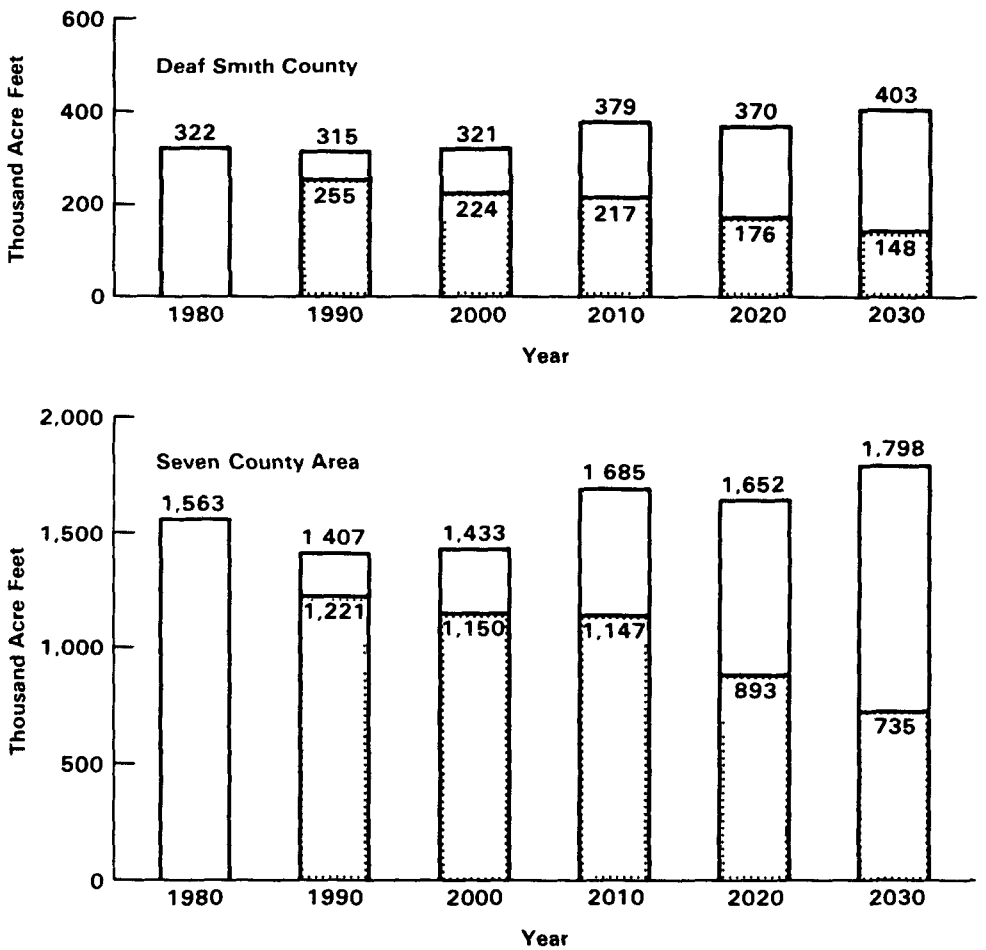
Table 3-34. Projected Annual Water Requirements and Supply (High Growth Rate) for the Seven-County Area, Texas, in Acre-Feet

Decade	Requirement/Supply	Demand Category: Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
1980	Requirement	47,944	10,082	9,599	535	1,474,093	20,286	1,562,539
	Supply							
	Ground Water	31,567	7,640	891	535	1,471,719	18,857	1,531,209
	Surface Water	16,377	2,442	8,708	0	2,374	1,429	31,330
	Total	47,944	10,082	9,599	535	1,474,093	20,286	1,562,539
	Surplus or (Shortage)	0	0	0	0	0	0	0
1990	Requirement	72,463	15,888	17,126	1,866	1,260,824	22,726	1,390,893
	Supply							
	Ground Water	41,700	11,925	17,126	1,866	1,166,898	20,786	1,243,175
	Surface Water	30,763	3,963	0	0	2,374	1,940	56,146
	Total	72,463	15,888	17,126	1,866	1,169,272	22,726	1,299,341
	Surplus or (Shortage)	0	0	0	0	(91,552)	0	(91,552)
2000	Requirement	80,300	20,535	17,126	2,205	2,010,312	26,340	2,156,818
	Supply							
	Ground Water	46,150	16,601	0	2,205	1,482,278	23,739	1,570,973
	Surface Water	34,150	3,934	17,126	0	2,374	2,601	60,185
	Total	80,300	20,535	17,126	2,205	1,484,652	26,340	1,631,158
	Surplus or (Shortage)	0	0	0	0	(525,660)	0	(525,660)

Table 3-34. Projected Annual Water Requirements and Supply (High Growth Rate) for the Seven-County Area, Texas, in Acre-Feet
(Page 2 of 2)

Decade	Requirement/Supply	Demand Category						
		Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
2010	Requirement	89,842	25,300	17,126	2,559	1,831,268	26,340	1,992,935
	Supply							
	Ground Water	54,958	21,366	0	2,559	1,271,203	19,858	1,369,944
	Surface Water	34,884	3,934	17,126	0	2,374	6,482	64,800
	Total	89,842	25,300	17,126	2,559	1,273,577	26,340	1,434,744
	Surplus or (Shortage)	0	0	0	0	(557,691)	0	(557,691)
2020	Requirement	103,605	31,207	17,126	2,914	2,449,602	26,340	2,630,794
	Supply							
	Ground Water	68,846	26,828	0	2,914	794,172	12,318	905,018
	Surface Water	34,759	3,739	17,126	0	2,374	14,022	72,020
	Total	103,605	30,567	17,126	2,914	796,546	26,340	977,098
	Surplus or (Shortage)	0	(640)	0	0	(1,653,056)	0	(1,653,696)
2030	Requirement	120,353	38,311	17,126	3,268	2,431,606	26,340	2,637,004
	Supply							
	Ground Water	85,446	34,312	0	3,268	542,111	8,641	673,778
	Surface Water	34,907	3,999	17,126	0	2,374	17,699	76,105
	Total	120,353	38,311	17,126	3,268	544,485	26,340	749,883
	Surplus or (Shortage)	0	0	0	0	(1,887,121)	0	(1,887,121)

Sources: TDWR, 1985d; TNRIS, 1982c.



Explanation

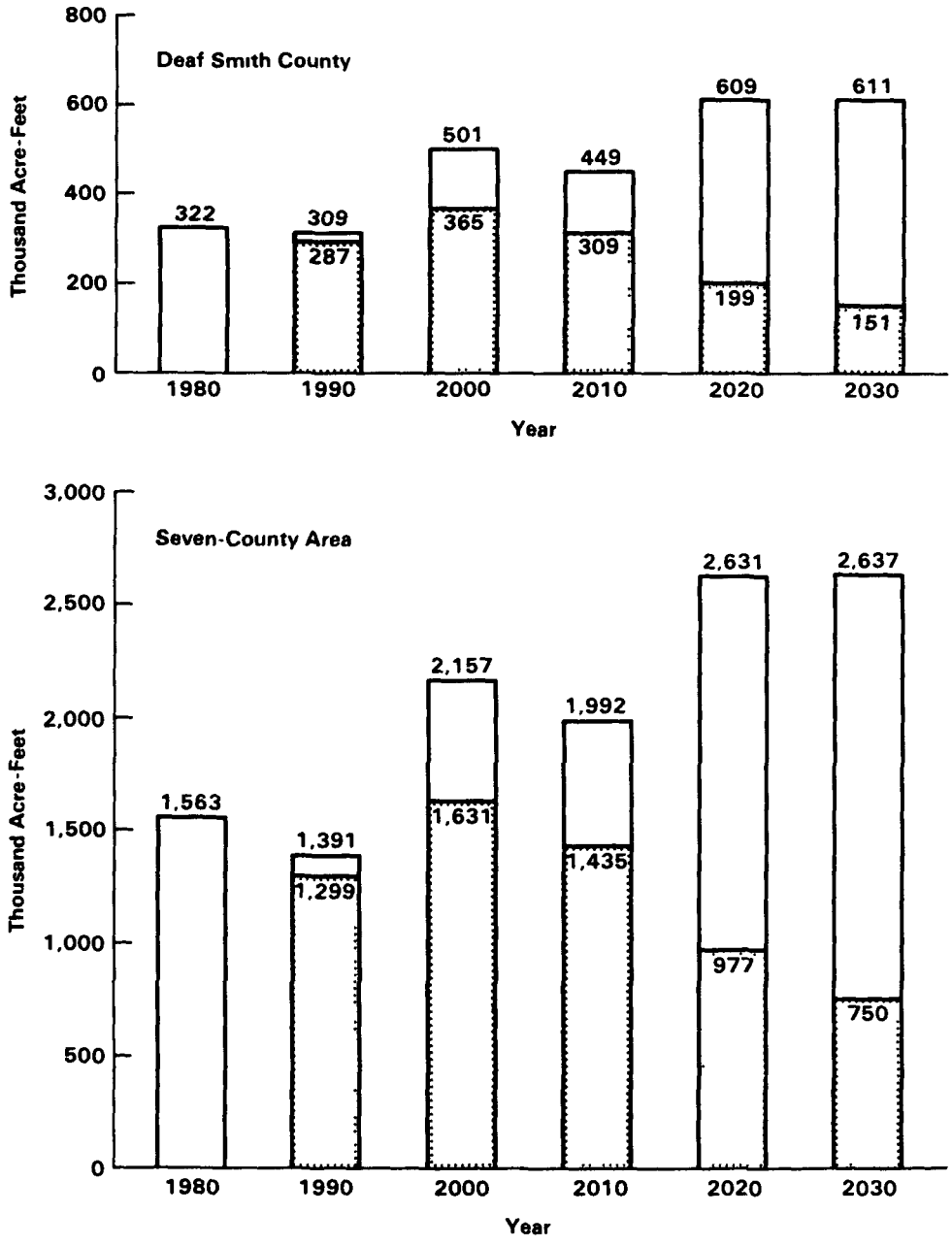
Requirement

Supply

Source TDWR 1985c TNRIS 1982c

Projected Water Requirements and Supply for Low Growth Rate in Deaf Smith County and in the Seven-County Area, Texas

Figure 3-74



Explanation

Requirement

Supply

Source TDWR, 1985b, TNRIS, 1982c

Projected Water Requirements and Supply for High Growth Rate in Deaf Smith County and in the Seven-County Area, Texas

Figure 3-75

Table 3-35. Projected Annual Water Requirements and Supply (High Growth Rate) for Deaf Smith County, Texas, in Acre-Feet

Decade	Requirement/Supply	Demand Category						
		Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
1980	Requirement	4,686	4,012	0	0	309,193	6,113	322,163
	Supply							
	Ground Water	4,686	4,012	0	0	309,193	5,850	321,900
	Surface Water	0	0	0	0	0	263	263
	Total	4,686	4,012	0	0	309,193	6,113	322,163
	Surplus or (Shortage)	0	0	0	0	0	0	0
1990	Requirement	6,975	2,803	0	0	291,823	7,271	308,872
	Supply							
	Ground Water	6,975	2,803	0	0	270,818	7,004	287,600
	Surface Water	0	0	0	0	0	267	267
	Total	6,975	2,803	0	0	270,818	7,271	287,267
	Surplus or (Shortage)	0	0	0	0	(21,005)	0	(21,005)
2000	Requirement	8,121	3,702	0	0	481,122	8,429	501,374
	Supply							
	Ground Water	8,121	3,702	0	0	344,330	8,102	364,255
	Surface Water	0	0	0	0	0	327	327
	Total	8,121	3,702	0	0	344,330	8,429	364,582
	Surplus or (Shortage)	0	0	0	0	(136,792)	0	(136,792)

Table 3-35. Projected Annual Water Requirements and Supply (High Growth Rate) for Deaf Smith County, Texas, in Acre-Feet
(Page 2 of 2)

Decade	Requirement/Supply	Demand Category						
		Municipal	Manufacturing	Steam Electric	Mining	Irrigation	Livestock	Total
2010	Requirement	9,418	4,643	0	0	426,428	8,429	448,918
	Supply							
	Ground Water	9,418	4,643	0	0	286,872	6,797	307,730
	Surface Water	0	0	0	0	0	1,632	1,632
	Total	9,418	4,643	0	0	286,872	8,429	309,362
	Surplus or (Shortage)	0	0	0	0	(139,556)	0	(139,556)
2020	Requirement	11,732	5,806	0	0	583,124	8,429	609,091
	Supply							
	Ground Water	11,732	5,806	0	0	172,590	4,286	194,414
	Surface Water	0	0	0	0	0	4,143	4,143
	Total	11,732	5,806	0	0	172,590	8,429	198,557
	Surplus or (Shortage)	0	0	0	0	(410,534)	0	(410,534)
2030	Requirement	14,637	7,194	0	0	580,571	8,429	610,831
	Supply							
	Ground Water	14,637	7,194	0	0	120,813	3,074	145,718
	Surface Water	0	0	0	0	0	5,355	5,355
	Total	14,637	7,194	0	0	120,813	8,429	151,073
	Surplus or (Shortage)	0	0	0	0	(459,758)	0	(459,758)

Sources: TDWR, 1985b; TNRIS, 1982c.

Table 3-36. Projected Annual Municipal Water Use (High Growth Rate) for the Seven-County Area, Texas, in Acre-Feet

County	City[a]	Requirement[b]	Decade 1980	1990	2000	2010	2020	2030
Castro	Dimmit	Ground Water	1,225	2,154	2,599	3,040	3,752	4,617
		Surface Water	0	0	0	0	0	0
		Total	1,225	2,154	2,599	3,040	3,752	4,617
	Hart	Ground Water	186	202	228	267	329	405
		Surface Water	0	0	0	0	0	0
		Total	186	202	228	267	329	405
	Other	Ground Water	532	762	782	915	1,129	1,389
		Surface Water	0	0	0	0	0	0
		Total	532	762	782	915	1,129	1,389
Deaf Smith	Hereford	Ground Water	4,012	6,350	7,584	8,803	10,977	13,707
		Surface Water	0	0	0	0	0	0
		Total	4,012	6,350	7,584	8,803	10,977	13,707
	Other	Ground Water	674	625	537	615	755	930
		Surface Water	0	0	0	0	0	0
		Total	674	625	537	615	755	930
Oldham	Vega	Ground Water	280	361	492	618	780	961
		Surface Water	0	0	0	0	0	0
		Total	280	361	492	618	780	961
	Other	Ground Water	169	361	473	592	749	922
		Surface Water	0	0	0	0	0	0
		Total	169	361	473	592	749	922

Table 3-36. Projected Annual Municipal Water Use (High Growth Rate) for the Seven-County Area, Texas, in Acre-Feet
(Page 2 of 3)

County	City[a]	Requirement[b]	Decade 1980	1990	2000	2010	2020	2030
Parmer	Bovina	Ground Water	501	633	731	848	1,059	1,328
		Surface Water	0	0	0	0	0	0
		Total	501	633	731	848	1,059	1,328
	Farwell	Ground Water	351	475	539	625	781	979
		Surface Water	0	0	0	0	0	0
		Total	351	475	539	625	781	979
	Friona	Ground Water	837	1,391	1,656	1,922	2,401	3,009
		Surface Water	0	0	0	0	0	0
		Total	837	1,391	1,656	1,922	2,401	3,009
	Other	Ground Water	553	552	534	614	757	939
		Surface Water	0	0	0	0	0	0
		Total	553	552	534	614	757	939
Potter	Amarillo	Ground Water	10,405	11,809	13,946	17,176	21,646	26,619
		Surface Water	10,226	18,578	18,609	18,584	18,459	18,631
		Total	20,631	30,387	32,555	35,760	40,105	45,250
	Other	Ground Water	910	1,040	407	170	725	1,240
		Surface Water	0	0	0	0	0	0
		Total	910	1,040	407	170	725	1,240
Randall	Amarillo	Ground Water	6,251	6,640	5,211	6,610	9,235	12,369
		Surface Water	6,151	11,723	14,462	15,000	15,000	14,976
		Total	12,402	18,363	19,673	21,610	24,235	27,345

Table 3-36. Projected Annual Municipal Water Use (High Growth Rate) for the Seven-County Area, Texas, in Acre-Feet
(Page 3 of 3)

County	City[a]	Requirement[b]	Decade 1980	1990	2000	2010	2020	2030
Randall (cont'd)	Canyon	Ground Water	1,919	3,103	3,383	3,760	4,132	4,594
		Surface Water	0	0	0	0	0	0
		Total	1,919	3,103	3,383	3,760	4,132	4,594
	Other	Ground Water	1,079	3,203	4,853	5,530	5,779	6,181
		Surface Water	0	0	0	0	0	0
		Total	1,079	3,203	4,853	5,530	5,779	6,181
Swisher	Tulin	Ground Water	1,132	1,165	1,123	1,494	2,171	3,111
		Surface Water	0	462	1,079	1,300	1,300	1,300
		Total	1,132	1,627	2,202	2,794	3,471	4,411
	Other	Ground Water	551	874	1,072	1,359	1,689	2,146
		Surface Water	0	0	0	0	0	0
		Total	551	874	1,072	1,359	1,689	2,146

(a) Municipal water use for individual city covers use by households, commercial establishments, light manufacturing establishments, public facilities, fire protection services, public recreational areas, and municipal facilities; the category "Other" covers rural domestic use.

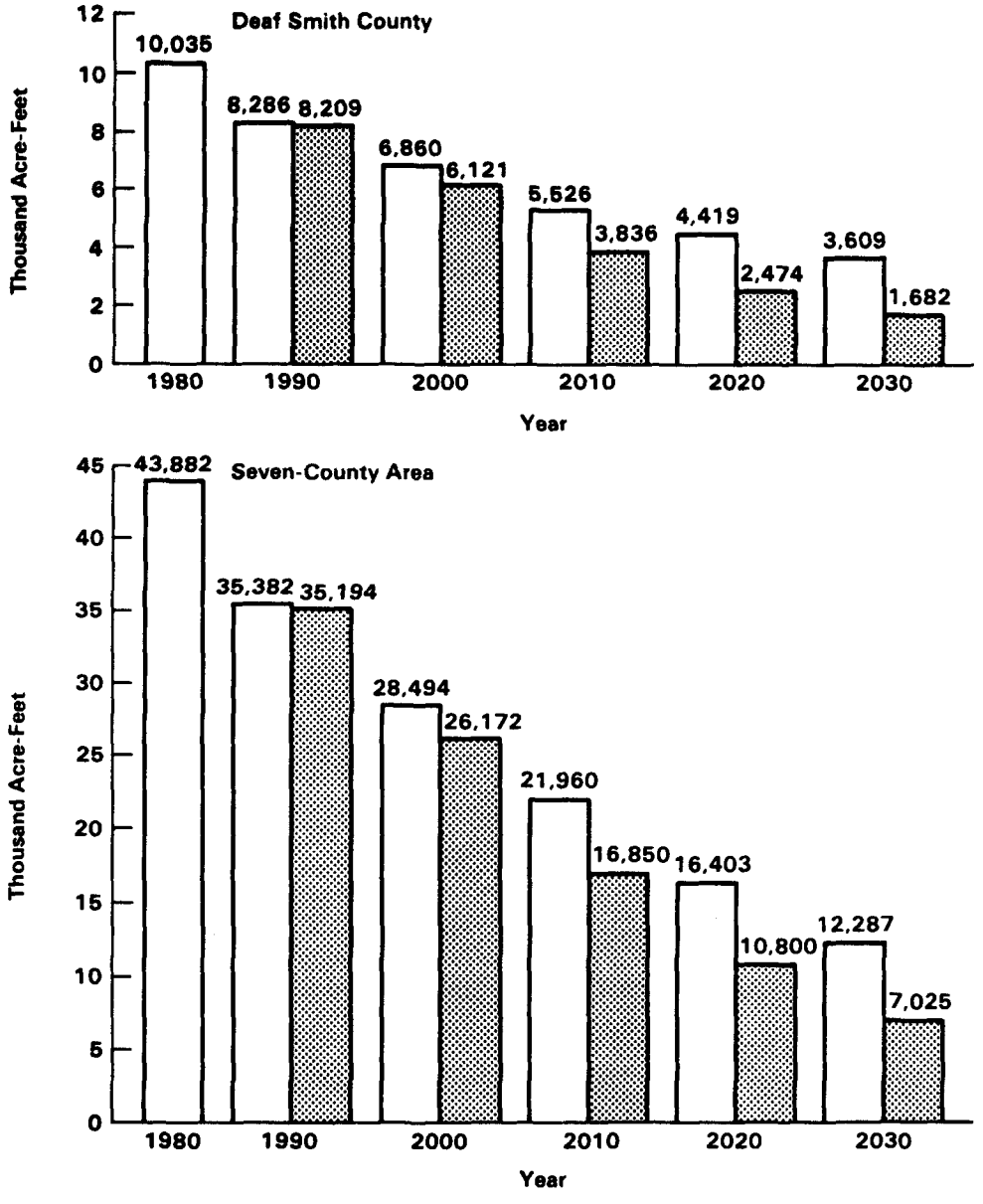
(b) The Texas Water Plan (TDWR, 1984, Vol. 2) assumes that projected municipal water requirements are completely satisfied.

Sources: TDWR, 1985b; TNRIS, 1982c.

Table 3-37. Annual Recharge and Projected Volume of Ground Water in Recoverable Storage in the Seven-County Area, in Acre-Feet

County	Effective Annual Recharge	Recoverable Storage					
		1980	1990	2000	2010	2020	2030
				Low Growth Rate			
Castro	3,310	12,323,488	9,782,404	7,646,075	5,559,511	3,715,066	2,289,717
Deaf Smith	4,550	10,034,672	8,236,124	6,860,005	5,525,918	4,419,155	3,608,512
Oldham	2,150	922,243	841,796	771,185	715,056	677,546	652,024
Parmer	3,260	10,390,818	7,980,781	6,096,044	4,259,462	2,700,201	1,670,547
Potter	3,020	2,764,497	2,507,760	2,296,280	2,110,805	1,943,004	1,786,891
Randall	3,420	3,451,905	2,887,455	2,447,819	2,045,086	1,690,636	1,384,924
Swisher	2,600	3,993,959	3,095,611	2,376,310	1,743,988	1,256,847	893,900
Total	22,310	43,881,582	35,381,931	28,493,718	21,959,826	16,402,545	12,286,515
				High Growth Rate			
Castro	3,310	12,323,488	9,799,373	7,522,616	5,181,354	3,207,745	1,736,774
Deaf Smith	4,550	10,034,672	8,209,123	6,122,125	3,836,022	2,474,242	1,681,914
Oldham	2,150	922,243	823,368	584,847	295,031	192,656	168,700
Parmer	3,260	10,390,818	7,953,357	5,779,221	3,530,533	1,883,918	924,504
Potter	3,020	2,764,497	2,460,194	2,146,266	1,919,966	1,768,400	1,640,532
Randall	3,420	3,451,905	2,864,062	1,963,511	1,072,218	782,499	648,580
Swisher	2,600	3,993,959	3,084,265	2,053,983	1,015,271	490,509	224,365
Total	22,310	13,881,582	35,193,742	26,172,569	16,850,395	10,799,969	7,025,369

Source: TDWR, 1985c, d.



Explanation

Low Growth Rate

High Growth Rate

Source: TDWR, 1985c,d.

Current and Projected Ground Water in Recoverable Storage in Deaf Smith County and in the Seven-County Area, Texas

Figure 3-76

3.3.3.4 Potential Supplemental Water Supplies

The Ogallala Formation is the principal source of fresh ground water on the Southern High Plains. The Dockum Group yields small to moderate amounts of fresh to slightly saline ground water in locally developed areas (Duffin, 1984, pp. 1, 2); Knowles et al., 1984, Vol. 1, p. 12). Well yields of 25 to 57 liters per second (400 to 900 gallons per minute) have been reported for wells completed in the Dockum near the Deaf Smith County site. In 1983, Happy, Hereford, and Tulia obtained approximately 1.42 x 10^6 cubic meters (1,155 acre-feet) of ground water from wells completed in the Dockum (Duffin, 1984, pp. 21, 25, 26).

Lake Meredith, on the Canadian River in Hutchinson, Moore, and Potter Counties, is the principal source of surface water on the Southern High Plains. It is operated by the Canadian River Municipal Water Authority. In accordance with the Canadian River Compact, the Authority can withdraw 1.27 x 10^8 cubic meters (103,000 acre-feet) annually for municipal and industrial use by the 11 member cities of the Authority. The cities are Amarillo, Borger, and Pampa in the Canadian River Basin; Levelland, Lubbock, O'Donnel, Plainview, Slaton, and Tahoka in the Brazos River Basin; and Brownsfield and Lamesa in the Colorado River Basin (TDWR, 1984, Vol. 2, pp. III-1 to III-4). There is no unappropriated surface water in the Canadian River Basin (Sweazy et al., 1978, p. 79).

Amarillo is allotted the largest volume of water per year, 4.71 x 10^7 cubic meters (38,200 acre-feet). However, in the water-short year 1980, actual delivery of water to Amarillo was 2.57 x 10^7 cubic meters (20,800 acre-feet) (TDWR, 1984, Vol. 2, pp. III-1 to III-4). In addition, Amarillo's well fields in the High Plains aquifer are capable of producing 8.09 x 10^7 cubic meters (65,600 acre-feet) per year (NUS, 1985, BMI/ONWI-557, p. 35).

The MacKenzie Municipal Water Authority operates MacKenzie Reservoir on Tule Creek in Briscoe County. Member cities include Silverton and Tulia in the Red River Basin and Floydada and Lockney in the Brazos River Basin (TDWR, 1984, Vol. 2, pp. III-2 to III-5). Total annual withdrawals of 3.32 x 10^6 cubic meters (2,690 acre-feet) are scheduled to begin in 1984. Tulia, which previously obtained its water from the Ogallala aquifer, will receive 1.42 x 10^6 cubic meters (1,150 acre-feet) per year (NUS, 1985, BMI/ONWI-557, p. 37).

Greenbelt Reservoir, on the Salt Fork of the Red River in Donley County, is operated by the Greenbelt Municipal and Industrial Water Authority. Member cities include Clarenden, Hedley, Childress, Crowell, Memphis, Quanah, and Wellington. Withdrawals in 1980 were about 5.43 x 10^6 cubic meters (4,400 acre-feet) (TDWR, 1984, Vol. 2, pp. III-2 to III-5).

Treated effluent from municipal wastewater treatment systems may be available to supplement the repository's water supply system. The Amarillo system has the largest discharge of all cities in the area. The combined discharge from the city's two plants is 2.45 x 10^7 cubic meters (19,900 acre-feet) per year, which is currently sold to irrigators and industry (NUS, 1985, BMI/ONWI-557, p. 37).

Other municipal wastewater treatment systems which have significant annual volumes of treated effluent include Plainview with 2.76 x 10^6 cubic meters (2,240 acre-feet), Canyon with 2.49 x 10^6 cubic meters (2,020 acre-feet), and Hereford with 2.21 x 10^6 cubic meters (1,790 acre-feet). The Canyon effluent is discharged to streams. The Plainview and Hereford effluents are used for irrigation. Effluent from the Tulia system totals only 4.14 x 10^5 cubic meters (336 acre-feet) per year and is sold for irrigation (NUS, 1985, BMI/ONWI-557 p. 37).

Concern about the rapid depletion of the Ogallala aquifer has led to discussions about the increased use of water conservation methods and conversion to dry land farming in the High Plains region. In addition, recent studies have demonstrated methods that have the potential for replenishing the Ogallala aquifer. The methods include artificial recharge (Schneider and Jones, 1984, p. 319; Urban and Claborn, 1984, p. 367) and secondary recovery of capillary water (Rauschuber, 1984, p. 514; Wyatt, 1984, p. 500). Over the nearly 60-year life of the repository, changes in agricultural practices, artificial recharge, and secondary recovery could have a positive effect on ground-water availability in the area.

3.4 ENVIRONMENTAL SETTING

This section describes the environmental setting of the Deaf Smith County site and vicinity with respect to land use; terrestrial and aquatic ecosystems; air quality and meteorology; noise; aesthetic resources; archaeological, cultural, and historical resources; and background radiation.

3.4.1 Land Use/Land Cover

The site is a 23-square-kilometer (9-square-mile) area in north-central Deaf Smith County, a part of the Southern High Plains of Texas. The vicinity of the site is defined as the area within a 10-kilometer (6.2-mile) radius of the center of the site. The Southern High Plains is an important source of agricultural products in Texas, and Deaf Smith County is one of the agricultural leaders there. In 1974, the county ranked 13th in the nation in the value of agricultural products sold (Bureau of the Census, 1978a).

3.4.1.1 Existing Land-Use Patterns

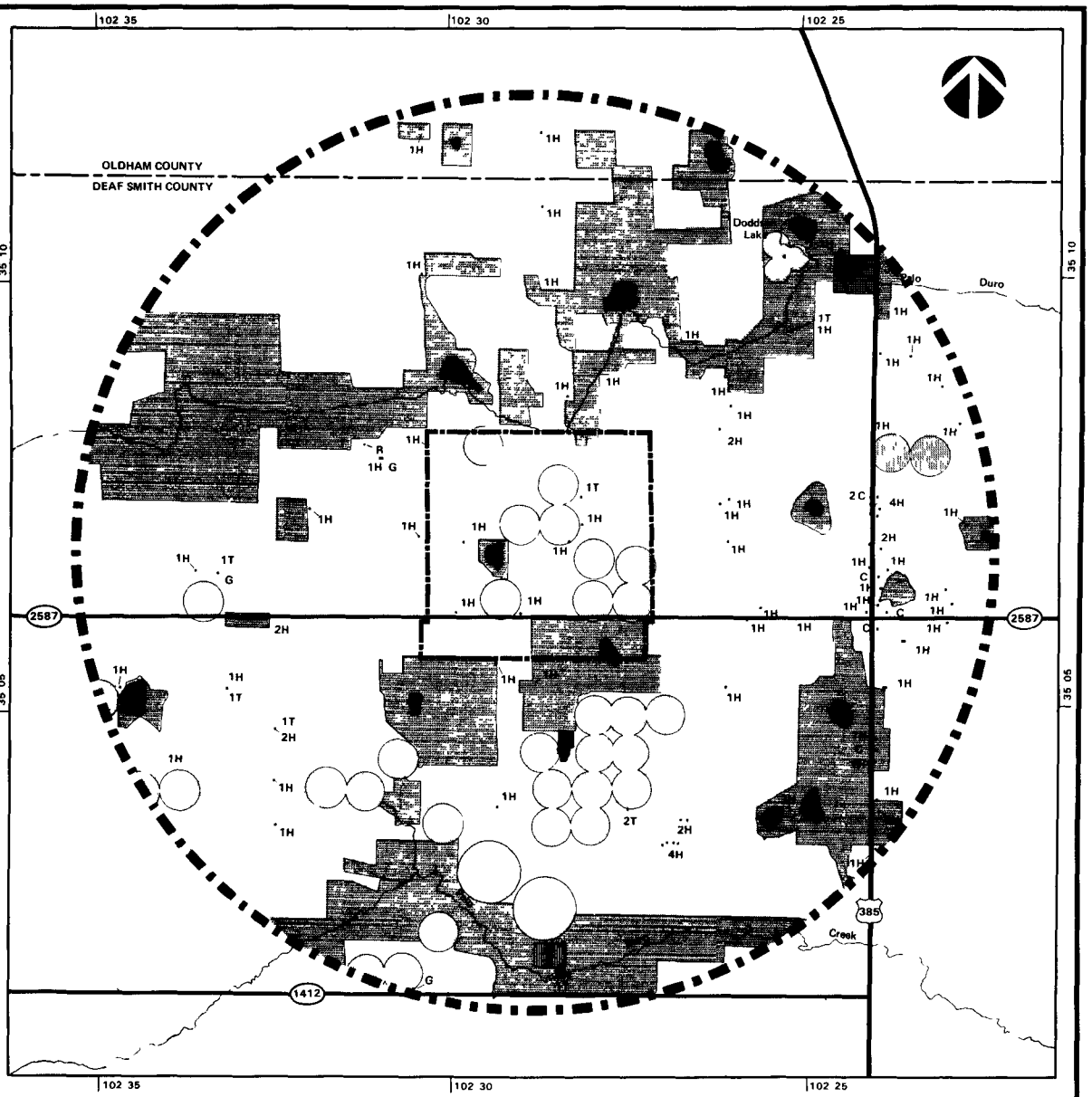
Land use and land cover at the site and in the site vicinity is predominantly agricultural with 2,093 hectares (5,168 acres) at the site and 23,036 hectares (56,879 acres) in the vicinity being classified as agricultural. Seventy-five percent of the land is used to grow crops. Approximately 82 percent of the site area contains soils classified as prime farmland by the USDA Soil Conservation Service (SCS) in Texas (Prendergast, 1985). The site's farmlands were classified by SCS during a land assessment of the site performed in compliance with the "Farmland Protection Policy Act (7 USC Sections 4201-4209)." During the summer of 1983, sugarbeets, wheat, and sorghum were grown at the site. Sugarbeets and sorghum are irrigated crops and the wheat may or may not be irrigated, depending on precipitation. Most irrigation on the site is done by the furrow method or pivot wheels. Nine pivot systems were operated on the site during the summer of 1983 (Figure 3-77). Each typically represents an initial investment of $75,000 to $100,000 (in 1983 dollars). Twenty-nine additional pivot systems were observed in the site vicinity. No determination of the total amount of irrigated land at the site and vicinity has been made. However, due to the large number of pivots found with the site and vicinity, it is believed that most, if not all, of the cropland is irrigated.

The High Plains of Texas are an important source of hybrid sorghum seed. A major producer of these seeds owns property within and adjacent to the nine-square-mile site. These seeds are distributed nationally to sorghum growers. Several conditions combine to make the High Plains an excellent area to grow hybrid seed, including isolation from contamination by other species of plants, cooperation with neighboring farmers in the production of hybrids, and semiarid climate and flat landscape.

The second most abundant land use and land cover in the site vicinity is rangeland, although relatively little rangeland is found at the site. Areas classified as rangeland on the land-use map (Figure 3-77) are those that are kept in rangeland year round. Rangeland is generally found in association with stream valleys and playa lakes. The largest bands of rangeland are found to the south and north of the site, along Palo Duro Creek and playa lakes. Rangeland that is used to graze cattle is also important to the agricultural economy of Deaf Smith County. The cash receipts from the selling of cattle are more than twice that derived from the sale of crops on a county basis (see Table 3-65).

Agricultural land and rangeland combined represent 99 percent of the land within the site vicinity. Playa lakes, farm residences, and a country club occupy the remaining 1 percent of the land area. There are no urban areas found in the vicinity. Vega is the nearest urban area and is approximately 14 kilometers (9 miles) from the center of the site. Nearby facilities, in addition to a seed company, include numerous grain storage facilities, commercial operations, and a dairy along Route 385.

The land resources of Deaf Smith County can be characterized as agriculture, rangeland, urban areas, and playa lakes (see Section 3.4.2). Agricultural uses of the land dominate, as shown in Table 3-38. The amount of land in farms and ranches declined between 1969 and 1974, but has remained fairly constant since 1974.



Explanation

- Croplands
- Rangeland
- Feedlot
- Country Club
- Playa Lake
- Pivot Irrigation
- Structures
  - C = Commercial
  - G = Grain Storage
  - H = House
  - R = Richardson Seed Inc.
  - T = Trailer

Source NUS, 1984, BMI/ONWI-509 1 12,000 CIR Photography and Field Reconnaissance Plotted on USGS Quadrangle Maps.

1 0 1 5 Kilometers

1 0 1 3 Miles

Deaf Smith County Site and Vicinity Land Use

Figure 3-77

Table 3-38. Deaf Smith County Land Use (in Thousands of Acres)

Land Use	1969	1974	1978	1982	1983
Approximate Land Area	966	966	966	966	966
Land Irrigated	235	238	222	260	200
Cropland Planted	532	510	551	397	287
Cropland Harvested	254	285	315	329	200
Pasture and Rangeland	NA	NA	299	392	(a)
Number of Farms	751	637	650	653	(a)
Average Farm Size	1.197	1.344	1.344	1.235	(a)

(a) Data unavailable.

Sources: NUS, 1984, BMI/ONWI-509; TCLRS, 1982, 1983.

Farming in Deaf Smith County continues to rely on irrigation. In 1969, 95,500 hectares (235,802 acres), or 44 percent of the total cropland planted in the county, was irrigated; by 1983 irrigated land had increased to 68 percent of total cropland (TCLRS, 1983). Water for irrigation originates primarily from the High Plains aquifer, especially from the Ogallala Formation (Section 3.3.3).

Furrow irrigation is the most commonly practiced method of irrigation in the county. Many farmers have installed pivot irrigation systems, lateral-wheel systems, or trickle systems as alternatives to furrow irrigation. The amount of land under sprinkler irrigation increased by over 6,000 percent between 1964 and 1979 (NUS, 1984, BMI/ONWI-509).

The primary crops in 1982, both in terms of planted and harvested acres, were wheat, grain sorghum, corn, sugar beets, hay, and upland cotton. The amount of wheat planted in Deaf Smith County has more than doubled since 1970; this amount rose by over 300 percent between 1970 and 1975, but has declined steadily since then. Most of the wheat planted is the hard red winter variety and is grown in nonirrigated fields (Table 3-39). Not only is wheat sold as a cash crop but it is also grazed by cattle in the winter.

In 1971, the amount of acreage devoted to sorghum for grain exceeded wheat acreage (62,000 hectares versus 53,000 hectares [153,000 acres versus 130,000 acres]); however, by 1982 it had fallen to slightly more than one-third of wheat acreage. The majority of the decrease has been in irrigated sorghums.

Area devoted to corn peaked in 1976, when there were 49,000 hectares (121,000 acres) planted (all irrigated), largely to support a growing feedlot industry. Corn plantings fell by 73 percent between the peak year and 1982, due primarily to increased costs of irrigation, which make corn less attractive as a feed crop.

Sugar beets are one crop that has had fairly constant planting, in spite of reliance on irrigation for all production. This may be attributable to the fixed capacity of the sugar beet processing plant in Hereford, the primary buyer of sugar beets grown in Deaf Smith and surrounding counties.

Hay is reported in acres harvested rather than acres planted because it is a perennial crop, typically planted only once every 4 years. It is usually sold locally as cattle feed.

The majority of the cotton grown in Deaf Smith County is irrigated. Although the amount of cotton planted declined by 69 percent between 1970 and 1976, the crop has rebounded since that time and in 1982 exceeded 1970 levels by 34 percent.

Other crops of importance to Deaf Smith County farmers include barley, oats, rye, soybeans, sunflowers, carrots, and potatoes.

Pastures for livestock and rangeland constituted 40 percent of the total area of Deaf Smith County in 1982. Harvested fields are sometimes used in addition to rangeland for grazing cattle. Cattle may also be grazed on winter wheat fields during the winter months. Deaf Smith County leads all other Texas counties in the production of cattle and calves. Although there have been fluctuations from year to year, the number of cattle marketings has increased 38 percent from 1970 to 1980 (Table 3-40). Income from livestock and livestock products exceeded income from crops by more than 100 percent in 1982.

Agriculture is expected to remain the major land use in Deaf Smith County, with dryland farming predominant in the western portion of the county and irrigated agriculture predominant in the eastern portion. Decreased availability of water from the High Plains aquifer will probably accelerate the application of refined irrigation technologies that allow for more efficient use of water. If energy costs again start to rise, shifts could occur from crops requiring high intensity irrigation, such as corn, to others that are compatible with dryland farming techniques.

Urban land is concentrated in the City of Hereford, the county seat of Deaf Smith County. Although the city occupies less than 1 percent of the total county land area, 75 percent of

Table 3-39. Deaf Smith County Crops Planted (in Thousands of Acres)

	1970	1975	1980	1981	1982	1983
Barley, All	3.5	6.3	3.0	2.1	2.2	(d)
Corn for Grain, All	14.4	95.6	55.0	35.5	33.2	26.0
Irrigated	14.4	95.6	55.0	35.5	33.2	26.0
Cotton, Upland, All	6.8	2.6	10.6	15.4	9.1	4.9
Irrigated	5.2	2.6	7.8	14.5	8.9	3.3
Nonirrigated	0.6	0	2.8	0.9	0.2	1.6
Hay, All[b]	6.4	7.9	6.7	7.0	8.2	14.5
Alfalfa	NA	7.0	2.2	3.0	3.8	(d)
Other	NA	0.9	4.5	4.0	4.4	(d)
Oats	2.0	2.7	3.5	3.4	1.3	(d)
Rye	10.1	2.2	3.0	1.0	(b)	(d)
Sorghum for Grain	(b)	98.4	102.9	116.0	87.5	47.0
Irrigated	(b)	90.0	56.0	51.8	55.0	35.5
Nonirrigated	(b)	8.4	46.9	64.2	32.5	11.5
Sorghum Hay[a]	1.9	6.4	2.1	2.3	(b)	(d)
Soybeans	5.6	3.3	2.9	1.8	(b)	2.0
Sugar Beets, Irrigated	13.7	14.8	11.2	10.2	12.0	(d)
Sunflowers, All	(b)	4.6	3.6	2.3	5.1	(c)
Wheat	111.7	354.0	287.0	281.0	231.9	(d)
Irrigated	39.7	147.8	104.0	93.3	91.2	(d)
Nonirrigated	72.0	206.2	183.0	187.7	140.7	(d)
Vegetables [a]	12.3	4.7	4.9	3.1	4.9	(d)

(a) Harvested crops.
(b) Not reported to avoid disclosure of individual information.
(c) Less than 1,000 acres planted.
(d) Data unavailable.

Source: TCLRS, 1972, 1975, 1980, 1981, 1982, 1983.

Table 3-40. Cattle and Calf Counts for Deaf Smith County, Texas (1970-1982, in Thousands of Head)

Count	1972	1975	1980	1981	1982
All Cattle[a]	305	243	361	365	361
Beef Cattle that have Calved[a]	15	12	12	26	20
Cattle on Feed[a]	186	123	283	240	--
Annual Fed-Cattle Marketings	400	359	550	--	--

(a) As of January 1 for each year shown.

Source: TCLRS, 1972-1982.

the county population resided in Hereford in 1982. The population in the remainder of the county tends to be located in small developments and communities and along major roads, including U.S. 60, a divided highway which connects Canyon (in Randall County) with Hereford; U.S. 385, connecting Vega and Hereford; and Farm Road 2587, which runs east-west in the northern portion of the county (NUS, 1984 BMI/ONWI-509).

Deaf Smith County is one of the 25 counties under the jurisdiction of the Panhandle Region Planning Commission. The Commission developed a Regional Land Resource Management Plan in 1978 that outlines broad planning goals for the 25-county area.

3.4.1.2 Land Ownership

Farm residences are typically found along or near the mile roads which are located along the boundaries of sections 1 square mile in size. There are six houses and a trailer located on the 9-square-mile site. All of the land at the site is privately owned. The average farmer in the county typically owns a section or two of land and leases an additional section or two. Although a third of the lands are currently leased for oil exploration, no producing oil fields have been found in the county to date (Section 3.2.8.1).

Buffalo Lake National Wildlife Refuge is the closest Federally owned land and is approximately 35 kilometers (22 miles) southeast of the site. No designated Wilderness Area, Wilderness Study Area, National Park, Bureau of Land Management land, or National Forest land is located within the Deaf Smith County site or vicinity (NUS, 1984, BMI/ONWI-508, p. 57; NUS, 1982, ONWI-102[2], p. 9). The Pantex plant, a DOE defense facility, is about 77 kilometers (48 miles) east of the site. There are no designated, proposed, or potential National Recreation, National Historic, or National Scenic Trails within a 160.9-kilometer (100-mile) radius of the Deaf Smith County site (Feuchter, 1984). Palo Duro State park is the closest State-owned park lands and is about 70 kilometers (44 miles) southeast of the site.

The site is not within the Federal Coastal Barrier Resources System (CBRS) nor within a coastal zone. This was verified by consulting official CBRS maps. There is no Texas coastal zone management program.

3.4.2 Terrestrial and Aquatic Ecosystems

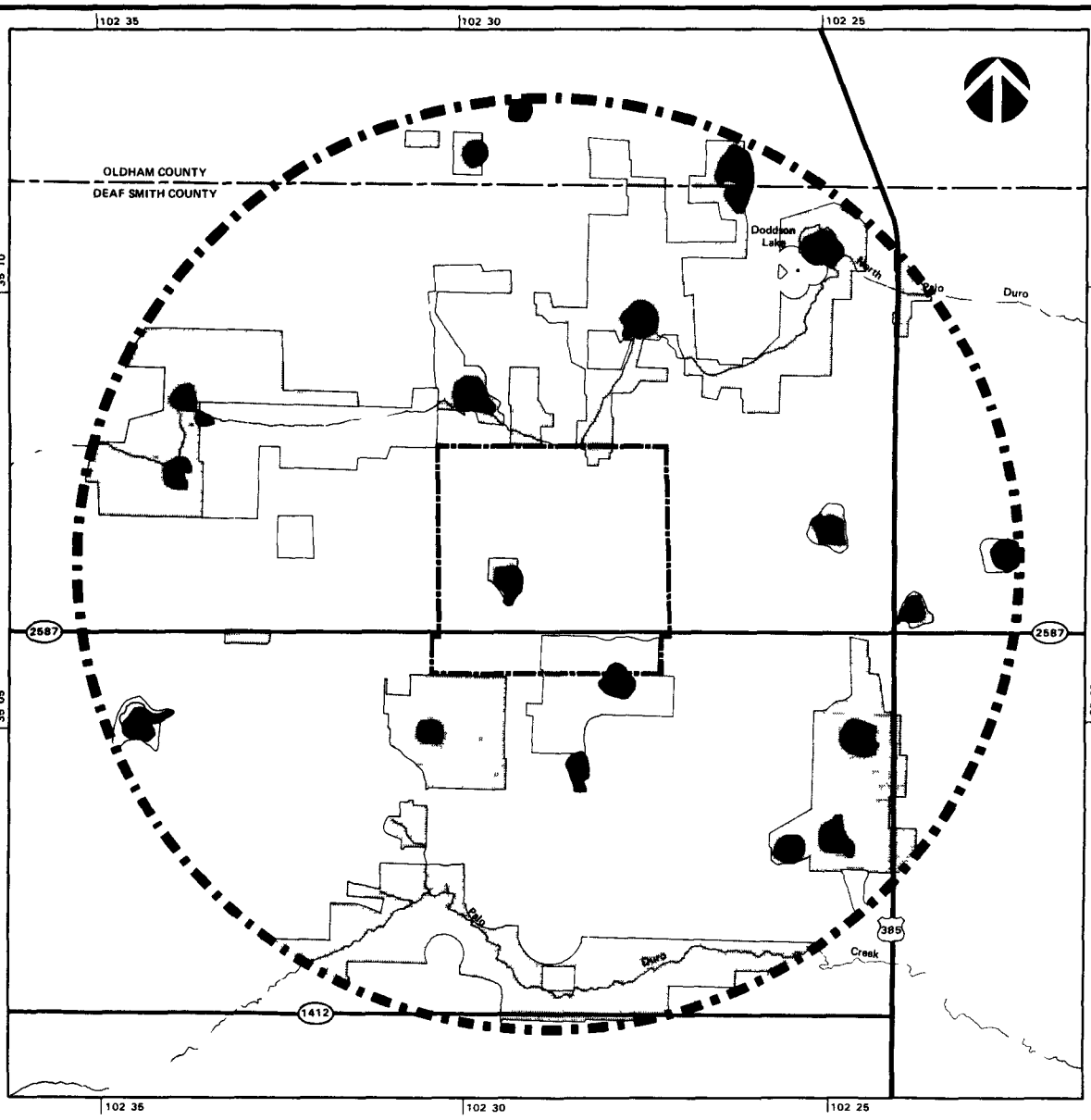
The terrestrial and aquatic flora, fauna, and ecological communities of the Deaf Smith County site and its site vicinity are typical of the Texas High Plains Ecological Area (Gould, 1975, p. 5; TPWD, 1982), which is a southern extension of the North American Great Plains. This area is characterized by semiarid to subhumid conditions and steppe or shortgrass prairie cover types and has been classified by Bailey (1978, pp. 45-46) as the shortgrass prairie province.

Because of fertile prairie soils (Mollisols) and abundant ground water, over 75 percent of the area surrounding the site has been converted to agriculture. Natural areas resembling the original ecosystems are generally absent in the region, although undeveloped playa wetlands, drainage valleys, and portions of the Caprock Escarpment exist as scattered remnants of original conditions.

The presence and extent of actual vegetative communities are primarily determined by the current land uses of farming and grazing (Table 3-41 and Figure 3-78). According to Gould (1975, p. 5), grassland communities under intensive grazing are dominated by a buffalo grass (Buchloe dactyloides)/blue grama (Bouleloua gracilis) association, whereas less heavily grazed areas contain a more diverse community of sideoats grama (Boutelous curtipendula), black grama (Bouteloua eriopoda), little bluestem (Schizachyrium scoparium), western wheatgrass (Agropyron smithii), indiangrass (Sorghastrum nutans), and switchgrass (Panicum virgatum). The long history of intense grazing in the site vicinity has probably eliminated all traces of presettlement prairie conditions. Most of the present rangelands are intensively grazed on an annual basis.

Table 3-41. Potential Natural Habitat Within the Deaf Smith County Site and Vicinity

	9-Square-Mile Site (%)		10-Kilometer Site Vicinity (%)	
Number of Playa Wetlands	2		17	
Acreage of Playa Wetlands	92	(1.6)	1,630	(2.1)
Acreage of R2 (Ungrazed) Rangeland	418	(7.3)	3,494	(4.5)
Acreage of R1 (Grazed) Rangeland	95	(1.6)	14,441	(18.6)
Acreage of Cropland and Other Features	5,155	(89.5)	58,073	(74.8)
Total Acreage	5,760	(100.0)	77,638	(100.0)



Explanation

- R1 Rangeland - Recently Grazed
- R2 Rangeland - Ungrazed
- Playa
- Other Features - Primarily Cropland

1 0 1 5 Kilometers

1 0 1 3 Miles

Source FWS, 1977 NUS, 1984, BMI/ONWI 509
1 12,000 CIR Photography and Field Reconnaissance
Plotted on USGS Quadrangle Maps

Deaf Smith County Site and Vicinity
Vegetative Cover and
Potential Natural Habitat

Figure 3-78

Shrublands are present where the overgrazed rangelands have been invaded by species such as sand sagebrush (Artemisia filifolia), honey mesquite (Prosopis glandulosa var. glandulosa), pricklypear (Opuntia spp.), soapweed (Yucca elata), and cholla (Opuntia imbricata). Such shrublands are scattered throughout the site vicinity. Shrubs and trees are also present at farmsteads, in shelterbelts, along riparian areas, and where ditches, drains, and playa lakes result in more persistent surface-water supplies. Near-natural assemblages of woody species such as species of Populus (cottonwood), Prunus (plum and cherry), and Salix (willow), may occur in areas having soils with relatively high moisture content and less disturbance from farming or grazing.

Wetlands on and in the vicinity of the site include playa wetlands and small areas of wetland vegetation along ephemeral streams. The National Wetlands Inventory of the U.S. Fish and Wildlife Service, using the system of Cowardin et al. (1979), has classified wetlands in the Texas Panhandle using 1:80,000-scale aerial photography (FWS, 1977). Playa wetlands on and near the site are identified as belonging to the palustrine system of wetlands, indicating nonflowing inland water. Three classes of wetlands are also noted: emergent, shrub-scrub, and open water. The emergent class indicates the presence of emergent vegetation, shrub-scrub indicates the presence of shrub vegetation, and open water indicates no vegetation. Any one playa basin could contain each of the three classes, depending on variations in water depth. The classification is further modified to indicate that all playa wetlands on and near the site are ephemeral (temporary, seasonal, or intermittently flooded). The majority of the playa basins on and near the site have been excavated to increase their water-holding capacity.

Playa wetlands, which result from seasonal precipitation, natural runoff and irrigation tailwater reception in the basins, are of ecological importance in the region. Although many playas are plowed or grazed during dry years, and most are modified to receive irrigation tailwater, natural and modified playa wetlands contain a distinct flora and fauna. There are 2 playas on the Deaf Smith County site, and 17 others within the site vicinity. Both playas on the site have been modified, as have 12 of the 17 within the site vicinity.

Palo Duro Creek, 3 to 5 kilometers (2 to 3 miles) south of the site, supports palustrine wetlands of an ephemeral nature, and small areas classified as intermittent riverine wetlands, or ephemeral streams (FWS, 1977). However, most of the drainage basin is heavily grazed.

A detailed characterization of the ecological resources of the region containing the Deaf Smith County site is given by NUS (1984, BMI/ONWI-508). Descriptions of the ecosystems of the site and vicinity have been developed from that topical report data base, literature review, and preliminary field trips in the site vicinity. However, no site-specific ecological surveys have been conducted.

Characterizations of regional wetlands and floodplains given in NUS (1985a) have been used to provide descriptions of wetlands or floodplains potentially affected by site characterization activities. A brief site visit (Barr, 1985), which did not include site-specific ecological surveys, was also conducted to provide information on floodplains and wetlands.

3.4.2.1 Terrestrial Biota

Preliminary vegetative reconnaissance surveys have been conducted in the site vicinity (NUS, 1984, BMI/ONWI-508, Tables 3-2, 4-1). The natural vegetative cover in this area is dominated by buffalo grass and blue grama. Plant communities containing natural assemblages of grasses and forbs (e.g., sunflowers [Helianthus spp.], prairie clovers [Petalostemum spp.], and asters [Aster spp.]) are limited to the Palo Duro Creek drainage basin, relatively ungrazed rangeland, drainage ditches, field edges, fencerows, and roadsides. Shrubby areas consisting primarily of sagebrush (Artemisia spp.), cholla, and yucca are present in overgrazed rangeland and along fencerows. Trees that have become established along ditches and dredged playas include Siberian elm (Ulmus pumila), Great Plains cottonwood (Populus sargentii), willows (Salix spp.), and mesquite.

Wildlife species observed during the reconnaissance surveys or expected to occur in the Deaf Smith County site and vicinity are typical of shortgrass prairie habitats, croplands, and playa wetlands (NUS, 1984, BMI/ONWI-508, Tables 3-4, 3-5). Croplands are of seasonal importance to wildlife as feeding and cover habitat. Grasslands provide few niches, but available niches can sometimes support many species and individuals of each species. Prime grasslands can support a diverse and densely populous fauna, particularly in proximity to playa wetlands. Wooded or brushy habitats, though scarce in the site vicinity, provide more cover than cropland or grassland, and wildlife diversity can be relatively high. Wetlands are of ecological importance in a semiarid to subhumid climate. Species observed in the region containing the site include 5 amphibians, 2 reptiles, 93 birds, and 11 mammals (NUS, 1984, BMI/ONWI-508, Tables 6-1,2,3). Because of current land use patterns, wildlife variety and abundance are expected to be low compared to unmodified areas in the region. Playa wetlands on and in the vicinity of the site are expected to be important to many species (i.e., waterfowl) of local and regional interest.

3.4.2.2 Aquatic Biota

Playa wetlands generally have a distinct flora (NUS, 1984, BMI/ONWI-508; NUS, 1985a). Dominant species in the ecotone between aquatic and upland areas include emergents such as cattails (Typha spp.), bulrushes (Scirpus spp.), sedges (Carex spp.), knotweed (Polygonum spp.), and various grasses. Some Great Plains cottonwoods and willows may be present around dredged playas or irrigation tailwater ditches. Typical aquatic plants include pondweed (Potamogeton spp.), water clover (Marsilea mucronata), and the southern naiad (Najas guadalupensis). Fourteen of the 19 playas on and near the site have been modified for increased water storage capacity. Eighteen of these playa wetlands support emergent vegetation (NUS, 1985a).

Aquatic invertebrates are important primary and secondary consumers in site vicinity wetlands, and also provide a food source for fishes, amphibians, birds, and mammals. Numerous invertebrate groups are expected to be abundant in the playa lakes of the site and vicinity (NUS, 1984, BMI/ONWI-508). As many as 60 species of fishes may be found within the region; most of these species are considered nongame fishes. In wetter years, game fishes such as channel catfish (Ictalurus punctatus), largemouth bass (Micropterus salmoides), and sunfish (Lepomis spp.) are occasionally stocked in the larger playa lakes. None of the playa wetlands on or near the site hold water permanently (NUS, 1985a).

3.4.2.3 Threatened and Endangered Species

Two species of reptiles, four species of birds, and one species of mammal whose biogeographic ranges include the Deaf Smith County site are considered to be threatened (protected) or endangered by the Fish and Wildlife Service (FWS, 1984a) and the State of Texas (TPWD, 1977). Two species of reptiles protected by Texas, the Texas horned lizard (Phrynosoma cornutum) and the central plains milk snake (Lampropeltis triangulum gentilis), may occur in the site vicinity in relatively natural grassland communities or old fields, and brushy draws. Because of habitat limitations, none of these species is expected in significant numbers. One species of mammal, the endangered black-footed ferret (Mustela nigripes), could be present in close association with existing colonies of black-tailed prairie dogs (Cynomys ludovicianus). However, prairie-dog towns are not extensive in the region; thus the presence of the ferret is unlikely. The endangered bald eagle (Haliaeetus leucocephalus), the whooping crane (Grus americanus), the American peregrine falcon (Falco peregrinus anatum), the threatened Arctic peregrine (Falco peregrinus tundrius), the protected osprey (Pandion haliaetus carolinensis), and the wood stork (Mycteria americana) may be attracted to playa wetlands during migration or at other times. Wintering bald eagles may be found throughout the Texas Panhandle; the Panhandle counties of Hutchinson, Moore, Potter, Randall and Bailey are considered wintering areas (FWS, 1984b). Both peregrine falcon subspecies are considered migrants throughout Texas (FWS, 1984b). The present usual migration route of the whooping crane is through central Texas and the eastern two-thirds of the Panhandle; it does not include Deaf Smith County, but does include the eastern two-thirds of neighboring Randall County (FWS, 1984b).

The FWS periodically promulgates lists of species under review for possible future addition to the List of Endangered and Threatened Wildlife and Plants. The most recent lists include several species that are or may be present in the vicinity of the site (FWS, 1985 a, b). Vertebrate species include the Swainsons hawk (Buteo Swainsoni), Ferruginous hawk (B. regalis), Western snowy plover (Chavadrius alexandrinus nivosus), mountain plover (C. mountanus), long-billed curlew (Numenius americanus), Palo Duro mouse (Peromyscus comanche), and swift fox (Vulpes velox). Plants include cylinder spike rush (Eleocharis cylindrica). Although these species do not receive substantive or procedural protection under the Endangered Species Act of 1973, the FWS does encourage Federal agencies to consider these species when planning major environmental actions.

The Texas Organization for Endangered Species (TOES), a professional advisory and research group, also maintains lists of plant and animal taxa considered rare, threatened, or endangered. These lists are more encompassing than both Federal and State lists, and although species on the lists do not have the same special legal status, the TOES lists indicate species of concern that may be upgraded in the future. NUS (1984, BMI/ONWI-508) presents a discussion of these species.

3.4.2.4 Important Species

For purposes of this report, important species are considered to be species of recreational importance and species protected by law. Several species of small game, upland gamebirds, and waterfowl are regionally and locally important. These include, in decreasing order of harvest numbers: mourning dove (Zenaida macroura), bobwhite and blue quail (Colinus virginianus, Callipepla squamata), rabbit and jackrabbit (Sylvilagus spp. and Lepus californicus), ring-necked pheasant (Phasianus colchicus), and various ducks and geese (NUS, 1984, BMI/ONWI-508). Site surveys will be conducted to identify the locations of migratory birds or their nests, protected under the Migratory Bird Treaty Act (16 USC Secs. 703-711). The sandhill crane (Grus canadensis), various shorebirds, and some furbearers are also hunted or trapped on a limited basis. There are no commercial or recreational fisheries within the site vicinity, although the larger playa lakes may be stocked on a put-and-take basis (NUS, 1984, BMI/ONWI-508).

Several species identified by the FWS as National Species of Special Emphasis (FWS, 1983, 1985a) occur in the area (Johnson, 1984). These species are of high biological, legal, and public interest and are the focus of FWS planning efforts on a national basis. Other than protection under the Migratory Bird Treaty Act, the Fish and Wildlife Coordination Act (16 USC Sections 661-666c), or State game laws, the listed species are afforded no additional protection by this designation. Such species, however, are generally taken into consideration during siting activities in natural areas.

Wild, free-roaming horses and burros, protected under the Wild, Free-Roaming Horses and Burros Act (16 USC 1331-1340; 43 CFR Part 4700), do not occur in the Texas Panhandle. The closest specifically designated wild horse and burro range is east of Socorro, New Mexico (Boyer, 1984; Sharp, 1984). Golden eagles (Aquila chrysaetos), their nests, or eggs, are protected under the Bald and Golden Eagle Protection Act (16 USC Secs. 668-668d). Field surveys have confirmed the presence of golden eagles in the region and in the vicinity of the site (NUS, 1984, BMI/ONWI-508). Nesting in the vicinity of the site has not been documented; the nearest nesting habitat is in Palo Duro Canyon, which is 71 kilometers (44 miles) from the site.

3.4.2.5 Sensitive Areas - Critical/Unique Habitats

Sensitive areas include lands set aside by government agencies to protect unique ecological resources. Examples include National and State Parks, Wilderness Areas, and Critical Habitats. The nearest National Park is Carlsbad Caverns, which is 400 kilometers (250 miles) southwest of the site, whereas the nearest Wilderness Area is 370 kilometers (230 miles) west-southwest of the site. Critical habitats, as designated by the Federal government for the protection of endangered species, do not exist within the Deaf Smith County site or site vicinity. Wetland ecosystems (playa lakes) are found throughout the site vicinity. Based on

available information, it is not likely that any of the playa lakes, or any existing terrestrial habitats, represent examples of undisturbed, presettlement ecosystems. Playas identified at the site are considered wetlands, and as such, are subject to protection and review under DOE regulations (10 CFR Part 1022, Floodplains/Wetlands Environmental Review Requirements). Protected natural areas of regional importance that are relatively close to the Deaf Smith County site include Buffalo Lake National Wildlife Refuge (35 kilometers [22 miles]), Caprock Escarpment (71 kilometers [44 miles]), and Palo Duro Canyon State Park (71 kilometers [44 miles]). However, there are no major ecological links between these natural areas and the site because of current land-use practices.

3.4.3 Air Quality and Climatology

Air quality of the Deaf Smith County site is described in terms of attainment status as declared by the U.S. Environmental Protection Agency (EPA) and in terms of available ambient air-quality monitoring data relative to Federal and State air quality standards. Figure 3-79 shows the locations of air monitoring stations relative to the site. These data were collected at locations around population centers and therefore represent, to some extent, activities associated with these centers. The data may not accurately represent ambient conditions in more rural and undeveloped areas such as the Deaf Smith County site. Meteorological data collected at the National Weather Service (NWS) Station at Amarillo, Texas, and from seven other nearby climatological stations were used to characterize the climate of the area. Figure 3-80 shows the locations of these stations relative to the site. Because of the flat, uniform terrain in the area and the proximity of these stations to the site, these data are considered representative of the site.

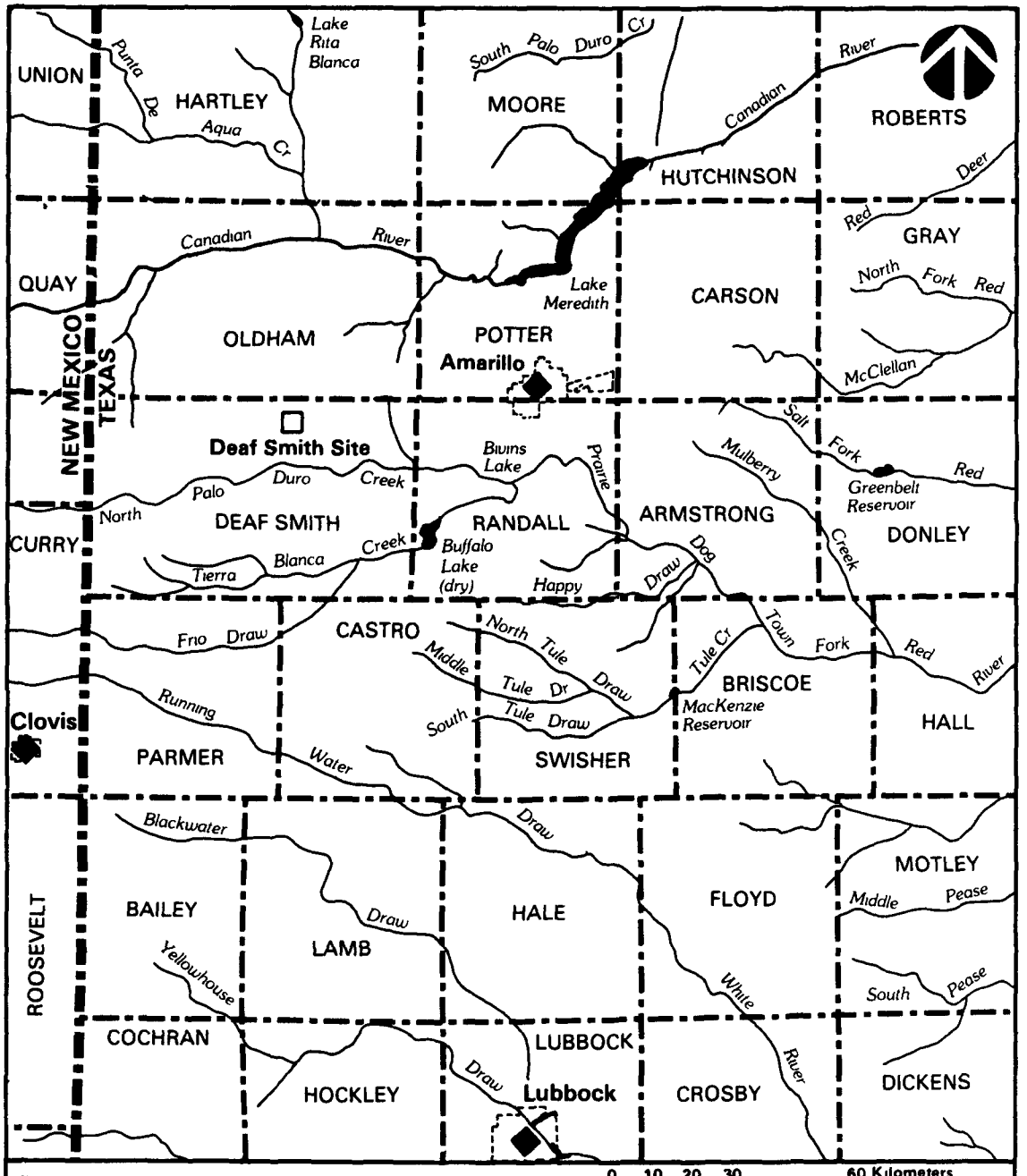
Additional information regarding the present and long-term climate, severe weather, atmospheric transport and diffusion conditions, and air quality characteristics of the site area is available (NUS, 1984, BMI/ONWI-527).

3.4.3.1 Existing Air Quality

The Deaf Smith County site is located in Air Quality Control Region 211 and is designated "attainment" or unclassified by EPA for total suspended particulates (TSP), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) (40 CFR Part 81.344). These are the pollutants expected to be emitted most prominently during site characterization, and repository construction and operation activities. Table 3-42 lists the National Ambient Air Quality Standards (NAAQS) for these criteria pollutants, which establish limits for the protection of public health (Primary Standards) and welfare (Secondary Standards) (40 CFR Part 50). These same limits apply to the State of Texas, as well (TACB, 1982). The EPA's Prevention of Significant Deterioration (PSD) program under the Clean Air Act (42 USC Sections 7470-7479) applies to major sources located in areas determined to be in "attainment" with the NAAQS. The project is not considered to be a major source during site characterization and repository construction and operation activities. Therefore, for the purposes of this EA, the DOE concludes that the project is not subject to Federal PSD requirements (see Sections 4.2.1.3.3 and 5.2.5.3).

A review of local existing permitted air pollutant emission sources in the site vicinity shows that most are particulate sources, such as grain elevators and feed-processing plants (NUS, 1984, BMI/ONWI-527, p. 44). Other local activities resulting in particulate emissions may include plowing, feedlot operations, traffic on unpaved roads, and blowing dust.

Tables 3-43 through 3-45 list the annual summaries of total suspended particulates, sulfur dioxide, and nitrogen oxides for regional monitoring stations near the Deaf Smith County site for the five-year period from 1978-1982. These data were collected at locations around population centers and, therefore, represent ambient air quality conditions in urban areas of the southwest, as opposed to more rural and undeveloped areas such as the Deaf Smith County site. The monitoring station closest to the site is located in Amarillo, about 80 kilometers (50 miles) northeast of the site. Use of these data to define background air quality levels at the site is likely to be conservative because sources of air pollutants tend to be more concentrated in urban areas than in rural areas.



Explanation

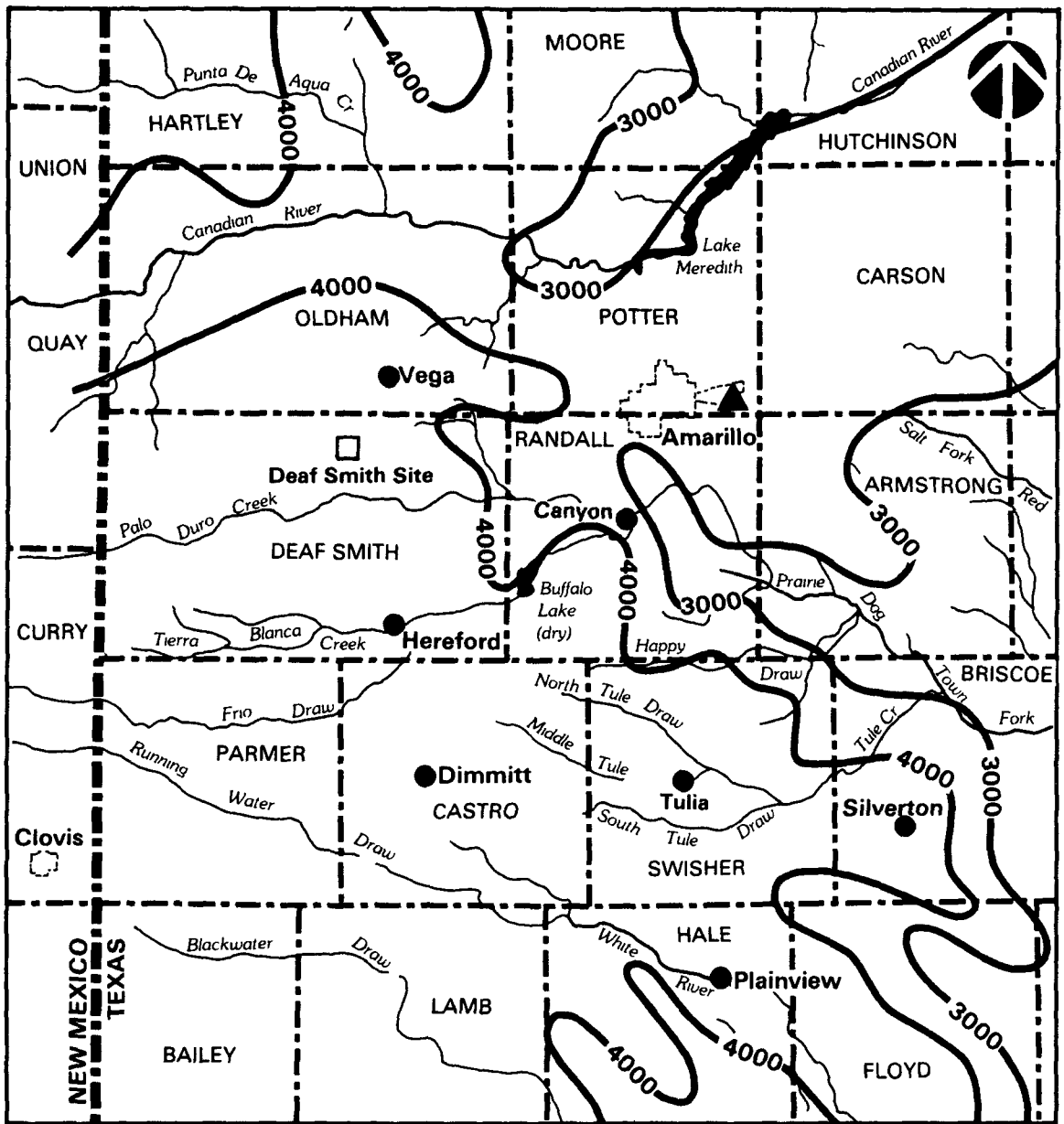
◆ **Monitor Locations**

□ **Deaf Smith Site**

Source: Adapted from USGS, 1976; EPA, 1983.

Locations of Air Quality Monitors and the Deaf Smith County Site

Figure 3-79



Explanation

- Deaf Smith Site
- National Weather Service Station
- Climatological Station
- 3000 Contour/Elevation (feet)

0 10 20 30 60 Kilometers

0 10 20 40 Miles

Source: Adapted from USGS, 1976; NOAA, 1968, 1969, 1978a, 1978b, 1980.

General Topographic Map Including Relative Locations of Climatological Stations and the Deaf Smith County Site

Figure 3-80

Table 3-42. National and Texas State Ambient Air Quality Standards

Criteria Pollutant	Averaging Time	Primary Standards[a] g/m^3	Secondary Standards[a] g/m^3
Carbon Monoxide (CO)	8-hour[b]	10,000	10,000
	1-hour[b]	40,000	40,000
Nitrogen Dioxide (NO_2)	Annual	100	100
Total Suspended Particulates (TSP)	Annual[c]	75	60[d]
	24-hour[b]	260	150
Sulfur Dioxide (SO_2)	Annual	80	--
	24-hour[b]	365	--
	3-hour	--	1,300

(a) Primary standards are for protection of health; secondary standards are for protection of welfare. Concentration units: g/m^3 = microgram per cubic meter

(b) Not to be exceeded more than once per year.

(c) Geometric mean; all other annual standards are arithmetic means.

(d) Guideline; not a standard. To be used in assessing implementation plans to achieve 24 hour standard.

Source: National Primary and Secondary Ambient Air Quality Standards, 40 CFR Part 50; Texas Clean Air Act, Texas Revised Civil Statutes, Annotated, Article 4477-5.

Table 3-43. Total Suspended Particulate Data ($\mu g/m^3$)

Location	Site ID Number	1978 Highest 24-Hour Values[a], 1st	1978 2nd	1978 Geo-metric Mean	1979 Highest 24-Hour Values[a], 1st	1979 2nd	1979 Geo-metric Mean	1980 Highest 24-Hour Values[a], 1st	1980 2nd	1980 Geo-metric Mean	1981 Highest 24-Hour Values[a], 1st	1981 2nd	1981 Geo-metric Mean	1982 Highest 24-Hour Values[a], 1st	1982 2nd	1982 Geo-metric Mean
Texas																
Amarillo	45 007 0002 F01	146	117	64	83[c]	78	42[b]	108	99	57[b,c]	337[c]	152[c]	60[c]	225[c]	177[c]	69[c]
								(108)	(99)	(54)	(113)	(112)	(57)	(119)	(113)	(65)
Lubbock	45 334 0001 F01	285	119	61	255[c]	178[c]	76[b]	1,082[c]	504[c]	80[b,c]	930[c]	178[c]	70[c]	224[c]	211[c]	77[c]
								(184)	(149)	(68)	(147)	(122)	(63)	(224)	(177)	(73)
Lubbock	45 334 0023 F01	184[c]	115	63[b]	218[c]	217[c]	61	782[c]	467[c]	74[c]	--	--	--	--	--	--
								(175)	(146)	(61)						
New Mexico																
Clovis	32 024 0001 F01	162	152	63	301	159	70[b]	280	250	62	--	--	--	--	--	--
Clovis	32 024 0002 F01	--	--	--	--	--	--	--	--	--	556	349	70	142	141	61[b]

(a) 1st = highest value; 2nd = second highest value.

(b) Mean does not satisfy U.S. Environmental Protection Agency summary criteria since the mean was not calculated with four valid quarters of data.

(c) Higher concentration owing to dust-storm activity. Values are as reported by U.S. Environmental Protection Agency and include days with dust-storm activity. Values in parentheses are as reported by the Texas Air Control Board and exclude days with dust-storm activity. This latter reporting procedure applies only for 1980, 1981, and 1982.

Concentration units: $\mu g/m^3$ = micrograms per cubic meter.

Source: EPA, 1979, 1980, 1981, 1982, 1983; TACB, 1978, 1979, 1980, 1981, 1982b.

Table 3-44. Sulfur Dioxide Data ($\mu g/m^3$)

Location (Texas)	Site ID Number	1978 Highest 24-Hour Values[a], 1st	1978 Highest 24-Hour Values[a], 2nd	1978 Annual Arithmetic Mean	1979 Highest 24-Hour Values[a], 1st	1979 Highest 24-Hour Values[a], 2nd	1979 Annual Arithmetic Mean	1980 Highest 24-Hour Values[a], 1st	1980 Highest 24-Hour Values[a], 2nd	1980 Annual Arithmetic Mean	1981 Highest 24-Hour Values[a], 1st	1981 Highest 24-Hour Values[a], 2nd	1981 Annual Arithmetic Mean	1982[d] Highest 24-Hour Values[a], 1st	1982[d] Highest 24-Hour Values[a], 2nd	1982[d] Annual Arithmetic Mean
Amarillo	45 007 0002 F01	2(38)[b]	2(26)	3[c](10)	34	27	15	28	24	9	22	21	8	—	—	—
Lubbock	45 334 0001 F01	2(176)	2(22)	3[c](11)	23	22	11	32	21	10	17	17	8	—	—	—

(a) 1st = highest value; 2nd = second highest value.

(b) Numbers in parentheses represent state data that differ from data reported by the U.S. Environmental Protection Agency. Only state data are reported for 1979, 1980, and 1981.

(c) Mean does not satisfy U.S. Environmental Protection Agency summary criteria since the mean was not calculated with four valid quarters of data.

(d) Sulfur dioxide air quality data are not reported for 1982.

Concentration units: $\mu g/m^3$ = micrograms per cubic meter.

Sources: EPA, 1979; TACB, 1978, 1979, 1980, 1981.

Table 3-45. Nitrogen Oxide Data ($\mu g/m^3$)

Location (Texas)	Site ID Number	1978 Highest 24-Hour Values[a], 1st	1978 Highest 24-Hour Values[a], 2nd	1978 Annual Arithmetic Mean	1979 Highest 24-Hour Values[a], 1st	1979 Highest 24-Hour Values[a], 2nd	1979 Annual Arithmetic Mean	1980 Highest 24-Hour Values[a], 1st	1980 Highest 24-Hour Values[a], 2nd	1980 Annual Arithmetic Mean	1981[c] Highest 24-Hour Values[a], 1st	1981[c] Highest 24-Hour Values[a], 2nd	1981[c] Annual Arithmetic Mean	1982[c] Highest 24-Hour Values[a], 1st	1982[c] Highest 24-Hour Values[a], 2nd	1982[c] Annual Arithmetic Mean
Amarillo	45 007 0002 F01	39	38	17	38	38	17[b]	67	51	23	—	—	—	—	—	—
Lubbock	45 334 0001 F01	53	37	20	50	46	20[b]	72	43	20	—	—	—	—	—	—

(a) 1st = highest value; 2nd = second highest value.
(b) Mean does not satisfy U.S. Environmental Protection Agency summary criteria since the mean was not calculated with four valid quarters of data.
(c) Nitrogen oxide air quality data are not reported for 1981 and 1982 for these stations.

Concentration units: $\mu g/m^3$ = micrograms per cubic meter.

Sources: EPA, 1979, 1980, 1981; TACB, 1978, 1979, 1980.

The TSP and NO_x air quality data presented in Tables 3-43 and 3-45, respectively, form the basis for determining background concentrations required for assessing the impacts of these pollutants emitted during site chracterization, and repository construction and operation (see Sections 4.2.1.3 and 5.2.5, respectively). For TSP, an average background value of 62 micrograms per cubic meter is calculated, based on the annual geometric mean values for 1978, 1981, and 1982. (For 1981 and 1982, the values selected excluded dust-storm days.) For NO_x, an average background value of 20 micrograms per cubic meter is calculated, based on the annual arithmetic mean values for 1978 and 1980. Those years not included in determining the average background values were excluded on the basis of unavailability or of not satisfying EPA summary criteria which require the annual mean to be calculated with four valid quarters of data.

3.4.3.2 Climate

Normal, mean, and extreme meteorological parameters recorded at the Amarillo NWS station are summarized in Table 3-46. Climatological summaries for the seven other stations shown in Figure 3-80 are presented (NUS, 1984, BMI/ONWI-527, pp. 3-13). In the following discussion, "area" refers to that area encompassed by the eight stations shown in Figure 3-80. For most of the stations, the summaries are based on a 30-year record, which the National Climatic Data Center commonly uses to represent climatological conditions. The discussion of normal, mean, and extreme conditions below are based on these summaries; means are composite means for all eight stations, and extremes are absolute extremes from any of the stations.

The annual average temperature is about 14 C (57 C) for the area. Monthly mean temperatures vary from 1.8 C (35.3 F) in January to 26 C (78.8 F) in July. Record low and high temperatures for the area are -31 C (-23 F) and 43 C (109 F), respectively. Prolonged periods of extreme temperature are rare, although large fluctuations in temperature, up to 33 C (about 60 F), have occurred over short periods of time (less than 12 hours) during the passage of a fast-moving cold front in winter (NUS, 1984, BMI/ONWI-527, pp. 3-14).

Most precipitation in the area occurs from April to October and results from thunderstorms and the intrusion of warm, moist tropical air from the Gulf of Mexico. Annual precipitation averages about 48 centimeters (19 inches) for the area and has ranged from 19.5 to 105.4 centimeters (7.7 to 41.5 inches). Based on all of the summarized data, the greatest daily precipitation recorded in this area occurred at Canyon, when 19.9 centimeters (7.8 inches) fell in August 1968 (NUS, 1984, BMI/ONWI-527, pp. 3-13).

Snowfall has occurred in the area from October to April, but is usually light and dissipates quickly. Annual mean snowfall totals are variable for the area and range from 12.4 to 53.3 centimeters (4.9 to 21.0 inches). The maximum monthly snowfall was recorded at Vega during February, 1956; 154.9 centimeters (61.0 inches) fell. The statistical effect of this inordinately large snowfall is reflected in the annual mean snowfall above. The greatest daily snowfall, 61.0 centimeters (24 inches) was recorded at Plainview in February, 1956. Annual mean snowfall totals for the remaining stations range from about 18 to 31 centimeters (7 to 12 inches) (NUS, 1984, BMI/ONWI-527, pp. 3-13).

Annual average relative humidity at Amarillo is 55 percent. Highest monthly average relative humidity, 61 percent, occurs in September; the lowest, 48 percent, occurs in April (NOAA, 1980).

The site area is classified as steppe. A steppe is, according to the Koeppen method of climatic zone classification, characterized by sparse vegetation, warm temperatures, and periods of little precipitation. These conditions, in combination with an annual mean wind speed of 6.1 meters per second (13.7 miles per hour) in the area, result in a relatively high potential for wind erosion of soil (NUS, 1984, BMI/ONWI-527, pp. 3-14).

3.4.3.3 Long-Term Climatology

Long-term climatology (paleoclimate) is discussed in Section 3.2.2.3. The possible effects of future climatic changes are discussed in Sections 6.3.1.4.

Table 3-46. Normals, Means, and Extremes of Meteorological Parameters for Amarillo, Texas

Month	Temperature, F: Normal: Daily Maximum	Temperature, F: Normal: Daily Minimum	Temperature, F: Normal: Monthly	Temperature, F: Extreme: Record Highest	Temperature, F: Extreme: Year	Temperature, F: Extreme: Record Lowest	Temperature, F: Extreme: Year	Normal Degree Days, Base 65 F: Heating	Normal Degree Days, Base 65 F: Cooling	Precipitation in Inches: Water Equivalent: Normal	Precipitation in Inches: Water Equivalent: Maximum Monthly	Precipitation in Inches: Water Equivalent: Year	Precipitation in Inches: Water Equivalent: Minimum Monthly	Precipitation in Inches: Water Equivalent: Year	Precipitation in Inches: Water Equivalent: Maximum in 24 hrs.	Precipitation in Inches: Water Equivalent: Year	Precipitation in Inches: Snow, Ice Pellets: Maximum Monthly	Precipitation in Inches: Snow, Ice Pellets: Year	Precipitation in Inches: Snow, Ice Pellets: Maximum in 24 hrs.	Precipitation in Inches: Snow, Ice Pellets: Year	Relative Humidity pct.: Hour 00 (Local Time)	Relative Humidity pct.: Hour 06 (Local Time)	Relative Humidity pct.: Hour 12 (Local Time)	Relative Humidity pct.: Hour 18 (Local Time)	Wind: Mean Speed, m.p.h.	Wind: Prevailing Direction	Wind: Fastest Mile: Speed, m.p.h.	Wind: Fastest Mile: Direction	Wind: Fastest Mile: Year	Pct. of Possible Sunshine	Mean Sky Cover, Tenths, Sunrise to Sunset	Mean Number of Days: Sunrise to Sunset: Clear	Mean Number of Days: Sunrise to Sunset: Partly Cloudy	Mean Number of Days: Sunrise to Sunset: Cloudy	Mean Number of Days: Precipitation .01 inch or more	Mean Number of Days: Snow, Ice Pellets 1.0 inch or more	Mean Number of Days: Thunderstorms	Mean Number of Days: Heavy Fog Visibility 1/4 mile or less	Mean Number of Days: Temperature, F: Max. 90° and above (b)	Mean Number of Days: Temperature, F: Max. 32° and below	Mean Number of Days: Temperature, F: Min 32° and below	Mean Number of Days: Temperature, F: Min 0° and below	Average Station Pressure, mb. Elev. 3604 Feet m.s.l
(a)				40		40					40		40		40		40		40		19	19	19	19	39	15	6	6		39	39	39	39	39	39	39	39	39	39	19	19	19	19	8
J	48.4	22.5	36.0	81	1980	11	1959	899	0	0.54	2.33	1968	T	1978	1.74	1968	12.9	1960	6.7	1960	64	70	51	47	13.1	Sw	41	36	1975	68	5.2	12	7	12	4	1	*	3	0	5	27	1	891.4
F	53.0	26.4	39.7	86	1963	14	1951	708	0	0.58	1.83	1948	T	1943	1.28	1971	17.3	1971	13.5	1971	63	71	49	41	14.2	Sw	46	35	1976	69	5.2	11	7	10	4	1	*	4	0	3	22	*	891.0
M	60.0	31.2	45.6	94	1971	3	1948	601	0	0.77	3.99	1973	T	1950	2.27	1973	14.7	1961	9.8	1957	55	66	41	33	15.6	Sw	58	34	1977	71	5.2	12	8	11	4	1	1	3	*	1	15	0	887.6
A	70.9	42.1	56.5	98	1985	14	1946	275	20	1.23	3.74	1942	T	1964	1.57	1942	6.4	1947	5.1	1947	54	67	38	31	15.5	Sw	43	17	1975	73	5.0	12	8	10	5	*	3	2	1	*	3	0	888.8
M	79.2	51.9	65.6	102	1953	28	1954	81	99	2.83	9.81	1951	0.19	1966	6.75	1951	0.5	1978	0.5	1978	61	73	42	36	14.7	S	41	32	1978	72	5.1	11	10	10	8	0	9	2	5	0	*	0	888.6
J	88.0	61.2	74.6	108	1953	42	1966	10	298	3.46	10.73	1965	0.01	1953	6.15	1960	0.0		0.0		63	76	44	38	14.4	S	40	15	1975	77	4.3	13	12	5	8	0	9	1	13	0	0	0	890.6
J	91.4	65.9	78.7	105	1978	53	1950	0	425	2.95	7.59	1960	0.12	1946	4.09	1943	0.0		0.0		60	73	42	38	12.5	S	41	36	1979	78	4.5	13	12	6	8	0	10	1	22	0	0	0	892.8
A	90.4	64.7	77.6	106	1944	49	1956	0	391	2.93	7.55	1974	0.39	1947	4.26	1945	0.0		0.0		66	76	45	42	12.2	S	35	02	1979	77	4.2	15	10	6	8	0	9	1	16	0	0	0	892.7
S	82.9	56.7	69.8	102	1947	33	1945	20	164	1.93	5.02	1950	0.03	1977	3.42	1941	T	1945	T	1945	70	79	49	45	12.9	S	37	34	1976	74	4.0	18	7	7	6	0	4	2	6	0	0	0	892.9
O	72.9	46.1	59.5	95	1954	21	1960	206	36	1.83	7.64	1941	0.00	1952	3.45	1948	3.9	1976	3.2	1976	61	70	41	40	13.0	Sw	58	31	1979	75	3.8	17	7	7	5	*	2	2	1	*	2	0	892.8
N	60.0	32.5	46.3	87	1960	0	1976	561	0	0.53	2.26	1961	T	1960	1.29	1971	13.6	1952	12.2	1952	66	73	48	49	13.1	Sw	44	26	1975	72	4.3	15	7	8	3	1	1	2	0	1	14	*	892.3
D	51.5	25.5	38.5	81	1955	-4	1978	922	0	0.73	4.52	1959	T	1976	3.11	1943	8.5	1943	7.4	1971	63	68	47	47	13.0	Sw	37	28	1977	68	4.7	13	8	10	4	1	*	3	0	3	26	*	891.7
YR	70.8	43.9	57.4	108	JUN 1953	14	FEB 1951	4183	1433	20.28	10.73	JUN 1965	0.00	OCT 1952	6.75	MAY 1951	17.3	FEB 1971	13.5	FEB 1971	62	72	45	41	13.7	Sw	58	31	OCT 1979	73	4.6	160	103	102	68	5	49	26	64	13	110	2	891.1

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows Lowest temperature 16 in February 1899, maximum monthly snowfall 28.7 in February 1903, maximum snowfall in 24 hours 20.6 in March 1934

(a) Length of record, years, through the current year unless otherwise noted, based on January data
(b) 70° and above at Alaskan stations.
* Less than one half
** September 1974 to present.
T Trace.

NORMALS — Based on record for the 1941-1970 period
DATE OF AN EXTREME — The most recent in cases of multiple occurrence
PREVAILING WIND DIRECTION — Record through 1963.
WIND DIRECTION — Numerals indicate tens of degrees clockwise from true north 00 indicates calm
FASTEST MILE WIND — Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Source USDC, 1980.

3.4.3.4 Severe Weather

Weather extremes are important in the structural design of repository surface facilities. The annual fastest mile wind (fastest passage of 1.6 kilometers (1.0 mile) of wind at 9.1 meters (30.0 feet) above the ground), and maximum 24-hour rainfall, each associated with a 100-year recurrence interval, are approximately 38 meters per second (85 miles per hour), and 16.5 centimeters (6.5 inches), respectively (NUS, 1984, BMI/ONWI-527, pp. 21-23). Note that the maximum 24-hour rainfall has been exceeded on several occasions in the area (at Amarillo, Canyon, and Plainview) (NUS, 1984, BMI/ONWI-527, pp. 3-13).

Information compiled by the National Severe Storms Forecast Center on the characteristics of tornadoes observed within a 231-kilometer (125-nautical-mile) radius of Amarillo from 1950 to 1978 was reviewed. These data were screened to include only those tornado paths beginning and ending within a 25,900-square-kilometer (10,000-square-mile) area encompassing the Deaf Smith County site. A total of 229 tornado observations occurred in this area over the 29-year period, averaging about eight tornados per year. A tornado would be expected to strike a point within the area approximately once every 7,400 years (NUS, 1984, BMI/ONWI-527, p. 22).

The intensity of tornadoes observed in the area seldom exceeds a Fujita-Pearson F value of 2, characterized by wind speeds of about 50 to 70 meters per second (113 to 157 miles per hour) and considerable structural damage. Considerable structural damage includes tearing the roofs from frame houses, destruction of trailer homes, and uprooting or snapping large trees. Most of the tornadoes observed in the area have F values of 0 or 1, characterized by wind speeds ranging from 18 to 50 meters per second (40 to 112 miles per hour) and light to moderate structural damage. Light structural damage includes pushing over shallow-rooted trees and some damage to chimneys and TV antennae. Moderate structural damage includes peeling roof surfaces, breaking windows, pushing or overturning light trailer homes, and uprooting or snapping trees (Fujita, 1971, pp. 3-9).

Weather extremes are also important in assessing the potential for interruption of normal facility operations. On the average, the area can expect thunderstorms about 50 days per year, hail 4 days per year, freezing rain 8 days per year, and heavy fog (with visibility less than 0.40 kilometer [0.25 mile]) 20 days per year (NUS, 1984, BMI/ONWI-527, pp. 23-24).

3.4.3.5 Atmospheric Transport and Diffusion

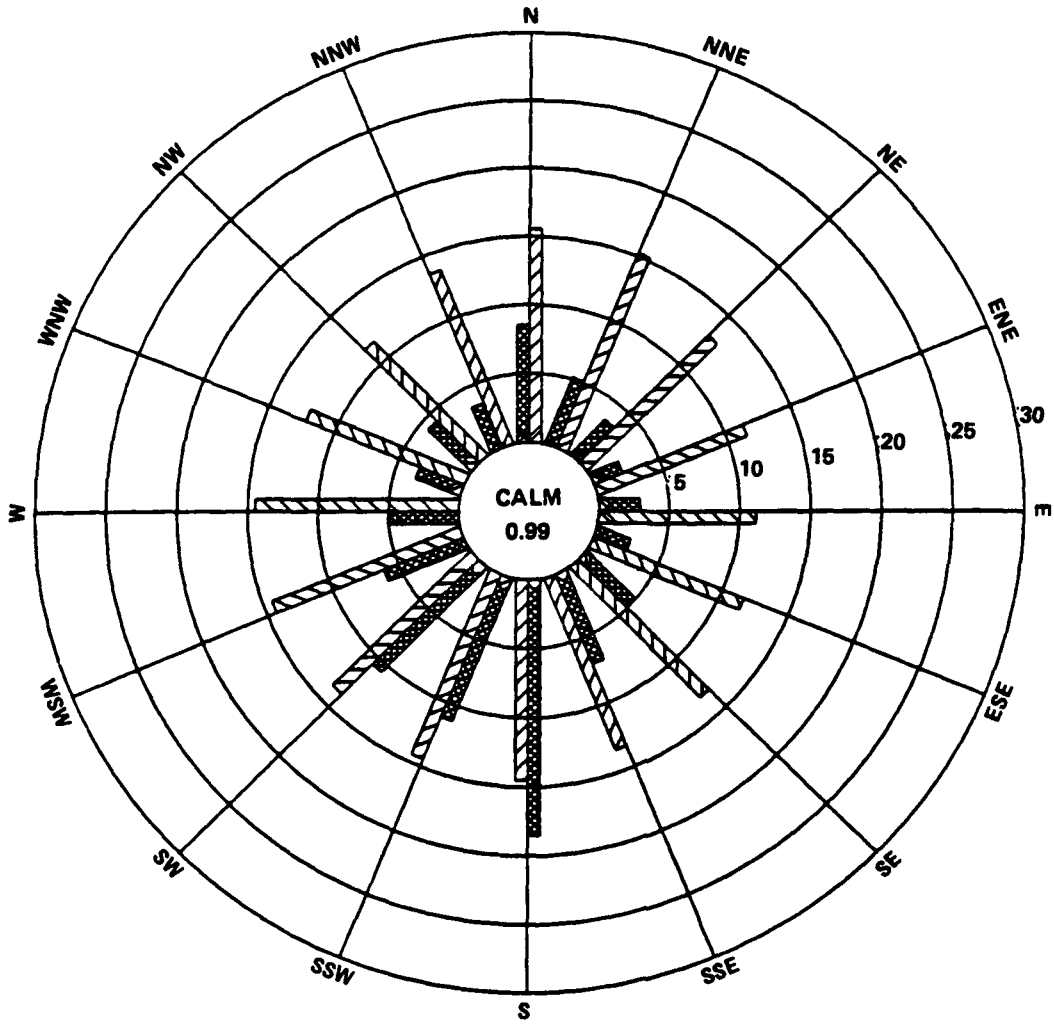
Atmospheric transport and diffusion depend on wind direction, wind speed, and atmospheric stability. Wind direction is predominantly from the south through southwest on an annual basis. Cold air masses from the north result in relatively more northerly and westerly winds from November to March. Figure 3-81 presents the annual wind rose for Amarillo, based on the five-year period from 1976 through 1980 (NOAA, 1981).

Turbulent characteristics of the atmosphere can be described in terms of varying stability class, ranging from extremely unstable to extremely stable, as listed below:

Class A -- Extremely Unstable
Class B -- Moderately Unstable
Class C -- Slightly Unstable
Class D -- Neutral
Class E -- Slightly Stable
Class F -- Moderately to Extremely Stable.

Table 3-47 presents seasonal and annual distributions of atmospheric stability classes for the 1976-to-1980 period (NOAA, 1981).

The mixing level depth represents the potential vertical limit of pollutant dispersion. The mixed layer develops during the day as a result of surface heating by the sun. In general, the higher the mixing level, the greater the dispersion potential. The annual average afternoon mixing level for Amarillo is 1,973 meters (6,473 feet). Seasonal average afternoon mixing levels are 1,171 meters (3,842 feet) for winter, 2,507 meters (8,225 feet)



PERIOD OF RECORD 1/1/76 - 12/31/80

Explanation

Wind Direction (%)

Wind Speed (mph)

CALM = Percent Calms

Note: To convert miles per hour to kilometers per hour, use conversion factor 1.6093.

Source: NOAA, 1981.

Annual Wind Rose for Amarillo, Texas

Figure 3-81

Table 3-47. Atmospheric Stability Distributions (Percent) for Amarillo, Texas (January 1, 1976 through December 31, 1980)

	Stability Class					
	Unstable			Neutral	Stable	
Period	A	B	C	D	E	F
Winter	0.00	0.61	4.56	71.85	15.87	7.11
Spring	0.30	1.96	8.37	74.32	11.28	3.77
Summer	0.54	3.56	13.53	68.61	11.66	2.10
Fall	0.14	2.17	8.82	60.71	19.26	8.90
Annual	0.25	2.08	8.84	68.88	14.50	5.45

Source: NOAA, 1981.

for spring, 2,520 meters (8,268 feet) for summer, and 1,693 meters (5,554 feet) for fall. The annual average morning mixing level for Amarillo is 328 meters (1,076 feet). Seasonal average morning mixing levels are 273 meters (895 feet) for winter, 379 meters (1,243 feet) for summer, and 323 meters (1,059 feet) for fall (Holzworth, 1972).

Poor dispersion conditions (episodes) that persist for several days may result in buildup of ground-level ambient concentrations. An episode is defined as the occurrence of mixing levels of less than 1,500 meters (4,921 feet) and wind speeds of less than 4 meters per second (9 miles per hour) on at least two consecutive days with no significant precipitation. In a five-year period at Amarillo, only two episodes were observed, totaling four episode days. The observations occurred in winter, when the average afternoon mixing level is at its seasonal minimum (Holzworth, 1972).

Analyses of the dispersion climatology indicate that neutral stability and high wind speeds predominate on an annual basis in the area. Class F stability, an indicator of the potential for reduced dispersion at night, occurs only 5 percent of the time.

Site-specific meteorological data are not currently available. The site is located about 80 kilometers (50 miles) southwest of the Amarillo NWS station. Because of the relatively flat, uniform terrain in the area and the proximity of the station to the site, these data are considered to be representative of meteorological conditions at the site.

The stability class distribution presented in Table 3-47 (i.e., a joint frequency distribution of wind speed, wind direction, and stability class) was used to model long-term (annual average) impacts discussed in Sections 4.2.1.3 and 5.2.5. Meteorological data from this station for the year 1964 was used in the modeling of short-term (24-hour) impacts discussed in those sections. These analyses required the use of sequential, hourly meteorological data. Data for the year 1964 were the most readily available for these analyses. The annual stability class distribution for 1964 indicates a slightly greater frequency of Class F stability (which produces relatively greater air quality impacts) as compared to the 1976-to-1980 data period (NUS, 1985b). Therefore, the use of the 1964 data for these analyses represents a comparable assumption of the dispersion conditons at the site.

3.4.4 Noise

Descriptive measures adopted by the Environmental Protection Agency (EPA, 1974) are used in this EA to describe the time varying sound and to assess the effects of noise. These measures are described in Table 3-48.

Sound levels near the Deaf Smith County site are characteristic of rural agricultural settings reported by the EPA (1974). Residual sound levels at the site are expected to be similar to those for the rural areas surveyed during the summer of 1982 (NUS, 1984, BMI/ONWI-528) and the winter of 1983 (NUS, 1984, BMI/ONWI-526). These measurements were conducted in areas of Deaf Smith County east of the site. They are summarized in Table 3-49 for the winter survey and in Table 3-50 for the summer survey. The measurement made near Interstate 40 and within 200 feet of US 385 include effects of traffic noise and are not considered to be representative of the site. Based on these surveys, and published levels of typical rural agricultural settings, the background L_{eq} is expected to be between 35 and 50 dBA during the summer, primarily from wind, insect, and agricultural activity. Irrigation pumps, tractors, and grain elevators are significant localized noise sources. During winter, the background L_{eq} is expected to be between 30 and 55 dBA. Background sound during the winter is primarily from wind and other natural sources. Agricultural noise decreases during the winter when such activities are limited.

Traffic noise dominates sound levels along U.S. 385 much of the time in both summer and winter. Within approximately 150 meters (500 feet) of US 385 the L_{dn} exceeds 55 dBA. Traffic along secondary roads (Farm Road 2587 and Farm Road 214) contributes to local sound levels. Occasional aircraft activity contributes to sound levels throughout the area.

Table 3-48. Sound Level Measures

Measure	Description
L_{eq}	The energy equivalent A-weighted level (dBA); the average of the time-varying sound energy.
L_{dn}	The day/night energy equivalent level (dBA). The 24-hour A-weighted energy equivalent level with 10 dBA added to the nighttime levels (10:00 p.m. to 7:00 a.m.).

Table 3-49. Representative Background A-Weighted Sound Levels in Deaf Smith County: Winter Survey, February 26 to March 1, 1983

Sampling Location[a]	Date	Time	Period[b]	Sound Level[c] L_{10}	L_{50}	L_{90}	L_{eq}	L_{dn}
1	02/28/83	0920-0932	1	54.4	48.7	43.2	60.0	59.8
1	02/28/83	2222-2232	2	53.6	45.3	39.5	49.5	
1	02/27/83	2035-2045	3	59.9	51.0	41.4	54.9	56.6
1	02/27/83	0230-0240	4	51.7	46.3	41.3	48.5	
2	02/28/83	0943-0955	1	64.0	51.9	41.8	59.4	64.2
2	02/28/83	2239-2249	2	62.5	48.8	42.4	57.5	
2	02/27/83	2052-2102	3	66.6	54.3	44.1	62.6	68.2
2	02/27/83	0206-0217	4	62.4	48.3	40.0	61.6	
3	02/28/83	1229-1241	1	53.3	48.4	44.5	50.2	50.3
3	03/01/83	0147-0157	2	42.7	39.9	37.1	40.5	
3	02/27/83	1117-1127	3	44.8	38.8	35.6	42.6	41.8
3	02/27/83	2230-2240	4	32.7	29.1	25.9	30.0	
4	02/28/83	1401-1412	1	56.6	50.1	44.1	56.0	57.8
4	03/01/83	0116-0126	2	48.7	32.3	25.8	49.8	
4	02/27/83	1920-1930	3	59.6	35.2	22.6	58.3	57.2
4	02/26/83	2252-2302	4	43.5	33.2	29.4	44.3	
5	02/28/83	1344-1354	1	51.3	46.1	42.0	48.1	55.1
5	03/01/83	0100-0110	2	53.4	32.2	26.7	48.8	
5	02/27/83	1903-1914	3	50.2	32.7	26.1	48.9	52.3
5	02/26/83	2220-2230	4	47.9	25.7	23.3	45.1	
6	02/28/83	1026-1040	1	45.8	41.0	36.7	44.1	49.0
6	02/28/83	2314-2323	2	45.1	41.2	37.3	42.3	
6	02/27/83	1700-1710	3	47.6	26.4	17.9	47.2	52.0
6	02/27/83	0055-0105	4	48.4	44.2	40.1	45.3	

(a) 1 1,056 feet south of centerline of Interstate 40 on dirt road 5 miles west of Route 809; representative of sound levels along I-40.
2 200 feet south of centerline of I-40 on dirt road 5 miles west of Route 809; representative of sound levels along I-40.
3 At intersection of dirt road 2 miles east of U.S. 385, and dirt road 5.5 miles north of FM 2587; representative of sound levels in an isolated area of Deaf Smith County.
4 100 feet west of centerline of U.S. 385 along gravel road 3 miles south of FM 2587; representative of sound levels along U.S. 385.
5 528 feet west of centerline of U.S. 385 along gravel road 3 miles south of FM 2587; representative of sound levels along U.S. 385.
6 100 feet north of the centerline of a paved road 2 miles north of FM 2587 at a dirt road 3 miles west of Route 809; representative of sound levels in an isolated area of Deaf Smith County.

(b) 1 = weekday daytime (0700-2200 hours)
2 = weekday nighttime (2200-0700 hours)
3 = weekend daytime (0700-2200 hours)
4 = weekend nighttime (2200-0700 hours).

(c) L_{10}, L_{50}, and L_{90} sound levels are those exceeded 10, 50, and 90 percent of the time, respectively; L_{eq} is the equivalent sound level; L_{dn} is the time-weighted day/night outdoor average sound level. Sound levels, expressed in dBA, represent a 10 to 15 minute measurement period.

Table 3-50. Background A-Weighted Sound Levels in Deaf Smith County: Summer Survey, August 4-8, 1982

Sampling Location[a]	Date	Time	Period[b]	Sound Level[c]				
				L_{10}	L_{50}	L_{90}	L_{eq}	L_{dn}
1	8/5/82	1105-1120	1	70.3	44.4	38.5	67.2	65.2
1	8/5/82	0100-0110	2	42.6	40.3	39.3	41.7	
1	8/7/82	1125-1135	3	69.1	64.1	63.1	66.0	74.2
1	8/8/82	0300-0305	4	68.8	68.0	67.2	68.0	
2	8/4/82	1855-1905	1	40.9	36.1	32.9	49.9	49.5
2	8/4/82	2325-2335	2	40.3	38.4	37.2	38.6	
2	8/7/82	1303-1313	3	44.8	42.7	41.1	43.1	47.9
2	8/8/82	0222-0228	4	42.6	41.2	39.4	41.2	

(a) 1 = 55 feet east of centerline of U.S. 385; 2.5 miles south of FM 1062; represents sound levels along U.S. 385
2 = 58 feet west of center of dirt road that is 7 miles east of U.S. 385; 4 miles south of FM 1062; represents sound levels in an isolated area of Deaf Smith County.

(b) 1 = weekday daytime (0700-2200 hours)
2 = weekday nighttime (2200-0700 hours)
3 = weekend daytime (0700-2200 hours)
4 = weekend nighttime (2200-0700 hours)

(c) L_{10}, L_{50}, and L_{90} sound levels are those exceeded 10, 50, and 90 percent of the time, respectively; L_{eq} is the equivalent sound level; L_{dn} is the time-weighted day/night outdoor average sound level. Sound levels are expressed in dBA, represent a 10 to 15 minute measurement period.

For the purpose of quantifying the ambient background sound level at the site, an average hourly L_{eq} of 35 dBA is considered an appropriate conservative value based upon the measurements and the range of values reported by the EPA for rural agricultural area (1974, pp. 33). A corresponding background L_{dn} value of 41 dBA is used in the prediction of sound levels in Sections 4.2.1.6.4 and 5.2.7.2. L_{dn} values of 45 dBA and higher are typical of areas near highways, residences and agricultural activities.

3.4.5 Aesthetic Resources

The method used to characterize the visual resources in the site vicinity (NUS, 1984, BMI/ONWI-559) was adapted from the Bureau of Land Management's Visual Resource Management (VRM) System and the U.S. Forest Service's Visual Management System. These two systems are designed to measure the scenic quality of a landscape in terms of its visual variety, transportation patterns, recreational resources, population distribution, and user expectations.

The landscape in the site vicinity shows little visual variety. Flat to gently rolling landforms and low-growing agricultural crops are predominant. Unobstructed views and little sense of enclosure are characteristic of the area (NUS, 1984, BMI/ONWI-559).

Approximately 18 percent of the site vicinity exhibits distinctive visual variety. The most prominant landforms are the playas, ephemeral playa lakes, and stream valleys. One playa and part of another lie on the site. Conspicuous in the northern part of the site vicinity is a series of playa lakes that form, at flood stage, a tributary of North Palo Duro Creek; Palo Duro Creek traverses the southern portion of the site vicinity. These landforms are included in the "distinctive" visual variety class (Figure 3-82) because their topographical and vegetative characteristics are not common to the area (NUS, 1984, BMI/ONWI-559).

Approximately 9 percent of the site vicinity exhibits common visual variety. Included are (1) rangeland areas not associated with stream valleys or semipermanent playa lakes and (2) dry playas. These landforms are included in the "common" visual variety class (Figure 3-82) because they exhibit either topographical or vegetative characteristics that contrast with the predominantly agricultural landscapes.

The remaining features of the regional landscape offer minimal visual variety.

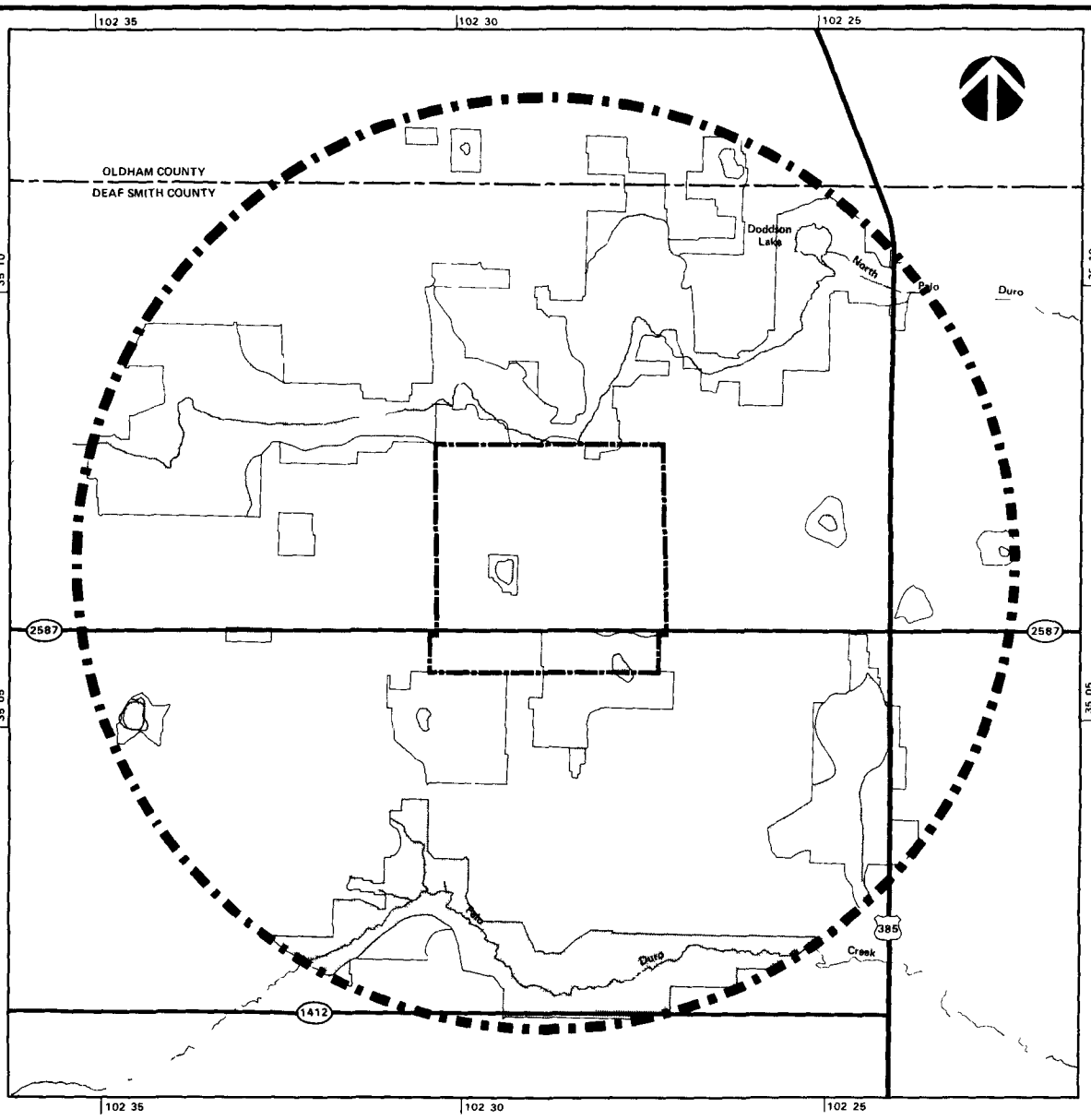
No Federally designated Wild and Scenic Rivers or potential additions to the Wild and Scenic Rivers System have been identified in the site vicinity (National Park Service, 1983, map).

3.4.6 Archaeological, Cultural, and Historical Resources

Archaeological, cultural, and historical resources are defined as prehistoric and historic districts, sites, structures, and other evidence of human use that are considered to be important to a culture or subculture or a community for scientific, traditional, religious, or other reasons. A preliminary assessment (Phase I) of cultural resources has been conducted for the Deaf Smith County site and vicinity (NUS, 1984, BMI/ONWI-560). This assessment consisted of a literature search and archival review, which provided an analysis and evaluation of recorded sites. Potentially sensitive locations where sites may be located were identified in the preliminary assessment and are found at the site and vicinity.

3.4.6.1 Archaeological Resources

The information presented in this section is summarized from the Phase I investigation done by Girard et al. (1984). There is archaeological evidence of human activity dating back to the Late Pleistocene (approximately 12,000 years ago) in the Texas Panhandle. The five development stages that have been identified for the area encompassing the site and vicinity are (1) Paleo-Indian (12,000 to 8,000 years BP), (2) Archaic (8,000 to 2,000 years BP), (3) Ceramic (2,000 years BP to the year 1450 AD), (4) Protohistoric (the year 1450 to 1600 AD), and (5) Historic (1600 AD to present). Sites from any of these development stages may be located on or near the site.



Explanation

Class A - Distinctive
Most Outstanding Characteristics

Class B - Common
Some Outstanding Characteristics

Class C - Minimal
Fairly Common to the Region

1 0 1 5 Kilometers

1 0 1 3 Miles

Source: NUS, 1984, BMI/ONWI-559, Visual Assessments for Swisher County and Deaf Smith County Locations.

Deaf Smith County Site and Vicinity
Visual Variety Classes

Figure 3-82

Most recorded Paleo-Indian sites in the area identified in the Phase I Assessment represent kill (e.g., buffalo) and butchering locales and tend to be located near former lakes or stream channels. Occupation sites may have been located in higher areas. Sites from the early Archaic period are not abundant in the region. Later Archaic sites have been found near upland playas, along canyon and valley rims, and on benches and terraces of stream valleys. During the Ceramic stage, there appears to have been a gradual shift toward a more sedentary lifestyle, with cultivated crops taking on increasing importance. More permanent settlements occurred on, or adjacent to, fertile bottomlands. Later Ceramic stage sites tended to be located near major streams. Cultivated crops appear to have been less important during the Protohistoric stage; however, too little is known about this stage to make valid generalizations concerning probable site locations. Protohistoric components have been identified in rock shelters and on slopes and terraces of major creeks.

To date, no archaeological sites have been recorded at the site or in the vicinity. Areas with the greatest potential for containing unrecorded historic sites are located near water sources, such as the unnamed tributary immediately north of the site. Archaeological sites are likely to be most numerous along Palo Duro Creek, about 6 kilometers (3.5 miles) south of the site, and near the two playa lakes on and around the site. Figure 3-83 illustrates areas with a high potential for prehistoric sites.

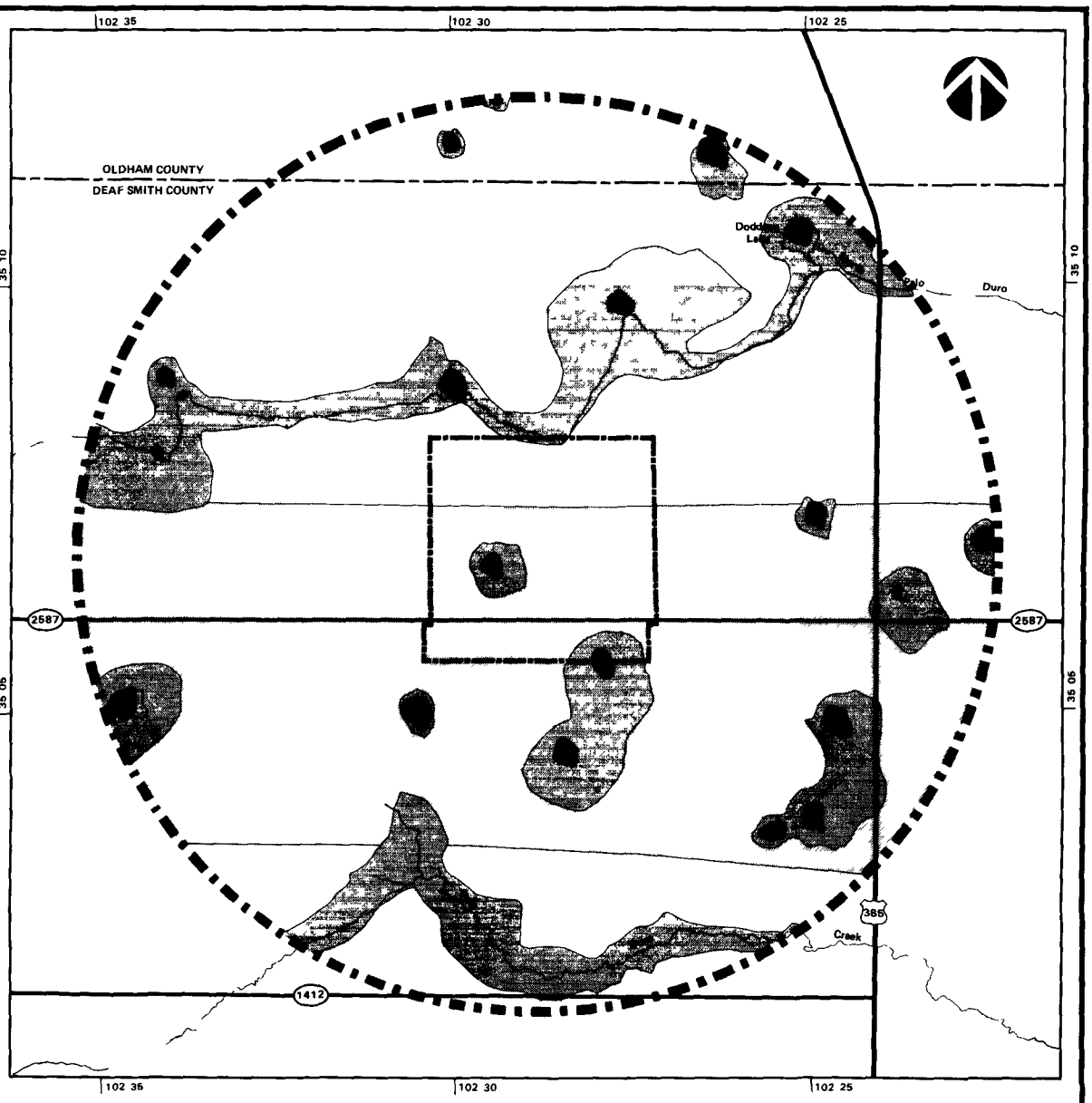
3.4.6.2 Historical Resources (the Year 1600 to the Present)

The area of the site and vicinity was initially inhabited by Jumanos and Apache Indians, who were eventually displaced by Comanche Indian bands. European explorers probably did not travel through the area until 1787. The Texas-Santa Fe Expedition is thought to have crossed the southern portion of Deaf Smith County in 1841. Members of the expedition encountered evidence of Comanchero and Cibolero groups that operated along Tierra Blanca and Palo Duro Creek. Another Hispanic group active in the area was the Pastores. The Pastores spread out over the grassland plains in the second half of the nineteenth century following major drainages with their large sheep herds. Anglo populations moved into the area in the last quarter of the century, forcing Pastores from Deaf Smith County into Oldham County and New Mexico. By 1880, large ranches became dominant. Evidence of ranch activities is expected throughout much of the area.

Settlers from the east moved into the area after 1885, establishing the community of La Plata, which became the county seat of Deaf Smith County. La Plata was located approximately 19 kilometers (12 miles) southwest of the site. Construction of the Pecos and Northern Texas Railway line to the south and a period of bad weather eventually resulted in the demise of La Plata as residents moved to Hereford, the new county seat.

By 1900, a number of small ranching communities had developed between Hereford, Vega, and the Randall County line. Using dryland farming techniques and newly developed irrigation wells, numerous farmers settled the area, establishing agriculture as the predominant economic activity. The development of irrigation technology allowed settlement to take place on the upland plains. Therefore, potential historic sites are not restricted to available surface-water sources and may be located throughout the site vicinity.

No recorded historic resources or National Historic Trails are located on the site or within the vicinity. However, the potential for historic resources within both is high. The development of irrigation technology allowed settlement to take place on the upland plains. Therefore, potential historic sites are not restricted to available surface-water sources and may be located throughout the site vicinity. Historic sites that may occur within the site include evidence of historic aboriginal sites associated with reliable sources of water, Comanchero and Cibolero trails located north of Palo Duro Creek, Pastores occupational sites along stream drainages, and evidence of ranching and farming activities. A trail from the Historic Period may be located in the southern two-thirds of the site. Figure 3-83 indicates potential areas for the occurrence of historic resources.



Explanation

- Area of Potential Prehistoric Resources
- Area of Potential Historic Resources
- Other Land
- Playa Lake

1 0 1 5 Kilometers

1 0 1 3 Miles

Source Adapted from Map Compiled by Girard et al , 1984, Plotted on USGS Quadrangle Maps

Deaf Smith County Site and Vicinity Archaeological, Cultural, and Historic Resources

Figure 3-83

3.4.7 Background Radiation

Radiation from cosmic rays, terrestrial sources, and fallout, in addition to radioactivity concentrations in environmental media (air, water, and milk), provide the necessary data for establishing background radiation at the site.

Individual and population doses from external radiation (total of cosmic rays, terrestrial, and fallout components), estimated from information in the literature, are presented in NUS (1984, BMI/ONWI-558), and are comparable with doses for the State of Texas (Bogen and Goldin, 1981; Oakley, 1972). The dose equivalent rate to an individual at the site is 95 millirems per year (see Table 3-51), which is about 25 percent higher than the average dose rate of 76 millirems per year for all residents the United States.* (Internal radiation associated with environmental media [e.g., air, water, and milk] is not included in this analysis; it would add about 24 millirems per year to the total individual dose rates.) The dose rate is higher at the site than the average rate for residents of the entire United States because most of these residents live (1) at lower altitudes where cosmic radiation doses are lower, and (2) in areas where terrestrial radiation is lower due to lower levels of naturally occurring radionuclides. The annual population dose to the 217,000 people who lived within 80 kilometers (50 miles) of the center of the site in 1980 was under 21,000 man-rem. This is about 0.12 percent of the 1.7×10^7 man-rems received by the entire population of the United States in 1980.

3.5 TRANSPORTATION AND UTILITIES AT THE DEAF SMITH COUNTY SITE

3.5.1 Roads

3.5.1.1 Pattern

Major highway routes providing access to the Deaf Smith site are Interstate 40 (I-40), connecting Amarillo, Vega, and Adrian; U.S. Route 60 (U.S. 60), connecting Canyon and Hereford; and U.S. Route 385 (U.S. 385), connecting Vega and Hereford. These are depicted in Figures 3-1 and 3-84. I-40 has replaced U.S. 66, although the latter still exists in many places and serves as a business route through populated areas. Other important access roads are Farm-to-Market Road (FM) 214 (shown on some state maps as FM 290), which runs from Adrian to FM 1412 and south; FM 1062, from U.S. 60 west of Canyon to U.S. 385; FM 2587, which runs through the southern portion of the site, connecting U.S. 385 and FM 809 with FM 214; and FM 1412, connecting FM 214 with U.S. 385. The site vicinity is bounded on the north by I-40 and U.S. 66, and on the south by FM 1412. To the west lies FM 214, and to the east lies U.S. 385.

3.5.1.2 Traffic Capacity

Table 3-52 provides information on segments of local highways, including speed limits (design and legal), maximum service volumes at the highest level of service, average daily traffic (ADT), peak hour traffic, maximum legal weight, and total accident rates per 1 million vehicle miles. On route segments for which ADT is provided as a range, traffic counts were taken at two or more points along the segment.

3.5.2 Railroads

3.5.2.1 Pattern

Amarillo is the center for railroad transport in the region. The closest operating and continuous railway route to the Deaf Smith County site is the Atchison, Topeka and Santa Fe

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*The dose equivalent rate from background radiation at the site can also be compared with the limit of 25 millirems per year to the whole body from normal repository operations as given in 40 CFR Part 191.

Table 3-51. Dose-Equivalent Rates From Background Radiation, Deaf Smith County Site

Source	Dose Equivalent Rates (millirems per year)
Cosmic Rays	44
External Terrestrial Radiation	46
Weapons Test Fallout	5
Total	95

Source: NUS, 1984, BMI/ONWI-558, p. 10.

Table 3-52. Characteristics of Roads Providing Access to the Deaf Smith County Site

Route Segment	Distance Kilometers (Miles)	Number of Lanes	Speed Limit (mph) Permitted (Design)	Annual Average Daily Traffic (1981)	Peak Hour Traffic[a] (Vehicles per Hour)	Maximum Service Volume, Ideal Conditions[b] (Vehicles per Day/per Hour)	Accident Rate[c]	Maximum Weight, Tonnes (tons)
I-40/U.S. 66 (Amarillo-U.S. 66 Business)	13.8 (8.6)	4	55 (70)	9,500-58,000	1,092-6,960	67,200/2,800	3.27	36.3 (40.0)
I-40/U.S. 66 (U.S. 66 Business-Vega)	41.0 (25.6)	4	55 (70)	7,700-9,500	924-1,140	67,200/2,800	0.56	36.3 (40.0)
U.S. 60 (Canyon-Hereford)	49.6 (30.8)	4	55 (70)	4,200-7,400	504-888	67,200 2,800	1.22	36.3 (40.0)
U.S. 385 (Vega-FM 2587)	16.7 (10.4)	2	55 (70)	1,450	174	9,600/400	0.57	36.3 (40.0)
U.S. 385 (Hereford-FM 1062)	19.0 (11.8)	2	55 (70)	1,500 6,000	180-720	9,600/400	3.20	36.3 (40.0)
U.S. 385 (FM 1062-FM 2587)	13.2 (8.2)	2	55 (70)	1,150	138	9,600/400	0.43	26.5 (27.2)
FM 1062 (U.S. 60-U.S. 385)	37.3 (23.2)	2	55 (unknown)	230-400	28-48	9,600/400	1.13	26.5 (29.2)
FM 2587 (U.S. 385-site boundary)	4.7 (2.9)	2	55 (unknown)	110-220	13-26	9,600/400	0.26	36.3 (40.0)
FM 214 (I-40/U.S. 66-FM 2587)	18.5 (11.5)	2	55 (unknown)	110-180	13-22	9,600/400	0.21	26.5 (29.2)

(a) 12 percent of Annual Average Daily Traffic (Hausmann, 1983).

(b) Maximum service volume is the maximum number of vehicles that can be accommodated by a roadway providing ideal driving conditions (i.e., highest level of service).

(c) Total accidents per 1 million vehicle miles per specified road segment, average for 1978 through 1982. These data reflect the total for all vehicle roadway accidents including fatal accidents, accidents in which both injuries and fatalities occurred, and those only involving property damage.

Sources: Goode, 1983; National Academy of Sciences National Research Council, 1965; NUS, 1984, BMI/ONWI-461; Perkins, 1984; Texas State Department of Highways and Public Transportation, 1978 through 1982.

route, which runs through Hereford and Canyon, parallel to U.S. 60 and into Amarillo (Figure 3-1). At its nearest point, the line passes within approximately 30 kilometers (19 miles) of the southeast corner of the site.

Rail tracks run west from Amarillo into Bushland, parallel to I-40 and U.S. 66 (Figure 3-1); the tracks west of Bushland have been removed. The existing track is managed by Burlington Northern. The remaining right-of-way lies 13 kilometers (8 miles) north of the site along I-40/U.S. 66. From the site, the nearest operating railroad is at Bushland, 39 kilometers (24 miles) from the site.

3.5.2.2 Traffic Capacity

Table 3-53 gives details on track segment distance and condition, speed and weight limitations, and traffic volume. Train capacity is not often used to measure potential rail service, because capacity depends on numerous variables, such as signalling, train speed, scheduling, and number and length of sidings. Many of these variables can be altered in response to local needs (Lang, 1984).

3.5.3 Airports

Amarillo and the surrounding area are served by the eighth busiest commercial airport in Texas, which is located approximately 70 kilometers (44 miles) northeast of the center of the site. In 1980, the Amarillo Airport reported 7,615 aircraft departures, serving 355,685 passengers (Civil Aeronautics Board and Federal Aviation Administration, 1980). The next closest commercial airport is at Lubbock, 179 kilometers (112 miles) south of the center of the site. Also nearby is Hereford Municipal Airport, approximately 37 kilometers (23 miles) southeast of the center of the site. This airport is for small aircraft and does not provide regular commercial service. Some ranches in the area maintain private airstrips for small planes.

3.5.4 Waterways

There are no navigable waterways in the site vicinity; however, the ports of Houston and Galveston could be used for barge transport of repository-related materials. Houston has a deep-water port capable of handling deep-draft barges though this facility is approximately 7 hours of ship travel time inland from the port of Galveston (NUS, 1985, BMI/ONWI-557). Houston also has multiple rail access routes as opposed to the single rail line that serves the port of Galveston.

The Burlington Northern (BN) and the Atchison, Topeka and Santa Fe (AT&SF) rail lines are the two possible rail access routes to serve the ports. Amarillo is the closest city to the site that the Burlington Northern Railroad Company serves. The trip to Amarillo would be approximately 1,000 kilometers (625 miles) from Galveston or 920 kilometers (575 miles) the port at Houston. Shipments on AT&SF could be transported either to Farwell or Canyon before continuing on to the site. The trip to Farwell is approximately 1,016 kilometers (635 miles) from the Port of Galveston and 936 kilometers (585 miles) from Houston. The route to Canyon is approximately 1,024 kilometers (640 miles) from Galveston and 968 kilometers (605 miles) from Houston.

A potential highway route connecting the port cities with the site vicinity includes I-45 from Houston or Galveston to the Dallas area. U.S. 287 could then be taken from Dallas to Amarillo where a connection could be made with a preferred access route to the site. From Houston to Amarillo on this route is approximately 1,000 kilometers (625 miles). If the port of Galveston were used, the distance would be an additional 80 kilometers (50 miles).

3.5.5 Utilities

3.5.5.1 Electric

The Texas Public Utilities Commission regulates electric utilities in Texas. In the study area, electricity is provided mainly by Southwestern Public Service Company (SWPSC) of

Table 3-53. Characteristics of the Atchison, Topeka & Santa Fe (AT&SF) Railroad Serving Deaf Smith County Site

Railroad Track Segments	Distance kilometers (miles)	Characteristics	Speed Restrictions	Maximum Weight Limit, Gross[a] Tonnes (tons)	Traffic Loads: Million Gross Tonnes (tons) per Year	Traffic Loads: Trains per Day
Amarillo to Canyon	26 (16)	Double main line track	60 miles per hour district speed; no slow orders[b]	119.7 (132)	47.8 (52.7)	34
Canyon to Dawn	26 (16)	Single main line track	60 miles per hour district speed; 20 and 30 miles per hour on curves; 55 miles per hour through Canyon; no slow orders[b]	119.7 (132)	39.6 (43.7)	28
Dawn to Farwell	97 (61)	Single main line track	60 miles per hour district speed; 20 and 30 miles per hour on curves; 45 miles per hour through Hereford; 55 miles per hour through Bovina; no slow orders[b]	119.7 (132)	39.6 (43.7)	28

(a) Rail car plus cargo.
(b) Temporary slow orders imposed when crews are working on tracks.

Sources: Mardellara, 1984.

Amarillo. While this company provides electricity directly within some municipalities, rural cooperatives can purchase electricity wholesale from SWPSC and, in turn, retail it to the public. Residents of the cities of Amarillo, Hereford, Canyon, and Vega purchase electricity from this company.

At the Deaf Smith County site, electricity is provided by the Deaf Smith Electric Cooperative, Inc., which provides electricity to portions of Oldham, Deaf Smith, Parmer, and Castro Counties. This rural cooperative purchases electricity wholesale from Southwestern Public Service Company of Amarillo. The closest electrical substation is a 7,500-kilowatt substation located east of the site at the intersection of U.S. 385 and FM 2587 (Figure 3-84).

3.5.5.2 Gas

The Westar Gas Company is the main provider of natural gas at the site. Local municipalities in Texas have authority to approve natural gas rate changes and the Texas Railroad Commission has appellate jurisdiction over such changes.

Primary utility structures at the site include 10.2-centimeter (4-inch) gas pipelines (Figure 3-84).

3.5.5.3 Water Supply and Sewage Treatment

There is no municipal water supply or sewerage at the site. The nearest public water supply and sewage treatment facilities are in Vega (NUS, 1984, ONWI-461).

3.6 SOCIOECONOMIC CONDITIONS

A nine-county study area was selected for socioconomic analysis of the site in Deaf Smith County (Figure 3-85). The study area comprises the communities and counties within a reasonable commuting distance of the site that could be affected by exploratory shaft and repository development. These anticipated effects include population and economic changes.

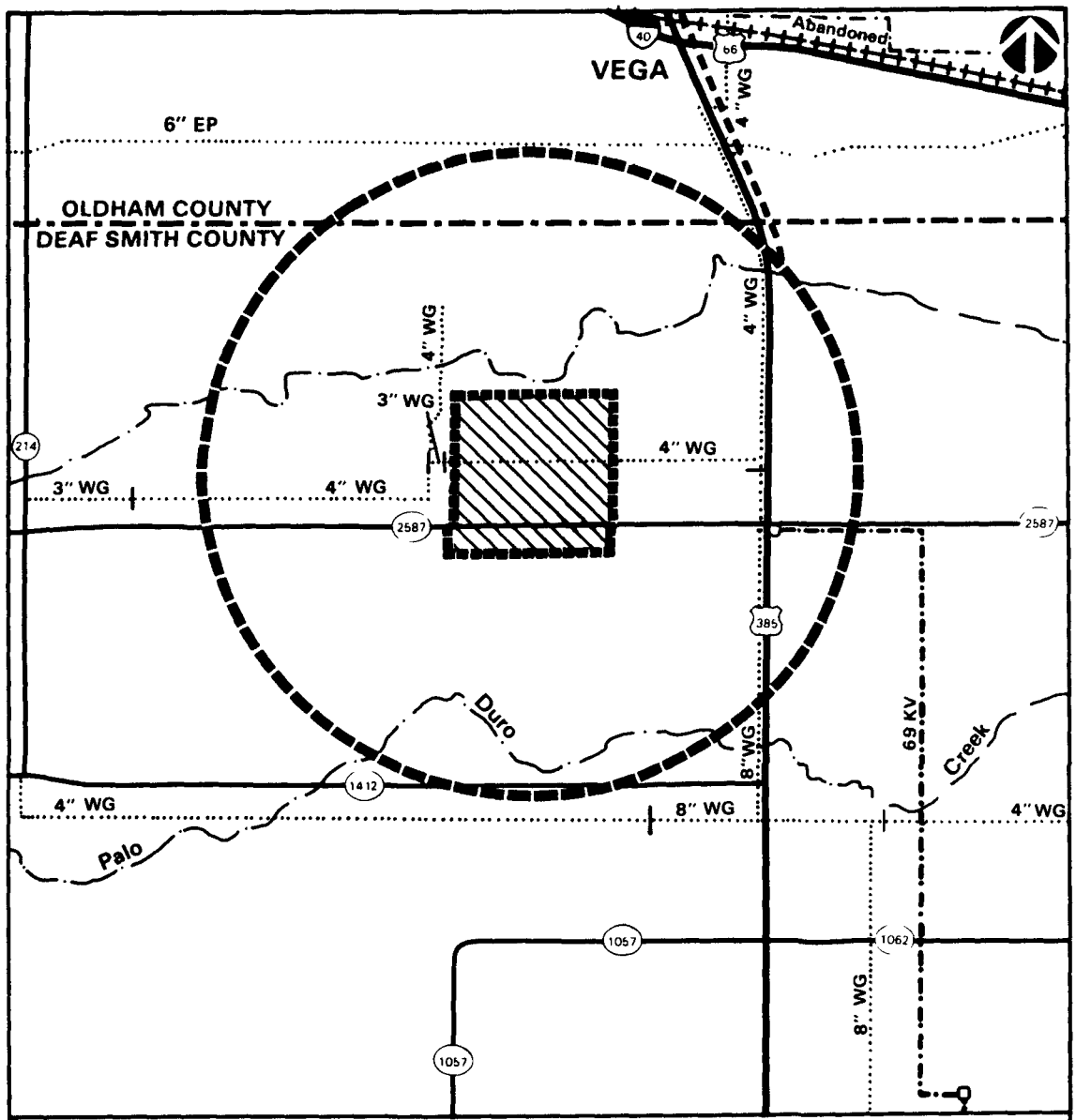
The socioeconomic study area for this site covers seven counties in Texas and two in New Mexico, including Deaf Smith County (the repository location) and the surrounding eight counties. These counties and the communities in them were included in the Socioeconomic Data Base Report (NUS, 1984, ONWI-461) prepared for the Permian Basin. Four communities, Amarillo, Hereford, Canyon, and Vega, were selected for socioeconomic baseline characterization in this analysis based on a gravity model which allocated new project-related residents within the study area (see Section 5.4). These communities fall within a 1-hour commuting distance of the site (approximately a 60-mile driving radius) and they offer an existing infrastructure and housing stock.

Economically, the major employment sectors in the nine-county area are government, retail trade, services, manufacturing, transportation, and agriculture (NUS, 1984, ONWI-461, Table 2-4). The Amarillo Standard Metropolitan Statistical Area (SMSA) (Bureau of the Census, 1971a; 1971b, p. 3), with a 1980 population of 173,699, is the major industrial and commercial center in the area (Bureau of the Census, 1982a, p. 50). This SMSA includes both Potter and Randall Counties.

3.6.1 Population

3.6.1.1 Population Density

Figure 3-86 presents the population distribution used for the radiological analysis. This demographic discussion of the site is formatted to conform with meteorological data which aids in the radiological assessment. Specifically, this means the area within a 50-mile radius of the site is divided into (1) 16 compass sectors; and (2) 0 to 5-, 5 to 10-, 10 to 20-, 20 to 30-, 30 to 40-, and 40 to 50-mile annuli. This circular grid is then superimposed on a map of the area to calculate the population in each grid segment.



Explanation

Transportation

- Interstate Highway
- 4 Lane U S Highway
- 2 Lane U.S Highway
- Farm to Market Road
- State Highway
- Railroad Right-of-Way

*Electric Distribution Lines Not Shown

Utilities

- Water Pipeline
- Transmission Line*
- Substation
- Natural Gas Pipeline
- Change in Diameter

EP - Emerald Products

WG - Westar Gas

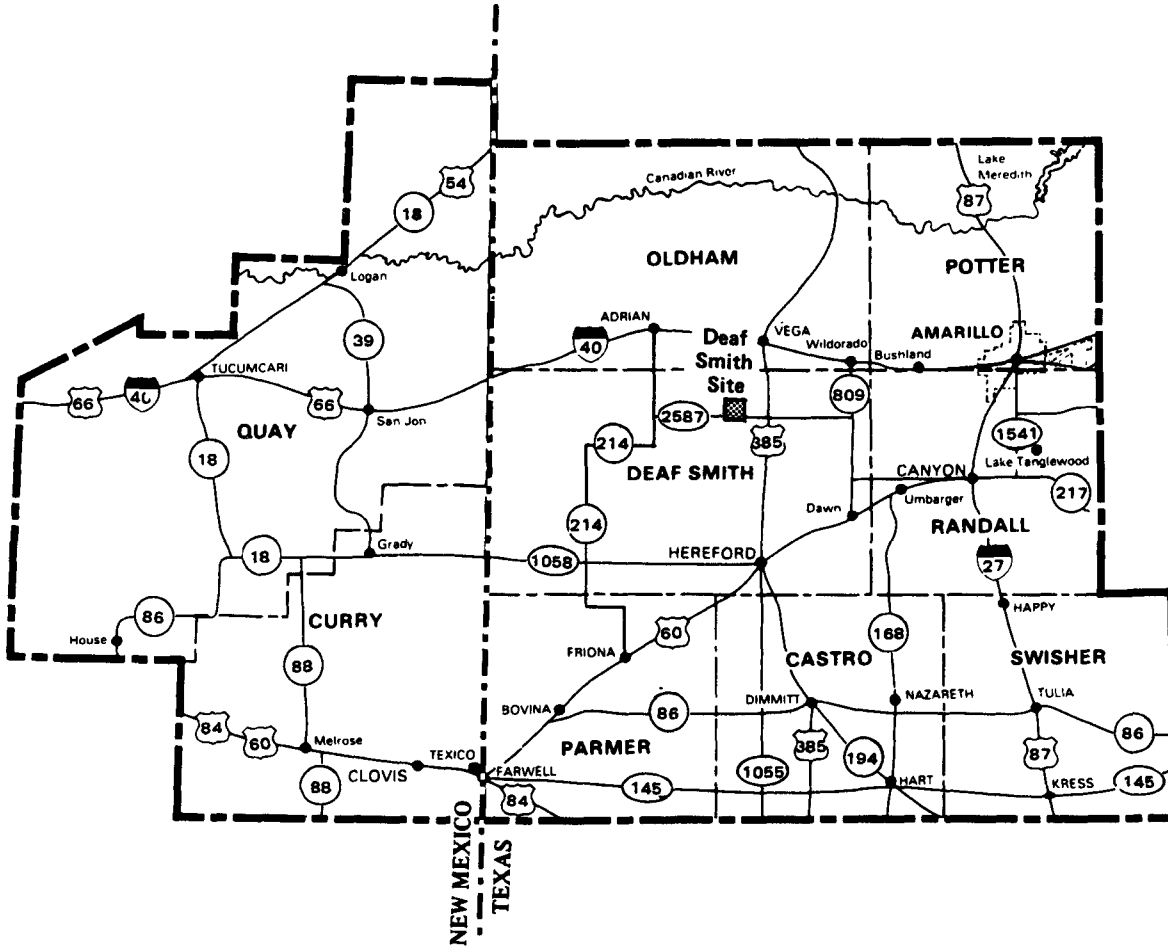
Sources Adapted from Dewitt Graphics, 1983, Southwestern Public Service Comapny, 1975-1980, Deaf Smith Electric, Inc, 1981-1982

0 2 4 6 8 Kilometers

0 1 2 5 Miles

Deaf Smith County Site and Vicinity Transportation and Utilities

Figure 3-84



Explanation

AMARILLO	Incorporated Place with 50,000 Population or Greater
HEREFORD	Incorporated Place with 10,000 to 50,000 Population
VEGA	Incorporated Place with Population Less Than 10,000
Wildorado	Unincorporated Place
▩	Deaf Smith Site

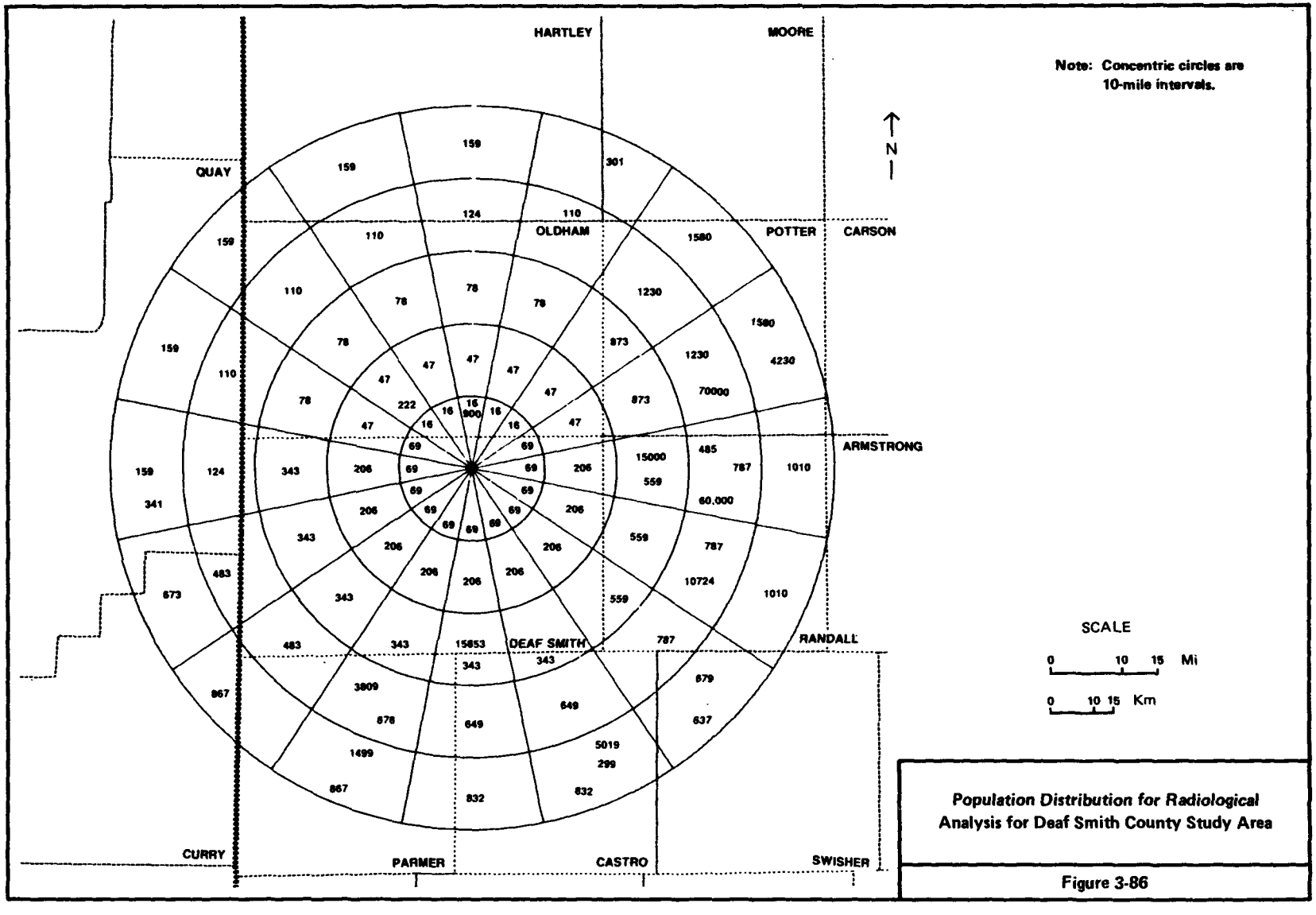
0 10 20 30 40 50 Kilometers

0 5 10 15 20 25 30 Miles

Source: Bureau of Census, 1982a.

Communities in the Nine-County Area

Figure 3-85



Population Distribution for Radiological Analysis for Deaf Smith County Study Area

Figure 3-86

The population values within each segment of the population diagram are calculated by (1) subtracting the contributions of population centers from the total county population to establish a rural population, (2) dividing this rural population value by the county area to get a rural population density, (3) multiplying this rural density by the area represented by the segment, and (4) recording this value on the diagram, along with the population center values for the centers which occur inside the segment.

As shown in Table 3-54, the population density in the nine-county socioeconomic study area was 24.0 persons per square mile in 1980. This is substantially below the national average density of 76 persons per square mile.

3.6.1.2 Population Distribution

The total population of the nine-county study area in 1980 was 281,060 people. Of these, 231,425 people, or 82 percent, lived in urban areas and 18 percent lived in rural areas. This urban-rural distribution was similar to that of Texas (80 percent urban, 20 percent rural) and somewhat higher than that of the United States (74 percent urban, 26 percent rural), and reflects trends of the past 20 years toward a higher percentage of people living in urban areas (Section 3.6.1.3). Deaf Smith County also had a similar distribution: 75 percent of the 21,165 persons in the county resided in urban areas and 25 percent lived in rural areas (NUS, 1984, ONWI-461, p. 8).

Incorporated areas closest to the site and their populations are Hereford (15,853), Canyon (10,724), Vega (900), and Amarillo (149,230). Populations for counties and incorporated places are presented in Tables 3-54 and 3-55, respectively.

3.6.1.3 Population Projections

This section presents data describing recent trends in population distribution in Deaf Smith County and the nine-county area. The trends in the nine-county area differ substantially from those in the two States and the country as a whole. During the 1960s, the total population of the United States, Texas, and New Mexico increased by about 13 percent, 17 percent, and 7 percent, respectively, while the nine-county area population grew by only 4 percent (NUS, 1984, ONWI-461, pp. 12-17).

During the 1970s, as the total populations of the two States increased greatly (27 percent in Texas; 28 percent in New Mexico), the population of the United States and the nine-county area also increased, but at a slower pace (about 14 percent for the nine-county area and 11 percent for the United States). Thus, while the direction of population changes in the nine-county area was the same as that of the States, the population increase was much smaller, resulting in a declining share of the State's population. The local area constituted 2.3 percent of the total population of the two States in 1960 and 1.8 percent in 1980.

The populations of the counties and the four major communities in the study area were projected to the years of expected peak in-migration associated with the construction (1997) and operation (2005) of the proposed facility. Table 3-56 shows the projected increase between 1980 and 1997 in the communities of Amarillo, Hereford, Canyon, and Vega. Increases are also projected for these communities between 1997 and 2005.

3.6.1.4 Population Characteristics and Temporary Population

Tables 3-57, 3-58, and 3-59 present distributions of age, race, and sex for the 1980 population of the study area counties. Of the total population in the study area (281,060), 25,291, or 9 percent, are under 5 years of age; 62,163, or 22 percent, are of school age; and 27,778, or 10 percent, are 65 years or older. Persons 25 to 65 years of age make up 45 percent of the population. These percentages correspond closely with age distributions for Texas, New Mexico, and the United States. Of the total study area population, 78 percent (217,874) are white, 16 percent (45,932) are Hispanic, 5 percent (12,747) are black, and 1 percent are of other races. The gender distribution for the study area is 51 percent female (143,650) and 49 percent male (137,410).

Table 3-54. County Population and Density

	1980	1980 Population Density (per sq mi)
Texas		
Castro	10,556	12
Deaf Smith	21,165	14
Oldham	2,283	2
Parmer	11,038	13
Potter	98,637	109
Randall	75,062	82
Swisher	9,723	11
New Mexico		
Curry	42,019	30
Quay	10,577	4
Total (9 counties)	281,060	24

Sources: Bureau of the Census, 1982a, b.

Table 3-55. Populations of the Incorporated and Census-Designated Places in the Nine-County Area

Place	County	1980
Texas		
Dimmitt City	Castro	5,019
Hart City	Castro	1,008
Nazareth City	Castro	299
Hereford City(a)	Deaf Smith	15,853
Adrian City	Oldham	222
Vega Town(a)	Oldham	900
Bovina City	Parmer	1,499
Farwell City	Parmer	1,354
Friona City	Parmer	3,809
Amarillo City(a)	Potter	149,230
Canyon City(a)	Randall	10,724
Lake Tanglewood Village	Randall	485
Happy Town	Swisher	674
Kress City	Swisher	783
Tulia City	Swisher	5,033
New Mexico		
Cannon AFB CDP	Curry	3,798
Clovis City	Curry	31,194
Grady Village	Curry	122
Melrose Village	Curry	649
Texico City	Curry	958
House Village	Quay	117
Logan Village	Quay	735
San Jon Village	Quay	341
Tucumcari City	Quay	6,765

(a) Cities in the immediate vicinity of the nominated site.

Sources: Bureau of the Census, 1982a, b.

Table 3-56. Population Projections for Selected Counties and Communities in the Study Area

	1980	1997	2005
Potter	98,637	111,574	115,290
Randall	75,062	103,248	115,760
Two County Total	173,699	214,822	231,050
Percent Increase[a]	-	24%	33%
Amarillo	149,230	184,746	198,480
Increase[a]	-	+35,516	+49,250
Deaf Smith	21,165	26,705	29,310
Percent Increase[a]	-	26%	28%
Hereford	15,853	20,028	21,873
Increase[a]	-	+4,175	+6,020
Randall	75,062	103,248	115,760
Percent Increase[a]	-	38%	54%
Canyon	10,724	14,455	16,514
Increase[a]		+3,731	+5,790
Oldham	2,283	3,116	3,720
Percent Increase[a]	-	36%	63%
Vega	900	1,215	1,470
Increase[a]		+315	+570

(a) Increases are in comparison with 1980.

Sources: County projections: NUS, 1984, ONWI-461.

City projections: City increases are assumed to be proportional to the counties in which they are located.

Table 3-57. Population Data by Age in the Nine-County Area, Texas, New Mexico, and the United States, 1980

County	Under 5	5 to 17	18 to 24	25 to 64	65 and over	Total Population	Median Age (years)
Texas							
Castro	1,149 (11)[a,b]	3,049 (29)	1,123 (11)	4,418 (42)	817 (8)	10,556	24.7
Deaf Smith	2,372 (11)	5,745 (27)	2,378 (11)	8,867 (42)	1,802 (9)	21,165	25.2
Oldham	150 (7)	804 (35)	201 (9)	933 (41)	194 (8)	2,283	24.5
Parmer	1,130 (10)	2,874 (26)	1,204 (11)	4,765 (43)	1,065 (10)	11,038	26.7
Potter	8,757 (9)	19,574 (20)	14,151 (14)	44,474 (45)	11,681 (12)	98,637	28.7
Randall	5,963 (8)	15,598 (21)	11,227 (15)	37,045 (49)	5,229 (7)	75,062	28.4
Swisher	847 (9)	2,396 (25)	1,012 (10)	4,212 (43)	1,256 (13)	9,723	29.9
New Mexico							
Curry	4,077 (10)	9,688 (23)	6,366 (15)	17,847 (42)	4,041 (10)	42,019	26.1
Quay	846 (8)	2,433 (23)	942 (9)	4,653 (44)	1,693 (16)	10,577	32.6
9-county area	25,291 (9)	62,163 (22)	38,614 (14)	127,214 (45)	27,778 (10)	281,060	
Texas	1,169,061 (8)	3,137,045 (22)	1,985,545 (14)	6,566379 (46)	1,371,161 (10)	14,229,191	28.0
New Mexico	114,731 (9)	303,176 (23)	178,274 (14)	590,807 (45)	115,906 (9)	1,302,894	27.3
United States	16,348,000 (7)	47,406,000 (21)	30,022,000 (13)	107,220,000 (47)	25,550,000 (11)	226,546,000	30.0

(a) Number of persons (percent of population).
(b) Percentages have been rounded to the nearest whole number and, therefore, totals may not equal 100 percent.

Sources: Bureau of the Census, 1982c,d.

Table 3-58. Ethnic Characteristics of the Population in the Nine-County Area, 1980

County	Total Persons	White[a]	Black[a]	American Indian	Asian & Islands[b]	Other[c]	Spanish[d]
Texas							
Castro	10,556	6,112	332	30	13	(c)	4,071
Deaf Smith	21,165	12,095	386	35	38	4	8,607
Oldham	2,283	2,128	12	13	12	1	117
Parmer	11,038	7,222	194	17	4	(c)	3,606
Potter	98,637	76,656	7,824	538	1,265	816	11,538
Randall	75,062	70,419	619	205	334	126	3,359
Swisher	9,723	6,558	456	9	7	15	2,678
New Mexico							
Curry	42,019	30,100	2,798	170	359	389	8,203
Quay	10,577	6,584	126	39	26	49	3,753
9-County Total	281,060	217,874	12,747	1,056[c]	2,058[c]	1,400[c]	45,932

(a) Not including persons of Spanish origin.
(b) Includes Eskimo, Aleut, Japanese, Chinese, Filipino, Korean, Asian Indian, Vietnamese, Hawaiian, Guamanian, Samoan.
(c) Some discrepancies appear with totals in Census documents because of double counting between ethnic groups; in particular some Filipinos may be counted in totals for individuals of Spanish origin. In calculating totals of all categories noted, the "Other" column occasionally shows negative values.
(d) Includes Mexican, Cuban, Puerto Rican, Other Spanish.

Source: Bureau of the Census, 1983a,b.

Table 3-59. Population by Gender for Nine-County Area, Texas and New Mexico

County	Male	Female
Castro	5,308	5,248
Deaf Smith	10,454	10,711
Oldham	1,318	965
Parmer	5,479	5,559
Potter	47,410	51,227
Randall	36,563	38,499
Swisher	4,734	4,989
Curry	20,978	21,041
Quay	5,166	5,411
TOTAL	137,410	143,650
9-County Total	281,060	

Source: Bureau of the Census, 1982c, d.

In the nine-county area, 22 percent of the population is school-aged and 10 percent is 65 and over. Persons 25 to 65 years of age make up 45 percent of the population. These percentages correspond closely with the population distribution in Texas, New Mexico, and the United States.

The most recent survey of the migrant population in Texas was conducted by the Governor's Office of Migrant Affairs and published in 1976. The results of this survey for the seven Texas counties are given in Table 3-60. Although the number of migrant workers is small compared to the total population of the seven Texas counties, there are substantial numbers of migrant workers in three counties: Castro, Deaf Smith, and Parmer.

Household sizes for the nine counties vary from a high of 3.34 in Castro County to a low of 2.58 in Potter County. The overall average household size for the area is 2.76, which is equal to that of the United States and slightly below the averages of Texas and New Mexico. Household size refers to the average number of persons not in institutions per housing unit. It differs from family size because the persons living in a single unit need not be related (NUS, 1984, ONWI-461, p. 29).

3.6.2 Economic Conditions

3.6.2.1 Employment

A distribution of employment in 1980 by major industrial sources for Deaf Smith County, the nine-county area, Texas, New Mexico, and the United States is presented in Table 3-61. Within the nine-county area, labor force participation rates were 50 percent for females and 81 percent for males. The major employment sectors in the nine-county area are government (18 percent), retail trade (15 percent), services (14 percent), manufacturing (10 percent), and agriculture (10 percent). Some of these employment sectors are closely related to, or support, regional agricultural industry activities. For example, in the manufacturing sector, production of food and food products, agricultural chemicals and fertilizers, and farm equipment compose 40 to 45 percent of the sector (Bureau of the Census, 1980a, b).

3.6.2.2 Unemployment

Unemployment rates have tended to be lower in Texas than for the nation as a whole (Table 3-62). In June 1983, the Texas unemployment rate was 8.5 percent, compared to the national average of 10 percent. In New Mexico, the rate was 10.8 percent. The situation was considerably better in the nine-county area, although the rates tended to be higher in 1983 than in 1980 for most of the counties. Deaf Smith County had the second highest rate, 9.7 percent in June 1983, behind Quay County with 10.5 percent. In the Amarillo SMSA, the rates were 6.8 percent for Potter County and 3.6 percent for Randall County.

3.6.2.3 Per Capita Income Trends

Table 3-63 presents personal income by major industrial sources for 1980. For the nine-county area as a whole, the major sources of personal income are government (15 percent), services (14 percent), manufacturing (13 percent), retail trade (11 percent), transportation and public utilities (11 percent), and farms (10 percent). The majority of jobs and income are concentrated in the Amarillo SMSA. In Deaf Smith County, farms represent the largest source of personal income by place of work (23 percent), with manufacturing as the second highest personal income source (17 percent of total).

The 1980 average per capita income in the area was $9,397, just below the national and Texas averages of $9,511 and $9,528. Table 3-64 shows per capita income trends for selected years, 1970, 1975, and 1980. Since 1970, the nine-county average has gained against the state and national per capita levels. In 1970, the nine-county average was 9 percent below the Texas average and 18 percent below the national average. In 1980, the nine-county average per capita income was 1 percent below both the Texas and national per capita income figures.

Table 3-60. Migrant Farmworker Populations in Texas Counties, 1975

County	1975 Migrants
Castro	6,030
Deaf Smith	10,440
Oldham	0
Parmer	11,410
Potter	40
Randall	0
Swisher	316

Source: NUS, 1984, ONWI-461, p. 20.

Table 3-61. Employment by Type and Broad Industrial Sources, by Place of Work, 1980

	Deaf Smith	9-County Area	Texas	New Mexico	United States
Total Employment	9,669	137,365	6,939,763	553,981	106,412,300
Number of Proprietors	1,693	17,117	673,045	49,553	9,778,000
Farm	800	5,765	210,433	13,580	2,771,000
Non-Farm	893	11,352	462,612	35,973	7,007,000
Number, Wage & Salary	7,976	120,248	6,266,718	504,428	96,634,300
Farm	1,595	7,414	78,674	9,196	1,336,300
Non-Farm	6,381	112,834	6,188,044	495,232	95,298,000
Private	5,171	88,735	5,017,764	349,315	76,497,000
Agricultural Services	488	D	52,074	3,497	565,000
Mining	L	D	238,560	29,270	1,029,000
Construction	321	5,699	421,277	32,066	4,332,000
Manufacturing	1,213	13,427	1,047,635	34,303	20,375,000
Non-Durable	1,153	D	422,352	13,790	8,124,000
Durable	60	D	625,283	20,513	12,251,000
Transportation & Public Utilities	475	9,354	362,328	28,296	5,156,000
Wholesale Trade	740	D	418,530	21,296	5,291,000
Retail Trade	948	20,350	1,020,143	82,025	15,086,000
Finance, Insurance, and Real Estate	217	4,941	336,717	21,489	5,268,000
Services	767	19,136	1,020,500	97,073	19,395,000
Government	1,210	24,099	1,170,280	145,917	18,801,000
Federal Civilian	75	2,986	165,759	29,916	2,988,000
Federal Military	68	4,968	187,602	21,865	2,451,000
State and Local	1,067	16,145	816,919	94,136	13,362,000
Percent Farm	25	10	4	4	3

Notes: D = Bureau of Economic Analysis is designation to denote figures withheld to avoid disclosure of information on individuals. For the nine-county summary figures, the designation is used if data for any one of the study area counties are not disclosed in the source data. L = Less than 10 jobs. Figures for the nine-county area are obtained by summing county figures.

Source: Bureau of Economic Analysis, 1983a.

Table 3-62. Unemployment Rates: Nine-County Area, Texas, New Mexico, and the United States

	1974	1977	1980	1983 April[a]	1983 June
County					
Castro	3.2	4.1	5.0	6.0	5.2
Deaf Smith	4.0	4.6	5.4	10.1	9.7
Oldham	4.0	2.5	4.9	4.2	5.7
Parmer	2.6	3.3	3.5	3.9	3.2
Potter	3.9	4.7	5.5	6.8	6.8
Randall	2.8	2.9	3.1	3.3	3.6
Swisher	2.6	3.0	4.6	5.2	4.7
Curry	5.3	6.1	6.6	8.9	8.7
Quay	5.6	5.8	5.8	10.5	10.5
9-County Area	3.8	4.1	4.9	6.5	6.5
Texas	4.3	5.3	5.2	8.1	8.5
New Mexico	8.2	7.8	7.5	9.8	10.8
United States	5.6	7.0	7.1	10.2	10.0

(a) April 1983 is included because it is generally most representative of the yearly rate.

Sources: State and County Data

Texas Employment Commission, Economic Research and Analysis Department, 1983a, b; New Mexico Employment Security Department, Research and Statistics Office, n.d.

United States Data

Bureau of Labor Statistics, 1975, 1978, 1982, 1983.

Table 3-63. Personal Income by Type and Broad Industrial Source, 1980
(Total figures in thousands of dollars, per capita figures in dollars)

	Deaf Smith County	9-County Area	Texas	New Mexico	United States
Labor and Proprietors Income by Place of Work					
Farm	29,363	192,739	1,745,935	270,280	29,247,000
Non-Farm	96,453	1,747,095	104,671,276	7,479,716	1,582,448,000
Non-Farm Private	82,974	1,450,601	89,355,477	5,465,268	1,320,946,000
Agricultural Services	3,553	D	505,602	26,850	7,074,000
Mining	330	D	6,763,893	776,554	28,910,000
Construction	6,139	119,569	8,681,420	571,450	93,575,000
Manufacturing	21,990	249,352	21,634,095	558,690	416,136,000
Transportation and Public Utilities	9,986	220,116	8,656,766	657,353	124,745,000
Wholesale Trade	12,522	D	8,996,673	378,217	111,235,000
Retail Trade	12,342	222,405	11,152,437	815,809	156,114,000
Finance, Insurance, and Real Estate	3,763	89,192	6,169,878	331,138	97,927,000
Services	12,349	279,864	16,794,713	1,349,207	285,230,000
Government	13,479	296,494	15,315,799	2,014,448	261,502,000
Federal Civilian	1,464	57,377	3,345,653	558,600	60,850,000
Federal Military	180	54,024	1,961,895	238,372	23,506,000
State and Local	11,835	185,093	10,008,251	1,217,476	177,146,000
Total by Place of Work	125,816	1,939,834	106,417,211	7,749,996	1,611,695,000
Total by Place of Residence[a]	172,421	2,610,451	135,901,071	10,266,300	2,160,629,000
Farm/Total by Place of Work (%)	23	10	2	4	2

Table 3-63. Personal Income by Type and Broad Industrial Source, 1980
(Total figures in thousands of dollars, per capita figures in dollars)
(Page 2 of 2)

	Deaf Smith County	9-County Area	Texas	New Mexico	United States
Farm/Total by Place of Residence	17	7	1	3	

Notes: D = Bureau of Economics Analysis designation to denote figures withheld to avoid disclosure of information on individuals. For the nine-county summary figures, the designation is used if data for any one of the study area counties are not disclosed in the source data.

(a) Includes labor and proprietor income plus dividends, interest, rent, and transfer payments. This is obtained by adjusting labor and proprietor income to account for persons who live in one county but work in another.

Source: Bureau of Economic Analysis, 1983b.

Table 3-64. Per Capita Income Trends: Nine-County Area, Texas, New Mexico, and the United States

	1970	1975	1980
Castro	$2,177	$3,684	$ 5,005
Deaf Smith	2,403	3,476	8,128
Oldham	2,354	3,403	15,512
Parmer	2,552	4,002	7,883
Potter	2,753	4,384	10,241
Randall	3,360	5,152	9,383
Swisher	2,488	3,878	12,909
Curry	2,517	3,687	8,050
Quay	2,348	3,133	7,462
9-County Average	2,550	3,867	9,397
Texas	2,792	4,188	9,528
New Mexico	2,437	3,601	7,878
United States	3,119	4,572	9,511

Source: NUS, 1984, ONWI-461, pp. 47-49.

Within the nine-county area, per capita income varies considerably from county to county. In 1970, the highest per capita income was in Randall County, which was 32 percent above that of the nine-county average. The lowest was in Castro County, which was 15 percent below that of the nine-county average. By 1980, the distribution of per capita income had shifted. Castro County still had the lowest per capita income, dropping to 47 percent below the nine-county average. Per capita income in Randall County in 1980 was 0.1 percent below the average while the highest per capita income was in Oldham County, which had jumped to 65 percent above the average (compared to 8 percent below in 1970). This variation in income trends can be explained, in part, by new emphasis on nonagricultural industrial activity in some of the counties.

3.6.2.4 Agriculture

The late 1970s and early 1980s have been years of transition for U.S. agriculture. Although major advances in production and management technologies occurred in this time period, resulting in the highest crop yields in agricultural history, the U.S. farm economy was in serious trouble. Worldwide economic conditions and record U.S. crop surpluses led to depressed prices, reduced exports, and sharply lower net farm income. Federal government expenditures for agricultural support reached record highs, but did not necessarily alleviate the plight of the farmer. Industries linked with agriculture, such as machinery, fertilizer, and farm chemical manufacturers, also suffered during this time period (Battelle Memorial Institute, 1983).

The general economic recovery initiated in 1983 has started to spill over into the agricultural sector. Crop prices for most agricultural commodities in 1984 were higher than 1983 levels, although net farm income may only increase moderately due to simultaneous increases in farm expenses. Export prices are also predicted to show moderate increases, due mainly to increased prices received for agricultural commodities, rather than to increases in volume (USDA, 1984).

Though net farm income dropped to an estimated $20 to $22 billion in 1983, compared to $30 billion in 1981, recovery to between $31 and $36 billion was expected in 1984 (USDA, 1984). The reduced farm income in the early 1980s was caused by a combination of factors including high farm input costs, reduced farm product exports, and expanded acreage of major food and feed crops resulting in record production and surpluses.

The number of farm laborers continued to decline during the late 1970s and early 1980s, while agricultural productivity showed significant increases. This increase in productivity with reduced labor was due to advances in agricultural production technologies in such areas as crop and livestock genetics, farm machinery, farm management techniques, and control of crop pests, as well as favorable weather.

Nationwide, agricultural production technologies have been developed to promote more efficient use of soil and water resources. Irrigated land in the United States increased from slightly over 40 million acres in 1974 to over 50 million acres in 1983. Because a large portion of the water used for irrigation comes from depletable sources such as aquifers, more efficient irrigation technologies became especially important in the later 1970s. Examples of improved irrigation technologies include drip irrigation systems, surgeflow irrigation, and low energy precision irrigation systems. These more efficient water-use systems, combined with development of drought-tolerant, higher yielding crops, may alleviate the need to return to dryland farming in many water-stressed areas of the United States (NUS, 1985, BMI/ONWI-557).

The State of Texas ranks first among all states in the production of rice, beef cows, calf crop, cattle on feed, and sheep and lambs. It ranks second in the production of onions, carrots, broccoli, and cotton. Texas has the second largest acreage of irrigated farmland in the United States, with 7.8 million acres in 1982. Over 42 percent of Texas irrigated land is located in the 23 counties comprising the Southern High Plains Region of the Texas Panhandle. This region is a major producer of corn for grain (50 percent of Texas production in 1982), grain sorghum (23 percent of Texas production), wheat (41 percent of Texas production),

sugarbeets (99 percent of Texas production), soybeans (48 percent of Texas production), potatoes (49 percent of Texas acres harvested), carrots (16 percent of Texas acres harvested), and cattle marketed from feedlots (71 percent of Texas-fed cattle marketed) (TCLRS, 1983).

The vast majority of water used for irrigation in Texas comes from the Ogallala aquifer. Because irrigation draws off water at a much greater rate than replenishment occurs in the Ogallala aquifer, depletion of the aquifer is a serious problem in Texas and other Plains States using the aquifer. Irrigation has made it possible to change the crop mix in the region significantly. The importance of wheat and corn crops, for example, is a direct result of increased irrigation. A return to dryland farming because of reduced water availability could have important ramifications to the region's crop and livestock producers in terms of reduced cash receipts from crops and potentially higher feed grain costs to cattle producers.

Irrigation has been essential to the agricultural sector of the economy of the entire High Plains region. However, the increasing cost of water extraction in recent years has led many farmers to decrease dependence on irrigated agriculture and to increase water-use efficiency, despite the fact that irrigated crops realize three to four times the yield of non-irrigated crops (NUS, 1984, ONWI-461; NUS, 1985, BMI/ONWI-557).

The future of irrigated agriculture in the High Plains will depend upon several factors, including stability of fuel prices, improvements in water use technology, and depletion rates of the aquifer. Recent trends in the region suggest, however, that a decreasing reliance on irrigation will continue, shifting production to dry land agriculture and away from some present irrigated crops such as corn. This is likely to result in declines in agricultural production, income, and employment. Such trends can be expected to continue to influence population migration from rural to urban areas in the High Plains.

Deaf Smith County farm marketing cash receipts rose 12 percent from 1978 to 1982, which was the second highest rate of increase in the seven-county region. As shown in Table 3-65, Deaf Smith County farm marketing cash receipts of $239 million in 1982 constituted almost 30 percent of the total for the seven-county region. Deaf Smith County's effective buying income of $132 million was 6.1 percent of total effective buying income for the seven-county region (TCLRS, 1982).

The region contained 3.5 percent of the State's agricultural service establishments, while total gross receipts from agricultural services in the seven-county region represented almost 5 percent of the State's total receipts (Bureau of the Census, 1978b).

There were 201 "agricultural services" establishments in the Deaf Smith seven-county region in 1978, compared to 118 in 1974. These 201 establishments had gross receipts of $24.1 million in 1978, compared to $11.4 million in 1974. In 1978, the total number of paid employees in agricultural service establishments was 2,869, with an annual payroll of $7.6 million. Approximately 28 percent of the seven-county region's total employees and almost 19 percent of the region's annual payroll engaged in agricultural services were located in Deaf Smith County. These establishments comprised (1) soil preparation services, (2) crop services, (3) veterinary services, (4) animal services except veterinary, (5) farm labor and management services, and (6) landscape and horticultural services (Bureau of the Census, 1978).

As shown in Table 3-66, the total number of farms in the seven-county region decreased by more than 5 percent between 1974 and 1982; the average number of acres per farm decreased by less than 0.2 percent. Almost 93 percent of the land in the region is devoted to farming. Farms in the seven-county area are considerably larger than the U.S. average. The region's farms average approximately 1,350 acres. In 1982 land prices per acre ($480) increased at a slower rate than prices for the State overall and remain well under the national average ($791 per acre).

Deaf Smith County has approximately 20 percent of the total number of farms and 18 percent of total farm acreage in the seven-county region. Average farmland value was $445 per acre in 1982, compared to an average of $549 for all of Texas and $791 for the United

Table 3-65. Cash Receipts From Farm Marketings, Deaf Smith County Region, 1975-82 Averages, and 1982

	1982 (in millions of dollars)	Average 1975-82 (in millions of dollars)	Average % of Total
Crops			
Castro	98.7	82.2	26.5
Deaf Smith	65.6	62.4	20.1
Oldham	9.4	5.4	1.7
Parmer	92.3	90.3	29.1
Potter	4.1	3.0	1.0
Randall	15.2	16.5	5.3
Swisher	61.0	50.2	16.2
Total, Crops	346.3	310	100
Total, Texas Crops	4,249	3,518	---
% of Texas Crops	8.2	8.8	---
Total, U.S. Crops	74,353	60,043	---
% of U.S. Crops	0.5	0.5	---
Livestock			
Castro	67.8	81	18.2
Deaf Smith	173.3	145.6	32.7
Oldham	16.1	16.9	3.8
Parmer	79.7	84.1	18.9
Potter	4.2	4.7	1.1
Randall	47.5	47.3	10.6
Swisher	67.7	65.7	14.7
Total, Livestock	456.3	445.3	100
Total, Texas Livestock	5,431	4,573	---
% of Texas Livestock	8.3	9.7	---
Total, U.S. Livestock	70,199	58,954	---
% of U.S. Livestock	0.7	0.8	---

Source: TCLRS, 1975-1982.

Table 3-66. Farms - Number, Acres, Percent of Land, and Average Value in Deaf Smith Seven-County Region

County	Number of Farms			Acres in Farms			Percent of Land Area			Acre Value/Acre Land & Buildings		
	1974	1978	1982	1974 (000)	1978 (000)	1982 (000)	1974 (%)	1978 (%)	1982 (%)	1974 ($/Acre)	1978 ($/Acre)	1982 ($/Acre)
Castro	616	556	483	581.5	579.5	548.5	103.2[a]	102.9[a]	97.4	416	534	650
Deaf Smith	637	650	653	856.1	873.8	806.3	88.6	90.4	83.4	291	386	445
Oldham	154	148	149	815.6	1,045.5	975.5	86.2	110.5[a]	103.1[a]	83	159	290
Parmer	704	751	661	580.1	590.8	544.9	105.5[a]	107.5[a]	99.1	427	595	689
Potter	132	166	178	480.4	522.4	490.9	83.6	90.9	85.4	107	254	246
Randall	486	552	575	529.2	511.0	481.9	90.5	87.4	82.4	261	360	477
Swisher	699	628	551	559.3	576.0	546.5	97.5	100.4	95.3	307	378	565
Total, Seven-County Region	3,428	3,451	3,250	4,402.2	4,699.0	4,394.5	93.6	98.6	92.2	270	381	480
Total, Texas	174,068	194,253	185,000	134,185	138,400	80.0	82.0	82.5	243	386	549	549
Total, United States	2,314,013	2,478,642	2,400,370	1,017,030	1,029,695	1,038,530	44.9	45.4	45.8	336	628	791

(a) Percent of land area exceeds 100% in counties where large farms extend over county lines. The acres in farms are assigned to the county in which the farm is headquartered.

Source: Bureau of the Census, 1978a, 1981, 1984.

States (Table 3-66). Average value of farmland in 1984 was $646 per acre statewide. Nationwide farmland value decreased to $739 per acre in 1984 (USDA, 1984, p. 14).

Livestock sales have remained the largest single item in the region's agricultural cash receipts (Table 3-65), amounting to $456 million in 1982. The seven-county region's share of total Texas livestock sales decreased from over 12 percent in 1978 to slightly over 8 percent in 1982 (Table 3-65). Deaf Smith County accounted for 38 percent of the seven-county region's livestock sales in 1982 and remains one of the most important beef production counties in the United States (Bureau of the Census, 1978a; 1982e).

Fluctuations in crop mix experienced by the Deaf Smith County region between 1974 and 1982 were similar to those in other parts of the Texas Panhandle (Table 3-67). In 1974, sorghum, wheat, and corn represented 86 percent of the total harvested cropland in the region. By 1982, corn acreage had declined to 15 percent of total cropland harvested, while cotton acreage declined to 8 percent of cropland harvested. Acreage devoted to soybeans quadrupled, although it represented only 5 percent of total harvested area. In 1982, wheat acreage more than doubled from 1978 levels and comprised 48 percent of total cropland harvested in the region, compared to only 31 percent in 1974 (Table 3-67).

Irrigation has significantly increased crop yields in the Deaf Smith County area. Yield improvements of almost 73 percent can be achieved by irrigating cotton, while yields of wheat and sorghum are improved by almost 200 percent. Approximately 1.26 million acres of cropland was irrigated in the seven-county region in 1982, which was about 76 percent of all harvested cropland (TCLRS, 1982).

Farm expenses for selected agricultural inputs (such as livestock purchases, feed, animal health products, seed, fertilizer and chemicals, and petroleum products) totaled $1.21 billion in 1982. The importance of cattle feed to the seven-county region's agricultural economy is denoted by the fact that over 85 percent of total farm production expenses in 1982 consisted of purchased livestock, feed, and animal health products. Comparable statistics for the State of Texas are 65 percent, and, for the United States, only about 50 percent of total production expenses allotted to these categories (Bureau of the Census, 1978a; 1982e). Deaf Smith County's total farm production expenses were $464 million in 1982, or about 38 percent of the total for the seven-county region, and 7.6 percent of Texas' total farm production expenses (TCLRS, 1982).

Seed production is one important component of the agricultural industry in Texas. Most of the State's seed is produced in the High Plains area. In the Deaf Smith County study area, a variety of seeds are produced, including barley, hybrid field corn, upland cotton, oat, hybrid sorghum, soybean, wheat, rye, peanut, and sorghum sudangrass. These seeds are used in commercial farming. The High Plains area is well suited to seed production for several reasons. The low humidity contributes to very high germination rates of approximately 90 percent. The soil and the climate of the High Plains contribute to high yields in seed production per acre. Low rainfall protects the quality of the seed during the harvest season.

The Texas Department of Agriculture estimates that 157,750,122 pounds of seed were produced in the Deaf Smith County study area and sold in the State of Texas in 1984. This estimate includes sales occurring within Texas of both certified and noncertified seed from the study area. The value of Texas seed retail sales was estimated to be approximately $94 million for the Deaf Smith study area. This represents only the portion of the seed sold within the State of Texas; a much larger proportion of the seed is exported outside the state.

Table 3-68 shows the number of acres producing certified, registered, and foundation seed by county for the Deaf Smith County study area. The number of acres producing certified, registered and foundation seed was up to 0.4 percent of the total amount of cropland in the study area between 1982 and 1984. In Deaf Smith County, in 1984, this type of seed production was occurring on 0.8 percent of the County's cropland. Although the land area is rather limited, the value of seed may be slightly higher than the average value of other crops. The Texas Department of Agriculture estimates that the average value of seed is 60 cents per pound in this area (Boatwright, 1985). This compares to a value of 81 cents per pound for

Table 3-67. Trends in Cropland Harvested for Major Crops in Deaf Smith 7-County Region, 1974, 1978, and 1982

County	Corn			Cotton			Sorghum			Soybeans			Wheats			All Other Crops			Cropland Total Harvested		
	1974	1978	1982	1974	1978	1982	1974	1978	1982	1974	1978	1982	1974	1978	1982	1974	1978	1982	1974	1978	1982
Number of Acres, in Thousands																					
Castro	99	132	87	44	62	41	89	34	31	4	8	28	80	57	98	14	23	17	330	316	302
Deaf Smith	52	86	24	6	3	6	89	80	82	1	7	-	117	114	183	20	25	27	285	315	322
Oldham	1	3	-	-	-	-	15	33	46	-	-	-	19	22	58	0	1	3	35	59	107
Parmer	159	187	101	34	57	34	64	28	57	3	7	31	75	54	178	14	17	17	349	350	358
Potter	1	2	-	-	-	-	6	10	15	-	-	-	8	15	25	1	0	1	16	27	41
Randall	4	7	1	1	1	-	59	50	27	1	1	-	52	47	162	6	7	10	123	113	199
Swisher	10	32	27	49	70	55	130	74	38	4	31	28	82	41	136	3	4	15	278	252	299
Total, Deaf Smith	326	449	239	134	193	136	452	309	296	13	54	87	433	350	780	58	77	90	1,416	1,432	1,628
Total, Texas	873	1,401	1,140	4,494	6,490	4,320	6,034	4,664	5,550	223	720	920	3,489	2,704	6,000	3,901	4,802	4,767	19,014	20,781	22,697
Total, United States	65,405	70,275	73,030	12,547	12,370	9,729	13,809	13,561	14,248	51,341	63,343	69,821	65,368	55,942	78,981	107,870	109,936	106,739	310,540	325,427	352,548
Percentage of Total Cropland Harvested in a Specified Area																					
Total, Deaf Smith Region	23	31	15	9	13	8	32	22	18	1	4	5	31	24	48	4	5	6	100	100	100
Total, Texas	5	7	5	24	31	19	32	22	24	1	3	4	18	13	26	21	23	21	100	100	100
Total, United States	21	22	21	4	4	3	4	4	4	16	19	20	21	17	22	34	34	30	100	100	100

Note: - Indicates no cropland harvested.

Source: TCLRS, 1972-1983; 1982.

Table 3-68. Acres in Certified, Registered, and Foundation[a] Seed Production in Deaf Smith County Study Region

County	Year 1982	1983	1984
Castro	1,410	1,078	963
Deaf Smith	2,085	1,966	3,382
Oldham	400	1,000	822
Parmer	850	307	1,123
Randall	85	406	132
Swisher	2,070	2,159	2,878
Potter	N/A	N/A	N/A
Total Seed-Producing Acres for Counties	9,300	6,916	6,900
Total Cropland in Counties (1981-82 Average)	2,125,000	2,125,000	2,125,000
Acres in Seed Production as a Percentage of Total Acreage	0.4	0.3	0.3

(a) Four classes of seed are recognized in seed certification: breeder, foundation, registered and certified. Foundation seed is the progeny of breeder seed (source for the production of seed of the certified classes) or foundation seed which is handled to maintain specific genetic purity and identity. Production must be acceptable to the certifying agency. Registered seed is the progeny of breeder or foundation seed handled to maintain satisfactory genetic purity and identity. This class is suitable for the production of certified seed. Certification is a voluntary process whereby inspections are made only for those firms or individuals who choose to qualify and are in position to qualify. Seed certification is a method for keeping pedigree records on approved crop varieties to ensure their purity (TDA, 1984b). Acres used for non-certified seed production are not included in these estimates.

Source: Texas Department of Agriculture, 1982; 1984a; 1985a.

cottonseed, 39 cents per pound for hay, 25 cents per pound for peanuts, 59 cents per pound for upland cotton, and $1.13 per pound for American-Pima cotton (TDA, 1984a). Thus, seed value is within the range of other crop values.

3.6.3 Community Services

Services and facilities in Amarillo, Canyon, Hereford, and Vega, as well as in the counties and school district in which they are located, are described in this section. National service averages or standards are presented and compared with local service ratios.

3.6.3.1 Housing

The number of households and year-round housing units in Amarillo, Canyon, Hereford, and Vega is presented in Table 3-69. The percentage of housing units lacking complete plumbing in 1980 ranged from 0.8 percent in Canyon to 1.3 percent in Hereford. Hereford had the largest percentage of owner-occupied units (65 percent), while Canyon had the lowest percentage (51 percent). As shown in Table 3-69, the number of mobile homes in each county ranged from 72 in Oldham County to 1,647 in Potter County. Vacancy rates for both homeowner and rental units are presented for each city and can be compared with state and national rates. The 1980 homeowner vacancy rate was 2.5 percent for Texas and 1.8 percent for the United States, while the rental vacancy rates were 10.9 and 7.1 percent, respectively. Amarillo had lower vacancy rates than the Texas and U.S. averages, although the other three cities had rates that were the same or higher. Amarillo has 65 motels, Hereford 7, and Canyon and Vega 3 each.

3.6.3.2 Education

A public school district is responsible for providing education for children living within district boundaries. The school districts in the study area are presented in Figure 3-87. Table 3-70 presents school attendance and capacities for the Amarillo, Canyon, Hereford, Vega, and Wildorado school districts that would serve the majority of new population associated with repository development. The Wildorado school district operates an elementary school. Secondary education students attend schools operated by the Vega school district. The student to teacher ratio for these districts ranges from 9 to 1 to 17 to 1. All ratios are lower than the 1981-82 Texas average of 18 to 1 and the U.S. average of 19 to 1. In comparison with the national average student teacher ratio of 19 to 1, the local communities have ratios that are lower, or better, by the following percentages: Amarillo and Canyon, 12 percent; Hereford and Vega, 26 percent.

The school districts have excess capacities ranging from 105 students in the Wildorado district to 9,603 students in the Amarillo district. The two major post-secondary educational institutions in the area are West Texas State University in Canyon and Amarillo College in Amarillo. In addition, the Texas State Technical Institute in Amarillo offers technical vocational programs.

3.6.3.3 Health Services

The number of hospitals and licensed beds (in 1980) and general practice physicians (in 1982) in four of the communities is presented in Table 3-71. Hospital districts and hospital authorities are special districts in Texas that are organized to provide health-care services. There are five hospitals in Amarillo, one in Canyon, one in Hereford, and none in Vega, although Vega has a health clinic. Residents of Vega, like those of many communities in the Panhandle, obtain a substantial number of health services in Amarillo.

The number of licensed hospital beds in the other communities ranges from 49 in Canyon to 1,021 in Amarillo. The number of beds per 1,000 population is 6.8 in Amarillo, 4.9 in Hereford, and 4.6 in Canyon. The 1976 national average for hospital beds in semirural areas was 5.0 beds per 1,000 population.

In 1982, there were 204 physicians in Amarillo, 8 in Hereford, and 8 in Canyon. Vega did not have any physicians residing in the community in 1982. The number of physicians per

Table 3-69. Housing Conditions in Hereford, Vega, Amarillo, and Canyon

County/City	Number of Households (1980)	Year Round Housing Units (1980)	Percent Lacking Complete Plumbing for Exclusive Use (1980)	Owner Occupied Units (%) (1980)	Mobile Homes or Trailers (1980)	Homeowner Vacancy Rate (1980)	Rental Vacancy Rate (1980)	Hotels/ Motels (1982)	Number of Hotel/ Motel Rooms (1982)
Deaf Smith	6,487	7,073	2.2	4,465 (63%)	455	1.8	10.2		
Hereford	4,969	5,371	1.3	3,493 (65%)		1.8	11.7	7	225
Oldham	674	793	2.3	422 (53%)	72	4.1	16.3		
Vega[b]	256	312	NA	166 (53%)		4.1	16.3	3	87
Potter	37,769	40,995	1.0	23,553 (57%)	1,647	1.0	11.0		
Amarillo[a]	56,216	60,242	0.9	37,490 (62%)		1.2	10.5	65	3,700
Randall	26,709	28,501	0.7	19,991 (70%)	1,160	1.6	11.3		
Canyon	3,626	4,128	0.8	2,121 (51%)		2.8	18.0	3	72

(a) Amarillo is located in both Potter and Randall Counties.
(b) Estimates based on city population and county housing data.

Sources: NUS, 1984, ONWI-461.

Key to School Districts

Oldham County

1 - Boys Ranch
2 - Vega
3 - Adrian
4 - Wildorado

Potter County

5 - Amarillo
6 - River Road
7 - Highland Park
8 - Bushland

Randall County

9 - Canyon

Deaf Smith County

10 - Hereford
11 - Walcott

Parmer County

12 - Bovina
13 - Farwell
14 - Friona
15 - Lazbuddie

Castro County

16 - Dimmitt
17 - Hart
18 - Nazareth

Swisher County

19 - Happy
20 - Tulia
21 - Kress

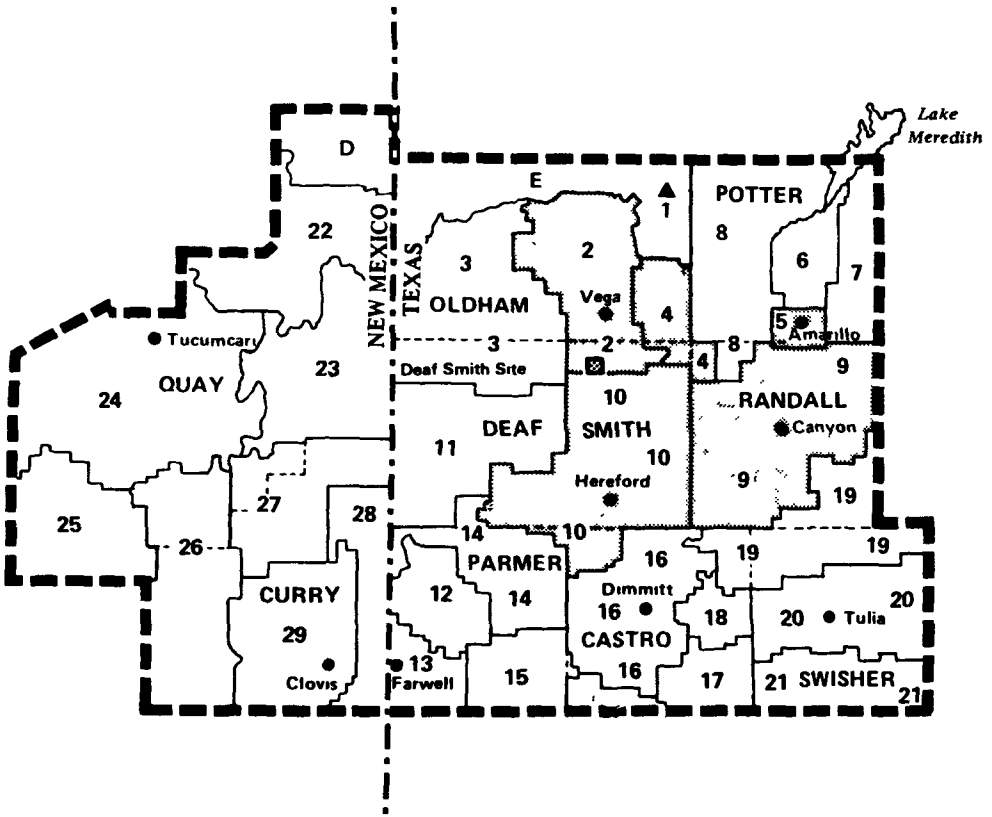
Quay County, New Mexico

22 - Logan
23 - San Jon
24 - Tucumcari
25 - House

Curry County, New Mexico

26 - Melrose
27 - Grady
28 - Texico
29 - Clovis

School District Boundaries
County Lines
County Seat
School Districts with potential for largest increase in student population
Deaf Smith Site



0 10 20 30 40 50 Kilometers
0 10 20 30 Miles

Source: Panhandle Regional Planning Commission, 1982.
New Mexico Dept. of Education, 1981.

School Districts in the Nine-County Area, 1982

Figure 3-87

Table 3-70. Education - Study Area School Districts, 1981 - 1982

County/ School District	Average Daily Attendance	Estimated Physical Capacity	Number of Teachers	Student/Teacher Ratio	Excess Capacity (Number of students)
Deaf Smith					
Hereford	4,594	5,600	319	14:1	1,006
Oldham					
Vega	324	500	24	14:1	176
Wildorado	45	150	5	9:1	105
Potter					
Amarillo	23,397	33,000	1,418	17:1	9,603
Randall					
Canyon	3,765	4,501	218	17:1	736

Sources: NUS, 1984, ONWI-461.

Table 3-71. Health Services in Hereford, Vega, Amarillo, and Canyon

City	Hospitals	Licensed Beds (1980)	Licensed Beds per 1,000 Population (1980)	Physicians (1982)	Physicians per 1,000 Population (1982)
Deaf Smith			3.6	9	0.4
Hereford	Deaf Smith General Hospital	77	4.9	8	0.5
Oldham			0	0	0
Vega	-	0	0	0	0
Potter			10.2	296	3.0
Amarillo	High Plains Baptist Hospital	304	6.8	204	1.4
	Northwest Texas Hospital	252			
	Southwest Osteopathic Hospital	50			
	St. Anthony's Hospital	276			
	Veteran's Administration Medical Center	139			
Randall			0.6	9	0.1
Canyon	Palo Duro Hospital	49	4.6	8	0.8

Sources: NUS, 1984, ONWI-461.

1,000 population was 1.4 in Amarillo, 0.5 in Hereford, and 0.8 in Canyon. The U.S. average for physicians in 1977 in semi-rural areas was 0.99 physician per 1,000 population (National Center for Health Statistics, 1983).

3.6.3.4 Recreation

Municipal parks and recreation facilities are operated by Texas cities. Table 3-72 presents data on public outdoor recreation land in the four communities. The number of acres of neighborhood park recreation land in each community is Amarillo, 288; Canyon, 13; Hereford, 28; and Vega, 10. The number of developed acres per 1,000 population ranges from 1 in Canyon to 11 in Vega. The 1979 national service standard for neighborhood parks was 1 acre per 1,000 population (International City Management Association, 1979).

3.6.3.5 Protective Services

Most daily police enforcement activities occur within the cities in Texas, although services are provided through mutual aid agreements that exist among city, county, and State law enforcement departments. Table 3-73 presents the number of police officers in the communities. The service ratio for police protection ranges from 0.9 police officer per 1,000 population in Canyon to 1.6 officers per 1,000 population in Amarillo. These figures can be compared with the 1979 national police protection service standard, which was 2.0 police officers per 1,000 population.

Fire protection in the study area is provided by individual towns and municipalities, which serve outlying county areas with or without formal mutual aid agreements. As shown in Table 3-73, fire protection is provided by paid personnel in Amarillo, volunteers in Vega, and combined paid and volunteer personnel in Canyon and Hereford. The ratios of total firefighters per 1,000 dwelling units in 1982 were: Amarillo, 3.3; Canyon, 10.4; Hereford, 6.5; and Vega, 80.1. The national service standard in 1979 was 2.0 firefighters per 1,000 dwelling units (International City Management Association, 1979).

3.6.3.6 Water Supply and Treatment

The study communities use ground-water aquifers as their primary water source, particularly the Ogallala aquifer (Table 3-74). This water requires minimal treatment, usually just the addition of chlorine. Some municipal water is also obtained from the Santa Rosa (Dockum Group) and Lake Meredith. Per capita municipal water use in 1980 ranged from 602 liters (159 gallons) per day in Canyon to 1,052 liters (278 gallons) per day in Vega. In 1984, water consumption in Vega decreased to 920 liters (243 gallons) per day (Merriman and Barber Consulting Engineers, 1985). The 1979 national service standard was 568 liters (150 gallons) per day per capita.

The Ogallala and other aquifers (Dockum) in the area are being reduced in potential water yield, however, and their availability as a source of water in the future is an important public concern. Past withdrawals from the Ogalalla Formation in the study area have exceeded the natural recharge rate (Section 3.3.3). These overdrafts have caused water-level declines and removed large volumes of ground water from recoverable storage (Texas Department of Water Resources, 1983a). Communities in the area are aware of the depletion of the aquifers. The city of Vega, for example, has established a lease option on a well that produces 3,400 liters (900 gallons) per minute from the Santa Rosa formation. The well is located south of the city in the 9-square-mile repository site area. The city of Vega expects to use this well by 1990 based on current population and declining water levels (Merriman and Barber, 1985). In addition, many communities belong to the High Plains Underground Water Conservation District and support the conservation efforts promoted by this district.

3.6.3.7 Sewage Treatment and Solid Waste Disposal

All of the study communities have sewage treatment facilities whose capacities range from 0.1 million gallons per day in Vega to 20 million gallons per day in Amarillo. Table 3-75 presents the type of treatment and excess capacity for each community. The 1979 national

Table 3-72. Recreation Acreage in Amarillo, Canyon, Hereford, and Vega, 1980

City	Total Recreation Acres	Neighborhood Park Acres	Neighborhood Park Acres per 1,000 Population
Amarillo	2,167	288	2
Canyon	2,407	13	1
Hereford	511	28	2
Vega	10	10	11

Source: NUS, 1984, ONWI-461.

Table 3-73. Protective Services in Amarillo, Canyon, Hereford, and Vega, 1982

City	Police		Fire		
	Municipal Police Officers	Police Officers per 1,000 Population	Firefighters		Firefighters per 1,000 Dwelling Units
			Paid	Volunteer	
Amarillo	233	1.6	196	0	3.3
Canyon	10	0.9	3	40	10.4
Hereford	21	1.3	1	34	6.5
Vega	1	1.1	0	25	80.1

Note: NA = Not available.

Source: NUS, 1984, ONWI-461.

Table 3-74. Water Supply in Amarillo, Canyon, Hereford, and Vega

City	Water Source	Well Yield, MGD (1982)	Municipal Use, MGD (1980)	Municipal GPD per Capita (1980)
Amarillo	Ogallala wells	58.6	29.4	197
	Lake Meredith	25.0		
Canyon	Ogallala wells	12.0	1.7	159
Hereford	Ogallala wells	14.0	3.6	225
	Santa Rosa wells	1.0		
Vega	Ogallala wells	0.7	0.3	278

Note: MGD = Million gallons per day.
GPD = Gallons per day.

Sources: NUS, 1984, ONWI-461; Bureau of the Census, 1982c.

Table 3-75. Sewage and Solid Waste Treatment in Amarillo, Canyon, Hereford, and Vega, 1982

City	Sewage			Solid Waste	
	Type Treatment	Capacity, MGD	Excess Capacity, MGD	Facility	Capacity
Amarillo	Secondary	2 plants total 20.0	2.2	Landfill	50-60 yr life
Canyon	Primary	2.0	0.2	Landfill	30 yr life
Hereford	Secondary	2.8	1.2	Solid Conical Burner/Dump	Undetermined
Vega	Secondary	.08	None	None - has contract for service	--

Note: MGD = Million gallons per day.

Source: NUS, 1984, ONWI-461; Merriman and Barber, 1985.

service standard for community sewage treatment is 100 gallons per day per capita. For solid waste disposal, Amarillo and Canyon use landfills (Table 3-75). In Hereford, a conical incinerator is used and material which cannot be burned is placed in a dump. An independent contractor collects and disposes of Vega's solid waste. A national service standard for estimating the generation of solid waste is 6.25 pounds per day per capita (International City Management Association, 1979).

3.6.4 Social Conditions

3.6.4.1 History and Lifestyle

Permanent settlement of the High Plains, including the Texas Panhandle and the Eastern Plains of New Mexico, is a fairly recent phenomenon, spanning little more than 125 years. As a consequence, the economic and social frameworks of the area still bear a strong resemblance to the initial motivations for development, namely agriculture, ranching, and oil and gas extraction.

Before the Civil War, there had never been any significant permanent population settlements on the High Plains. For hundreds of years prior to the 1500s, nomadic, agrarian Indian tribes had wandered the area attracted, in part, by the Alibates formation, a major source of flint for tools and weapons. Numerous tribes frequented the area, including Apaches, Cheyennes, Arapahos, Kiowas, and Comanches. The evidence of these people are scattered remains of campsites and burial sites, particularly in Palo Duro Canyon, which provided caves and shelter (NUS, 1984, ONWI-461, p. 258).

In the mid to late 1800s, development pressure westward continued from the expanding United States. Several technological developments were pivotal in the settlement of this area. Among these developments were the invention of the repeating revolver in 1844, the invention of barbed wire in 1873, railroad penetration in 1887, and irrigation development and the discovery of oil and gas in the early 1900s.

The continuous skirmishes between the Comanches and the U.S. Army Cavalry and settlers became the basis for much of the romantic lore of west Texas. The antagonism was created as the buffalo hunters depleted the major Indian food supply, and the tribes sought to protect this food supply and dislodge the offending settlers. By 1871, most of the buffalo had been removed, and by 1873, most of the Indians had been defeated and relocated to government-owned reservations (NUS, 1984, ONWI-461, p. 259).

Population origins for Texas and New Mexico, as with the rest of the nation, are quite diverse, although predominant historical trends are still reflected in the overall composition of the population. Demographic statistics show the population of the area to be predominantly white (about 78 percent) although in the individual counties there tends to be some variation in the ethnic distribution (NUS, 1984, ONWI-461, p. 263-265). Many of the white population trace their roots back to early settlers who came from the rural southern and eastern sections of the United States and who had primarily English and German origins. Persons of Spanish origin compose the second largest group in the nine-county area (16 percent). Although the majority claims to be of Mexican origin, tracing back to the original Mexican sheepherders and, in more recent times, to farm workers and other Mexicans seeking employment north of the Mexican border, this segment of the population also includes descendants of early Spanish settlers. Population characteristics such as age and gender distribution are presented in Section 3.6.1.

Many counties in the area have a relatively large percentage of families with money incomes below the poverty level (NUS, 1984, ONWI-461). In some counties, these families are seasonal and migrant farmworkers, an important social and economic subgroup in the area's population. Statistics describing these groups are somewhat dated, because the Texas Governor's Office of Migrant Affairs, responsible for gathering these data, was dissolved in 1976 (NUS, 1984, ONWI-461).

The seasonal workers live and work within the respective counties, typically not moving from one job location to another. They rent or own a home on a year-round basis, holding a job other than in farming in the off-season. By contrast, the migrant farmworkers do move from one job location to another, often between states. Obtaining adequate living quarters is a continuing problem for these workers, especially since many of these workers earn salaries well below the poverty level (NUS, 1984, ONWI-461).

Over recent years, military facilities, the oil and gas industry, and various other industries have attracted in-migrants from various parts of the country. However, despite the diversity in population and ethnic origins, predominant attitudes and culture in the region still strongly reflect the origins of the early settlers. Much of the area is rural in character and lifestyle, and social value is still placed on individual independence, strength, and self-reliance.

Amarillo, as the largest city in the region, serves as a focus of business, financial, and cultural activity. It provides a wide range of communication media, organizations, and institutions to serve the social needs of the population of the city and region. It also has a central library system with branches in various neighborhoods. A convention center is in Amarillo and museums on the history of the Panhandle are in Canyon and Hereford (NUS, 1984, ONWI-461, pp. 260-261).

3.6.4.2 Attitudes Toward Growth and the Project

The Texas Department of Agriculture (TDA) conducted three surveys in the summer of 1984 to document the views of Texas Panhandle residents regarding a high-level nuclear waste repository (TDA, 1985b). Telephone interviews were conducted in Deaf Smith and Swisher counties, as well as in Crosby and Moore Counties. TDA also conducted a specialized survey of farm operators in Deaf Smith and Swisher Counties. Survey participants for the general surveys were chosen randomly from local telephone books. This method excludes those people without telephones, those with unlisted numbers, and those with new telephone listings. The data, however, do reflect the attitudes of those responding to the survey.

The general questionnaires attempted to measure overall attitudes toward growth, the repository and expectations about potential repository effects. The surveys also attempted to measure knowledge about the repository, perceived psychological stress, and participation in the public process concerning the repository program.

Sixty percent of the survey participants said they had read a government publication about the nuclear waste repository, and 28 percent said they had gone to a government meeting or hearing about the repository. About 26 percent said they attended a community meeting about the repository, and 7 percent said they had joined a community group to deal with the repository issue.

The surveys indicated that a high proportion of residents were opposed to putting a high-level nuclear waste repository in Texas. Results showed that opinions about nuclear facilities generally were sharply different from views on other types of development. More than half of the respondents in the Deaf Smith and Swisher Counties survey said they "strongly favor" or "somewhat favor" new development in the areas of agriculture and natural resources. Nuclear facilities received less than 15 percent support.

One factor involved in Deaf Smith and Swisher Counties residents' opposition to the repository is a concern that a nuclear facility would change the economy and community life in the area. Nearly one-half of the respondents expected the amount of industry in their county to decline and tax rates to increase if their county were chosen for a repository. Sixty percent anticipated increased traffic, and 57 percent expected an increase in the cost of living. In general, residents expected little change in their own household income, the quality of local services, or the number of places to go for entertainment.

3.6.4.3 Social Problems

One indicator of the social problems in an area is the crime rate. The Federal Bureau of Investigation, through its Uniform Crime Reporting Program, receives voluntary monthly and annual reports from law enforcement agencies throughout the country. These monthly reports now include the following eight serious crime categories: murder and nonnegligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny-theft, motor vehicle theft, and arson. However, at the time of collection of statistics to be used in this document, only the first seven were included.

The crime rate per 1,000 people in 1975 and 1980 for the counties in the study area is presented in Table 3-76. In 1980, the rate varies from a low of 12 crimes per 1,000 people in Oldham County to a high of 60 crimes per 1,000 people in Potter and Randall Counties combined. This compares to the averages of Texas and the United States of 61 and 60 crimes per 1,000 people, respectively.

3.6.5 Government and Fiscal Conditions

3.6.5.1 Government

Three different institutional structures provide services at the local levels: counties, cities, and special districts. County government in Texas acts as an agent through which State programs are administered, and county courts handle most of the initial judicial proceedings of the State court system. Counties operate through a commissioners' court that sets tax rates, administers programs, controls the county budget, and conducts elections. Counties may develop plans to guide growth and regulate the subdivision of land, but cannot control land use. The commissioners court consists of four members elected from precincts and a county judge elected at large. Other county officers are the sheriff, county attorney, tax assessor, county clerk, one or more justices of the peace, constable, and county treasurer. All are elected positions (NUS, 1984, ONWI-461, pp. 184-186).

Counties in New Mexico are governed by a three-member board of county commissioners, except for urban counties, which have a five-member board. The county commissioners are responsible for all county operations including finance, taxes, appointments to boards, health and safety, personnel policies, plans for public improvements, and land use through zoning and subdivision regulation. Other elected county officials in New Mexico are the assessor, clerk, sheriff, surveyor, treasurer, and probate judge (NUS, 1984, ONWI-461, p. 186).

Communities in Texas of over 200 inhabitants may incorporate under the State laws. If the population is greater than 5,000, a home rule charter may be adopted by the residents. Texas cities are organized into one of three forms: council-manager, mayor-council, or commission. Cities provide services in the areas of law enforcement; fire protection; health; solid waste disposal; street development, maintenance, and safety; water supply and wastewater treatment and disposal; and park and recreation facilities and programs. The cities also plan for and control growth through design and implementation of plans and growth management controls including zoning and subdivision regulation within the city and annexation, utility extension policies, and subdivision regulation in the area surrounding the city (NUS, 1984, ONWI-461, pp. 186-188).

Cities in New Mexico are organized under State laws or by a home rule charter. Most are of the commission-manager or commission-mayor-manager form. Cities provide services in the areas of law enforcement; utility services; fire services; park and recreation facilities and services; and streets and public buildings. Cities have authority to control land use through zoning, subdivision regulation, street plotting, and a master plan (NUS, 1984, ONWI-461, p. 188).

There are a variety of special districts, including school districts, water districts, soil and water conservation districts, hospital districts, and sewer districts, as well as regional councils of government or planning agencies serving the study area. All were created to provide a specific service as their names imply. Each type is organized differently

Table 3-76. Crime Rate Per 1,000 Population in the Study Area

Jurisdiction	1975	1980
Castro	14.3	23.0
Deaf Smith	8.7	37.4
Oldham	14.4	12.3
Parmer	20.6	29.2
Potter/Randall[a]	65.2	59.4
Swisher	19.5	22.5
Curry	47.3	53.6
Quay	57.5	53.9
New Mexico	58.6	59.8
Texas	54.0	61.4
United States	52.8	59.0

(a) These counties are combined because data collected for Amarillo is not separated into Potter or Randall Counties.

Sources: Bureau of the Census, 1978;b, 1983c.

although most require voter approval to become operative. Many districts have some form of taxing power (NUS, 1984, ONWI-461, pp. 195, 197-198).

3.6.5.2 Fiscal Conditions

Revenues are generated from property taxes, sales and gross receipt taxes, user fees and miscellaneous revenue, and intergovernmental transfers. Texas law requires that property be assessed at 100 percent of its valuation, with the tax rate being chosen by each individual government. New Mexico assesses property at one-third of assessed value (NUS, 1984, ONWI-461, pp. 195, 197-198).

The three governmental units that provide the majority of services, thus collecting the majority of revenues, are the cities, counties, and school districts. There are a variety of other special districts in the study area including hospital districts, sewer districts, soil and water conservation districts, water districts, and river authorities. These districts are discussed in more detail in ONWI-461 (NUS, 1984). Table 3-77 presents fiscal year (FY) 1981 total and per capita revenues and expenditures for the cities and counties in Texas which will be most affected by the repository. Revenues per capita varied from $187 in Hereford to $463 in Amarillo. Expenditures varied from $184 in Hereford to $467 in Amarillo. New Mexico cities and counties will not be significantly affected (Section 5.3). School district total revenues and total and per student expenditures for FY 1981 are presented in Table 3-78.

All local governmental jurisdictions discussed in Section 3.6.5.2 are combined into county areas for revenue and operational expenditure trend analysis. Revenues per capita increased from approximately $348 to $946 in the 10-year period from 1967 to 1977. The percentage of revenue from each source fluctuated during the period, but remained in the same general proportions. Per capita expenditures for operations varied from approximately $235 in 1967 to $945 in 1972 and declined to $712 in 1977 during the 10-year period. The percentage distribution changed during the period, but a great part of the change is due to accounting changes in education, which represents approximately half of all expenditures (Bureau of the Census, 1971c, pp. 547, 550, 558, 559, 581; and Bureau of the Census, 1979, pp. 546, 549, 557, 559, and 561).

In Texas, cities, counties, and school districts all have the authority to issue bonds to finance capital construction. The Texas constitution allows these government jurisdictions to issue general-purpose bonds up to one-fourth of assessed value of real property in the district. Bonded indebtedness cannot result in the jurisdiction's requiring a property tax rate exceeding constitutional limits (Texas Legislative Council, 1980, pp. 43-44).

Table 3-77. City Revenue and Expenditures: Total and Per Capita FY 1981
(Dollars)

Jurisdiction	Revenues ($)		Expenditures ($)	
	Total	Per Capita	Total	Per Capita
Potter County	10,806,400	110	10,806,400	110
Amarillo	69,121,200	463	69,716,500	467
Randall County	4,192,900	56	5,232,200	70
Canyon	2,651,300	247	2,362,600	220
Deaf Smith County	3,057,900	144	3,500,600	165
Hereford	2,966,700	187	2,922,900	184
Oldham County	840,200	368	1,065,100	467
Vega	250,200	278	228,200	254

Source: NUS, 1984, ONWI-461.

Table 3-78. School District Revenue and Expenditures: Total and Per Student FY 1981 (Dollars)

County	School District	Total Revenue ($)	Expenditures ($)	
			Total	Per Student
Deaf Smith	Hereford	10,604,200	10,897,900	2,372
Oldham	Vega	1,036,900	1,038,000	3,204
	Wildorado	281,300	279,200	6,204
Potter	Amarillo	51,815,500	61,249,700	2,618
Randall	Canyon	8,106,000	8,198,300	2,177

Source: NUS, 1984, ONWI-461.

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10 CFR Part 1022, Floodplain/Wetlands Environmental Review Requirements.

40 CFR Part 50, National Primary and Secondary Ambient Air Quality Standards.

40 CFR 81.344, Attainment Status Designations Amended through October 22, 1981.

40 CFR Part 191, Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (Draft).

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3.7.3 State of Texas Laws

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Chapter 4

EXPECTED EFFECTS OF SITE CHARACTERIZATION ACTIVITIES

This chapter describes proposed site characterization activities for the Deaf Smith County site, and the expected effects of these activities on the public health and safety the physical environment and socioeconomic conditions. Site characterization activities will be undertaken to establish the site's geologic conditions and the ranges of parameters needed to evaluate the site's suitability for a repository. These activities are intended to expand the existing data base:

- To determine the suitability of the site for a repository based on established guidelines (10 CFR Part 960)
- To compare the sites that have been characterized
- To provide site-specific information necessary for final repository design if the site is selected as a repository
- To obtain information required for the environmental impact statement
- To comply with repository licensing requirements.

Section 4.1 contains descriptions of the site characterization activities. In general, field studies and other activities would begin before construction of the exploratory shaft facility (ESF). Section 4.2 discusses expected effects of site characterization activities on the physical environment and socioeconomic conditions and measures to monitor, and, where appropriate, mitigate adverse effects of the activities. Section 4.3 describes alternative site characterization activities that would minimize adverse impacts, and Section 4.4 presents a summary of impacts.

4.1 SITE CHARACTERIZATION ACTIVITIES

The proposed characterization activities are designed to expand the data base to determine site suitability, to resolve issues remaining from previous studies, to provide data for engineering design, and to insure compliance with "Disposal of High Level Radioactive Wastes in Geologic Repositories; Technical Criteria" 10 CFR Part 60, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" 40 CFR Part 191, and "General Guidelines for Recommendations of Sites for Nuclear Waste Repositories" 10 CFR Part 960. The level of information presented here is sufficient to assess the expected effects of these activities. A site characterization plan (SCP) will be prepared which will present more detail on the rationale and extent of the proposed studies. In addition to the SCP, a number of detailed study plans will be prepared prior to each activity (or group of activities).

The description of the proposed activities is divided into three subsections:

- Geotechnical Field Studies: geotechnical research activities
- Exploratory Shaft Facility: land acquisition, construction, and subsurface testing activities
- Other Activities: environmental and socioeconomic activities.

4.1.1 Geotechnical Field Studies

The geotechnical field studies program includes exploratory boreholes, hydrologic testing and monitoring, geophysical surveys, and field mapping.

Table 4-1 lists the geotechnical field activities currently proposed for site characterization. The proposed schedule for field activities is shown in Figure 4-1. The proposed list of activities (Table 4-1) may need to be augmented or modified to answer questions that arise during evaluation of data obtained from early phases of this program.

The location or method of investigation also may vary slightly from those described herein. Borehole locations may change following an evaluation of site-specific topography, soil conditions, land use, proximity to water wells, or a reevaluation of data needs. The proposed borehole locations are typical of what will be the actual locations. The actual impact of site characterization field activities can be expected to be similar to those assessed for these proposed study locations. This evaluation overestimates the likely level of field activity and impact to allow for uncertainties inherent in the process.

The locations of boreholes illustrated in Figure 4-2 are tentative. This figure illustrates the expected distribution of various activities in and around the site; however, actual locations of some boreholes may be different. The shaft locations were selected within the preferred site area using avoidance and favorability criteria (Carbiener, 1985). The shaft locations were positioned to be stratigraphically updip of the proposed repository underground excavations, while avoiding existing structures and dwellings, playas, drainage basins, probable maximum flood (PMF) areas, and specialized farming endeavors. The proposed borehole locations (Figure 4-2) were selected to be consistent with requirements for engineering design data, stratigraphic confirmation data, and issue resolution data needs. The location of deep hydrologic test wells and playa investigations may change as test plans are finalized during preparation of the SCP.

These activities use conventional techniques that have short-term effects on surface or subsurface conditions. Most field activities will occur over several months. Exploratory shaft facility construction and testing will occur over several years. The environmental disturbance from each activity is described, and expected effects of each are presented in Section 4.2.1.

Access and Permitting. Before field work begins, agreements for land access and applicable permits will be obtained. Sites will be evaluated to determine environmental sensitivities.

Drill Site Preparation. Site preparation is expected to take up to 10 days depending upon the size and depth of the individual hole. Access road construction will be kept to a minimum by using existing roads wherever possible. Access road and site preparation will require clearing surface vegetation, blading and stockpiling topsoil, and leveling the site. Surface stabilization for both the access road and site will require the use of caliche or sand and gravel. Drill pad sizes will be based on surface conditions and rig size, support equipment, and the drilling and testing to be performed. Drilling will be conducted using techniques and equipment that are standard for oil and gas exploration, geotechnical, or water-well drilling. Boreholes that penetrate beyond the upper hydrostratigraphic unit require a pad having adequate space for a water-supply well or storage tanks, reserve mud pit, mud pits or tanks, drill rig, drill pipe and well-casing racks, pumps, generators, trailers, well-service and borehole logging equipment, and other light vehicles. A typical layout for these drill sites is shown in Figure 4-3.

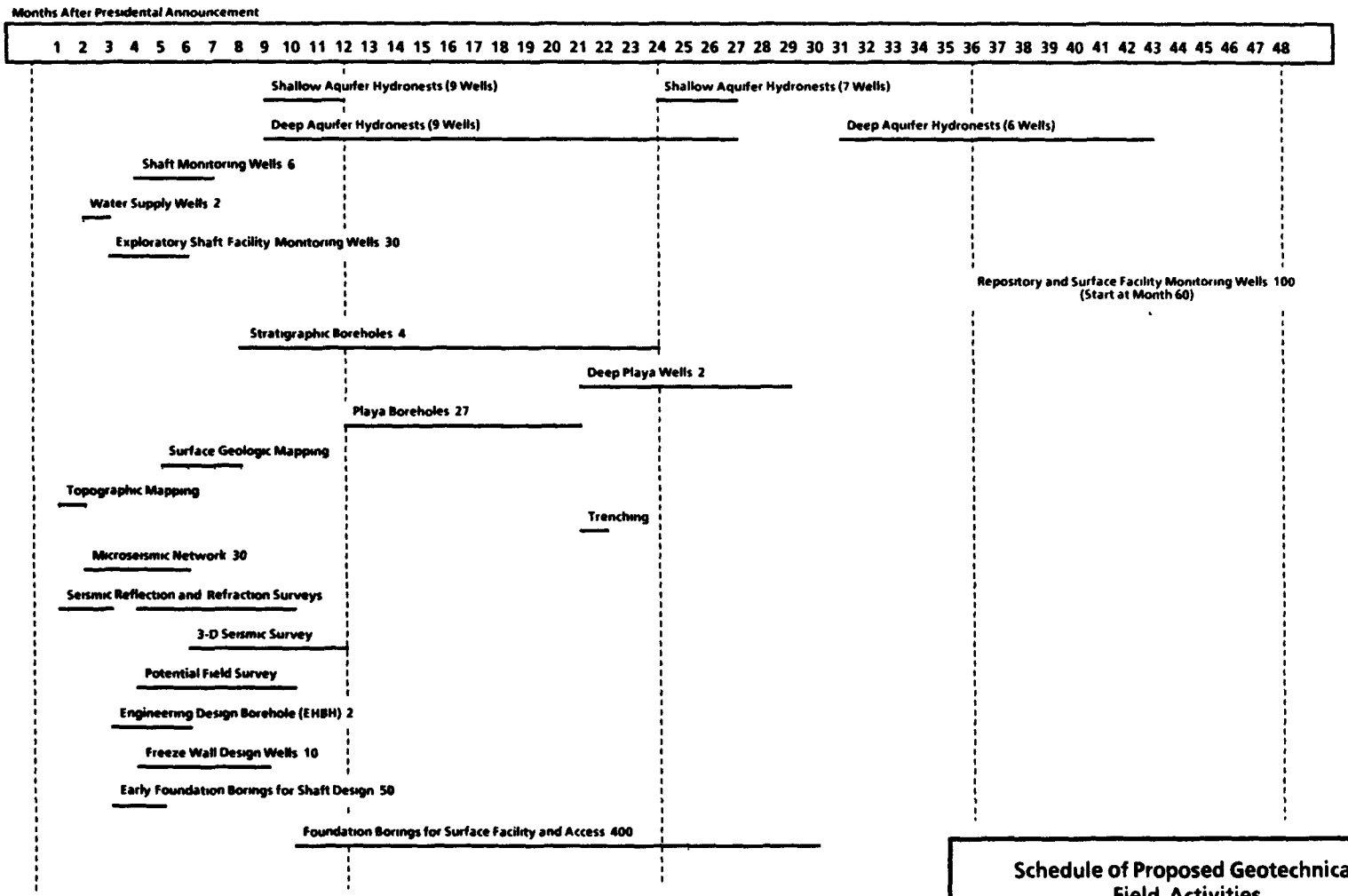
Three types of drilling rigs will be used to drill boreholes, large platform rigs, large truck-mounted rigs, and small truck-mounted rigs. Platform rigs require 4-hectare (10-acre) sites for a single borehole, although no more than 1.6 hectares (4 acres) are expected to be disturbed. Large truck-mounted rigs require 1.6-hectare (4-acre) sites. Small truck-mounted rigs require 0.04-hectare (0.1-acre) sites. Some sites will contain multiple boreholes (Section 4.1.1.1) and require 6.1 hectares (15 acres), although no more than 4.9 hectares (12 acres) are expected to be disturbed.

Water will be required at each well site for drilling operations, drilling fluids, potable water supply, and site restoration. Water for this purpose may be purchased from the landowners, or wells may be drilled on site.

Table 4-1. Geotechnical Field Activities to be Performed During Site Characterization, Deaf Smith County

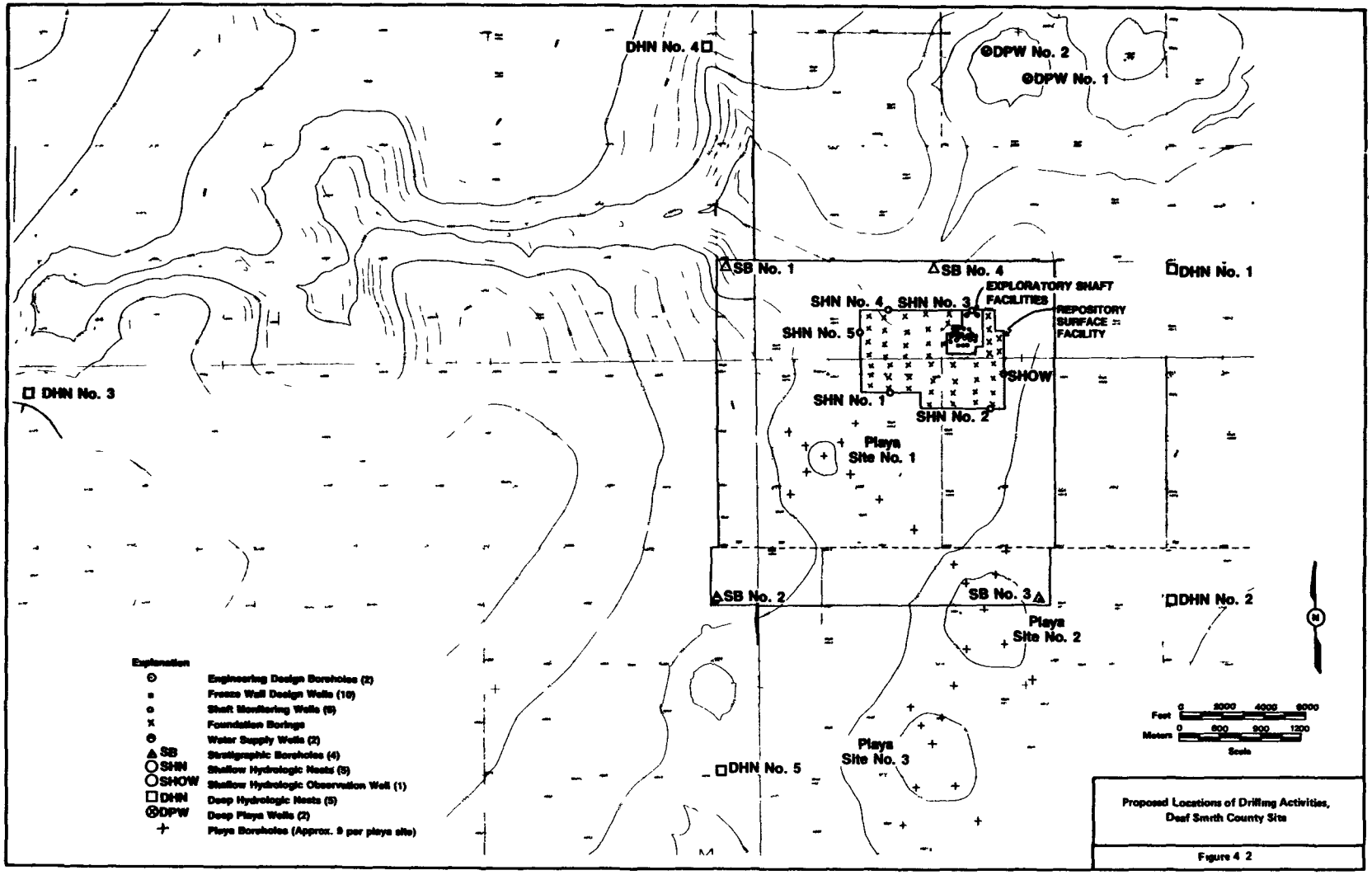
Activity Name	Activity Discussion
10 CFR 960.4 - Postclosure Guidelines[a]	
Geohydrology (960.4-2-1)	
Deep Aquifer Hydronests	4.1.1.1.1
Shallow Aquifer Hydronests	4.1.1.1.2
Shallow Playa Boreholes	4.1.1.1.8
Deep Playa Boreholes	4.1.1.1.8
Playa Trenching	4.1.1.1.8
Geochemistry (960.4-2-2)	
Determination of Pre-Waste-Emplacement Geochemical Conditions	4.1.1.1.6
Rock Characteristics (960.4-2-3)	
Stratigraphic Boreholes	4.1.1.1.7
Surface Geologic Mapping	4.1.1.1.13
Tectonics (960.4-2-7)	
Microseismic Network	4.1.1.1.9
Seismic Reflection and Refraction Survey	4.1.1.1.10
3-D Seismic Survey	4.1.1.1.11
Potential-Field Surveys	4.1.1.1.12
Human Intrusion (960.4-2-8)	
Borehole Search and Characterization	4.1.1.1.14
10 CFR 960.5 - Preclosure Guidelines	
Surface Characteristics (960.5-2-8)	
Near-Shaft Surface Mapping	4.1.1.2.1
Rock Characteristics (960.5-2-9)	
Engineering Design Boreholes (EDBH)	4.1.1.2.1
Shaft Design, Surface Facilities, Access Route and Utility Foundation Boreholes	4.1.1.2.3
Hydrology (960.5-2-10)	
Shaft Monitoring Wells	4.1.1.1.3
Water Supply Wells	4.1.1.1.4
Exploratory Shaft Facility Monitoring Wells	4.1.1.1.5
Repository Surface Facility Monitoring Wells	4.1.1.1.5
Freeze-Wall Design Wells	4.1.1.2.2

(a) Dissolution (960.4-2-6) is not listed as a separate topic, but the required activities will be performed under the Geohydrology and Geochemistry guidelines.



Schedule of Proposed Geotechnical Field Activities Deaf Smith County Site

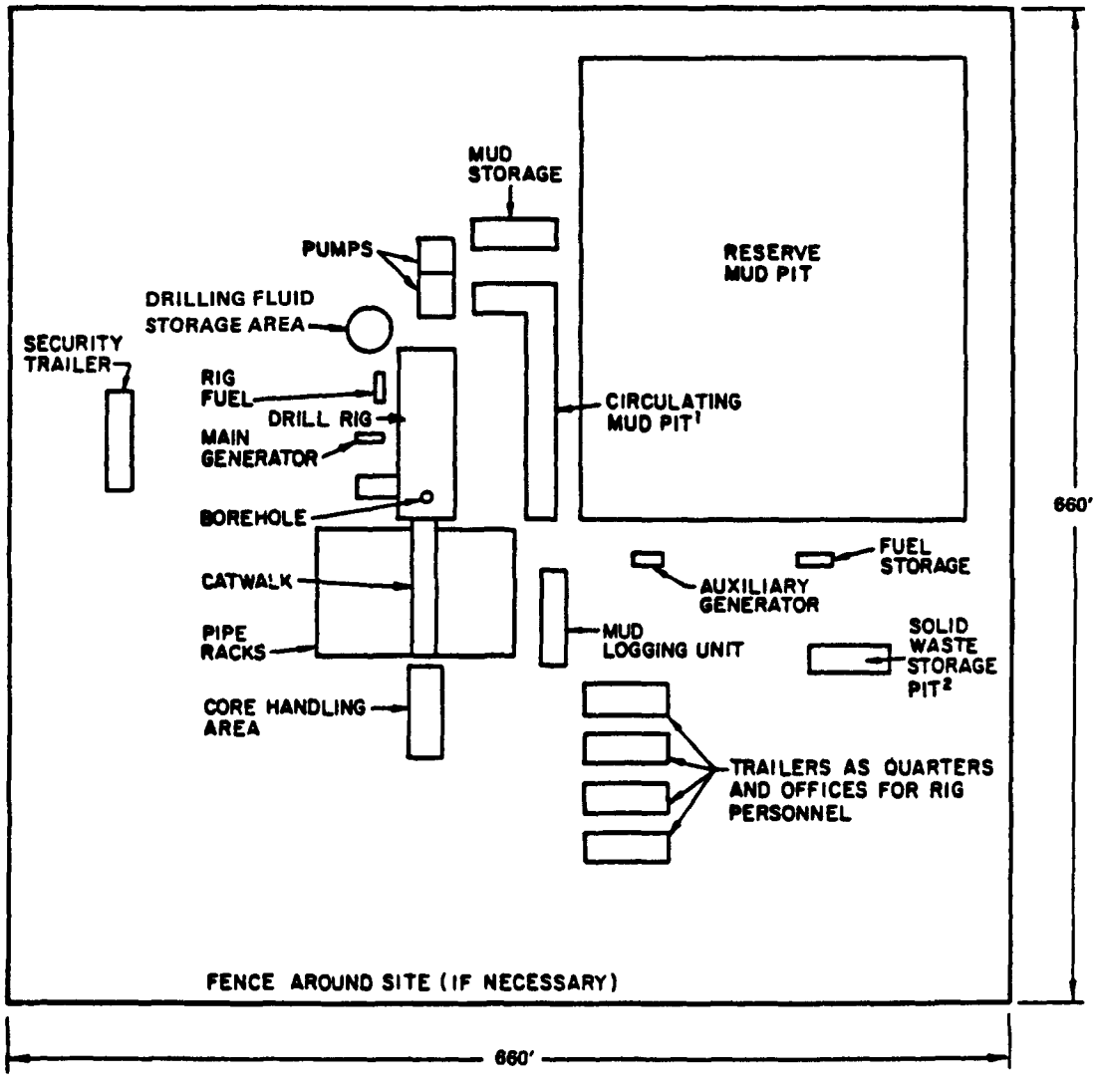
Figure 4-1



Proposed Locations of Drilling Activities, Deaf Smith County Site

Figure 4 2

A larger reproduction of this figure appears at the back of this volume.



[1] MAY BE A METAL TANK

[2] MAY BE A COVERED CONTAINER

Note: Drawing Not to Scale

Typical Layout of a Well Drilling Site

Figure 4-3

Drilling. Drilling activities will fall into two general categories: shallow boreholes drilled with small truck-mounted rigs and deep wells drilled using large truck-mounted or conventional oil-field techniques and equipment.

Shallow, small-diameter boreholes generally will penetrate less than 400 meters (1,300 feet) below ground. Truck-mounted drill rigs will be used. Conventional coring methods will be used to drill and sample caliche and other consolidated materials. Elsewhere, rotary tri-cone or auger bits will be used to advance the borehole, and split-spoons and thin-walled tubes will be used for sampling soil layers. Casing will be used locally to maintain borehole stability. Drilling fluid will be water or mud mixtures. Drilling fluids will be recirculated and disposed of in compliance with existing regulations, by using standard oil and gas industry procedures. Casing generally will be removed after completion of a borehole, and the borehole will be grouted.

Deep wells are advanced by breaking up the rock through a downward force applied to a rotating drill bit. Drilling fluid, usually consisting of water mixed with bentonite or chemical additives to form a mud, is circulated through the drill rod to cool the drill bit, flush cuttings out of the hole, and stabilize the borehole walls. Drilling fluid will be contained on site in either tanks above ground or excavated reserve mud pits. Under normal operating conditions, the drilling fluid circulates in closed cycle and there is no discharge of liquid waste. At the end of drilling activities, or during changes in drilling fluid composition, it will be necessary to dispose of some quantities of drilling fluid. Estimated total depth for deep holes is anticipated to be 2,590 meters (8,500 feet).

For deep wells, the waste drilling fluid and drill cuttings will be collected in the reserve mud pit, which is expected to be less than 0.4 hectare (1 acre) in size. The pit will be diked to prevent overtopping. At the end of drilling activities, any liquids in the reserve pit will be pumped out and disposed of by a licensed contractor in an approved manner such as a disposal well. The mud will be allowed to dry out, after which the pit will be backfilled with soil in essentially the reverse order in which it was removed in order to reestablish vegetation. This reclamation method is consistent with that used by the oil and gas industry in Texas.

At various stages of drilling, casing will be installed in the borehole and cemented into place to stabilize or isolate the borehole from adjacent rock units. Cementing the casing will require additional equipment at the site. The surface casing serves to protect the freshwater (potable) aquifers from contamination by drilling activities and oil or gas zones, and from cross connection with deeper aquifers.

Drilling fluid will be flushed from the well and surrounding formations as the well is developed (pumped). Saline fluids produced during drilling or developing of the well will be stored on site in aboveground tanks or reserve mud pits until the fluid can be transported off site and disposed of in licensed injection wells. If fresh water is produced, it may be reused on site or be discharged from the site if it meets discharge water quality standards.

Activities associated with the drilling of eight wells, and extensive testing in four of those wells, as part of the Civilian Radioactive Waste Management (CRWM) program in the Texas Panhandle generated approximately 120,000 barrels of brine that required disposal (Peck, 1985). While being drilled, a 914-meter (3,000-foot) well produces an average of 300 barrels per day of waste brine; a 2,438-meter (8,000-foot) well produces 450 barrels per day; and pump testing produces about 40 barrels per day (Washer, 1985). If, during the peak of site characterization, three each of the above activities were performed simultaneously, about 2,400 barrels per day of waste brine would be generated.

As of July, 1985, there were 19 commercially licensed brine disposal wells in Texas within 160 to 240 kilometers (100 to 150 miles) of the site (Peck, 1985). Each well is capable of accepting 200 to 600 barrels per hour, and a conservative estimate for the Texas Panhandle is 70,000 barrels per day of available disposal capacity (Peck, 1985). Thus, it appears that there is more than sufficient disposal capacity in the region in existing licensed injection wells to handle waste brine produced by site characterization activities.

Geophysical Logging. Downhole geophysical logging is routinely performed after wells are drilled and sometimes at intermediate stages. Logging involves lowering measuring tools down the hole and recording data as the tools are withdrawn. A suite of geophysical logs will be run in most deep boreholes; not all boreholes at multiple well sites will be logged with the entire suite of logs.

General procedures and equipment for the various logging techniques are quite similar. Some tools contain limited amounts of radioactive isotopes (Section 4.2.1.9). The logging will be conducted using specially equipped trucks that are brought to the site over existing roads.

Hydrologic Testing. Short-term hydrologic testing (drill-stem tests and repeat-formation tests) will be done during drilling and after the hole is completed. Testing will occur in the three hydrostratigraphic units (HSU) associated with the local geology (Section 3.3.2.1.1). Short-term testing will be done in formations above the uppermost salt bed in HSU A and the upper part of HSU B, in the lower part of HSU B below the uppermost salt bed, above and below the host rock in HSU B, and in the Wolfcamp and Pennsylvanian saline aquifers in HSU C. Testing will provide data for calculation of hydrologic parameters.

Long-term pumping, testing, and sampling will likely be performed in the middle and lower hydrostratigraphic units (the Permian evaporite section, and also in the Wolfcamp and Pennsylvanian saline aquifers). Long-term pumping tests will be performed using pumping equipment capable of handling variable yields from 1,500- to 2,600-meter (5,000- to 8,500-foot) depths. Other testing methods such as injection, pressure decay, and low-rate production testing with low permeability testing tools may be used in the Permian evaporite section. Tracers, which are not harmful to the environment, will be used in hydrologic tests where required.

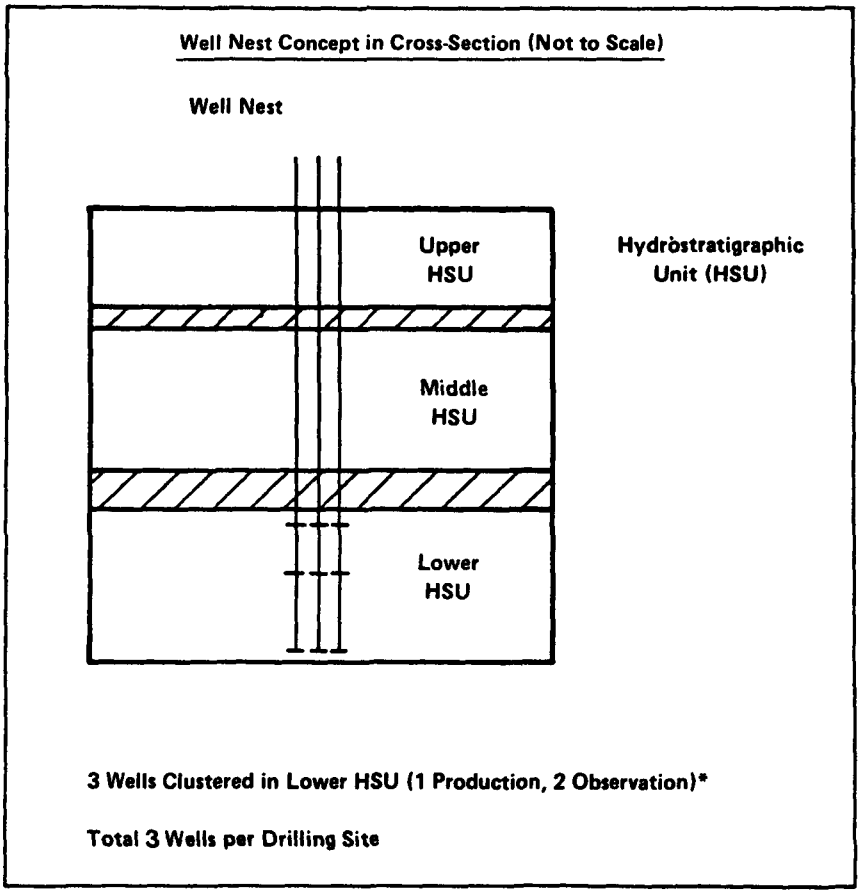
Three-well hydraulic interference tests will be conducted in the upper hydrostratigraphic unit (HSU A). The feasibility of conducting such tests will be evaluated for the lower hydrostratigraphic unit (HSU C) (Figure 4-4). These tests will consist of the production or injection of fluid into one well while monitoring pressure in the other wells. The upper unit tests will each last about 1 week. Deeper tests may last considerably longer due to low permeabilities. All tests will require a pump, generator, and water storage tank. Hydrologic testing and sampling will occur on a portion of the drill pad.

Casing and Plugging. Casing and plugging requirements are designed to prevent commingling of water, gas, or oil from different formations. Casing is not required in shallow wells which have not been drilled below the base of usable-quality water strata. The DOE will consult with the Texas Water Commission regarding casing requirements for deep wells. Surface casing in these deeper wells cannot be removed when abandoning the wells.

Plans to plug and abandon wells will be considered in consultation with the local Railroad Commission district office. Wells must be plugged in a manner which protects fluid-bearing formations. In all cases, site characterization boreholes will be drilled, completed, and plugged in a manner which meets or exceeds regulatory requirements.

Site Restoration. Upon completion of the drilling and testing, which may require several years, the wells will be plugged in accordance with applicable regulations. The site will be restored as much as possible to its original condition. The area around the drill site, access route, and storage area will be cleared of equipment and debris. Surfacing material will be excavated and removed from drill sites.

In areas where other investigations occur, i.e., seismic, trenching, and test pits, the area will be restored, as much as possible, to the original condition, by backfilling, compacting, and recontouring the land.



*Horizontal tick marks are schematically representative of possible test zone levels within the hydrostratigraphic unit.

Schematic Diagram of Deep Aquifer Hydronest Drilling Program

Figure 4-4

Retention ponds in the drilling area will be filled and regraded as nearly as possible to original contours. Topsoil, stockpiled during site preparation, will be spread over the site, the soil stabilized to reduce erosion, and the area revegetated.

4.1.1.1 Basic Geologic and Hydrologic Studies

Proposed field activities and their requirements are summarized in Table 4-2. The relationship of the planned activities to the preclosure and postclosure guidelines is shown on Table 4-1.

4.1.1.1.1 Deep Aquifer Hydronests. Additional hydrologic data are needed to precisely define and model the deep basin saline ground-water flow regime. Data will be collected from the lower hydrostratigraphic unit at five sites (Figure 4-2).

The drilling would require 6 hectares (15 acres) for each drill site. This drill site would be somewhat larger than the standard oil and gas exploration field site because of increased space requirements for equipment and personnel. Major facilities at each drill site, shown on Figure 4-3, would include the following:

- Drilling rig and auxiliary equipment
  - Platform drilling rig with a 40-meter (130-foot) mast using diesel engines to power the drawworks, the drilling fluid circulation pumps, and the electrical generator. Total drilling configuration is operated on 597 kilowatts (800 horsepower).
  - Drill pipe, drilling and coring tools, and clean-out equipment.
- Mud storage tanks or pits - three 15,898-liter (4,200-gallon) tanks or pits
- Solid waste storage area - one waste container or pit
- Equipment laydown storage areas
- Core-handling shed - a 5-by-18-meter (15-by-60-foot) portable building
- Supervisory quarters, offices, and laboratory space - up to nine trailers
- Blowout preventers
  - One annular-type blowout preventer
  - One ram-type blowout preventer
  - One rotating head
- Fluid storage tanks - three 79,480-liter (21,000-gallon) storage tanks
- Casing.

Each site may have as many as three wells completed in the lower hydrostratigraphic unit (Figure 4-4). Core samples will be taken within the stratigraphic intervals to be tested. Drilling, testing, and site restoration activities will be performed by the methods described in Section 4.1.1. Each well is expected to take 5 to 8 weeks to drill, depending on depth and amount of coring and testing. A work force of 27 people is expected at each multiple-well site.

Drilling and initial testing at each site is expected to last 6 months. After drilling and initial testing have been completed, long-term testing and monitoring will be performed in these wells. Testing will occur at each of the geohydrologic test wells in accordance with

Table 4-2 Summary of Geotechnical Field Activity Requirements, Deaf Smith County Site

Activity	Scope	Quantity per Site	Total Number of Boreholes	Land Use: Number of Sites	Land Use: Requirements per Site	Work Force per Site	Major Equipment per Site	Duration of Activity	Duration at Each Site
Shallow Aquifer Hydronests	Drilling, coring, logging, testing, and monitoring	3 wells[a]	16	6	4-10 acres	27	1 large truck-mounted drill rig and auxiliary equipment, 8-10 light vehicles	6 months	1 months
Deep Aquifer Hydronests	Drilling, some coring, logging, testing, and monitoring	3 wells	15	5	12-15 acres	27	1 platform drilling rig and auxiliary equipment, mud tanks, core handling shed, generators, blowout preventers, air compressors, fluid storage tanks, casing, 8-10 light vehicles	30 months	6 months
Shaft Monitoring Wells	Drilling, some coring, logging, testing, and monitoring	3 wells	6	2	None, on land cleared for EDBH	27	1 large truck-mounted drill rig and auxiliary equipment, 8-10 light vehicles	3 months	3 months
Water Supply Wells	Drilling, casing, well development, and production	1 well	2	2	0 1 acre	6	1 small truck-mounted drill rig and auxiliary equipment, 2 light vehicles	1 month	1 month
Exploratory Shaft Facilities Monitoring Wells	Drilling, casing, some coring, logging, and monitoring	1 well	30	30	0 1 acre	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	3 months	3 days
Repository and Surface Facilities Monitoring Wells	Drilling, casing, some coring, logging, and monitoring	1 well	100	100	0 1 acre	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	9 months	2 days
Stratigraphic Boreholes	Coring, logging, and testing	1 borehole	4	4	4 acres	27	1 large truck-mounted drill rig and auxiliary equipment, 8-10 light vehicles	16 months	4 months
Deep Playa Wells	Deep coring to investigate potential for anomalous fracture conditions	1 borehole	2	2	4 acres	27	1 large truck-mounted drill rig and auxiliary equipment, 8-10 light vehicles	8 months	4 months
Playa Boreholes	Shallow borings, coring, geophysical surveys, and testing	9 boreholes	27	3	0 1 acre per boring	6	1 small truck-mounted drill rig, 2 light vehicles	9 months	3 months
Surface Geologic Mapping	Detailed geologic structure, and geomorphic mapping	9+ square miles	--	--	Access, test pits, hand augers	2-4	2 light vehicles	3 months	--
Topographic Mapping	Establish ground control of reference points	--	--	40	0 01 acre	2	1 light vehicle	1 month	--
Borehole Search and Characterization	Possible reentry and plugging of found holes	1	0+	0+	Access only or 0 1+ acre	15	1 light vehicle, drilling equipment as required	1-6 months	1-6 months
Trenching	Shallow excavation as needed	--		3	3 acres	3	1 light backhoe, 2 light vehicles	1 month	1 week
Microseismic Monitoring Network	Installation of seismographs in shallow boreholes	1 station per site	30	30	0 1 acre	3	1 small truck-mounted drill rig, 2 light vehicles	4 months	2-3 days
Seismic Reflection Lines	Infilling data base	155 line-miles	--	--	Access only	25	7 heavy trucks, seismic equipment, and 5 light trucks	6 months	1 to 2 line-miles/day
Seismic Refraction Lines	Detailed near-shaft and shallow subsurface profiling	6 5 line-miles		--	Access only by trucks	4	2 light trucks	2 months	0 5 line-miles/day
3-D Seismic Survey	Detailed seismic reflection survey over site	10 square miles	--	1	Access only by trucks	15	7 heavy trucks, seismic equipment, and 5 light trucks	6 months	6 months
Potential Field Surveys	Over-site gravity, magnetic, electric potential field surveys	Grid with 0 16 mile spacing		--	Access only on foot	15	2 light vehicles	6 months	10 to 20 sites/day
Engineering Design Borehole (EDBH)	Coring, logging, and testing	1 borehole	2	2	10 acres	27	1 platform drilling rig and equipment, 8-10 light vehicles	3 months	3 months
Freeze Wall Design Boreholes	Drilling, coring logging, testing, and monitoring	5 boreholes	10	2	None, will be on land cleared for EDBH	27	1 Large truck-mounted drill rig and auxiliary equipment	5 months	5 months
Early Foundation Borings	Sampling, coring and logging	1 borehole	50	50	0 1 acre	6	1 small truck-mounted drill rig and auxiliary equipment, 2 light vehicles	2 months	1 day
Foundation Borings for Surface Facilities and Access	Drilling test pits, and sampling	1 borehole	400	400	0 1 acre	6	1 small truck-mounted rig or cone penetrometer truck, 2 light vehicles	20 months (parttime)	1 day

(a) One of the six sites will have only one well

general practices described in Section 4.1.1. The work force on site will vary from two to eight persons. Most testing at a site is expected to require about 1 year. Long-term water level measurements and water sampling activities will occur throughout the site characterization program. Monitoring and sampling will take place once every 3 months for at least 1 year, followed by semiannual or annual monitoring and sampling. Tasks requiring sampling, analysis, and stream-flow measurements will be done in accordance with U.S. Geological Survey procedures (USGS, 1967; Riggs, 1972; 1973).

Fresh water which meets applicable requirements will be discharged into existing drainages. Saline water will be contained on site in pits or tanks until it can be properly disposed of in accordance with applicable regulations. Samples will be analyzed for a range of major and minor dissolved elements, isotopes, and dissolved gases. Where possible, environmental information required (Section 4.1.3.1) will be collected as part of this activity.

4.1.1.1.2 Shallow Aquifer Hydronests. The shallow aquifer hydronests will be constructed to obtain data necessary to model ground-water flow in the Ogallala and Dockum units and to collect water quality samples. Data on the hydrologic characteristics of the upper hydrostratigraphic unit will be acquired by drilling 16 wells located around the surface facilities, as shown in Figure 4-2. Fifteen of the 16 wells will be constructed at five sites (three wells at each site) located at the perimeter of the surface facilities. A sixth site will be a single-well installation. The depth of the wells will vary based on data needs at a particular drilling site, but will be restricted to the HSU A. Each well will be sampled within the stratigraphic interval to be tested.

Drilling, aquifer testing, geophysical logging, and site restoration will be performed as described in Section 4.1.1. These wells will be monitored throughout the site characterization program to further evaluate what effects, if any, shaft construction and surface activities have on the shallow aquifer systems. Approximately 27 personnel will be on site each operating and testing day. Drilling and testing of boreholes at each site will occur over a period of 1 month. This activity at 6 sites will be completed over a period of 6 months.

Each hydronest site would occupy approximately 4 hectares (10 acres). Major facilities at each drill site would include the following:

- Drilling rig and auxilliary equipment:

  - A large truck-mounted drilling rig with a 30-meter (97-foot) mast using diesel engines to power the drawworks, the drilling fluid circulation pumps, and the electrical generator. Total drilling configuration is operated on 672 kilowatts (900 horsepower).

- Mud tanks or pits - a minimum of two 75-barrel (11,923-liter [3,150-gallon]) steel tanks or pits constructed for drilling fluid circulation

- Solid waste storage area - one waste container or pit

- Equipment laydown and storage areas

- Supervisory quarters, offices, and lab space - Up to nine trailers

- Blowout preventers:

  - One annular type blowout preventer
  - One ran-type blowout preventer
  - One hydraulically operated preventer control unit
  - One rotating head

- Fluid storage tanks - Two 500-barrel (79,480-liter [21,000-gallon]) steel tanks.

4.1.1.1.3 Shaft Monitoring Wells. Six wells (three, at each of two shaft locations) will be drilled within a 61- to 152-meter (200- to 500-foot) radius of the two exploratory shafts and will penetrate the entire upper hydrostratigraphic unit. The wells will be used to determine baseline ground-water level and quality conditions prior to and during construction of the exploratory shafts. Initial drilling, testing, and sampling is expected to occur over a 3-month period. Sampling and monitoring of these wells will be conducted as described in Section 4.1.1.1.1. Since this acitvity will use the engineering design borehole (EDBH) drill pad, no additional access road construction or site preparation is required. Wells will be drilled and tested as described in Section 4.1.1. A work force of 27 people (9 per shift) is required.

Drilling equipment needed to complete each of these wells is as described for the shallow aquifer hydronests in Section 4.1.1.1.2. Two large truck-mounted rigs will be operating simultaneously.

4.1.1.1.4 Water Supply Wells. Two water wells will be drilled and developed to supply water. These wells will be drilled by a small truck-mounted rig in a period of less than 1 month. Six personnel are anticipated to be involved in this drilling. The wells will penetrate less than 244 meters (800 feet) and disturb approximately 0.04 hectare (0.1 acre) of land each. Testing and pumping data will be acquired for modeling of the upper hydrostratigraphic unit.

4.1.1.1.5 Exploratory Shaft and Repository Surface Facilities Monitoring Wells. Approximately 130 wells will be drilled to monitor water quality and water-level changes in the vicinity of these surface facilities. These wells will be installed around engineered structures such as muck and salt storage piles, refuse pits, and onsite retention ponds. The wells will be drilled to a depth of approximately 110 meters (360 feet) using a small truck-mounted rig. The 30 exploratory shaft facility monitoring wells will be installed during a 3-month period prior to shaft facility construction. The 100 repository surface facilities monitoring wells will be installed if the site is selected for construction of the first repository. A work force of six persons is required for these activities. Less than 0.04 hectare (0.1 acre) of land will be disturbed at each site.

4.1.1.1.6 Determination of Pre-Waste-Emplacement Geochemical Conditions. Rock and fluid samples will be collected for chemical, petrographic, mineralogic, and isotopic analyses to provide information necessary for testing and design of waste package components, calculation of waste package performance, and evaluation of potential radionuclide release rates. Samples will be obtained from the EDBH (Section 4.1.1.2.1), the exploratory shafts and associated underground openings (Section 4.1.2), the stratigraphic boreholes (Section 4.1.1.1.7), and selected hydrologic test wells (Sections 4.1.1.1.1 through 4.1.1.1.3). No additional field disturbance results from this effort.

4.1.1.1.7 Stratigraphic Boreholes. Four boreholes will be drilled beyond the perimeter of the repository to investigate the stratigraphy and geologic structure of rock surrounding the underground repository workings. Data from these holes and the EDBHs will be used to determine the layout and design of the underground workings, and to evaluate site suitability. A schematic representation of the locations of the four boreholes is shown in Figure 4-2. It is expected that environmentally and culturally sensitive areas can be avoided during the selection of the actual location. Boreholes will extend to a depth of about 61 meters (200 feet) below the repository horizon. These boreholes will be located at least 244 meters (800 feet) beyond the perimeter of the underground repository. Drilling, coring, testing, and sampling activities will last approximatley 4 months at each site. Twenty-seven personnel (9 per shift) will be required. Approximately 1.6 hectares (4 acres) of land will be disturbed at each site.

Drilling equipment needed to complete each of these boreholes is as described for the shallow aquifer hydronests in Section 4.1.1.1.2. One large truck-mounted drilling rig will drill the boreholes consecutively.

4.1.1.1.8 Deep Playa Boreholes, Playa Investigations, and Playa Trenching. Selected studies will be performed to address the question of the origin of playas. Two deep playa boreholes as deep as 2,590 meters (8,500 feet) will be drilled to investigate the potential for anomalous fracture condition or stratigraphic thinning beneath a playa. Approximately 1.6 hectares (4 acres) of land will be disturbed for a period of 4 months at each site. A work force of 27 persons (9 per shift) will be required.

Drilling equipment needed to complete each of the 2 deep playa boreholes is as described for the shallow aquifer hydronests in Section 4.1.1.1.2. One large truck-mounted drill rig will drill these boreholes consecutively.

A series of 27 shallow exploration boreholes will be drilled over three playas (Figure 4-1). These wells will be drilled to various depths, some to the base of the Upper Seven Rivers Formation salt unit to investigate the potential influence of shallow salt dissolution, and others to the base of the Ogallala to investigate the possibility of caliche dissolution influence on playa development. A small truck-mounted rig will be used for this investigation; minimal site preparation or disturbance is anticipated. A crew of six will be on site during investigations, which may last 3 months at each playa. Additional very shallow augering may be done on the upper edges of playas to establish depth to caliche.

Shallow trenches may be excavated proximate to but not within three playas to explore for near-surface evidence of fractures in caliche, and for possible correlation with surface lineament trends. These excavations will require access by light vehicles. Three-person crews working over a total period of one month are anticipated. Potential trench locations have not been selected and are, therefore, not illustrated on Figure 4-2.

4.1.1.1.9 Microseismic Monitoring. Seismograph records provide data on ground motion which will be utilized in design of the repository surface and subsurface facilities, as well as for assessment of tectonic stability. It is anticipated that some of the existing 16 seismograph stations will be relocated or reconstructed (placed deeper in the ground) to improve network areal coverage and sensitivity. The existing microearthquake network will also be supplemented by installation of an additional 10 to 15 seismograph stations. Installation of a seismograph station involves three persons for 2 to 5 days. A 6- by 6-meter (20- by 20-foot) parcel of land will be leased from a landowner; approximately a 3- by 3-meter (10- by 10-foot) parcel will be used. The seismometer will be buried up to 30 meters (100 feet) below ground surface. The remainder of the installation consists of a solar panel and an antenna 6 to 9 meters (20 to 30 feet) high for radio transmission to a central recording station, and a small enclosure of about 0.06 to 0.11 cubic meters (2 to 4 cubic feet) for electronic components. The 3- by 3-meter (10- by 10-foot) area will be fenced. A total of 30 sites may be disturbed by this operation. A small truck-mounted drill rig may be required at some sites. The locations for new or modified stations have not been determined.

4.1.1.1.10 Seismic Reflection and Refraction. Common depth point (CDP) seismic data will be obtained to evaluate selected subsurface structural features in the area. Two CDP surveys will pass near the two EDBH locations. High resolution surveys may also be run over playas as part of overall playa investigations.

It is anticipated that some surveys will be carried out with VIBROSEIS energy sources, although alternative energy sources will be considered. Approximately 155 line-miles will be completed within a 3-month period. The estimated daily work force is 25 persons. Land is required for access only. Disturbance is temporary from heavy equipment driven on land. Some of the surveys will be run on or adjacent to existing roads. Potential seismic reflection survey lines are not illustrated on Figure 4-2 because their specific locations are yet to be determined.

Four short refraction surveys, each about 0.8 kilometer (0.5 mile) long, will be run in the vicinity of the exploratory shaft facility (ESF) to determine shallow seismic velocities for engineering purposes. These surveys will use portable equipment, two light trucks, and a crew of four persons. Disturbance will be limited to walking and driving along the lines.

The seismic energy source will be a surface weight drop, buried explosions, or rifle bullet impact. Four or five similar refraction surveys, about one mile in length, will be run across potential channels at the Dockum-Ogallala contact.

4.1.1.1.11 Three-Dimensional Seismic Reflection. The 3-D seismic reflection survey will be used to collect data that will define the site geologic structure and demonstrate continuity of rock units between boreholes for characterization and design purposes. The 3-D survey will be conducted over approximately 26 square kilometers (10 square miles). A typical grid survey includes line spacing of 100 meters (328 feet) or less. The actual energy sources, subsurface spatial sampling, and data acquisition arrangements are yet to be determined. For the purposes of this environmental assessment, the following conservative design assumptions have been made.

A grid will be laid out with lines spaced 23 to 46 meters (75 to 150 feet) apart, and about 5.6 kilometers (3.5 miles) long. Vehicles needed to conduct the survey include seven heavy trucks and five light trucks for geophones, auxiliary equipment, and crew. Seismic lines will be surveyed by a two-person crew walking the lines. The energy source will be either truck-mounted vibrators or explosives. If explosives are required, shallow (approximately 7.6-meter-deep or 25-foot-deep) drill holes will be loaded and detonated with 0.5- to 2-kilogram (1- to 5-pound) charges. This may cause local disruption of soil.

4.1.1.1.12 Potential-Field Surveys. Regional gravity and magnetic data for the region are being reviewed. New high-resolution surveys will be run over the site and other selected areas, if it is determined there are data gaps, structures, or lateral data variations which require investigation. Electrical surveys, such as resistivity profiles or soundings, may be conducted to investigate shallow geologic features. Various grids may be run over the area to be investigated. Control points will be surveyed. Small, light trucks and four- to six-man crews will be on site at various times during a 6-month interval. Little or no site preparation or disturbance is required. Hole-to-hole resistivity and seismic surveys may be run to investigate stratigraphy and potential discontinuities. Hole-to-surface surveys may be run. Locations for potential-field surveys have not been determined and, therefore, are not illustrated on Figure 4-2.

4.1.1.1.13 Surface Geologic and Topographic Mapping. The objectives of this activity are to produce topographic and surficial geologic maps of the surface facilities areas (Figure 4-2) and site access routes. Detailed maps are required for grading, site drainage, and access road design. Topographic control will be established by a small survey crew. Geologic mapping may involve shallow-auger holes or test pits. Detailed surface mapping will be conducted in selected areas to investigate faulted or potentially faulted areas. These activities will utilize small vehicles and two- to four-man crews working on foot. Field work activities will be intermittent over an estimated 4-month period. Land disturbance will be minimal. These activities will also provide fundamental data required to characterize the site and to assess mineral resource potential.

4.1.1.1.14 Borehole Search and Characterization. A search will be conducted for unrecorded wells within the site vicinity. Those that could have a potential impact on the stability of the repository may need to be reentered for testing and evaluation by methods similar to those described in Section 4.1.1. No such boreholes are thought to exist at the site. Search techniques may include review of state and local drilling records, review of historic newspaper accounts and aerial photographs, door-to-door surveys, discussions with various historical societies, and possible walking of the site with hand-held metal detectors. If an abandoned well is discovered, it may be necessary to excavate the site. Borehole plugging may require disturbance of a few acres over a period of up to 6 months.

4.1.1.2 Engineering Design Studies

The activities relating to design and construction and their activity requirements are summarized in Table 4-2.

4.1.1.2.1 Engineering Design Boreholes (EDBH). This activity results in the collection of stratigraphic and geotechnical data at each of the two exploratory shaft sites. The EDBHs will be sampled continuously from ground surface to approximately 61 meters (200 feet) below the repository horizon. Site preparation, drilling, testing, and reclamation are discussed in Section 4.1.1.

Two platform drill rigs will operate simultaneously. Drilling and completion will require 3 months. The work force on site is expected to be approximately 27 people (9 per shift). Approximately 4 hectares (10 acres) within the exploratory shaft facility area is required for each drill site.

4.1.1.2.2 Freeze-Wall Design Boreholes. Ten special-purpose boreholes will be drilled through the upper hydrostratigraphic unit to obtain data necessary to design a program to freeze the water-bearing zones during construction of the exploratory shafts. These boreholes will also provide information for shaft liner and seal design. Because these holes will be drilled close to the EDBHs, no additional land will be disturbed. Large truck-mounted drilling rigs will be utilized. A work force of approximately 27 persons (9 per shift) is expected at each drill site over a period of 5 months.

4.1.1.2.3 Shaft Design, Repository and Surface Facility Design, Access Route, and Utility Foundation Boreholes. An estimated 450 foundation borings will be drilled using techniques described in Section 4.1.1. The first 50 borings (Foundation Borings in Table 4-2) are needed for design of the exploratory shaft facility and preliminary design of the repository and will be completed within the first several months after site access. The remaining 400 borings are needed for preliminary and final design of the repository and access and utility corridors. The depth of the foundation borings will be generally less than 46 meters (150 feet). Drilling will be accomplished with small truck-mounted rigs requiring little site preparation. Some boreholes may be fitted with piezometers for long-term monitoring. Drilling of the latter 400 borings will occur periodically throughout site characterization to meet design needs. A drilling crew of 6 persons per rig is expected. Borehole locations are not illustrated on Figure 4-2; specific hole locations will be designated when final facility configurations are available.

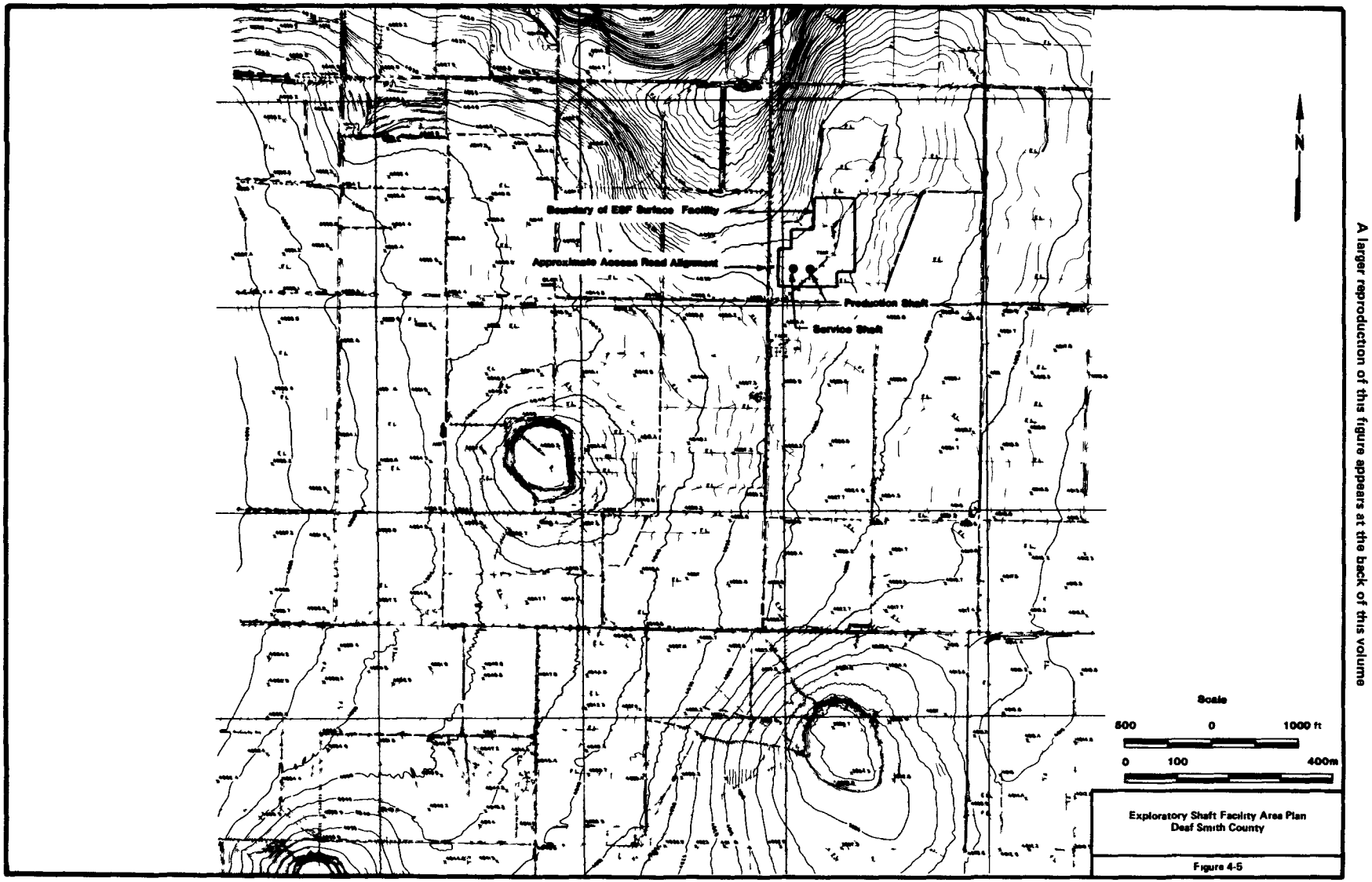
4.1.2 Exploratory Shaft Facility (ESF)

The ESF is to be constructed to gain access to the potential repository salt horizon and to perform in situ tests for site characterization (PB/PB-KBB, 1985; 1986). The facility will include two shafts, a production shaft and a service shaft. The service shaft is required for personnel safety (Section 4.3.2) and ventilation. Both shafts will be constructed by conventional shaft sinking techniques and will have a finished diameter of 3.6 meters (12 feet). The underground excavation totals approximately 1,652 linear meters (5,420 linear feet) to support testing. The remainder of this section is based on a preliminary level design that reflects compliance with gassy mine regulations. ESF design elements are conservative in nature and will be finalized upon completion of engineering boreholes described in the previous section.

The ESF site will occupy approximately 25 hectares (61 acres) (Figure 4-5). Access to the ESF site will be from an adjacent existing public road which extends 2.65 kilometers (1.65 miles) south to FM 2587. The access road will be approximately 0.06 kilometers (0.04 mile) long and 7.3 meters (24 feet) wide with 1.2-meter (4-foot) rounded shoulders on each side. The roadway design will conform to applicable State and local requirements and applicable environmental standards.

The ESF site (Figure 4-6) will be arranged to accommodate the following:

- Simultaneous construction of two shafts
- Functional arrangement to support construction



Exploratory Shaft Facility Area Plan
Deaf Smith County

Figure 4-5

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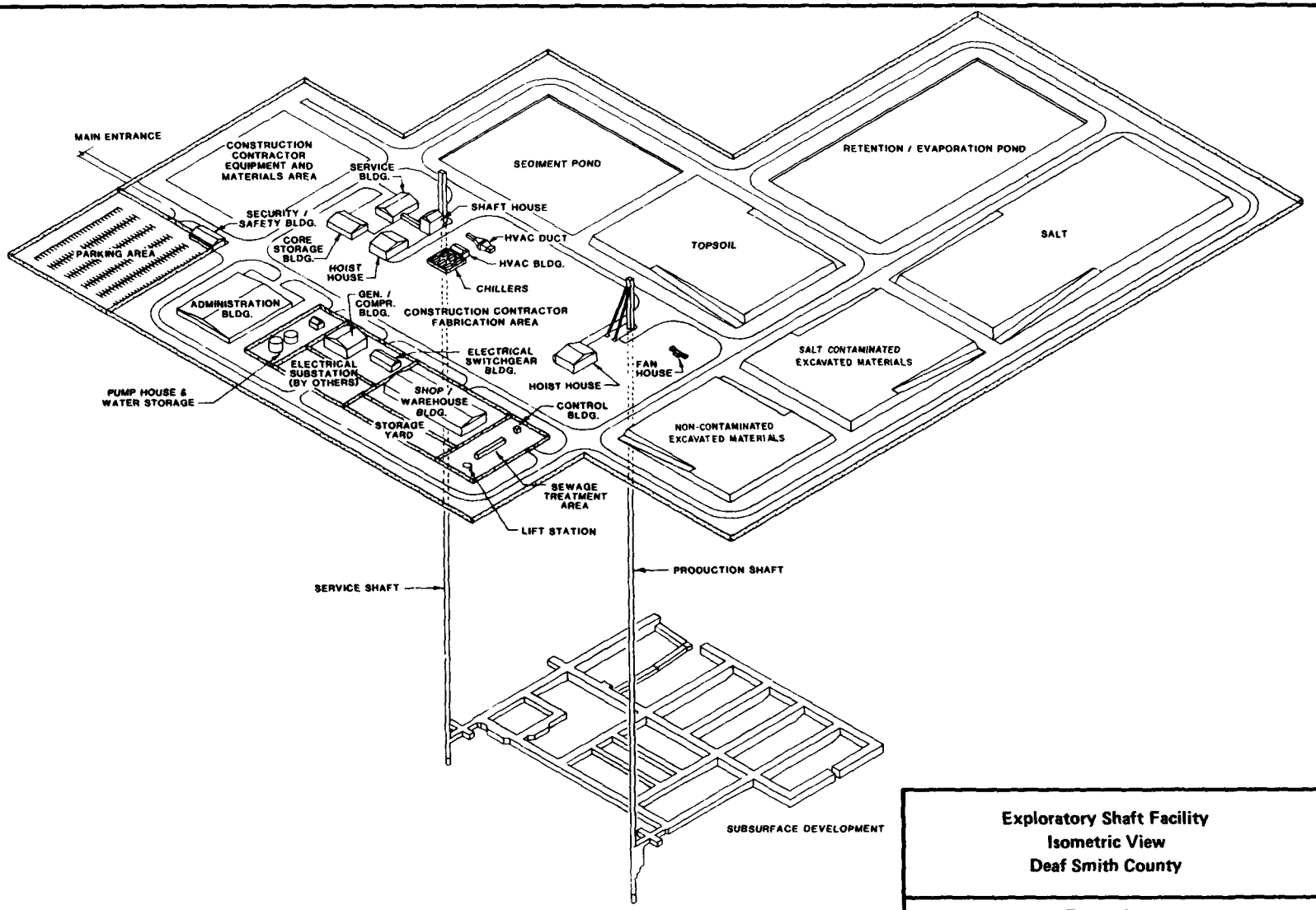


Exploratory Shaft Facility
Isometric View
Deaf Smith County

Figure 4-6

- Consolidation of all excavated wastes into one area for ease of handling, maintenance, and control of salt-contaminated material.

The site consists of construction areas for contractor equipment and materials, storage piles to accommodate excavated materials obtained during shaft and subsurface construction, and separate evaporation/retention and sediment ponds. The site arrangement also provides for administrative facilities, including office facilities, laboratory facilities, a security building, utilities, and parking.

A perimeter roadway will provide security control and emergency access to the entire site. A 2.1-meter (7-foot)-high chain link security fence will be constructed along the outside perimeter. The ESF site arrangement has been designed to do the following:

- Fit the natural contour of the land as closely as possible and practical, and minimize erosion and sedimentation within and around the site

- Minimize clearing and disturbance

- Restrict grading to requirements for structures and facilities, roadways, parking areas, utilities, drainage ditches, and surface storm-water runoff control.

4.1.2.1 Land Requirements

The total amount of land required for the Deaf Smith County ESF is approximately 25 hectares (61 acres), not including land for the access roadway. Access to the site is expected to require 0.06 kilometers (0.04 miles) of new road construction. The access road will be approximately 7.3 meters (24 feet) wide with 1.2-meter (4-foot) shoulders on each side and an 18-meter (60-foot) right-of-way requiring approximately 0.12 hectares (0.29 acres). These land requirements will be confirmed during final design. The access road will start from the nearest public road and extend to the site entrance (Figure 4-5).

The ESF location is currently on privately owned land. The U.S. Department of Energy (DOE) will obtain the needed access by purchasing surface and subsurface rights on 25 hectares (61 acres). To gain access to the exploratory shaft facility site, rights-of-way or other appropriate interest will be obtained from private landowners. Boundary surveys and establishment of construction survey monuments will be included in the activities leading the access agreements.

4.1.2.2 Construction

The stages of ESF construction will be site preparation, shaft and surface facility construction, shaft outfitting, and subsurface excavation. Shafts will be constructed by conventional drill-and-blast shaft-sinking techniques. A summary of the ESF project characteristics is provided in Table 4-3.

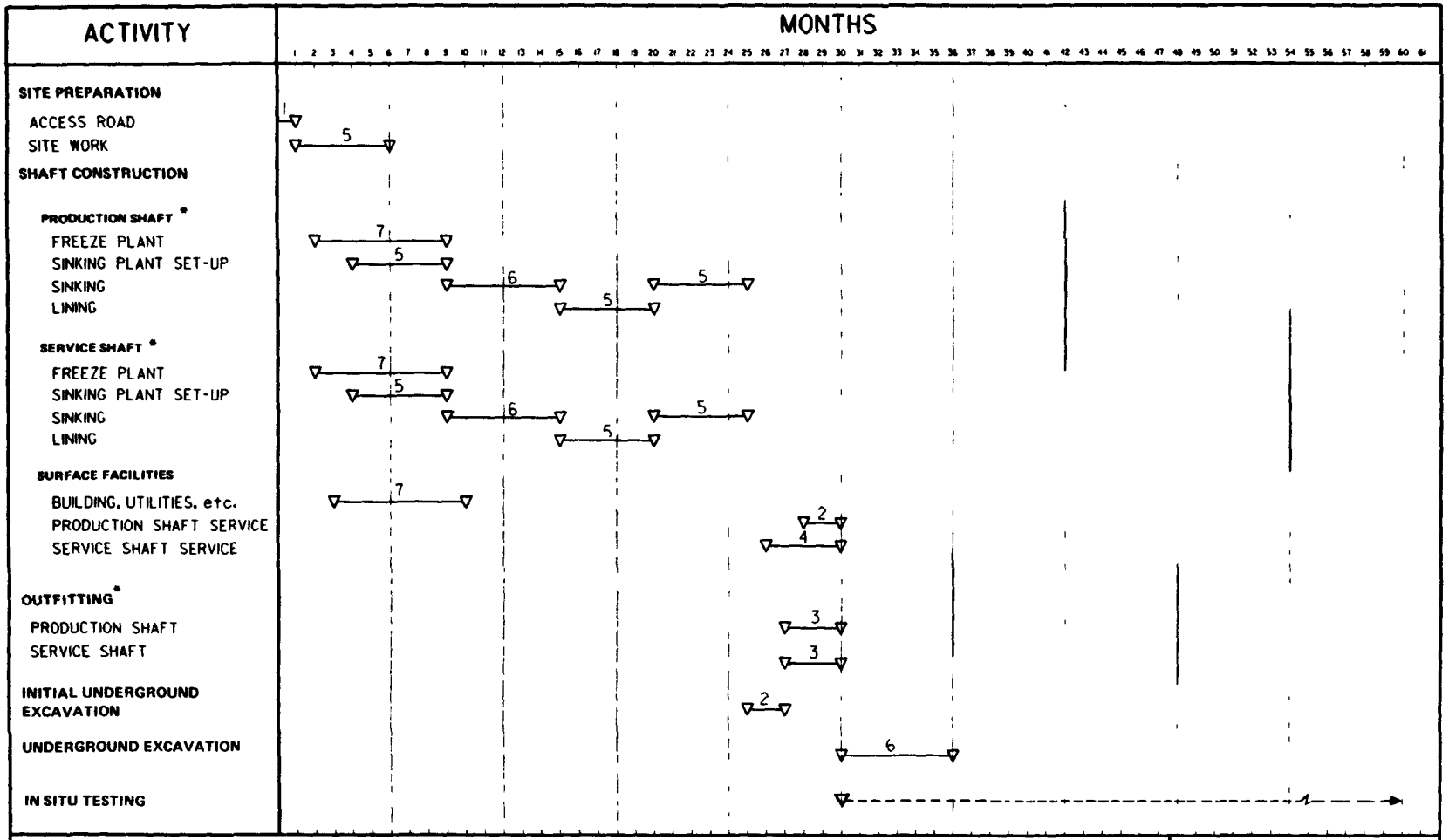
Subsurface excavation will be accomplished in two stages: initial subsurface excavation and expanded subsurface excavation. Initial subsurface excavation will occur before outfitting the shafts. The initial excavation stage will include enough drift to support equipment set-up and the additional subsurface excavation required to connect the two shafts. Once the shafts are connected and the subsurface ventilation circuit installed, both shafts will be available for evacuation should an emergency arise. The remaining excavation for testing is then completed. The estimated schedule for construction and testing activities is summarized on Figure 4-7. The estimated average number of personnel at the site during each construction and testing phase is listed in Table 4-4.

The phasing of construction activities determines those periods when the impact of site operations may be the greatest. Table 4-5 identifies 17 discrete periods defined by different sets of concurrent activities during construction and testing operations. By reference to ensuing equipment usage tables, Table 4-5 lists the peak cumulative horse-power usage by period. From this, two conservative cases have been identified and form the basis for the air quality impact analysis presented in Section 4.2.1.3.

Table 4-3. Exploratory Shaft Project Characteristics, Two 12-Foot Conventionally Mined Shafts

Construction Detail	Approximate Quantitative Description[a]
Surface area for exploratory shaft activities	61 acres
Conventionally mined shafts:	
Finished diameter	12 feet
Lining depth	2,475 feet
Finished shaft depth	
Production shaft	2,664 feet
Service shaft	2,590 feet
Depth to shaft stations	2,555 feet
Horizontal workings at base of shafts	5,420 feet
Initial excavation and connection drift between shafts	825 feet
Expanded excavation	4,595 feet
Access road (length)	210 feet
Access road (width)	24 feet, 4-foot shoulders
Access-road right-of-way (width)	60 feet
Highest structure (headframe)	125 feet
Electric power source	Offsite commercial electric power
Standby power	3-800 kW diesel generators
Capacity of excavated material storage pile areas	
- Noncontaminated	45,000 cu yd
- Contaminated	70,000 cu yd
Capacity of salt storage pile area	170,000 cu yd
Capacity of topsoil storage pile area	73,000 cu yd
Material excavated	207,000 cu yd
- Noncontaminated	33,000 cu yd
- Contaminated	56,000 cu yd
- Salt	118,000 cu yd
Maximum height of salt and other spoil piles	30 feet
Capacity of evaporation/retention pond	10.2 million gallons
Capacity of sediment pond	5.0 million gallons
Surface facilities	
- Prefabricated building units	70,000 sq ft (total)
Foundations	Concrete slabs for prefabricated building units, concrete footings for shaft collar and shaft hoisting equipment
Total freshwater demand	237 acre-feet (77.4 million gallons)

(a) Based upon preliminary design information. Site-specific data used for final design may change these parameters.



*Should a full liner be necessary, an additional 11 months shaft construction and outfitting will be required for each shaft
Source PB/PB KBB, 1985, 1986, McIntosh, 1986

Exploratory Shaft Facility Construction/ Testing Schedule Permian Basin Texas Deaf Smith County

Figure 4 7

Table 4-4. Estimated Personnel Requirements by ESF Phase, Deaf Smith County

Exploratory Shaft Facility Phase	Number of Personnel (average)[a]
Site preparation	130
Shaft and surface facility construction/outfitting	305
Initial underground excavation	245
Expanded underground excavation	280
Testing	280
Final disposition	100

(a) Includes contractor and noncontractor personnel.

Table 4-5. Concurrent Construction Activities

Period	Month	Tables Used	Peak Cumulative HP
1	1	Access Road (4-6)	2,250
2	2	Site Work (4-6)	3,325
3	3	Site Work (4-6) Freeze Plant for Production Shaft (4-10) Freeze Plant for Service Shaft (4-10)	9,595
4	4	Site Work (4-6) Freeze Plant for Production Shaft (4-10) Freeze Plant for Service Shaft (4-10) Surface Facility Construction (4-10)	11,054
5	5	Site Work (4-6) Freeze Plant for Production Shaft (4-10) Sinking Plant Set-up for Production Shaft (4-10) Freeze Plant for Service Shaft (4-10) Sinking Plant Set-up for Service Shaft (4-10) Surface Facility Construction (4-10)	13,394
6	6	Site Work (4-6) Freeze Plant for Production Shaft (4-10) Sinking Plant Set-up for Production Shaft (4-10) Freeze Plant for Service Shaft (4-10) Sinking Plant Set-up for Service Shaft (4-10) Surface Facility Construction (4-10)	7,394

Table 4-5. Concurrent Construction Activities
(Page 2 of 3)

Period	Month	Tables Used	Peak Cumulative HP
7	7-9	Freeze Plant for Production Shaft (4-10) Sinking Plant Set-up for Production Shaft (4-10) Freeze Plant for Service Shaft (4-10) Sinking Plant Set-up for Service Shaft (4-10) Surface Facility Construction (4-10)	4,069
8	10	Shaft Sinking for Production Shaft (4-10) Shaft Sinking for Service Shaft (4-10) Surface Facility Construction (4-10)	3,699
9	11-15	Shaft Sinking for Production Shaft (4-10) Shaft Sinking for Service Shaft (4-10)	2,240
10	16-20	Final Lining Installation for Production Shaft (4-10) Final Lining Installation for Service Shaft (4-10)	2,240
11	21-25	Shaft Sinking for Production Shaft (4-10) Shaft Sinking for Service Shaft (4-10)	2,240
12	26	Initial Underground Excavation (4-11)	1,370
13	27	Service Facilities for Service Shaft (4-10) Initial Underground Excavation (4-11)	2,649
14	28	Service Facilities for Service Shaft (4-10) Outfitting Production Shaft (4-12) Outfitting Service Shaft (4-12)	2,109

Table 4-5. Concurrent Construction Activities
(Page 3 of 3)

Period	Month	Tables Used	Peak Cumulative HP
15	29-30	Service Facilities for Production Shaft (4-10) Service Facilities for Service Shaft (4-10) Outfitting Production Shaft (4-12) Outfitting Service Shaft (4-12)	3,131
16	31-36	Underground Excavation (4-13) Testing (4-15)	2,655
17	37-66	Testing (4-15)	900

Note: Activities associated with the final lining are optional.

Table 4-6. Equipment for Construction of Access Road and Site Preparation, Deaf Smith County

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
SITE PREPARATION				
Access road (1 month)	1	Dozer	300	300
	1	Grader	180	180
	2	Trucks	250	500
	1	Vibratory compactor	210	210
	1	Excavator	195	195
	1	Paver	145	145
	1	Oiler	200	200
	1	Water truck	250	250
	2	Pickup trucks	135	270
				2,250
Site Work (5 months)	1	Dozer	300	300
	1	Scraper	450	450
	1	Grader	180	180
	4	Trucks	250	1,000
	1	Vibratory compactor	210	210
	1	Hydraulic excavator	195	195
	1	Wheel loader	270	270
	1	Water truck	250	250
	1	Oiler	200	200
	2	Pickup trucks	135	270
				3,325

Table 4-7. Estimated Resources Consumed During Exploratory Shaft Facility Activities, Deaf Smith County

Resource, Unit	Site Prep. (6 mos)	Shaft & Surface Facility Const. (31 mos)	Initial Underground Excavation (2 mos)	Shaft Outfitting (13 mos)	Underground Excavation (6 mos)	Testing (36 mos)	Final Disposition (38 mos)	Total Consumption
Diesel fuel, 1,000 gal	56	740	14	23	65	49	214	1,161
Electric Energy 1000 kWh	-	45,000	1,400	6,300	3,100	31,000	6,600	93,400
Water, 1,000 gal	1,100	21,000	860	2,300	1,100	16,000	35,000	77,360
Concrete, 1,000 yd^3	-	31	-	-	-	-	1	32
Plastic liner, 1,000 yd^2	217	-	-	-	-	-	-	217
Steel, tons	-	6,100	19	540	35	-	-	6,694
Polymer sealant, 100 gal	-	32	-	-	-	-	32	64
Blasting powder, 1,000 lb	-	180	13	-	-	-	-	193
Resin, 1,000 lb	-	90	14	-	56	-	-	160
Polyurethane, 1,000 gal	-	16	-	-	-	-	-	16
Fertilizer, ton	-	-	-	-	-	-	2	2
Seed, 1,000 lb	-	-	-	-	-	-	2	2
Gravel, 1,000 yd	16	-	-	-	-	-	-	16
Asphalt & Bitumen, tons	130	2,400	-	-	-	-	-	2,530

4.1.2.2.1 Site Preparation. Construction activity begins with construction surveys and the establishment of field monuments. Equipment for construction of the access road and for ESF site preparation is shown in Table 4-6. Estimated resources consumed during site preparation and during the ensuing phases of ESF construction, testing, and final disposition are shown in Table 4-7.

Access road construction consists of approximately 0.06 kilometer (0.04 mile) of roadway. Construction of an access route will begin as soon as possible so that shaft collar work and freeze hole drilling can proceed. The access road right-of-way selected will require approximately 0.12 hectares (0.29 acres) of land.

The roadway design will minimize environmental damage, present an acceptable appearance, and minimize the modification of surface terrain. This will be accomplished by limiting the alteration of natural features. Natural land drainage patterns will be maintained to the maximum extent practicable to ensure that the roadway does not impede natural drainage patterns. Improvements to the existing roadside drainage ditches and the installation of a culvert will be necessary for access road construction. Geometric elements of the access road will be arranged for safe and efficient traffic operations. The location of the access roadway is not within the limits of the 25-year floodplain. Where the roadway crosses an established drainage course, characteristics and flow elevations will be established to ensure a compatible design.

The access road will be designed as an all-weather road 7.3 meters (24-feet/two 12-foot lanes) wide with 1.2-meter (4-foot) rounded shoulders on each side. Grading will be minimal to maintain adequate site distances and grades. The roadway will have a flexible base constructed of an acceptable material that is used locally for roadway base construction and has demonstrated its performance in strength and serviceability. The subgrade will be prepared in-place or constructed of a suitable material to provide a uniform, continuous, and permanent base support. The road will be surfaced and paved with asphalt.

The access road will be designed to support a 14,545 kilogram- (32,000-pound)-per-axle loading. The roadway design will conform to applicable State and local requirements and environmental standards. Intersection of the access road and existing roadways will comply with applicable Federal, State, and local alignment and sign regulations.

Power for the site will require a hookup to an existing transmission line. The line to be tapped will be selected by the utility company and will have a voltage of at least 69 kilovolts. Double poles as shown on Figure 4-8 will be used.

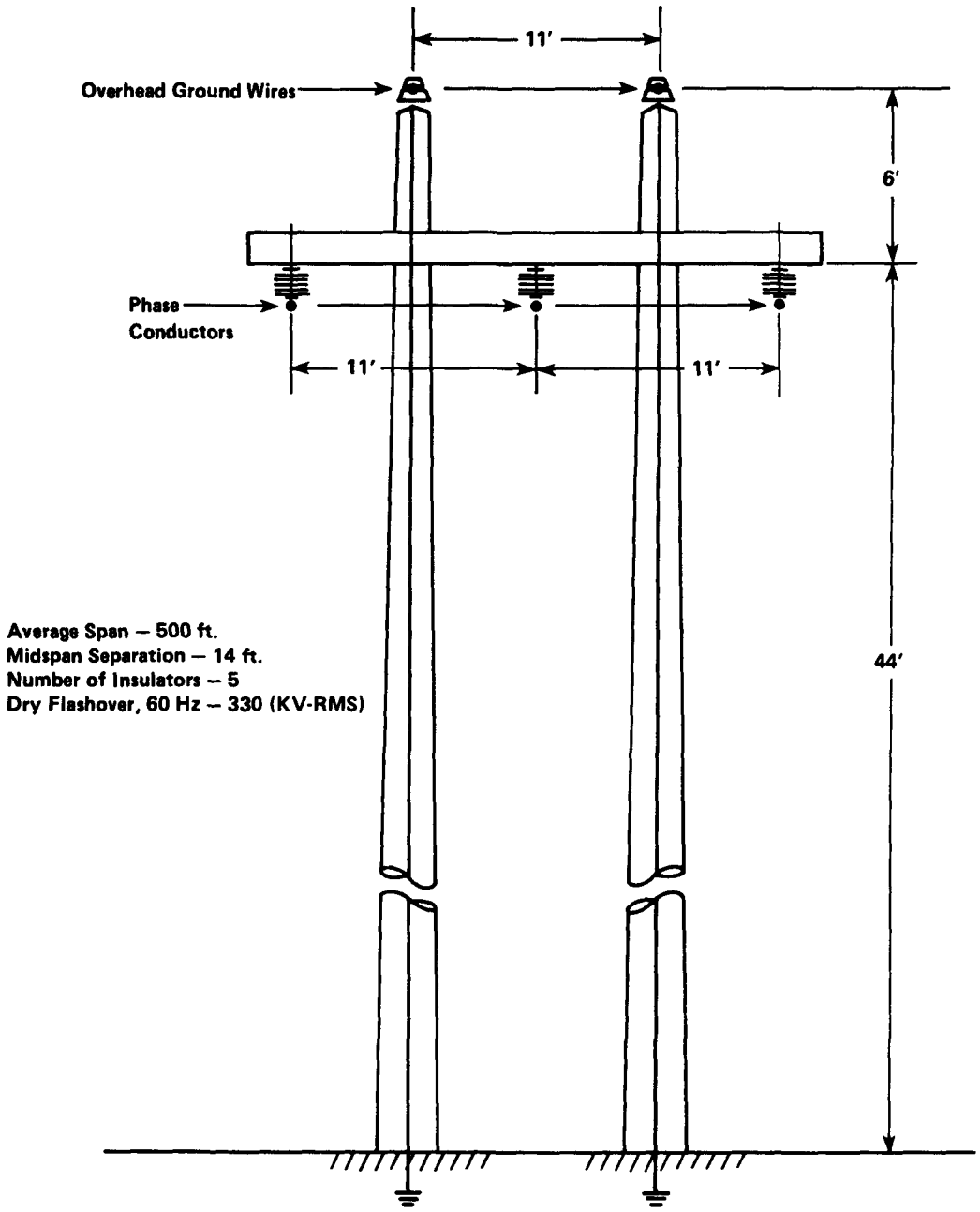
Because woody vegetation at the site is scarce, the need for clearing will be minimal. Of the 25 hectares (61 acres) making up the ESF site, 22 hectares (55 acres) will be disturbed during construction. Prior to grading, topsoil will be removed and stockpiled. Rocky materials, if any, will be removed and stockpiled separately within the same area.

Earthwork will be required to excavate the evaporation/retention pond and sediment detention pond. Additional earthwork will be required near the service buildings associated with each shaft and the administrative area to direct storm runoff to the appropriate pond.

Average daily automobile traffic would increase from preproject (baseline) levels to include approximately 120 round trips to the site by passenger vehicles during the site preparation stage. Truck traffic would result in an additional increase from baseline levels to include approximately 335 round trips to the site per month during site preparation. The estimated vehicular traffic during ESF construction, testing, and final disposition is given in Table 4-8.

4.1.2.2.2 Shaft and Surface Facility Construction.

Purpose of Shafts. The purpose of the exploratory shafts is to gain access to the potential repository horizon and perform in situ tests for site characterization. These shafts will also be used to circulate fresh air to the subsurface operations and contain conveyances for material or personnel handling requirements.



Typical Two-Pole Structure
Capable of 69 Kilovolts

Source: Parsons Brinckerhoff/PB-KBB, 1985.

Figure 4-8

Table 4-8. Estimated Vehicular Traffic During ESF Construction and Testing, Deaf Smith County

Phase[a]	Daily Automobile Round Trips[b]	Monthly Truck Round Trips
Site preparation	120	335
Shaft and surface facility construction	280	270
Initial underground excavation	220	95
Shaft outfitting	280	25
Underground excavation	250	40
Testing	250	90
Final disposition	90	40

(a) Phases are as shown in the schedule appearing in Figure 4-7. When schedule phases overlap, truck traffic is additive; passenger vehicle traffic is not.
(b) Based on Table 4-4 and 1.1 persons/vehicle.

From the surface to its final depth, a shaft passes through many different rock types. Whereas competent rocks may not require any external support, unconsolidated material or weakly cemented rocks may require some form of support to maintain shaft integrity. The rocks may either be completely dry, partially saturated, or when below the water table, saturated; therefore, in addition to supporting the rocks, safety depends upon controlling water inflows. This is especially critical in water-soluble evaporites such as rock salt and potash. The support of rocks and control of water are the functions of the shaft lining and of the seals constructed at strategic locations.

Mined shafts have been constructed to depths exceeding 3,045 meters (10,000 feet). Shaft depths of 915 meters (3,000 feet) have been constructed for North American and European mining operations. South Africa and India have some of the deepest shafts in the world.

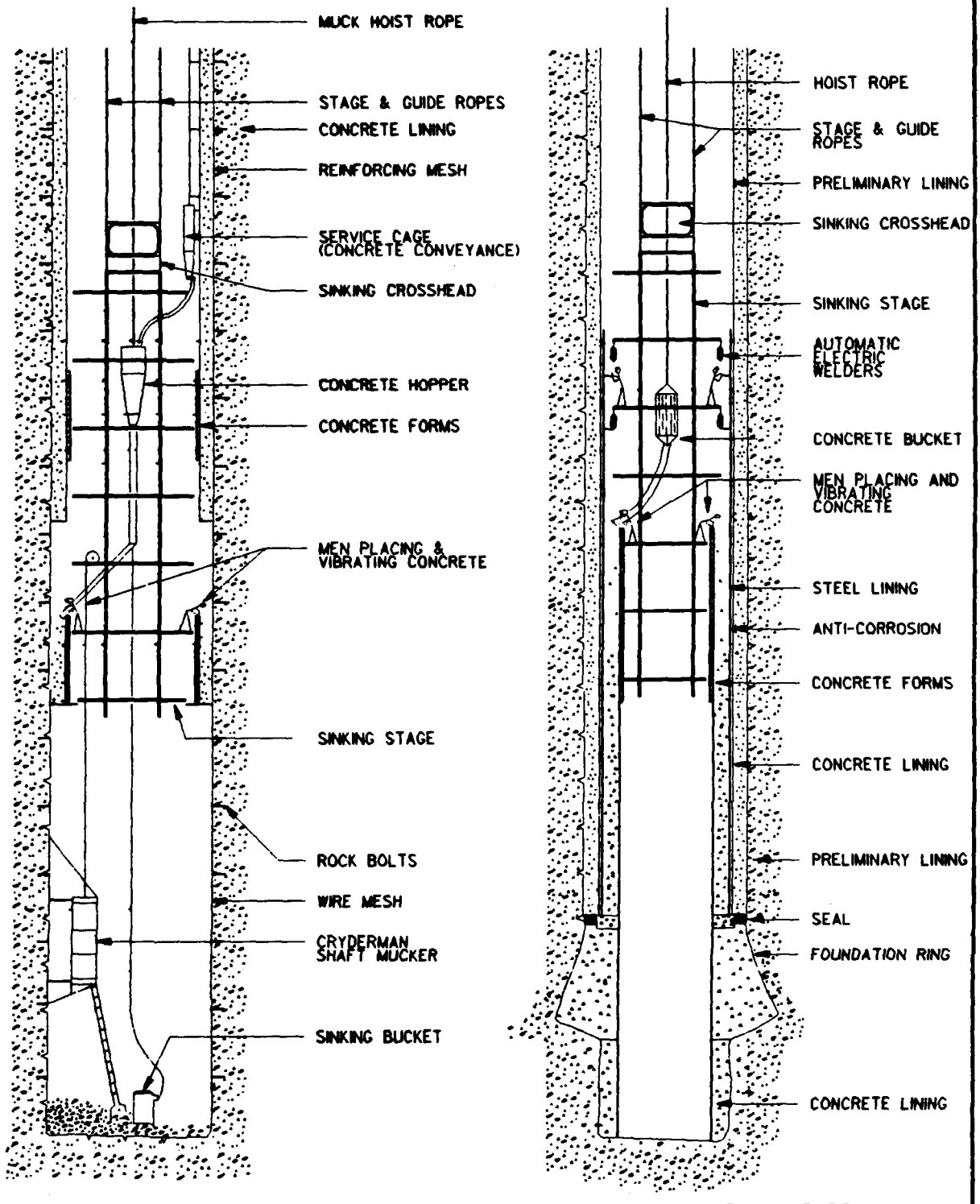
A circular cross-sectional shape is most prevalent in modern shafts. The circular shape is the most stable configuration for resisting lithostatic and hydrostatic pressures acting against the shaft lining. For ventilation purposes also, a circular shaft is more efficient than other shapes since it offers the least resistance to the ventilating current.

Shaft-Sinking Methods, and Ground and Water Control. The drill-and-blast method of shaft sinking employs the basic cycle of drilling, blasting, and removing muck from the shaft. A preliminary ground support system follows a few feet behind the advancing shaft bottom. A number of holes are drilled in the shaft bottom, loaded with an explosive, and blasted; the blasted material (muck) is hoisted to the surface in the muck bucket. For efficiency of operations and schedule, two buckets are usually used for muck removal. Once the excavated material has been removed to the surface, the cycle is repeated. Figure 4-9 is a schematic showing the drill-and-blast method of shaft sinking. A preliminary lining is installed in the shaft as the sinking progresses to protect the workers in the shaft from loose rock falls. Information obtained from the engineering design boreholes is used to determine the extent and method of ground and water control in the shaft during sinking.

The ground support system required to support the preliminary lining, and if necessary, the final shaft lining will be designed for the anticipated mechanical behavior of the shaft walls.

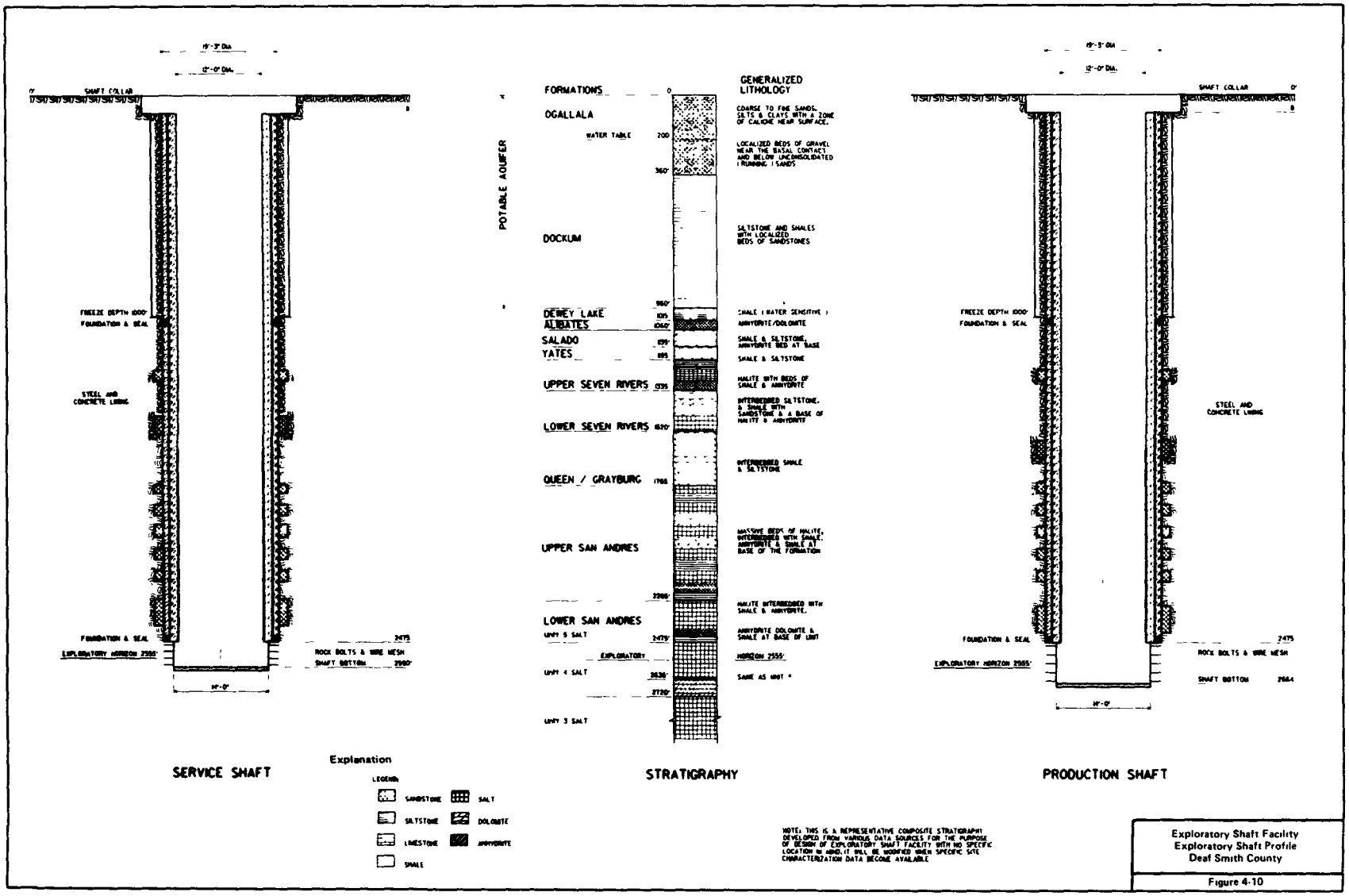
Shaft Construction. At the Deaf Smith County site, both shafts will be constructed using the conventional drill-and-blast method. The production shaft, 812 meters (2,664 feet) deep, will be used for hoisting excavated material; the service shaft, 790 meters (2,590 feet) deep, will be used for hoisting personnel and materials. The production shaft is deeper to accommodate the material handling and loading area at the bottom of the shaft. The shafts will be excavated to a diameter of approximately 6 meters (20 feet), which will allow a finished diameter 4 meters (12 feet) after completion of the final lining.

Figure 4-10 depicts the basic characteristics of the service and production shafts, as well as the referenced stratigraphy of the Deaf Smith County site. The Ogallala and portions of the Dockum Formations are potable water aquifers and contain unconsolidated soil and rock formations. To control water migration and to stabilize the ground sufficiently for the shaft penetration, the ground is frozen to a depth of approximately 305 meters (1,000 feet). The freezing process is accomplished by excavating a 1.5-meter (5-foot)-deep freeze collar and drilling approximately 28 freeze holes to an approximate depth of 305 meters (1,000 feet) and at a diameter of approximately 10 meters (33 feet) from the centerline of the shaft. A central hole is drilled as a relief hole, and additional holes will monitor the ground temperature. All holes for the freezing process are drilled by controlled means to stay within a 51-centimeter (20-inch)-radius about the hole collar. A steel freeze pipe equipped with a plastic brine circulation pipe is installed in the freeze hole casing. The cooled brine is circulated from the freeze plant through each freeze pipe. Brine volume and temperature are controlled. The temperature control holes are equipped with thermocouples at strategic locations to permit constant temperature control of the frozen ground structure. The center relief hole acts as a vent for the formation water forced out of the ground by the freezing action.



Exploratory Shaft Facility
Drill and Blast
Method of Shaft Sinking

Figure 4-9



NOTE: THIS IS A REPRESENTATIVE COMPOSITE STRATIGRAPHY DEVELOPED FROM VARIOUS DATA SOURCES FOR THE PURPOSE OF DESIGN OF EXPLORATORY SHAFT FACILITY WITH NO SPECIFIC LOCATION IN MIND. IT WILL BE MODIFIED WHEN SPECIFIC SITE CHARACTERIZATION DATA BECOME AVAILABLE

Exploratory Shaft Facility
Exploratory Shaft Profile
Deaf Smith County

Figure 4-10

When the ground is sufficiently frozen, a 30-meter (100-foot) shaft collar is constructed, a headframe is erected on the surface, a sinking stage is installed in the shaft, and the shaft sinking commences. A sinking stage is a multideck work platform (a seven-deck stage is shown in Figure 4-9). During shaft-sinking operations, it supports the shaft bottom operations of drilling, loading with explosives, and mucking. The preliminary rock support measures (rockbolting, preliminary lining, etc.), and temporary utilities are installed directly from the stage, simultaneously with shaft bottom operations.

Probe holes are drilled during shaft sinking, extending to a depth of several blasting rounds in advance of the shaft bottom. These probe holes are drilled at constant intervals to safeguard against unexpected water or gas occurrences during shaft sinking.

Through the frozen section the ground is carefully excavated to ensure that the ice wall is not damaged. It may require presplitting or other controlled blasting techniques. The shaft is sunk to a depth of 335 meters (1,100 feet), and a 25-centimeter (10-inch)-thick preliminary concrete lining is placed concurrently with the progress of shaft sinking. A foundation for final lining is constructed at an approximate depth of 313 meters (1,025 feet). A final lining is then installed from this base upwards, leaving a gap of 15 centimeters (6 inches) between it and the preliminary lining. This final lining consists of an outer welded steel shell 1.2 centimeters (0.5 inch) thick, and about 63 centimeters (25 inches) of concrete. The welded steel shell serves as a water barrier. The annulus between the final lining and the preliminary lining is filled with bitumen. This continuous seal from the base of the final lining to about 2.4 meters (8 feet) from the surface, with interruptions of several feet each in the preliminary lining at 110 meters (360 feet) and 292 meters (960 feet), ensures isolation of the Ogallala and Dockum aquifers.

Until completion of the final lining, the freeze plant operates continuously; once the final lining is installed from 313 meters (1,025 feet) to the surface, freezing operations are discontinued. Thereafter, the shaft is sunk conventionally to its final depth, using a 25-centimeter (10-inch) concrete lining to 755 meters (2,475 feet), and installing rockbolts and wire mesh as required from 755 meters (2,475 feet) to 795 meters (2,607 feet) in the service shaft and to 816 meters (2,677 feet) in the production shaft. Concrete shaft plugs are then constructed at the shaft bottom to prevent uplift. These plugs are 5 meters (17 feet) and 4 meters (12 feet) thick in the production and service shafts, respectively.

During the process of shaft sinking below the Dockum Formation, the shafts will pass through certain formations which are subject to creep, the Dewey Lake Shales and halites in the Upper Seven Rivers and the Upper San Andres Formations. In these formations the shaft will be overexcavated by a radius of approximately 30 centimeters (12 inches), and the annulus between the preliminary lining and shaft walls will be filled with resin foam.

Since the formations below the Dockum produce only a small amount of water, the installation of the final lining below 313 meters (1,025 feet) may not be necessary and can be postponed to a later date. Small amounts of water can be collected through water rings at the shaft bottom and pumped out. The two shafts are connected by a drift at a depth of 779 meters (2,555 feet).

The foundation for the final lining, if necessary below the Dockum Formation, will be constructed at approximately 755 meters (2,475 feet). The final lining will consist of an outer 2-centimeter (0.625-inch) welded steel shell, an inner shell ranging from less than 1 to 4-centimeter (0.25- to 1.625-inch)-thick steel (depending upon the depth of the shaft at which the lining is installed), sandwiching 61-centimeter (24-inch)-thick concrete. There is a 15-centimeter (6-inch) gap between the final lining and the preliminary lining. The gap is first filled (going upwards from the foundation) 76 centimeters (30 inches) high with sanded cement grout, then 2 meters (6 feet) high with a chemical polymer seal, another 2 meters (7 feet) high with sanded cement plug, and finally with regular grout to the top of lining at 313 meters (1,025 feet). Installation of the final lining will result in a 4-meter (12-foot) finished inside shaft diameter. The design life of the shaft lining is 100 years.

Preliminary Lining. The type of preliminary support can vary from rockbolts and wire mesh in competent rock to consolidation by grouting or freezing in waterbearing materials. A single ground control system is seldom sufficient for shafts except for shallow, near-surface openings. The initial ground support for deep shafts is generally augmented by lining the shaft walls with monolithic concrete or precast concrete blocks grouted in place.

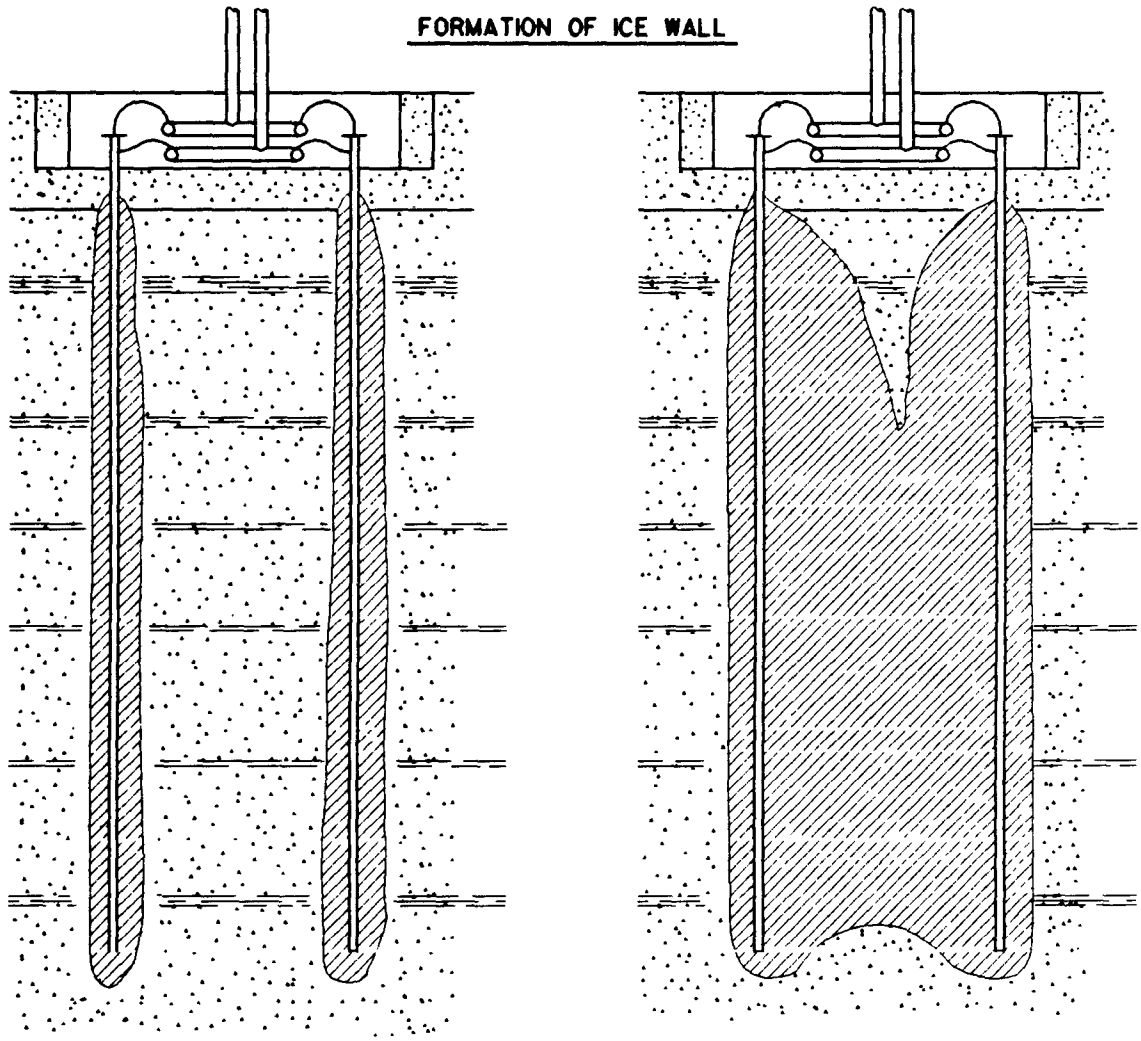
The ground support and shaft lining system used during excavation is dependent upon the stability of the free-standing shaft walls. This unsupported height, which provides some flexibility about how soon after excavation the preliminary lining is installed, is a function of the time-dependent behavior of the material being excavated. Zones of structural weaknesses, joints, and fractures may require ground support systems using steel ribs, liner plates, and shotcrete among others, which may be combined for specific intervals of shaft walls or sections of excavation. Soils or rocks too weak to support themselves long enough to place ground support systems may require pretreatment consisting of stabilization by grouting, dewatering, or by freezing the strata. Where the average rock particle size is large (perhaps greater than 5 millimeters [0.2 inch]) and the water volumes are not excessive, grouting or dewatering can be used for water control and ground stabilization. However, in unconsolidated materials with small particle size, the most frequent water control method is freezing. Freezing has been used for over 100 years as a means of stabilizing weak strata for shaft sinking (Jessberger, 1979; Braun and Nash, 1982; Shuster, 1972; Roesner, 1980). Freezing not only controls ground movement, but also prevents water from entering the shaft excavation. Figure 4-11 shows a typical ground freezing arrangement.

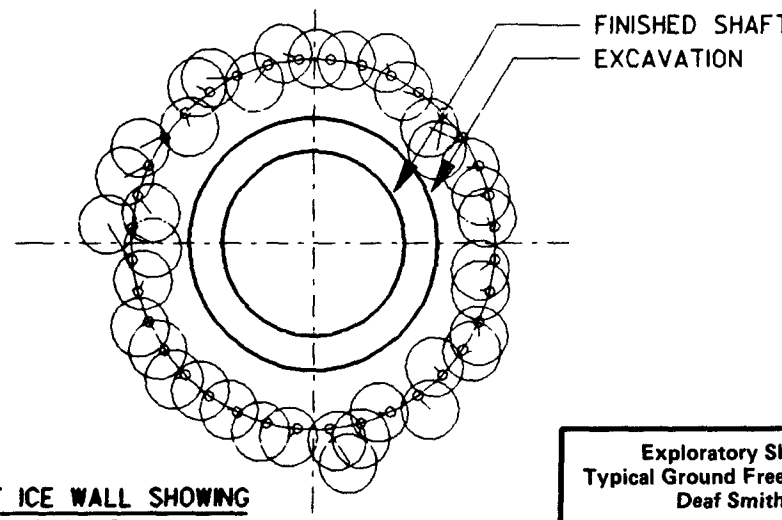
Water control in shaft construction is basically a two-phase system approach. The first phase deals with the control of water during shaft sinking while the second phase is based on the control of water inflows after construction has been completed. Water control systems employed in shaft construction are, therefore, based on the ultimate dryness criteria for the completed shaft. While the ultimate dryness is part of the design of the final shaft lining, the methods used during shaft construction can be different. Strata producing minor water inflows usually do not require any controlling action; they are either handled with the excavated rock and hoisted to the surface or collected by water rings, drained to a sump, and then pumped or bailed to the surface.

Grouting with cement slurries, resins, or gels by pressure injection has been used successfully to control water flows in shafts. Joints and fractures in impermeable rock are usually more easily sealed by grouting than are sections of permeable rocks or soils; some rocks with very fine cracks, and most soils, do not readily lend themselves to water control by grouting. In addition to grouting, water is sometimes controlled by pumping around the prospective shaft area from wells on the surface.

For deeper shafts, waterbearing soils and rocks are usually frozen. The ice wall must be designed for stability, i.e., for strength sufficient to bear the stresses acting on it. Both compressive and tensile strengths of the frozen material increases as the temperature is lowered. The temperature is lowered by circulating a freezing agent in holes drilled around the shaft. The freezing point of any solid depends on the natural salt content; the greater that salt content, the lower the freezing point, and hence the more difficult the water and soil are to freeze.

A review of the literature indicates that the technique of ground freezing has stabilized saturated sediments during the sinking of mine shafts, driving of mine drifts, tunnelling, and during foundation excavation in civil and nuclear projects. Table 4-9 summarizes the North American mining experience with ground freezing. The first ground freezing in North America was carried out in 1888 on a shaft for Chapin Mining Company in Iron Mountain, Michigan. Since this first application of the technology, at least 30 additional mine sites in North America have employed ground freezing. A majority of these shaft-freezing projects have been completed for evaporite mines. Many of these projects had similar shaft dimensions to those required for proposed repository sites, and several involved greater shaft diameters and freeze depths (Jessberger, 1979; Braun and Nash, 1982; Shuster, 1972; Roesner, 1980).





TYPICAL PLAN OF ICE WALL SHOWING COMPLETE CLOSURE

Exploratory Shaft Facility
Typical Ground Freezing Arrangement
Deaf Smith County

Figure 4-11

Table 4-9. North American Mine Shaft Ground Freezing

Mine	Location	Year Started/ Ended	Shaft Dimensions (m)	Shaft Depth (m)	Freeze Depth (m)	Type of Formation	Remarks
Chapin Mining Co.	Iron Mt., MI	1888	4 x 5		30	Glacial till	
Morton (Myles Salt Co.)	Louisiana	1901/1903	4.9	228	761	Domal salt	
Potash Corp. of America	Carlsbad, NM	1952	4.6	233	107	Bedded Potash	
Potash Corp. of America	Sask., Canada	1955	4.9	1,051	914	Bedded Potash	
International Minerals & Chemicals Corp.	Esterhazy, Sask., Can.	1957	5.5	1,030	0-70 363-437	Bedded Potash	
Morton (Weeks Island)	Louisiana	1958	5.5	243	76		
Duval Corporation	Carlsbad, NM	1963	4.26 & 3.65	305 & 279	128	Bedded Potash	
International Minerals	Esterhazy, Sask., Can.	1963/1967	5.64	1,021	468	Bedded Potash	Glacial till, Blairmore Wet dolomites and salt Freezing 0 to 473 m; Grouting 473 to 915 m
PCS[a] (Allan Potash Mines #1)	Sask., Canada	1964	4.9	1,089	625	Bedded Potash	
PCS (Allan Potash Mines #2)	Sask., Canada	1964	4.9	1,089	625	Bedded Potash	
PCS (Alwinsal Potash of Can. #1)[b]	Canada	1964	5.5	1,004	527	Bedded Potash	
Noranda Mines Ltd. #1	Canada	1965/1968	4.9	1,052	591	Bedded Potash	Glacial till, Blairmore Wet dolomites and salt Freezing 0 to 548 M; Grouting 548 to 915 m

Table 4-9. North American Mine Shaft Ground Freezing
(Page 2 of 3)

Mine	Location	Year Started/ Ended	Shaft Dimensions (m)	Shaft Depth (m)	Freeze Depth (m)	Type of Formation	Remarks
Noranda Mines Ltd. #2	Canada	1965/1968	4.9	1,052	591	Bedded Potash	Glacial till, Blairmore Wet dolomites and salt. Freezing 0 to 548 m; Grouting 548 to 915 m
Cominco Ltd.	B.C., Canada	1965/1968	4.9 & 5.64	1,089	684	Bedded Potash	Glacial till, Blairmore Wet dolomites and salt Freezing 0 to 610 m; Grouting 610 to 915 m
Potash Corp. of America	Sask., Canada	1967/1969	5.5	1,068	548	Bedded Potash	Glacial till, Blairmore Wet dolomites and salt. Freezing 0 to 548 m; Grouting 548 to 915 m
PCS (Sylvite #1)	Canada	1967	4.9	1,021	461	Bedded Potash	
PCS (Sylvite #2)	Canada	1967	4.9	1,000	469	Bedded Potash	
Cargill, Inc.	Louisiana Belle-isle	1967/1971	4.9	378	70	Domal Salt	
Cargill, Inc.	Louisiana Belle-isle	1973/1976	4.9	478	76	Domal Salt	Extensive ground investigation, ground frozen to 76 m.
PCS (Alwinsal #2)[b]	Canada	1974	4.26	1,004	527	Bedded Potash	
Amax Coal Co.	Illinois	1974	6.09	228	38	Coal	
Diamond Crystal	Louisiana	1975	2.44	470	70	Domal Salt	
Island Creek Coal Co.	Kentucky	1975	6.09	122	54	Coal	
Mortan Salt Co.	Louisiana	1977	5.5	381	64	Domal Salt	
Peabody Coal Co.	Illinois	1978	6.09	122	53	Coal	

Table 4-9. North American Mine Shaft Ground Freezing
(Page 3 of 3)

Mine	Location	Year Started/ Ended	Shaft Dimensions (m)	Shaft Depth (m)	Freeze Depth (m)	Type of Formation	Remarks
Selco Mining Corp.	Quebec, Can.	1979	3.65	61	61		
White County Coal Corp.	Illinois	1979	6.7 x 9.8	335	41	Coal	
Domtar, Inc.	Goderich, Ont.	1980	6.09	518	61	Bedded salt	Involves freezing to 107 m and grouting to 229 m.
Les Mine Salin	Mad. Is., Can.	1980	6.70	122	43	Bedded Salt	
Turris Coal Co.	Illinois	1981	5.5, 6.09 & 7.3	87	64	Coal	
Asarco Exploration	Timmons, Ont.	1981	3.65	174	43	Glacial Till	

(a) PCS: Potash Corporation of Saskatchewan

(b) The PCS's Lanigan Mine was originally built, owned, and operated by Alwinsal Potash of Canada, Ltd.

Although few problems have been encountered with the actual freezing of soils, thawing must be carefully monitored. During the thawing process, materials, especially fine-grained plastic clays, have reduced void ratio (overconsolidation) and increased vertical permeability. The geologic texture of the Ogallala is coarse to fine sands, silts, and some clays, and for the Dockum siltstone and shales, with localized beds of sandstone. The degree of reduced void ratio and increased vertical permeability, therefore, is expected to be minimal. The rate and distribution of thawing can be regulated to ensure that uniform thawing is achieved. Uniform thawing can regulate the settling of the concrete lining and reduce the possibility its being deformed.

Shaft linings may consist of rockbolts and wire mesh, brickwork, precast concrete blocks, monolithic concrete, cast iron with concrete, single and double shells of steel with concrete, and combinations of steel profiles with concrete.

The shaft lining may be bonded to the strata by grouting or separated from the strata by an annulus filled with viscous material such as bitumen. The structural load of a free-standing shaft lining in a bituminous envelope is carried by a substantial foundation. This design has the advantage of isolating the shaft liner from the stresses of mining and tectonic activities, as well as forming a continuous waterproof seal.

Final Lining. A final shaft lining constructed with monolithic concrete is the standard lining where water-tightness is not required. It may be combined with a compressible material placed between it and the shaft wall in plastic zones. This material will deform with the creeping strata and thus result in a reduction of strata pressure on the concrete lining. The concrete lining may be installed in dry or water-bearing strata.

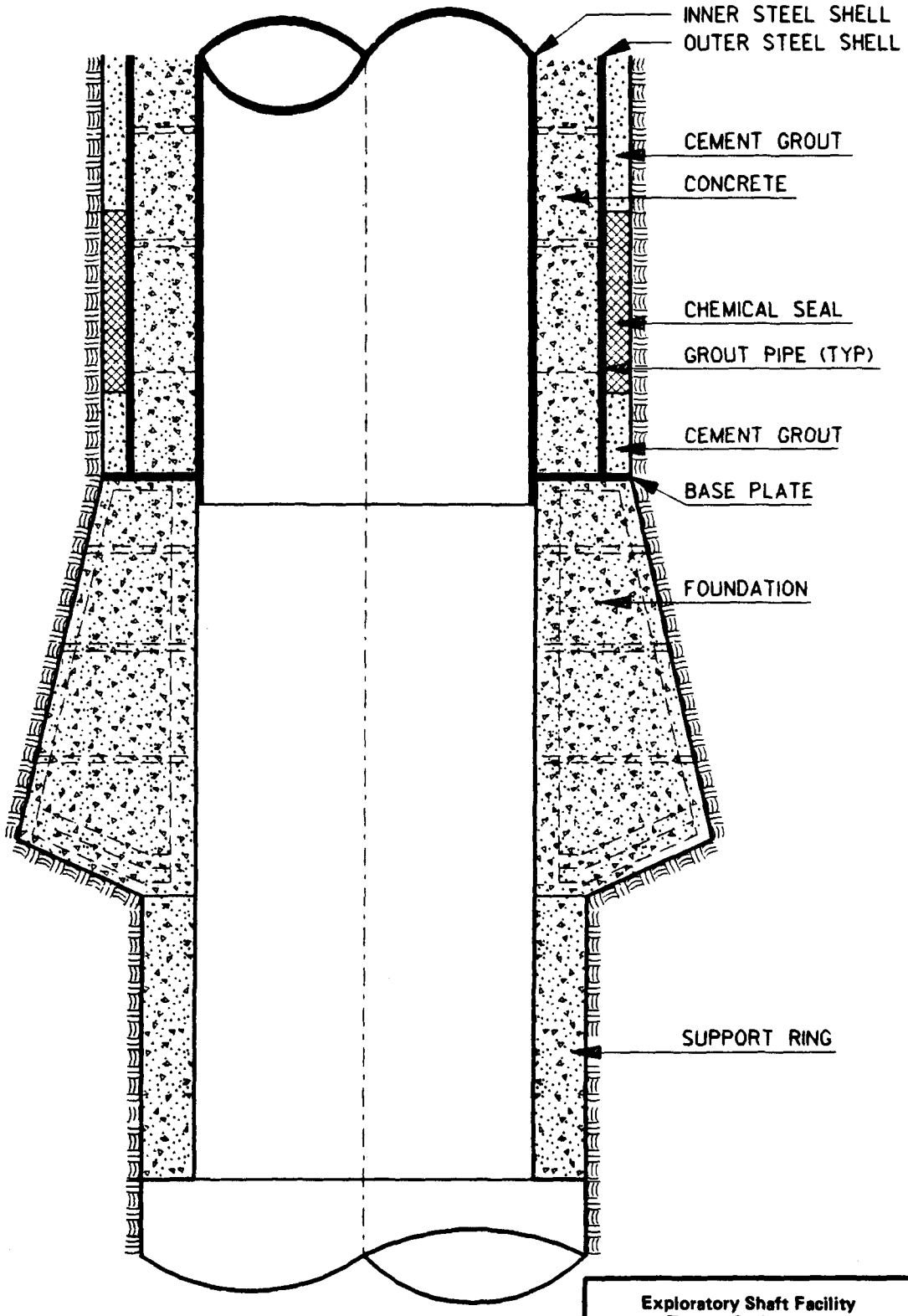
Final shaft lining which requires various degrees of watertightness may be constructed in stable and unconsolidated water-bearing strata. These linings are composed mainly of cast iron tubbings with concrete, or of various cast or rolled steel segments as a watertight membrane in combination with concrete.

Seal System. In salt and other evaporite mining operations, it is necessary to prevent the movement of water along the liner and host rock interface to ensure that progressive dissolution of salt behind the lining does not occur. A seal is also required to isolate various aquifers and prevent cross-contamination.

A seal system consists of the shaft lining, which prevents the movement of water in a horizontal direction, and a shaft seal between the liner and the host rock to prevent water movement in a vertical direction. The seal system thus consists of the host rock in which the seal is placed, the seal material itself, and the shaft lining. The location of the seal below an aquifer and above the salt bed is, therefore, an important consideration since a seal is only as effective as the rock in which it is placed. It should be located in an impervious rock.

Three types of seals are in common usage. The traditional sealing method used with cast iron tubbing, commonly used in water-bearing rocks in early mining practice, employs a wedge ring set between the tubbing rings. This wedge ring has a greater horizontal depth than the rings above and below. The space between the wedge ring and the shaft walls is sealed by hammering in precisely cut wooden wedges, or "pikotage," until the space is so tightly packed that even a tapered steel needle can not be driven in. The wood, when it comes in contact with water, expands and the seal is further tightened. The material cost for this type of seal is low, but the labor cost and installation time requirements are high.

For complete effectiveness, chemical seals are currently in use, especially in salt and potash mines. These chemical seals use a polymeric sealing compound called chemical seal ring (CSR). CSR mixed with gravel is placed as a pumpable slurry pliable enough to penetrate the cracks. This polymer material expands considerably when it comes into contact with water, further tightening the seal. The slurry hardens to form an insoluble plastic solid. The design allows for pressurizing this seal for greater effectiveness. A schematic design for such a seal system is shown in Figure 4-12.



Exploratory Shaft Facility
Typical Seal System
Deaf Smith County

Figure 4-12

The third form of seal uses a continuous column of asphalt or bitumen from below the lowest aquifer to within a few feet of the surface. In this system, the annular space between the lining and the shaft walls is filled with a mixture of asphalt and limestone blended to a specific gravity slightly higher than that of brine. Since the hydrostatic head of the asphalt mixture is higher than the brine head, the mixture flows into any cracks that may be present.

Surface Facilities Construction. Surface facilities will be erected concurrently with shaft construction operations. Included are the fuel storage system, excavated material storage areas, evaporation and retention and sediment detention ponds, sewerage system, water supply system, power system, fire protection system, safety system, shaft buildings, and services. The resources to be consumed during this phase are listed in Table 4-7.

Diesel fuel would be stored on site in a buried fiberglass storage tank with a capacity of approximately 162,755 liters (43,000 gallons). The tank would be located near the standby turbine generators which are the primary fuel users. The supply level would be monitored by a liquid-level gage, wall-mounted in the generator building. Leak detection requirements as applicable at the time of installation will be satisfied.

The storage area will accommodate a mixture of overburden and interbedded salt estimated to be approximately 53,500 cubic meters (70,000 cubic yards), nonsalt-contaminated overburden estimated to be approximately 34,400 cubic meters (45,000 cubic yards), and salt from the shaft and drifts estimated to be approximately 130,000 cubic meters (170,000 cubic yards). The storage area capacities shown in Table 4-3 exceed the anticipated volume of excavated materials.

Liners will be used to prevent possible leaching of brine into the ground. The liners can be natural (clays) or synthetic (polyvinyl chloride, polyethylene, or polypropylene). The existing topsoil will be stripped and an engineered subbase established before the liner is emplaced. If a synthetic liner is used, an additional layer of compacted backfill material will be placed on top of the liner so that heavy equipment can move across it without causing damage.

When salt is exposed to the weather, a hard surface crust that tends to shed rain water forms in a few days (Ver Planck, 1958; DOE, 1983, WIPP-DOE-161). According to the experience of the salt industry, stockpiled salt is not a source of wind-blown particles, and crusting can be accelerated by wetting the pile. Freshly deposited material will be wetted after spreading and compacting to mitigate any wind effects.

It is possible that during salt handling, that is, transferring the salt from the hoist system to trucks or other conveyances and building the salt pile (on the pile working surface), salt particles may become windblown.

Salt-contaminated and potentially salt-contaminated runoff from the shafts area, haul roads, and mined material stockpiles will be collected by a system of lined drainage ditches which gravity-flow to an evaporation and retention pond. Water collected in the production and service shaft sumps will be pumped to the lined ditches for collection at the evaporation and retention pond. The ditches will be sized to convey the runoff from a 500-year storm of a duration and intensity based on the time of concentration of the local watershed. This will allow the drainage ditches to have the capability to convey short duration storms which produce higher peak flows than a 24-hour storm event.

The evaporation and retention pond will be sized to provide an operational volume equivalent to 100 percent of the rainfall volume from a 500-year, 24-hour storm falling on the areas of salt and potential salt contamination. The maximum volume of the pond will include an additional 61 centimeters (2 feet) of freeboard above the operational level. The pond will be designed to the maximum extent practicable to take advantage of the high evaporation rates applicable in this region.

If during design it becomes evident that the goal of total evaporation of the water cannot be achieved due to area or depth constraints of the pond, the water would be periodically removed for transport to an acceptable, offsite disposal facility. Disposal of similar liquids (brines) is a common practice in the oil industry.

The current design concept for the evaporation and retention pond and its system of drainage ditches is a double liner constructed of suitable materials to prevent salt-contaminated water from seeping into the ground. Lining brine ponds is commonly practiced in the oil and salt industries (Staff Industries, Inc., 1983). Ponds as large as 20 hectares (50 acres) have been successfully lined with polyvinyl chloride membranes where the liner is not exposed to direct sunlight, or chlorinated polyethylene with fabric reinforcement where the liner is exposed to sunlight. Natural materials such as brine-resistant clay can also be used with or in place of synthetic liners.

The evaporation and retention pond liners are installed over an engineered subgrade with one or more networks of perforated pipes in an aggregate backfill separated by one or more liner systems. The perforated pipe system connects to vertical pipes which terminate above finished grade at the perimeter of the pond. These vertical pipes serve as a gas vent for gases which may collect under the membranes and a monitoring well for the effectiveness of the liner system to contain liquids (leachate) above the liner. Monitoring wells, if necessary, can also function as wells through which to pump out leachate for transport to an acceptable offsite disposal facility. The observation wells will be sampled frequently to ensure the integrity of the liner system.

Runoff from areas not subject to salt contamination, such as the administration area, parking area, topsoil stockpile, and roads not used for hauling mined material, will be collected in drainage ditches which gravity-flow to the sediment detention basin. The basin will be designed to contain 100 percent of the rainfall volume from a 25-year, 24-hour storm falling on the noncontaminated areas. The design of the sediment basin will provide sufficient retention time to settle suspended solids to the extent necessary to meet discharge parameters for solids concentration.

The efficiency of the sediment pond to accomplish solids removal may be increased by the addition of baffles, partitioning, inlet energy dissipator, coagulants, or siphon-type riser and spillway design. Periodic removal of collected sediment for transport to an acceptable offsite disposal facility will be required.

The drainage ditches to convey runoff to the sediment pond will be designed for a 25-year storm of a duration and intensity related to the time of concentration in the local watershed. This allows the drainage system to convey short-duration storms that produce higher peak flows than a 24-hour storm.

A system of subsurface pipes will carry sanitary wastes to a treatment facility. During construction, the collection system will be supplemented by chemical toilets. These wastes will be trucked to an offsite treatment facility. The onsite wastewater treatment and disposal facility will have a capacity of about 49,400 liters per day (13,000 gallons per day) designed to service project and construction personnel. The aerated waste sludge will be periodically transported to a permitted offsite disposal facility.

Oily wastewater from surface facilities, such as the maintenance shop, firetruck garage, and mechanical equipment room, will also be collected by the network of subsurface sanitary piping. Oil and water separators will be provided in the appropriate maintenance drains in the service building, generator building, and other buildings which may have oil or grease contributions. Effluent from the oil and water separators will flow to the sanitary waste collection system. Liquids from the oil and water separators, waste cleaners, solvents, thinners, and other similar materials that may be hazardous will be properly disposed of off site in a licensed facility. Solid waste such as wood, metal, plastic, and paper generated at the ESF site will be collected for offsite disposal.

The potable water system is a pressurized distribution network required for domestic and construction usage. Water will be supplied by wells located on site. Sufficient ground water exists at the site to satisfy the expected average ESF demand of 147,600 liters (39,000 gallons) per day.

Commercial sources are preferred for onsite power, to be supplemented by three diesel generators for emergency power. This arrangement will require a new power line to deliver the electrical service from the utility-selected connect point to the site. The poles for the new line will probably be located along existing roads, then along the access road right-of-way to the site, thereby requiring minimal clearing and grubbing.

The ESF fire protection system will provide detection and alarms for smoke, gases, and fires in designated surface structures and in the subsurface area. The water supply for the fire protection system will be stored in a dedicated tank with a capacity of about 227,000 liters (60,000 gallons), which would provide a 2-hour water supply for fire fighting. Chemical fire suppression systems, including Halon, foam, dry chemical, and carbon dioxide where applicable, will be used in those areas where water is not suitable. A four-wheel-drive firetruck, a foam truck, and an ambulance will be located in the security building. Fire and smoke detectors will be installed in the buildings and will activate audible alarms and extinguishing systems.

The operating status of all safety systems will be monitored to assure proper performance. Especially important will be methane and hydrogen sulfide gas detectors located in the shafts and subsurface workings. If excessive gas levels are detected, alarms will sound on underground mining equipment as well as in monitoring rooms on the surface. Individual detectors provided on heavy equipment in the subsurface workings will give an audible alarm and automatically shut off equipment if a gas concentration above a preselected level is detected.

Prefabricated buildings will house the equipment and systems in the activity area. These buildings will provide 6,500 square meters (70,000 square feet) of working area, including the various office and laboratory facilities required for the project. The equipment associated with shaft and surface facility construction is listed in Table 4-10; resources to be consumed are summarized in Table 4-7.

Based on expected staffing for this phase, average daily automobile traffic will increase from baseline levels to include approximately 280 round trips to the site by passenger vehicles per day. Truck traffic would result in an additional increase from baseline levels to include approximately 270 round trips to the site by trucks per month based on the quantities of fuel, building material, and other items required. These values are for both shaft and surface facilities construction activities and represent the maximum increase in vehicular traffic for the ESF. The estimated vehicular traffic during the shaft construction and testing periods is given in Table 4-8.

Worker Health and Safety. Provisions for health and safety will be provided at key points throughout the subsurface and surface facilities. These provisions will include subsurface refuge chambers, Mining Safety and Health Administration (MSHA)-approved self-rescuers, first aid kits, and an onsite ambulance.

The Mine Safety and Health Administration (MSHA) is authorized to administer and enforce certain kinds of safety and health standards for protecting employees in the mining industry, pursuant to the Mine Safety and Health Act of 1977 (30 USC Section 801 et. seq.). The question of formal involvement of MSHA with the Civilian Radioactive Waste Management program is not resolved at this stage. The principal design, construction, and operating features of the exploratory shaft facility will include provisions for worker protection by following the relevant requirements of "Safety and Health Standards - Metal and Nonmetal Underground Mines" (30 CFR Part 57). Fire control, ventilation, illumination, and use of equipment and explosives are being designed to comply with MSHA regulations governing gassy mine conditions.

Table 4-10. Equipment for Shaft and Surface Facility Construction Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
SHAFT CONSTRUCTION				
Freeze Plant for Production Shaft (7 months)	2	Freeze hole drill rigs	1,500	3,000
	1	Freeze plant	1,350	-
	1	Pickup truck		135
				3,135/135
Sinking Plant Set-up for Production Shaft (5 months)	1	Crane	180	180
	1	Forklift	50	50
	1	Truck	250	250
	2	Welding rigs	50	100
	1	Wheel loader	270	270
	1	Backhoe	135	135
	1	Mobile compressor	50	50
	1	Vent fan	25	-
	1	Pickup truck	135	135
				1,170
Shaft Sinking for Production Shaft (11 months)	1	Forklift	50	50
	1	Crane	180	180
	1	Hoist	1,000	-
	4	Stage hoists	40	-
	1	Vent fan	60	-
	3	Compressors	200	-
	1	Mucker winch	20	-
	1	Batch plant	70	-
	1	Truck	250	250
	1	Wheel loader	270	270
	1	Welding rig	50	-
	1	Freeze plant	560	-
	1	Oiler	200	200
	2	Pickup trucks	135	270
				1,220
Final Lining Installation for Production Shaft (11 months)	1	Forklift	50	50
	1	Freeze plant	560	-
	1	Vent fan	60	-
	1	Hoist	1,000	-
	1	Compressor	80	-
	1	Batch plant	70	-
	1	Truck	250	250
	3	Welding rigs	50	-
	4	Stage hoists	40	-
	1	Crane	180	180
	1	Wheel loader	270	270
	1	Oiler	200	200
	2	Pickup trucks	135	270
				1,220

Table 4-10. Equipment for Shaft and Surface Facility Construction Stage
(Page 2 of 3)

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Freeze Plant for Service Shaft (7 months)	2	Freeze hole drill rigs	1,500	3,000
	1	Freeze plant	1,350	1,350
	1	Pickup truck	135	135
				3,135/135
Sinking Plant Set-up for Service Shaft (5 months)	1	Crane	180	180
	1	Forklift	50	50
	1	Truck	250	250
	2	Welding rigs	50	100
	1	Wheel loader	270	270
	1	Backhoe	135	135
	1	Mobile compressor	50	50
	1	Vent fan	25	-
	1	Pickup truck	135	135
				1,170
Shaft Sinking for Service Shaft (11 months)	1	Forklift	50	50
	1	Crane	180	180
	1	Hoist	1,000	-
	4	Stage hoists	40	-
	1	Vent fan	60	-
	3	Compressors	80	-
	1	Mucker winch	20	-
	1	Batch plant	70	-
	1	Truck	250	250
	1	Wheel loader	270	270
	1	Welding rig	50	-
	1	Freeze plant	560	-
	2	Pickup trucks	135	270
				1,020
Final Lining Installation for Service Shaft (11 months)	1	Forklift	50	50
	1	Freeze plant	560	-
	1	Vent fan	60	-
	1	Hoist	1,000	-
	2	Compressors	80	-
	1	Batch plant	70	-
	1	Truck	250	250
	4	Welding rigs	50	-
	4	Stage hoists	40	-
	1	Crane	180	180
	1	Wheel loader	270	270
	2	Pickup trucks	135	270
				1,020

Table 4-10. Equipment for Shaft and Surface Facility Construction Stage
(Page 3 of 3)

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Surface Facility Construction (7 months)	1	Batch plant	70	-
	2	Concrete finishers	7	14
	2	Cranes	180	360
	1	Forklift	50	50
	2	Trucks	250	500
	2	Welding rigs	50	-
	1	Backhoe	135	135
	1	Track loader	65	65
	1	Compressor	200	-
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,459
Service Facilities for Production Shaft (2 months)	1	Forklift	50	50
	1	Crane	180	180
	1	Batch plant	70	-
	1	Truck	250	250
	1	Welding rig	50	-
	1	Compressor	200	-
	1	Backhoe	135	135
	1	Track loader	65	65
	1	Concrete finisher	7	7
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,022
Service Facilities for Service Shaft (4 months)	1	Track loader	65	65
	1	Backhoe	135	135
	1	Forklift	50	50
	1	Crane	180	180
	1	Batch plant	70	-
	2	Trucks	250	500
	2	Welding rigs	50	-
	1	Compressor	200	-
	2	Concrete finishers	7	14
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,279

Specific areas of interest in maintaining occupational safety during mining include the following:

- Mining methods
- Fire prevention and control
- Working environment
- Ventilation systems
- Materials handling and storage
- Underground utility systems
- Occupational safety programs and personnel protection
- Emergency plans
- Inspection, testing, and maintenance.

The Occupational Safety and Health Administration (OSHA) administers the Occupational Safety and Health Act of 1970 (29 CFR Part 1910), as amended. The purpose of OSHA is to establish standards with which industries are generally familiar, and on whose adoption interested and affected persons have already had an opportunity to express their views. Such standards are either (1) national consensus standards whose adoption is commonly agreed upon, or (2) Federal standards already established by Federal statutes or regulations. The DOE will utilize the OSHA regulations, in particular, "Occupational Safety and Health Standards" (29 CFR Part 1910), and "Safety and Health Regulations for Construction" (29 CFR Part 1926), as applicable.

MSHA has compiled statistics regarding recent injury experience in the nonmetal (except coal and stone) mining industry. During the period 1976 through 1982, an average of 5.86 injuries (values range from 4.57 in 1982 to 7.62 in 1978) were reported for labor and administrative personnel for every 250,000 work hours. This same group experienced an average of 0.04 fatality (values range from 0.03 to 0.05) per 250,000 work hours over this same period.

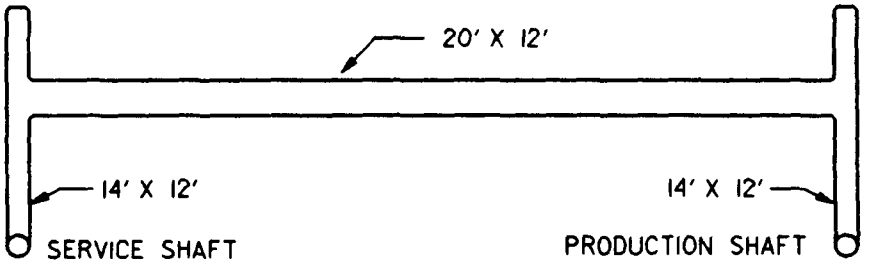
Based on MSHA's experience, during the 5-year life of the ESF project, with approximately 2.94 million work hours, 69 injuries and 1 fatality are projected.

However, by rigid implementation of DOE Orders 5480.1A and 5480.4 for "Environmental Protection, Safety and Health Protection Program for DOE Operations," the actual injury experience should be less than projected.

4.1.2.2.3 Initial Subsurface Excavation. A shaft station consisting of approximately 46 linear meters (150 linear feet) of drifts will be developed from both shafts. The initial drifts will be excavated by conventional drill-and-blast methods. A small load, haul, and dump scooptram will be used to move muck for hoisting to the surface.

The initial excavation, shown in Figure 4-13, consists of approximately 252 meters (825 feet) of linear excavation (which includes the 46 meters [150 feet] constituting the shaft station) with a general cross section varying from 3.6 by 4.3 meters (12 by 14 feet) to 3.6 meters by 6 meters (12 feet by 20 feet). Excavation may be performed initially by drill and blast until continuous miner can be assembled under the surface. The initial excavation stage will support some of the requirements for testing, which will be performed concurrently with the expanded excavation of the connection drift. When the connection drift and shaft outfitting are completed, ventilation and alternate egress from the subsurface workings sufficient to support the testing phase will be provided. Figure 4-7, the exploratory shaft facility construction and testing schedule, illustrates the relationship between subsurface excavation and the testing programs.

By this time, most construction materials will have been delivered, and vehicular traffic will begin to decrease. Vehicular traffic is expected to increase from baseline levels to include approximately 220 round trips to the site by passenger vehicles per day and 95 round trips to the site by trucks per month, as given in Table 4-8. Equipment necessary for this phase of construction is listed in Table 4-11 and the resources consumed are summarized in Table 4-7.



Exploratory Shaft Facility Subsurface Plan – Initial Underground Excavation Deaf Smith County

Figure 4-13

Table 4-11. Equipment for Initial Underground Excavation Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
INITIAL UNDERGROUND EXCAVATION (2 months)	1	Wheel loader	270	270
	2	Vent fans	60	-
	1	Auxiliary fan	25	-
	1	Hoist	1000	-
	1	Hoist	500	-
	8	Stage hoists	40	-
	2	Compressors	200	-
	1	Mucker winch	20	-
	1	Continuous miner	410	-
	2	Welding rigs	50	-
	1	Scooptram (5 cu. yd.)	150	150
	1	Crane	180	180
	1	Forklift	50	50
	1	Truck	250	250
	1	Oiler	200	200
	2	Pickup trucks	135	270
				1,370

Table 4-12. Equipment for Shaft Outfitting Stages

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
OUTFITTING Production Shaft (3 months)[a]	1	Vent fan	60	-
	1	Crane	180	180
	2	Forklifts	50	100
	4	Stage hoists	40	-
	1	Hoist	500	-
	1	Compressor	80	-
	2	Welding rigs	50	-
	1	Pickup truck	135	135
				415
OUTFITTING Service Shaft (3 months)[a]	1	Vent fan	60	-
	1	Crane	180	180
	2	Forklifts	50	100
	1	Hoist	500	-
	4	Stage hoists	40	-
	1	Compressor	80	-
	2	Welding rigs	50	-
	1	Pickup truck	135	135
				415

(a) Should a full final liner be necessary, an additional 5 months will be required.

4.1.2.2.4 Outfitting. Outfitting is the equipping of the shafts with conveyances and utilities necessary for testing and drift excavation. The shaft outfitting phase will commence after completion of initial underground excavation. The installation and construction of shaft service facilities will coincide with shaft outfitting. These facilities include a permanent ventilation system, the tie in with site utilities (power and communications) and a shaft service building.

Both shafts are to be outfitted to accommodate underground excavation and testing. The service shaft will be outfitted for personnel access and will supply the underground workings with fresh air and utilities. The production shaft will be used for transporting muck to the surface during excavation for the subsurface exhaust, and for redundant utilities.

The increase to local traffic over baseline levels during outfitting is estimated at 280 round trips to the site by passenger vehicles per day and 25 round trips to the site by trucks per month. These values are given in Table 4-8. The equipment associated with the outfitting is listed in Table 4-12 and the resources consumed are listed in Table 4-7.

4.1.2.2.5 Subsurface Excavation. In situ testing will occur concurrently with subsurface excavation. The ESF consists of an additional 1,401 linear meters (4,595 linear feet) of drifts (Figure 4-14) with a cross section from 4.3 meters wide by 2.4 meters high (14 feet by 8 feet) to 6.1 meters wide by 7.3 meters high (20 feet by 24 feet). Equipment necessary for this phase of construction is listed in Table 4-13; primary consumable resources are listed in Table 4-7. Vehicular traffic is expected to increase from baseline levels to include 250 round trips to the site by passenger vehicles per day and 40 round trips to the site by trucks per month (Table 4-8).

4.1.2.3 Testing

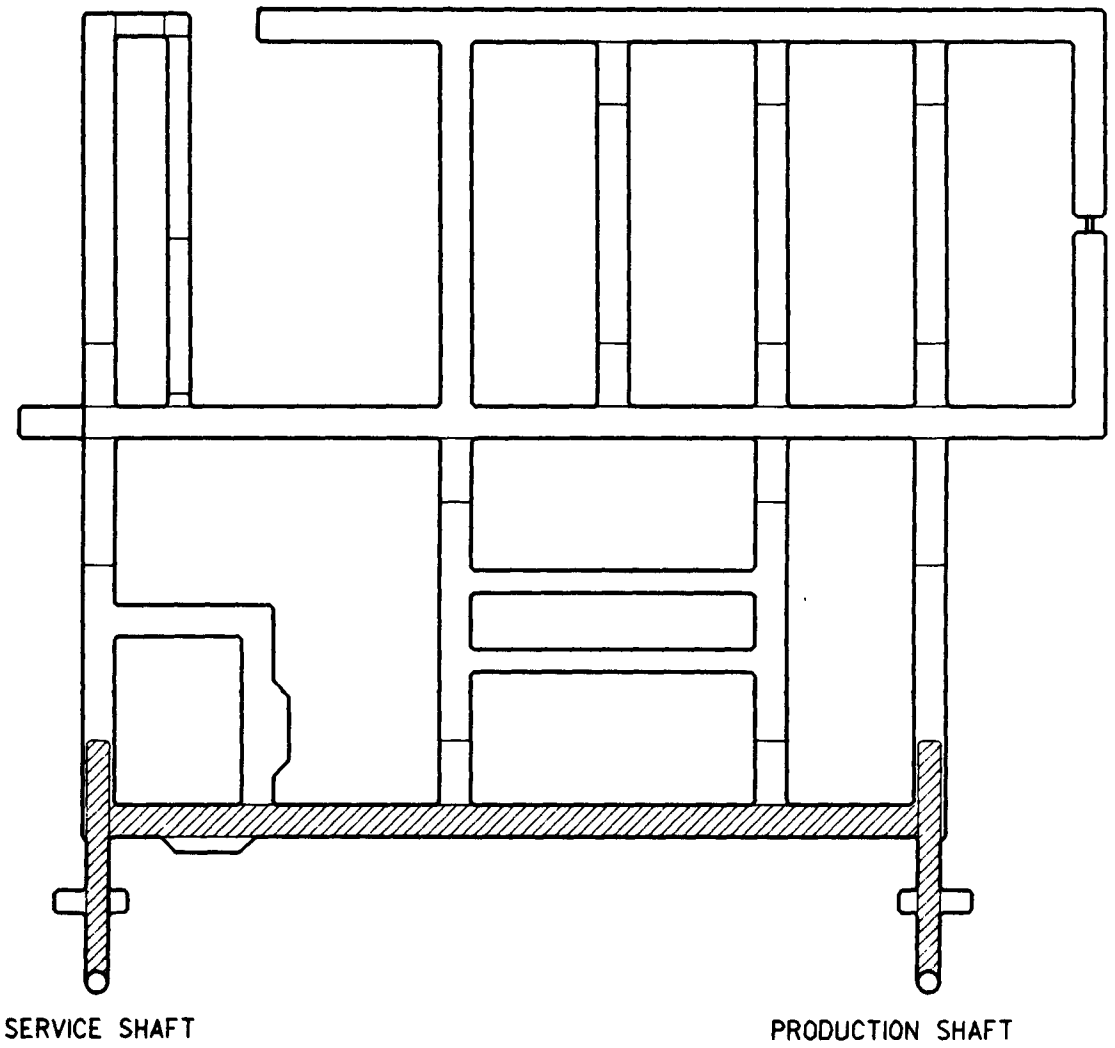
A test plan for the candidate salt sites has been developed. This plan (1) outlines a proposed program of in situ testing which constitutes part of overall efforts to determine site suitability for development as a repository, (2) provides data for repository design and performance assessments, and (3) prepares licensing documentation for radioactive waste disposal in salt. The latter includes compliance with the regulatory requirements for performance [e.g., 10 CFR 60.113 (a)(2)], information [e.g., 10 CFR 960.4-2-1 (b)(4)(i)], and testing (e.g., 30 CFR 57.3-53).

The proposed test methods can be categorized as being either surface-based within boreholes drilled from the surface in the laboratory or within an in situ test facility. All available test methods are being considered because many information needs may be more satisfactorily addressed by surface-based and laboratory testing, thus possibly eliminating the need for certain in situ tests. However, in situ tests are generally more suitable for model validation or design evaluation.

Testing will be performed in two phases. The first phase, construction testing, starts with the beginning of shaft construction and ends when the shafts are connected under the surface. Specifically, construction testing includes such activities as:

- Initial monitoring of shaft behavior
- Initial monitoring of aquifer seal performance
- Horizon selection and verification
- Geologic mapping of shafts
- Geologic mapping of initial subsurface openings
- Blasting performance monitoring
- Initial air quality measurements
- General observations of subsurface stability
- Documenting any evidence of ground-water inflow or seeps
- Initial ground closure observations.

Following completion of the underground connection between the two shafts, the second phase of testing can begin. This second phase of testing, in situ testing, will include



NOTES:

1. Room Size Varies from 14'w x 8'h to 20'w x 24'h
2. Initial Excavation
3. Expanded Excavation

Exploratory Shaft Facility
Subsurface Plan –
Expanded Underground Excavation
Deaf Smith County

Figure 4-14

Table 4-13. Equipment for Expanded Underground Excavation Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
UNDERGROUND EXCAVATION (6 months)	1	Wheel loader	270	270
	1	Hoist	1,000	-
	1	Scooptram (2 cu. yd.)	100	100
	2	Scooptram (5 cu. yd.)	150	300
	2	Trucks	250	500
	2	Continuous miners	410	-
	1	Roof bolter	40	-
	1	Scaler	85	85
	2	Auxiliary fans	50	-
	1	Crane	180	180
	1	Forklift	50	50
	2	Pickup trucks	135	270
				1,755

Table 4-14. Proposed In Situ Test Program

Geology	Thermomechanics
Geologic Mapping (Exploration Drifts)	Thermal Conductivity Probe
Drilling (Core Sampling/Field Logging)	Canister Scale Heater Test
Geophysical Well Logging	Facility Thermal Response Monitoring
Electric Surveys	Room Backfill Test
Underground Gravity Surveys	Room Scale Heater Test
Radar Probing	**Geohydrology**
Seismic Surveys	Single Borehole Hydraulic Conductivity Test
Seismicity Monitoring	Cross-Hole Hydraulic Conductivity Test
Block Sampling (for Laboratory Testing)	Cross-Hole Tracer Test
Geomechanics	Tracer Diffusion Test
In Situ Stress Measurement	Borehole Seal Performance Test
Borehole Pressuremeter/Jacking	Room Seal Performance Test
Borehole Condition/Convergence Monitoring	Brine Migration Test
Torsional Shear Test	Grout Injection Test
Acoustic Emission Monitoring	Facility Hydrological Response Monitoring
Mine-by Test	**Geochemistry**
Rock Bolt Pullout Test	Formation Fluid Sampling
Facility Mechanical Response Monitoring	

Table 4-15. Equipment for Testing Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
TESTING (3 years)	4	Auxiliary fans	25	-
	1	Vent fan	350	-
	1	Vent air conditioning system	900	-
	1	Hoist	500	-
	1	Compressed air system	200	-
	-	Test equipment	80	-
	-	Heaters	260	-
	1	Forklift	50	50
	1	Shop (Subsurface)	80	-
	2	Core drills	50	-
	1	Dewatering System	200	-
	1	Scooptram (2 cu. yd.)	100	100
	1	Utility truck	100	100
	1	Crane	180	180
	1	Shop (Surface)	150	-
	1	Oiler	200	200
	2	Pickup trucks	135	270
				900

on-going construction testing activities such as geologic mapping and geomechanical and hydrological performance monitoring of the expanded facility. In addition, detailed site characterization testing (e.g., in situ stress measurement, in situ strength of bedding surfaces, thermal conductivity, hydraulic conductivity, etc.) will be undertaken during and immediately following the completion of ESF construction. Finally specific engineered system designs will be evaluated, and performance and design models validated by a series of major in situ tests (e.g., canister scale and room scale heater tests, backfill tests, etc.). The in situ testing phase will support the environmental impact statement and the license applications.

The in situ testing program consists of five major categories, each category being supported by a suite of specific tests. Table 4-14 lists the categories and their respective tests. Details of the current test program for the salt sites can be found in the "Draft Test Plan for In-Situ Testing in an Exploratory Shaft in Salt" (Golder Associates, 1985).

An estimate of the equipment required to conduct testing is identified in Table 4-15. Resources expected to be consumed during the testing period can be found in Table 4-7. Vehicular traffic for this phase is expected to increase from baseline levels to include approximately 250 round trips to the site by passenger vehicles per day and 90 round trips to the site by trucks per month.

4.1.2.4 Final Disposition

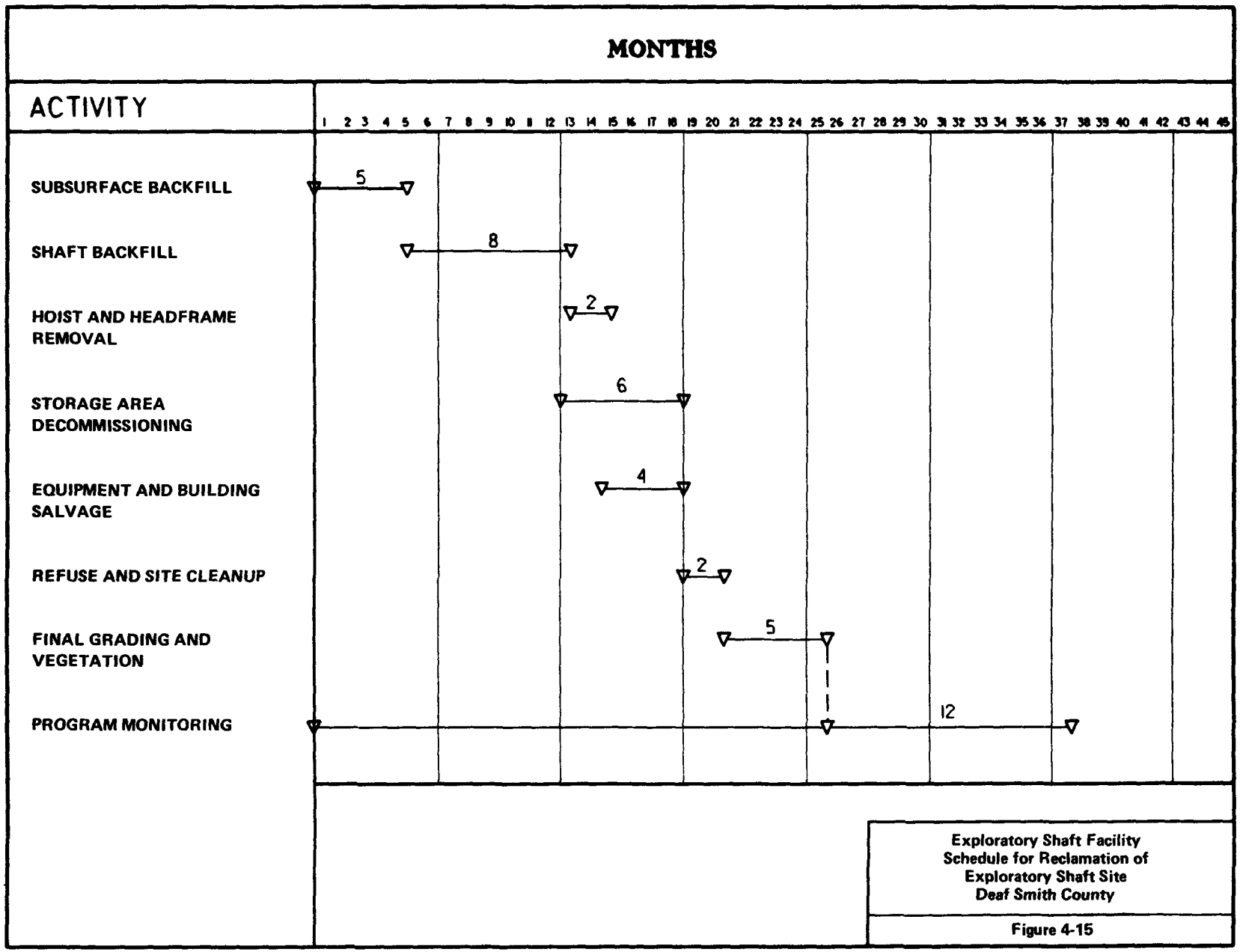
If the site is found suitable and is selected for the first repository, part or all of the exploratory shaft facility may be incorporated into the repository design. If the site is not selected for the first repository but is considered as an option for the second repository, the site, including all buildings, the headframes, and the access road, will be kept operational and fully secure.

If the site proves unsuitable for further development, it will be restored as closely as possible to its original condition. Site restoration will proceed in accordance with applicable Federal and State regulations, including the following:

- Filling the subsurface excavations and the shafts with stored salt and other mined rock, as needed, to provide structural stability
- Limiting the use of salt or salt-contaminated material to layers below potable water-bearing strata to protect water quality
- Placing concrete, polymer seals, clay plugs, or some combination at required intervals to prevent vertical migration of water; one plug will be located at the bottom of the lined portion of each shaft
- Disposing of excess salt off site
- Removing buildings, temporary pipelines, and other surface facilities, including the electricity and communication lines
- Returning the site to its approximate original contour, including the site access road (topsoil stockpiled on site will be used as needed)
- Topsoiling, mulching, reseeding, and revegetating the disturbed areas.

Estimates are that site restoration could take approximately 26 months (Figure 4-15). The actual time needed for site restoration will be based on the final reclamation plan which will be prepared in accordance with applicable Federal, State, and local regulations. The necessary activities and the sequence could be as follows:

- Subsurface backfill
- Shaft backfill
- Hoist and headframe removal



Exploratory Shaft Facility
Schedule for Reclamation of
Exploratory Shaft Site
Deaf Smith County

Figure 4-15

- Surface storage area reclamation
- Equipment and building salvage
- Excess salt disposal
- Refuse and site cleanup
- Final grading, topsoil replacement, and revegetation.

The current plans for site characterization at the Deaf Smith County site do not include the use of high-level radioactive waste. Therefore, no decontamination of the site is required after site characterization.

4.1.2.4.1 Subsurface Backfill. The subsurface backfilling will begin by setting up a bulkhead in the center of the connection drift and working back toward each shaft, then backfilling the test alcoves and drill set-up areas farthest from the shaft stations and working forward. Previously excavated salt stored above ground in the salt storage stockpile area will be transported by truck from the stockpile to the headframes and loaded into crusher units that will reduce the salt to a size acceptable for transport down to the shaft stations. Backfilling the drift areas using a pneumatic stowing system will assure that void areas will be filled to approximately 65 percent of the original in situ salt density. This will facilitate proper roof support and ground stabilization for the test alcoves, drill set-up areas, and main access drifts.

As the farthest drift areas are completely backfilled, the pneumatic stowing operation will work back to the shafts until the subsurface drift area has been completely backfilled, including the shaft station and sump areas. Pneumatic stowing will continue placing crushed salt in the unlined portion of the shafts to the bottom of the lining of each shaft. Excess salt will be disposed of off site.

Concrete plugs with polymer seal rings will be constructed at the location of the seals at the bottom of the lining of each shaft. A keyway will be cut into the shaft walls. The concrete plugs will then be poured into place.

4.1.2.4.2 Shaft Backfill. After the concrete plugs are in place, the remaining section of the shafts will be backfilled. The backfill material to be used in the shaft will be salt-contaminated mined material up to the base of the potable aquifer. Concrete plugs with polymer seals will be located at the base of the potable aquifer and will isolate the salt-contaminated backfill. Above the plugs, uncontaminated mined materials will fill the part of the shafts that extend through the aquifers of the Dockum Group and Ogallala Formation to within approximately 5 meters (17 feet) of the surface.

Final concrete plugs approximately 3 meters (10 feet) thick will then be constructed. The remaining 2.1 meters (7 feet) above the plugs will be backfilled with surface material and topsoil. The final concrete seals and caps will be below the root zone of crops and the normal cultivation zone. The plugs will be designed to support the backfill weight and activity that will be conducted over it in the future. These final seals and caps will also prevent the seepage of ground water into the abandoned, backfilled shafts.

4.1.2.4.3 Hoist and Headframe Removal. When shaft backfilling operations are complete, equipment will be removed from the shaft collar areas. The headframe foundations, structural steel supports, and shaft collars will be removed to a depth of 2.1 meters (7 feet), the depth of the shaft plugs and surface material backfilling. The final concrete seals and caps will be below the root zone of crops and the normal cultivation zone.

4.1.2.4.4 Surface Storage Area Reclamation. The drainage system around the shafts, which empties into the storage area, will be kept intact until backfilling has been completed. The remainder of the mined materials stockpiled in the storage area will be removed from the site and disposed of in a permitted offsite landfill.

The sediment pond will be maintained throughout the reclamation period until the disturbed area is restored, vegetation requirements met, and all drainage entering the basin meets the applicable State and Federal water quality requirements. The sediment pond will be reclaimed after final site grading, soil stabilization, and revegetation.

The evaporation/retention pond will remain functional until all stockpiled material is removed and all associated salt-contaminated soil is properly disposed of. The concrete pavement around the shaft houses and service buildings and the subsurface drainage system will be removed before the evaporation/retention pond is reclaimed. Fluids in the pond will be reduced by evaporation and residuals transported to an acceptable offsite disposal area.

The liner under the storage area will be removed in such a way that it does not contaminate the soils beneath. Once the material and liner are removed, the pit will be backfilled with acceptable material and graded to a final configuration consistent with the surrounding topography and land-use patterns.

4.1.2.4.5 Equipment and Building Salvage. Salvageable items are to be separated, stockpiled in a protective manner, and prepared for offsite salvage. All buildings and structures are to be emptied of their contents, disassembled, and trucked off site. All unsalvageable items will be disposed of in an appropriate offsite landfill.

Underground utilities less than 61 centimeters (24 inches) from the final reclamation grade will be removed from the site. Utilities that are buried at depths greater than 61 centimeters (24 inches) will be left in place unless they are considered a hazard or would preempt future land-use plans. The sewage treatment facility and system will be removed for salvage.

4.1.2.4.6 Excess Salt Disposal. Approximately 65 percent of the salt excavated from the exploratory shaft and subsurface test areas will be required for backfilling the shaft and underground excavations if the site is not selected for a repository. The variety of options currently being evaluated for the disposal of the remaining 35 percent (Section 4.3.4.2) include the following:

- Commercial disposal
- Ocean disposal by dumping solid salt
- Land surface disposal at the exploratory shaft site
- Land surface disposal in desert salt flats
- Subsurface disposal in abandoned potash mines
- Surface disposal at the site of existing mine tailings.

Additional evaluation of these and any other available options are required before the preferred salt-disposal alternative is identified.

Contact has been made with Federal, State, and local officials regarding the disposal of salt and salt-contaminated wastes. As a result, it has been concluded that these wastes can be disposed of in commercially operated hazardous waste facilities because there is more available capacity in these commercially operated facilities than in either nonhazardous commercial facilities or those operated by local units of government.

In Texas, a hazardous waste management facility with capacity for at least 10 years is located in Port Arthur Texas, approximately 1,120-1,200 kilometers (700-750 miles) southeast of the site. The waste management cells are excavated, surface-bermed, and double-lined and incorporate a leachate collection and monitoring system to meet applicable standards for hazardous solid waste disposal sites. The preferred route for the transportation of excess salt is via U.S. 385 to Vega, I-40 to U.S. 287, U.S. 287, to I-35, Ft. Worth-Dallas route to I-45, I-45 to Houston, I-10 to Beaumont, U.S. 69/287 to Port Arthur, and local routes to the site.

The excess salt and salt-contaminated material to be transported can be contained and cleaned up relatively easily if a traffic accident occurs. The nature of the material is such that long-term effects will not persist after cleanup. Proper loading and protection of the load from wind during transport will minimize the adverse effects of routine operation.

4.1.2.4.7 Refuse and Site Cleanup. Waste generated during construction and testing of the ESF includes sewage treatment effluent; combustible solids such as paper and cartons; and

excavated solids other than salt. These wastes are not expected to be hazardous. The sewage treatment facility will be designed so that the effluent can be discharged to surface waters or used on site for nonpotable purposes.

Other nonhazardous construction wastes will be disposed of in a licensed landfill. The nearest landfill sites operating in compliance with the applicable State of Texas regulations are in Wichita and Ellis Counties. The Wichita County site is closest and is a licensed Class III industrial solid waste landfill. The Ellis County site is licensed for Texas Class II industrial solid wastes.

Access to the Wichita County site follows U.S. 287 to Wichita Falls and local routes to the site.

4.1.2.4.8 Final Grading, Topsoil Replacement and Revegetation. Grading and backfill may commence in a sequential fashion as various areas of the site are decommissioned or in accordance with procedures specified by regulatory agencies. The preparation and development of the site were based on minimal grading and earth moving to provide adequate drainage and acceptable slopes. Fill used during site development will come from the stockpiled materials excavated from the ponds, pits, and site areas. The site will be regraded to a configuration consistent with the surrounding topography. Stabilized areas will be disked, and stockpiled material will be replaced.

When a road or pad is to remain for continued use, the surrounding surface grading and the associated drainage structures will also remain. Adjacent areas will be blended to provide surface drainage suitable for use.

Backfilling will be accomplished to minimize the movement of earth and dust generated by the grading activity. After backfilling and surface grading are finished, the topsoil will be replaced and graded to a final contour consistent with normal land-use patterns.

Regraded subsoil will be scarified before topsoil is redistributed so that the topsoil will adhere to the subsoil. Topsoil material will then be replaced over the disturbed areas to a depth corresponding to the amount removed from any given area. The area will be mulched with clean straw or cotton gin waste at the rate of 6.7 metric tons per hectare (3 tons per acre) to provide protection from erosion. At the first appropriate season, the site area will be reseeded. Fertilizer requirements have been addressed in Table 4-7. Actual types and quantities of fertilizer and water requirements will be influenced by the time of planting, sodding, and seeding, and by rainfall amounts. Procedures will follow recommended and acceptable agronomy practices. The revegetation process will be monitored by project personnel.

Equipment for the post-testing effort is listed in Table 4-16. The projected consumable resources for the final disposition stage are presented in Table 4-7. Vehicular traffic would slightly increase from baseline levels to include approximately 90 round trips to the site by cars per day and 40 round trips to the site by trucks per month.

4.1.2.5 Required Permits and Approvals

The DOE intends to comply with all applicable Federal, State, and local permits not inconsistent with its responsibilities under the NWPA. The DOE intends to consult with State and local officials concerning sites that are recommended.

4.1.2.6 Detailed Discussion of ESF Waste Management

Waste disposal planning is based on an analysis of the type of wastes generated by ESF activities and a telephone survey to identify existing municipal and commercial disposal facilities.

Table 4-17 organizes those details important to waste management by type of waste; column 5 identifies a feasible method of disposal for each type of waste. Existing permitted offsite facilities that appear to be available for disposal of ESF wastes are preferred over the DOE-constructed facilities.

Table 4-16. Equipment for the Final Disposition Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Subsurface Backfill (5 months)	3	Compressors	125	-
	2	Hoists	500	-
	1	Vent fan	350	-
	1	Vent air conditioning system	900	-
	2	Auxiliary fans	50	-
	2	Crushers	75	-
	2	Trucks	250	500
	2	Wheel loaders	270	540
	1	Crane	180	180
	1	Forklift	50	50
	1	Oiler	200	200
	1	Dozer	300	300
	2	Pickup trucks	135	270
				2,040
Shaft Backfill (8 months)	1	Compressed air system	200	-
	2	Hoists	500	-
	4	Stage hoists	40	-
	2	Vent fans	60	-
	2	Crushers	75	-
	2	Trucks	250	500
	2	Wheel loaders	270	540
	1	Dozer	300	300
	1	Crane	180	180
	1	Forklift	50	50
	1	Oiler	200	200
	2	Pickup trucks	135	270
				2,040
Hoist and Headframes Removal (2 months)	2	Cranes	180	360
	1	Wheel loader	270	270
	2	Trucks	250	500
	1	Compressor	100	-
	1	Pickup truck	135	135
				1,265
Storage Area Decommission (6 months)	1	Dozer with ripper	300	300
	2	Trucks	250	500
	1	Wheel loader	270	270
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,405
Equipment and Building Salvage (4 months)	2	Cranes	180	360
	1	Forklift	50	50
	2	Trucks	250	500
	1	Cherry picker	50	50
	1	Dozer	300	300
	1	Wheel loader	270	270
	2	Breakers	50	100
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,965
Refuse and Site Cleanup (2 months)	1	Wheel loader	270	270
	1	Dozer	300	300
	1	Oiler	200	200
	2	Trucks	250	500
	1	Pickup truck	135	135
				1,405
Final Grading and Vegetation (5 months)	1	Grader	180	180
	1	Scraper	450	450
	2	Trucks	250	500
	1	Dozer	300	300
	1	Water truck	250	250
	1	Oiler	200	200
	1	Hydroseeder	100	100
	1	Pickup truck	135	135
				2,115

Table 4-17 Description of Wastes and Estimated Quantities Relating to Disposal
Deaf Smith County Site

Waste Type	Nature of Waste	Volume[b] Generated	Rate of Generation	Disposal Method[c]	Volume[d] Disposed (Truckloads)	Location[e]
1. Rubbish[a]	Combustible with no more than 20 percent garbage. Nonhazardous.	21,600 cu yd.	13.2 cu. yd/day	Offsite landfill, disposed offsite.	21,600 cu. yd. (1,030)	Rubbish hauled to permitted landfill within 50 miles near Amarillo to Hereford[1].
2 Excavated Material, Non-salt-Contaminated	Rock and unconsolidated material removed from the shaft which has not been intimately mixed with salt. Expected to be nonhazardous.	33,000 cu. yd.	270 yd^3/day	Used as backfill during reclamation; residual will be disposed of in approved offsite landfill.	15,000 cu. yd. (714)	Can be disposed of within 50 miles of site in the DOE-selected site without acquiring separate site.
3. Salt-Contaminated Rock	Rock and unconsolidated material removed from the shaft which has been intimately mixed with salt. Expected to be nonhazardous.	56,000 cu. yd.	270 yd^3/day	Used as backfill during reclamation; residual will be disposed of in approved offsite landfill.	24,000 cu. yd. (1,143)	Port Arthur, Texas.
4. Salt	Essentially pure salt excavated from the target horizon. Nonhazardous.	118,000 cu. yd.	466 yd^3/day	Used as backfill during reclamation; residual will be disposed in approved offsite landfill.	41,000 cu. yd. (1,952)	Port Arthur, Texas.
5. Potentially Salt-Contaminated Runoff[a]	Runoff from salt-handling and storage areas and water pumped out of the mined shaft during construction. Expected to be nonhazardous.	6,800,000 ft^3	Varies with rainfall	Injected at commercial facility.	3,700,000 ft^3 (85.5 acre-ft)	Commercial injection well Odessa, TX, about 270 miles from site[2]
6. Domestic Wastewater[a]	Wastewater from human activities and vehicle washwater. Nonhazardous.	9,900,000 gal.	4.2 gal/min	Treatment on site for non-contractor staff; off site for contractor. Liquids discharged or reused for nonpotable purposes; sludges disposed of off site.	9,900,000 gal.	Discharged to drainage for onsite plant; municipal sewage plant for contractor.
7. Nonsalt-Contaminated Runoff[a]	Runoff from areas not contaminated by salt. Suspended solids reduced in sediment retention pond. Nonhazardous.	8,900,000 ft^3 (203.4 acre-ft)	Varies	Discharged from site.	7,000,000 ft^3 (159.2 acre-ft)	Discharged to drainage.
8. Miscellaneous[a]	Oils and other fluids drained from vehicles during maintenance; cleaners and solvents etc. Hazardous.	To be determined	To be Determined	Collected and stored in drums for recycling or disposal at a permitted offsite facility.	To be determined.	Port Arthur, Texas.

(a) Waste streams expected to continue through testing at the following generation rate:
Rubbish - 15 lb/person/day
Potentially salt-contaminated runoff - 1,500,000 ft^3/yr (34.4 acre-feet)
Domestic wastewater - 35 gal/cap/day
Nonsalt-contaminated runoff - 45.2 acre-feet per year
Miscellaneous - to be determined.
(b) Estimated total volume generated through end of expanded underground excavation.
(c) Most reasonable method based on information currently available.
(d) Remaining volume after allowing for backfill or discharge as appropriate.
(e) A facility which has capacity and accepts wastes of the type generated is located at or within distance indicated. References to cities does not imply any landfill has agreed to accept ESF generated waste, now or in the future.

Sources: (1) Messenger, 1984; Pole, 1984; Weston, 1984.
(2) Beuerlein, 1984.

Table 4-17 indicates the location of usable disposal facilities available for each waste. "Usable" means that it can lawfully accept wastes of the type generated and can accommodate the volume of waste to be disposed. "Available" means the operator (or owner) has indicated that the DOE should be able to obtain the applicable permits or approvals necessary to use the facility.

Other existing disposal locations, at approximately the same distance indicated in the table, were not surveyed once a usable and available facility was identified for each waste. Selection of one or a combination of facilities requires additional information, and final selection could be based on competitive bidding. Therefore, final selection of disposal facilities for the various types of waste will be deferred until after ESF site selection.

Eight types of waste have been identified. Rubbish, defined to be combustible with not more than 20 percent garbage, can be reduced in volume by onsite incineration. However, current plans call for disposal of rubbish in a permitted offsite sanitary landfill.

The volume of excavated solids to be disposed of is reduced by using this material for backfilling the underground workings and shafts, if the site is to decommissioned. If the site is selected for a repository, this material would be included in repository planning. There are few limitations on the disposal of excavated material that is not contaminated by salt or brine. It was assumed that all material would be disposed of off site. The characteristics of the strata to be excavated suggest that the excavated material would be classified as nonhazardous.

The ESF is designed to minimize the runoff volume that could be contaminated by salt. Runoff from the area around the headframe where salt may be spilled is directed to the evaporation/retention pond. This pond, designed to accommodate a 500-year storm event, also collects runoff from the storage area. A concrete apron around the headframe will facilitate cleaning up salt spills to minimize the potential for contamination. The waste collected in the evaporation/retention pond is expected to have a low ionic content after the salt storage pile has been formed and the contents exposed to atmospheric conditions. Water will be discharged from the evaporation/retention pond only if testing verifies that it meets applicable discharge criteria; if it does not meet discharge criteria, the water will be evaporated or trucked to a permitted offsite disposal facility. If chronic elevated ion concentrations are detected, improved house cleaning, covering the salt pile, isolating salt pile runoff, or other management techniques will be investigated. Runoff from those areas of the site where salt handling has not occurred will be directed to a sediment detention basin. The accumulation of solids in both the evaporation/retention and sediment detention ponds will be dependent upon actual suspended solids concentrations, evaporation rates, etc. These solids will be disposed of as required in offsite facilities.

Domestic wastewater from commodes will be treated in an onsite sewage treatment facility. Effluent from the waste water treatment facility will undergo tertiary treatment consisting of duplex dual media gravity filters. Such treatment will reduce effluent suspended solids to approximately 1 milligram per liter and produce an effluent containing not more than 20 milligrams per liter of biological oxygen demand (BOD). Any liquid discharge to surface systems will not exceed the maximum permissible levels for such discharge.

Construction contractors will provide chemical toilets and truck waste to an offsite facility.

The only wastes generated at the ESF that will be classified as hazardous will be oils, thinners, solvents, and lubricants. These wastes were not included in the waste report, and their volume has not been estimated. If a recycling facility is not readily available, these fluids can be disposed of in hazardous-waste landfills as indicated in Table 4-17.

4.1.3 Other Activities

This section describes other site-specific investigations that will be performed in conjunction with site characterization, including environmental and socioeconomic studies. Many

of these activities would begin before construction of the exploratory shaft. The total onsite work force for these activites would range from 4 to 20 persons. The presentation of this section has two objectives. The first is the description of the type and extent of environmental and socioeconomic field studies necessary to allow identification of potential impacts arising from these activities.

The second objective is to give a brief description of the planned environmental and socioeconomic studies. These studies are predicated on information needed to satisfy diverse requirements for the following:

- Permits and statutory compliance information for site characterization activities
- Monitoring of site characterization impacts
- Development of monitoring and planning reports on the effects of site characterization
- Analyses of the repository and the site to determine safety
- Analyses of the repository and the site for evaluation against the DOE guidelines (10 CFR Part 960)
- Determination of engineering design parameters for the ESF (final design) and for the repository.

After the environmental impact statement scoping hearings, environmental studies for the environmental impact statement will be developed and implemented.

Regulatory agencies and the public will have opportunities to comment on the design of the environmental and socioeconomic studies. Specific opportunities will occur during the permitting process.

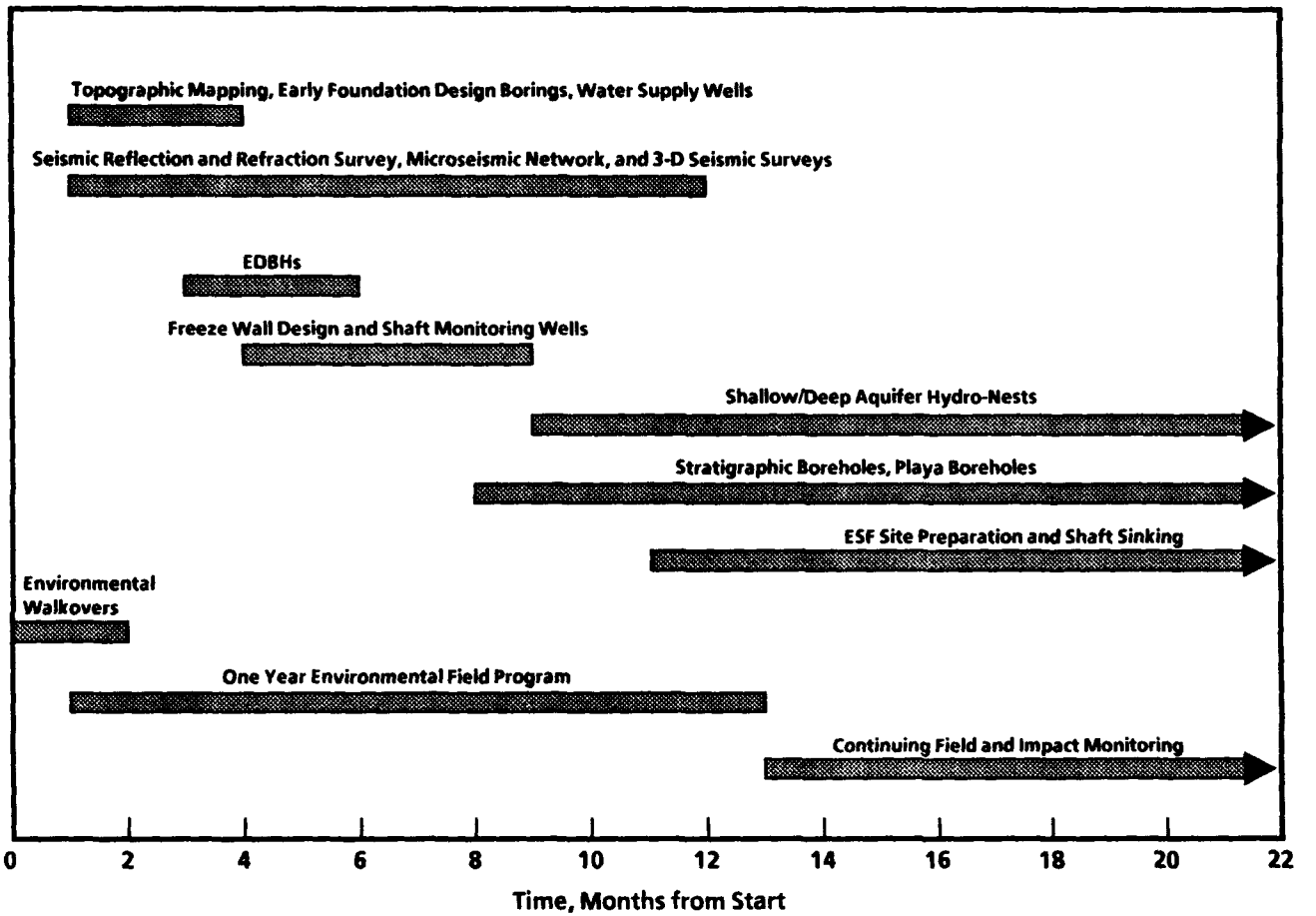
The scheduling of the environmental field studies is tied to the activities described in Sections 4.1.1. and 4.1.2, and is shown in Figure 4-16. The ESF construction is scheduled to begin 11 months after site selection. That provides adequate time to collect and digest environmental and socioeconomic field data undisturbed by ESF construction. In addition, there is an initial period without any site activities, to allow qualitative biological surveys and archaeological field work. Subsequent to this period, but prior to the start of the ESF, there are borehole drilling activities and geophysical surveys neither of which are expected to significantly interfere with environmental and socioeconomic field data collection.

4.1.3.1 Environmental Field Studies

This section describes the following environmental studies to be conducted during site characterization: land use and mineral resources; terrestrial and aquatic ecosystems; air quality and meteorology; water quality and hydrology; soils; noise; aesthetic resources; archaeological, cultural, and historical resources; radiological background; and transportation and utilities.

4.1.3.1.1 Land Use and Mineral Resources. The initial purpose of these studies is to document specific land uses to allow for the layout of utilities and roads to the repository stie, and to determine whether there are sensitive land uses that need to be protected during repository development. This land-use determination, out to a radius of 80.5 kilometers (50 miles), will support repository safety analyses, which, in turn, determine repository design.

The land-use study will expand the existing data base described in Section 3.4.1 by acquiring detailed information on existing and planned uses at the site and in proximity to the site. Additional data to be collected include the following:



Relationship of Environmental Field Program to Geotechnical and Exploratory Shaft Programs Deaf Smith County Site

Figure 4-16

- Extent of land-use areas, including agriculture (e.g., crop type), pasture, public areas, and built-up areas
- Productivity for each land use (e.g., crop yields, grazing capacities)
- Soil survey to identify prime farmland
- Economic value of harvested crops and livestock
- Land ownership.

Data will be based on the interpretation of aerial photographs, supplemented by site reconnaissance and review of data from local planning agencies and other resource agencies. Geologic data obtained from site characterization will be reviewed for indications of mineral resources. The study areas to be examined are presented in Figure 4-17.

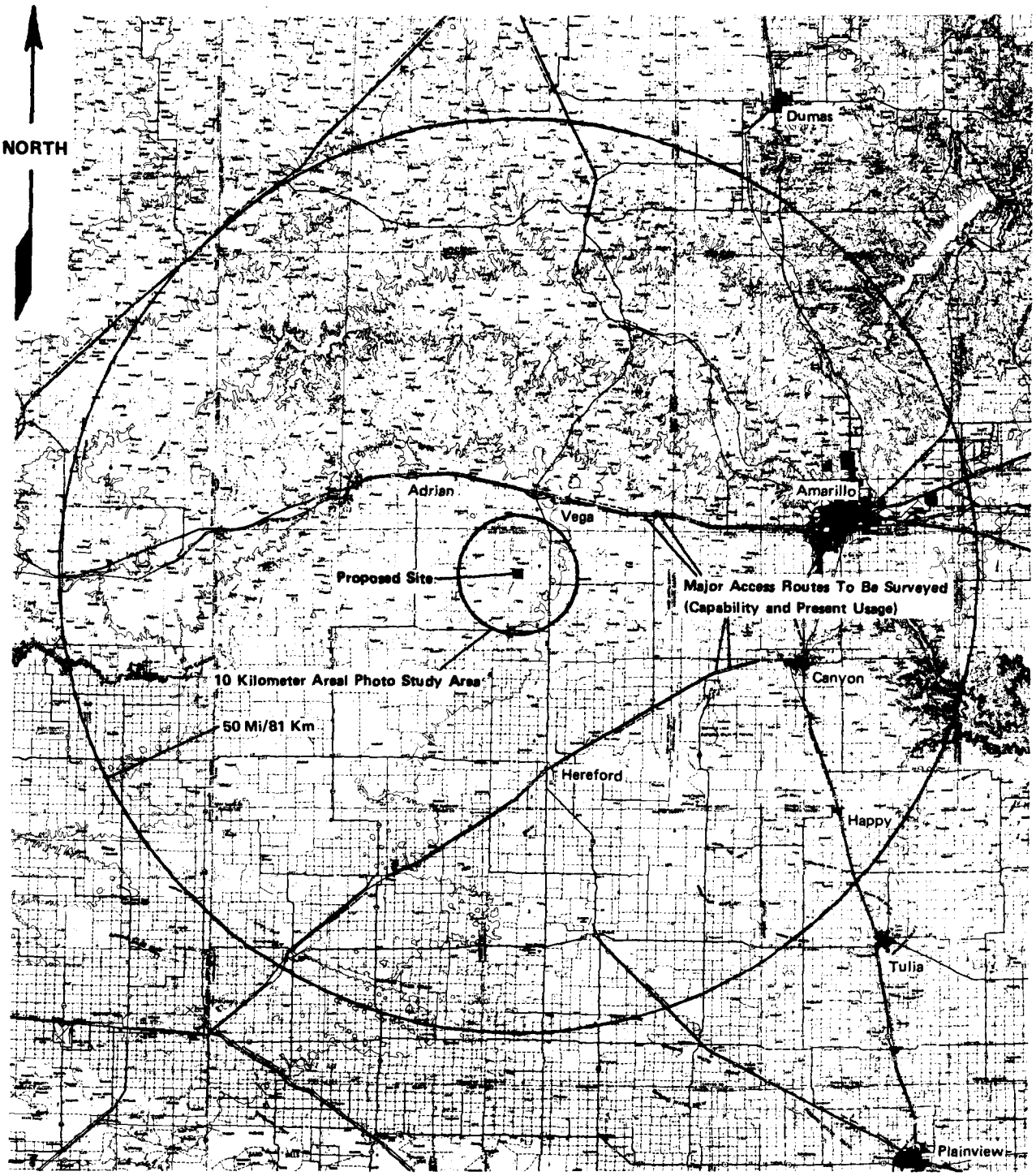
4.1.3.1.2 Terrestrial and Aquatic Ecosystems. These studies serve two purposes. The first purpose is to conduct biological surveys of the site for evidence of species protected by Federal and State statutes. The second purpose is to perform a quantitative assessment of biological pathways for repository safety studies and repository design work. Terrestrial and aquatic studies will be conducted in the following two separate programs: (1) site reconnaissance of areas affected by field activities (Section 4.1.1), and (2) seasonal ecological studies in areas affected by exploratory shaft construction (Section 4.1.2) and by potential repository development (Section 5.1). These studies will allow for both a site-specific assessment of impacts and the identification of any required mitigation measures.

Prior to initiation of geologic and hydrologic borehole activities described in Section 4.1.1, site reconnaissance for threatened and endangered species will be conducted at each activity site. Each reconnaissance will require a plant ecologist and a wildlife ecologist to investigate both the area to be disturbed and a surrounding buffer strip. If threatened or endangered species or their habitats are identified at any site, discussions will be conducted between the DOE and the Fish and Wildlife Service to either modify the field activities or in some other way provide adequate mitigation of impacts for the species of concern.

The second set of studies includes the seasonal ecological characterization studies for the exploratory shaft facility area, the controlled area, and access corridors. These studies will focus on qualitative and quantitative assessments of existing terrestrial and aquatic ecosystems. A comprehensive radiological program will be integrated into these studies for an evaluation of radionuclide uptake and content in edible crops and natural vegetation, livestock, wildlife, milk, and components of the aquatic ecosystem.

The seasonal ecological studies will involve a seasonal characterization of the terrestrial and aquatic environments, from which species lists will be generated and major habitats defined and mapped. Special emphasis will be given to surveys of State and Federally listed threatened and endangered species and for other important species of recreational, commercial, or ecological value. Control sites for ongoing monitoring will be selected in adjacent areas where no impacts are anticipated. These will provide a means for comparing project-induced changes with natural environmental changes in the vicinity.

Terrestrial Ecology. The plant communities of the Deaf Smith County site will be quantitatively sampled to obtain data to characterize the vegetation structure. An inventory of plant species within each vegetative community will be compiled during the sampling program. The species list will be annotated to include data on plant forms, habitat preference, and relative abundance. Standard ecological sampling procedures will be employed (e.g., rectangular quadrants, nested quadrants). From the sampling data, descriptive parameters such as density, abundance, frequency, percent cover, and dominance will be calculated. This information will also help determine productivity and the successional stage of the plant community. Approximate locations of sampling sites are presented in Figure 4-18.



0 5 10 20 30 35 Mi

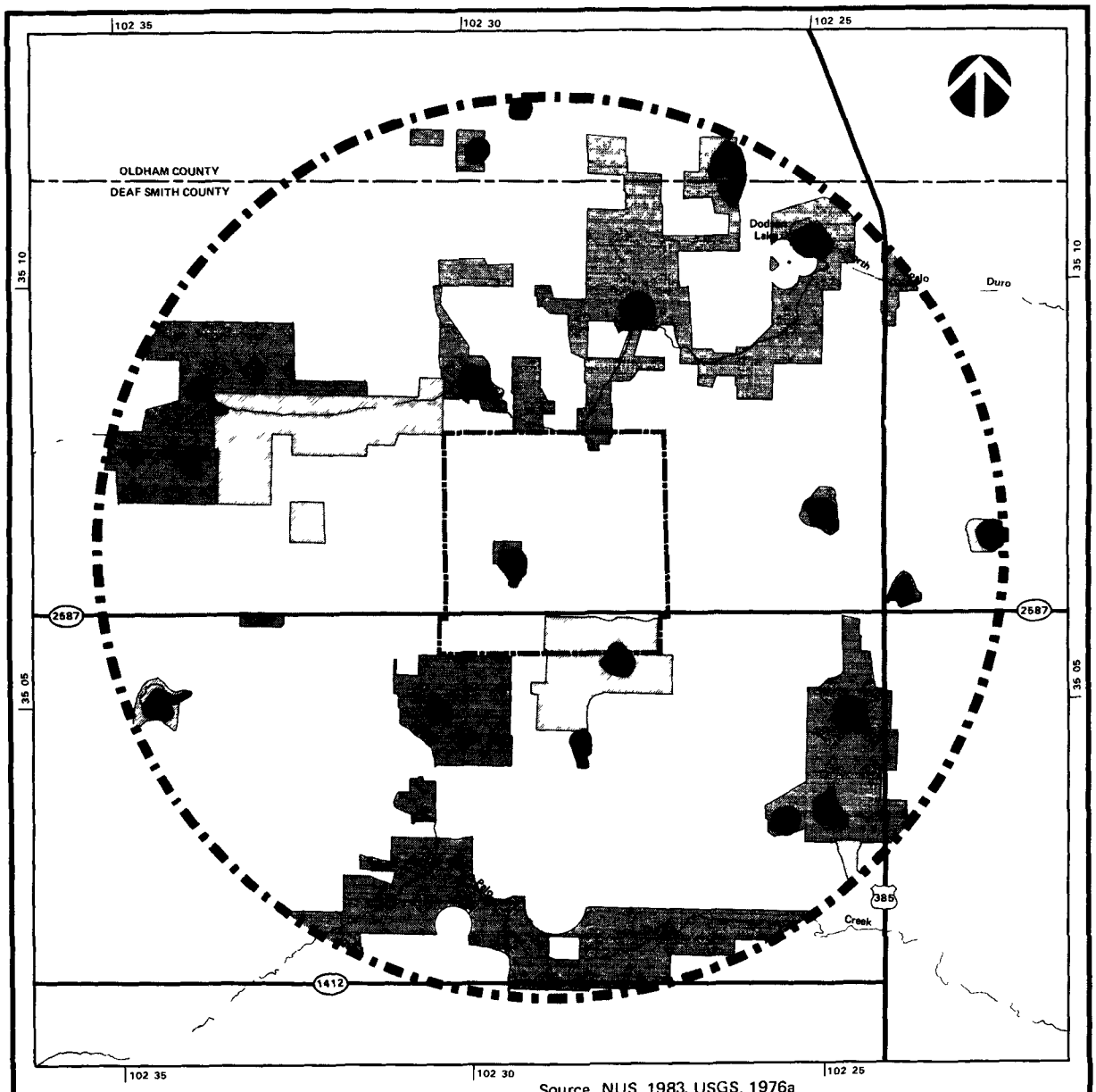
0 5 10 20 30 35 Km

Scale

Source: USGS, 1973, 1974, 1975, 1977

Proposed Locations (Approximate)
for Environmental Study Sampling
Land Use and Transportation
Deaf Smith County

Figure 4-17



Source NUS, 1983, USGS, 1976a

Explanation

- R1 Rangeland Recently Grazed
- R2 Rangeland - Ungrazed
- Playa
- Other Features - Primarily Cropland

These Identified Ecotypes Will Contain Approximately 30 Random Sampling Locations Each.

1 0 1 5 Kilometers

1 0 1 3 Miles

Proposed Locations (Approximate) for Environmental Study Sampling Biota/Ecosystems Deaf Smith County

Figure 4-18

Wildlife studies will use existing published and unpublished information pertinent to the study area, as well as specific field surveys to confirm information on species' presence, abundance, seasonal distribution, and important ecological interrelationships. The local value of wildlife to sport, commercial, and recreational users will also be evaluated. Standard field sampling techniques will be used for these studies, including trapping small- to medium-sized mammals, spotlighting for large mammals, and trapping and visual survey for reptiles, amphibians, and invertebrate species.

The terrestrial field program will survey and sample all major components of the terrestrial ecosystem. The focus of the field program will be a thorough ecological description, including species composition, population abundance, location and extent of vegetation types and wildlife resources, successional stage of plant community, wildlife movement patterns, preferred habitats and habitat requirements, trophic structure and productivity, and pre-existing environmental stress.

A program to monitor salt impacts will be established. Test plots (see Figure 4-19) established both close to and distant from the salt pile will be intensively studied. During and after salt excavation, the salt conditions and biotic response in the test plots will be monitored.

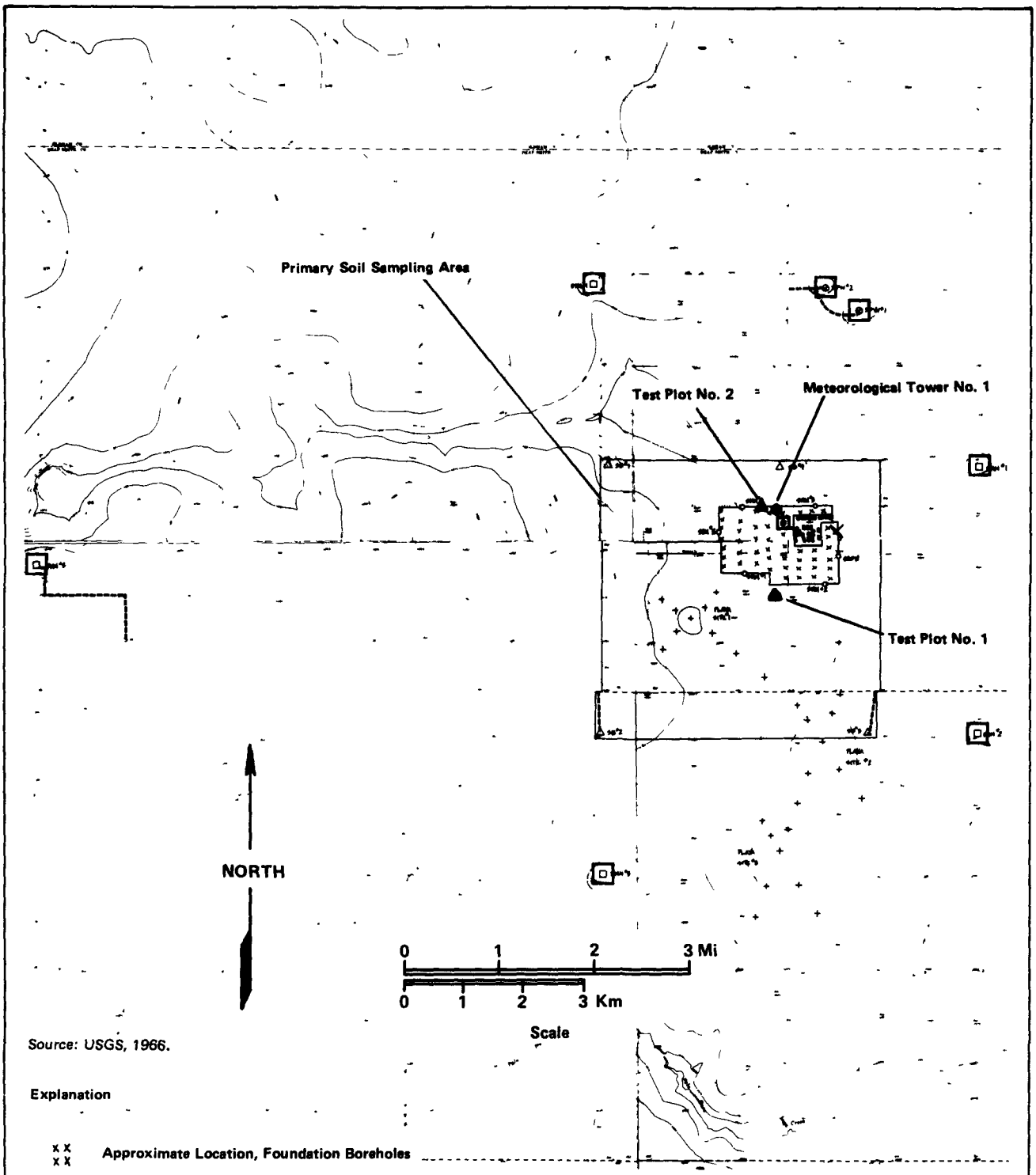
Aquatic Ecology. A field program will be implemented to obtain additional information regarding the biological characteristics of the local aquatic environment. Biological water quality parameters such as phytoplankton and indicator organisms will be sampled. Physical and chemical surface water data will be collected during the surface-water field program. In addition, the locations of point and nonpoint sources of pollution will be identified, and data on temporal variations, quantities, and characteristics of pollutants will be presented.

Selected surface water resources will be surveyed to complete a data base on aquatic flora and fauna. Sampling will be undertaken to characterize species composition and relative abundance. Major groups to be surveyed include aquatic and wetland plants, aquatic invertebrates (benthos, nekton, plankton), fishes, and higher vertebrates. Emphasis will be placed on special status species and species that are indicators of environmental stresses. Efforts will be coordinated with terrestrial field surveys.

Investigations of fisheries-resource characteristics will be conducted to determine any possible distribution patterns, breeding and spawning grounds, and immigration patterns. If needed, quarterly field collections will be conducted at representative locations within the site vicinity. A variety of sampling devices will be used to ensure that resident fish species are adequately sampled. Concurrent with the fisheries resource field survey program, benthic invertebrates and emergent aquatic insects, which may be critical to the structure and function of the ecosystem or a necessary food item for other important species, will be collected.

Threatened and Endangered Species. Although initial data indicate that there are no known endangered or threatened species in the site vicinity, the potential occurrence of such species cannot be dismissed. Sites of all project activities and adjacent areas will be surveyed for the presence of designated and proposed threatened and endangered plant and animal species. Field survey programs will be developed to determine the actual presence of threatened and endangered species and their habitats in the project area. These surveys will coincide with the terrestrial and aquatic baseline programs.

4.1.3.1.3 Air Quality and Meteorology. The immediate need for onsite meteorology is to satisfy information requirements for the design of the repository. Depending upon State agency requirements, local meteorology and air quality data will probably be required for the permitting of site characterization activities. To characterize local weather conditions and atmospheric transport and dispersion processes, onsite meteorological monitoring will be conducted. The construction of a 60-meter (197-foot) meteorological tower will allow continuous study of airflow patterns and atmospheric stability.



Source: USGS, 1966.

Explanation

x x
x x Approximate Location, Foundation Boreholes

☐ 10 Acre Soil Sampling Area For Remote Boreholes (4 Samples Per Borehole Location)

⊡ Salt Particulate Monitoring Station

*Note : Radiological monitoring (i.e. grab samples and pole mounts) will coincide with these and other mapped sampling locations.

Proposed Locations (Approximate) for Environmental Study Sampling Soils, Radiological, Meteorological/ Air Quality, and Salt Impacts Deaf Smith County

Figure 4-19

Meteorological parameters to be monitored at the station will include wind direction, wind speed, temperature at two or three levels, dew-point temperature, precipitation, solar insulation, and barometric pressure. Additional meteorological data will be collected from records available from the National Weather Service, Amarillo Station, and nearby climatological stations at Vega, Hereford, Tulia, and Canyon. The location of the planned tower is shown in Figure 4-19.

Air quality monitoring or sampling may be conducted to obtain estimates of background concentrations of all atmospheric contaminants regulated by the National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50) and the State Air Pollution Control Regulations (Texas Clean Air Act). Air quality parameters such as total suspended particulates, PM_{10} particulates, sulfur oxides, nitrogen oxides, carbon monoxides, ozone, and lead would be measured, as required.

Information from the onsite meteorological and air quality monitoring station and recent nearby air quality and meteorological records will be used to describe the site with respect to the following:

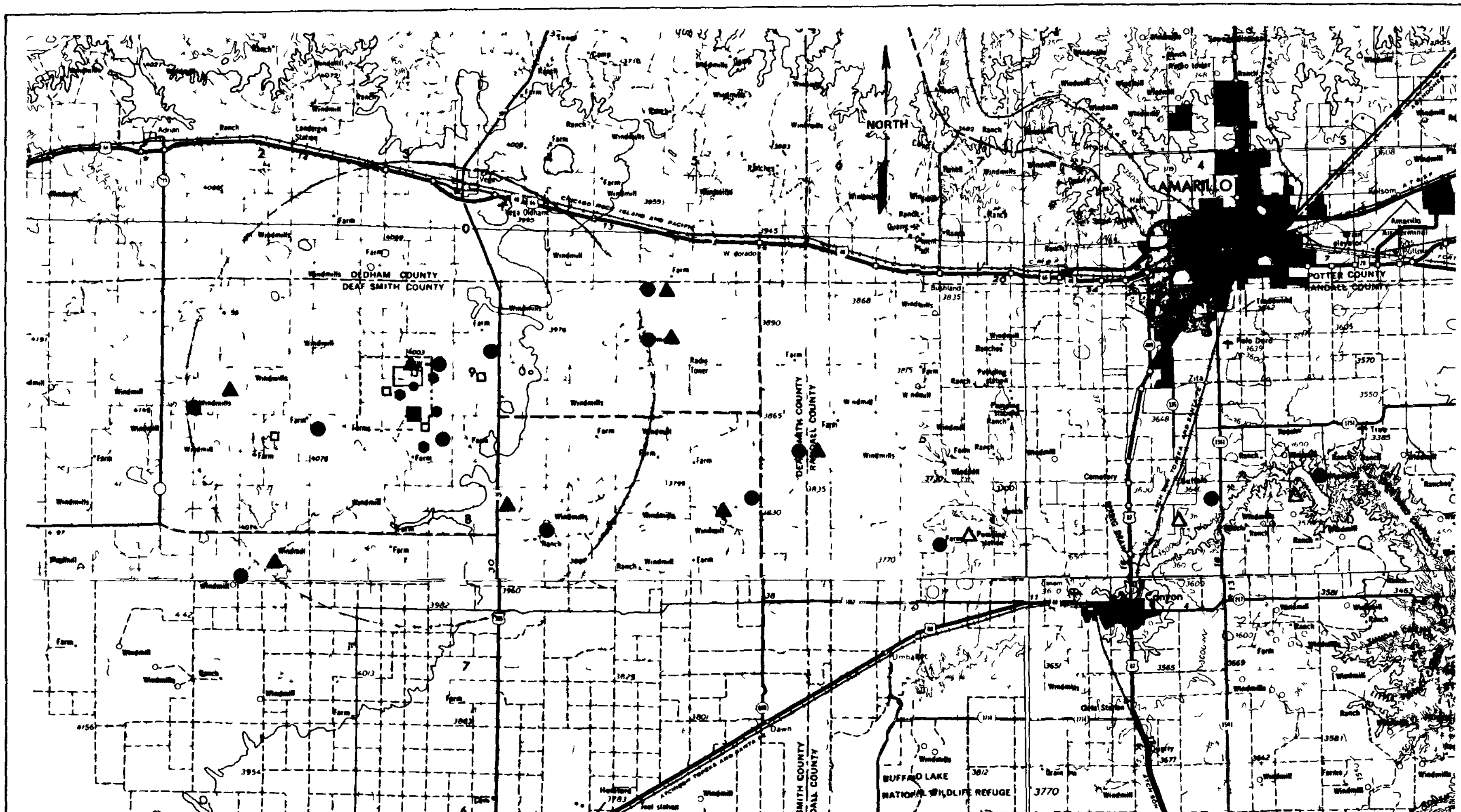
- The influence of terrain on meteorological factors
- Monthly and annual frequencies of wind speed and direction by atmospheric stability class
- Total precipitation (rain and snow) by month, the number of hours with precipitation, and the rainfall rate distribution
- Ambient air quality
- Cumulative frequency curves of monthly average precipitation and evaporation
- Estimates of the wind erosion index
- Monthly and annual dry bulb air temperature, vertical temperature difference, and dew-point temperature summaries, including averages, measured extremes, and diurnal range.

The land area required for the tower and equipment shelter is 1.4 hectares (3.5 acres). The site will require some grading and construction of a road to allow installation of the tower and equipment shelter. Access will have to be obtained through private land.

4.1.3.1.4 Hydrology and Water Quality. An intensive field investigation and data collection program is planned to define the baseline hydrologic and water quality conditions of the area, to monitor the impact of site characterization activities and future repository operations, and to identify site-specific mitigating measures. Initial studies will be directed at the collection of data to satisfy National Pollutant Discharge Elimination System (NPDES) permitting requirements for site characterization activities, and to support additional floodplain analyses for the repository design. Subsequent studies will include monitoring to the provisions of the NPDES permit and confirm the floodplain analyses. The surface-water hydrologic data will be collected to characterize creeks, playas, and impoundments with respect to geometry, drainage area, water surface elevations and fluctuations, and sediment load. Chemical data will be obtained by standard sampling and analytical procedures and will include hardness, dissolved oxygen, pH, and chemical and biological oxygen demand. A full range of sampling for ions will be performed.

Surface-water quality sampling will be limited by the ephemeral character of the streams and the playa lake in the vicinity of the site. The sampling schedule will be flexible to respond to significant precipitation events.

Water quality sampling stations will be installed for the Deaf Smith County site. Suggested stations may include the unnamed tributary to Palo Duro Creek, North Palo Duro



Explanation

- ▲ Stream Discharge and Water Quality Station
- △ Lake Level and Water Quality Station
- ● Rainfall Station
- ■ Evaporation Station
- - - - Site Boundary
- □ Playa Water Level and Water Quality Sampling Station
- ⬢ Proposed Sound Level Monitoring Locations

Source USGS 1973 1974 1975 1977

Scale: 0 – 5 Mi; 0 1 – 5 Km

Proposed Locations (Approximate) for Environmental Study Sampling Sound Levels and Water Resources Deaf Smith County

Figure 4-20

A larger reproduction of this figure appears at the back of this volume.

Creek, Palo Duro Creek, each of the four playas near the site, Bivens Lake, Palo Duro Club Lake, and Lake Tanglewood (Figure 4-20). Additional grab sampling may be performed in support of the aquatic biology studies.

Ground-water quality samples will be obtained from existing wells in the vicinity of the site. The same parameters sampled for surface water will be sampled for ground water using standard techniques. Geohydrologic properties of the aquifer and water quality samples of the deep aquifers will be obtained from the geologic field studies program as part of site characterization (see Section 4.1.1).

The surface-water and ground-water quality field study will require access and entrance to private or State lands to sample wells or surface-water bodies.

4.1.3.1.5 Soils. The purpose of these studies is to provide repository and exploratory shaft design data. Specifically, the data needed include shallow soil engineering property data, soil depth and classification (to allow development of a stripping and stockpiling and reclamation plan), and soil hydrologic properties (to estimate and investigate soil erosion). Information on soils in the areas to be disturbed will be obtained by conducting a standard soil survey. Using a hand auger, the soil corings will be taken to a depth of 1.5 meters (5 feet) or to bedrock, whichever occurs first. General locations for soil sampling are shown in Figure 4-19. Soil characteristics such as texture, color, calcium carbonate percentage, volume of coarse fragments, and depth to a limiting layer, such as caliche, will be assessed. Field estimates will be made of permeability, drainage, and structures. Slope, aspect, nature, and extent of native vegetation will be recorded. Cropping history for cultivated soils will be collected and documented. Erosion and reclamation potential will be estimated for each mapping unit. The soil surveys will require two persons for field activities.

4.1.3.1.6 Noise. Several goals are established for the noise field program. The first goal is to determine existing background sound levels. The second is to collect site-specific attenuation data for calibration and validation of noise propagation models. The models will be used for future noise analyses. The third is to monitor sound levels from site characterization activities and repository development for determining the effectiveness of noise mitigating measures and for determining if further mitigation may be necessary.

The surveys of existing sound levels will collect data for the site vicinity for each season, including weekdays and weekends, and for day and night. These data will be used in future noise analyses. Survey points and sampling periods will be designed to develop a representative statistical statement of the background sound levels at the Deaf Smith County site. Planned survey points are identified on Figure 4-20. Existing noise sources at the site will be identified and octave-band analyses will be performed to characterize significant noise sources. Octave-band and a weighted sound levels will be reported for each sampling point. To provide correlations with measurements, additional information on other parameters will also be recorded during the survey. Meteorological observations including wind speed, wind direction, temperature, and relative humidity will be made at each sampling location. Measurements obtained near roadways will be accompanied by a traffic count. Sound source observations will be recorded during each sample and include a notation of the predominant sound sources.

4.1.3.1.7 Aesthetic Resources. An inventory of visual resources at and near the site and along access corridors will be performed as a basis for determining project-related visual impacts and for developing mitigation measures. Field studies to determine the potential visual impacts associated with repository construction, operation, and decommissioning activities will be conducted. Potential impacts attributable to dust plumes and to transportation and utility corridors will be identified and evaluated.

4.1.3.1.8 Archaeological, Cultural, and Historical Resources. Intensive cultural resource surveys will be conducted in the project area, pursuant to requirements of Federal regulations and under the provisions of a Programmatic Memorandum of Agreement, which is being negotiated between the DOE, the Advisory Council on Historic Preservation, and the Texas State Historic Preservation Officer (SHPO) (DOE, 1985a). The DOE will consult with the SHPO regarding studies to be performed which may include the following:

- A walkover of 100 percent of the areas occupied by the exploratory shaft, access routes, and those parts of the study area that are judged to have a probability of containing prehistoric and historic cultural resources

- A walkover of a sample of the remainder of the study area to test the proposition that the area has a low probability of containing prehistoric and historic sites

- An intensive archival and information search to identify important historic sites in the study area, followed by a reconnaissance survey of the historic site locations identified.

The goals of the investigations will be to locate all cultural resources in the areas surveyed, to assess the significance of the resources located, and to make projections concerning the number, kind, and significance of the resources located. Projections of the number, kind, and significance of resources in areas not surveyed will also be made. In addition, recommendations for further cultural resources work will be provided.

The results of the surveys will be used to determine the location and significance of cultural resources that may be affected by site characterization and repository activities.

4.1.3.1.9 Background Radiation. A radiological baseline sampling program will be established to further evaluate background radiation levels in and adjacent to the site. The initial purpose of this program is the development of a safety analysis to determine repository design. Subsequent work would support the repository license application to the NRC. Preoperational radiation surveillance of the environment will be carried out in order to do the following:

- Identify the probable critical exposure pathways
- Identify affected geographical areas
- Characterize sample media and sample site locations
- Interpret data to determine background levels.

Collection of samples will be coordinated with the soils, ecosystems, water quality, and air quality monitoring programs as discussed below, and as shown on Figure 4-19.

Soil. Samples would be collected (Section 4.1.3.1.5) to measure radionuclides in the soil. Livestock feed, grass, and edible crop areas would be included in the sample locations.

Terrestrial and Aquatic Ecosystems. Radiological analyses of background radiation conditions in terrestrial and aquatic ecosytems will be integrated into the ecosystem program described under Terrestrial and Aquatic Ecosystems (Section 4.1.3.1.2). These studies will emphasize radionuclide uptake and content in important food chains (including edible crops and vegetation, livestock, wildlife, milk, fish, invertebrates, benthic sediment, and plankton).

Surface and Ground Water. Surface- and ground-water samples will be collected and analyzed for radionuclide contamination in conjunction with the water quality program (Water Quality and Hydrology, Section 4.1.3.1.4). Surface-water samples will be taken upstream and downstream from the site. Ground-water samples will be taken upgradient and downgradient from the site. Several stations will measure domestic water supplies, as well as recreational areas of lakes and rivers.

Air and Precipitation. The background radiation monitoring program will be operated in conjunction with the air quality monitoring program (Air Quality and Meteorology, Section 4.1.3.1.3). Air samples to be used for measuring airborne particulates and gaseous radionuclides will be collected from onsite and offsite locations.

Precipitation samples will be collected at the sampling station nearest the site in the direction of the prevailing wind.

Ambient Beta/Gamma Radiation. Environmental levels of beta and gamma radiation will be monitored at several onsite and offsite locations. Locations will include points along the perimeter of the site and locations within a 16-kilometer (10-mile) radius of the site in the greatest and least prevalent annual wind direction.

4.1.3.1.10 Transportation. This section discusses the transportation-related studies that will be conducted while site characterization activities are ongoing. Transportation requirements of site characterization are specified in Section 4.1.2 and consequential environmental impacts are discussed in Section 4.2. These studies are primarily conducted to support engineering design of access corridors for the exploratory shaft facility (ESF) and for the repository. These efforts include environmental and safety analyses of alternative repository corridor alignments, and monitoring for possible traffic congestion during site characterization.

Monitoring programs for congestion, traffic problems, and road deterioration caused by site characterization activities will take place during site characterization. This may include traffic monitoring along U.S. 385, FM 2587, and other local roads, the I-40/U.S. 385 interchange, and the U.S. 385/FM 2587 intersection. Section 4.2.1.10 identifies mitigation measures that might be employed, if monitoring results determine a need.

During site characterization, detailed repository transportation studies will be conducted to further assess the existing transportation infrastructure, State and local emergency response capability, overflight hazards, and potential sites for development of highway and railroad access for repository operations. This information will be used to support the decision regarding preferred transportation routes.

These studies will be performed to determine necessary infrastructure development and mitigation for anticipated repository-related traffic congestion at key locations in the site vicinity. Detailed studies of the existing highway and rail transportation infrastructure will include: evaluation of the local and regional highway and rail characteristics, condition, and need for upgrading; planned changes or improvements; present traffic levels and capacities; accident and weather disruption experience; transportation infrastructure compatibility with repository-generated traffic; and assessment of costs and types of potential mitigative actions. The results of these studies will be used to better define potential impacts from repository-related traffic and the necessity for and location and nature of any improvements or modifications to the existing infrastructure.

Studies will be performed to assess the capabilities of local and State agencies to respond to transportation-related emergencies. Evaluations will be made of agencies responsible for disaster and accident response; response plans, available equipment, and trained personnel; degree of interagency coordination; and the need for Federal assistance and funding. These studies will ultimately be used to determine the necessity of improving existing capabilities and the nature of such improvements.

Studies of the overflight hazard will include detailed examination of the use of airspace in the repository area by volume and type of aircraft as well as an assessment of capabilities and use characteristics of airports at various distances from the repository.

Studies will be conducted to further identify engineering requirements and environmental and social impacts from the siting of highway and rail access routes (Section 5.1.2.2). The studies will include defining and locating the constraints to and opportunities for siting which exist in the region.

Siting the rail and highway access route will be guided by the siting guidelines, program and engineering requirements, public concerns and applicable local, State, and Federal laws. The evaluation of environmental impacts will require the conduct of studies to assess existing environmental conditions along proposed alignments. The DOE will conduct additional studies to further assess environmental conditions along proposed alignments.

Additional studies will be conducted to investigate nationwide transportation issues, including the feasibility of barge transport with rail connections made in Memphis, Tennessee, and the Texas port cities of Houston and Galveston (Appendix A).

4.1.3.1.11 Utilities. Utility-related studies during site characterization will center around supplying the utilities required for repository construction and operation and meeting the repository-generated waste disposal needs. Utility requirements for site characterization are specified in Section 4.1.2 and consequential environmental impacts are discussed in Section 4.2.

Initially, an evaluation of project utility needs will be made. These include natural gas, electric power, water, sewage sludge disposal, and communications. It is anticipated that water will be supplied from onsite wells. Natural gas, electricity, and communications capabilities will be supplied by connecting with existing offsite systems. Studies will involve assessing current and forecasted demand and capacity of these offsite systems and the effects that the project will have on them. Connecting the existing systems with the repository will involve the study of alternative utility access corridors (Section 5.1.2.2) and the impacts associated with the alternatives.

Waste disposal studies will involve defining the quantities, types, and production schedule for projected generated wastes. An inventory will be developed based on evolving repository designs of potential offsite disposal areas for hazardous and non-hazardous wastes. This will include locations, projected capacities, and waste types which each facility will accept. These studies will also assess regional waste disposal plans and the potential need for new facilities.

4.1.3.2 Socioeconomics

Impact assessment, monitoring, and planning activities will occur during site characterization. The purpose of assessment activities will be to project repository impacts. The role of impact monitoring will be to provide the data necessary to make the repository assessments more accurate and to identify potential site characterization effects. If the monitoring program were to identify impacts of site characterization, mitigation activities would be established. Mitigation plans would outline the process that the DOE would follow in working with the States and local communities to minimize or mitigate adverse impacts which may be identified by the monitoring program.

Of the many different effects that communities could experience from a repository project, five types of impacts have been identified at other large-scale facility sites. Demographic impacts result from the influx of new project workers and their families. There will be a larger community population, as well as potential change in the age and family characteristics of the population. Economic impacts include changes in business activity and employment in rural areas. At least temporarily, wages and costs often increase from levels existing before the project begins, and business sales and income from project-related activities increase the overall economic activity in the area.

Community Service impacts may also be experienced with local population growth. This growth may affect the fire protection, schools, water and sewer systems, and road maintenance. Fiscal impacts may be experienced with the additional service demands and costs associated with the rapid population increases that accompany large-scale development. Offsetting possible increase in demands and costs, there may be an increase in local tax revenues. These new revenues are often a resource for much needed service improvements, such as new schools, water and sewer systems, and service facilities. Social impacts may result from the influx of large numbers of people. The informality and intimate nature of social relationships in a rural area may change. As a result, longtime residents sometimes feel that the communities become less familiar, less friendly, and less harmonious.

Assessing these socioeconomic impacts is a critical element in meeting the requirements of the Nuclear Waste Policy Act and the Mission Plan. The DOE has developed a modeling system that may be used in evaluating repository impacts. This model has six major components: an

economic module, a demographic module, an economic-demographic interface module, a residential allocation module, a community service requirements module, and a fiscal module.

The modeling system projects demographic and economic changes. In addition, the residential allocation module distributes new residents to communities near the site. Community service and fiscal impacts are then evaluated for communities receiving new population. A social assessment methodology will be used to analyze social impacts.

For the impact assessment activities, site and area visits would be made to verify existing data and to collect additional data. The types of data to be collected and data sources are listed below:

Economic

- Employment by industrial group and occupation: Census data, Bureau of Economic Analysis, State and regional planning agencies
- Income per capita, family: Census data, Bureau of Economic Analysis
- Economic trends and projections: Bureau of Economic Analysis, State and regional planning agencies
- Land uses, current and projections: State, regional, local planning offices, field surveys
- Sales by industry, trade patterns: Bureau of Economic Analysis, State and regional planning agencies
- Planning regulations: State and local agencies
- Input-Output coefficients: State economic and planning agencies research institutions

Demographic

- Total population trends: Census data and estimates
- Age, sex, race-ethnicity of population: Census data
- Birth, death, migration trends: Census data, State health department
- Characteristics of families and households: Census data
- Nonresident, temporary population: Local and regional planning agencies, State and Federal park service
- Population by type of urban center: Census data, local and regional planning agencies
- Population density: Census data and local surveys

Fiscal

- Tax revenues, type and jurisdiction: State revenue department
- Assessed valuation, rate and jurisdiction: State revenue department, local assessor's office
- Federal and State revenue distribution: State revenue department, local and regional planning agencies, local treasurer's office

- Government expenditures, types and trends: State revenue department, local government offices

- Bonding status and capacity: Local governments

Community Service

- Housing units, type, condition, vacancy: Census of housing, State, and regional planning agencies

- Education, enrollment, school capacity: State department of education, local school districts

- Medical and mental health services: State health departments, department of human resources, National Center for Health Statistics

- Law enforcement: State police, county sheriff, and local police offices

- Fire protection: State fire marshal and local stations

- Water supply, wastewater treatment, and solid waste: Environmental Protection Agency, State health department, and community governments

- Transportation: State transportation department, community governments

- Social services: State department of human resources and local offices

- Recreation services: State recreation agency, local and regional planning agencies

Social

- Community organizations, type and size: Community agencies

- Community leadership: Community sources

- Government organization and activity: Community leaders

- Attitudes, perceptions of community concerning repository development, economic development, community growth and change: Community leaders and citizens

- Local cultural heritage: Local historical society and other agencies

- Social disorganization, types and incidence of crimes: State and local crime reports.

These activities will occur during the first 2 years of site characterization and 4 staff persons would be in the site area periodically for 2 weeks at a time. Impact monitoring, occurring throughout site characterization, involves periodic field visits to collect data and analyze key indicators of local economic and social change. Some indicators that will be analyzed in communities and counties projected to receive new residents include project information and community information.

The kind of project information that will be required during site characterization can be divided into project-worker characteristics and project purchases:

1. Project-worker characteristics, such as family size, housing needs, number of school-age children present and marital status; changes in the scheduling of the project; and worker settlement patterns will be monitored. These factors will

affect the number of persons which will be present in any community and affect the demands on community services.

2. Project purchases will be monitored during site characterization. The magnitude of project purchases during site characterization will affect the local economy and be related to the number of secondary jobs created. To obtain this data, project purchase orders could be sorted out by purchase location.

Community information which may be required during site characterization can be divided into indicators of the economic, demographic, land use, community service, social and fiscal conditions. The factors to be monitored will be keyed to impacts identified in Section 4.2.2. The staff involved in collecting impact data will also participate in the monitoring effort. Monitoring reports will be prepared for quarterly project reports and semiannual community reports.

If impact mitigation activities are required during site characterization, area visits will be conducted to discuss mitigation measures with project management, State and local officials, and public groups.

4.1.3.3 Land Acquisition

The land within the Deaf Smith County site is all privately owned. No lands owned by the DOE are located within the vicinity of the site.

The DOE expects to commence land acquisition for the site characterization program including construction of the exploratory shaft following Presidential approval of recommended sites. The exploratory shaft site will require approximately 25 hectares (61 acres). The DOE plans to purchase the surface and subsurface rights to the land for the exploratory shaft site.

Land protection is necessary to prevent uncontrolled human activities which could affect the licensability of the proposed site as a repository. On a technically conservative basis, a minimum of 4,060 acres was recommended for protection (Chen and Raines, 1985). Because the DOE will not know precisely what and how much land it will need to acquire for a repository site until site characterization studies are completed, and data collected in those studies are evaluated, the DOE plans to protect a larger area that corresponds to section lines which is approximately 2,331 hectares (5,760 acres) (the protected area). Preliminary analyses indicate that a site area of this size would allow all EPA and NRC repository performance requirements to be met (see Sections 6.3 and 6.4). The DOE expects to protect this area by purchasing or leasing surface and subsurface rights or by acquiring some lesser interest that adequately protects the proposed site. This process will begin at about the same time that land for the exploratory shaft is acquired. The DOE may permit the surface owner(s) the right to continue to conduct their present activities. Some activities on the land would require prior approval of the DOE. The DOE will also conduct site characterization field studies as described in Section 4.1.1 within portions of the protected area.

The DOE expects to conduct some site characterization activities outside the protected area. These activities may include drilling boreholes, conducting seismic surveys, and performing environmental studies (see land requirements in Table 4-2). The DOE plans to obtain license, lease, purchase, or easement agreements for parcels of land or access required for these activities.

Land requirements also include an access roadway and roadway rights-of-way (see land requirements in Section 4.1.2.1).

In the area immediately surrounding the exploratory shaft facility, the DOE will conduct intensive activities for a period of more than 2 years. These activities are described in Section 4.1. Because of the presence in this area of large numbers of drill rigs, other equipment, and personnel, the DOE will establish a buffer area up to approximately 130 to 170 meters (400 to 500 feet) beyond the "repository surface facility" area. This area,

including the ESF and repository surface facility area, is approximately 500-600 acres, and has been designated as a limited-access area to ensure the safety of project personnel and the general public and to enhance the security of supplies and equipment. The DOE will acquire appropriate interests in this land. The limited-access area will be suitably marked.

Some landowners will be disrupted by site characterization activities on these lands or by uncertainties regarding the future use of the affected land. While there is no remedy for some of the disturbance which will be caused by land acquisition, the DOE intends to minimize disturbance whenever practicable, consistent with the requirements to obtain and evaluate data on the characterizations of the site, and to compensate landowners for the real property and improvements it acquires.

4.2 EXPECTED EFFECTS OF SITE CHARACTERIZATION

This section describes the environmental effects expected to result from the site characterization activities discussed in Section 4.1. These impacts have been assessed by comparing specific project activities with information on existing site and area conditions presented in Chapter 3.

This description of site characterization effects is divided into two subsections. Effects on the physical environment are presented in Section 4.2.1, and effects on the socioeconomic conditions are presented in Section 4.2.2. The discussion of effects for each discipline generally follows the order of the site characterization activities presented in Section 4.1, i.e., geotechnical field studies (Section 4.1.1), exploratory shaft facility (Section 4.1.2), and other activities (Section 4.1.3). Both beneficial and adverse effects are discussed.

4.2.1 Expected Effects on the Physical Environment

This section describes the expected effects of site characterization activities on various components of the physical environment, including land and mineral resources; terrestrial and aquatic ecosystems; air quality; surface-water and ground-water quality and availability; soils; noise; aesthetic resources; archaeological, cultural, and historical resources; radiological levels; and transportation and utilities.

4.2.1.1 Effects on Land Use and Mineral Resources

The geotechnical field studies and exploratory shaft activities will occupy a total of 308 hectares (761 acres), of which 283 hectares (700 acres) are devoted to geotechnical field studies. The following sections examine the impact of geotechnical field studies and exploratory shaft facility activities on land use within the Deaf Smith County site vicinity (the area within a 10-kilometer [6.2-mile] radius of the site center, or approximately 313 square kilometers [121 square miles]), and on individual farmers at the site.

No significant impacts are expected relative to the regional mineral, and hydrocarbon base because no known unique mineral resources exist near the Deaf Smith County site (The Dallas Morning News, 1983) also see (Section 3.2.8). As the DOE acquires subsurface rights including mineral and water rights (Section 4.1.3.3), the opportunity to conduct subsurface exploration will cease. The DOE will compensate the owners of subsurface rights for the loss of any of these rights.

Deaf Smith County is currently within the jurisdiction of the Panhandle Regional Planning Commission. The Commission issued a Regional Land Resource Management Plan in 1978 that provides broad guidelines and goals for the Panhandle area of Texas.

4.2.1.1.1 Geotechnical Field Studies. The geotechnical field studies will involve drilling deep and shallow holes, trenching, and laying seismic lines (as described in Section 4.1.1 and illustrated in Figures 4-1 and 4-2). The field studies that will disrupt the largest amount of land are the seismic surveys. Regional seismic surveys will disrupt 76 hectares (188 acres) of land, primarily along existing roadways. The three-dimensional

seismic survey will disrupt an additional 101 hectares (250 acres), in isolated parcels, within the 23.3-square-kilometer (9-square-mile) controlled area and adjacent land. Total disruption of land use as a result of seismic surveys is estimated to be 177 hectares (438 acres). The seismic surveys will conflict with agricultural use of the land in some areas for a total of up to 11 months. If all of the testing were conducted on cropland, it would represent 8 percent of the cropland at the site and 0.7 percent of the cropland in the site vicinity. In addition, disruption on additional acreage to farm management practices, such as irrigation practices and grazing activities, may result from the seismic surveys. The DOE will consult with affected land owners or lessees on the location of such lines and will compensate for disruption to land use to the extent allowed by law. The DOE will use existing roadways for seismic testing, to the extent possible, to further reduce the disruption of agricultural land.

Other geotechnical field studies will involve drilling deep and shallow boreholes as described in Section 4.1.1. These boreholes will disrupt land use at the sites and along any access roads to be constructed. The length of time land use will be disturbed generally will vary from 2 days to 20 months, although certain observation holes will be maintained throughout the site characterization phase and through decommissioning. A total of 85 to 106 hectares (211 to 262 acres) will be preempted from use for different durations of time (see Table 4-2). If all of these activities take place on agricultural land, it will represent a maximum of 5 percent of the cropland at the site and 0.4 and 0.09 percent of the cropland within the site vicinity and county, respectively.

To the individual landowner, the amount of disruption to farming or grazing activities will depend on the specific location of field study activities. As many as 694 boreholes will be drilled (locations are defined in Section 4.1). The locations of these boreholes on individual units of land will determine the extent of disruption to land use. Temporary disruptions to irrigation practices, cattle grazing, and other land management practices can be expected.

Playa studies could disrupt farming activities at four playas. Because landowners often use playas to collect runoff irrigation water, the activities scheduled within playas will be coordinated with them to minimize disruption of irrigation practices to the extent practicable.

A hybrid sorghum seed operation is currently located adjacent to the northwestern portion of the 23.3-square-kilometer (9-square-mile) site. Part of the northwestern portion of the site is used to grow hybrid sorghum seed. A stratigraphic borehole (SB No. 1) is scheduled for the northwest corner of the site; however, it is situated in an area of rangeland and should not disrupt hybrid seed production.

There are currently 1,902 hectares (4,696 acres) of prime farmland within the site and 24,022 hectares (59,315 acres) within the site vicinity. Some, if not most, of the previously mentioned geotechnical activities will briefly disrupt prime agricultural soils. At the completion of geotechnical tests, disturbed areas will be restored to their original condition, to the extent possible. Soil improvement crops or artificial methods (i.e., fertilizer) may be applied to mitigate disruption of the soil (Section 4.2.1.5). The DOE has filed Form AD1006 with the Soil Conservation Service (SCS) to comply with the Farmland Protection Policy Act (Wheeler, 1985). In locating planned activities, the DOE has attempted to minimize the impact on prime farmland. In order to further lessen the effect of project activities on prime agricultural soils, the DOE has considered locating geotechnical activities in areas not designated as prime agricultural soils. Relocating field activities will be considered to the extent feasible and consistent with the objective of collecting necessary onsite geotechnical data.

The DOE will consult with individual landowners to locate geotechnical field studies and associated access roads in a way that will minimize the disruption to agricultural practices. In addition, landowners will be compensated for any losses resulting from these activities to the extent allowed by law.

4.2.1.1.2 Exploratory Shaft Facility (ESF). The DOE will purchase 25 hectares (62 acres) for the exploratory shaft facility (ESF). The exploratory shaft site is located on land currently used as cropland. The removal of 25 hectares (61 acres) of cropland represents 1.0 percent of the cropland at the site and 0.08 percent of cropland in the vicinity.

The impact on the farmer or farmers whose land is selected for exploratory shaft facility construction is expected to be twofold: a loss of agricultural land use and possible disruption of adjacent land use or management practices depending upon access road alignment and the location of the ESF in relation to the remaining property.

The ESF and access roads will disrupt irrigation practices. The DOE will consult with affected landowners and may redesign the irrigation system in a way that will minimize disruption, to the extent feasible, to the irrigation of crops. In addition, the DOE will reimburse the owner for any loss of revenue resulting from the disruption of irrigation practices to the extent allowed by law. If the access road is fenced it will present a barrier to the movement of any cattle on the land. Access road alignment will be discussed with the affected landowner to attempt to minimize disruption to grazing practices.

Minor, short-term disruption of agricultural lands is expected as a result of the installation of utilities (e.g., electric transmission lines) along existing corridors or roadways. If an alternative route for a utility corridor is selected that bisects croplands, then irrigation and other farming practices may be disrupted for a short period of time.

Residences are located within one-half mile of the ESF site. Residents will experience increases in traffic, noise, and dust as a result of mining activities (Sections 4.2.1.10, 4.2.1.6, and 4.2.1.3). Some owners may be disrupted by uncertainties regarding the future use of affected land and the resulting dilemma of whether to make further land improvements.

Salt excavated during exploratory shaft facility construction will be stored on site as discussed in Section 4.2.1.4.2. The predicted rates of salt deposition are very low, and based on studies on the effects of salt deposition (see Section 4.2.1.11.2), insignificant effects on crop productivity are anticipated. Transport of salt and salt-contaminant materials by truck on existing roadways is not expected to affect land uses along the routes due to use of coverings on the vehicles (see Sections 4.1.2.2 and 4.2.1.11).

As indicated in Section 4.1.2.8, disposal of solid wastes composed of residues from the evaporation of fresh water, brine drilling fluids, salt-contaminated runoff, salt-contaminated and noncontaminated excavated materials, and waste salt will be to an offsite landfill. The effects of disposal of the material to an offsite landfill could include (1) a decrease in the design life of that facility, (2) a potential for land-use conflicts if additional space is required, and (3) concern over long-term integrity of the landfill with respect to erosion, ground-water infiltration and subsequent leaching of salt, and potential ground-water contamination. While these effects could occur in a poorly sited and designed landfill, operators of the landfills in Port Arthur, Texas, and Clovis, New Mexico, have indicated that their facilities will have sufficient capacity at the time of disposal and the necessary permits to handle the anticipated kinds and amounts of solid wastes generated during site characterization (Caspers, 1984; Messenger, 1984; Pole, 1984; Weston, 1984; Hensch, 1984; Reis, 1985).

4.2.1.1.3 Environmental Field Studies. The only environmental field study expected to potentially affect land use is the air quality field study that requires a 60-meter (197-foot) meteorologic tower. This tower could be sited at the edge of a field to minimize disruption to irrigation practices. However, crop dusting may be affected by the meteorologic tower. The DOE will evaluate crop-dusting practices at the site. Some prohibition on aerial crop dusting may be required near the tower.

4.2.1.1.4 Cumulative and Long-Term Impacts. The cumulative and long-term impacts on land use will depend on the exact location of the site characterization studies. As described in Sections 4.2.1.1.1 and 4.2.1.2, a total of 308 hectares (761 acres) of land will be disturbed for different durations of time. If all of this disruption occurs on agricultural lands, it will represent 15 percent of the agricultural land at the site and approximately

1.0 percent of the agricultural land in the site vicinity. If all of these activities occur on prime farmland, disruption will occur on 16 percent and approximately 1.0 percent of the prime agricultural lands at the site and vicinity, respectively.

Most disruption will occur for a short period of time. Land used for testing will be restored to near its original condition. The DOE will maintain access rights to all deep hydrologic well sites and other monitoring well sites through the period of site characterization (see Section 4.1.1). This could continue to disrupt agricultural practices in the future. The DOE will consult with affected landowners regarding site characterization activities in order to attempt to minimize disruption to farming and grazing activities.

The cumulative effects of salt deposition as described in Section 4.2.1.11 are not expected to affect agricultural use of the land in the future. The DOE will closely monitor the soils around the site. Techniques for soil restoration are described in Section 4.2.1.5.

4.2.1.2 Effects on Terrestrial and Aquatic Ecosystems

The impacts that may occur to local ecological resources due to site characterization activities, which include geotechnical field studies (Section 4.1.1), exploratory shaft facility (ESF) construction and operation (Section 4.1.2), and Other Studies (Section 4.1.3), are addressed in this section. The habitat types, flora, and fauna potentially occurring on and in the vicinity of the Deaf Smith County site are described in Section 3.4.2 and in the report, Characteristics of Terrestrial and Aquatic Ecosystems of Two Locations in Deaf Smith and Swisher Counties, Texas (NUS, 1984, BMI/ONWI-508).

4.2.1.2.1 Geotechnical Field Studies. Construction of drilling sites and access roads for geological, geophysical, and other field studies is expected to require approximately 283 hectares (700 acres) for all of the test sites. The geotechnical field studies consist of borehole drilling in playas (discussed in Section 4.2.1.2.4) and upland areas, drilling monitoring wells, and conducting seismic surveys. Test sites and field crews will be widely scattered throughout the site vicinity. The duration of the field studies will be approximately 42 months, although no single activity will take more than 20 months to complete, and most are 6 months or less in duration (Figure 4-1 in Section 4.1.1).

As discussed in Section 3.4.2, the site vicinity contains primarily cropland and rangeland interspersed with numerous playa wetlands. Although intensively used by landowners, these areas do provide limited habitat for vegetation and wildlife. Species of local importance include waterfowl (mallard, pintail, Canada goose, and others), upland game birds (sandhill crane, mourning doves, etc.), and various raptors (hawks, eagles, falcons, owls), which are protected under the Fish and Wildlife Coordination Act (16 USC Sections 661-666c), the Migratory Bird Treaty Act (16 USC Sections 703-711), and the Bald and Golden Eagle Protection Act (16 USC Sections 668-668d). Since geotechnical field studies will alter habitat and affect wildlife species protected under these statutes, the DOE has consulted with the Fish and Wildlife Service (FWS) (Malone, 1985).

The FWS has also been consulted on the presence of species protected under the Endangered Species Act of 1973 (16 USC Sections 1531-1543) and the Bald and Golden Eagle Protection Act (16 USC Sections 668-668d). The FWS indicates that no currently listed species, critical habitat, or candidate species for listing exists in the 233-square-kilometer (9-square-mile) project area (Johnson, 1984a). Section 3.4.2.3 indicates that playa wetlands may attract endangered bald eagle, whooping crane, wood stork and American peregrine falcon, the threatened Arctic peregrine, and the State of Texas protected osprey (TPWD, 1977). Golden eagles have been observed in the vicinity, but are known to nest only in Palo Duro Canyon, which is 71 kilometers (44 miles) from the site. If during site characterization any of these species are found near the study sites, the DOE will consult with the FWS to determine appropriate project modifications to avoid adverse impacts (Malone, 1985).

Several species identified by the FWS as National Species of Special Emphasis (FWS, 1983, 1985) occur in the area (Johnson, 1984a), and are shown in Table 4-18. These species are of high biological, legal, and public interest and are the focus of FWS planning efforts on a

national basis. These species would be considered during site planning and site investigations, although they have no formal status under this designation.

Geotechnical field studies will cause habitat alteration through vegetation removal at each drill site, soil disruption and loss of soil nutrients through seismic survey work, and construction of drill pads and access roads. Impacts to wildlife will include direct mortality to small mammals and reptiles, periodic disturbances due to noises from drilling, generator vehicles, and the general presence of humans, and potential collisions with vehicles or structures such as fences. The reduction of carrying capacity at each site through habitat loss and increased competition in surrounding habitats may occur. However, due to the relative lack of habitat in the test site areas and the dispersion of field study activities,geotechnical field studies will cause no long-term negative impacts to available habitat in the region or to the regional populations of flora and fauna. With the exception of testing in playas (which is discussed in detail in Section 4.2.1.2.4), all of the proposed field studies will occur in cropland or heavily grazed rangeland (Figure 4-2 in Section 4.1.1). These areas do not have abundant foraging or cover habitat (Section 3.4.2, NUS, 1984, BMI/ONWI-508). Impacts to the sensitive species listed above would be limited to potential reduction of foraging habitat rather than any direct loss of nesting opportunities or cover. However, even if habitat loss were kept to a minimum, the presence of additional humans would be disturbing to these sensitive species.

By clearing no more than the actual land needed for each field study, maintaining study schedules, and minimizing the amount of time field crews are present, impacts will be minimized. Revegetation following completion of the studies has been incorporated in the site characterization program. The USFWS and Texas Parks and Wildlife Department will be consulted on appropriate mitigative measures under the Fish and Wildlife Coordination Act.

4.2.1.2.2 Exploratory Shaft Facility Construction and Operation. Development of the exploratory shaft facility will require acquisition of a 25-hectare (61-acre) site, with the additional acquisition of an 18-meter (60-foot) right-of-way for the construction of a 0.06-kilometer (0.04-mile) access road (Section 4.1.2). Depending on whether the exploratory shaft facility site eventually becomes a nuclear waste repository, the duration of any loss of habitat could range from 5 to 50 years. The ESF site will be located in cropland. Loss of cropland will have less impact on available habitat than a similar loss of rangeland or playa wetlands which also occur in the site vicinity (Section 3.4.2). The intensively farmed areas of the Deaf Smith County site are also of relatively little value to the wildlife species protected under the Fish and Wildlife Coordination Act, Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, Endangered Species Act of 1973, and Texas Endangered Species and Other Protected Wildlife Act (Texas Parks and Wildlife Code Annotated) discussed in Section 4.2.1.2.1 above and in more detail in Section 3.4.2. Species such as doves, sparrows, blackbirds, rodents, some reptiles, raptors, and medium-sized carnivores that forage in croplands, will be displaced (NUS, 1984, BMI/ONWI-508). The amount of cropland required for the ESF site represents approximately 1.0 percent of the total cropland within the 23.3-square-kilometer (9-square-mile) site. The loss of this habitat is insignificant from an ecological standpoint.

Other habitats within the site that may be affected by these activities include 208 hectares (513 acres) of rangeland and 37 hectares (92 acres) of playa wetlands. Table 3-41 in Section 3.4.2 indicates that more extensive acreages of these habitat types occur in the site vicinity, but distances to these other habitats would eliminate any direct impacts due to ESF development. As discussed in Section 3.4.2.3, there is no legally designated critical habitat (50 CFR 17.95) that would be affected by shaft development and its associated activities, nor are there any known populations of Federal threatened or endangered species (Johnson, 1984a). The peregrine falcon, listed as endangered by the Federal government, may occur in the vicinity of the site (Johnson, 1984a). This species could be affected by loss of foraging opportunities if its principal prey, such as waterfowl and other

Table 4-18. National Species of Special Emphasis Occurring in the Deaf Smith County Project Area

Common Name	Scientific Name
Coyote	*Canis latrans*
White-fronted goose	*Anser albifrons*
Snow goose	*Chen caerulescens*
Canada goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Pintail	*Anas acuta*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Golden eagle	*Aquila chrysaetos*
Sandhill crane	*Grus canadensis*
Mourning dove	*Zenaida macroura*

birds, avoided the area during migration. The FWS has also recommended consideration of the endangered whooping crane in project planning, due to a possible range expansion in the future (Johnson, 1984).

Exploratory shaft facility activities may affect some wildlife species protected under the Fish and Wildlife Coordination Act (16 USC Sections 661-666c), the Migratory Bird Treaty Act (16 USC Sections 703-711) and the Bald and Golden Eagle Protection Act (16 USC Sections 668-668d). Although the Deaf Smith County site is within the known range of bald and golden eagles (Section 3.4.2.3), neither of these birds are expected to occur on site. However, further consultation with the FWS will define compliance procedures if any eagles are found.

Construction activities will cause an increase in vehicular traffic, noise, dust, and erosion, as well as the potential for fires or occasional spills of potentially hazardous materials (such as diesel fuel or motor oil). Wildlife behavior could be adversely affected by the increased human presence, particularly if the humans are close to nesting or feeding areas during breeding season or migration. The most sensitive areas would occur around playa wetlands. The ESF will be over 3.2 kilometers (2 miles) from the nearest playas, thus few direct impacts will occur. The drilling rig, headframe, and their supports will be 38 meters (125 feet) high and could be hazardous to birds migrating at night and during periods of poor visibility, especially to the large numbers of migrating waterfowl present in the region. Mitigation measures will be developed in consultation with the USFWS under the Migratory Bird Treaty Act, and could include the use of flashing lights on the tallest structures to warn flying birds of the potential hazards (Malone, 1985).

Plant stress or reduced productivity both on and off the site could result from erosion of soil and from deposition of salt due to handling and storage on site. Dust suppression, prevention of soil erosion, and soil restoration are discussed in detail in Section 4.2.1.5. These measures will effectively eliminate adverse impacts due to blowing dust.

Section 4.2.1.11 addresses the ecological effects of increased salt levels resulting from mining, handling, storing, and transporting excavated salt. Salt in sufficiently high quantities can reduce plant productivity either indirectly from excess accumulations of salt in the soil, or from direct deposition of salt on the foliage. Any reductions to plant productivity result in a subsequent reduction in habitat-carrying capacity.

During the ESF program, approximately 133,000 cubic meters (174,000 cubic yards) of excavated salt and salt-contaminated rock will be stored in a 2-hectare (5-acre) pile approximately 9 meters (30 feet) high and in a 1.2-hectare (3-acre) pile approximately 7.6 meters (25 feet) high, respectively. They will contain 90,000 cubic meters (118,000 cubic yards) and 43,000 cubic meters (56,000 cubic yards) of material, respectively. Any saline runoff will be contained within a 1.8-hectare (4.4-acre) evaporation pond designed to prevent runoff into any local drainages. Control of salt dust and the natural crusting characteristic of piled salt will limit deposition of airborne salt to a maximum of 3.8 kilograms per hectare (3.4 pounds per acre) per year less than 0.8 kilometer (0.5 mile) from the source. Deposition falls off rapidly from that point. (The numbers given represent maximums; the actual amounts of salt generated in the ESF phase will probably be less.) As indicated in Section 4.2.1.11, the maximum amount of salt deposited is between 2 and 4 percent of the amount of salt generated from underground aquifers used to irrigate crops.

Electrical power for exploratory shaft facility activities is expected to be generated off site and transmitted either via 13.7-meter (45-foot) single or 15.2-meter (50-foot) double wooden pole transmission lines (Section 4.1.2.2). Collision or electrocution may cause deaths of large birds, particularly raptors such as eagles protected under the Endangered Species Act of 1973 and the Bald and Golden Eagle Protection Act. Both hazards can be reduced by locating the power lines away from existing natural areas, wetlands, and flight paths. The potential for electrocution can be reduced if phase and ground conductors are separated beyond the maximum wingspan of local species that may roost on them. Since eagles are the largest raptors potentially present in the region, a spacing of over 2.5 meters (8 feet) should be sufficient to protect these species as well as birds with shorter wingspans. These measures will be considered and incorporated as appropriate in the project design (See Section 4.1.2).

4.2.1.2.3 Other Activities. Impacts from environmental baseline studies are expected to be relatively insignificant to ecological resources of the site and surrounding areas. Field studies may require collection of voucher specimens of plants and animals, tissue samples for productivity and radiological critical path studies, and soil sampling. Removal of small numbers of individual organisms will not significantly affect regional populations, and none of these field studies will entail major habitat modifications.

Other environmental field studies will result in varying effects on the site ecosystem. Most disturbances will involve field crews conducting soil, noise, or land-use surveys, although it is expected that any effects will be very short term and of minor impact. The construction and operation of a 60-meter (197-foot) meteorological tower will require clearing and grading of a 1.4 hectare (3.5 acre). The most significant impact of this activity will be the potential for birds to fly into the tower during periods of low visibility. Such impacts could be mitigated by installing various warning devices such as lighting and horns.

4.2.1.2.4 Impacts on Floodplains and Wetlands. Floodplains on the Deaf Smith County site and in the site vicinity have been mapped by NUS (1985, BMI/ONWI-574) and are described in further detail by NUS (1985a). Wetlands on the site and in the vicinity have been mapped by the National Wetlands Inventory (FWS, 1977) and are described by NUS (1985a). These areas are shown on Figure 4-21 and are depicted as potentially wet areas containing wetlands.

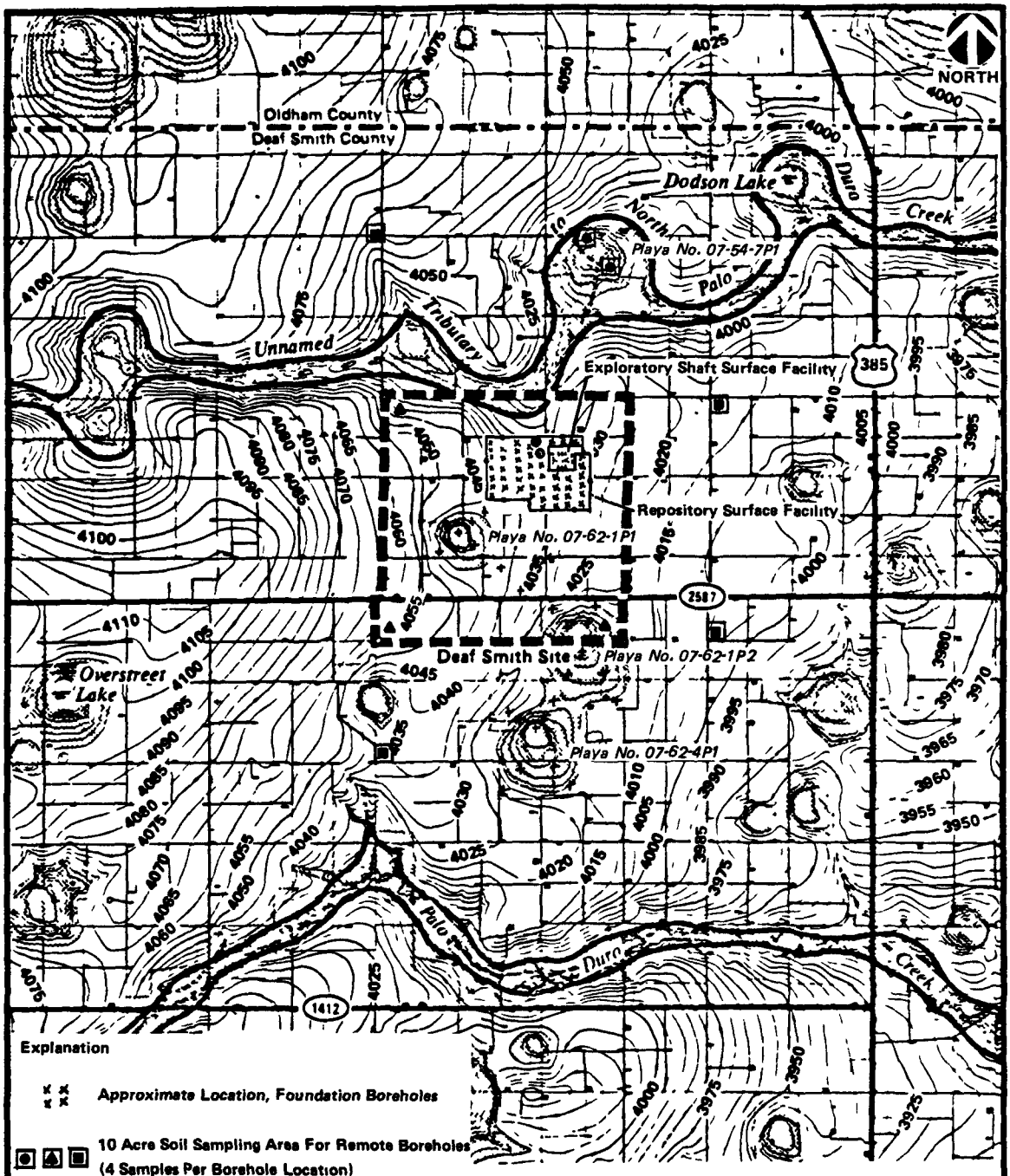
Floodplains are found along intermittent stream drainages and within playa basins on and near the Deaf Smith County site (Section 3.4.2 and NUS, 1985a). The Corps of Engineers considers playa basins to be floodplains (Brown, 1984). Floodplains occur south and north of the site along Palo Duro Creek and an unnamed tributary to North Palo Duro Creek, respectively. Both drainages are intermittent, and rarely flood in the vicinity of the site (Section 3.3.3). Riparian areas in the region with high soil moisture and little disturbance from farming and grazing occasionally have small populations of woody vegetation such as Populus spp., Prunus spp., and Salix spp. (Section 3.4.2 and NUS, 1984, BMI/ONWI-508). This cover type has not been observed within the Deaf Smith County site vicinity.

Wetlands found within playa basins are also on and in the vicinity of the site. There is one playa wetland and part of another within the 23.3-square-kilometer (9-square-mile) site, with an additional 17 playa wetlands within a 10-kilometer (6.2-mile) radius of the site. All of these playas are classified by the National Wetlands Inventory as palustrine wetlands (that is, inland non-flowing water) with emergent vegetation (NUS, 1985a.). Each of these playas is also classified by the National Wetlands Inventory as holding water only temporarily during the year. The FWS further classifies the playa wetlands of the area into the following:

- Farmed wetland
- Palustrine emergent
- Palustrine emergent, excavated
- Palustrine open water
- Palustrine open water, excavated
- Palustrine emergent - open water
- Palustrine emergent - open water, excavated
- Palustrine forested
- Lake.

Fourteen of the 19 playas within the site vicinity have been excavated, probably to increase their water-holding capacity. Other playas are periodically used as cropland and rangeland depending on the time of year their basins are dry (NUS, 1984, BMI/ONWI-508).

Playa wetlands within the region may contain natural habitat supporting a diverse assemblage of flora and fauna. Barr (1985) indicates that, in a region devoted largely to intensive agriculture, playas may provide the most significant remnant of native vegetation in the region. NUS (1984, BMI/ONWI-508) reports at least 45 species of plants are expected to occur in and around playas. As discussed in Section 3.4.2, the most common species include emergents such as cattails, pond sedges, bulrushes, and other grasses.



Explanation

- Approximate Location, Foundation Boreholes
- 10 Acre Soil Sampling Area For Remote Boreholes (4 Samples Per Borehole Location)
- Salt Particulate Monitoring Station
- Meteorological Monitoring Tower
- Potentially Wet Areas, Containing Wetlands
- Proposed Access Routes

Source: Compiled from USGS 1965-1971. 1:24,000 quadrangle maps of Ford, Overstreet Lake, Simms NE, and Vega South, Texas.

SCALE

0 1 2 3 4 5 Kilometers

0 1 2 3 Miles

Potentially Wet Areas Containing Wetlands — Deaf Smith County

Figure 4-21

Playa wetlands within the region can also be important to resident wildlife (NUS, 1984, BMI/ONWI-508; 1985a). NUS (1985a) lists 12 species of amphibians and 14 species of reptiles associated with playa wetlands. Frogs, toads, and most turtles would be abundant when playas have standing water, whereas snakes could be common whenever sufficient cover is available.

NUS (1985a) lists 151 species of birds associated with playa wetlands. The list includes species protected under the Fish and Wildlife Coordination Act (16 USC 661-666c) and the Migratory Bird Treaty Act (16 USC Sections 703-711), the Bald and Golden Eagle Protection Act (16 USC 668-668d), and the Endangered Species Act of 1973 (16 USC Sections 1531-1543). Species of particular interest that have been observed in the region (NUS, 1984, BMI/ONWI-508) include waterfowl (mallard, pintail, Canada goose, gadwall, green-winged teal, American widgeon, and scaup ssp.); raptors (golden eagle, rough-legged hawk, marsh hawk, and American kestrel); and upland game birds (ring-necked pheasant, sandhill crane, bobwhite quail, and scaled quail). Endangered species, such as the bald eagle, peregrine falcon, wood stork, and whooping crane, along with State-protected species such as the osprey may be attracted to playa wetlands of the region during migration, but in extremely low numbers, if at all (NUS, 1984, BMI/ONWI-508).

Eleven species of mammals are associated with playas (NUS, 1985a). These include bats, rodents, raccoon, and opossum. Such species are protected under the Fish and Wildlife Coordination Act and the Texas Parks and Wildlife Code.

Using the National Wetlands Inventory (FWS, 1977) and the numbering system employed in Texas to number wells (Knowles et al., 1982, LP-173), each of the four playas to be studied during site characterization are shown and numbered on Figure 4-21 (NUS, 1985a). Reconnaissance of the site in September 1985 (Barr, 1985) found that each of the four playas had been modified and were dry at the time.

Playa 07-54-7P1, north of the ESF, had been deepened to collect runoff. There appeared to be no emergent vegetation. The basin was being grazed and the surrounding upland areas were cropland. Playa 07-62-1P1, southwest of the site, was planted to sorghum. Playa 07-62-1P2, the closer of the two south of the ESF, contained an excavated livestock watering tank and was being grazed. The playa farther south, Playa 07-62-4P1, had also been excavated to hold water. Upland areas included fallow rangeland and cropland. With the exception of the cultivated playa, all of the playas contained low vegetation.

Despite the fact that playas on or near the site are excavated and were dry during recent observations, they may provide good habitats for migratory and wintering waterfowl and other wildlife. The playas appeared typical of such areas in the Texas Panhandle in that most hold water only temporarily and have been modified for agricultural purposes (NUS, 1985a). Yearly variation in the amount and timing of precipitation could affect the value of wetlands for waterfowl and other wildlife. NUS (1984, BMI/ONWI-508) estimated that over 20,000 waterfowl were observed on playa wetlands in Deaf Smith and Swisher Counties during a winter survey. Wintering ducks in flocks of 50 to well over 2,000 birds were observed on approximately one-third of the playa wetlands containing water that were not completely frozen. Small numbers of waterfowl were observed in April and July surveys. There was little open water available during the April survey, while a moist summer had filled most playa basins with water during the July survey.

Proposed Actions. Proposed site characterization and ESF construction activities are described in Sections 4.1.1 and 4.1.2. The ESF has been sited to avoid direct disturbance of floodplains and wetlands, but some ESF activities could affect floodplains and wetland resources. Site characterization activities, particularly geotechnical investigations, will result in some direct impacts to floodplains and wetlands. These site characterization and ESF investigations will affect floodplains and wetland resources:

1. Deep playa boreholes. Two deep boreholes will be drilled through Playa 07-54-7P1, north of the site (Figure 4-21). Approximately 4 hectares (10 acres) will be disturbed for a period of 4 months at each borehole site during the drilling operation. An access road approximately 1.6 kilometers (1 mile) long will be

constructed. This road will allow monitoring of the wells for the duration of the project.

2. Shallow exploration boreholes. A series of 27 shallow boreholes will be drilled in and around Playas 07-62-1P1, 07-62-1P2, and 07-62-4P1. Drilling at each playa will take 3 months (9 months maximum for all three), will require approximately 0.04 hectare (0.1 acre) per drill site, and will require a small drill rig and a crew of six personnel. This activity will not require access roads.

3. Seismic surveys. Approximately 177 hectares (438 acres) of seismic survey lines, including 248 line-kilometers (155 line-miles) of seismic reflection lines, will be established which may cross some floodplains and wetlands. Truck-mounted vibrators or explosive charges will be the energy source. Surveys will take 11 months to complete, and many of the test sites will be along established roadways.

4. Structures. A tower for meteorological instruments, the ESF headframe, other drill rigs, and ESF buildings will be constructed. The heights of the meteorological tower and ESF headframe will be 60 meters (197 feet) and 38 meters (125 feet), repectively. Other structures will be considerably shorter.

5. Salt management during ESF construction, operation, and decommissioning. Salt mining, handling, and surface storage of 133,000 cubic meters (174,000 cubic yards) of salt and salt-contaminated rock, and ultimate offsite disposal will result in some salt drift and some saline runoff to detention ponds.

Effects of the Proposed Actions. Ecological effects on floodplain and wetland resources will be limited to temporary disturbance of wildlife and wildlife habitat where they occur. No permanent habitat loss will occur. Species that may be affected by activities include waterfowl, shorebirds, passerines, and raptors, described above. The DOE may consult with the FWS to determine appropriate mitigative measures under the Fish and Wildlife Coordination Act, Migratory Bird Treaty Act, and Bald and Golden Eagle Protection Act. Temporary loss of foraging habitat for endangered species such as the bald eagle, peregrine falcon, or whooping crane may occur. However, these species are not likely to occur at the site in such numbers that an impact would require modification of site characterization activities pursuant to the Endangered Species Act.

Of all the site characterization activities listed above, the deep playa borehole drilling would have the greatest potential for causing the most disturbance to habitat and wildlife. Because of the duration of the activity, it would be difficult to schedule around breeding seasons and migration. Although the playa is heavily modified, it may be used by wildlife at times during the year when it contains water or when other land use disturbances are minimal. Since the playa has been deepened, the construction of an access road may require fill material, potentially disrupting flow of runoff to the playa. Since the playa is probably fed by overland runoff, the presence of the roadway will not significantly disrupt flow. After drilling is completed and the monitoring wellheads installed, the periodic use of the access road and presence of monitoring personnel will cause only brief disturbance to wildlife during each visit. The environmental impact of the deep-borehole study should not be significant because the playa is already heavily modified and there is relatively little habitat value at this time.

Disturbance of migratory birds (particularly waterfowl and raptors), small mammals such as mice and ground squirrels, and some reptiles and amphibians from the shallow playa drilling will be minimal. Each of the three playas may provide habitat. If the playa planted to sorghum fills with water during waterfowl migration, waste grain in the uplands would be a food source. Nearby playas would also provide nesting areas. High concentrations of waterfowl and other migratory birds will attract raptors and other predators.

The major impacts to these habitats will be from equipment noise and from compaction, litter, and human presence. These impacts will be limited to a 3-month period in each playa, which can be scheduled to avoid critical times in species life cycles. There will be no

permanent loss of habitat. Site restoration will require removal of drill muds and cuttings, replacement of soils, and revegetation if appropriate.

Seismic surveys will be conducted along established grids, many of which can be conducted from roadways. Overland surveys, however, can be expected to cross floodplains and wetlands. In the process of following the grids, the large vibrator trucks will disturb habitat and wildlife. Impacts include vegetation damage, soil compaction, noise, and human presence. Crossings of drainage areas will not result in major, long-term impacts since these areas rarely contain flowing water. As stated above, these areas do not contain communities of woody vegetation that would be damaged by large trucks; grasses will rapidly recover from the weight of such trucks. Playa crossings will not take place where they are filled with water. Surveys conducted when playas are dry will result in similar disturbances as those in the drainage areas. No permanent habitat loss or destruction will occur.

Impacts to wildlife from the seismic surveys will occur only for the duration of the surveys, which is expected to be about 11 months. Truck noises will be similar to those of farm machinery, to which local wildlife have become accustomed. Wildlife will also avoid the test areas while crews are present, resulting in a temporary loss of foraging habitat. Surveys will be scheduled in cooperation with the FWS to avoid the loss of migratory birds, their nests, and eggs under the Migratory Bird Treaty Act. In addition, since the trucks are not likely to cross wet areas, species present when playas contain water, particularly waterfowl, raptors, shorebirds, and most passerines will not be affected. Thus the potential for adverse impacts to these species will be small.

Seismic surveys may also employ the use of explosive charges. When set off, these explosives will cause soil mounding at the shot holes and will startle nearby wildlife. The presence of field crews will also cause local wildlife to avoid the area. Habitat disturbance will be minimal, with no permanent habitat loss. Although surveys conducted when sensitive species are present will cause many species (particularly waterfowl and raptors) to vacate the area (as indicated above) these surveys can be scheduled around critical times in the species' life cycle.

Because of the playa wetlands, the region attracts large numbers of migrating waterfowl, shorebirds, and raptors. Tall structures such as the meteorological tower, shaft headframe, and utility poles may present a collision hazard during times of poor visibility. Although none of these structures will be within wetlands, consultation with the FWS has determined that the meteorological tower and ESF shaft headframe should be lighted (Malone, 1985). To avoid the additional potential for avian mortality, utility poles will be constructed to prevent electrocution of large birds, such as eagles protected under the Bald and Golden Eagle Protection Act and, in the case of the bald eagle, the Endangered Species Act of 1973 (see Section 4.2.1.2.2 for conductor spacing on utility poles).

Section 4.2.1.2.2 discussed the amount of salt generated during ESF construction. The ecological impacts of salt deposition are discussed in Section 4.2.1.11. Salt impacts to wetlands would occur only if large quantities of salt get into playa wetlands via airborne deposition on soils and subsequent concentration in the playa basins. Given the amount of salt generated, salt dust suppression measures discussed in Section 4.1.2, and the characteristics of salt dust in the environment, the amount of salt potentially deposited in the nearest playa downwind of the site will be so small as to be undetectable.

Other impacts to floodplains and wetlands will include some effects on water quality and land use. Although the majority of the site characterization activities will not take place near these areas, nor during times when they contain water, drilling in playas could potentially cause impacts. There is some concern that boreholes in the playas will reduce their water-holding capabilities (Malone, 1985). The relative impermeability of the basin soils (Section 3.2.9) indicates that if these soils are used to seal the boreholes, little percolation will result. In addition, Section 3.3.1 states that playa water tends to be of higher quality than water in the High Plains aquifer; thus, percolation should not degrade ground-water quality.

Additional water-quality impacts, such as increased sedimentation and turbidity, may occur if soils not fully stabilized or revegetated are subjected to runoff and inundation. Since each drill site will be 0.04 hectare (0.1 acre) or less, relatively less soil would be exposed to erosion than would occur during routine agricultural practices. The DOE will revegetate all disturbed areas where appropriate.

Land-use impacts would occur through the preemption of ongoing practices during the drilling activities. Construction of an access road in Playa 07-54-7P1 will reduce the playa's water-holding capacity. This can be mitigated through further deepening of the playa. Grazing and cultivation in other playas would have to be suspended during drilling and testing; however, borehole drilling will not reduce the playa's subsequent potential for either land use. Site restoration and revegetation will return the areas to their previous uses.

Recreational use of local playas may include fishing (in stocked playa lakes during moist years), trapping, and hunting small game, upland game birds (doves, ring-necked pheasants, quail), and waterfowl (ducks, geese) (NUS, 1984, BMI/ONWI-508). Section 3.4.2.4 lists the popular local game species in decreasing order of lowest numbers as mourning dove, quail, rabbit and jackrabbit, pheasant, and various ducks and geese, all of which utilize habitats in and around wetlands. Testing in playas during periods of recreational use would be disruptive; thus, in compliance with the Migratory Bird Treaty Act and the Fish and Wildlife Coordination Act, the DOE intends to conduct such studies during periods of time that are not critical to the life cycles of important game species.

Following completion of all studies in wetlands, each site will be restored to its previous condition or use as appropriate. Stockpiled soils will be returned in the order of their removal, and any grading or stabilization will be conducted. Revegetation will utilize native species and will be monitored to ensure complete restoration. Soils reclamation will follow recommended procedures, if available, of the U.S. Department of Agriculture or agencies of the State of Texas. The USFWS will be consulted on habitat restoration techniques.

Alternatives to the Proposed Actions. Alternatives to the proposed deep and shallow borehole activities include drilling from outside the playa basin itself (directional drilling) and, as indicated above, drilling at times when ongoing land use practices are not being conducted. Directional drilling outside of the playa basin could result in a tradeoff, in that impacts to habitat, wild life, and land use practices outside of the basin would be proportionately greater. Mitigation of such impacts would also include scheduling of activities during times of less intensive use.

Barr (1985) indicates that the habitat values of wetlands in the site vicinity vary with the amount of rainfall during any particular year, available habitat for food and shelter, and current land-use practices. A method to mitigate impacts would be to conduct a detailed biological monitoring of the study areas to determine optimal times for testing. Drilling and other studies would then avoid critical wildlife-use times at the expense of delays in obtaining the requisite geohydrologic data.

The DOE has reevaluated the practicability of the proposed floodplain/wetlands actions, taking into account public comments received, and finds that no practicable alternative exists. The DOE has taken into account mitigating measures and has designed the proposed floodplain/wetland actions to minimize potential harm to or within the floodplain/wetlands. No State and local floodplain standards exist.

Alternatives to the seismic surveys include avoidance of wetlands in running the survey lines. Testing would occur around or on either side of a wetland, but no access to wetlands would be required. Alternatives to access-road construction (at the deep-playa boreholes) would be to forego construction and monitor the wells only on foot (or offroad vehicle) during dry periods. No other access roads are anticipated.

4.2.1.2.5 Cumulative and Long-Term Effects. Site characterization studies are not expected to produce any adverse ecological effects resulting from an accumulation of materials

such as salt or dust. The decommissioning plan has been designed to remove any potential pollutants including excess salt or contaminated soil from the site or area. Closure and decommissioning of test facilities and access routes will include site restoration and revegetation (Thomas, 1984). Revegetation of rangeland using native species of grass and forbs would, within 10 to 20 years, result in the development of a relatively natural short grass prairie ecosystem providing habitat for numerous species. Restoration of cropland will not affect surrounding natural ecosystems. While important from a local ecological standpoint, restoration of the test facility and access-route acreages would be regionally insignificant. If the testing program results in the development of a repository on the site, some impacts would be expected to continue for the lifetime of the project (Section 5.2.4).

4.2.1.3 Air Quality Effects

The analyses presented below are based on geotechnical and engineering data (e.g., schedules, equipment inventories, and specifications) and air quality source terms reported in NUS (1985b).

Site characterization will affect air quality as a result of emissions from vehicles, drilling rigs, earthmoving equipment, and wind blown dust. The process of determining air quality impacts includes (1) an estimate of emissions from project activities, (2) selection of an air quality model by which air quality concentrations can be estimated from emissions, (3) meteorological data, (4) background air quality concentrations (to which estimated air quality concentrations from proposed activities must be added), and (5) an understanding of how estimated air quality concentrations may affect human health and welfare, as established by the National Ambient Air Quality Standards (NAAQS) (Table 3-42). Project-related emissions analyzed are particulates, oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and carbon monoxide (CO) (emission rates derived from EPA documents such as "AP-42" are used; see NUS, 1985b for details). To determine compliance with the appropriate NAAQS, particulate and NO_x emissions and their impacts are examined in detail. Estimated concentrations of SO_2 and CO, based on maximum annual emissions for these pollutants, are small relative to the respective NAAQS (NUS, 1985b). Consequently, SO_2 and CO are not considered further.

4.2.1.3.1 Activities and Emissions. Site characterization activities having the potential for producing the most emissions are associated with geologic field studies and exploratory shaft facility (ESF) construction (Section 4.1).

Geologic Field Studies. Activities during the approximate 42-month period of geologic field studies include the drilling of the following:

- Stratigraphic boreholes
- Shallow and deep hydrologic test wells
- Engineering design boreholes
- Shallow foundation boreholes.

Exploratory Shaft Facility. Activities during the approximate 36-month period of ESF construction include the following:

- Access road construction
- Site clearing
- Drilling of freeze holes and freeze plant setup
- Sinking the two 3.7-meter (12-foot) diameter shafts
- Final lining* of the shafts (optional)
- Construction of surface facilities*
- Underground excavation.

The primary source of particulate emissions during geologic field studies and ESF construction is earthmoving activities. Particulate emissions from engine exhausts, are included

*These activities require cement mixed at an onsite batch plant.

in the earthmoving fugitive dust emission rates. Other sources during ESF construction include operation of a concrete batch plant and mined materials handling. Sources of NO_x emissions include the operation of borehole and freeze hole drilling rigs as well as exhaust emissions from mobile equipment.

Maximum daily particulate emissions are 622 pounds per day (see Table 4-19). This maximum is expected to occur during months 5 through 8 of the ESF construction schedule. Figure 4-22 presents a plot of the mean monthly particulate emissions for that portion of the ESF construction schedule which includes the expected maximum emissions (NUS, 1985b).

Maximum annual particulate emissions are 72 tons per year (see Table 4-19). This maximum is expected to occur during months 2 through 13 of the ESF construction. This period includes the emissions due to access road construction and site clearing (Section 4.1.2), the activities which cause the most particulate emissions (see Figure 4-23). This figure presents a plot of the 12-month running total particulate emissions due to all sources for the ESF construction schedule. Figure 4-23 does not present individual monthly mean emission rates as in Figure 4-22. Running totals for the latter portion of the schedule are represented by a dashed line indicating that particulate emissions decrease with time (NUS, 1985b).

Particulate emissions due to wind erosion from disturbed areas of the site are not included in Table 4-19 or in Figures 4-22 and 4-23, but are considered in estimating project-related impacts. The determination and application of these emissions is discussed further in Section 4.2.1.3.2.

The analysis here of the periods of maximum daily and annual particulate emissions does not include excavation of salt. Sources of particulate salt emissions will include handling of mined salt and transferring it to the salt storage pile, maintaining the pile, and wind erosion of the active pile area. Relative to the activities associated with constructing the much larger salt storage pile during repository development (see Section 5.2.5), fugitive salt emissions are expected to be less during site characterization because the pile is much smaller. Salt deposition impacts during site characterization are discussed relative to repository impacts in Section 4.2.1.11.

Maximum annual NO_x emissions are 242 tons per year (Table 4-19). This period is expected to occur during the months 12 through 23 following the Presidential approval of a recommended salt site to undergo site characterization. This time schedule differs from that required to identify maximum periods of particulate emissions because a significant amount of the NO_x emissions are due to geologic field studies which begin prior to ESF construction. Geologic field studies and ESF construction begin in months 2 and 10 following the Presidential approval, respectively. Therefore, the maximum annual period includes NO_x emissions due to geologic field studies (borehole drilling) and ESF construction activities (freeze-hole drilling and mobile sources). Borehole and freeze-hole drilling activities represent stationary sources, which account for 232 tons per year of the maximum. Mobile sources account for the remaining 10 tons per year (ONWI, 1986).

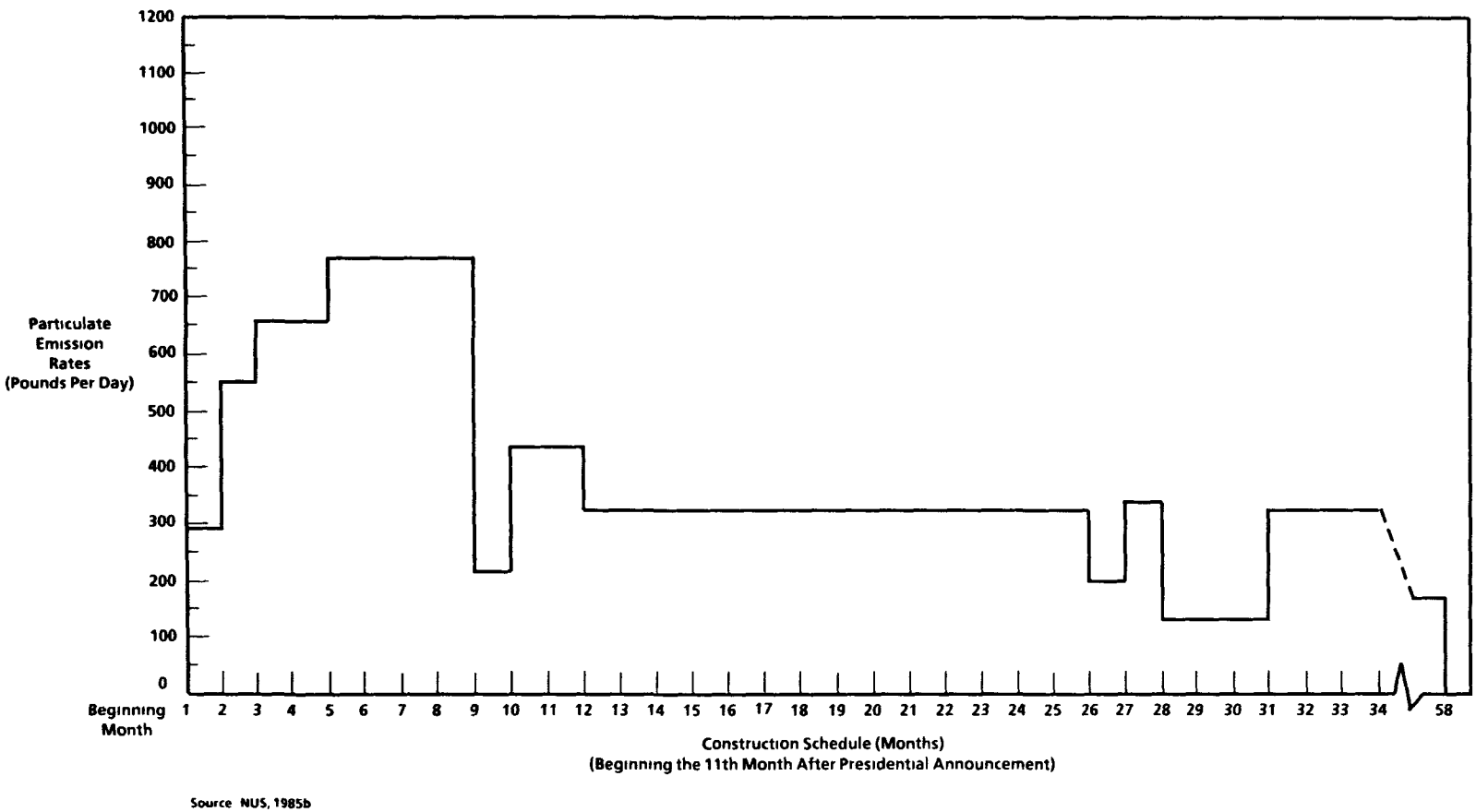
Figure 4-24 presents a plot of the 12-month running total NO_x emissions due to stationary and mobile sources and to all sources combined from the initiation of geologic field studies through the ESF construction. This figure also indicates the threshold emission level for stationary sources (250 tons per year) which would trigger Prevention of Significant Deterioration (PSD) requirements. The plot of emission values due to stationary sources indicates that site characterization activities will not be subject to PSD requirements (Section 4.2.1.3.3 contains further discussion).

Mitigation. Fugitive dust mitigation measures planned for the project include the application of water and chemical suppressants to disturbed areas and haul roads in a carefully designed control program. EPA (1984, pp. 3-17) describes such a program to control fugitives from paved and unpaved roads by up to 90 percent. Additional controls may be applied, such as speed controls on earthmoving vehicles and haul trucks, paving of haul roads, minimizing the size of disturbed areas, and covering storage piles. Control efficiencies are dependent on three parameters: (1) application intensity; (2) application frequency; and (3) chemical

Table 4-19. Maximum Emissions From Geologic Field Studies and Exploratory Shaft Construction

Pollutant	Emission Rate	
	Maximum Daily (Pounds per day)	Maximum Annual (Tons per year)
Particulate	622	72
NO_x		
Drilling Rigs (Borehole and Freeze Hole)	---	232
Mobile Equipment	---	10
Total	---	242

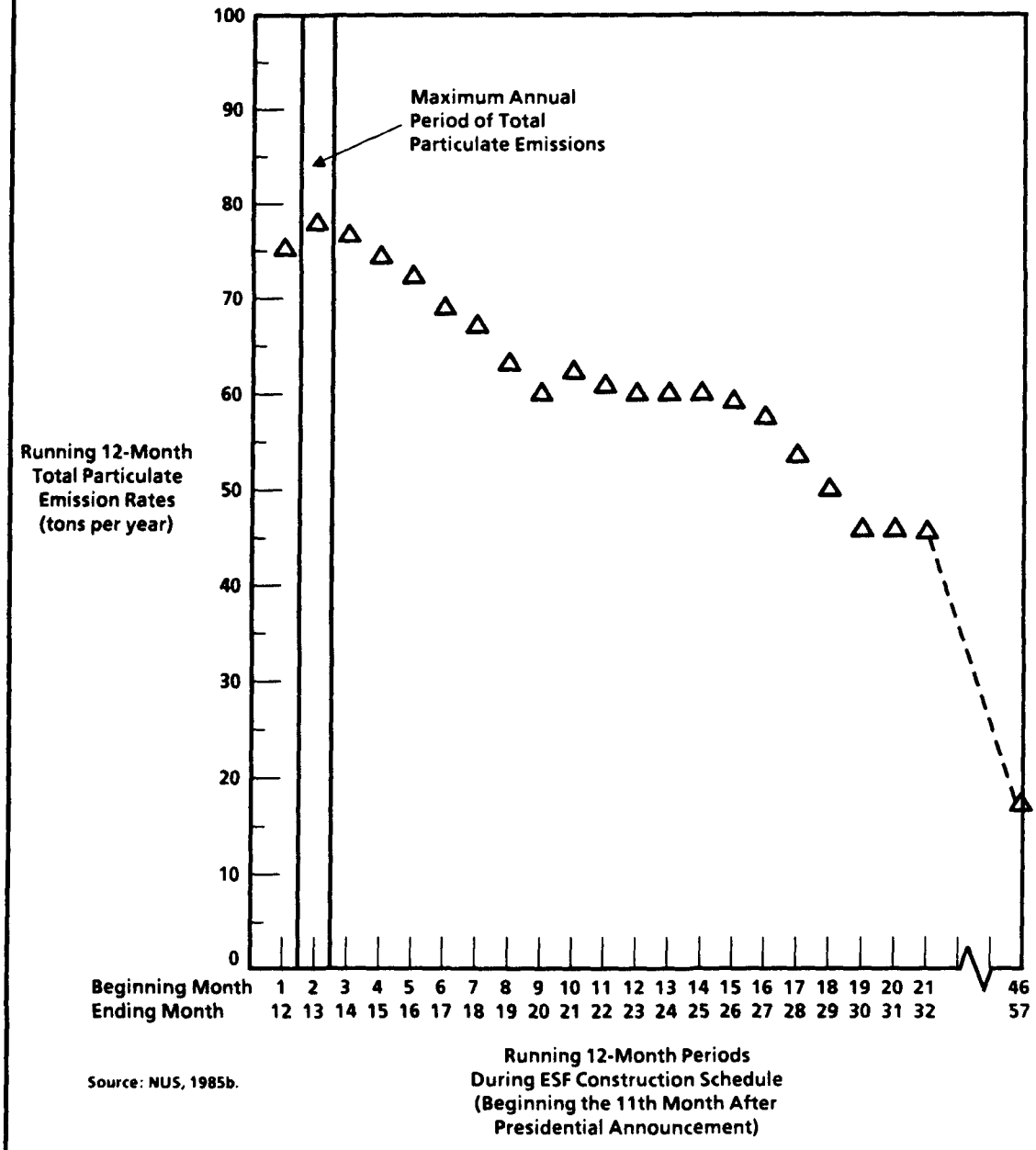
Source: ONWI, 1986.



Source NUS, 1985b

Monthly Particulate Emission Rates Due to ESF Construction Activities at the Deaf Smith County Site

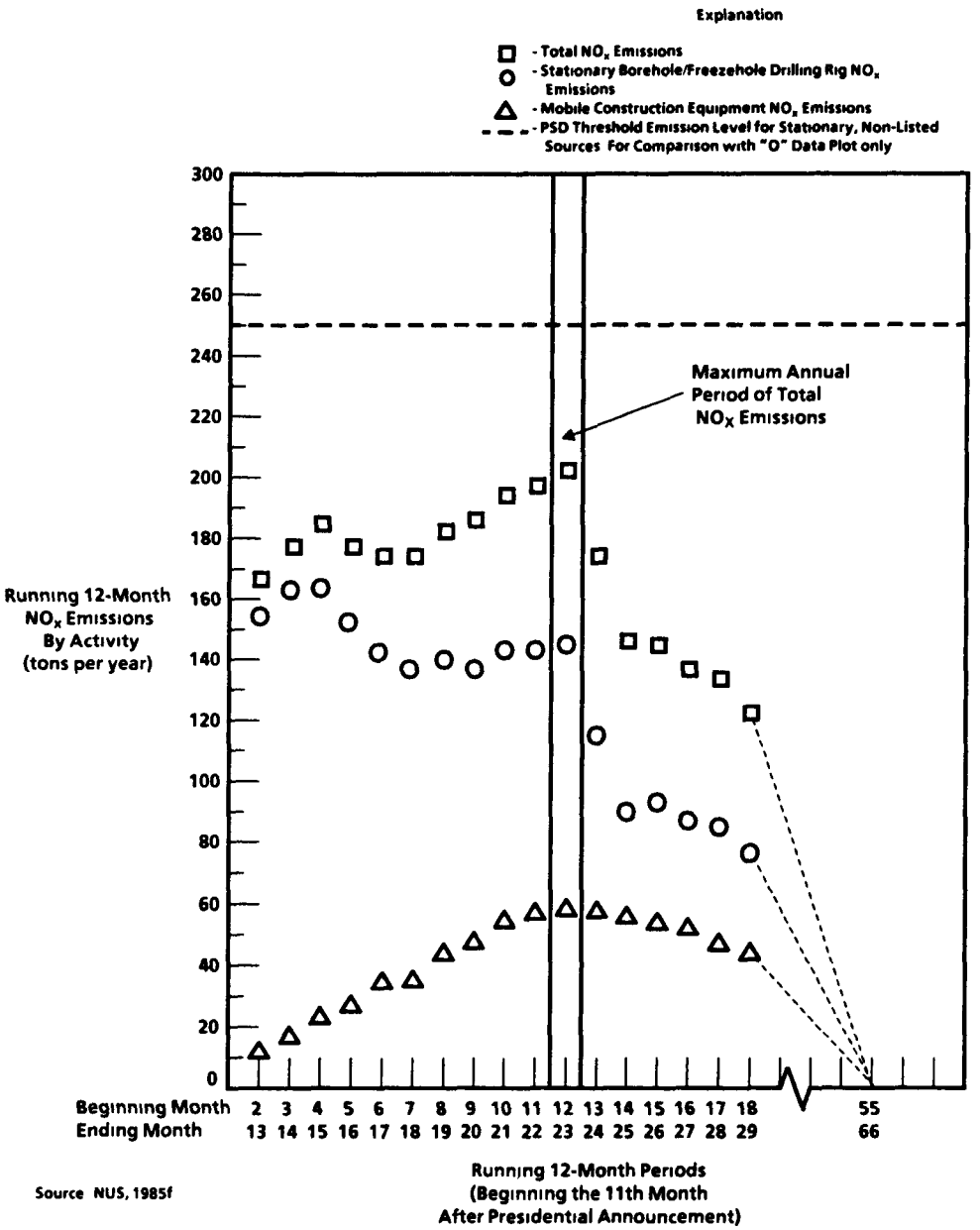
Figure 4-22



Source: NUS, 1985b.

Running 12-Month Total Particulate Emission Rates Due to ESF Construction and Underground Testing Activities at the Deaf Smith County Site

Figure 4-23



Source NUS, 1985f

Running 12-Month NO_X Emissions Due to Drilling Rig Operations and Mobile Sources at the Deaf Smith County Site

Figure 4-24

dilution ratio. By adjustment of these parameters it should be possible to obtain higher (or lower) control efficiencies than those documented in the EPA report. The 90 percent control efficiency (EPA, 1984) is for travelled roadways. By applying the same control measures to disturbed areas and then limiting traffic access to them, control efficiencies in excess of 90 percent should be achievable. The control program for the proposed Deaf Smith County ESF activities has a goal of 90 percent. This degree of control was assumed in the modeling discussed below.

Mitigative measures are required to reduce the amount of particulate salt emissions associated with the salt storage pile. Water sprays may be used to suppress dust during salt handling activities. Wind erosion emissions from the salt pile will be reduced due to the natural crusting tendency of salt (Ver Planck, 1958). Crusting will be promoted by watering the pile. Inactive areas of the salt pile will be covered (e.g., with soil or asphalt) as the pile is being developed and after it is filled to capacity. Transport vehicles for hauling excess salt to offsite disposal areas will be covered.

Control of NO_x emissions from diesel exhaust is required of manufacturers by Federal regulations. Inspection and maintenance of these controls by contractors will be a project requirement.

4.2.1.3.2 Methodology. The EPA Industrial Source Complex Dispersion model (ISC) (Bowers et al., 1979) was used to estimate atmospheric concentrations of TSP and NO_2. ISCST (short-term) was used to estimate 24-hour average TSP concentrations. ISCLT (long-term) was used to estimate annual average TSP and NO_2 concentrations. The model was selected because of its ability to accommodate emissions from point and area sources, to allow for variable emission rates with time and with meteorological conditions (e.g., wind erosion), and because the model contains an option to consider particle deposition by gravitational settling. This latter phenomenon occurs with a significant fraction of the relatively large particle sizes found in fugitive dust emissions.

The ISC model requires a particle size distribution as input in order to use this option. The distribution used in this analysis is adopted from the results of fugitive dust measurements at western surface coal mines and is discussed in NUS (1985b).

Particulate emissions were modeled as area sources based on engineering design information (NUS, 1985b). Maximum fugitive particulate emissions generated by earthmoving activities, materials handling, and vehicle movement were apportioned to one of two area sources depending on the ESF construction activity causing them. Wind erosion emissions were also apportioned to these two area sources, but were assumed to occur only when the wind speed at the eroding surface exceeded the threshold of 12 miles per hour. The model requires area sources to be represented as a square. Site work activities were assumed to occur in an area that is 350 meters (1,148 feet) on a side (or approximately 12.1 hectares [30 acres]). Surface-facility construction and sinking-plant setup activities for the production and service shafts were assumed to occur in an adjacent area also 350 meters (1,148 feet) on a side. On an annual basis, maximum particulate emissions were assumed to occur over the entire 24.7-hectare (61-acre) ESF site area, represented by a square that is 500 meters (1,640 feet) on a side (NUS, 1985b).

Maximum annual NO_x emissions were modeled as a combination of one area source based on engineering design information and one point source (NUS, 1985b). The mobile sources of NOx were assumed to occur over the 24.7-hectare (61-acre) ESF site area. Emissions from the freeze hole drill rigs at the service and production shafts, which last only two months, were treated conservatively as one point source, centered in the ESF site area. Emissions from drilling rigs associated with geologic field studies were also assumed to occur at this same point. This assumption is conservative in that these drilling rigs will be located throughout the proposed repository site area and will be stationary for periods of only one to six months before relocating (see Section 4.1.1). Maximum annual incremental concentrations from any one or group of these widely separated drill rigs are much less than the concentration resulting from these modeling assumptions.

One year of sequential, hourly meteorological data (for the year 1964) and five years of meteorological data (1976 to 1980, STAR format) from Amarillo, Texas National Weather Service Station were used in the modeling analysis (see Section 3.4.3.4).

No site-specific air-quality data are available. For the purposes of this environmental assessment, background values, from a station maintained by the Texas Air Control Board for EPA in Amarillo, Texas, of 62 micrograms per cubic meter of TSP, and 20 micrograms per cubic meter of NO_2 were assumed (see Section 3.4.3.1).

4.2.1.3.3 Air Quality Impacts. This section addresses the results of the air-quality modeling analyses. Additional details appear in NUS (1985b).

Since the analyses were completed, updates and corrections to the equipment list have been made. Furthermore, a quality assurance check of the computation of the air quality emission levels has indicated errors in some terms, many of which have a cancelling effect with most of the others, leading to reduced impacts. Also, a review of the methodology employed in the air quality modeling revealed that the maximum 24-hour prediction (instead of the second highest) was the more appropriate value to use considering that one year of meteorological data was used. The above changes will affect the concentrations of total suspended particulates (TSP) predicted in the air quality modeling as compared to what is presented below. A comparative evaluation has been performed of the expected changes in projected air quality impacts and is documented in "Evaluation of Air Quality and Noise Impact Assessments - Deaf Smith" (ONWI, 1986). This document lists the changes in some detail and presents the results of those changes in terms of revised air quality impacts. That document concludes that small differences in expected impacts results, none of which are large enough to invalidate any of the conclusions presented herein.

Regulatory Review. The primary criterion in determining PSD applicability is whether a facility is a "major source" of criteria air pollutants. The sources of particulate and NO_x emissions discussed earlier are not included in the list of 28 major stationary sources subject to an emission limitation of 100 tons per year. To be considered a major source, project-related stationary source emissions would have to be greater than 250 tons per year (40 CFR Part 52.21 [b][1]).

Particulate emissions are primarily fugitive emissions. For that reason, PSD requirements are not applicable (40 CFR 52.2303 and 40 CFR 52.21 [b][1][iii]). Table 4-19 indicates the maximum annual emission level is 78 tons per year. NO_x emissions are due to both stationary and mobile sources. Borehole and freeze-hole drilling rigs are stationary sources operating for 1-to-6-month periods at any one location. On an annual basis, the maximum total NO_x emissions from these aggregate stationary sources are 142 tons per year (see Table 4-19), which is well below the threshold limit.

For the purposes of this EA, the DOE concludes that site characterization is not subject to PSD requirements because stationary source emissions do not exceed the threshold limit of 250 tons per year.

In the interpretation of the modeling results presented below, air quality impacts are considered to be significant if the NAAQS are exceeded, i.e., those ambient concentrations which "...allowing an adequate margin of safety, are requisite to protect the public health" and those levels which "...are requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants in the ambient air" (42 CFR Part 410).

Uncertainties. Prior to discussing modeling results, it is important to point out that there are uncertainties in the air quality impact analysis associated with particulate emission rates. Emission factors, particle size distributions, and control factors used to estimate particulate emission rates are drawn from the published literature. While the DOE considers that these data are the best available for use in the impact analysis, the DOE recognizes that there are uncertainties inherent in their use. For example, fugitive dust emission factors are based on limited measurements at other locations and for other types of

earth-moving activities where natural soil characteristics such as silt and moisture content are different from those existing at the site. Particle size distributions from studies of western coal mines were used for both fugitive dust and salt emissions. Dust control efficiency values (50 percent using water application and vehicle speed limits, and 90 percent using chemical suppressant application and vehicle speed limits) can involve errors. The DOE believes the values used herein are achievable with a well designed and carefully conducted mitigation program. Uncertainties inherent in emission rate estimates have not been quantified; they could result in either higher or lower air quality impacts.

Estimated Concentrations. The highest and second-highest 24-hour TSP concentrations offsite were estimated. The second-highest offsite values are reported as maximums for comparison with the 24-hour NAAQS, which are not to be exceeded more than once per year. The highest annual offsite concentrations of TSP and NO_x are also reported. "Offsite" refers to points at or beyond a 243-hectare (600-acre) secured area surrounding the ESF.

Maximum offsite 24-hour TSP, and annual average TSP and NO_2 concentrations are summarized in Table 4-20. Total concentrations representing the sum of incremental concentrations plus background values identified earlier in Section 4.2.1.3.2 are presented.

The results indicate that the primary and secondary 24-hour NAAQS for TSP, and the annual NAAQS for TSP and NO_2 will be met during site characterization. On this basis, DOE concludes that site characterization activities will not have a significant impact on air quality.

Impacts due to salt deposition are discussed in Section 4.2.1.11, as mentioned earlier.

4.2.1.4 Water Quality Effects

All drilling, construction, and sampling programs associated with the characterization of the Deaf Smith County site are planned so that program goals will be met with minimum environmental disturbance. Appropriate mitigative measures will be implemented during site characterization activities. Reclamation efforts will be conducted throughout and following the characterization program. The purpose of these efforts is to avoid or minimize long-term environmental impacts on the region's water resources.

Authority granted under the Federal Water Pollution Control Act as amended by the Clean Water Act of 1977 (33 USC Sections 1351-1376) has been retained by the U.S. Environmental Protection Agency (EPA). If the proposed project is to discharge pollutants into navigable waters, a National Pollutant Discharge Elimination System (NPDES) permit must be acquired from the U.S. E.P.A. under Section 402 of the Clean Water Act. Another permit will be required from the U.S. Army Corps of Engineers, under Section 404 of the Clean Water Act, since construction activities occur in a playa.

The Fish and Wildlife Service and the U.S. Army Corps of Engineers have been consulted on the identification, location, and extent of wetlands and floodplains in the vicinity of the site that may be protected under Executive Order 11990 (Protection of Wetlands) and Executive Order 11988 (Protection of Floodplains) (Reyer, 1984; Neff, 1984; Johnson, 1984b). An assessment of wetlands is included in Section 4.2.1.2.5.

Consultation with the U.S. Department of the Interior (National Park Service) and U.S. Department of Agriculture (U.S. Forest Service) confirms that no designated or potential Wild and Scenic Rivers exist in the vicinity of the proposed repository site (Reyer, 1984; Peterson, 1984). This has been verified against the list of protected rivers and potential additions published in the Wild and Scenic Rivers Act (16 USC Sections 1271 and 1287). Therefore, the act is not applicable to the Deaf Smith County site.

Withdrawals of ground water are regulated under the Rules of the High Plains Underground Water Conservation District No. 1 (HPUWCD). If any project boreholes or water wells are expected to produce water in excess of 95,000 liters (25,000 gallons) per day, a permit may be required from the HPUWCD.

Table 4-20. Air Quality Impacts During Site Characterization, Deaf Smith County

Pollutant	Averaging Time	Location	Maximum Concentration (micrograms per cubic meter)	NAAQS (micrograms per (cubic meter)
TSP	24-hour	Limited Access Area Boundary	105	260/150[a]
TSP	Annual	Limited Access Area Boundary	69	75
NO_2	Annual	Limited Access Area Boundary	31	100

Note: Background TSP value is 62 micrograms per cubic meter, Background NO_2 value is 20 micrograms per cubic meter

(a) Primary Standard/Secondary Standard

Sources: NUS, 1985b; 40 CFR Part 50.

4.2.1.4.1 Field Studies. The geotechnical field program for the Exploratory Shaft Facility (ESF) will span 43 months and will include exploratory boreholes, hydrologic testing and monitoring, geophysical surveys, and mapping, (see Figure 4-1). These activities, described in Section 4.1.1, will start 10 months before and continue through ESF construction and testing.

Surface-Water Resources. Surface disturbance from construction of access roads and drilling pads and localized shallow borings will be done in such a manner as to minimize changes to natural drainage and to minimize erosion. Field activities are not expected to significantly affect water quality in Palo Duro Creek or playas.

Drilling operations are not expected to significantly affect surface-water quality or availability. Water needed for drilling activities, drilling fluids, potable water supplies, and site restoration will be obtained from wells located at the ESF. Under normal operating conditions, the drilling fluids will be circulated in a closed cycle and there will be no discharges of waste. At the end of drilling activities, or during changes in drilling fluid composition, it will be necessary to dispose of some quantities of drilling fluid. Drilling fluids will be stored, recirculated, and disposed of in compliance with Texas regulations. Onsite storage of fluids will be in aboveground tanks or excavated mud pits. Freshwater fluids will be released to surface drainage only if the discharge meets discharge water quality standards. Saline fluids will be stored on site until the fluid can be transported off site and disposed of in a licensed disposal facility. Pump discharges from hydrologic testing and monitoring will also be disposed of in this manner.

Ground-water Resources. The water used for the geotechnical field program will total about 2.09×10^8 liters (55.2 million gallons or 169 acre-feet) over a 42-month period (Table 4-21). The water will be supplied from two onsite wells at the ESF. Since these wells will also supply the water for the concurrent shaft construction activities, the impact of the total water use is estimated in Section 4.1.2.4.2.

Drilling activities are not expected to affect ground-water quality. The surface casing serves to protect the freshwater aquifers from surface-water contamination. Deep wells will be cased to prevent cross connection with deep saline aquifers. Upon the completion of drilling and hydrologic testing and monitoring, wells will be plugged.

4.2.1.4.2 Exploratory Shaft Facility. Activities at the exploratory shaft facility (ESF) will span about 5 years, divided between site preparation, shaft and surface facility construction, shaft outfitting, underground excavation, and testing (Figure 4-7). The shafts will be constructed using conventional mining methods. These activities, described in Section 4.1.2.2.2 will begin during the geotechnical field program.

Surface-Water Resources. Potential deterioration of water quality in Palo Duro Creek and playas could result from contaminated runoff from the site or from deposition of windblown salt and subsequent runoff from salt-contaminated soils. However, the impacts on surface-water quality are not expected to be significant because of the mitigation measures discussed below. There will be no impacts to surface-water quantity near the site because all water requirements will be supplied using ground water from onsite wells.

The ESF has been planned to fit the natural contour as close as practical to minimize erosion. Site grading will be done in such a manner as to minimize changes to the natural drainage and to prevent concentration of runoff on adjacent properties. An interceptor drain will be constructed along the south and west boundaries of the ESF to divert runoff from upland areas around the ESF to natural water courses. Soils will be stabilized over the entire construction area, storage areas, roadways, and parking areas. No construction activities will take place in the 100- or 500-year floodplain of Palo Duro Creek and its tributaries, or in playas.

Topsoil stripped from the construction area will be stored in the top-soil stockpile area. Overburden and salt from the shafts and drifts will be stored in the mined materials storage areas (Figure 4-6). Salt-contaminated runoff from the mined materials storage area,

the shaft loading area, and internal roads will be impounded in the evaporation/retention pond which is designed to retain runoff from a single event 500-year, 24-hour duration storm with a 0.6-meter (2-foot) freeboard. The impounded water will be disposed of by evaporation or, if needed, by removal from the pond and transportation to a licensed disposal facility. Salt-contaminated runoff will not be discharged to the environment.

Non salt-contaminated runoff from the topsoil stockpile area, perimeter roads, and other areas will be collected in the sedimentation pond (Figure 4-6) which is designed to provide a 24-hour detention for a single event 25-year, 24-hour duration storm. During detention in the pond, most of the suspended solids will settle out. Runoff that does not evaporate will be discharged to natural watercourses at flow rates and velocities that minimize erosion.

Salt emission at the site will result from salt pile wind erosion and salt-handling operations. The maximum salt deposition rate for repository operations at 840, 1,050, and 1,300 meters (0.5, 0.6, and 0.8 miles) from the edge of the salt pile is estimated to be 3.8, 2.1, and 1.3 kilograms per hectare (3.4, 1.9, and 1.1 pounds per acre) per year, under average meteorological conditions, and has been used here as a very conservative estimate of salt emissions during site characterization. By way of comparison, the natural salt burden associated with irrigated farming can be estimated from water quality data for water wells near the site. The average sodium concentration in 22 wells in the Ogallala aquifer is 33 milligrams per liter; the average concentration in 1 well in the Santa Rosa aquifer is 238 milligrams per liter (TNRIS, 1985). For the years 1958 through 1979, annual water use for irrigated farming in Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). The lower water application rate of Ogallala water will add about 110 kilograms per hectare (100 pounds per acre) of sodium per year to the soil; Santa Rosa water will add about 800 kilograms per hectare (710 pounds per acre) of sodium per year. A deposition of 3.8 kilograms per hectare (3.4 pounds per acre) of salt per year to the soil from the site represents about 1 percent of the sodium deposited by irrigation using the lower-salinity Ogallala water, assuming the lower application rates. Since this percentage is both small and conservative, impacts are not expected to be significant.

The area of greatest annual windblown salt deposition extends to the northeast from the ESF. Overland flow from this area drains predominantly to three playas, one to the north, one to the northeast, and one to the east (Figure 4-21). A forecast of the quantity of salt that will accumulate in playas and of the salt concentration in playa lake water requires a verified model. The site-specific data needed for model verification are not yet available. The concentration of salt in the playa lake water will vary over the course of a year and from year to year due to variation in the amount of rainfall, evaporation and infiltration. The infiltration and overland transport at the ESF will be simulated as part of site characterization using site-specific data and a water quality model; the salt concentration in playa lake water will be estimated as a function of time. However, impacts are not expected to be significant since, when compared with the salt loading due to irrigation, the windblown salt load is very small.

Ground-Water Resources. Potential impacts on ground-water availability in the Ogallala and Santa Rosa aquifers near the ESF could result from dewatering during shaft construction or from pumping to supply the ESF water requirements. Potential impacts on ground-water quality in the Ogallala and Santa Rosa aquifers could result from infiltration of salt pile runoff and windblown salt into the ground water or from shaft construction activities. However, these impacts are not expected to be significant.

The water used for exploratory shaft facility construction and testing activities will total about 160 million liters (42.4 million gallons or 130 acre-feet) over a 66-month period. The water used for the geotechnical field program plus the shaft construction and testing activities will total about 3.69×10^8 liters (97.5 million gallons or 299 acre-feet) over the

77-month period (Table 4-21). The water will be supplied from two onsite wells in the Ogallala Formation.*

Due to the limited volume of water required for the geotechnical field program and the shaft construction and testing activities, impacts on local water supplies will be minimal. The average annual water use at the site will be about 58,300 cubic meters (47 acre-feet). For the years 1958 through 1979, annual water use for irrigated farming in Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). On an annual basis, water consumption at the site will be comparable to that needed to irrigate 11 to 17 hectares (28 to 43 acres).

Pumping the two onsite wells will cause a drawdown in ground-water level in the surrounding area. Where pumping wells are spaced relatively close together, pumping one well will cause a drawdown in the others. Drawdowns are additive, so the total drawdown in a pumping well is equal to its own drawdown plus the drawdowns caused at its location by other pumping wells. The drawdown in pumping wells caused by withdrawals from other pumping wells is referred to as "interference" (Heath, 1983, p. 44).

The interference caused by pumping the two onsite wells was estimated using a ground-water model developed by Prickett and Lonnquist (1971, p. 8-19, 27-29). Pumping from nearby privately owned wells was not included in the model due to the unavailability of data. The onsite wells were assumed to be in the Ogallala aquifer. The saturated thickness within the site ranges from 15 to 35 meters (50 to 115 feet) (Figure 3-55); it was assumed to be 24 meters (80 feet). The hydraulic conductivity and specific yield were estimated to be 10 meters (34 feet) per day and 0.16, respectively (Knowles et al., 1984, Report 288, p. 141, 145). For the pumping schedule shown in Table 4-22, the maximum interference to wells 1.6 kilometers (1.0 mile) from the onsite wells is estimated to be about 0.1 meter (0.2 feet). Given the assumed saturated thickness of the Ogallala aquifer (24 meters [80 feet]), this maximum interference represents 0.25 percent of the saturated thickness.

Salt-contaminated runoff from the mined materials storage area, the shaft loading area, and internal roads will be impounded in the evaporation and retention pond. According to the current ESF design the storage area, the pond, and the ditches that convey salt-contaminated runoff from the internal roads to the pond will be constructed with two impermeable liners to prevent seepage of salt-contaminated water into the ground. Lining of brine ponds is commonly practiced in the salt industry and has proven effective and reliable in preventing seepage of brine into the ground. The integrity of the liner system will be monitored. A system of perforated pipes will be installed between the liners beneath the storage area, the pond, and the drainage ditches to detect and collect any salt seepage. Thus, significant seepage of salt-contaminated water into the ground is not expected.

If the impermeable liner system under stockpiled materials should fail, the saline leachate will flow downward through the unsaturated zone to the water table at a rate dependent on the soil characteristics and the presence of clay or caliche aquicludes. Infiltration studies at irrigated sites (Knowles et al., 1984, Report 288, pp. 23-26) have shown that the percolation rate and the wetting front filtration rate are highly variable on the High Plains. For the six counties near the site with infiltration data (Oldham, Deaf Smith, Randall, Castro, Lamb, and Floyd), the wetting front infiltration rate varies from 0.24 to 2.65 meters (0.8 to 8.7 feet) per year with a mean rate of 0.83 meter (2.7 feet) per year. This slow rate of percolation will permit timely corrective action. Such action will protect the water quality of the Ogallala and Santa Rosa aquifers by limiting the volume of leachate that may enter the unsaturated zone.

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*Well yields of 25 to 57 liters per second (400 to 900 gallons per minute) have been reported for wells completed in the Dockum Group in Deaf Smith County (Duffin, 1984, p. 25, 16). Consequently, the Dockum will be evaluated during site characterization to determine its suitability as a supplementary water supply.

Table 4-21. Freshwater Consumption at the Exploratory Shaft Facility

Activity	Months of Occurrence	Water Consumption	
		Gallons	Acre-Feet
Geotechnical Field Program			
Water-Supply Wells	2-3	63,000[a]	0.2
Foundation Borings	3-5	63,000	0.2
Engineering-Design Boreholes	3-6	2,646,000	8.1
ESF Monitoring Wells	3-6	384,300	1.2
Shaft-Monitoring Wells	4-7	1,512,000	4.6
Freeze-Wall Design Wells	4-9	2,520,000	7.7
Stratigraphic Boreholes	8-24	4,032,000	12.4
Shallow HydroNests	9-12, 24-27	1,512,000	4.6
Deep Hydronests	9-27, 31-43	39,640,000	121.7
Site-Foundation Borings	10-30	504,000	1.5
Playa Boreholes	12-21	284,000	0.9
Deep-Playa Wells	21-29	2,016,000	6.2
	TOTAL	55,176,000	169.3
ESF Construction and Testing[b]			
Site Preparation	11-17	1,100,000	3.4
Shaft- and Surface-Facilities Construction	13-41	21,000,000	64.4
Initial Underground Excavation	36-38	860,000	2.6
Outfitting	38-41	2,300,000	7.1
Underground Excavation	41-47	1,100,000	3.4
Testing	41-77	16,000,000	49.1
	TOTAL	42,360,000	130.0
	GRAND TOTAL	97,536,000	299.3

(a) The water needed to drill the two onsite wells will be obtained from offsite sources. Subsequent water needs will be supplied from the onsite wells.

(b) These data do not include water consumption during site decommissioning. Should the Deaf Smith County site not be selected for the repository, an additional 35 million gallons will be consumed over a 38-month decommissioning period.

Source: Ballman, 1985a,b; 1986; PB/PB-KBB, 1985.

Table 4-22. Freshwater Consumption Rate at the Exploratory Shaft Facility

Months of Occurrence	Water Consumption Rate[a]	
	Gallons Per Month[b]	Gallons Per Minute[c]
1	0	0
2	63,000	1
3	1,042,000	24
4	2,050,000	47
5	2,018,000	46
6	1,008,000	23
7	504,000	11
8	756,000	17
9	1,825,000	42
10	1,850,000	42
11	2,033,000	46
12	1,813,000	41
13-16	2,563,000	58
17-20	2,380,000	54
21-26	2,600,000	59
27-28	1,027,000	23
29	775,000	18
30	750,000	17
31-35	2,071,000	47
36-37	2,501,000	57
38-40	2,838,000	65
41-42	1,948,000	44
43-46	627,000	14
47-77	444,000	10

(a) Estimated from water consumption data in Table 4-21 by assuming water consumed 30.5 days per month and 24 hours per day.
(b) Rounded to nearest 1,000 gallons per month.
(c) Rounded to nearest gallon per minute.

Infiltration followed by deep percolation is the pathway by which wind-blown salt could affect ground-water quality in the Ogallala and Santa Rosa aquifers. This assumes that salt deposited on the soil surface is dissolved by rainfall or irrigation water and percolates down through the surface soils to the underlying Ogallala or Santa Rosa aquifers.

Most of the area is a flat plateau covered by fine textured soils. Pullman clay loam is the predominant upland soil type. It is characterized by a slow infiltration rate, less than 0.25 centimeter per hour (0.10 inches per hour), and a zone of calcium carbonate accumulation, or caliche, 1 to 2 meters (3 to 6 feet) below the soil surface (NUS, 1984, BMI/ONWI-510, p. 40). The presence of a caliche layer suggests that percolation rarely moves beyond the first few meters of soil. Field measurements of deep soil moisture on the Southern High Plains have shown this to be the case. Klemt (1981, pp. 1-29) found that, with few exceptions, fields that had been irrigated 25 years or more showed evidence of deep percolation only to depths ranging from 6 to 10 meters (20 to 30 feet). With the exception of basin-irrigated fields, deep percolation was not detected through the Pleistocene sediments overlying the Ogallala aquifer (Aronovici and Schneider, 1972, pp. 71-73). The results of these studies indicate that windblown salt is not likely to affect ground-water quality when present in water that infiltrates upland area.

Wood and Osterkamp (1984, pp. 337-349) agreed with Theis (1937, pp. 564-568) that the overall recharge rate to the Ogallala aquifer from rainfall is less than 1.3 centimeters (0.5 inch) per year. However, they proposed that most recharge of the Ogallala is through the annular zones immediately surrounding the playa floor. Thus, salt-contaminated runoff that collects in playa lakes near the site could adversely affect ground-water quality in the Ogallala. Due to the unavailability of data, it is not possible at this time to quantify this effect. However, impacts are not expected to be significant, since when compared with the salt loading due to irrigation, the wind-blown salt load is small. The hydraulic characteristics in the saturated and unsaturated zones underlying a playa will be determined during the site characterization program. These data will be used to simulate the potential changes in ground-water quality as a function of time, and to develop mitigation measures as required.

Shaft construction will be essentially isolated from contact with potable ground water, at first by the freeze wall and the preliminary and final shaft lining as construction proceeds through the Ogallala and the Dockum, and if necessary, by the permanent shaft lining as construction proceeds into the lower formations (see section 4.1.2.2.2). In addition, if any localized ground-water flow in the immediate vicinity of the shaft construction should take place, this flow will be into, not away from, the shaft. Thus, there is not expected to be any mechanism by which potential contaminants associated with shaft construction could be transported away from the shaft and adversely effect ground-water quality.

Upward vertical flow around the shaft of saline water from the lower formations into the Ogallala and Santa Rosa aquifers is not expected to occur, primarily because the predominant vertical gradient in potentiometric levels is downward from the shallow fresh-water system (Section 3.3.2.1.1). Thus, regardless of whether or not any preferential pathways for ground-water flow are temporarily created around the shaft, any vertically upward will be impossible under conditions of normal ground-water movement. In addition, before shaft construction proceeds below the base of the Dockum, the permanent shaft lining and sealing systems, including seals around the shaft at the base of the Ogallala and the Dockum, will be in place. The integrity of these systems will be continuously monitored and corrective action taken if potential problems develop.

4.2.1.4.3 Other Activities. Environmental studies will be carried out to survey existing well sites and collect water-quality samples from ephemeral streams and playa lakes near the site. These studies will require staff access to surface water bodies and well locations and will require equipment installation (e.g., building of weirs and stilling wells, and installation of equipment shelters). Only minimal, temporary impacts on surface or ground-waters are expected as a result of these activities.

4.2.1.4.4 Cumulative and Long-Term Effects. No significant cumulative impacts on surface and ground-water resources are expected to result from site characterization activities. It is expected that the ground and surface waters in the vicinity of the exploratory shaft site would not experience cumulative or long-term impacts after the shaft is decommissioned.

4.2.1.5 Effects on Soils, Geology, and Paleontology

This section summarizes the potential impacts resulting from geotechnical and environmental field studies and from construction, testing, and closure of the exploratory shaft facility (ESF). As activities are completed, and if the site is not selected for repository development, reclamation will be implemented as described below.

4.2.1.5.1 Field Studies. Soil impacts from geotechnical field studies are expected to be localized, mitigable, and relatively insignificant. Soils will undergo some compaction, loss of structure, and possible change in chemistry in the area immediately surrounding each geologic field test site due to vehicular and heavy equipment traffic and possible spills of fuel, drilling mud, or other wastes from tests. Up to 283 hectares (700 acres) could be disturbed.

Waste drilling fluids and drill cuttings will be stored in a lined drilling mud pit to prevent soil contamination. Upon completion of field activities, the drilling mud pit will be reclaimed following removal of the drilling fluid, drill cuttings, and synthetic liner. These materials will be disposed of in an offsite licensed landfill. The mud pit will then be backfilled and graded to be nonimpounding, self-draining, and mechanically stable.

Excavated salt will not be brought to the surface during field studies, so salt drift and runoff will not contaminate soils. Table 4-2 summarizes field activities, land requirements, and the duration for each activity.

Topsoil will be stripped from the area directly impacted by geotechnical studies and stockpiled off site until needed for reclamation. Approximately 70 percent of the soils on the site and in the site vicinity are Pullman clay loam, which is a deep prime native soil, with textures of clay loam, clay, and silty clay loam throughout the profile. Although the A and B horizons are relatively low in calcium carbonate, the significant increase in the C horizon which can be root limiting. Most of the soils in the area have similar textures and carbon percentages. U.S. Soil Conservation Service has classified 82 percent of the area as prime farmland (Prendergast, 1985).

The area will be inspected with a hand gauge by a soil scientist prior to stripping to determine the depth and thickness of the A and B horizons. These will be salvaged and stockpiled together, separate from the salvaged C horizon material. The primary concern is to prevent mixing of high-carbonate C materials with low-carbonate A and B material. The A and B horizons can be mixed since the primary difference between them is the amount of organic matter, which will quickly deteriorate as soon as it is stockpiled.

The stockpiles will be seeded with suitable grasses and mulched and irrigated until the grass cover is established enough to prevent wind and water erosion. The high-carbonate C materials stockpile will require different grass species than the low-carbonate A and B material stockpile and may require more irrigation to establish the cover. Fertilizer needs will be determined by soil sampling, and a chemical soil stabilizer will be used to prevent erosion if the stockpiles cannot be mulched immediately. Clean straw at the rate of 4 tons per acre, anchored with a spray-on tackifier, will be used to mulch the piles. Seeding will be accomplished with a standard range drill or by hand if the size of piles do not warrant the use of equipment.

Mulch on the high-carbonate C material stockpile will be anchored with netting material to keep it in place for the longer time needed to establish effective ground cover on carbonaceous soils.

During reclamation, the carbonaceous C material will be replaced first, then covered by the combined A and B horizon material. Regraded C material will be scarified using a spring tooth or disc harrow prior to placement of the A and B material to provide good adhesion of the surface to the subsoil. The replaced soil material will be mulched and seeded as described for stockpiled protection.

This treatment of the disturbed areas will insure that the soils will reestablish their structure and permeability as quickly as possible and restore them to high productivity as prime farmland.

4.2.1.5.2 Exploratory Shaft Facility. The primary impacts to soils resulting from construction, testing, and closure of an exploratory shaft facility are expected to be as follows:

- Compaction and loss of structure from heavy equipment traffic
- Changes in soil chemistry from possible contamination from salt, drilling chemicals, oil, and grease
- Changes in physical properties such as permeability and organic matter content
- Increase in erosion potential.

Prior to construction, the ESF site will be stripped of soil. This will result in soil compaction, loss of structure, and increased surface runoff on the 25-hectare (61-acre) site. Construction of access roads to the facility will similarly affect 0.12 hectare (0.3 acre). Compaction and disruption of site soils from these activities will also occur during construction and operation. These impacts are unavoidable but will be confined chiefly to the shaft site and access road. Because soils in this area are especially susceptible to wind and water erosion (Geiger et al., 1968), special erosion control measures will be exercised. Stripped topsoil will be stored and protected on site for redistribution after shaft operations are complete. Topsoil will be protected by seeding with suitable grasses, mulching, and irrigation until the grass cover is capable of preventing wind and water erosion. The organic matter in the soil, piled and covered for 3 to 6 years, will decompose and the soil chemistry will change. Soil structure will not be quickly reestablished when the stockpile is redistributed. However, if the site is not chosen as a repository site, it can and will be reclaimed to an acceptable and agriculturally productive condition.

Possible spills of grease, oil, diesel fuel, or other wastes would change soil chemistry in the areas immediate to the shafts . Precautions will be taken to avoid soil contamination; however, should that occur, contaminated soils would be disposed of off site. Impacts of spills are expected to be minimal because the extensive or widespread use of potentially toxic chemicals is not planned.

Several retention ponds of varying sizes will be excavated. Retention and evaporation ponds for runoff are to remain in place through construction, testing, and until closure is complete. They will require disturbance of soil and overburden, but both types of impoundments can be reclaimed as discussed in Section 4.2.1.5.1.

Soils will be compacted and disrupted by the installation of the utility pole corridor. However, only small areas will be affected and impacts will be minor. Erosion control measures will be exercised as needed. If the site is not chosen as a repository, land reclamation will follow site characterization activities.

Construction of the ESF will result in salt being brought to the surface, some of which may be transported off site by wind. The amount is expected to be less than that generated by repository construction and operation. Modeling based on current source terms for the repository estimates that maximum salt deposition at 840, 1,050, and 1,300 meters (0.5, 0.6, and 0.8 mile) from the site would be 3.8, 2.1, and 1.3 kilograms per hectare (3.4, 1.9, and 1.1 pounds per acre) per year, respectively, for repository construction and operation. Because of the

much smaller amount of salt mined during site characterization, salt deposition will be less than the amounts projected for the repository.

Estimates of the potential for damage to soils and vegetation must be based on the nature of the soils, crops grown in the area, and the quality of surface and ground water. Agriculturally important natural soils in the area are described as "prime native" by the Texas State Office of the Soil Conservation Service. They are described as producing economic yields of crops normally grown in the area, which suggests they do not presently have any noticeable salinity problem. This may be a reflection of natural soil chemistry. However, soil factors which reduce crop yields due to salinity buildup are a consequence of the ratios between calcium, sodium, and magnesium; the mineralogy of the clays in the soil; the amounts and ratios of soluble salts in irrigation water; soil drainage related to natural structure and permeability, artificial drainage installed as a management tool; and the anions present in the soil and irrigation water (Allison, 1964). Plant responses to salinity will also differ according to tillage practices, irrigation practices, growth stage, varietal factors, and the nature of the climate related to temperature, humidity, and ozone content (Maas and Hoffman, 1977).

The quality of the water used for irrigation is a large factor in soil salinity buildups that reduce crop yields. All water contains certain amounts of soluble salts, and the salt content may be relatively high. However, if the ratios among the cations are favorable and the soils are well drained, no salt buildup will occur. As an illustration, the average sodium content of 22 wells producing water from the Ogallala aquifer, which is the water source of choice in the area, is 33 milligrams per liter (TNRIS, 1985). In the years 1958 through 1979, annual water use for irrigated farming in Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). The higher water use will add 110 kilograms per hectare (100 pounds per acre) per year of sodium to the soil. Santa Rosa water will add 800 kilograms per hectare (710 pounds per acre) per year of sodium to the soil. These are additional to the sodium present as a natural soil component.

Salt deposited at predicted rates on the soil and absorbed by the plant roots will not result in reduced crop productivity (see Section 4.2.11.1). Blowing salt during ESF activities will add less than 3 percent of the amount of salt that irrigation water contributes to the soil. Cropland in the site vicinity is regarded as producing high yields. Existing management practices are capable of alleviating the salt buildup incidental to irrigated farming and could be expected to negate the effect of any small additional increment from the ESF.

4.2.1.5.3 Other Activities. Installation of a meteorological tower involves grading a site, constructing concrete footing, and grading an access road. Changes in physical properties of the soil, drainage, and erosion potential would result from grading and compacting at the meteorological tower site. However, these changes will affect a small area, and the site will be reclaimed when the studies are complete.

Other environmental studies will have insignificant and localized soil impacts. Soil tests and archaeologic surveys will require scattered shallow diggings that will be backfilled. Surveys for noise, ecology, land use, and background radiation will involve several people driving or walking on the site and its vicinity. There will be minimal soil impact from these studies.

4.2.1.5.4 Cumulative and Long-Term Effects. Areas that are stripped for exploratory shaft facility construction and related field studies will undergo compaction and reduction of soil permeability. Soil that is removed and stockpiled will lose its structure. Soil chemistry will change to some degree. Some soil might be lost to wind and water erosion. Some soil materials will become contaminated from salt, drilling chemicals, oil, grease, and other additives and may have to be disposed of off site. Topography and surface and subsoil drainage would be slightly altered. Reestablishment of drainage patterns would produce some sediment movement. Soil profiles that ultimately develop may be unlike others nearby. Soil biota may also differ from those in the surrounding area. These should be considered the maximum long-term effects on soil as a result of shaft construction. However, the site can be returned to agricultural production as soon as reclamation is completed.

4.2.1.5.5 Geology. Site characterization activities are not expected to adversely affect the geology of the Deaf Smith County site. Backfilling the underground excavations with salt will fill at least 65 percent of the void space, thereby reducing the potential impacts of underground failure and surface subsidence. Given the depth of the underground excavation, little or no subsidence of the surface is anticipated. Small cracks in the subsurface strata will result from drilling and fracturing tests. The generally poor consolidation of the deposits, however, will limit the lateral propagation of the cracks, and the fracturing is not anticipated to cause surface subsidence or contribute to salt strata fault reactivation.

4.2.1.5.6 Paleontology. No areas of unique or readily accessible fossil occurrence have been identified at the site. If such areas are identified during site characterization field studies, a paleontologist can be consulted prior to and during excavation at the exploratory shaft. The paleontologist may conduct field surveys prior to excavation and may recommend mitigation measures. No significant loss of paleontologic information is expected.

4.2.1.6 Noise Effects

The analyses presented below are based on geotechnical and engineering data (e.g., schedules, equipment inventories, and specifications) and noise source terms reported in NUS (1985b). Since the analyses were completed, updates and corrections to the equipment list have been made. Furthermore, a quality assurance check of the computation of the noise emission levels has indicated errors in some terms, many of which have a cancelling effect with most of the others, leading to reduced impacts. A comparative evaluation has been performed of the expected changes in projected noise impacts and is documented in "Evaluation of Air Quality and Noise Impact Assessments - Deaf Smith" (ONWI, 1986). This document lists the changes in some detail and presents the results of those changes in terms of revised noise impacts. That document concludes that small differences in expected impacts results none of which are large enough to invalidate any of the conclusions presented herein.

This section discusses noise impacts from site characterization activities, in particular geologic and hydrologic boring activities and exploratory-shaft construction and testing activities. Site characterization activities also include various field studies discussed in Section 4.1.3 which are not discussed in this section since they would make no significant contribution to noise levels. This section first discusses the criteria selected for assessing noise impacts, followed by a description of the activities considered in the noise analyses, a summary of the noise modeling methodology, a discussion of noise impacts and ground vibration impacts, and possible mitigation measures.

4.2.1.6.1 Noise Criteria. Two indicators of broadband environmental noise impacts are used in this section to assess anticipated impacts resulting from site characterization activities. First, the U.S. Environmental Protection Agency (EPA) has identified energy-equivalent sound levels to protect the public (EPA, 1974). L_{dn} of 55 dBA has been identified as the level sufficient to protect the public from the effects of environmental noise in typically quiet outdoor areas (see Section 3.4.4 for a description of L_{dn}). The EPA has recommended adoption of L_{dn} less than 55 dBA as a goal in project planning of future programs.

The effects on humans for outdoor L_{dn} sound levels of 55 dBA and above (EPA, 1974) include the following:

1. Slight speech communication interference beyond 1 meter (3 feet) may be noted.

2. Less than 3 percent of the population may be highly annoyed, depending on attitude and other nonacoustical factors.

The EPA (1974) has concluded that nonimpulsive outdoor noise levels having a yearly average energy-equivalent level (L_{eq}) of 70 dBA or less over a 40-year period will protect against hearing loss from nonimpulsive noise in the general population.

The guidelines for limiting exposure to impulsive noise, such as from blasting which are expressed in terms of peak pressure level, duration of individual pulses, and number of pulses per day, have also been summarized by the EPA (1974). At an exposure rate of 100 impulses per day of 125 dBA peak pressure, the exposed population will not experience noticeable hearing loss. Protection of residential structures from the effects of blast-induced ground vibration is provided by a vibration limit of 13 to 18 millimeters (0.5 to 0.75 inch) per second (Siskind et al., 1980). The same reference shows that ground vibration due to blasting will be kept to barely perceptible levels by limiting vibration to 2 millimeters (0.08 inch) per second.

In order to express the cumulative effects of activity interference from noise, a second indicator of noise impact relates L_{dn} to annoyance. Although other factors, such as an individual's attitude toward a noise source, may influence one's reaction to activity interferences, the percentage of people highly annoyed in a given environmental situation provides a useful indication of the severity of the impacts. Results of 11 surveys involving transportation noise show a correlation between measured L_{dn} values and annoyance (Schultz, 1978). The types of sounds from transportation involved in the 11 studies are similar to those expected from construction activities.

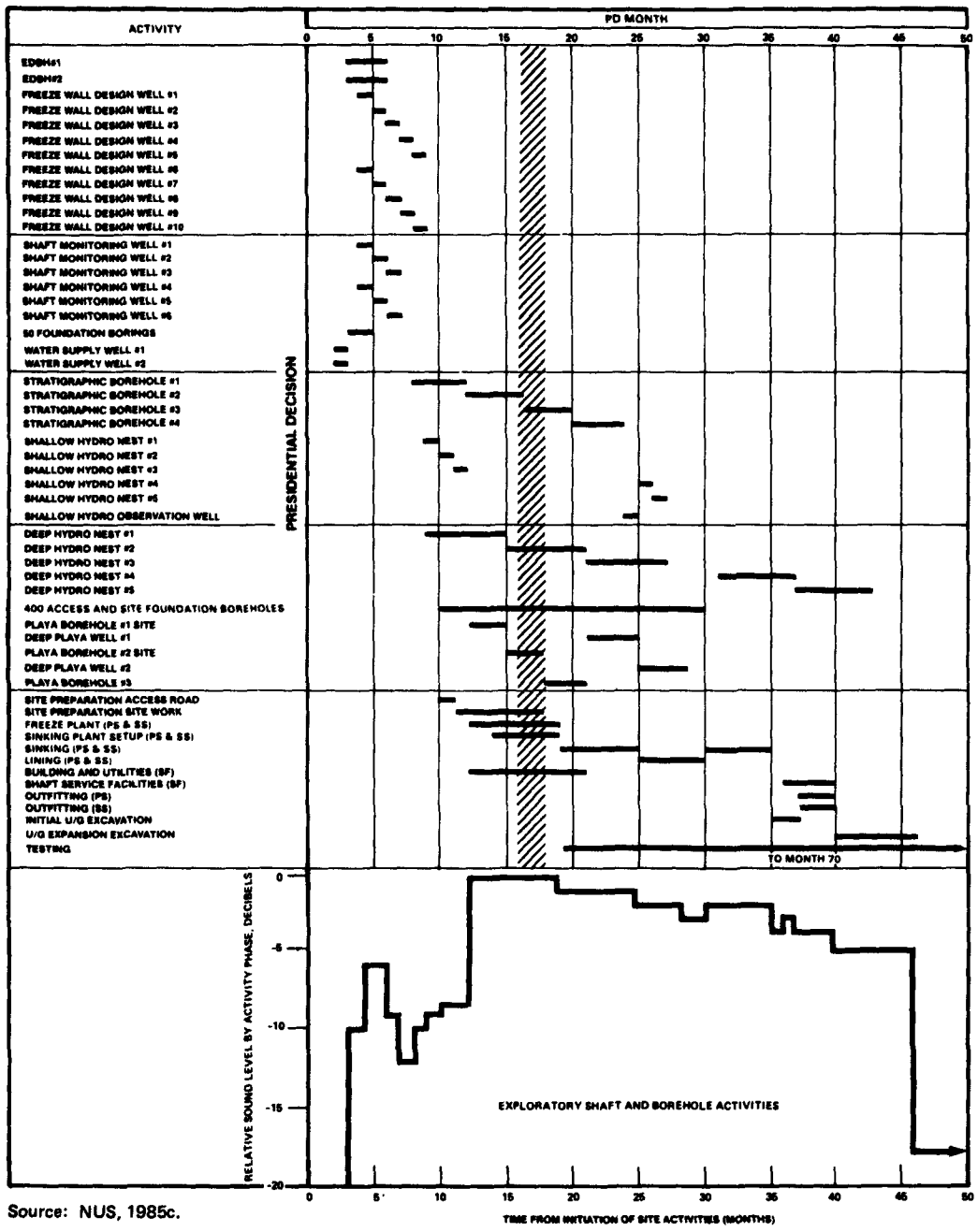
In this EA, noise levels are assumed to be acceptable when L_{dn} sound levels are below 55 dBA at noise-sensitive receptors such as residences, schools, churches, and parks. The EPA has not promulgated any community noise regulations pursuant to the Noise Control Act of 1972 (42 USC Sections 4901-4918), as amended by the Quiet Communities Act of 1978 (42 USC Sections 4901-4918). The Act requires Federal agencies to comply with State and local noise regulations. There are no local, State, or Federal regulations which specify limits for acceptable environmental sound levels at this site.

The Occupational Safety and Health Administration (OSHA) regulates noise in the workplace. Noise control measures will be applied as necessary to meet OSHA regulations.

4.2.1.6.2 Geologic Field Studies. Geologic and hydrologic boreholes will be located both within and outside of the exploratory shaft facility (ESF) area (Figure 4-2). The drilling activities will be of varying duration, depending on the type of boring (see Figure 4-25). While the drilling rigs will be in the general area over a period of 40 months, the drilling at each location will last only from 1 to 6 months. Field study activities will result in some additional vehicular activity in the area of the boreholes and the site (see Section 4.1.1). Increases in sound levels from vehicular activity will be small, localized and of short duration. Noise impacts from these activities are discussed in Section 4.2.1.6.5.

Short-term increases in sound levels will result from the operation of truck-mounted generators for conducting geologic resistivity surveys. These generators are small (about the size of the engine-generator for a motor home) and will only produce noticeable increases in sound levels for short periods of time within about 100 meters (325 feet) of each survey location. If explosives are used for field seismic surveys, the seismic surveys will occur during daylight hours (Section 4.1.1.1).

4.2.1.6.3 Exploratory Shaft Facility. Development of the ESF will begin with the drilling of the two engineering design boreholes (EDBH). Additional drilling activities will occur within the ESF area over a 40-month period. In addition to these activities, site preparation, shaft sinking, and facility construction activities will extend over 30 months, followed by underground excavation and testing (see Section 4.1.2). If this site is not chosen for the repository, the testing will be followed by decommissioning and reclamation. Noise impacts from these activities are discussed in Section 4.2.1.6.5.



Source: NUS, 1985c.

Explanation

PERIOD MODELED ////
EDBH — ENGINEERING DESIGN BOREHOLE
PS — PRODUCTION SHAFT
SS — SERVICE SHAFT
SF — SURFACE FACILITIES
U/G — UNDERGROUND

Activity Schedule and Relative Sound Levels During ESF Construction and Boring Deaf Smith County Site

Figure 4-25

4.2.1.6.4 Methodology. The noise impact of activities at the shaft site was evaluated using sound-power levels for equipment items associated with site preparation, freeze plant operation, sinking plant set-up, and surface facility construction of buildings and utilities. These activities occur concurrently during months 17 and 18, after initiation of site activities, along with boring of a stratigraphic borehole, a deep hydronest, a set of playa boreholes, and an array of access and site-foundation borings. Sound levels during this period and several months before and after (months 13 through 19) were determined to be the noisiest period (NUS, 1985c).

Sound levels near the Deaf Smith County site were estimated using sound power levels from construction equipment and stationary equipment and a noise level prediction model, SOCON-5, (NUS, 1985c). The model uses equations for sound dispersion and attenuation coefficients given by Bolt, Beranek, and Newman (BBN, 1977, pp. C-1 through C-12; EEI, 1983, pp. 5-1 through 5-5). Using equipment inventories for each phase of ESF development, octave band sound power levels were developed from vendor data or published reports (NUS, 1985c). In cases where data were incomplete or unavailable, levels were synthesized from related data, known characteristics of comparable equipment, and published standards. Equipment sound power levels were adjusted to reflect the typical time at various loads. Distance terms for hemispherical spreading, molecular absorption, and anomalous excess attenuation are applied by the model. No adjustments for vegetation, terrain, meteorological effects, or seasonal conditions were applied. Standard day conditions were assumed (15 C [59 F], 70 percent relative humidity). Estimated sound levels included existing background sound levels, which were assumed to be an Leq of 35 dBA, which corresponds to a L_{dn} of 41 dBA (Section 3.4.4). Source locations correspond to the facilities arrangement shown in "Exploratory Shaft Facility Isometric View" (Figure 4-6). A qualitative estimate of the effect of vegetation indicates that some reduction in sound levels due to vegetation can be expected to occur during the growing season. Since the terrain in the area is generally flat, there is expected to be little reduction in sound levels due to terrain. However, this analysis is expected to overestimate sound levels since attenuation from vegetation and special measures to reduce noise from ESF activities were not considered.

Estimates of sound levels for each traffic route were made based on methods in BBN (1977, pp. C-29 through C-40). The ratio of trucks to cars on each route was estimated on the basis of traffic counts from summer and winter sound level surveys (NUS, 1984, BMI/ONWI-528, pp. 11-14; NUS, 1984, BMI/ONWI-526, pp. 10-16).

4.2.1.6.5 Uncertainties. It is believed by the DOE that the noise modeling carried out in this section was based on the best available meteorological data, the latest literature on sound emission levels, and the state of the art of noise modeling techniques. However, uncertainties do exist in this modeling and are caused largely by:

- Uncertainties in sound emission levels to approximately ± 5 dB
- Consideration of wind and temperature gradient effects on noise propagation. Unfavorable gradients (when occurring) can significantly increase noise propagation toward a given receptor whereas favorable gradients can significantly reduce such impacts.

The accumulated effects of these uncertainties can be large at any point and at any time outside the site boundary.

4.2.1.6.6 Noise Impacts. Exploratory shaft construction and testing activities and boring activities will increase sound levels at nearby residences. According to aerial photographs and field surveys, the nearest residence to ESF activities is located near the southwest corner of the exploratory shaft facility area. Other nearby residences are described in Table 4-23 and are shown on Figure 4-26. Estimated L_{dn} sound levels at nearby residences are given in Table 4-23 for the period modeled, as described in Section 4.2.1.6.4. Sound-level contours and nearby residences within 1.6 kilometers (1 mile) of the controlled area boundary are shown in Figure 4-26. The sound levels at the three nearest residences are

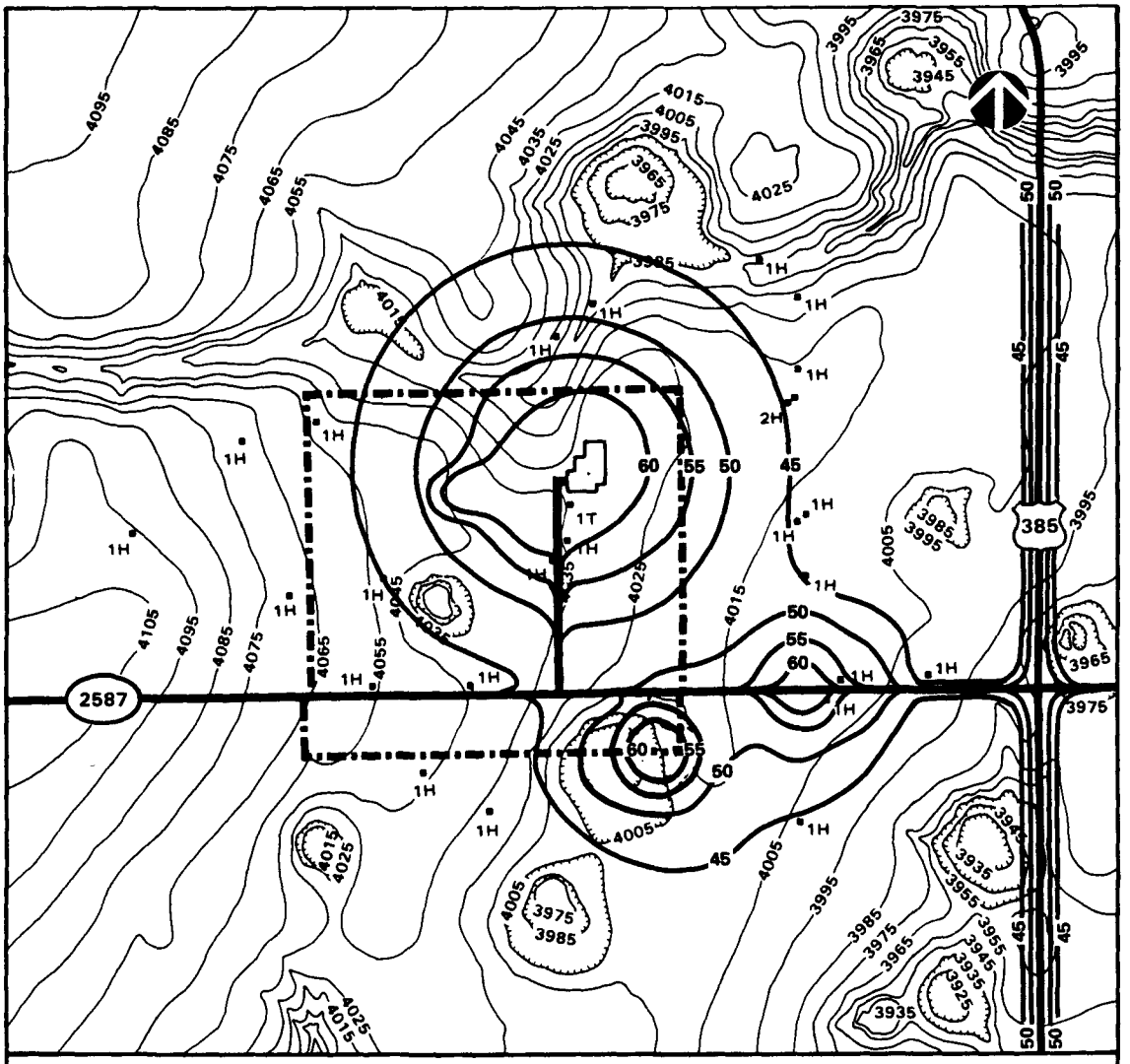
Table 4-23. Predicted Sound Pressure Levels, L_{dn} (dBA)[a]

Receptor[b]	1	2	3	4	5	6
L_{dn}	68	62	57	45	53	48

(a) Reference pressure is 2×10^{-5} Newtons per square meter (4.2×10^{-7} pounds per square foot).

(b) Receptors:

1. Nearby residence (trailer) near SW corner of ESF facilities area
2. Nearby residence 700 meters (0.4 mi) south of SW corner on access road
3. Nearby residence 1000 meters (0.6 mi) south of SW corner on access road
4. Nearby residences (two houses) 3000 meters (1.8 mi) east of SW corner of ESF
5. Nearby residence 1800 meters (1.1 mi) north of SW corner of ESF
6. Nearby residence 2800 meters (1.7 mi) north of SW corner of ESF



Explanation

1H / 1T — Nearby Residence
H = House
T = Trailer

L_{dn} Sound Levels	Community Reaction "Percent Highly Annoyed"
L_{dn} = 45	0
L_{dn} = 50	0
L_{dn} = 55	3
L_{dn} = 60	8
L_{dn} = 65	15
L_{dn} = 70	24

0 1 3 Kilometers
0 1 2 Miles

Source: NUS, 1985c.

Deaf Smith County Exploratory Shaft Construction L_{dn} Sound Levels (dBA)

Figure 4-26

predicted to exceed the EPA guideline level of 55 dBA (NUS, 1985c). This condition is expected to continue 44 months for residence 1 (see Table 4-23), 36 months for residence 2, and 13 months for residence 3. No other sensitive receptors such as schools and churches lie within the L_{dn} 55 dBA contour.

Increased sound levels around the boring activities are also shown in Figure 4-26. Similar increases in sound levels for boring activities will occur when drilling rigs are moved to other locations. Residents within approximately 0.8 kilometer (0.5 mile) of drilling activities will experience noise levels exceeding the EPA guideline of L_{dn} 55 for 6 months. Two residences near FM 2587 have been identified within this impact zone for the period modeled.

The EPA guideline of 70 dBA for a 24-hour L_{eq} for farmland is estimated to be met beyond 0.2 kilometer (0.1 mile). This guideline will be met at the nearest residence.

The correlation between the average subjective reaction of being highly annoyed and L_{dn} levels provides a perspective of the expected human response to noise from the project. Comparison of the predicted sound levels at the nearest residences with Schultz' (1978) estimate of percentages of the population highly annoyed at various L_{dn} values suggests that there is some potential for annoyance at the three nearest residences. A legend relating L_{dn} values to percent highly annoyed is shown in Figure 4-26. It should be noted that "percent highly annoyed" is applicable to a large community but may be statistically less meaningful when applied to estimating the reaction to noise from the few individuals near the Deaf Smith County site.

Relative L_{dn} sound levels for ESF and boring activities is presented in Figure 4-25. These figures are based on the total sound power level of equipment used during each month, with usage and load factors included and day and night weighting applied. They are intended for general comparison and do not accurately account for source frequency spectra or source location.

The impact of tonal noise from the equipment is more difficult to quantify on the basis of available information. Tonal noise may be produced by any particular equipment item, depending on the specific type and condition (wear) of the equipment. Although typical octave-band information exists for the specific equipment to be used, the presence of tonal components and their magnitudes depend on the manufacturer of the equipment. The following two factors aid in minimizing tonal noise impacts:

1. The broadband noise caused by equipment such as engines (mobile equipment) tends to mask the tones, reducing the likelihood that the tones would be audible in noise-sensitive areas.

2. Many of these tones (for noise sources such as welders and air compressors) are at high frequencies (greater than 1,000 hertz) and are reduced by atmospheric attenuation.

Shaft sinking will take place during months 20 through 25. Blasting will not be required for the first 8 to 16 meters (25 to 50 feet) of shaft sinking. Blasting noise below this depth will be reduced by the sinking stage and is not expected to be audible at the nearest residence. There are expected to be no more than 3 blasts per day, per shaft. Cumulative adverse health effects to the general public from blasting noise are not anticipated (see Section 4.2.1.6.1). An estimate of ground motion at the nearby residence during shaft blasting indicates that ground vibration from blasting is not expected to be perceptible.

If explosives are used during seismic surveys, they would create occasional pulses of noise in the vicinity of the surveys. The seismic surveys will occur during daylight hours. The number of explosive charges will vary but will probably average 70 per day. Assuming 2.3-kilogram (5-pound) charges at a 7.6-meter (25-foot) depth, and the use of electric blasting caps, there will be no impact beyond 100 meters (326 feet) from blasting activity (Wiss and Linehan, 1978). See Section 4.1.1 for a further description of the seismic survey program.

Analysis of traffic noise from ESF construction was performed using existing traffic volumes and the traffic volumes expected from the site preparation and shaft construction phase (Table 4-8, Table 3-52, and Table 4-24). No noticeable increase in sound levels along the major highways (Interstate 40, U.S. 385, and U.S. 60) is expected since these routes already carry large volumes of traffic. No noticeable increase in sound levels along Farm-to-market (FM) roads 1062 and 214 is expected since these routes are not expected to carry a significant portion of ESF traffic.

The L_{dn} values for traffic along the access road and FM 2587, shown in Figure 4-26, indicate at 61 meters (200 feet) the value is estimated to be 45 dBA. Peak traffic during ESF activities occurs during months 37 to 40 and coincides with the greatest manpower requirement (see Section 4.2.2). During this peak traffic period, the L_{dn} value along FM 2587 is estimated to be 51 dBA at 61 meters (200 feet).

In summary, potential significant impacts from the ESF activities include the following:

1. Noise levels at two residences near a borehole location during the period modeled will exceed the EPA guideline of L_{dn} 55 dBA for up to 6 months.

2. Noise levels at the 3 residences nearest to the site will exceed the EPA L_{dn} 55 dBA guideline for up to 44 months.

4.2.1.6.7 Noise Impact Mitigation. Noise levels exceeding the EPA guidelines at the three nearby residences will be mitigated by the application of noise-control measures. Mitigation measures and their effectiveness are as follows:

- Geologic Field Studies

  - Enclosing engines on borehole rigs - up to 10 dB reduction

  - Scheduling of borehole locations to avoid operating more than one drilling rig in an area near a residence

  - Installing "residential" grade exhaust silencers on diesel engines - 5 to 10 dB reduction

  - Locating borehole sites at least 0.8 kilometer (0.5 mile) from any residence.

- Exploratory Shaft Facility

  - Installing equipment noise controls such as sound enclosure around engines and hydraulic systems and residential grade mufflers on engine exhaust - up to 10 dB reduction

  - Purchasing homes or relocating residents currently living in the immediate area of the site.

Mitigative measures will be selected and implemented as necessary to limit impacts. If the Deaf Smith County site is selected, mitigative measures will be established based on discussions with appropriate agencies.

4.2.1.7 Effects on Aesthetic Resources

This section contains a discussion of the potential impacts on the visual character of the landscape from introduction of large structures and associated development in the Deaf Smith County site area during site characterization. Visual impacts may result from dust plumes, construction equipment, sky glow from night lighting, and disturbance of surface conditions.

Table 4-24. Expected Distribution of Site-Related Traffic During Peak Period of Site Characterization Activities, Deaf Smith County Site

Route Segment	Current ADT[a]	Percent of Maximum Daily Service Volume for Ideal Conditions[b]	Peak Hour Traffic[b] (vehicles) per hour)	Percent of Maximum Hourly Service Volume for Ideal Conditions (peak hour)[b]	Expected Increase in Daily Private Vehicle Trips[c]	Expected Increase in Daily Truck Trips[d]	Expected Percent of Maximum Service Volume for Ideal Conditions daily (peak hour)[e]
I-40/U.S. 66 (Amarillo-U.S. 66 Business)	9,100-58,000	14-86	1092-6960	39-249	371	40	14-87 (45-255)
I-40/U.S. 66	7700-9500	11-14	924-1140	33-41	371	40	12-15 (39-47)
U.S. 60 (Canyon-Hereford)	4,200-7,400	6-11	504-888	18-32	40	0	6-11(19-32)
U.S. 385 (Vega-FM 2587)	1,450	15	174	44	395	40	20 (91)
U.S. 385 (Hereford-FM 1062)	1,500-6,000	16-63	180-720	45-180	184	0	18-64 (65-200)
U.S. 385 (FM 1062-FM 2587)	1,150	12	138	35	224	0	14 (59)
FM 1062 (U.S. 60-U.S. 385)	230-400	2-4	28-48	7-12	40	0	3-5 (11-16)
FM 2587 (U.S. 385-site boundary))	110-220	1-2	13-26	3-7	618	40	8-9 (75-78)
FM 214 (I-40/U.S. 66-FM2587)	110-180	1-2	13-22	3-5	2	0	1-2(3-6)

(a) ADT = Average Daily Traffic, from Table 3-54.
(b) From Table 3-54.
(c) See Section 4.2.1.10.2 for discussion.
(d) Assumes all trucks routed through Amarillo.
(e) Assumes 43 percent of private vehicle trips (based on the number of workers per shift) and 50 percent of truck trips coincide with peak hour traffic.

4.2.1.7.1 Geological Field Studies. The geological field studies will involve the construction of access roads, erection of drill rigs, adding fences and trailers, clearing and grading land, and activities in the playa lakes. The visibility of the taller drill rigs will be similar to that of the exploratory shaft head frame (see Section 4.2.1.7.2). However, there will probably be many rigs in operation at the same time on the site (Table 4-2). The visual intrusion of the drill rigs will be greater than that of the exploratory shaft in the short term, but as soon as the boreholes are completed, the rigs will be removed. Approximately 694 boreholes are required, although not all boreholes will require taller, more visibly intrusive drill rigs. Some may require additional access roads. The compatibility of drilling activities with the background landscape will depend on their location with respect to features such as playas, rangeland, or agricultural areas.

The proposed activities in playas will disrupt the visual quality of these features to a moderate extent. The disrupted areas will be backfilled and restored nearly to their original condition as soon as activities are completed. Thus, these operations will exert a temporary effect on the visual quality of the region.

4.2.1.7.2 Exploratory Shaft Facility. Given the localized effects of most exploratory shaft facility activities and the short duration of shaft construction and site characterization, long-term, irreversible impacts on the visual character of the site and surrounding area are unlikely. Approximately 63 percent of the site is included in the "partial retention" visual variety class (Figure 4-27) because of its proximity to concentrations of people or areas of scenic value (NUS, 1984, BMI/ONWI-559). This means that any changes or modifications in these areas should be compatible with, and subordinate to, the area's character, if the area is to maintain its visual integrity. Over 10 percent of the site is classified in the "retention" visual quality objective class. For areas in this class, no changes should be evident if visual integrity is to be maintained. Nearly 27 percent of the site is classified as "modification," the least restrictive visual quality class. Despite their high visibility, facilities developed in this portion of the site would not disturb the visual integrity of the surrounding area. It is probable that most of the activities will occur in parts of the site in the "partial retention" visual variety class (Figure 4-27). In general, visual intrusion would be temporary; it would be similar to that associated with exploratory drilling for oil and gas, and therefore not atypical of the region.

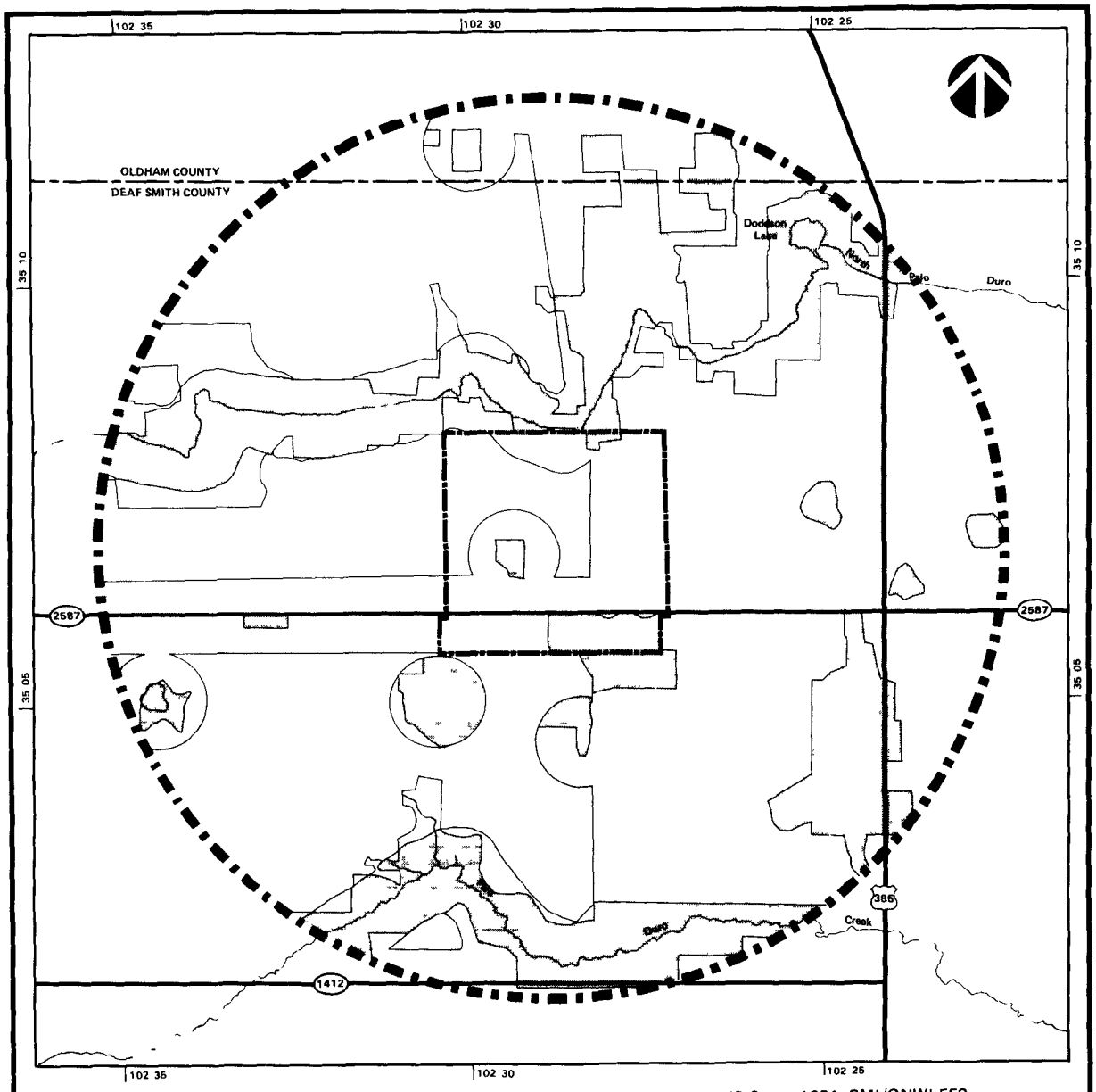
The two exploratory shaft facility headframes are 38 meters (125 feet) high. They will be visible from FM 1412, FM 2587, State Highway 214, I-40, and U.S. 385. While the headframes may be seen from as far away as 25 kilometers (15.6 miles), the visual effect will be comparable to that of the microwave relay tower of similar height and structure near FM 809.

The salt and nonsalt spoil piles are expected to be visible to residents in the vicinity of the site and to people driving along FM 2587. The piles (mounds), which will vary in height, up to a maximum of 9 meters (30 feet), will contrast with the otherwise flat terrain and their light-tan color is expected to contrast somewhat with the predominantly earth-tone surroundings.

Fugitive dust emissions will result from site characterization activities. Activities such as excavation, the movement of major equipment, and traffic on unpaved access roads will produce localized dust clouds. Dust plumes will be local and visible for short periods, resulting in no detectable loss of visual range from the surrounding area.

Many of the workers commuting to the site may pass through Vega on I-40 and U.S. 385 and through Hereford on U.S. 385 (see Section 4.2.2 for number of workers). This increase in traffic may have a slight visual impact on the normally lightly travelled intersections and the residences located there. The addition of an access road should have little or no such impact because of the predominantly flat land in the vicinity of the site.

Of the several prefabricated buildings and various trailers to be installed on site, at least one is expected to be constructed of corrugated steel. This material reflects sunlight and this will be more noticeable than other, less reflective building materials. These buildings will be seen only from FM 2587 and areas immediately adjacent to the site.



Source NUS Corp , 1984, BMI/ONWI 559, Visual Assessments for Swisher County and Deaf Smith County Locations

1 0 1 5 Kilometers

1 0 1 3 Miles

Explanation

Retention
Changes Would be Evident and Would not be Compatible with the Area's Character.

Partial Retention
Changes Would be Evident and Should be Made Subordinate to the Area's Character.

Modification
Changes Would be Evident and Might Dominate Locally but Would be Compatible with the Area's Character.

Deaf Smith County Site and Vicinity
Visual Management Objectives

Figure 4-27

The light from night operations may be visible from FM 1412, FM 2587, State Highway 214, I-40, U.S. 385, and the scattered farm settlements within the site vicinity and beyond. Directional lighting will be used to minimize the visibility of night lights on the surrounding area.

New transmission lines to the ESF will appear as dark lines on the horizon and cause some visual impact. An example of the type of power pole used for this new line is presented in Section 4.1.2, Figure 4-8. Temporary visual impacts during the construction phase will basically consist of an occasional observance of construction personnel and equipment. If the site is not selected as a repository, and there is no public use for it, the line will be removed and the tower and power pole sites restored.

4.2.1.7.3 Environmental Field Studies. During environmental characterization, from 1 to 20 people will be in the field at various times to sample and collect data. Typically, these field visits will be short and will have no impact on the visual character of the area.

The only environmental characterization activity expected to affect the visual character of the area is the installation of a meteorological tower and guy wire anchor foundations. The 60-meter (197-foot) meteorological tower will be visible from FM 2587, FM 1412, State Highway 214, I-40, and U.S. 385. It will be similar in visual character to the windmills in the region, appearing as a thick, vertical line on the horizon.

4.2.1.7.4 Cumulative and Long-Term Impacts. Based on the above discussions, the structures of site characterization are expected to be visible for 25 kilometers (15.6 miles). The impacts are not considered unusual compared with those from other structures in the area, such as the microwave transmission tower. If the site is not selected for repository use, all lands and natural features are to be restored to near their predevelopment state, and all structures and facilities dismantled and removed from the site. Thus, there should be no cumulative and long-term impacts on the visual character of the area from site characterization and exploratory shaft construction activities (Thomas, 1984).

4.2.1.8 Effects on Archaeological, Cultural, and Historical Resources

There are no known archaeological and historic sites located within the site or vicinity (NUS, 1984, BMI/ONWI-560); however, sensitive locations (areas that have a high potential for containing undiscovered cultural resources) exist (Section 3.4.6). During the field studies conducted for detailed site characterization, potentially sensitive locations could be disrupted by the construction of the exploratory shaft facility, deep boreholes, seismic lines, shallow boreholes, a meteorological tower, playa investigations, and access roads. Prior to ground disturbances, the DOE will conduct an intensive survey to determine the presence of any significant cultural resources.

The DOE, the Advisory Council on Historic Preservation, and the Texas State Historic Preservation Officer (SHPO) will enter into a Programmatic Memorandum of Agreement (PMOA). The implementation of the PMOA would avoid, or satisfactorily mitigate, the potential adverse effects of this project on historic and cultural properties. The DOE will fulfill the following PMOA requirements:

1. A workers' awareness program for archaeological and historic resources will be initiated.

2. In consultation with the Texas State Historic Preservation Officer (SHPO), the DOE will develop and implement a research design to guide archaeological survey and data recovery during site characterization.

3. The DOE will ensure completion of archaeological surveys of a unit of land prior to its disturbance. These surveys will address areas which are subject to direct and indirect project effects.

4. The DOE will make every effort to design project activities to avoid damage to any historic or archaeological property. If avoidance is not possible, the DOE will develop and implement a data recovery plan in consultation with the Texas SHPO.

The surveys will be designed to collect information to respond to research questions identified in the Phase I investigation (Section 3.4.6) and also in the "Resource Protection Planning Process for Texas" (RP3) document (Brown et al., 1982). The RP3 document, published by the Texas Historical Commission, serves as the basis for the development of regional study units that are designed to help focus research activities. In addition, current prehistoric research problem areas identified in the Phase I investigation (Girard et al., 1984, BMI/ONWI-560) include the establishment of a local chronology, identification of the material correlates of cultural groups, investigation of settlement and subsistence patterns, investigation of patterns of interregional contact and trade, and identification of social groups and relationships.

In accordance with the American Indian Religious Freedom Act (42 USC Section 1996), the Bureau of Indian Affairs (BIA) has been contacted to determine if federally recognized Native American Indian tribes with Federal Trust relationships are located in Deaf Smith County (Oxendine, 1984). Consultation revealed that there are no Federally recognized Indian Tribes with cultural ties to the site. However, according to the BIA the definition of Native American is cultural and not political so that the lack of Federal acknowledgement of a Native American group in no way implies a lack of political status of that group. Consequently, the list of tribes also needs to include those recognized by the State. There are two State-recognized Tribes, the Alabama-Coushette and the Tigue, neither of which have a cultural affiliation with the area (Feuchter, 1984; Spitzer, 1984).

4.2.1.8.1 Geologic Field Studies. Up to 283 hectares (700 acres) of land will undergo some surface disturbances as a result of geologic field studies. Some of these activities will occur in areas identified as sensitive (i.e., areas with a high potential for unrecorded archaeological sites) in Figure 3-83. Prior to initiation of any construction activities, intensive surveys of areas of disturbance will be undertaken. Deep and shallow boreholes and seismic lines could disrupt archaeological and historical resources located within the drill sites, access road rights-of-way, or seismic lines. Activities in playas could also disrupt or destroy unrecorded cultural resources. As indicated in Section 3.4.6, playas are considered particularly sensitive locations for unrecorded archaeological sites. Surveys will be performed at playas where activities will take place. Mitigative measures such as avoidance, recording, excavation, and removal could be required for any cultural resources located in or adjacent to playas. Efforts will be made to avoid the sensitive locations identified in Section 3.4.6. However, some sensitive areas will most likely be disturbed. An intensive survey of such locations will be conducted to determine whether or not as yet undiscovered resources will be affected. The SHPO will be consulted (as required by a PMOA) in determining the significance and anticipated effect to any discovered cultural resources. Mitigative measures, including excavation, salvage operations, and avoidance may be required for any resources identified in the intensive survey.

Because downhole testing and reentry of existing drill holes will not require any additional excavation, borings, or access roads, impacts to cultural resources are not expected from these activities. Surface field studies will be conducted primarily from existing roads and are not expected to involve earthmoving activities. Therefore, no significant impacts to cultural resources are expected as a result of surface field studies.

4.2.1.8.2 Exploratory Shaft Facility. Exploratory shaft facility construction activities could affect undiscovered prehistoric or historic archaeological resources located within the 25-hectare (61-acre) area required for the ESF site and access if proper mitigative measures are not taken. Ground disturbances associated with the construction of the shaft, earthen fluid impoundments, support facilities, and the storage of excavated materials could disturb the integrity of archaeological sites, if they exist, through grading and clearing actions. Therefore, surveys will be performed (as specified by a PMOA) in consultation with the SHPO to identify all unrecorded sites within the exploratory shaft facility surface area. A qualified archaeologist will monitor construction activities to assure that no unexpected

resources are disturbed until a determination of significance can be accomplished. The acquisition of additional knowledge of the area's cultural resources through research and field reconnaissance would be an indirect benefit of this project.

Avoiding sensitive locations is preferable to conducting salvage operations as a mitigation of impacts. For this reason, sensitive areas, as verified by field reconnaissance, will be avoided if possible.

Construction of access roads could also disrupt unrecorded cultural resources located within or adjacent to the required rights-of-way. Access roads will be designed to avoid sensitive locations. If the access roads are to be located in areas determined by field reconnaissance to be sensitive, an intensive survey will be conducted.

Utility corridors will also be selected following field surveys. Identified sensitive areas will be avoided if possible in utility corridor selection. Otherwise, operations will be conducted to gather information associated with the archaeological site prior to site disturbance.

Based on the preliminary assessment, no impacts to historical resources located outside the site's vicinity are expected to occur as a result of exploratory shaft construction or construction of access roads. Most recorded historical resources are located in the towns of Hereford and Vega, and along major highways. Hereford and Vega are approximately 43 kilometers (27 miles) and 11 kilometers (7 miles) from the site, respectively. Because of their distance from the site, no direct or indirect impacts to historical resources located in these towns are expected from shaft construction.

No significant impacts to cultural resources are expected to occur as a result of in situ testing operations. Any direct adverse effect on cultural resources would be limited to the period of site characterization. Indirect impacts would be more diffuse and long-term and include the potential loss of cultural resource sites due to induced growth and increased visitation to known cultural resources. Implementation of the PMOA would avoid or satisfactorally mitigate these potential adverse effects.

4.1.2.8.3 Meteorological Tower Installation. Excavation and grading activities associated with the installation of the meteorological tower could disturb any archaeological resources located within the tower site. However, if the tower is erected within the site, field reconnaissance conducted for the site should have provided adequate information to avoid any potentially significant cultural resources. Construction of access roads will also avoid sensitive locations.

4.2.1.9 Effects on Radiological Levels

No radiological impacts are expected as a result of site characterization activities. Releases of radioactivity to the environment during drilling activities will be negligible. No radioactive wastes will be used for testing; their thermal effect will be simulated using electric heaters.

Some of the tests carried out during detailed site characterization use instrumentation procedures that involve small amounts of radioactivity. Three examples of these tests are (1) measurement of soil density, (2) measurement of soil moisture, and (3) nondestructive testing of welds.

The measurement of soil density will be made as a downhole well logging procedure. A cesium-137 source of 1.5 curie strength, creating a field of 0.33 roentgen per hour per curie at 1 meter (3.3 feet) when unshielded, will be slowly lowered down a borehole. Its gamma emissions are reflected back from the soil to an appropriate detector or recorder; the intensity of the reflected signal is proportional to the density of the reflecting medium. When the measurement is completed, the source is withdrawn from the hole into a shield that reduces the radiation field to about 2 milliroentgen per hour. This dose rate allows continuous occupational exposure of personnel without exceeding the applicable 5 rem per year limit. The

cesium-137, as contained in this instrument, is a short, solid metallic rod that is enclosed in another metallic sheath. When the source is withdrawn, no residual radioactivity remains behind.

The soil moisture measurement is similarly made. The radioactive source used in this case, however, emits neutrons. This source is an intimate mixture of americium-241 and beryllium of 16 curie strength, emitting 2.7 million neutrons per second per curie. As the source is lowered down the hole, the neutrons reflect back from water molecules in the soil into an appropriate detector. The signal from the detector is recorded, with the signal being proportional to the moisture content. As with the soil density source, this neutron device is encapsulated and shielded when not in use to approximately 2 millirad per hour. During the passage of the neutron source past the geologic materials, some activation may occur. Because of the short exposure time and the low probabilities of activation, the radioactivity of these activated materials will be at an extremely low level and of short duration.

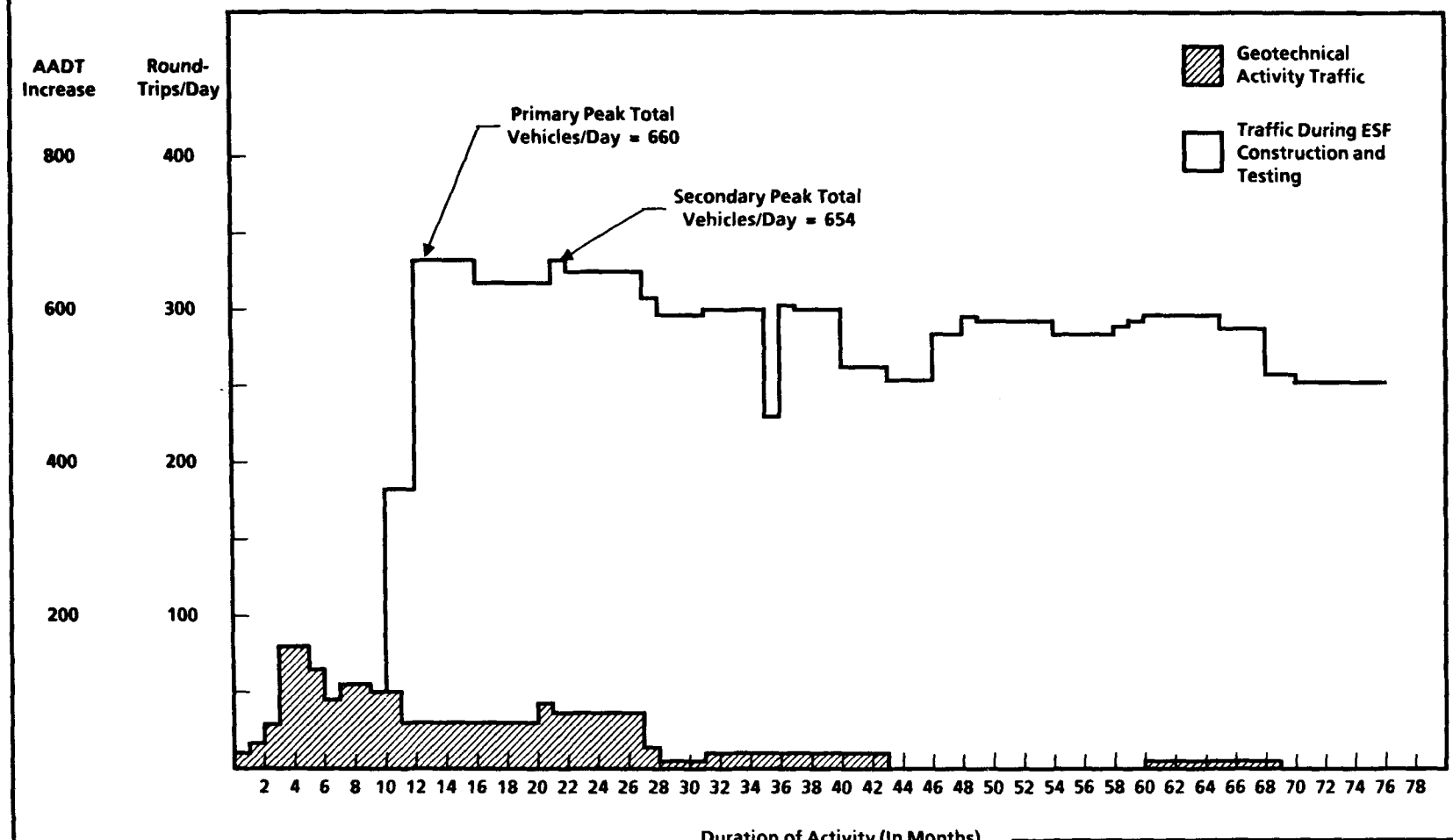
One technique used to nondestructively test welds made on the site will be gamma radiography. This technique is similar to the same procedure using X-rays, but uses instead the more energetic gamma rays from radionuclides. The nuclides most commonly used in industrial radiography are cesium-137, cobalt-60, and iridium-192. Bare sources of these materials yield radiation fields of 0.33, 1.32, and 0.48 roentgen per hour at 1 meter per curie. Physically, these sources are similar to the cesium-137 source described for the soil density measurement. When not in use they are shielded as described earlier. During use, which is generally above ground, personnel protection is achieved by maintaining a minimum distance from source to personnel. No radiation or radioactivity remains after termination of the exposure.

Routine releases of naturally occurring radioactivity will take place during the construction of the exploratory shafts. This radioactivity will consist of radon and its daughter products contained in soil and rock and, to a lesser extent, salt. However, the impact of these radioactive elements on the environment will be insignificant. As indicated in Section 3.4.7, it is estimated that the background (ambient) whole-body dose rate at the Deaf Smith County site is approximately 95 millirem per year. An evaluation of the amount of radon and daughter products likely to be contained in excavated overburden and salt from exploratory shaft development (Waite et al., 1985) indicates that up to 0.09 curie of radioactivity could be released to the environment, equivalent to a whole-body dose rate of about 0.3 millirem per year or about 0.3 percent of ambient. Consideration of this information, plus other individual and population dose estimates given in the literature (DOE, 1980, DOE/EIS-0046F; BPNL, 1979, DOE/ET-0029), indicates that increases in radioactivity due to exploratory shaft development will be so small as to be considered negligible.

4.2.1.10 Effects on Transportation and Utilities

Site characterization will consist of numerous activities including field studies, exploratory shaft facility construction, underground testing, and decommissioning. The distribution of expected cumulative traffic increases resulting from overlapping project activities is presented in Figure 4-28. In this figure, field studies consist primarily of geologic studies (drilling and seismic studies) occurring throughout the 23.3 square-kilometer (9-square-mile) area and in the offsite corridors. The other activities represented on this figure are related to shaft facility construction and testing. Many of these activities overlap to create the theoretical peak which occurs between months 13 and 16. It is this peak value which is used for traffic volume prediction to estimate transportation impacts. Exploratory shaft facility completion and underground testing activities continue through month 76, after which the site will either be chosen for repository construction or decommissioned.

Impacts of transportation resulting from field studies, construction, operation, and decommission of the exploratory shafts will be related to the expected increase in traffic on local and regional roads resulting from the movement of personnel and materials to and from the site. The local and regional transportation routes are discussed in Section 3.5.1, with pertinent roadway characteristics presented in Table 3-52. The primary access route to the site is via U.S. 385 to FM 2587 which traverses the site. Spur roads will be constructed from FM 2587 to provide access to specific project areas.



Notes:

- The numbers shown for geotechnical activities and ESF construction are combined to give the top line representing monthly peak totals
- Geotechnical traffic distribution from Table 4-2 and Figure 4-1
- ESF traffic distribution from Table 4-8 and Figure 4-7

Deaf Smith County
Site Characterization
Vehicular Traffic

Figure 4-28

As the exploratory shaft facility (ESF) will require a shaft headframe 38.1 meters (125 feet) in height, and the meteorological tower will be 60 meters (197 feet) in height, the Federal Aviation Administration (FAA) must be notified. Appropriate forms for this action will be completed and submitted to the FAA so that the agency can advise the DOE of subsequent compliance requirements.

4.2.1.10.1 Field Studies. Geologic field studies are expected to have a transient impact on the existing regional and local transportation network. Temporary congestion will result from the movement of equipment to and from access roads or off-road sites. Movement of workers to and from field study sites will contribute to the average daily traffic (ADT) carried by roads in the vicinity of the site. These roads generally have more than 80 percent excess capacity to provide ideal driving conditions except near Hereford and Amarillo (Table 4-24), so that the impact of worker transport on driving conditions is not likely to be significant. Traffic congestion occurs in Amarillo and Hereford, but geotechnical field study workers will be traveling to dispersed work sites at various times, so they will not be likely to contribute significantly to congestion. The extent of the overall impact on the transportation network will be determined by the number of personnel required to perform the field studies, the number and type of vehicles required to transport both personnel and supplies, and the number, length, and location of additional access roads. However, impacts will be less than those described under Exploratory Shaft Facility (Section 4.2.1.10.2). The distribution of the expected increase in ADT during field studies is presented in Figure 4-28.

4.2.1.10.2 Exploratory Shaft Facility Activities. The distribution of ADT increases during exploratory shaft facility activities is presented in Figure 4-28. The main supply route for construction and operation equipment probably will be from Amarillo, west on Interstate 40 to Vega (55.0 kilometers [34.2 miles]), south on U.S. 385 to FM 2587 (16.7 kilometers [10.4 miles]), and then west on FM 2587 to the site access road (6.4 kilometers [4 miles]). Approximately 18 truck trips per day will be required to transport supplies to the construction site during the 28 months of exploratory-shaft and surface-facility construction (Table 4-8). These trucks can be expected to cause more road-surface wear per trip than cars. It is not possible to predict roadway surface wear accurately without precise measurements of roadway conditions over time (Neukam, 1983).

The estimated peak of project-related traffic is anticipated to occur between months 13 and 16, as shown on Figure 4-28. During this period, shaft- and surface-facility construction, shaft outfitting, and some testing all occur simultaneously, creating an estimated peak in personnel and traffic. The estimated average increase in passenger-vehicle traffic will be approximately 280 private vehicle round trips per day (based on 1.1 persons per vehicle) and 20 truck round trips per day. (In terms of ADT, this is equivalent to 560 one-way private vehicle trips and 40 one-way truck trips each day.) Increases in ADT on various roads (Table 4-24) were calculated by distributing the total vehicle trips among the communities where workers are likely to reside, and by assuming that workers will take the most direct routes to the site. It is recognized that this is a reasonably conservative analysis and that some percentage of the traffic will not travel what is assumed to be the most direct route to the site. Though insufficient information exists at this time to predict the percentage of traffic which will use the other roads, such as FM 809, the DOE believes this percentage will be low. The use of these other roads will reduce the potential impact predicted here for the increase in ADT on the most direct routes.

FM 2587, which crosses the southern portion of the 23.3-square-kilometer (9-square-mile) site, will receive all the traffic directed to the site. This additional traffic will be travelling predominantly between U.S. 385 and the site access road, with a small amount of traffic travelling between FM 214 and the site. FM 2587 had a 1981 ADT of 110 to 220, which was among the lowest ADTs of the routes designated as principal roadways to the site (Table 4-24). An increase of 618 private vehicle trips and 40 truck trips per day between U.S. 385 and the site during the first month peak would cause a 349 to 698 percent increase in ADT on FM 2587. With this increased ADT, FM 2587 would be operating on a daily basis at up to 7 percent of its maximum service volume for ideal driving conditions. Other routes used by site-related traffic would carry smaller portions of the total traffic volume. Site-related traffic would use 7 percent or less of the total daily maximum service volumes (ideal

conditions) of each route considered in Table 4-24. On an average daily basis I-40/U.S. 66 west of Amarillo and U.S. 385 north of Hereford currently provide a lower level of service than other routes discussed. However, the incremental contribution of site-related traffic to these high-volume routes will be small.

While available data on ADT indicate that roads in the vicinity of the site are underused on a daily basis, there will be short-term decreases in the levels of service on these roads during shift changes, which are the peak periods of use. No data are available on current peak use of these roads. However, one can assume that peak-hour traffic will be approximately 12 percent of ADT (Hausmann, 1983). Peak-hour traffic is an estimate of the maximum number of vehicles expected to use a segment during one 60-minute period. These estimates are shown in Table 4-24. The route segments I-40/U.S. 66 west of Amarillo, U.S. 385 north of Hereford, and, to a lesser degree, U.S. 385 south of Vega currently provide diminished levels of service during such peak use periods.

Site-related traffic during the 4-month estimated peak period will result in a diminished level of service (LOS) during peak-hour use on FM 2587, U.S. 385, and FM 1062. Level of service is a qualitative classification of attainable driving speed, convenience, and maneuverability under uninterrupted flow conditions (National Academy of Sciences, 1965). LOS-A is the highest classification, assigned to free flow, driver-controlled travel conditions, and LOS-F is the lowest and corresponds to stop-and-go or stand-still conditions. LOS classifications and their respective conditions are presented in Table 4-25.

The level of service on U.S. 385 between Vega and FM 2587 will decrease from LOS-A to LOS-B during peak hour periods. The level of service on I-401, U.S. 66 west of Amarillo, and U.S. 66 will decrease from LOS-B to LDS-C during peak hours. The level of service on U.S. 385 from Hereford to FM 1062 will remain LOS-B. However, the presence of a slow-moving and turning vehicles on all these routes will interrupt the free flow of traffic, with resulting driving conditions slower and more congested than implied by the actual level of service classification. The level of service on I-40/U.S. 66 will be unchanged.

Offsite traffic generated by exploratory-shaft activities may result in the number of accidents per year shown in Table 4-26. These statistical predictions are totals for all types of accidents and are based on the average increase in ADT over the 76-month period from initial field activities to decommissioning. This analysis does not consider planned mitigative actions which will reduce congestion, facilitate traffic flow, and reduce the probability of accidents.

The State of Texas has a Statewide fatal accident rate of 3.5 per 100 million vehicle miles (National Safety Council, 1983). By applying this rate to the total vehicle miles per year for all segments considered, a statistical value of 0.2 fatality is predicted per year of site characterization activities to decommissioning.

4.2.1.10.3 Decommissioning. If the Deaf Smith County site is not chosen for repository construction, the site will be decommissioned, including permanent disposal of the estimated 50,000 cubic meters (65,000 cubic yards) of rock salt and salt-laden rock which will remain after backfilling the shafts. The number of vehicles required for decommissioning activities is significantly less than that required for earlier site characterization activities. Transportation impacts during these periods are expected to be minimal. A significant part of decommissioning activity will be disposal of the salt and rock materials.

This disposal will begin midway through the shaft backfilling period and continue for 12 months until the end of site clean-up (Figure 4-15). Approximately 10 truck loads per day will be required for disposal. One of the possible disposal options is to transport these materials to a landfill in Port Arthur, Texas. The proposed route from Deaf Smith County to the disposal site is approximately 1,190 kilometers (740 miles). The highway route includes U.S. 385 to Vega, I-40 to U.S. 287, U.S. 287, U.S. 287 to I-35, Ft. Worth-Dallas route to I-45, I-45 to Houston, I-10 to Beaumont, and U.S. 69/687 to Port Arthur.

Table 4-25. Level Of Service Classifications For Highways

Level of Service (LOS)	Traffic Conditions
A	Free flow; speed controlled by driver's desires, speed limits, or physical roadway conditions.
B	Stable flow; operating speeds beginning to be restricted; little or no restrictions on maneuverability from other vehicles.
C	Stable flow; speeds and maneuverability more closely restricted.
D	Approaches unstable flow; tolerable speeds can be maintained but temporary restrictions to flow cause substantial drops in speed. Little freedom to maneuver, comfort and convenience low.
E	Volumes near capacity; speed typically in neighborhood of 30 mph; flow unstable; stoppages of momentary duration.
F	Forced flow, low-operating speeds, volumes below capacity; queues formed.

Source: Oglesby, 1975.

Table 4-26. Estimated Traffic Accidents (Total) Per Year Based on Average Increase in ADT During Site Characterization

Route Segment	Accident Rate per Million Vehicle Miles[a]	Site-Related Trips per Day[b]	Site-Related DVM[c]	Offsite Accidents per Year of Shaft Construction[d]
I-40/U.S. 66 (Amarillo-U.S. 66 Business)	3.27	374	3,212	3.8
I-40/U.S. 66 (Vega-U.S. 66 Business)	.56	374	9,562	2.0
U.S. 60 (Canyon-Hereford)	1.22	40	181	0.1[e]
U.S. 385 (Vega-FM 2587)	.57	398	4,139	0.9
U.S. 385 (Hereford-FM 1062)	3.20	185	2,184	2.5
U.S. 385 (FM 1062-FM 2587)	.43	225	1,848	0.3
FM 1062 (U.S. 60-U.S. 385)	1.13	40	935	0.4
FM 2587 (U.S. 385-site boundary)	.26	623	1,808	0.2
FM 214 (I-40/U.S. 66-FM 2587)	.21	2	19	0.0

(a) Table 3-52.
(b) Private vehicles plus trucks (offsite only), from Table 4-8.
(c) Daily vehicle-miles (offsite).
(d) Associated with travel to and from the site.
(e) Site-related traffic will use 7.2 kilometers (4.5 miles) of this segment.

Environmental impacts of salt transportation under normal conditions are expected to be negligible since no new routes would be constructed and since trucks used for transport would be covered, reducing potential impacts from wind dispersal of salt. Additional information on the impacts of salt escaping the transport vehicle are found in Section 4.2.1.11.5. If the decision is made to construct a repository at the Deaf Smith County site, no immediate salt disposal or decommissioning will occur.

4.2.1.10.4 Airports. Air transportation is not expected to contribute significantly to the daily movement of people and materials associated with site characterization activities. It is likely that the site will be visited by technical personnel, representatives of government bodies, and other individuals who will use the airports for access. The amount of air travel generated by these people is unknown, but is expected to be small. Therefore, no significant impact on the Amarillo International or Hereford Municipal Airports are expected as a result of site characterization activities.

4.2.1.10.5 Transportation Mitigation Measures. Nearly all site traffic will converge from U.S. 385 and turn onto FM 2587, resulting in congestion problems. This congestion will be mitigated by construction of a cloverleaf interchange during the first year of site characterization activities prior to anticipated periods of traffic congestion. Traffic controls such as intersection improvements and turn signals will be implemented during peak-hour congestion periods in other locations such as north Hereford along U.S. 385. Possible further mitigation measures include staggered work shifts, intersection improvements such as turn signals and turning lanes, restricted delivery times for equipment and supplies, and alternative worker transport modes (buses, van pools). Investigation of these potential mitigation measures is discussed in Section 4.1.3.1.10. DOE, in consultation with State and local governments, will determine what financial assistance is needed and legally allowable to construct network improvements and mitigate potential road damage.

4.2.1.10.6 Utilities. There would be no expected adverse impacts on local or regional utility resources. Electric power will be supplied from the electric substation at the intersection of U.S. 385 and FM 2587. The transformers at the substation could be changed to provide additional capacity (Louder, 1983). Communications would be supplied by connecting with preexisting phone lines which generally follow the farm-to-market roads in the area. Water requirements will be met by onsite wells and holding tanks. Sewage will be treated and residues will be retained on site for later disposal. If gas is required during site characterization activities, it can be obtained by tapping the 20-centimeter (8-inch) gas pipeline which parallels U.S. 385 east of the site. The use of these resources will not adversely affect current users.

Communication, electric power, and gas pipeline would be made along FM 2587 to minimize disruptions to land use and other impacts. These impacts are expected to be minimal. The installation of utility lines will result in short-term impacts along local roads such as minor delays due to construction equipment movement and use. The 10-cm (4-inch) gas pipeline which crosses the site will be moved if site activities will adversely affect its operation.

4.2.1.10.7 Cumulative and Long-Term Effects. There will be no long-term adverse effects on transportation from increased traffic or the establishment of temporary access roads during site characterization and field studies. The potential improvement of permanent roads will produce long-term beneficial effects within the site and immediate surrounding area. Existing county roads that are upgraded for access purposes will be left in their improved conditions. Unpaved access roads will be decommissioned, if requested by the landowner. This will involve returning the area, as much as possible, to its original condition, including contours, drainage patterns, and vegetation. If preferred, unpaved access roads could be turned over to landowners for their use. Such roads would be left with adequate surface drainage, drainage structures, and in a general condition suitable for continued use after site decommissioning.

There will be no significant cumulative or long-term impacts affecting the utilities as a result of site characterization and field studies. Onsite utility lines that have been buried will be uncovered and either salvaged or disposed of off site. If such lines have been placed at a depth greater than 60 centimeters (24 inches) below the final reclamation grade, they

will remain in place, unless they are considered a hazard to future land use. The onsite sewage treatment system will be dismantled and removed. The removal of power supply and communication lines which will have been constructed from an offsite location to supply these services will be left to the discretion of the commercial authority responsible for them.

4.2.1.11 Effects of Salt Management and Disposal

This section summarizes the potential environmental impacts associated with the management of salt and salt-laden rock during site characterization, and measures for mitigating those impacts. The discussion is presented in three parts: (1) the management practices are briefly described in the context of their potential for releasing salt to the environment; (2) measures for mitigating the impacts from these sources are discussed and the basis for assessing the impacts is described; and (3) the options for permanently disposing of the excess salt if the site is not selected for the development of a repository and the basis for selecting one option are presented.

4.2.1.11.1 Salt Management and Control. The exploratory shaft facility (ESF) will involve mining, handling, transport, and disposal of salt and salt-laden rock. The discrete elements of this salt management process are illustrated in Figure 4-29 along with each element's potential contribution to an overall salt emission and likely mitigation measures for each source point.

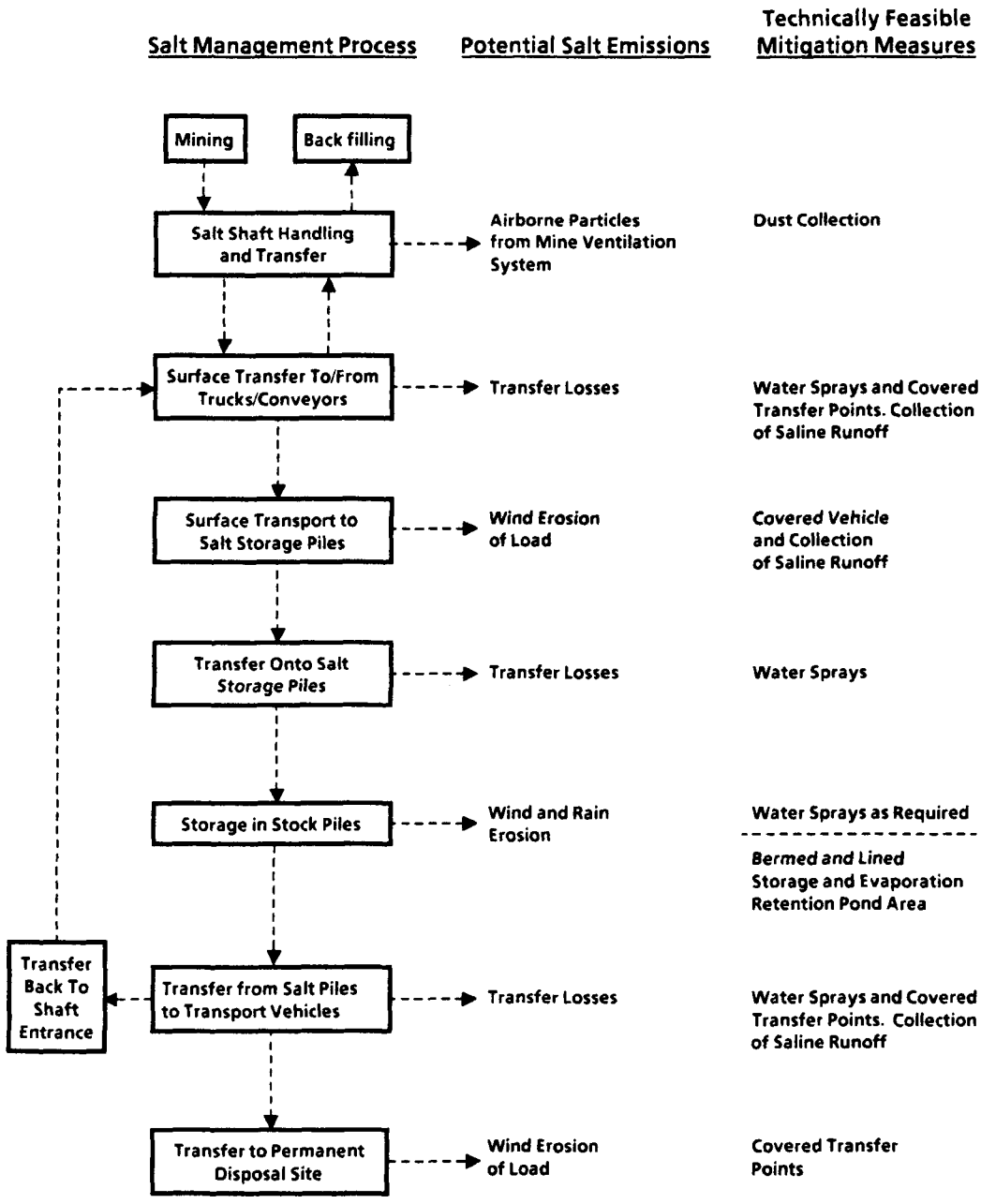
Mined salt is lifted to the surface via a skip and transferred to covered haul trucks for transfer to the salt storage pile. Emissions of salt to the atmosphere occur at the outlet of the mine ventilation system and at the point of transfer of the mined salt to the surface transport vehicle. These emissions can be minimized by the use of dust collection and suppression devices at the mine exhaust facility and a covered transfer device and water sprays at the point where subsurface salt is transferred to the surface haulage vehicle. Saline water, from either the salt control devices or as storm runoff, will be collected and conveyed to the evaporation and retention pond.

Although the surface haulage vehicle will be covered, small losses may occur along the haulage route. These will be collected as saline runoff and moved to the evaporation/retention pond.

When salt is exposed to the weather or another source of moisture, a hard surface crust forms in a few days which tends to shed rain water (Ver Planck, 1958; DOE, 1983, WIPP-DOE-161). According to the experience in the salt industry, stockpiled salt is not a source of windblown particles, and crusting can be accelerated by wetting the pile. After spreading and compacting, freshly deposited material will be wetted to mitigate any wind effects (Section 4.1.2) (Parsons-Redpath, 1984). The salt storage pile will be kept moist as required to accelerate crust formation.

Possible leaking of brine from the evaporation/retention pond into the ground will be prevented by using double liners. These can be made of natural clays or synthetic materials (polyvinyl chloride, polyethylene, or polypropylent). A leachate collection system will be installed between the liners to monitor the integrity of the liners and remove any leached effluent. The existing topsoil overburden will be stripped before emplacement of the liner and an engineered sound subbase established. If a synthetic liner is used, an additional layer of compacted backfill material will be placed on top of the liner to accommodate heavy equipment.

Saline runoff from the shafts area, haul roads, and mined material stockpiles will be collected by a system of lined drainage ditches which gravity-flow to an evaporation/retention pond. In addition, water collected in the shaft sumps will be periodically pumped to the ditch system for collection at the evaporation/retention pond. The drainage ditches will be designed to convey the runoff from a 500-year storm of a duration and intensity based on time of concentration of the local watershed. This will provide the capability to convey the runoff from duration storms which produce higher peak flows than a 24-hour rainfall event.



Salt Management Flow Diagram

Figure 4-29

The evaporation/retention pond will be designed for an operational volume equivalent to 100 percent of the rainfall volume from a 500-year, 24-hour storm falling on the areas which drain to the evaporation pond. The maximum volume of the pond will include an additional 61 centimeters (2 feet) of freeboard above the operational level (Section 4.1.2). Due to the greater volume available per unit depth in the top of a pond, the freeboard volume available will be almost equivalent to a second 500-year, 24-hour storm volume.

Project GNOME and the Waste Isolation Pilot Plant (WIPP) used salt management practices similar to those to be employed at the ESF. Activities associated with the December, 1961, Project GNOME underground nuclear test resulted in a substantial volume of sodium chloride (salt) being excavated and stored on the site. The storage facility for the salt is an area of approximately 1.2 hectares (3 acres) enclosed by a dike and fence. The salt pile is stored inside the dike and fence but is otherwise open and exposed to the elements of the environment. The project GNOME test site is located approximately 48 kilometers (30 miles) southeast of Carlsbad, New Mexico. Soil samples and ecology surveys indicate that insignificant wind erosion and dispersion is occurring at the Project GNOME salt pile, and that there is little, if any, attendant adverse impact on the immediate surrounding environment due to salt dispersion by wind (INTERA, 1978).

The Waste Isolation Pilot Plant (WIPP), presently under construction approximately 40 kilometers (25 miles) east of Carlsbad, New Mexico, will test the feasibility of storing nuclear defense wastes in salt. Excavated salt has been stored in an uncovered, unlined pile holding about 136,170 metric tons (150,000 tons) of salt. The pile is surrounded by a bermed ditch which collects and evaporates the precipitation which falls on the pile (average rainfall: 22.9 centimeters (9 inches) per year). The salt is crusted over, and rainfall does not penetrate the pile. No problems with wind dispersion of the stored salt have been experienced (Reith et al., 1985).

4.2.1.11.2 Impact of Salt Management. Soil productivity, water quality, ecosystems, and land use can be impacted by salt transported through air and water pathways. Assessment of the potential impacts requires identification and quantification of the various factors involved. For example, airborne salt can impact crop productivity through root uptake by the plants and foliar deposition. In these cases, not only must deposition rates be estimated but irrigation rates, rainfall patterns, etc., must be taken into account. The airborne particulate deposition rates for site characterization are expected to be much less than those for the repository, which are predicted to be: 3.8, 2.1, and 1.3 kilograms per hectare (3.4, 1.9, and 1.1 pounds per acre) per year at 840, 1,050, and 1,300 meters (0.5, 0.6, and 0.8 mile), respectively (Section 5.2.5). Most of this deposition would occur within the fenced area, and use of these values for assessing the impact of site characterization activities is considered to be conservative because of the smaller quantity of salt to be mined during ESF activities. The probability of a tornado strike to the site is addressed in Section 5.2.5. Factors are identified in the following sections for each category of impact, and numerical values are provided to the degree that current information allows.

Effects on Soils. Soils on the site and in the site vicinity are generally rated as Prime Native by the Texas State Office of the Conservation Service. This implies that they have the physical and chemical properties necessary to produce consistently high yields of crops suited to the climate of the area. The agriculturally important soils in the area are described as moderate, to fine-textured, deep, moderately to slowly permeable, and having a high volume of calcium carbonate in the subsoil. The subsoils are generally fine-textured and limit drainage. Soil salinity which affects crop yields is a combination of many factors. These factors include the ratios of cations such as sodium, calcium, and magnesium to each other, the minerology of the clays in the soil, the amounts and ratios of soluble salts in irrigation water, soil drainage related to soil structure and permeability, and the nature of the anions present in both soil and irrigation water (Allison, 1964). Plant responses to salinity can also be significantly affected by tillage, irrigation practices, growth stage, varietal factors, and the nature of the climate related to temperature, humidity, and the amount of the ozone present (Maas and Hoffman, 1977).

Effective salinity in the plant root zone is controlled by the quantity and quality of irrigation water and the timing of its application. Plants can tolerate water containing a considerable amount of soluble salts if that water passes freely through the soil. If the roots are not long in contact with the water, no adverse osmotic gradient is established. The roots will withdraw only the water and the ions needed to maintain growth. If drainage is restricted, either by poor soil structure or a high water table, and water of better quality is not available for some portion of the roots, then salinity effects may be seen in reduced transpiration (Lunin and Gallatin, 1965), reduced ratio of top growth to roots (Eaton, 1942; Maas and Hoffman, 1977) and generally reduced yields (Allison, 1964; Shannon, 1984).

If poor soil conditions exist, management practices can be instituted to cope with these conditions. They consist of installing artificial drainage at a suitable soil depth; occasionally flushing the soil with irrigation water containing cations in the proper ratio to leach harmful buildups of salts below the root zone; and adding soil amendments such as gypsum, calcium chloride, or sulfuric acid to alleviate salt buildups if irrigation water quality cannot be changed (Rhoades, 1982).

Such practices are common when producing crops in arid and semiarid areas where evapotranspiration exceeds natural precipitation. Under these conditions, salts naturally increase in the soils since the soils are seldom saturated to the point where they drain freely. Also, water applied for irrigation naturally contains salts of some kind, which adds to the salt burden, and crops never remove more than a small percentage of these additions (Hoffman and Meyer, 1982). The range of salt tolerance of crop plants grown in the vicinity of the Deaf Smith County site is as follows: barley, cotton, and sugar beets have a high tolerance; alfalfa, corn, oats, rye, soybean, sunflower, and wheat have a medium tolerance; and field beans show low tolerance (SCS, 1971).

The natural salt burden associated with irrigated farming in Texas can be drawn from information available on water quality for irrigation wells near the site. The natural sodium concentration in 22 wells pumping irrigation water from the Ogallala aquifer average 33 milligrams per liter (33 parts per million) of sodium (TNRIS, 1985a). For the years 1958 through 1979, annual water use for irrigated farming for Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). Irrigation with Ogallala water will add 110 to 170 kilograms per hectare (100 to 155 pounds per acre) per year of sodium to the soil. The Santa Rosa aquifer water would add 800 to 1,225 kilograms per hectare (710 to 1,120 pounds per acre) per year of sodium to the soil.

Since cropland in the site vicinity is regarded as producing a high return in crop yields, the existing management practices are capable of alleviating the salt buildup incidental to irrigated farming and could be expected to negate the effect of any additional increment (no more than 3.8 kilograms per hectare [3.4 pounds per acre] per year) resulting from ESF development and operation.

Accidental spills of salt could adversely affect soils in a limited area by drastically altering the cation ratios, producing sodic conditions that would lead to dispersion of soil aggregates and loss of soil permeability. Reclamation would consist of containing the area within a berm and flooding it with water to which amendments such as calcium chloride have been added (Hoffman and Meyer, 1982; Rhoades, 1982). The amendment would restore permeability as the water penetrated the soil, and the leachate would be collected by drains and disposed of properly.

Effects on Surface-Water Quality. Salt-laden runoff will not be discharged to the environment. Runoff from the mined materials storage area, the shaft loading area, and internal roads will be impounded in the evaporation and retention pond which is designed to retain runoff from a single event 500-year, 24-hour-duration storm with a 2-foot freeboard. The impounded water will be disposed of by evaporation or, if necessary, by removal from the pond and transportation to a licensed disposal facility (Section 4.1.2).

Given the direction of the prevailing winds, the area of greatest potential for windblown salt deposition extends to the northeast from the ESF. Overland flow from this area drains predominantly to three playas, one to the north, one to the northeast, and one to the east. A forecast of the quantity of salt that will accumulate in playas and of the salt concentration in playa water requires a verified model. The site-specific data needed for model verification are not yet available. The concentration of salt in the playa water will vary over the course of a year and from year to year due to variation in the amount of rainfall, evaporation, and infiltration.

The amount of salt deposited in the soil from site characterization activities would be very small, less than 0.4 to 3.0 percent of the sodium added annually by irrigation. This amount is smaller than the variation of salt concentration among individual wells. As discussed in Section 4.2.1.11, "Effects on Soils," the natural salt burden associated with irrigated farming in Texas using lower water application will add about 110 kilograms per hectare (100 pounds per acre) and 800 kilograms per hectare (710 pounds per acre) of sodium per year to the soil considering Ogallala and Santa Rosa water, respectively. A deposition of 3.8 kilogram per hectare (3.4 pounds per acre) of salt per year to the soil from the ESF activities (Section 4.2.1.11) represents 0.4 to 3.0 percent of the sodium contribution by irrigation waters on an annual basis.

Effect on Ground-Water Quality. Any area that is used for storage and handling of salt-contaminated material will be constructed with two impermeable liners to prevent seepage of salt-laden runoff into the ground. Lining brine ponds is commonly practiced in the salt industry and has proven effective and reliable in preventing seepage of brine into the ground. A monitoring system will be installed to monitor the integrity of the liner system. A system of perforated pipes will be installed between the liners beneath the storage area, the pond, and the drainage ditches to detect and collect any salt seepage. Thus, no significant seepage of salt-laden runoff into the ground is expected.

If the impermeable liner system under the stockpiled materials should fail, saline leachate will flow downward through the unsaturated zone to the presence of clay or caliche aquicludes. Infiltration studies at irrigated sites (Knowles et al., 1984, Report 288, pp. 23-26) have shown that the percolation rate and the wetting front filtration rate are highly variable on the High Plains. For the six counties near the site with infiltration data (Oldham, Deaf Smith, Randall, Castro, Lamb, and Floyd), the wetting front infiltration rate varies from 0.24 to 2.65 meters (0.8 to 8.7 feet) per year with a mean rate of 0.83 meter (2.7 feet) per year. The slow rate of percolation will permit timely corrective action, such as restoring the integrity of the liner or leachate collection system and pumping leachate back to the surface. Such action will protect the quality of the Ogallala aquifer by limiting the volume of leachate that may enter the unsaturated zone.

Infiltration followed by deep percolation is the pathway by which windblown salt could affect ground-water quality in the Ogallala and Santa Rosa aquifers. This assumes that salt deposited on the soil surface is dissolved by rainfall or irrigation water and percolates down through the surface soils to the underlying Ogallala.

Most of the area is a flat plateau covered by fine-textured soils. Pullman clay loam is the predominant upland soil type. It is characterized by a slow infiltration rate, less than 0.25 centimeter (0.10 inch) per hour, and a zone of calcium carbonate accumulation, or caliche, 1 to 2 meters (3 to 6 feet) below the soil surface (NUS, 1984, BMI/ONWI-510, p. 40). The presence of a caliche layer suggests that percolation rarely moves beyond the first few meters of soil. Field measurements of deep soil moisture on the southern High Plains have shown this to be the case. Klemt (1981, p. 129) found that, with few exceptions, fields that had been irrigated 25 years or more showed evidence of deep percolation only to depths ranging from 6 to 10 meters (20 to 30 feet). With the exception of basin-irrigated fields, deep percolation was not detected through the Pleistocene sediment overlying the Ogallala aquifer (Aronovici and Schneider, 1972, pp. 71-73). The results of these studies indicate that windblown salt is not likely to affect ground-water quality when present in water that infiltrates upland areas.

Wood and Osterkamp (1984, pp. 337-349) agreed with Theis (1937, pp. 564-568) that the overall recharge rate to the Ogallala aquifer from rainfall is less than 1.3 centimeters (0.5 inch) per year. They proposed that most recharge of the Ogallala is through the annular zones immediately surrounding the playa floor; thus, the salt-laden runoff that collects in playa lakes near the site could be a part of that recharge. However, impacts are not expected to be significant; the salt contribution by the ESF activities to this recharge zone is less than 0.4 to 3.0 percent of the Ogallala and Santa Rosa irrigation waters' contribution.

Effects on Ecosystems. Any impact on the terrestrial ecosystem will be small and highly localized because of the low rate and extent of deposition. There will be little deposition in aquatic environments; however, some of the deposited salt will be carried into playa environments by precipitation runoff. Since the maximum sodium contributed by salt deposition from site characterization ranges from 0.4 to 3.0 percent of the sodium occurring in the Ogallala and Santa Rosa irrigation water on an annual basis, the impact will be negligible.

The ions present in common salt, sodium and chloride, are universal components of plant materials. However, excessive amounts of these ions deposited on vegetation or present in the soil are harmful to plant growth. The major toxic effect is osmotic inhibition of water absorption; a common symptom is leaf-tip burn. Salinity levels (generally expressed as electrical conductivity) at which a definite productivity reduction occurs have been reported (Wadleigh and Sherman, 1978; Bernstein and Howard, 1958).

Effects on Land Use. Salt deposited at predicted rates on the soil and absorbed by the plant roots will not result in reduced crop productivity. As noted earlier, the natural sodium content in the water used for irrigation of crops in the area is adding 110 to 175 kilograms per hectare (100-155 pounds per acre) per year of sodium to the soil (see Section 4.2.1.11.1). Blowing salt during ESF activities will add less than 3 percent of irrigation-water contribution to the soil in the area less than 0.8 kilometer (0.5 mile) from the ESF site. The ESF addition is insignificant in comparison to the amount added to the soil by irrigation each year.

Gratten et al. (1981) has shown that foliar deposition (salt deposited on leaf surfaces) does not cause leaf injury unless high humidity conditions exist (greater than 70 percent) and deposition rates exceed 65 kilograms per hectare (58 pounds per acre) per year. Salt deposition from ESF activities is predicted to be much lower than 5 percent of this amount at the point of highest deposition. Therefore, no reduction in productivity is expected as a result of foliar deposition, even if it is assumed that all of the salt is deposited on the leaf surface.

Soil salinity and vegetation effects will be monitored during site characterization activities. If the data suggest that harmful levels of salt are being approached, impacts can be mitigated by using management practices discussed previously.

The onsite area will be restored following site characterization, should the site not be selected for the repository (see Sections 4.2.1.1.2 and 4.1.2.4).

4.2.1.11.3 Salt Disposal and Impacts. If the ESF site is not chosen for the development of a repository, 35 percent of excavated salt and salt contaminated rock, which is 50,000 cubic meters (65,000 cubic yards) of material will require permanent disposal. This section summarizes the basis for choosing a preferred option from among the candidate options and the environmental impacts associated with that option.

Disposal Options. In addition to the selected disposal method, offsite landfill, five alternative methods for disposal of the waste salt are available (see Section 4.3.4):

- Onsite landfill
- Disposal in existing, unused salt mines or flats
- Deep-well brine injection
- Offshore disposal
- Transfer, gift, or sale to Federal, State, or private parties.

For site characterization, all of the alternatives have greater potential to create environmental impacts than disposal in a landfill that is licensed, bermed, and double lined with leak monitors. An investigation identified the availability of a candidate landfill in Port Arthur, Texas (McCutchen, 1985). The facility has the capability to handle the waste salt from site characterization (McCutchen, 1985) and will be considered for use along with any other candidate landfills subsequently identified. Dust generation during transportation and disposal operations will be controlled by use of covered trucks and water sprays. Leachate collection will control leakage from the landfill.

Impacts of Disposal. Because the potential for environmental impact is negligible once the excess salt is emplaced in a licensed landfill, the only other potential impacts to be assessed are those associated with the transport of the salt from the ESF to the landfill.

The excess salt and salt-laden rock will be disposed of over a 12 to 18 month period. A total of approximately 3,100 truck loads of salt and salt laden rock will be transported off-site for disposal. Each truck will contain approximately 16 cubic meters (21 cubic yards) of material. The proposed route from Deaf Smith County to the disposal site in Port Arthur, Texas, is approximately 1,190 kilometers (740 miles). The highway route includes U.S. 385 to Vega, I-40 to U.S. 287 to I-35, Ft. Worth-Dallas route to I-45, I-45 to Houston, I-10 Beaumont, and U.S. 69/687 to Port Arthur.

Environmental impacts of salt transportation under normal conditions are expected to be negligible since no new routes would be constructed, and trucks used for transport would be covered, reducing potential impacts from wind dispersal of salt.

In the event of an accidental spillage of salt during transport, the potential impacts will depend on several factors:

- Location and quantities involved in the spill
- Proximity to a body of water
- Cleanup response time
- Water conditions during that period.

Impacts resulting from accidental transportation spills on land will be localized and short-term. Spills occurring during precipitation could lead to infiltration of saline run-off. During dry conditions, a small plume of dust would be generated at the accident site, settling out within a short distance. Some vegetation that is not otherwise crushed or broken by either the vehicle or its load may demonstrate symptoms of salt stress after prolonged exposure to salt drift or runoff in the event the site is not rapidly cleaned up. Procedures will be established to reload the salt into another vehicle, test soils for elevated salt concentrations, reclaim soil, and remove and replace soil or vegetation as necessary.

Accidental spillage into a body of water is less probable. In that event, mitigation action would be more difficult and time-dependent. If effective mitigation is not feasible, precautions, e.g., route selection and vehicle speed control, could possibly reduce the probability even lower.

4.2.2 Expected Socioeconomic Effects

The magnitude of socioeconomic impacts that may affect surrounding communities depends upon several major factors: characterization work force requirements, in-migrating workers' profiles, the location preferences of the workers, and the number of local residents that can be employed for characterization activities. The subcontractor services needed for shaft facility construction are an indication of the wide range of skills that will be needed. An assessment of where the subcontractors are located will help determine the percentage of local hires to expect. Many services will be subcontracted; many subcontracts will probably be subject to competitive bidding. Subcontractors are responsible for hiring their own crews. So, depending on whether local business or outside business concerns are awarded contracts, the percentage of local residents who would take jobs as welders, plumbers, electricians, miners, heavy equipment operators, laborers, and others could vary substantially. Approximately 350 shaft workers will be needed at the peak of construction.

In addition to the shaft construction work force, 107 geologic characterization workers and 23 environmental and socioeconomic workers will be present during the peak of construction. According to the scheduling estimates, about 480 workers will be in the area during the peak, which occurs in the nineteenth month of the project (Figure 4-30). Based on experience at other projects of this nature and magnitude, the minimum percentage of local hires might be 10 percent of the 480 peak site characterization workers. Although it is likely that a higher percentage of local workers would be employed during characterization, the 10 percent estimate is used in this analysis because it would represent the realistic, conservative case.

The duration of each workers' stay in the site area will vary with scheduled tasks. Some tasks, such as socioeconomic data collection, will require workers to be in the area for 2 weeks, while other tasks, such as project management activities, will require workers to be in the area for the entire site characterization period. The various schedules for engineering, geologic, environmental, and socioeconomic activities are presented in Section 4.1. Workers associated with the shorter term tasks will occupy available temporary housing and will have few effects on community services. The work force number used for the following analysis is a short-term peak lasting for 1 month (see Figure 4-30) but represents a conservative case. As site activities change, specific workers used will vary, thus reducing the number of workers living in the site area for the entire site characterization period. Because many of the workers are temporary, the accompanying demand for services will result in intensive use of services over the short duration of the peak. Peak project demand is used in this analysis, however, to identify the maximum requirement which could occur.

The Population In-Migration Model (Goldsmith, 1984) was used to project the number of people who will be in the area as a result of site characterization activities (engineering, geologic, environmental, socioeconomic). The percentages and multiplier inputs to the model for site characterization are shown in Table 4-27. A logic diagram and discussion of the model is contained in Section 5.4.

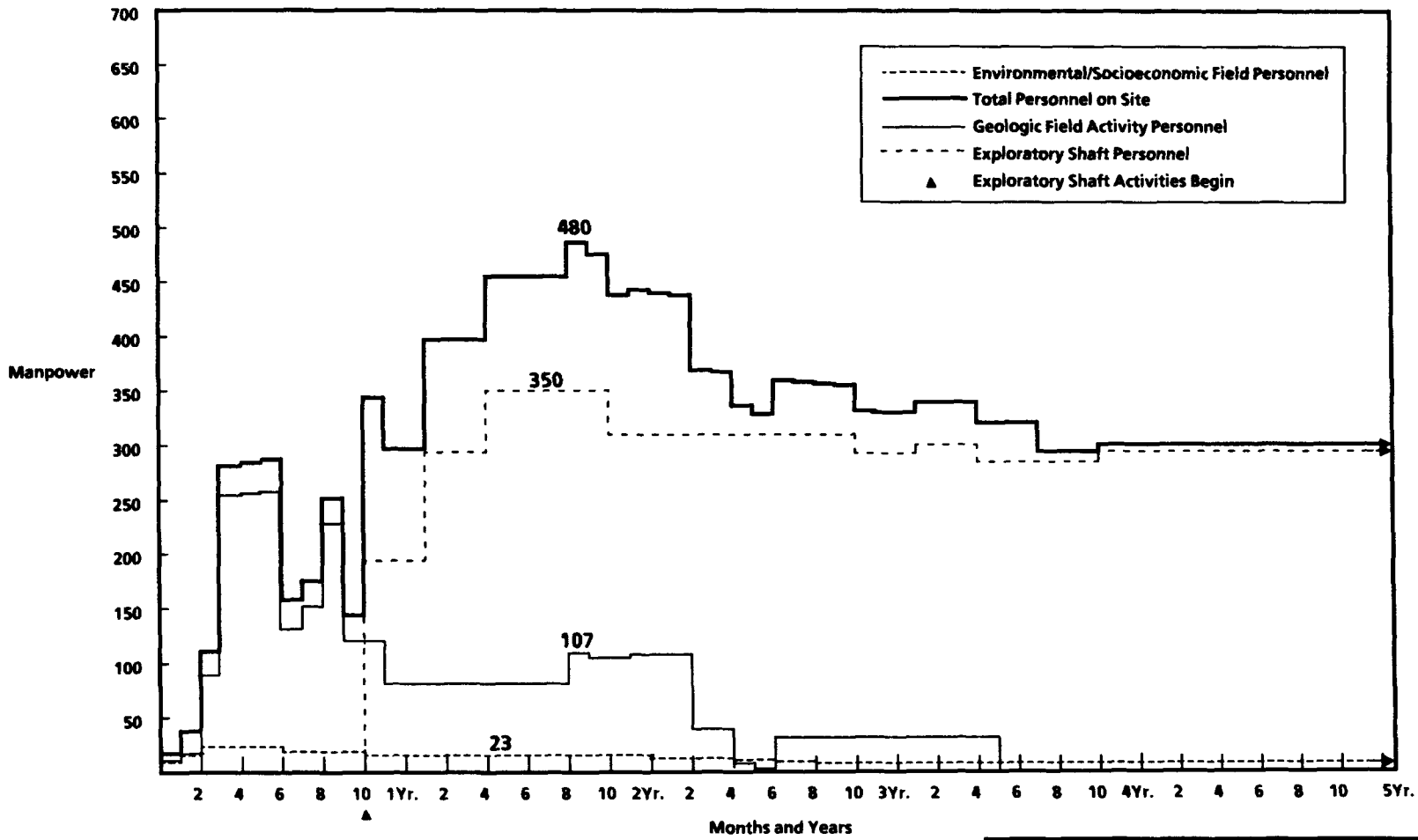
Based on the assumption that 10 percent of the work force will be hired locally, 432 in-migrating workers would move to the area. The total in-migration would be 937 because some workers would bring families to the area.

Based on a population allocation model distribution of the in-migrants (Section 5.4.1), Amarillo would expect 60 percent, Hereford would receive 25 percent, Canyon would receive 6 percent, and Vega would receive 4 percent of the total in-migration related to site characterization. This represents approximately 95 percent of the total in-migration. The other 5 percent of the population (47 people) would most likely locate in rural areas of the county and in other nearby communities. Table 4-28 provides a description of the expected total number of in-migrants, school-age children, single workers (in-migrating workers including married workers who do not relocate with their families) and married in-migrating workers with family present in Amarillo, Hereford, Canyon, and Vega under these distribution assumptions.

Baseline growth to the communities in the area at the time of peak site characterization activities is shown in Table 4-29. Both baseline growth and in-migration will be used to assess the impact on local housing and services.

Economic impacts are both worker- and site-related. Site-related impacts will result partially from the land required for site characterization activities. Approximately 24.7 hectares (61 acres) of land will be required for the exploratory shaft site. Land required for the shaft site will be purchased. An additional amount of land will be leased for drilling boreholes, conducting seismic studies, and environmental studies. The approximate land area to be protected (leased or purchased) for a repository is 2,331 hectares (5,760 acres).

The total land area (5760 acres) required and protected for site characterization activities represents approximately 0.6 percent of the land in Deaf Smith County. The 25 hectares (61 acres) to be acquired for site characterization activities are primarily cropland; this represents about 0.01 percent of the average cropland planted in Deaf Smith County in 1981 and 1982. Crop mix and value in a particular area will vary from year to year.



Site Characterization
Work Force
Deaf Smith County

Figure 4-30

Table 4-27. Inputs for the Population In-Migration Model for Site Characterization

Direct In-Migration	
Percent of work force in-migrating • Parsons-Redpath, 1984	90.0
Percent of in-migrating workers with family members present • Murdock and Leistritz, 1979	45.0
Family size multiplier • Department of Energy, 1978	3.6
Percent of children who are school age • Bureau of the Census, 1982	65.0
Indirect In-Migration	
Indirect employment multipliers • Available labor force within commuting distance (Section 3.6) • Economic activities in the study area (Section 3.6) • Murdock and Leistritz, 1979	0.50

Table 4-28. Peak (1987) Site Characterization In-Migration Distribution to Amarillo, Hereford, Canyon, and Vega

Characteristic	Amarillo	Hereford	Canyon	Vega	Rural Area
Number of total in-migrants	562	234	56	3	47
Number of in-migrating school-age children	121	51	12	8	10
Number of single in-migrating workers including married without family present	143	60	14	9	12
Number of married in-migrating workers with family present	116	48	12	8	10
Number of married in-migrating workers and their family members who are present	419	175	42	28	35

Source: Hines, 1986.

Table 4-29. Additional Baseline Growth Present at the Peak (1987) of In-Migration for Amarillo, Hereford, Canyon, and Vega

Characteristic	Amarillo	Hereford	Canyon	Vega
1980 Population	149,230	15,853	10,724	900
Additional baseline growth	19,239	1,848	1,504	62
Number of additional school-age children	4,040	480	316	22
Number of additional households	6,871	660	537	22

Note: An average household size of 2.8 was used to calculate the above information (NUS, 1984, ONWI-461, p. 29).

The number of school age children estimated for 1987 reflects the proportion of school age children to total population for each county in 1980 (NUS, 1984, ONWI-461, p. 23).

In estimating revenue loss resulting from removal of these acres from production, a mix of crops similar to the average of mix of crops found in the county during 1981 and 1982 was assumed for the site (see Section 5.4.2.4.2). The average crop receipts per acre are projected to be $185.00 in 1986 (TCLRS, 1982). The total loss in crop receipts would be $11,285 or 0.1 percent of the projected crop receipts in Deaf Smith County in 1986. Thus, the lost revenues that would be generated by the crops would be extremely small when compared to the total crop revenues generated in Deaf Smith County. Perceptions of contamination of agricultural products and potential impacts on sales are not expected during this phase. Site characterization is a testing phase, and waste will not be emplaced during this time.

Owners whose land is purchased and taken out of production for site characterization will be compensated under the Uniform Federal Relocation Assistance and Real Property Acquisition Policies Act of 1970 (42 USC Sections 4601 et seq). Under this Act, the DOE will compensate businesses, farmers, and residents who are displaced as a result of characterization activities. The DOE will offer fair market value for property on the basis of appraisals.

Businesses in the local area would benefit from purchases related to site characterization and purchases by the work force for personal needs: food, clothing, housing, and entertainment. The exploratory shaft project would spend approximately $250 million (1985 dollars) on materials and labor. Other site characterization activities (primarily geologic activity) would cost approximately $225 million (1985 dollars). Of the total dollars, approximately 70 percent will be used for materials and 30 percent for salaries. It is likely that some materials will be purchased locally (including fuel, concrete, small equipment, lumber, and other building supplies). Not all wages paid as personal income will be captured in local or even regional economies. For example, the local personal consumption expenditure for those workers without families present would be very low compared to those who relocate with their families. The same would be true of workers who are only present for a short time. Indirect jobs generated by the project will total 240 during the peak period and are expected to be filled by local residents and by the spouses of in-migrating project workers.

For this assessment of impacts on community services, the additional demand created by the site characterization related in-migration at its peak and the baseline growth demand will be compared to the local supply indicated in Section 3.6. Table 4-30 presents the service needs for the communities of Amarillo, Canyon, Hereford, and Vega. Baseline service requirements and project needs are identified for the peak which will last approximately one month. Some of the baseline needs can be met by existing capacity, especially those of workers who are in the site area for a short duration of time. These workers will use available temporary housing, which will reduce the need for additional community services. The community with the greatest cumulative increase in population is Vega with a 4.0 percentage increase. If temporary housing is not available in Vega, these workers can find such housing in other communities in the region, such as Amarillo. Peak project demand does not represent average yearly demand. Peak demand can sometimes be met by more intense use of a service over the short duration of the peak. Peak project demand is more suitable for planning purposes in that it identifies maximum requirements.

If all in-migrating workers are considered as potential household heads, the Amarillo area would need to supply 259 units of housing. Hereford would need to supply 108 units, Canyon would need to supply 26 units, and Vega would need to supply 17 units. No workers would live on the site.

The projected number of in-migrating school-age children during the peak of characterization activities would be 121 students at Amarillo, 51 students at Hereford, 12 students at Canyon, and 8 students at Vega. The additional baseline number of students during the peak would be 4,040 students for Amarillo, 480 students for Hereford, 316 students for Canyon, and 22 students for Vega. Amarillo currently has the capacity to accept 9,603 additional students, Hereford could accept 1,006 students, Canyon could accept 736 students, but most classrooms in the Vega Independent School District are operating above capacity.

Table 4-30. Deaf Smith County Projected (1987) Baseline and Project-Related Service Requirements[a]

Service	Amarillo		Hereford	
	Baseline	Project-Related	Baseline	Project-Related
Additional housing required	6,871	259	660	103
Education				
Additional teachers required (student/teacher ratio 17:1)[b]	238	7	28	3
Protective Services				
Additional municipal police officers required/population (2:1000)[c]	38	1	4	0
Additional fire service personnel required/dwelling units (2:1000)[c]	14	1	1	0
Health				
Additional physicians required/ population (1:1000)[d]	19	1	2	0
Additional hospital beds required/ population (5:1000)[d]	96	3	9	1
Water				
Additional municipal water needs (150 gallons/capita/day)[e]	2.9 million gpd[g]	84,300 gpd	277,200 gpd	35,100 gpd
Sewage				
Additional effluent (100 gallons/ day/capita)[f]	1.9 million gpd	56,200 gpd	184,800 gpd	23,400 gpd

Note: Service estimates are rounded to nearest whole number.

Table 4-30. Deaf Smith County Projected (1987) Baseline and Project-Related Service Requirements[a]
(Page 2 of 3)

Service	Amarillo		Hereford	
	Baseline	Project-Related	Baseline	Project-Related
Recreation				
Additional developed acres required (1 acre/600 children-playground)[e]	7 acres	0	3 acres	0
(1 acre/1000 population-neighborhood parks)[e]	19 acres	0	2 acres	0
Solid Waste				
(6.25 pounds/capita/day)[e]	120,243 pounds per day	3,513 pounds per day	11,550 pounds per day	1,463 pounds per day

Service	Canyon		Vega	
	Baseline	Project-Related	Baseline	Project-Related
Additional housing required	537	26	22	17
Education				
Additional teachers required (student/teacher ratio 17:1)[b]	19	1	4	0
Protective Services				
Additional municipal police officers required/population (2:1000)[c]	3	0	0	0
Additional fire service personnel required/dwelling units (2:1000)[c]	1	0	0	0

Note: Service estimates are rounded to nearest whole number.

Table 4-30. Deaf Smith County Projected (1987) Baseline and Project-Related Service Requirements[a]
(Page 3 of 3)

Service	Canyon		Vega	
	Baseline	Project-Related	Baseline	Project-Related
Health				
Additional physicians required/ population (1:1000)[d]	2	0	0	0
Additional hospital beds required/ population (5:1000)[d]	8	0	0	0
Water				
Additional municipal water needs (150 gallons/capita/day)[e]	225,600 gpd	8,400 gpd	9,300 gpd	5,700 gpd
Sewage				
Additional effluent (100 gallons/ day/capita)[f]	150,400 gpd	5,600 gpd	6,200 gpd	3,800 gpd
Recreation				
Additional developed acres required				
(1 acre/600 children-playground)[e]	1 acre	0	0	0
(1 acre/1000 population-neighborhood parks)[e]	2 acres	0	0	0
Solid Waste				
(6.25 pounds/capita/day)[e]	9,400 pounds per day	350 pounds per day	388 pounds per day	238 pounds per day

Note: Service estimates are rounded to nearest whole number.

Source:

(a) Stenehjem and Metzger, 1976.
(b) National Center for Education Statistics, 1983.
(c) Federal Bureau of Investigation, 1984.
(d) National Center for Health Statistics, 1983.
(e) International City Management Association, 1979.
(f) This EPA Standard appears in (e).
(g) gpd = gallons per day.

The Texas Legislature has recently (1985) adopted legislation specifying student to teacher ratios for particular grades (Merriman and Barber, 1985). These ratios are likely to be different than the ratios currently found in some school districts. Compliance with the new law may alter the capacities of the school districts receiving in-migrants. Funding through the Federal program, School Assistance in Federally Affected Areas for School Construction and Operation, would be available to these and any other school districts affected by increased Federal activities in the area. Under this program, grants are provided to local educational agencies for construction and operation of school facilities where federal activities have caused substantial increases in the school age population (Office of Management and Budget, 1983).

There are some additional requirements for housing, hospital beds, fire protection, and police protection in some of these communities as a result of project-related in-migration. Fire protection, first aid, and security will be provided on site by the contractor. This should reduce the site demand for these services from Deaf Smith County and surrounding communities.

With the removal of 25 hectares (61 acres) from crop production, requirements for irrigation water would be displaced by water needs for site characterization activities. Assuming that the proportion of irrigated land relative to cropland planted at the site is similar to that found in the county, approximately 57 percent of the site is currently irrigated. Irrigating 57 percent of the site requires approximately 56,700 cubic meters (46 acre-feet) of water per year. This estimate assumes the 1980 level of 3,960 cubic meters per hectare (1.3 acre-feet per acre) of water of irrigated land. The site characterization activities will require about 292,300 cubic meters (237 acre-feet) of water over a 5-year period. The average annual water requirement during site characterization is 58,000 cubic meters (47 acre-feet) of water. Compared to the 56,700 cubic meters (46 acre-feet) of water needed to irrigate land in the site area, site characterization activities use a similar amount of water.

Assuming the use of 568 liters (150 gallons) per day of water for each new in-migrant, Amarillo would need to supply an additional 318,654 liters (84,300 gallons) per day, Hereford would need to supply an additional 132,678 liters (35,100 gallons) per day, Canyon would need to supply an additional 31,752 liters (8,400 gallons) per day, and Vega would need 21,546 liters (5,700 gallons) per day. The baseline growth would require 10.5 million liters (2.8 million gallons) per day in Amarillo, 1,047,816 liters (277,200 gallons) per day in Hereford, 852,768 liters (225,600 gallons) per day in Canyon, and 35,154 liters (9,300 gallons) per day in Vega.

The Texas Department of Water Resources (TDWR) (1983, TRY-5; 1983, TRY-4) has projected water supply and demand for this region. TDWR estimates indicate that water will be available to meet municipal and industrial water demands in the future. However, a shortage of irrigation water, resulting from both the depletion of the Ogallala aquifer and increased water costs associated with a more limited resource, is projected by 1990. Municipalities and industries are expected to meet their demand because they require a relatively small amount of water compared to total demand and because they can afford to pay the higher cost of water. Thus, additional municipal and onsite water demands during site characterization are expected to be met.

Assuming the use of 379 liters (100 gallons) per day per capita of effluent requiring sewage treatment, Amarillo's in-migrants would produce 212,436 liters (56,200 gallons) per day. Hereford's in-migrants would produce 88,452 liters (23,400 gallons) per day, Canyon's in-migrants would produce 21,168 liters (5,600 gallons) per day, and Vega's in-migrants would produce 14,364 liters (3,800 gallons) per day. Amarillo's baseline growth would produce 7.1 million liters (1.9 million gallons) per day; Hereford's baseline growth would produce 698,544 liters (184,800 gallons) per day; Canyon's would produce 568,512 liters (150,400 gallons) per day; and Vega's would produce 23,436 liters (6,200 gallons) per day. Amarillo's treatment facility had 8.3 million liters (2.2 million gallons) per day excess capacity, and Hereford and Canyon had 4.5 million liters (1.2 million gallons) per day and 0.8 million liters (0.2 million gallons) per day, respectively, excess capacity in 1982. Vega had no excess capacity.

Solid waste generated by the new in-migrants would result in 1,593 kilograms (3,513 pounds) per day from Amarillo, 663 kilograms (1,463 pounds) per day from Hereford, 153 kilograms (350 pounds) per day from Canyon, and 107 kilograms (238 pounds) per day from Vega. Solid waste generated by the baseline growth in these communities would result in 54,470 kilograms (120,243 pounds) per day from Amarillo, 5,232 kilograms (11,550 pounds) per day from Hereford, 4,258 kilograms (9,400 pounds) per day from Canyon, and 176 kilograms (388 pounds) per day from Vega. Amarillo and Canyon have excess landfill capacity. Vega contracts for solid waste collection service.

Under Section 116(c)(3) of the NWPA (42 USC Sections 10101-10226), the DOE is authorized to make annual grant payments to States and units of general local government where a site has been approved for characterization. These payments will be made in amounts equal to the taxes that States and units of general local government would have received where they authorized to tax site characterization and repository development activities as they tax other real property and industrial activities occurring within their jurisdictions. Payments are to be made each fiscal year until activities at the site are terminated.

The major types of taxes imposed by the State of Texas and its units of general local government on real property and industrial activities occurring within their jurisdictions include the following:

- Real property tax
- Personal property tax
- Franchise tax
- Severence tax
- Sales and use taxes
- Other excise taxes.

Some of these taxes might be applied to site characterization and repository development if such activities were taxed in a manner similar to the way in which other real property and industrial activities are taxed. One of the important considerations involved in calculating the annual grant-equal-to-tax (GETT) payment is establishing which taxes might be applicable. Other considerations include jurisdictional eligibility and grant administration.

The GETT payments will begin during site characterization and continue throughout repository construction and operation. This fund is not designated as a mitigation grant as are those payments described in Section 116 (c)(2)(A) of the NWPA (42 USC Sections 10101-10226). Therefore, jurisdictions receiving GETT payments will not necessarily correspond to jurisdictions affected by project-related activities.

The NWPA also provides grants to States for a variety of other activities. States having an approved candidate site are eligible for grants under Section 116 (c)(1)(B). These grants will be made available to eligible States for the purpose of, among other things, (1) reviewing site characterization activities and determining socioeconomic, public health and safety, and environmental impacts; (2) developing a request for repository-related impact assistance; and (3) monitoring site characterization activities. The grants are also available for several other activities not specifically related to socioeconomics.

In developing a request for repository-related impact assistance, the State and local governments will identify impacts relating to public health and safety, the environment, and socioeconomics and associated mitigation measures. This activity will involve community planning during the site characterization phase. Funds for planning activities related to the project can be provided through this provision of the NWPA.

In addition to increased revenues from NWPA grants and payments, other types of local revenues will increase and can be supplemented. For example, the Federal School Assistance Program described earlier, can provide additional monies for offsetting the increased school population.

Government revenues will increase from several sources. Amarillo, Hereford, Canyon, and Vega could receive some revenue from sales tax on goods and services purchased by the new in-migrants and the site characterization contractors. Additional occupancy of area motel and hotel rooms would generate transient room taxes in the socioeconomic study area.

Impacts on social structure and quality of life are related largely to the population change in the community. The project-related population change for Amarillo during the peak would be about 0.3 percent, while Hereford's population change would be 1.3 percent, Canyon's would be 0.5 percent, and Vega's 4.0 percent. The area has experience in hosting seasonal populations (in-migrant laborers) and should not be overwhelmed by the in-migrating site characterization workers. However, some social problems related to the differences in in-migrant worker versus local lifestyles may occur. Although social problems could occur, the number of in-migrants compared to the number of current local residents would not be enough to significantly alter the social structure of the nearby communities.

The DOE is looking for alternative ways to assist communities that require mitigation assistance. Measures to reduce any social or economic impacts can include several different programs. Before site characterization, the DOE will review requests for impact mitigation assistance on a case-by-case basis (DOE, 1985b, DOE/RW-0005, Vol II, p. 88). One measure to reduce impacts would be to encourage the site contractor to hire local residents. This would reduce the number of workers and families relocating to an area and increase the economic benefit to the region by increasing local employment opportunities for existing residents. In addition, wages spent outside the region are likely to be less for existing residents than for in-migrants who may be there for a shorter period of time.

Encouraging contractors to procure materials within the region can also increase the economic benefits to businesses in the area. Such purchases will stimulate additional employment opportunities in the region. Other measures to reduce impacts might include scheduling site characterization activities in a way that will lower the peak work force requirements and thus lower in-migration. New residents could be encouraged to locate in communities that have the service capacity to handle them.

The DOE can also provide technical assistance to aid local planning efforts. This assistance could be used to develop job-training programs for local residents, programs for worker transportation, and any other mitigation measures which require coordination between the DOE, the State, and the local governments. DOE technical assistance could also be used to help local governments form an impact management committee, as well as in the development and implementation of a comprehensive impact monitoring program. A monitoring program will be established during site characterization so that actual impacts can be identified and appropriate planning initiated.

4.3 ALTERNATIVE SITE CHARACTERIZATION ACTIVITIES

This section discusses some alternative methods and approaches to site characterization. Some of these could be used to avoid adverse impacts; however, they may not all be feasible because of unavailable technology, costs, or secondary effects.

Site characterization involves the following two major groups of activities:

1. Collection of geological, hydrological, and environmental data using standard, readily available procedures, such as the drilling of 15-centimeter (6-inch) boreholes and seismic surveys. These activities cause only local and temporary disturbances to the physical environment that can be mitigated to acceptable levels (Section 4.2). No alternative test procedures causing less environmental impact are available; however, the location where these tests are performed can be shifted in many cases to accommodate the existence of newly discovered archaeological or other environmentally sensitive finds.

2. Construction of an exploratory shaft facility to permit in situ testing of thermomechanical and other properties of the host rock. This activity is required to verify site suitability and fulfill data needs for the repository, and cannot be replaced by alternate procedures. However, various aspects of the construction and operation of the exploratory shaft facility can be carried out using alternate procedures of varying impact; some of these alternatives are described in the following sections.

4.3.1 Alternative Exploratory Shaft Facility Locations

The location of the exploratory shaft facility was selected based on a conceptual repository layout for a salt repository. This location was selected using scientific, engineering, environmental, and nontechnical (such as land-use) criteria. The favorability of a particular location as a potential repository site will be verified through geologic mapping and geological, environmental, and engineering surveys during site characterization. Other ESF locations, as alternatives to those given in this Environmental Assessment, will be considered if investigations indicate that location changes are necessary to avoid such problems as destruction of significant archaeological resources or severe impacts on sensitive biological communities. However, the location of alternative ESF sites would remain within a limited area around each reference location.

4.3.2 Exploratory Shaft Facility Alternatives

It is physically possible to conduct the subsurface characterization activities from only one shaft. This alternative would eliminate the environmental impacts associated with constructing one of the two planned exploratory shafts. There are compelling reasons why this alternative is not preferred. The first and foremost of these reasons is safety. A prime consideration for occupational safety is to provide at least two escapeways from any potentially hazardous work station, a principle evidenced in the regulations of the Mine Safety and Health Administration (MSHA). Although an exploratory shaft facility is not a mine in that the purpose of a mine is to extract minerals for commercial use, it does consist of shafts and underground openings constructed by mining techniques. Therefore, safety standards developed for mines are the most applicable safety standards for constructing and operating an exploratory shaft facility.

Section 57.11-50 of the MSHA regulations (30 CFR Part 57) states:

> Every mine shall have two or more separate, properly maintained escapeways to the surface from the lowest levels which are so positioned that damage to one shall not lessen the effectiveness of the others. A method of refuge shall be provided while a second opening to the surface is being developed. A second escapeway is recommended, but not required, during the exploration or development of an ore body.

The exploratory shaft facility could be considered equivalent to "exploration or development of an ore body" and therefore not be required by MSHA to have two shafts. However, the U.S. Department of Energy policy is that merely meeting minimum safety standards is not adequate. DOE Order 5480.1A and 5480.4, Environmental Protection, Safety, and Health Protection Program for DOE Operations, involves, in addition to MSHA regulations, the California Mine Safety Orders (Title 8, Industrial Relations, Part I, Chapter 4, Subchapter 17). Article 27, Section 7080 states:

> Every mine shall have two separate escapeways to the surface which are so positioned that damage to one shall not lessen the effectiveness of the other, or method of refuge shall be provided when only one opening to the surface is possible.

Therefore, since two openings to the surface are possible during site characterization, both DOE Order 5480.1A and 5480.4 and prudent occupational safety practices require two shafts.

Additionally, it is possible that personnel working in any underground opening in evaporites, such as salt, may encounter releases of flammable gases. MSHA regulations, Section 57.21 (30 CFR Part 57), detail the conditions that would cause a mine to be declared a gassy mine. If a mine is declared gassy, Section 57.21-22 states:

> The main intake and return air currents in mines shall be in separate shafts, slopes, or drifts....

Exploratory shaft sizes discussed herein were selected based on project needs. Each shaft must be large enough to contain utility lines and a conveyance for people and materials, as well as provide necessary ventilation.

4.3.3 Alternative Water Supply

The ESF water requirements, with a maximum of 21.5 cubic meters per hour (95 gallons per minute), can be satisfied from local wells or trucked in. The first alternative is preferred. Because water demand is small, it is believed that the impacts of either supply are equivalent and minor.

4.3.4 Alternative Waste Disposal

It is believed that the procedures selected for control and disposal of liquid waste described in Section 4.1.2.6, represent the best available control technology, and alternative control and disposal procedures would have greater environmental impact.

Section 4.1.2.6 also describes selected disposal methods for solid refuse and excess salt; however, alternative procedures for disposal of these solid wastes have been identified and are discussed below.

4.3.4.1 Combustible Refuse

The selected disposal method for rubbish is to haul it to a permitted landfill within 80 kilometers (50 miles) of the site. The impacts of this method are discussed in Sections 4.2.1.1, Land Use; 4.2.1.3, Air Quality; and 4.2.1.4, Water Quality Effects.

Alternatives to this disposal method include (1) onsite incineration with offsite disposal of ash residue, or (2) disposal in a landfill developed on site.

A permitted sanitary landfill near Amarillo is currently available for disposal of combustible waste. Its capacity is limited, but other potentially suitable landfill sites in the area are available for future development. Additional permitted disposal sites are located within 160 kilometers (100 miles) of Deaf Smith County, near Clovis, New Mexico (Caspers, 1984).

Onsite landfill disposal involves obtaining the required permit, dedicating a land area, protecting ground water, using diesel-operated equipment for salt spreading and compacting, and controlling gaseous (methane) emissions.

4.3.4.2 Disposal of Excess Salt

Approximately 65 percent of the salt excavated from the exploratory shaft and subsurface test areas will be used to backfill the shaft and subsurface if the site is not selected for a repository. As discussed in Section 4.1.2.6, waste salt and residues from runoff detention ponds may be disposed of off site in a licensed landfill located near Clovis, port Arthur, Texas (McCutchen, 1985). The effects of this method are discussed in Section 4.2.1.1, Land Use, and Section 4.2.1.4, Water Quality Effects. The discussion indicates that one or more landfills can accommodate the amount of waste expected and are licensed to do so (Messenger, 1984; Pole, 1984; Weston, 1984; Hensch, 1984). Additional facilities may also be available if required. Thus, problems including preempting land use, shortening the design life of an

existing facility, and guaranteeing the long-term integrity of the landfill with respect to erosion, leaching of salt, or contamination of ground water are not expected to be significant.

The offsite disposal option for salt and salt-contaminated materials was chosen because of the need to return the site to its original condition if it is not selected for a repository. The facility identified for the disposal of these materials was selected in part to satisfy concerns for having the salt in a caretaker-type licensed facility. The offsite alternative and the facility identified represent the most conservative case for disposal of salt and salt-contaminated materials.

Impacts resulting from transportation of the salt and salt-contaminated wastes, including greater cost and the potential for contamination along the routes, have also been discussed in Section 4.2.1.1.

In addition to the selected disposal method, five alternative methods for disposal of waste salt are available (NUS Corporation, 1985d; Parsons-Redpath, 1984):

- Disposal in an onsite landfill
- Disposal in existing, unused salt mines or salt flats
- Deep-well brine injection
- Offshore disposal
- Transfer, gift, or sale of salt to Federal, State, or private parties.

All offsite alternatives require transport of excess salt. Most would also cause some environmental impacts in addition to those associated with rail or truck transportation. A qualitative environmental analysis is presented below.

4.3.4.2.1 Onsite landfill. Primary issues associated with this disposal option include land use preemption and ground-water infiltration. If the salt is buried to sufficient depth, particularly if covered with a substantial soil layer, the land above the salt may be put to beneficial use, thus minimizing land-use impacts. Liners above and below the salt would minimize ground-water infiltration. Long-term integrity of the landfill might become an issue, particularly if sited in a floodplain area. The primary advantages of this option are as follows:

- Relatively low cost (Parsons-Redpath, 1984)
- Absence of transportation impacts
- Relatively slight environmental impacts (primarily ground-water and land-use).

Disadvantages include:

- Potential long-term preemption of land use

- Problems in guaranteeing long-term integrity of the landfill with respect to erosion, subsequent leaching of salt, or subsequent water quality contamination.

4.3.4.2.2 Mine Disposal. Offsite disposal in existing or abandoned mines or salt flats has the primary disadvantage of increased cost and the environmental impacts associated with rail or truck transports. The primary advantages include:

- Elimination of onsite impacts

- Minimal offsite environmental impacts other than those associated with rail or truck transport.

If existing or abandoned salt mines are used, there would be no alteration of the existing environment, hence no ground-water contamination. An additional benefit might be reduced subsidence as the mine is backfilled. If an existing or workable mine is used in this way, this option might adversely impact resource exploitation for the mine that is used.

4.3.4.2.3 Deep-Well Injection. Deep-well injection would require offsite transport and the creation of an offsite brining facility, both of which would result in additional costs over onsite land disposal. The environmental impacts associated with brining and deep-well injection would be different compared to land disposal (NUS, 1985d). Construction of the brining facility would temporarily affect land use, soils, resident biota, and air quality, which are typical of any construction project. Production of brine would require substantial amounts of water and might impact the local water supply. Deep-well injection of brine might impact ground-water quality.

The major advantage of deep-well injection is that most environmental impacts (with the possible exception of ground-water quality) are short-term and reversible. The major disadvantages over onsite land disposal include

- Additional cost
- Additional impacts from rail or truck transport
- Water supply requirements
- Potential deterioration of ground-water quality
- Substantial but temporary environmental impacts associated with the construction and operation of a brining facility.

4.3.4.2.4 Offshore Disposal. Offshore disposal would most likely involve transport of the excess salt to the Gulf of Mexico (NUS, 1985d). It is expected that the salt would be loaded on barges and dispersed in the ocean over a wide area. Costs (Parsons-Redpath, 1984) and environmental impacts are expected to be low (but higher than onshore disposal), as indicated by performance of the DOE Strategic Petroleum Reserve Project (BPNL, 1979, DOE/ET-0029). For this project, large amounts of saturated brine (on the order of 32,000 cubic meters [200,000 barrels] per day) are being discharged in the Gulf. Findings for this project indicate negligible impacts to offshore marine biota (DOE, 1983, DOE/EP-0045/1, p. 6). This indicates that impacts from dispersion of excess salt from the exploratory shaft will also be negligible. If this method is chosen, activities will be conducted in a manner consistent with the Federal Coastal Barrier Resources System and with any approved State coastal zone management programs of the Gulf States involved.

The primary advantage of offshore disposal is that the impacts of disposal will be, for the most part, temporary. The primary disadvantages are

- Increased cost, due primarily to transportation requirements
- Additional impacts from rail or truck transport
- Minor adverse impacts on offshore aquatic biota.

4.3.4.2.5 Sale or Transfer of Salt. Mined salt also could be offered first to Federal agencies through sale or transfers for use in road salting and other applications. If the material is not needed by Federal agencies, it could be offered to interested State and local governments as a donation. If it is refused by these governments, it could then be offered for public sale. The feasibility of this disposal procedure has not been verified. Primary disadvantages would be the cost and impacts from rail or truck transport of the salt.

4.4 SUMMARY TABLE

The expected impacts of exploratory-shaft construction and operation, and geologic and environmental field studies are summarized in Table 4-31.

The summary table indentifies impacts that are projected to occur as well as those not expected to occur. Impacts are discussed in terms of their duration and intensity or significance. As applicable, location of the impact is also identified.

Table 4-31. Summary of Site Characterization Impacts at Deaf Smith County

I. Geologic Field Studies

I. Geologic Field Studies (Section 4.2.1)

Primary activities are as follows:

Seismic surveys, disrupting 177 hectares (438 acres) of land; use of well water; drilling boreholes, including storage of drilling mud, saline fluids, and drill cuttings in pits; transport of personnel and materials to and at the site; long-term pump testing; borehole profiles (including possible blasting) in four playas; drilling deep playa wells; digging shallow auger holes or test pits for geologic surface mapping; site restoration, including removal of equipment and surfacing material, regrading, and revegetation.

Summary of Impacts

1. Land Use (Section 4.2.1.1.1)

- Approximately 283 hectares (700 acres) of agricultural and rangeland will be temporarily disturbed. The length of time land will be disturbed will vary from 2 days to the end of site characterization.
- Playas used by farmers to collect irrigation water may be disturbed.
- Prime farmland will be temporarily disturbed during geologic field studies.
- Temporary disruption to farming and other land management practices can be expected.

2. Terrestrial/Aquatic Ecosystems (Section 4.2.1.2.1)

- Wildlife populations will be minimally disrupted by habitat loss. No permanent habitat loss will occur.
- Ecological impacts are likely to be of local importance and relatively short term.
- Adverse impacts to wetlands will be minimal. No permanent habitat loss will occur.

3. Air Quality (Section 4.2.1.3.1)

- Estimated concentrations of TSP from fugitive dust will be generated by road construction, vehicular traffic on unpaved roads, drill site preparation, and drilling, which will not exceed the NAAQS.
- Estimated concentrations of gaseous NO_x emissions from mobile vehicles and drilling rig exhausts will not exceed the NAAQS.

Table 4-31. Summary of Site Characterization Impacts at Deaf Smith County (Page 2 of 7)

I. Geologic Field Studies

4. Surface-Water Quality (Section 4.2.1.4.1)

- No significant impacts are expected to Palo Duro Creek or playas.

5. Ground-Water Quality (Section 4.2.1.4.1)

- Minimal drawdown interference at local wells is expected; the maximum interference to wells 1.6 kilometers (1.0 mile) from onsite wells is expected to be approximately 0.1 meter (0.2 foot).

6. Soils (Section 4.2.1.5.1)

- Soil impacts are expected to be localized and insignificant.

7. Noise (Section 4.2.1.6)

- Increased sound levels in areas around borehole locations and near truck-mounted generators are expected.

8. Aesthetic Resources (Section 4.2.1.7.1)

- Short-term visual disruption by drill rigs is expected.
- Temporary moderate disruption of visual quality of the playas is expected due to proposed activities.

9. Archaeological, Cultural, and Historical Resources (Section 4.2.1.8.1)

- Sensitive areas will be disturbed; surveys may identify undiscovered resources.

10. Radiation Levels (Section 4.2.1.9)

- No radiological impacts from site characterization are expected.

11. Transportation and Utilities (Section 4.2.1.10.1)

- Transient, minor impact on transportation network and temporary congestion during moving of equipment on and off public roads is expected.
- No adverse impacts on local or regional utilities are expected.

12. Socioeconomic

- Socioeconomic impacts for all site characterization activities are summarized under Environmental Field Studies.

Table 4-31. Summary of Site Characterization Impacts at Deaf Smith County (Page 3 of 7)

II. Exploratory Shaft

II. Exploratory Shaft

Primary activities are as follows:

Clearing, grading, and topsoil storage for ES site and access road totaling 25 hectares (61 acres); excavation and lining of evaporation and retention pond; excavation of sediment detention ponds; shaft construction and outfitting with seals and collars; disposal of salt and salt-contaminated materials in approved landfill; storage of overburden and salt from shaft construction; construction or erection of surface facilities; transport of personnel and materials to and at the site; water and energy use; underground excavation of drifts by continuous miner; final disposition possibly involving continuous miner; final disposition possibly involving continued operation, site maintenance, or restoration; restoration by filling drifts and plugging shaft; removal of surface facilities, regrading to original contours, and revegetation.

Summary of Impacts

1. Land Use (Section 4.2.1.1.2)

   - Shaft and access road will occupy 25 hectares (61 acres) of agricultural land.
   - Agricultural land used for ESF represents 0.08 percent of total cropland in the site vicinity.
   - The shaft and access roads could disrupt irrigation practices.
   - ESF will disturb some prime farmland.

2. Terrestrial/Aquatic Ecosystems (Section 4.2.1.2.2)

   - Loss of cropland foraging habitat will be regionally insignificant.
   - Drilling rig supports, two headframes and transmission lines are potentially hazardous to migrating birds at night and during periods of poor visibility.
   - Some mortality to sedentary organisms will occur and other species will be forced to emigrate from the shaft site and access road. Impacts are expected to be regionally insignificant.

3. Air Quality (Section 4.2.1.3.2)

   - Estimated concentrations of TSP from fugitive dust from access-road construction, site clearing and preparation, vehicle movement, development and wind erosion of spoils piles, and vehicle or machinery exhaust will meet the NAAQS.

Table 4-31. Summary of Site Characterization Impacts at Deaf Smith County (Page 4 of 7)

II. Exploratory Shaft

- Estimated concentrations of gaseous NO_x emissions from mobile vehicles and machinery exhausts will meet the NAAQS.

4. Surface-Water Quality (Section 4.2.1.4.2)

- Minimal impacts to surface-water quality due to shaft construction are expected.
- Minimal water-quality impacts are expected from windblown salt transported via surface runoff to playas.

5. Ground-Water Quality (Section 4.2.1.4.2)

- Minimal impact on local water supplies is expected.
- Minimal drawdown interference at local wells is expected; the maximum interference to wells 2.4 kilometers (1.5 miles) from onsite wells is expected to be approximately 0.1 meter (0.3 foot).
- No significant impact to ground-water quality is expected from salt-runoff seepage and percolation through the soil.
- Minimal water-quality impact is expected from windblown salt transport via percolation through playa annular zones.
- No impacts due to shaft leakage are expected.

6. Soils (Section 4.2.1.5.2)

- Compaction and loss of existing soil structure from heavy equipment and traffic will occur.
- Changes will occur in physical and chemical properties due to soil stripping and stockpiling.
- Increase in erosion potential is expected.
- Minimal impact on soil productivity following reclamation is expected.

7. Noise (Section 4.2.1.6.2)

- EPA sound level guideline of 55 dBA L_{dn} will be exceeded at the nearest residence for about 44 months, at the second nearest residence for about 36 months, and at the third nearest residence for about 13 months.
- EPA sound level guidance of 70 dBA L_{eq} will not be exceeded at the nearest residence.

Table 4-31. Summary of Site Characterization Impacts at Deaf Smith County (Page 5 of 7)

II. Exploratory Shaft
• Noticeable increase in traffic noise on FM 2587 is expected during peak periods.
8. Aesthetic Resources (Section 4.2.1.7.2)
• Temporary visual intrusion from two shaft headframes is expected.
• New transmission lines to the ESF will cause some visual impact.
9. Archaeological, Cultural, and Historic Resources (Section 4.2.1.8.2)
• Surveys will be performed to identify unrecorded resources; no significant impacts are expected.
10. Radiation Levels (Section 4.2.1.9)
• Insignificant radiological impacts are expected.
11. Transportation and Utilities (Section 4.2.1.10.2)
• Transient, minor impact is expected to transportation network and temporary congestion during moving of construction equipment on and off public roads.
• Trucks will cause road-surface wear.
• Level of service on roads near site during peak hours will decrease.
• No adverse impacts to local or regional utilities are expected.
• No significant impacts to Amarillo International or Hereford Municipal airports are expected.
12. Salt Management and Disposal (4.2.1.11)
• Deposition of windblown salt from site characterization activities will be less than from the repository activities; expected salt deposition during repository activities is 3.8 kilograms per hectare (3.4 pounds per acre) at 840 meters (0.5 miles).
• No significant impact to soil productivity is expected from windblown-salt deposition.
• Minimal impact to surface and ground-water quality from surface handling of salt is expected.

Table 4-31. Summary of Site Characterization Impacts at Deaf Smith County (Page 6 of 7)

II. Exploratory Shaft

- Adverse impacts on terrestrial ecosystems will be minimal and highly localized.
- Impacts to playa environments due to deposited salt carried by runoff will be minimal; no significant impact to other aquatic environments is expected.

III. Environmental Field Studies

Primary activities are as follows:

Sampling plant and animal specimens for voucher specimens and radiation analysis; constructing a 60-meter (197-foot) meteorological tower, equipment shelter, and access road; transporting personnel on site and in vicinity.

Summary of Impacts

1. Land Use (Section 4.2.1.1.3)

   - Minor disruption of land use is possible if meteorology tower is on agricultural land.

2. Terrestrial/Aquatic Ecosystems (Section 4.2.1.2.3)

   - Potential exists for birds to collide with meteorological tower during periods of poor visibility.
   - Individuals of species may be removed from populations for voucher collection under provisions of State-issued collecting permits.

3. Air Quality (Section 4.2.1.3.3)

   - Impacts on air quality are expected to be negligible.

4. Surface-Water Quality (Section 4.2.1.4.3)

   - Minimal, temporary impacts due to equipment installation and staff access are expected.

5. Ground-Water Quality (Section 4.2.1.4.3)

   - Minimal, temporary impacts are expected due to equipment installation.

6. Soils (Section 4.2.1.5.3)

   - Meteorological tower installation may cause minor changes in the physical properties of soil, drainage, and erosion potential.

Table 4-31. Summary of Site Characterization Impacts at Deaf Smith County (Page 7 of 7)

III. Environmental Field Studies
• Other environmental studies may cause insignificant and localized soil impacts.
7. Noise (Section 4.2.1.6)
• No significant contribution to noise levels is anticipated.
8. Aesthetic Resources (Section 4.2.1.7.3)
• Visual character of area will be affected by meteorological tower, which is comparable to a radio tower.
9. Archaeological, Cultural, and Historical Resources (Section 4.2.1.8.3)
• Surveys will be performed to identify unrecorded resources; no significant impacts are expected.
10. Radiation Levels (Section 4.2.1.9)
• No radiological impacts are expected.
11. Transportation and Utilities (Section 4.2.1.10.3)
• Little or no impact to transportation and utilities is expected.
12. Socioeconomics (Section 4.2.2)
• Relatively small amount of revenue is likely to be lost due to change in land use.
• No major disturbance or relocation of residents expected.
• Additional government revenues from sales tax on purchases, transient room tax on increased motel and hotel occupancy, and grants equal to tax payments are expected.
• Social problems due to differences in in-migrant worker versus local lifestyles are possible.
• The greatest cumulative increase in population is 937. The majority of these residents (562) are expected to locate in Amarillo. The expected percentage change in population of the affected communities is as follows: Amarillo (0.3 percent), Hereford (1.3 percent), Canyon (0.5 percent), and Vega (4.0 percent).
• There will be a need for some additional services in the affected communities. However, demand for services such as housing, teachers, sewage treatment, and solid waste disposal may be met by using existing service capacity.

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4.5.4 State of Texas Laws

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Chapter 5

REGIONAL AND LOCAL EFFECTS OF LOCATING A REPOSITORY AT THE SITE

This chapter is intended to meet the requirements of Section 112(b)(1)(E)(vi) of the Nuclear Waste Policy Act of 1982 (NWPA) (42 USC Sections 10101-10226) that mandates the environmental assessment (EA) include "an assessment of the regional and local impacts of locating the proposed repository at such site." This chapter meets these requirements by describing the environmental, transportation, and socioeconomic effects of locating a representative repository at the Deaf Smith County site.

This chapter is organized into four sections:

5.1 Section 5.1 describes a representative repository and those activities that occur during repository construction, operation, and decommissioning, and presents the impacts of some recent design variations.

5.2 Section 5.2 describes effects of representative repository activities on the physical environment.

5.3 Section 5.3 describes the effects of transportation and utilities access to the repository site.

5.4 Section 5.4 describes the socioeconomic impacts of a repository.

5.1 THE REPOSITORY

The representative repository concept described in this chapter is based on site-specific engineering feasibility studies for constructing and operating a repository at candidate salt sites (SCC, 1984a). The impact analyses presented in this chapter are based on engineering parameters developed using this feasibility study which will hereafter be referred to as the "Reference Repository Design." This concept had the most complete design information available during the time that the EA impact analyses were prepared. However, this reference design must not be construed to represent a final site-specific conceptual design. Rather, the design feasibility data generated should be treated as the first step of the design process that progresses from feasibility studies to the conceptual design phase (Site Characterization Plan Conceptual Design and Advanced Conceptual Design), and to the Title I and II design phase (License Application Design and Final Procurement and Construction Design). The site-specific conceptual design and license application design will resolve remaining uncertainties and serve as the basis for the environmental impact statement (EIS) that will be prepared prior to submittal of a license application. The Salt Repository Project Office (SRPO) is currently developing the Site Characterization Plan (SCP) Conceptual Design for the SCP. Development of the Advanced Conceptual Design will follow completion of SCP conceptual design.

To illustrate differences which could occur in the future as the design process matures, two alternative repository design concepts are presented in Table 5-1 for comparison of design characteristics and impacts (environmental, socioeconomic and transportation). The reference design in the table is the design concept upon which, as mentioned previously, regional and local impacts are assessed in this EA. The reference design is a single-phase concept; that is, all surface and initial underground construction activities are completed prior to acceptance of nuclear wastes. The reference design was based on receipt of both spent fuel (SF) (36,000 metric tons of heavy metal [MTHM] [39,690 tons]) and commercial high-level waste (CHLW) (36,000 MTHM [39,690 tons]) plus approximately 3,510 MTHM (3,870 tons) of defense high-level waste (DHLW). Gassy mine conditions were not assumed in the reference design.

The second concept presented in Table 5-1 is the "Current Two-Phase Concept." This is a modification of the reference design to meet the requirements presented in the DOE final Mission Plan (DOE, 1985, DOE/RW-0005). This concept differs from the reference design in

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
1. Incorporation of exploratory shaft into repository[b]	Not included	Being evaluated	If one or more exploratory shafts are not incorporated into the repository, repository-related impacts are expected to be identical because the number and size of repository shafts are the same. However, if one or more exploratory shafts are incorporated into the repository and the number of shafts to be constructed during the repository phase is reduced, there would be a slight reduction in work force and supplies required during repository construction and, in turn, worker and truck traffic in the locality would be less.	If one or more exploratory shafts are not incorporated into the repository, repository-related impacts are expected to be identical because the number and size of repository shafts are the same. However, if one or more exploratory shafts are incorporated into the repository and the number of shafts to be constructed during the repository phase is reduced, there would be a minimal reduction in environmental impacts. Impact reductions would be attributable to less emissions and less resource consumption.	If one or more exploratory shafts are not incorporated into the repository, repository-related impacts are expected to be identical because the number and size of repository shafts are the same. However, if one or more exploratory shafts are incorporated into the repository and the number of shafts to be constructed during the repository phase is reduced, there would be a minimal reduction in socioeconomic impacts. Impact reduction would be attributable to reductions in the required work force.
2. Number and sizes of exploratory shafts[b] (feet, inside diameter)	Not included	Two: 12, 12	See response to Characteristic 1.	See response to Characteristic 1.	See response to Characteristic 1.
3. Number and sizes of repository shafts (feet, inside diameter)	Five - 21, 22, 23, 25, 31	Five: 21, 22, 23, 25, 31	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
4. Gassy conditions assumed	No	Yes	Gassy mine conditions require increased ventilation. This may require additional passageways and consequent increases in the amount of excavated salt. The transportation consequences of gassy mine conditions result from the possible increased amount of salt to be disposed of and increased work force. These potential impacts are addressed in Characteristics 7 and 18.	Gassy mine conditions require increased ventilation. This may require additional passageways and consequent increases in the amount of excavated salt. More or larger equipment to power ventilation fans will be required. Because the fans are electrically driven, no additional impact on air quality is expected. Additional or larger equipment to handle increased ventilation air flow may increase noise levels unless noise mitigation equipment is used. For the reference case, mitigation	Gassy mine conditions require increased ventilation. This may require additional passageways and consequent increases in the amount of excavated salt. The socioeconomic consequences of gassy mine conditions result from the increased work force requirements associated with additional underground excavation. These impacts are addressed in Characteristic 18.

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Gassy conditions assumed (Continued)				was applied to the ventilation exhaust system to reduce noise levels attributable to ventilation fans. A 50 percent increase in air flow will produce about a 1.8 dB increase in emismision sound levels. Reduction of 1.8 dB of the source of noise is achievable within the current state of the art through the use of baffles and muffling equipment. Thus, noise impacts for the current concept can be held within those of the reference case through mitigation. Estimated normal use of the steam plant is 18 percent of capacity to heat buildings and supply miscellaneous needs for both the reference case and current concept. Because the reference case modeled emissions assuming 100 percent capacity usage, the impacts modeled are conservative. Steam plant capacity is established to meet the emergency backup air conditioning requirement. Impacts from additional excavated salt are addressed under Characteristics 6, 7, and 18.	
5. Approximate repository depth (feet)	2,570	2,570	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
6. Salt Total quantity excavated (tons) Quantity stored on site (tons)	 23,600,000 3,682,000	 32,100,000 4 750 000	The alternative to the reference case will increase by about one-third the amount of salt to be excavated and stored on site. The increase in salt excavation and onsite	The alternative to the reference case will increase by about one-third the amount of salt to be excavated and stored on site. Airborne emissions of salt from salt	The alternative to the reference case will increase by about one-third the amount of salt to be excavated and stored on site. The increase in salt excavation is expected to result in a pro-

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
(Page 3 of 10)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Salt (Continued)			storage is expected to result in a larger work force. The transportation impact is addressed in Characteristic 18.	handling operations are expected to increase over the life of the facility. Fugitive salt is conservatively estimated to increase up to 30 percent more than the 15 tons per year estimated for the reference case even though the salt pile will have formed a hard crust and the working face will be kept about the same siz . Salt particulates from the mine exhaust will increase due to, roughly, a 50 to 60 percent increase in air flow. Repository salt deposition rates (used also for the site characterization deposition estimates) between 1 and 2 kilometers (0.6 and 1.2 miles) from the salt storage pile and exhaust ventilation shaft are projected to be 0.1 kilogram per hectare (0.09 pound per acre) per year for the reference case. This deposition rate is expected to net: • Less than 3.8 kilograms per hectare (3.4 pounds per acre) of salt per year compared with 110 to 170 kilograms per hectare (100 to 155 pounds per acre) per year of sodium from irrigation with high-quality Ogallala water (Section 5.2.10.2.1). • Insignificant impacts on crops because deposition rates will be below levels shown to cause leaf injury (65 kilograms per hectare 58 pounds per acre per year with greater than 70 percent humidity, Section 5.2.10.2.5).	portion of the total work force increases associated with the two-phase repository and higher project expenditures. The impacts of these are addressed in Characteristic 18.

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Salt (Continued)				If through the life of the facility the rate of deposition or the total accumulated salt increased by 50 percent due to increased salt handling and increased exhaust ventilation shaft air flow, the values reported above, even if doubled, would be below levels expected to cause impacts. Salt storage pile and retention pond areal dimensions do not change in the two-phase concept; the salt pile is extended higher by roughly 3 meters (10 feet) and the salt-runoff retention pond is deepened. Hence, no additional surface area is disturbed (Characteristic 8). The visual impact will be similar to that stated for the reference case. Indirect impacts of additional workers are addressed under Characteristic 18. Indirect impacts from increased traffic-induced air and noise emissions are minor and are not considered to provide significant differences in impacts.	
7. Nonradioactive offsite disposal requirements					
Salt (tons)	11,330,000	16,300,000	The two-phase concept will result in an increase of 42 percent in offsite salt disposal. This can be accommodated within current plans (Section 5.3.3) by increasing the number of covered hopper cars in the daily and weekly trains estimated to accommodate the reference case.	The two-phase concept will result in an increase of 42 percent in the offsite disposal requirement. Salt disposal options, especially ocean, surface (salt flat) and mine disposal, have large capacities to accept the reference or two-phase concept volumes of waste salt. For example, a Stearns Catalytic Corporation study (SCC, 1984b) cites that numerous evaporite mines were available with the	The two-phase concept will result in an increase of 42 percent in offsite salt disposal. Because this can be accommodated within current plans, no significant differences in socioeconomic impacts are expected.
Repository-generated wastes (truck loads/year)	135	170	The increase in other repository-generated waste of		The increase in other repository-generated waste of 35 truck loads per year (1/10 truck load per day) is not large enough to create a

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Nonradioactive offsite disposal (Continued)			35 truck loads per year is about 1/10 truck load per day and will cause no significant transportation impacts.	capacity to accept the anticipated waste salt volumes. These options can typically accommodate more salt than is to be disposed under the two-phase concept. Transporting salt in closed hopper cars would minimize the potential for salt to be released to the environment during shipment. Because the additional salt can be disposed of with additional hopper cars on each salt train, noise and air quality impacts are expected to to be about the same. Air quality impacts from NO_x, the primary emissions from diesel locomotives, are not expected to be significant because the emissions will be small. The addition of cars does not alter this conclusion. Because the Ldn 55 dBA contour is expected to remain about the same, and no sensitive receptors are expected to be within this contour, noise impacts for the two concepts are expected to be about the same. A 26 percent increase in truck loads of repository-generated wastes exists between concepts. The estimated increase of 35 truck loads per year (1/10 truckload per day) will cause negligible changes in impacts to the noise and air quality environments and negligible increased utilization of a disposal facility.	significant difference in the work force requirements for the repository.

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
8. Total area required Surface facilities (acres) Underground development (acres) Access and utility corridors (acres) Land control rights (acres)	 408[c] 2,240 330 5,760	 408[c] 2,960 330 5,760	Impacts of increases in underground development acreage of 32 percent affect transportation only in terms of increased salt disposal and work force. The impacts associated with these increases are addressed in Characteristics 7 and 18.	No significant difference in impacts is expected because surface land areas are the same for the two concepts and the impacts attributable to the increased underground area relate to gassy mine conditions and increased salt considerations discussed in Characteristics 4 and 6.	The increase of 32 percent in the underground development acreage will require a larger work force. The effects of additional two-phase repository work force requirements are addressed in Characteristic 18.
9. Repository duration - years (1) Construction period (years) (2) Operational period (years) (3) Decommissioning period[f]	 7.25 50 (26 emplacement, 24 caretaker) 5	 4.5[d,e] 50 (25 emplacement, 25 caretaker) 5	The more concentrated construction period will favorably reduce the time period over which worker-, equipment-, and supplies-traffic have to be accommodated in the local transportation infrastructure. However this is somewhat offset by the increased worker traffic volume during the shorter period. The same applies to equipment and supplies. On balance, the impacts of increased traffic volume resulting from the more concentrated construction period can be accommodated even though additional improvements and traffic controls may be required on local roads as discussed in Section 5.3.3.	As indicated in footnote "e," the construction period for the two-phase concept overlaps with operations and thus extends 7.5 years. The schedule influences air and noise emission rates. Major schedule differences include: 1) overlapping freeze plant and batch plant operations with site preparation and 2) delaying the start of the waste, exhaust, and service shafts by 6 months. Schedule adjustments, such as the slowing of site preparation to extend over a 2-year period, may also be implemented to mitigate impacts. Taken together, these schedule changes have the effect of achieving a more uniform distribution of emissions over the construction period for the two-phase case. Shortening the shaft construction schedule by one-half year will cause activities beyond 12 months into the schedule to be more intensive. Because NO_x emis-	The two-phase concept will require a more concentrated construction effort in the early years and therefore contributes to a higher peak work force. The estimated differences in peak work force requirements between the reference and two-phase concepts are presented and the incremental impacts are discussed in Characteristic 18.

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Repository duration - years (Continued)				sions from shaft sinking for the reference case are projected to be below NAAQS, it is expected that this intensification will not result in exceedences of NAAQS. Emissions from increased traffic are discussed under Characteristic 6. The above factors form the basis on which the impact differences are judged not to be significant.	
10. Total repository capacity (MTHM)	36,000 SF (47.7%) 36,000 CHLW (47.7%) 3,510 DHLW (4.6%)	62,000 SF (88.6%) 8,000 HLW[g] (11.4%)	The change in waste mix and loading will result in a slight decrease in waste shipments to the repository but an increase in worker traffic and salt disposal transportation. The impacts of these increases are addressed in Characteristics 7 and 18.	Differences between concepts in impacts attributable to repository waste loading and waste mix are reflected in differing salt volumes and shipment amounts discussed in Characteristics 6, 7, and 18.	The change in waste mix and loading will contribute to increased work force requirements based on the need to expand the size of the underground area. The effects of the additional work force associated with the two-phase repository are addressed in Characteristic 18.
11. Approximate waste receipt rate planned (MTHM/year)	2,050 (initial) 3,250 (max)	400 (initial) 3,400 (max)	Although initial waste receipt rates are much lower for the two-phase concept, over the long term waste receipt rates are similar. The maximum receipt rate variation between the two concepts (approximately 5%) is less than variations already anticipated in fleet operations due to other causes. No significant impact differences are expected.	Although initial waste receipt rates are much lower for the two-phase concept, over the long term waste receipt rates are similar. Therefore, no significant differences in environmental impacts between the concepts are expected.	Although initial waste receipt rates are much lower for the two-phase concept, over the long term waste receipt rates are similar. The differences between the concepts have little effect on the total number of repository workers required. Therefore, no significant differences in impacts are projected.
12. Emplacement configuration	Vertical	Vertical[h]	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
13. Number of waste handling buildings on site	One	Two	Two waste handling buildings will require more workers, equipment, and supplies, resulting in a slight increase	The requirement for an additional waste handling building is not expected to create any significant differences in	The requirement for two waste handling buildings in the two-phase concept results in increasing the size of the

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Number of waste handling buildings on site (Continued)			in auto and truck traffic. However based on current estimates (see Section 5.3.3) the additional traffic can be accommodated by the existing network with no further improvements.	impacts to the aesthetic values of the area due to its relatively low profile. Construction and operational impacts of the second waste handling building are part of the overall construction and operations schedules. The impact discussion of schedule differences is presented in Characteristic 9.	work force. The effects of the additional work force associated with the two-phase concept are addressed in Characteristic 18.
14. Highest structure on site (by name)-feet (height)	Service shaft headframe - 265	Service shaft headframe - 265	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
15. Utilities, consumption			Offsite transportation is not impacted by utility requirements.	No difference in electrical utility access is expected because the larger electrical load can be handled within the utility corridor plans of the reference case. Noise impact differences from additional or slightly larger ventilation equipment (which use more electricity) are expected to be negligible as discussed in Characteristic 4.	The design changes are not large enough to create a significant difference in socioeconomic impacts.
Electricity, diversified load - kVA	34,100	37,500			
Natural gas - cubic feet per day	2,400,000	2,400,000			
Water, construction, gallons[i]	180,000,000	180,000,000			
operation, gallons[j]	2,450,000,000	2,430,000,000			
16. Repository wastes generated on site			An increase in the amount of underground storage needed for more onsite-generated radioactive waste containers for the two-phase concept will account for approximately 2 percent of the total increase in the amount of excavated salt estimated to be required for the two-phase concept. This will contribute slightly to the larger work force and greater offsite salt disposal addressed in Characteristics 7 and 18.	An increase in the amount of underground storage needed for more onsite-generated radioactive waste containers for the two-phase concept will account for approximately 2 percent of the total increase in the amount of excavated salt estimated to be required for the two-phase concept. These impacts are discussed in Characteristics 6, 7, and 8. No significant differences in	An increase in the amount of underground storage needed for more onsite-generated radioactive waste containers for the two-phase concept will account for approximately 2 percent of the total increase in the amount of excavated salt estimated to be required for the two-phase concept. This will contribute slightly to the larger work force which is addressed in Characteristic 18.
Radioactive - canisters	2,706	4,660			
drums	18,392	31,250			
Non-radioactive - cubic yards per year	4,000	5,000			

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Repository wastes generated on site (Continued)			The increase in non-radioactive waste disposal is addressed in Characteristic 7.	impacts from the 25 percent increase in non-radioactive waste volume are expected because the increase can be accommodated by additional space in a licensed facility or in additional facilities.	The increase in non-radioactive waste is not large enough to create a significant difference in the work force requirements for the repository.
17. Retention ponds, total area-acres	39.3	39.3	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
18. Repository personnel requirements, number of people - construction (peak)	1,506	2,149[k]	The increase in workers of 43 percent during construction and 26 percent during operations will result in proportional increases in worker auto traffic on local roads. This may require additional road improvements and traffic controls. However, based on current estimates (see Section 5.3.3) the additional traffic can be accommodated by the existing network with improvements discussed in Section 5.3.3.	Because total water use is assumed to be roughly the same, and becsuse additional commuter vehicles will contribute only slightly to increased noise levels and air pollution along roads to the site, no significant differences in impacts are projected.	Higher work force requirements for peak construction will increase by 43 percent and will occur in a shorter time frame. This will result in an increased amount of in-migration to the region, although measures such as increased local hiring for project jobs and job training will reduce the increase in the number of in-migrating workers expected. Demands for housing and community services will increase in communities receiving new residents. Smaller communities may experience a slight increase in social problems. Consequently, government expenditures for services and planning will increase. Increases in tax revenues from property taxes, sales taxes, and user fees should help meet local government's revenue needs. In addition, project expenditures by workers and their families will increase in the region. Additional local employment opportunities will be created through the additional project jobs and indirect jobs. The
operation (average)	1,000	1,260			
decommissioning (average)	930	1,220			

Table 5-1. Comparison of Alternative Repository Design Concepts - Deaf Smith County Site
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Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts	Environmental Impacts	Socioeconomic Impacts
Repository personnel requirements, (Continued)					Nuclear Waste Policy Act of 1982 provides for mitigation funds to the states affected by a repository development.
19. Access options, length					
Railroad - miles[1]	34.7	34.7	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
Highway - miles	1.0	1.0			

(a) The repository design concept in this column assumes a requirement to meet MSHA proposed rule for gassy mines (30 CFR 57.31). The major result of this assumption is an increased underground ventilation requirement with a corresponding increase in total excavated salt, power consumption, and personnel. The Mission Plan does not specifically require that gassy mine regulations be included. Elimination of the gassy mine requirement would therefore reduce a number of parameters listed in this column. (e.g., salt quantities, power consumption, and personnel).

(b) Incorporation of exploratory shafts in the repository was not included by the design contractor during the development of the reference design concept. However, the salt project has considered exploratory shaft facility (ESF) incorporation in the past and is continuing to evaluate various ESF incorporation scenarios. No decision has been reached whether the ESF will be included or integrated into the repository.

(c) Includes Visitor Center and parking.

(d) This schedule assumes both ESF shafts, one of which is usable by the repository, are available at construction authorization.

(e) The total construction period for the phased repository is estimated to be 7½ years. Repository construction will be in two phases, which will start simultaneously. The Phase 1 construction period lasts approximately 4½ years and consists of construction, acceptance, and start-up testing of the Stage I surface facility, shafts, and underground facilities needed to accept 400 MTU per year by 1998. The Phase 2 construction continues for an additional 3 years (ending in the year 2001) and consists of the completion of all the facilities, including the Stage II waste building, needed to consolidate and accept 3,000 MTU per year. The Phase 2 construction period overlaps with the beginning of the Operations Period, which starts in 1998. The underground excavation will continue well into the Operations Period as required to accommodate waste emplacement schedules.

(f) Approximate value.

(g) Includes DHLW and West Valley CHLW.

(h) Horizontal emplacement is now being considered.

(i) Construction water requirements for both repository concepts are assumed to be the same because total construction person-hour and earthmoving requirements are assumed to be similar. Actual water consumption numbers would differ slightly because of differing schedule and personnel loadings between the two concepts.

(j) Operations water requirements are slightly less because the operating period is shortened by one year.

(k) Includes 180 personnel for Phase I operations concurrent with 1,969 personnel for Phase II construction.

(l) The number listed is for the longest among six alternative railroad routes listed in Table 5-4.

three basic ways, namely, (1) the repository is developed in two phases, (2) the repository subsurface is designed on a gassy mine basis, and (3) the waste received is 62,000 MTHM (68,355 tons) spent fuel and 8,000 MTHM (8,820 tons) DHLW and West Valley CHLW.

The current two-phase concept is designed to receive waste in two phases because the phased approach provides a mechanism for waste acceptance according to the Mission Plan schedule. The first phase is to be operational by January 1998 with an initial waste receipt rate of 400 MTU (441 tons) per year of spent fuel. Construction of the second phase will start concurrently with the first phase and will begin accepting spent fuel in 2001. The repository will begin to receive DHLW at a rate equivalent to 400 MTU (441 tons) per year beginning in the year 2003. (DHLW shipments may be by either truck or rail, but, if by truck, approximately three shipments per day for defense waste would result.)

Several factors are now being considered by the DOE in conducting repository engineering design activities. These factors may change the characteristics of the repository and will have the potential to increase or decrease the environmental impacts of repository construction and operation. These factors include (1) the density of the salt used as a backfill material, (2) the rate of closure of repository emplacement rooms due to lithostatic pressure, (3) the horizontal emplacement of waste packages, (4) the presence of gassy mine conditions, and (5) the age of the waste to be emplaced. A discussion follows that illustrates potential impacts of varying characteristics of each of these factors (when considered independently) on volumes of salt excavated, stored on site, and shipped off site for disposal. Impacts associated with the repository relate closely to these salt volumes. While other impacts would occur, e.g., those relating to changes in personnel and utilities requirements, they would be minor compared to impacts associated with the management of salt.

Backfill Density. The reference repository design assumes that backfill is emplaced at a density of 95 pounds per cubic foot, occupying 97 percent of the available volume. This assumed density was based on the "natural density" of crushed salt, i.e., the weight of crushed salt occupying 1 cubic foot of volume. The density of undisturbed salt (prior to mining) was assumed to be 135 pounds per cubic foot. Because of the gradual creep closure of the repository openings, not all of the excavated salt can be replaced in the repository. Increases in the backfill densities that can be achieved would reduce the salt quantities to be shipped off site.

Assuming that a conventional technology is used and that some moderate compaction of backfill material is achieved, an estimate of the backfill density to be achieved is 115 pounds per cubic foot. This would result in 8.7 million tons of salt being disposed off site (a 2.6-million-ton or approximately 30 percent reduction), compared to 11.3 million tons in the reference case. In addition, the onsite salt storage pile would increase by approximately 800,000 tons (a 21 percent increase) to permit backfilling (repository closure) to take place with this increased density of backfill material.

Room Closure. In the reference design, it was assumed that the anticipated closure of the underground openings (other than the waste emplacement rooms) was 10 percent of the cross-sectional area in 3 years. This value was based on structural stability limitations but would still allow the access of mining equipment. Waste emplacement rooms were assigned design dimensions that would accommodate 3 years of closure before instability and equipment access problems started to occur. In the reference design, 2 years are required to open a room, emplace waste in it, and close it; thus there is a 1-year conservative margin contained in the design.

Calculations that were utilized in the design based on commercial high level-waste (CHLW) with areal thermal loading of 25 watts per square meter indicate a range from 5 percent to 16 percent volumetric closure in 3 years. These calculations, however, were performed for CHLW alone and not for a 50/50 mix of spent fuel (SF) and CHLW which would cause lower temperatures in the 3-year period because of the lower areal thermal loading used for SF. The reduced temperatures would cause lower room closure rates than those indicated. It is anticipated, therefore, that the 10 percent closure value in 3 years is realistic. It should be noted, however, that the repository depths used in these calculations are only approximate.

Uncertainities in the predictive capability of the exponential-time law (salt constitutive model) exist and at present the state-of-the-art in such model development does not allow a quantitative evaluation of the reliability of the model. Qualitatively, such reliability can only be estimated based on limited laboratory and in situ testing. Qualitatively, results to date indicate that calculations for preemplacement room closure would underpredict closure, whereas postemplacement closure calculations for a 3-year period after emplacement would either be approximately correct or overpredicted. The degree of which overprediction or underprediction occurs cannot be evaluated effectively at this time.

Results obtained from modeling of room closure at ambient preemplacement temperatures at the Waste Isolation Pilot Plant (WIPP) site indicate that the best calculations underestimate room closure by about a factor of three. If it is accepted that the predictive capability of the salt constitutive model seems to improve as the 75 to 100 C (167 to 212 F) range (approximate emplacement room maximum temperatures in the first 3 years) is approached, it may be assumed that predictions of closure would be a factor of three, or less, too low (since the maximum room temperature in the first 3 years lies in this approximate range). This therefore gives rise to a qualitative uncertainty of about 30 percent in 3 years. This discussion assumes that the WIPP constitutive model and the exponential-time law are not vastly different, which is the case.

A very approximate estimate of the amount of extra salt that will need to be excavated to accommodate this uncertainty is therefore about 20 percent (the salt which is allowed for in the initial 10 percent closure has already been included in the initial excavation quantities estimate). The additional amount of salt that may need to be excavated is therefore about 4.7 million tons.

Overall, it is difficult to make any firm statements about the amount of salt that may need to be excavated to maintain stability and access to the emplacement rooms and passageways. The numbers presented are estimates based on limited data. It should further be recognized that a significant amount of judgement has been used to interpret these data.

Horizontal Emplacement. In the reference design the vertical mode of waste package emplacement is the assumed method of storing high-level waste in the subsurface facilities of the repository. The horizontal mode of waste package emplacement is also being considered as a method for storing the high-level waste in the subsurface facilities. The waste package, instead of being emplaced in the floor of the storage rooms, would be placed in the pillars of the storage rooms.

This emplacement configuration changes the storage room size and provides a reduction in the cross-sectional area of the storage room by about 20 percent. The reduction in the size of the storage room results in an overall excavated tonnage reduction of 2.1 million tons, a reduction of the surface salt stock pile of 0.3 million tons, and a reduction of salt shipped off site by 1.0 million tons, compared to the reference design.

The selection of the mode of waste package emplacement will be established in subsequent design activities to manage environmental impacts. The studies will consist of cost tradeoff analysis and repository long-term stability analysis.

Gassy Mines. Gassy conditions were not assumed in the reference design, and, based on the borehole data available, the presence of gas is not expected in any significant quantities. Recently, the DOE has directed that gassy mines be considered in future repository design efforts. Assuming that the repository subsurface is designed to gassy mine criteria (Mine Safety and Health Administration's [MSHA] proposed rule for gassy mines, 30 CFR 57.31), there are substantial changes to the number of underground openings due primarily to increased ventilation requirements. Based on the reasonable assumption that the proposed rule (30 CFR 57.31) will become effective, incorporation of gassy mine regulations to the reference case would increase the total salt quantities excavated by about 26 percent (6.1 million tons). Offsite disposal would increase by 4.0 million tons.

Waste Age Waste Loading. Waste age for the reference repository design has been assumed to be 10 years. This is a conservatively low estimate of the expected average age of the waste, and future design activity will refine this estimate. The range of the age of spent fuel that will arrive at the repository will vary, depending on the growth of nuclear power demand, and is from 5 to about 40 years. The average age of the waste received over the life of the repository is likely to be no less than 15 years, with older waste emplaced initially, which is the current emplacement plan. Thus, 15 years average waste age is reasonable and still conservatively low. If the overall average age of the waste at emplacement is 15 years, the mass areal density at emplacement can be increased approximately 10 percent above the reference case (based on preliminary sensitivity studies). A 10 percent increase in emplacement density would lead to a total quantity of excavated salt of about 21.6 million tons, which is 2.0 million tons or about 10 percent less than that of the reference design of 23.6 million tons. Offsite disposal would be reduced by about 0.75 million tons. Specific emplacement strategies could affect this conclusion, e.g., a strategy of emplacing oldest waste first would lead to older average ages of emplaced waste. Conversely, a strategy of minimizing handling of waste would lead to younger average ages at emplacement.

Summary. Each of the factors considered above would have impacts on the volumes of salt excavated, stored on site, disposed off site, or backfilled into the repository compared to the reference design in Table 5-1. The presence of gassy mine conditions and accelerated room closure could cause an additional 11 million tons of salt to be excavated, whereas the use of a horizontal emplacement mode and receipt of older aged waste could cause 4 million tons less to be excavated. Changes in procedures for operation, not discussed above, would also decrease the amount of excavated salt.

The presence of gassy mine conditions and accelerated room closure could also be associated with an additional 6 million tons of salt being shipped off site for disposal, whereas the use of horizontal emplacement, receipt of older aged waste, and increased density of backfilled salt could be associated with 4.4 million tons less being shipped off site. The maximum size of the onsite salt storage pile would be affected by these considerations, with some factors causing the pile to increase by 1.5 million tons and other factors causing the pile to decrease by 0.5 million tons.

The principal environmental impact is associated with offsite disposal of salt. Taking the possible increases and decreases in offsite salt disposal together, it is therefore possible that the offsite disposal estimates could increase from 11.3 million tons in the reference design to 12.9 million tons, approximately a 14 percent increase over the reference design discussed in this chapter.

Of the factors considered, only the physical forces associated with room closure are beyond the capacity of the DOE to manage. Consequently, it can be concluded that with proper management, and using realistic and conservative assumptions, the impacts of future repository design concepts are approximately the same as those for the reference repository design and are contained within the impacts of the Mission Plan case discussed in Table 5-1.

The current two phase concept assumes that the subsurface area of the repository be designed to the Mine Safety and Health Administration's (MSHA) proposed rule for gassy metal and nonmetal mine requirements (30 CFR 57.31001 et seq.). The major impacts of this requirement compared with the reference design are (1) the need for enhanced ventilation capability and (2) a corresponding increase in subsurface excavation to handle the increased ventilation air. It should also be noted that MSHA's current gassy mine regulations (30 CFR 57.21000 et seq.) require crosscuts every 100 feet whereas the proposed rule is based on maintaining minimum air-flow standards which correspond to the amount of gas actually present in the mine.

Recent work by Fluor Technology, Inc. (1985) which was used as a basis for the "Two-Phase Concept" presented in Table 5-48 of the draft EA, was reviewed to reassess qualitatively the impacts which may result from a repository conservatively designed in accordance with the 30.5-meter (100-foot) crosscut regulation. Because the impacts resulting from such a large repository may be significantly greater than those shown for the reference design (as discussed in the draft EA, Section 5.5) and because the 30.5-meter (100-foot) crosscut interval

regulation is not in accord with the desire to minimize underground disturbance, such large repository designs are no longer being pursued by the DOE. Further, if the 30.5-meter (100-foot) crosscut regulation remains as a MSHA requirement in the future, the DOE will apply for a variance on this issue. Increasing the crosscut intervals minimizes the environmental impacts and increases the underground safety.

A consideration from the 1985 Mission Plan not reflected in Table 5-1 is the impact of incorporating a monitored retrievable storage (MRS) facility. The possibility of including a MRS facility is being evaluated by the DOE as part of the overall waste management strategy. Specifically, Section 141 of the NWPA directs the DOE to study the need for and the feasibility of an MRS facility for spent fuel and high-level waste. The DOE analyzed the provisions of the NWPA and programmatic options in the 1985 Mission Plan (DOE, 1985) and is evaluating an integrated waste-management system that consists of both storage and disposal components. The primary function of the MRS is waste preparation for emplacement in a geologic repository; its role in providing temporary backup storage is secondary. Performing the waste-preparation functions (i.e., spent-fuel consolidation and packaging) in an integral MRS facility may simplify the design, construction, and operation of the repository facilities. By providing a processing and storage capacity between waste acceptance from the utilities and emplacement in a repository, the MRS would help maintain better and more consistent control over the transfer of waste from reactor to repository.

An integral MRS facility would also provide a central location for the management of spent-fuel transportation, cask-fleet operations, and cask-fleet servicing. Because facilities and activities at the repository site would be less in an integrated MRS/Repository System, since waste consolidation would be accomplished at the MRS site, the nonradiological environmental impacts and socioeconomic impacts discussed in this EA should encompass those for a repository design coupled with the MRS, if Congress authorizes the MRS facility.

The NWPA directs the DOE to submit to Congress a proposal that establishes a program for the siting, construction, and operation of MRS facilities. To provide a technical basis for the Congressional decision, the following documents would be included in, or would accompany, the proposal to Congress: (1) site-specific facility designs, (2) need and feasibility report, (3) program plan (funding, integration, deployment), and (4) environmental assessment.

The DOE has not yet conducted studies to assess the impact of accommodating the potential amount of 5-year-old waste which might be received by a repository. Therefore, Table 5-1 does not fully reflect this consideration. The "Standard Contract for Disposal of Spent Nuclear Fuel and/or High Level Radioactive Waste" (10 CFR Part 961) establishes the contractual terms and conditions under which the DOE will make available nuclear waste disposal service to the owners and generators of spent nuclear fuel and high-level radioactive waste as provided in Section 302 of the NWPA. The contract designates spent fuel aged as little as 5 years out of the reactor as "standard spent fuel." Both the Standard Contract (10 CFR Part 961) and the Mission Plan (DOE, 1985) specify that the DOE will accept fuel for disposal on an "oldest first" basis. Therefore, for the most of the first repository receiving and emplacement period, the average age will be greater than 10 years with an estimated 5 to 10 percent aged as little as 5 years. The EA reference design (SCC, 1984a) is based on receipt of 10-year-old fuel. At this point, the DOE believes that the incremental impacts of a repository designed to accommodate the requirement to accept 5-year-old fuel should be minor.

Appendix A of this EA presents general background information on transportation topics and issues. Qualitatively, the nonradiological environmental impacts discussed in the EA will encompass those involving transportation coupled with the MRS, if Congress authorizes an MRS facility. The MRS transportation analysis is also found in Appendix A.

Table 5-1, in presenting a comparison of the current two-phase concept with the Chapter 5 reference repository, and with the limitations noted above, provides a reasonable representation of the range of impacts expected from repository designs in salt. It is, however, not the purpose of Table 5-1 to provide a limiting analysis for design and impacts.

In summary, the DOE believes that the environmental, socioeconomics, and transportation impacts for the reference design concept are within reasonable limits or are mitigable. Similarly, the current two-phase concept also has impacts comparable to the reference case and are mitigable. The DOE believes, therefore, that the conclusions reached on the guideline findings in EA Chapter 6 would not change due to variations in the repository design concepts analyzed.

5.1.1 General Description

An operating nuclear waste repository consists of surface and subsurface facilities licensed by the U.S. Nuclear Regulatory Commission (NRC) for the permanent, deep geologic disposal of nuclear waste. The repository design is a fully integrated facility for the receipt and long-term geologic disposal of nuclear waste and can be designed to handle, package, and dispose of spent fuel, commercial high-level waste (CHLW) from reprocessing of spent fuel, transuranic (TRU) waste, defense high-level waste (DHLW), and low-level wastes generated on the repository site. Final design may or may not include all of these storage capabilities, depending on future programmatic decisions. The reference repository facility concept is depicted in Figure 5-1, while the major project characteristics are listed in Table 5-1. The current estimate of personnel requirements per year is listed in Table 5-2.

5.1.1.1 Repository Site Layout

Repository surface facilities will include the following four major components:

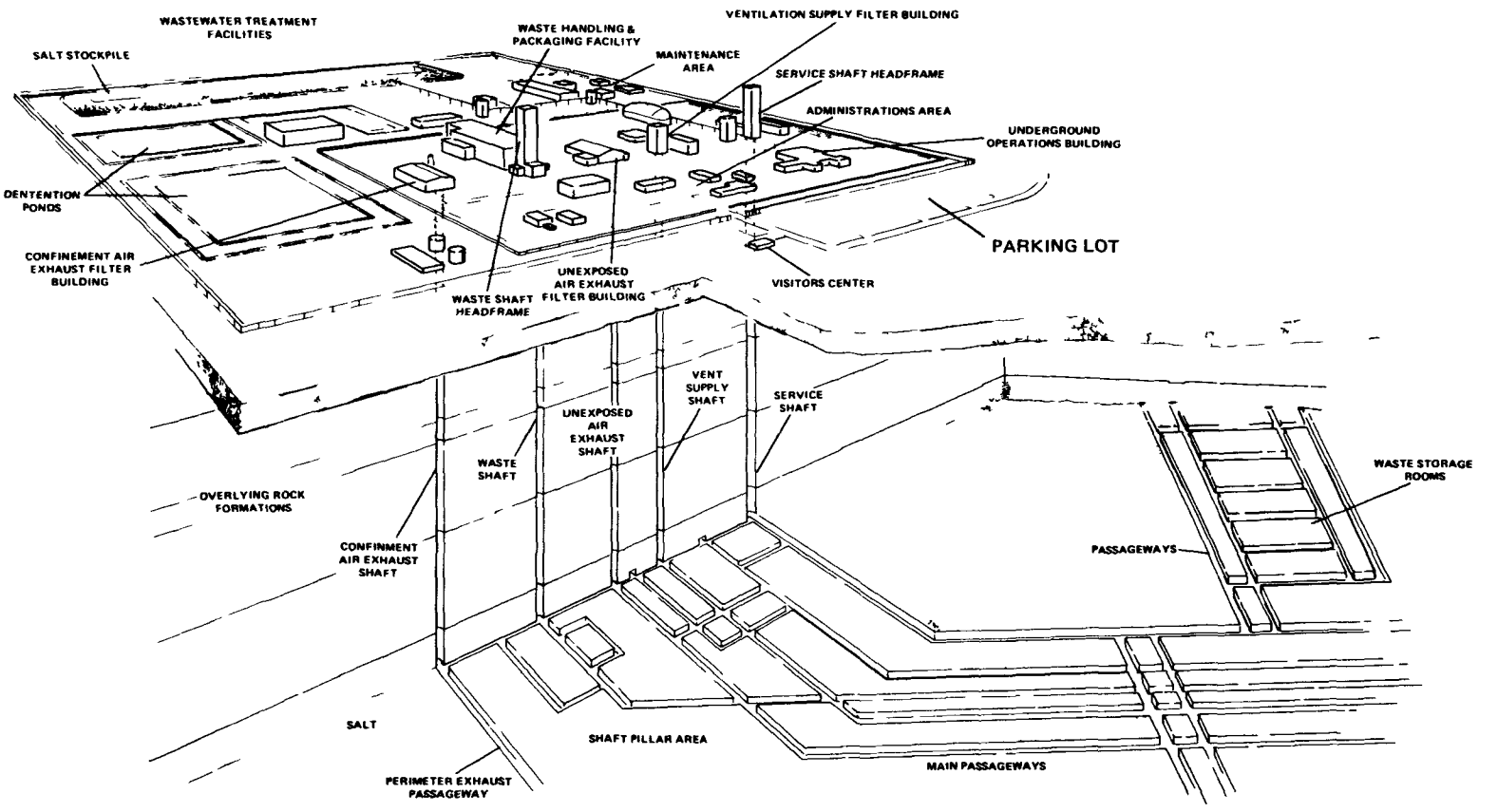
- Waste handling building
- Mine support facilities (headframes, salt storage pile, ventilation exhaust, and supply buildings)
- Administration and support buildings
- Utilities and utility support facilities (steam plant and tank farms).

These surface components will be located on approximately 165 hectares (408 acres) of land, exclusive of the access corridors (i.e., road, rail, and utilities) discussed in Section 5.5.1.2.3 and 5.3.2. The underground facilities will extend beyond the surface facility; therefore, a control area will be established. Future subsurface activities such as drilling or mining will be prohibited within this area, but various controlled surface uses may be permitted. The controlled area is estimated to be about 23.3 square kilometers (9 square miles) but will be determined explicitly during site characterization; definition of its extent will be based on ability to comply with 10 CFR Part 60, 40 CFR Part 191, and 10 CFR Part 960. The minimum controlled area for the Deaf Smith County site was determined by adding a buffer zone around the area required for the underground repository. The buffer zone extends out to the controlled area perimeter and allows for protection from radionuclide release. Figure 5-2 presents the controlled area for the Deaf Smith County site.

Road and rail access to the site will be designed and constructed to support the expected shipments of personnel, material, and waste. Offsite acquired utilities, such as electrical power and natural gas, will run to tie-in points to service the repository.

During construction, topsoil will be removed, used for onsite landscaping, or stockpiled for future restoration. During construction and operation, excavated salt will be stockpiled in a storage area designed to minimize runoff.

Estimated surface drainage and wind conditions were considered in the layout of the surface facilities, including the waste water ponds. Nonradioactive liquid wastes will be shunted to a treated waste water storage pond. A salt runoff pond sized for a greater than 100-year, 24-hour precipitation event will collect runoff from the salt pile. Storm water detention ponds will have sufficient capacity to hold rainfall runoff. All these ponds will be designed to minimize water seepage into the ground. All waste water will be recycled to the maximum extent possible.



Source Adapted from SCC, 1984a

Nuclear Waste Repository Facility Concept

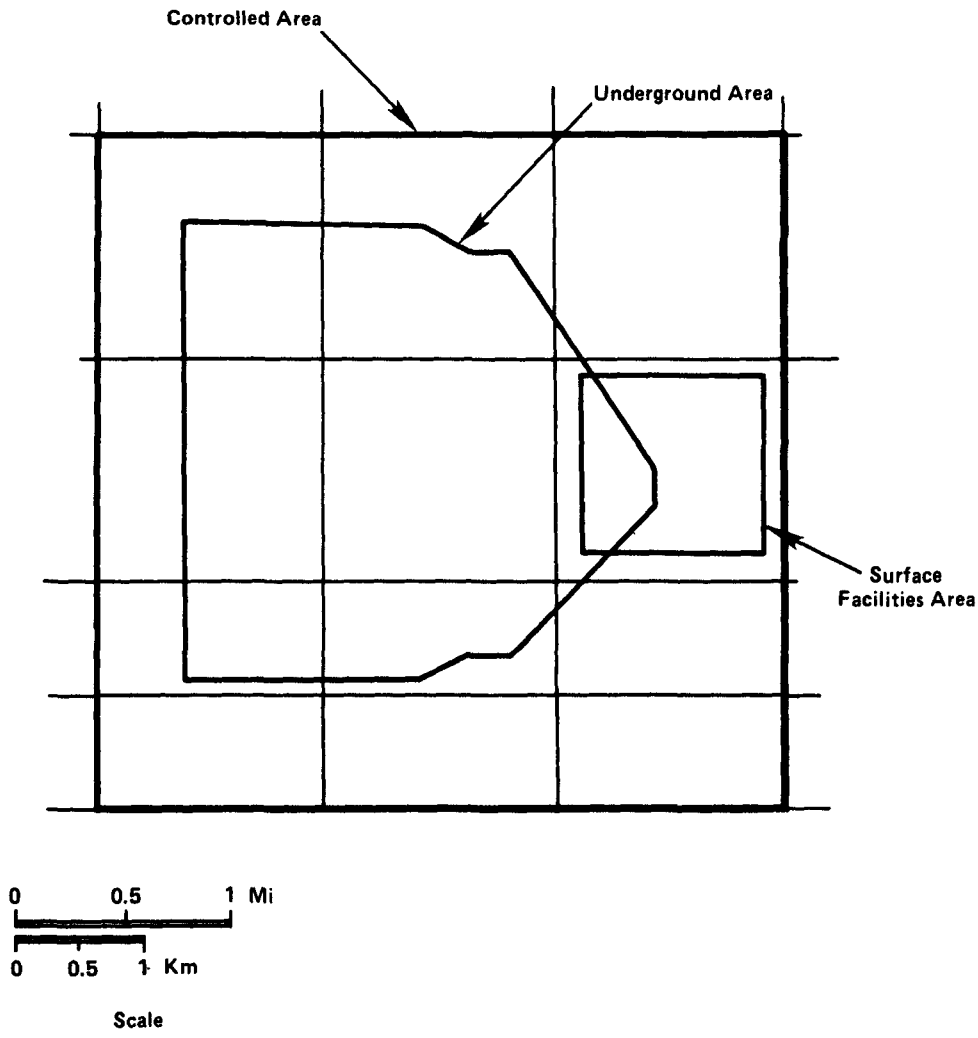
Figure 5-1

Table 5-2. Average Annual Repository Personnel Requirements, Deaf Smith County

Years Into Project	Construction	Operation	Caretaker	Decommissioning
1	517			
2	823			
3	832			
4	1,213			
5	1,388			
6	1,438[a]			
7	1,094			
8-33		1,000		
34-57			230	
58-62				930

(a) The peak of 1,506 personnel is expected to be reached in this year.

Sources: SCC, 1984a; Eschen, 1985.



Source: Adapted from SCC, 1984a; DOE, 1984, DOE/CH-10(1) and (2).

Generalized Placement of the Controlled, Underground, and Surface Facilities Areas, Deaf Smith County, Texas

Figure 5-2

All disturbed areas not paved, graveled, or otherwise covered will be landscaped. Buildings and other structures will be painted to minimize their contrast with the surrounding site environment.

A perimeter fence will enclose the entire surface facility with the exception of the visitor center and parking lot. An inner security fence will surround the radiological operations area including the shafts, the receiving and packaging facility, and other waste-related support facilities.

5.1.1.2 Waste Receiving/Handling/Packaging Facilities

The primary functions of the repository surface-waste receiving, handling, and packaging facilities are to receive, handle, and package nuclear waste arriving at the repository and to transfer the packaged waste to the repository subsurface.

The waste handling and packaging facility (WHPF) (Figures 5-3 and 5-4) provides for washing down contaminated shipping casks, unloading the cask from the transport vehicle, removing the waste from the shipping casks, inspecting and recording identification of waste forms, temporarily storing waste forms and waste packages, packaging waste forms, welding waste packages closed, inspecting completed waste packages, and transferring waste packages in a transfer cask to the waste shaft.

The WHPF (Figure 5-4) is the largest building on the repository site. The building will be adjacent to the waste shaft headframe and will be accessible by both road and rail.

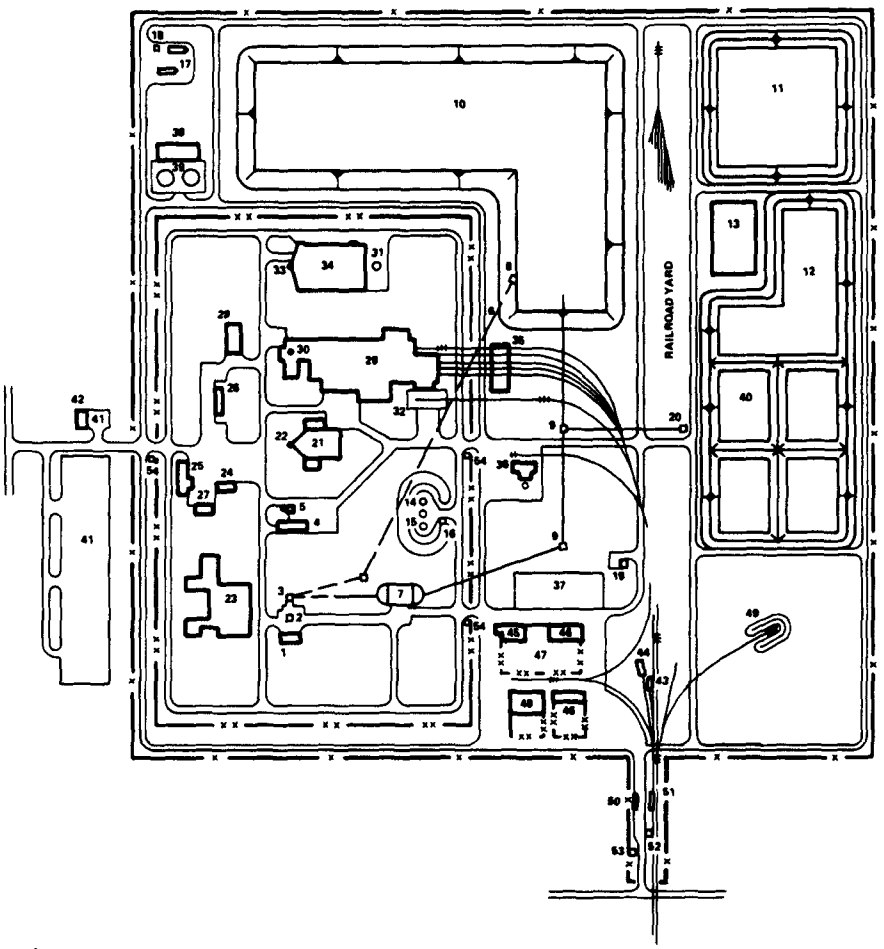
The functions required to receive the shipping casks from the rail and truck transport vehicles and to prepare the waste form for underground emplacement, up to and including the transfer to the waste shaft hoist, will be performed within the confines of the WHPF. The overall functional-flow schematic diagram for the WHPF is shown in Figure 5-5.

Waste-handling activities will begin with the receipt of the transport vehicle from the cask contamination survey station. As necessary, the casks will be reinspected and contaminated casks will be washed down in a separate decontamination wash bay. Casks will then be unloaded from the transport vehicle and positioned for removing their radioactive waste forms.

With the exception of contact-handled TRU, all the waste forms will be removed from the shipping casks into the hot cell portion of the facility where the waste forms will be inspected, sorted, and temporarily stored. Contact-handled TRU is not highly radioactive and will be handled outside the hot cells. It will be unloaded, inspected, and placed on pallets before being transferred to the waste hoist.

The functions performed within the hot cell depend upon the waste type. Spent fuel assemblies will be disassembled and spent fuel pins will be repackaged. These packages and canisters of CHLW and DHLW will be placed in containers. Typically, remote-handled TRU will be inspected and passed through the hot cell without repackaging. However, if any remote-handled TRU canisters are found to be externally contaminated, they will be cleaned or enclosed in overpacks to provide a contamination-free exterior. These waste packages will pass out of the hot cell area via transfer casks used to move the waste packages to and down the waste hoist and through the underground workings to the emplacement area.

The WHPF will have several support areas not directly involved in handling radioactive waste. The most significant of these in size and importance will be the heating, ventilating, and air conditioning (HVAC) system, which constitutes the major engineered safety system for the containment of the radioactive materials. The largest is the hot cell HVAC "once-through" system, which will move air through the hot cells and then through 60-percent, 90-percent prefilters and double high efficiency particulate air (HEPA) filters in series, and charcoal adsorbers. The system will have 100 percent flow and filtering redundancy. Separate ventilation systems similar to the hot cell HVAC system will be provided for other major functional areas such as the shipping cask handling area, personnel area, and the contact TRU handling area.



Explanation

1 Service shaft filter building
2 Service shaft
3 Transfer tower
4 Ventilation supply filter building
5 Ventilation supply shaft
6 Reclaim tunnel
7 Live storage & surge building
8 Reclaim hopper
9 Salt transfer tower
10 Salt stockpile
11 Salt run-off pond
12 Treated wastewater holding pond
13 Wastewater treatment facilities
14 Potable water tank
15 Fire water storage tanks
16 Fire/potable water pumphouse
17 Cooling towers
18 Chemical feed building
19 Railroad control tower
20 Salt loadout structure
21 Unexposed air exhaust filter building
22 Unexposed air exhaust shaft
23 Underground operations building
24 Firehouse, security & medical treatment center
25 Administration & operation control center
26 Electric power building
27 Environmental & instrument laboratory
28 Compressor chiller building
29 Waste handling & packaging facility
30 Waste shaft
31 Confinement exhaust stack
32 Storage yard
33 Confinement air exhaust shaft
34 Confinement air exhaust filter building
35 Non-contaminated railcar/truck washdown area
36 Steam plant
37 Abandoned material & equipment storage yard
38 Raw water treatment
39 Raw water storage tanks
40 Storm water detention ponds
41 Parking lot
42 Visitors center
43 Railroad inspection pit
44 Railroad maintenance building
45 Maintenance building
46 Storage shed
47 Storage yard
48 Warehouse
49 Suspect Railcar/truck storage area
50 Truck inspection pit
51 Railcar inspection pit
52 Monitoring station
53 Guardhouse

Source: Adapted from SCC, 1984a.

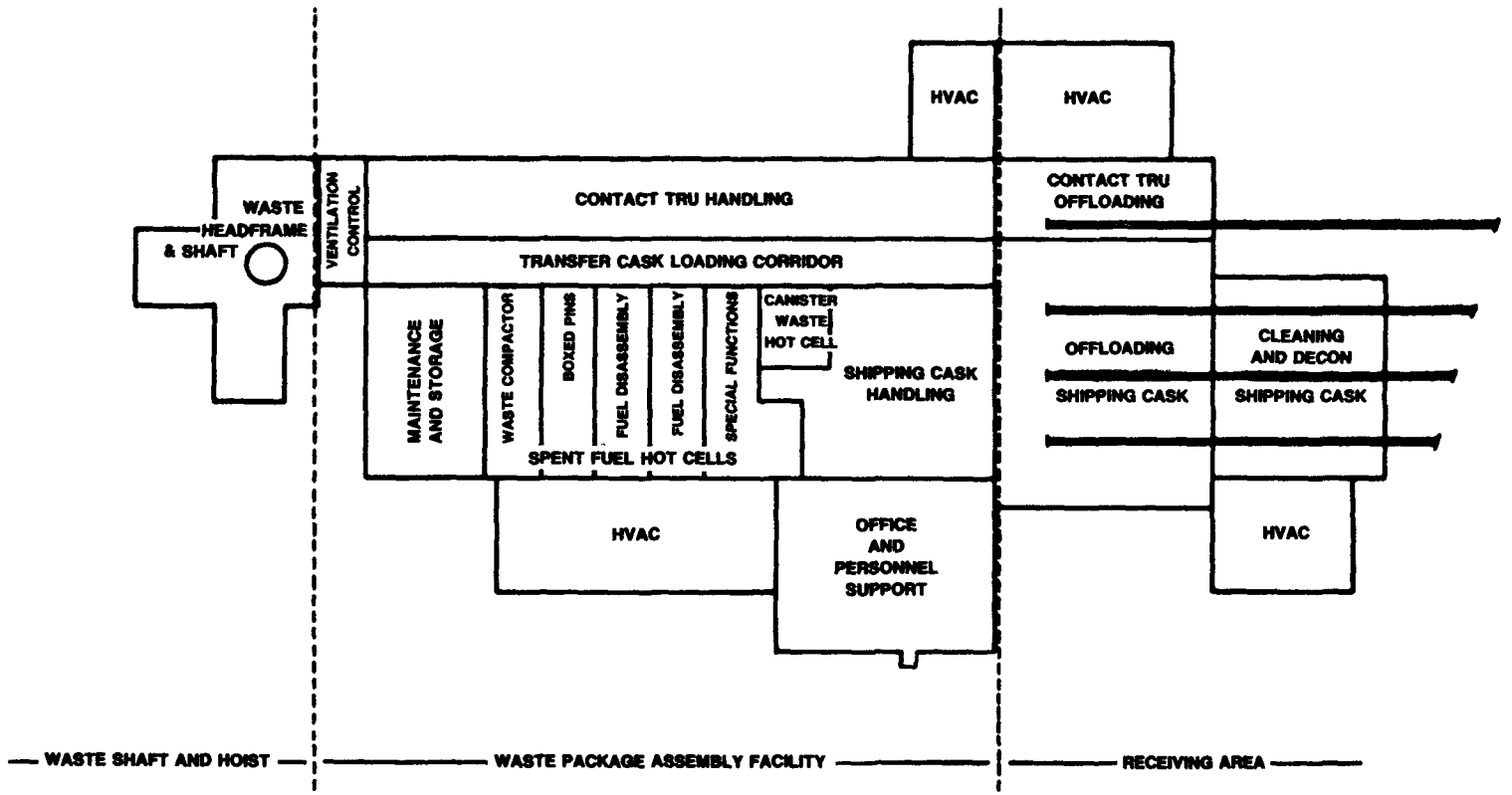
Scale

0 500 1000 Feet

0 150 300 Meters

Repository Site Layout Plan
Deaf Smith County

Figure 5-3



Scale

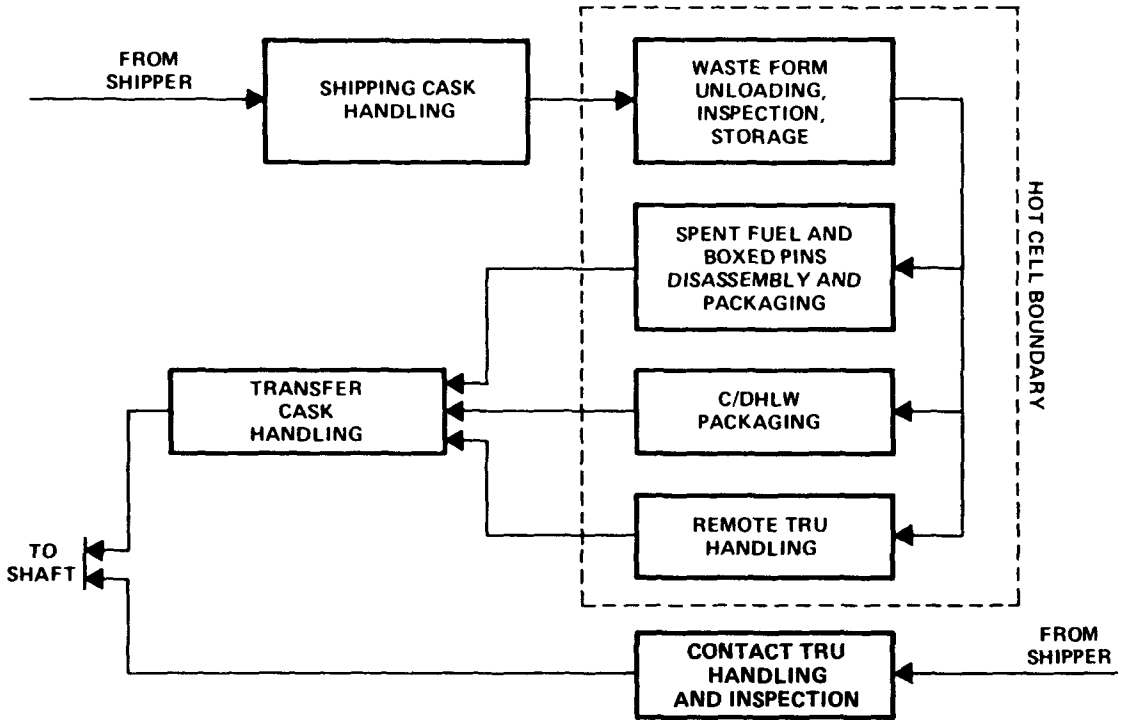
0 40 80 120 Feet

0 10 20 30 Meters

Source: Adapted from SCC, 1984a.

Waste Handling and Packaging Facility Layout Deaf Smith County

Figure 5-4



Source: SCC, 1984a.

Waste Handling and Packaging Facility Overall Functional Schematic Deaf Smith County

Figure 5-5

5.1.1.3 Repository Shafts

Repository shafts will provide the means for ingress and egress of personnel, transport of materials and nuclear waste packages, and ventilation of the underground workings of the repository. The reference design in Table 5-1 (SCC, 1984a) proposes five shafts to serve the requirements of the repository:

- Waste Shaft - Transport of waste containers from surface to subsurface
- Service Shaft - Transport of personnel, equipment, material, salt, supply air, and utility lines
- Ventilation Supply Shaft - Supply air, utility lines, and emergency egress
- Unexposed Air Exhaust Shaft - Exhaust air from the subsurface development area, utility access
- Confinement Air Exhaust Shaft - Exhaust air from the waste emplacement area.

All shafts will be circular in cross section and range in size from 6.4 to 9.4 meters (21 to 31 feet) finished inside diameter. The depths of the shafts into the repository horizon will vary from the repository depth to 107 meters (350 feet) below the repository depth to accommodate the excavated salt hoist skips in a loading position, the salt spillage storage area, and hoist equipment. The service shaft headframe will be 81 meters (265 feet) in height. The DOE will comply with regulation 14 CFR Part 77, Objects Affecting Navigable Airspace, which requires notification to the Federal Aviation Administration of plans to construct structures 61 meters (200 feet) or greater in height.

The shaft pillar, which encompasses all five shafts, is an area containing little excavation and no emplaced nuclear waste. It will be offset or placed to one side of the underground facilities. This shaft pillar offset will isolate the shafts and main surface facilities from any potential effects of subsidence or uplift over the storage room panels.

The shaft liner designs and installation will take into account the site-specific stratigraphy and major aquifers. Seals will be installed to isolate the aquifers from the waste storage level and from each other. The design and construction of the shafts and liners will take into account the eventual decommissioning of the repository.

The waste shaft, service shaft, and ventilation supply shaft will be equipped with hoisting systems. The ventilation exhaust shafts will not have hoisting facilities.

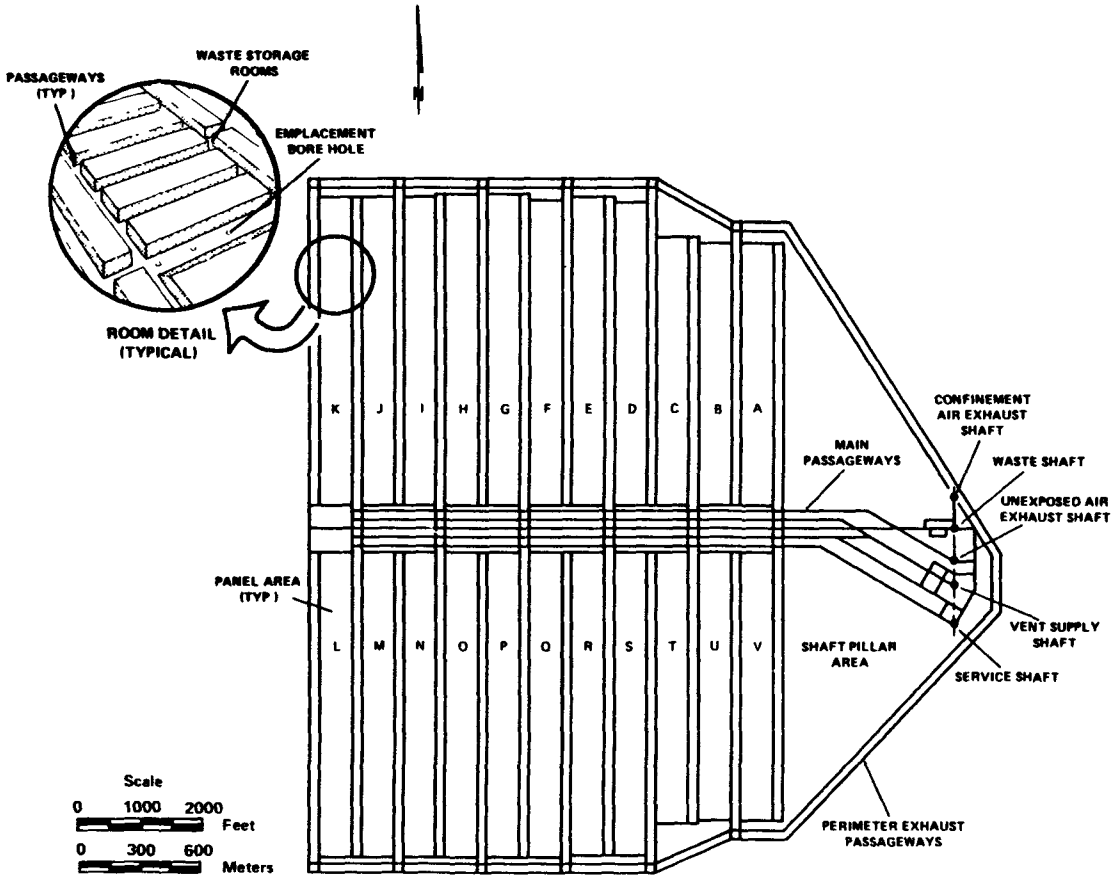
The repository ventilation system will use the shafts to provide ventilation air to the underground facility. The ventilation system will provide air flow throughout the repository to service the two underground functions of mine development and waste emplacement operations. Exhaust ventilation air from the mine development operations will be kept separate from exhaust air from waste emplacement activities.

5.1.1.4 Repository Subsurface Facilities

The repository subsurface will consist of the excavated rooms for waste emplacement, branch and main passageways for transporting the mined salt and waste packages, and corridors for ventilation. Additional areas will be excavated for equipment maintenance, parts and materials storage, operations control and monitoring, first aid and emergency systems, and other miscellaneous facilities normally associated with underground operations.

Figure 5-6 is a simplified layout of the repository subsurface area showing a completed repository development at the end of operations. There will be five horizontal main passageways driven down the approximate centerline of the repository storage room area:

- A path for fresh air to both development areas and emplacement areas



PANEL TABLE		
PANEL	WASTE	NO ROOMS
A	TRU	46
B	TRU	46
C	DHLW/CHLW	25/29
D	CHLW	56
E	CHLW	57
F	SF	73
G	SF	74
H	SF	74
I	SF	73
J	SF	73
K	SF	73
L	SF	73
M	SF	73
N	SF	73
O	SF	73
P	SF	73
Q	SF	73
R	CHLW	56
S	CHLW	56
T	DHLW/CHLW	26/29
U	TRU	47
V	TRU	47

NOTES:
1 ALL ROOMS ARE NOT SHOWN, SEE ROOM DETAIL

Source: Adapted from SCC, 1984a.

Repository Underground Layout
Deaf Smith County

Figure 5-6

- An exhaust air path from development areas
- A corridor for waste transport
- Access to both development areas and emplacement areas for personnel and equipment
- A corridor for mined salt transport.

The cross section of the passageways will be rectangular with major dimensions of approximately 9 meters wide by 5 meters high (30 feet wide by 15 feet high). There will be a total of 10,200 meters (33,500 feet) of drifts in the main passageways and 6,100 meters (20,000 feet) of drifts in the shaft pillar zone.

The waste storage areas of the repository will consist of branch passageways, exhaust branch passageways, and 22 panels of storage rooms. The branch passageways will provide access to the individual storage rooms and will be interconnected by cross cuts. During the excavation of storage rooms, the passageways will provide a path for intake and exhaust air. During emplacement operations, the branch passageways will be used to transport waste to the individual rooms and provide fresh air. The exhaust passageways will be connected to the exhaust end of the storage rooms and to the perimeter exhaust passageways. These passageways in conjunction with the perimeter exhaust passageways will provide a completely isolated path for confining exhaust air.

Each waste type will be located in separate panels of the repository, according to the repository feasibility study (SCC, 1984a). The storage room quantities and related parameters are shown in Table 5-3.

The waste package concepts for defense and commercial high-level waste and spent fuel consist of the canisterized waste form, surrounded by a steel waste package container, and, after emplacement, a packing and cover of crushed salt. This concept is described in Section 6.4.2.2.1 and as the Alternate II concept in Westinghouse (1983, ONWI-438).

The defense and commercial high-level waste forms consist of high-level waste melted into borosilicate glass that is poured into thin-walled stainless steel canisters by the waste form producer. They are then shipped to the repository for assembly into the waste package container.

The spent fuel waste form consists of spent fuel rods which have been removed from several fuel assemblies and consolidated into a close-packed bundle. The bundle of spent fuel rods is surrounded by a thin-walled canister of low carbon steel.

The waste package container is a thick-walled low carbon steel vessel surrounding the waste form. It is designed to provide containment for the desired period when exposed to the external geologic pressure and corrosive environment.

Waste package concepts for transuranic wastes are in the very early stages of development. At this time, it is anticipated that the disposal containers for both contact- and remote-handled transuranic wastes will be either standard 0.24 cubic meter (55-gallon) drums or other milled steel containers.

5.1.1.5 Repository Land Acquisition

The requirements for ownership and control of interests on land for a repository are established in "Disposal of High-Level Radioactive Waste in Geologic Repositories," 10 CFR 60.121, which states:

(a) Ownership of land. (1) Both the geologic repository operations area and the controlled area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for

Table 5-3. Approximate Waste Storage Room Quantities

Waste Package	Rows of Waste Pkgs Per Room	Waste Pkg Pitch Feet[a]	No. Waste Pkgs/Room	Total No. of Waste Pkgs
Spent Fuel	1	60	9	7,899
CHLW	1	40	13	3,673
DHLW	2	7 square	138	7,020
Remote TRU	3	7 triangular	200	37,050
Contact TRU	3	N/A	480	18,406 pallets

(a) "Pitch" is the center-to-center spacing between adjacent waste packages.

its use. (2) These lands shall be held free and clear of all encumbrances, if significant, such as: (i) rights arising under the general mining laws; (ii) easements for right-of-way; and (iii) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

The DOE is also required to exercise jurisdiction and control over surface and subsurface estates outside of the controlled area to prevent adverse human actions that could significantly reduce the geologic repository's ability to achieve isolation (10 CFR Part 60.121 b).

The DOE currently estimates that a repository site in Deaf Smith County would consist of (1) a fenced central area of about 165 hectares (408 acres) for support buildings and repository surface facilities, (2) the geologic repository underground operations area of about 906 hectares (2,240 acres), and (3) a controlled area extending outward from the edge of the underground facility. The site area could be a maximum of approximately 2,331 hectares (5,760 acres). On a technically conservative basis, a minimum 4,060 acre site was recommended (Chen and Raines, 1985). Because of the uncertainties involved in developing the recommended size for the controlled area, the DOE has added an additional margin around this area to bring the site area up to the 5,760 acre size. Preliminary analyses indicate that a site area of 5,760 acres would allow all EPA and NRC repository performance requirements to be met (see Sections 6.3 and 6.4). The total site land control requirements have been estimated by conservative technical analysis. (Chen). See Figure 5-2 for a schematic drawing of the controlled area. The exact size of the controlled area will depend on the rate of groundwater flow and other site characteristics and will be established after completion of site characterization in accordance with EPA standards and NRC regulations.

For the Deaf Smith County site, the DOE will purchase surface and subsurface rights to the required private land.

5.1.2 Repository Construction Activities

5.1.2.1 Construction Schedule and Personnel

The sequence and duration of repository construction activities are depicted in Figure 5-7. The total time estimated for construction is 7.25 years, including three months for equipment tests.

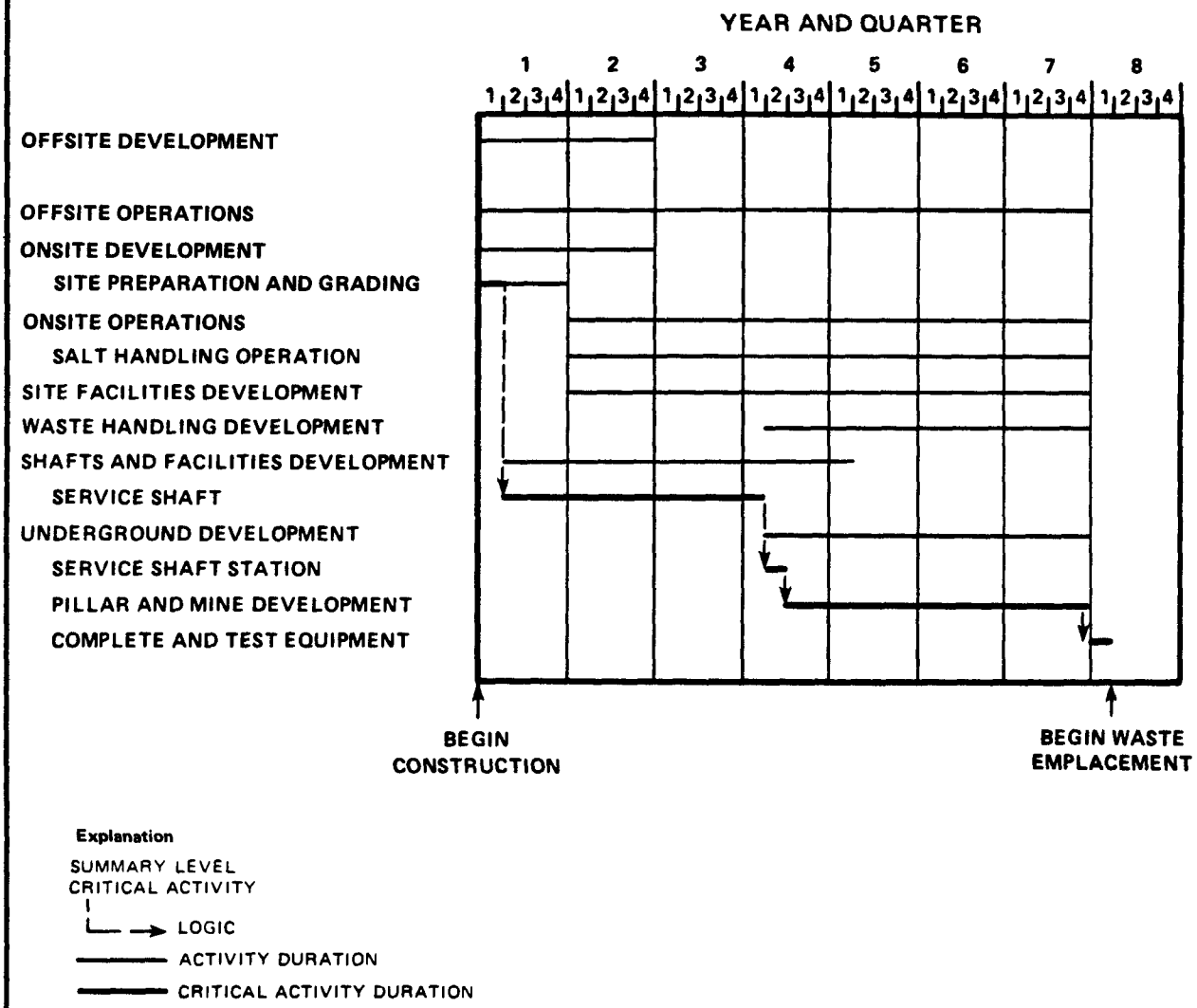
The construction of the repository will begin with development of offsite utilities and transportation access corridors and establishment of the permanent water supply. Site preparation and grading would begin immediately, using the water supply established as part of the site characterization program. As indicated in Figure 5-7, these activities will be completed in the service shaft vicinity before shaft sinking activities start. The site preparation and grading activities are estimated to require approximately twelve months, of which the first three months are on the critical path.

The next phase will involve sinking, lining, and equipping the service shaft and stations, which will be completed before at-depth excavation begins. The shaft and shaft station construction activities are estimated to require approximately 48 months, of which the first 39 months are on the critical path.

Before waste emplacement operations begin, the shaft pillar and mine development will be completed to a point at which one year's waste receipt could be emplaced. This activity is estimated to require approximately 42 months and is on the critical path.

Preoperations testing of emplacement equipment and ventilation systems will be completed before actual waste emplacement activities begin. This testing is estimated to require approximately three months.

The estimated personnel requirements for underground work and the total project are shown in Figure 5-8. Corresponding estimated construction personnel requirements per year are listed in Table 5-2. The construction estimate (Table 5-2) includes personnel for DOE, NRC, Architect-Engineer, Construction Manager, and others.



Explanation

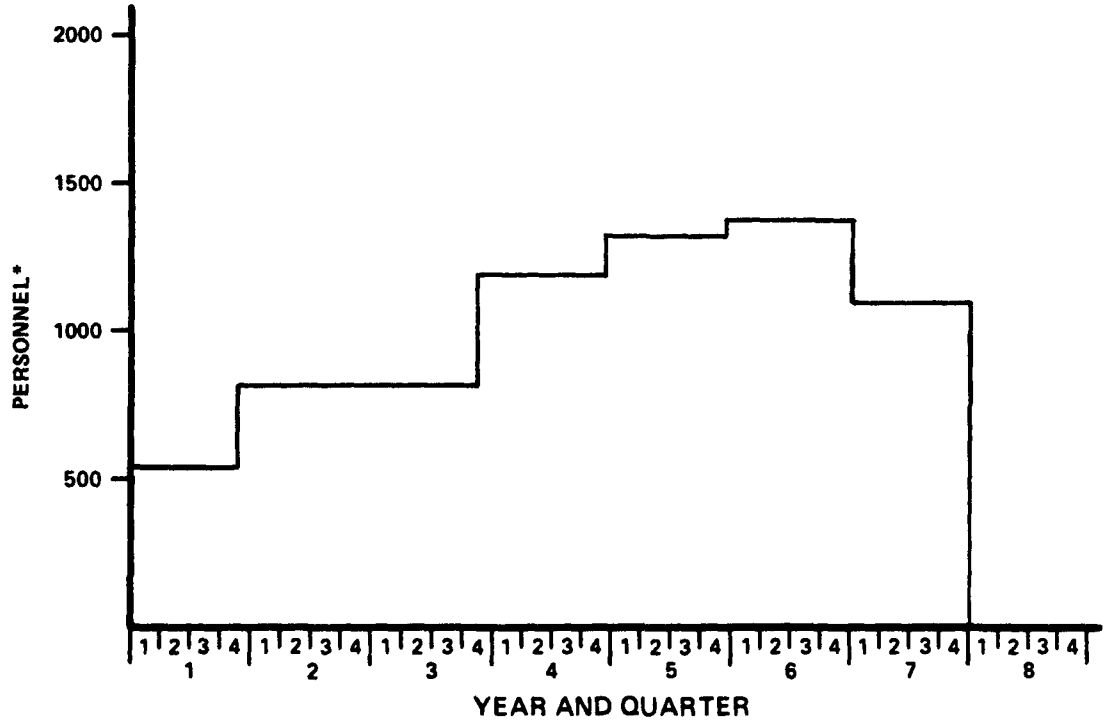
SUMMARY LEVEL
CRITICAL ACTIVITY
LOGIC
ACTIVITY DURATION
CRITICAL ACTIVITY DURATION

THIS INFORMATION IS BASED ON PRELIMINARY AND INCOMPLETE DATA AND IS SUBJECT TO CHANGE.

Source: SCC, 1984a.

Schedule Summary Bar Chart
Deaf Smith County

Figure 5-7



Explanation

TOTAL PROJECT

Note: Values were taken from Table 5-2.

THIS INFORMATION IS BASED ON PRELIMINARY AND INCOMPLETE DATA AND IS SUBJECT TO CHANGE.

Average Construction Personnel Requirements
Deaf Smith County

Figure 5-8

Over 50 percent of the water projected to be required for construction at the repository site is associated with earthwork. For estimation purposes, it has generally been assumed that all of the voids in the soil must be filled with water to achieve proper compaction. This provides an overestimate of the amount of water required and does not attempt to take into account probable water conservation practices employed. Water required for dust suppression is considered to be covered by this estimate. The majority of the earthwork will be done in the first four years. The remaining portion of water use will be associated with concrete production, personnel, and minor miscellaneous uses. The scheduling of these water demands is linked to the schedule for concrete production and the approximate distribution of personnel at the site over time.

5.1.2.2 Offsite Development

Offsite development activities consist of constructing the transportation access corridors and utility supply lines from the public and commercial domain to the repository site. The selection of preferred transportation routes to the site will occur later in the siting process and will use the results of detailed investigations conducted during site characterization (Section 4.1.3.1.10). For the purposes of this EA and in order to fulfill the requirement of the siting guidelines, the approach taken has been to select alternative routes as described below and shown in Figure 5-9. It is assumed that impacts of construction and operation of these routes will be similar to the impacts of the route which will be finally selected as the preferred route. The selection process will include participation of state and local officials and the public as well as further economic and environmental analyses.

For highway access to the site from I-40 (Section 3.5), the U.S. 385 exit near Vega and the Farm to Market (FM) 214 exit near Adrian (Figure 5-9) were both considered as possible access points to the Deaf Smith County Site. Both require about the same amount of travel to get to the site. However, the route from Adrian would require much more upgrading. Also, since most of the traffic will come from the east, use of the Adrian exit would increase transport mileage and risk. Thus the route using U.S. 385 to FM 2587 was chosen as the route for this environmental assessment.

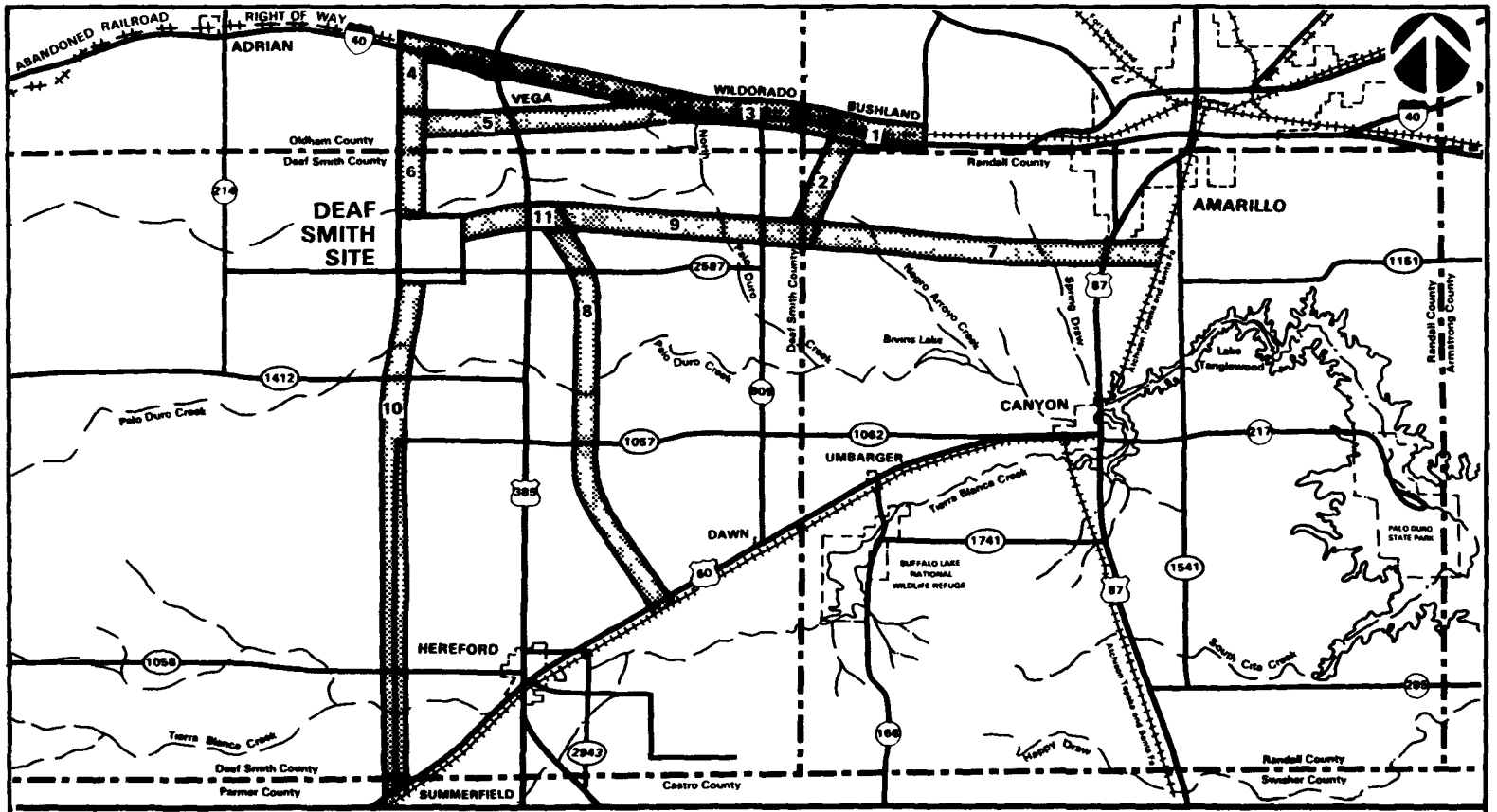
This highway access route leaves Interstate 40 at Vega and follows U.S. 385 south for 16 kilometers (10 miles). The access then turns west on FM 2587 for a distance of 6.4 kilometers (4 miles) and then north for 1.6 kilometers (1 mile) to the surface facility.

Construction of the new access route is estimated at a cost of $600,000, and upgrading of FM 2587, $1 million (SCC, 1984b).

Unlike highway access routes, railroad access will involve construction of an entirely new spur line which connects existing rail lines with the site. The closest mainline railroad to the site is the Atchison, Topeka, and Santa Fe (AT&SF) line between Amarillo, Texas and Clovis, New Mexico that runs through Hereford, Texas. North of the site is an abandoned railroad right-of-way (ROW), formerly part of the now bankrupt Chicago, Rock Island, and Pacific (CRI&P), which extends from Bushland, Texas into New Mexico. Though the tracks have been removed from this section, a portion of that line from Amarillo to Bushland is still being operated, currently by the Burlington Northern Railroad.

A number of potential rail access corridors have been investigated (NUS, 1985a). Six of these alternative access corridors are illustrated in Figure 5-9. These are shown as 1.6-kilometer (1-mile)-wide corridors within which a standard 18-meter (60-foot)-wide route alignment right-of-way could be sited and constructed. These six were chosen because they illustrated the range of opportunities which exist and the impacts which would result from rail line construction and operation.

The six representative routes are described in this section, including approximate lengths of key segments. Routes 1, 2, and 3 represent three different approaches to taking advantage of the abandoned railroad corridor which extends from Bushland to the west. Characteristics of the various corridors are presented in Table 5-4.



Explanation

- Interstate Highway
- 4 Lane U S Highway
- 2 Lane U S Highway
- Farm to Market Road
- State Highway
- Railroad Right-of Way

CORRIDORS	SEGMENTS
1	1-2-9 11
2	1-3-5 6
3	1 3-4-6
4	7 9-11
5	8-11
6	10

Source NUS, 1985a

0 1 8 20 Kilometers

0 1 5 10 Miles

Offsite Development – Deaf Smith County Location of Highways and Potential Rail Access Corridors

Figure 5-9

Table 5-4. Alternative Rail Access Corridors

Corridor	Total Lengths Km (miles)	Length on Abandoned Railroad ROW Km (miles)	Total[a] Area, ha (acres)	Number of at-grade Road Crossings[b]	Number of Stream Crossings	Estimated Costs[c] $Millions
1	43.7 (27.1)	7.9 (4.9)	7,020 (17,340)	15	1	23.7
2	49.1 (30.5)	23.4 (14.5)	7,910 (19,520)	22	1	24.7
3	56.2 (35.0)	36.5 (22.7)	9,000 (22,210)	21	1	26.6
4	55.2 (34.3)	-0-	8,890 (21,950)	18	3	43.5
5	41.5 (25.8)	-0-	6,690 (16,510)	10	1	21.1
6	39.6 (24.6)	-0-	6,380 (15,740)	22	2	26.9

(a) Based on 1.6-km (1-mile)-wide corridors.
(b) Each route requires one grade-separated crossing (overpass).
(c) Does not include costs for land acquisition.

Source: NUS, 1985.

1. Corridor 1 begins in Bushland, follows the abandoned right-of-way for 8 kilometers (5 miles), turns southwest following a pipeline right-of-way for 8 kilometers (5 miles) and then goes almost directly west for 27.4 kilometers (17 miles). This route would require one grade-separated crossing of I-40 and one stream crossing.

2. Corridor 2 begins in Bushland and follows the abandoned railroad right-of-way to a point between Wildorado and Vega. Then the route diverges and heads directly west and then south to the site. The total length requiring new construction is 49.1 kilometers (30.5 miles) of which 23.4 kilometers (14.5 miles) would take advantage of the abandoned right-of-way. This route would require a grade-separated crossing of I-40 and probably one stream crossing.

3. Corridor 3 takes maximum advantage of the abandoned railroad right-of-way by beginning in Bushland and extending westward for 36.5 kilometers (22.7 miles) to a point directly north of the site. This corridor departs from the abandoned right-of-way and heads south for 19.3 kilometers (12 miles) crossing over I-40 and an unnamed tributary of North Palo Duro Creek.

4. Corridor 4 departs from the Santa Fe rail line south of Amarillo, in the vicinity of Hollywood Road, and heads almost due west toward the site for 55 kilometers (34 miles). This route would require one grade-separated crossing of US 87/I-27 and three stream crossings.

5. Corridor 5 departs from the AT&SF line 9.7 kilometers (6 miles) northeast of Hereford, proceeds in a north and northwest direction for 33.5 kilometers (20.8 miles) and then west to the site for 8 kilometers (5 miles). This 41.5-kilometer (25.8-mile) route would require construction of an overpass on U.S. 60 and one stream crossing.

6. Corridor 6 branches off from the Santa Fe rail line near Summerfield and proceeds directly northward for 39.6 kilometers (24.6 miles) to the site. Construction of this route would require one grade-separated crossing of U.S. 60 and two stream crossings.

The environmental assessment of these alternatives is discussed in Section 5.3.2, Construction, and 5.3.3, Operation.

The normal operating electrical power for the Deaf Smith County repository site will be supplied from the substation located at the intersection of U.S. 385 and FM 2587 (Section 3.5). Alternatively, power could be supplied from a substation located at Bushland if the capacity of the substation at U.S. 385 and FM 2587 proves inadequate. This will require a new power line to deliver the electrical service to the Deaf Smith County site as shown in Figure 5-10.

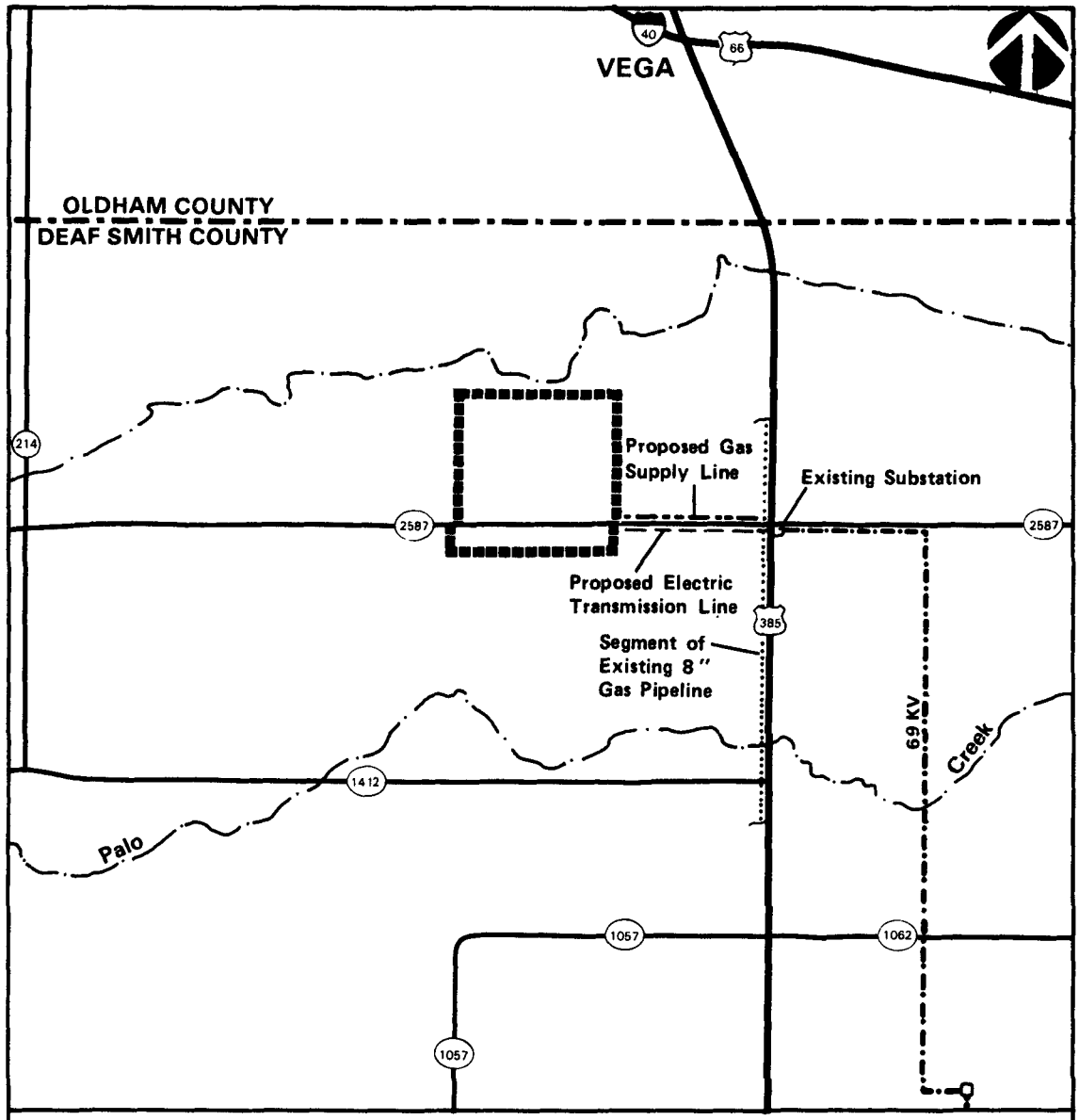
Natural gas for the repository could be obtained by tapping a 20-centimeter (8-inch) pipeline about 5.0 kilometers (3 miles) east of the surface facilities. A new 10-centimeter (4-inch) branch line will be installed to deliver the gas to the repository site (Section 3.5).

The water supply for the Deaf Smith County repository site will be obtained from onsite wells.

5.1.2.3 Onsite Development

Onsite development will consist of site preparation and grading, completion of the onsite sections of the rail lines and site roadways, and construction or erection of the repository surface facilities.

Site preparation will encompass approximately 165 hectares (408 acres). An estimated 1,520,000 cubic meters (1,985,000 cubic yards) of fill and 1,580,000 cubic meters



Explanation

Transportation

- Interstate Highway
- 4 Lane U.S. Highway
- 2 Lane U.S. Highway
- Farm to Market Road
- State Highway

Utilities

- Transmission Line*
- Substation
- Natural Gas Pipeline

Sources: Adapted from Dewitt Graphics, 1983.
Southwestern Public Service Company, 1975-1980.
Deaf Smith Electric Inc., 1981-1982.

0 2 4 6 8 Kilometers

0 1 2 5 Miles

*Electric Distribution Lines Not Shown

Offsite Development – Deaf Smith County Proposed Utility Connections To Repository Site

Figure 5-10

(2,067,000 cubic yards) of excavation will be required to level the site and develop the desired drainage patterns. The fill will be provided from excavation on the site and approximately 62,700 cubic meters (82,000 cubic yards) will be stockpiled for site restoration. Excavated topsoil will be used for landscaping the site and recovered during decommissioning for restoration of the site.

The primary excavated material storage area will be the salt stockpile containing approximately 3.4 million metric tons (3.7 million tons) of mined salt, which is the estimated maximum needed to backfill all open underground excavations at any time in the repository operating life. The excavated salt will be mechanically conveyed to this 22.5-hectare (55.5-acre) area and stockpiled to an approximate height of 12 meters (38.6 feet).

Although it is not a standard practice in the salt industry to line salt storage areas, possible leaching of brine into the ground will be prevented through use of liners. These can be natural clays or synthetic plastics (polyvinyl chloride, polyethylene, or polypropylene). Before emplacement of a liner, the existing topsoil will be stripped, the subsoil material will be excavated to a certain depth, and selected backfill materials will be placed and compacted to form a sound subbase for the liner and for the retention ponds and storage areas as a whole. Once the liner has been placed in the salt pile area, an additional layer of compacted backfill material will be placed on top of the liner. This added backfill will allow use of heavy construction equipment on the salt pile without tearing or puncturing the liner.

When salt is exposed to the weather, a hard surface crust that tends to shed rain water forms in a few days (Ver Planck, 1958; DOE, 1983, WIPP-DOE-161). According to the experience of the salt industry, stockpiled salt is not a source of windblown particles and crusting can be accelerated by wetting the pile. It is possible, however, that during salt handling, that is, the transfer of the salt from hoist to railcars or other conveyances, and salt pile buildup (pile working surface), salt particles may become windblown.

Three major retention ponds will be constructed. The first pond will serve as the salt runoff detention pond, a land area of 5 hectares (12.1 acres), sized to hold more than a 100-year, 24-hour storm.

Because of the positive net evaporation rate in this region (evaporation exceeds precipitation), use of this pond and the other ponds for evaporation disposal of the storm-water runoff or waste water is feasible.

The second major retention system will serve as the treated waste-water holding pond. This pond would be the collection point for all nonradioactive liquid wastes (e.g., cooling tower blowdown, sewage plant effluent) and would cover approximately 4 hectares (9.9 acres) of the repository site.

The third major pond would be the receiving point for other storm-water runoff excluding the previously mentioned salt pile storage area. This storm-water detention pond will cover approximately 7 hectares (17.3 acres) of the repository site and be sized to handle a greater than 100-year, 24-hour storm event.

All three retention pond systems will be lined with a suitable material to prevent contaminated water from seeping into the ground. Lining brine ponds is a common practice and has proved effective and reliable. Ponds as large as 20 hectares (50 acres) are in use which are lined with, for example, 20-mil polyvinyl chloride on the bottom, where the plastic sheet is not reached by sunlight, and 30-mil hypalon (chlorosulfonated polyethylene) reinforced with nylon webbing on the sides, where the sheet is exposed to sunlight. It is a common practice to remove the existing topsoil before emplacement of the membrane and set in place a network of plastic pipes perforated at the top, to be covered by a compacted backfill material. These pipes perform a dual function: they permit gases that may collect under the lining to escape through vertical side vents, and provide access to leachate samples, for monitoring the effectiveness of the liner. Natural materials, such as brine-resistant clays, also can be used in place of the synthetic liners. Monitoring is performed as above. It is presently planned to

provide a monitoring system for the retention ponds and storage area that will characterize atmospheric emissions, surface runoff, subsurface seepage, and soil disturbance interactions.

Onsite roadways, along with the onsite rail yard, will be constructed during this phase. Interim site roads will be crowned while the perimeter site roads will be sloped inward to contain all surface runoff.

Major buildings will be constructed of concrete and steel. Building areas which will confine radioactive materials will be designed to withstand a design-basis earthquake, a design-basis tornado and all other natural and human-induced events.

The waste-handling and packaging facility is the largest building on the repository site and will encompass approximately 18,580 square meters (200,000 square feet) of ground floor area. The tornado- and earthquake-resistant sections of the building will have walls and roofs constructed of thick reinforced concrete. All other areas of the building will be constructed of either steel or concrete.

It is estimated that 15,000 truck visits will be required to deliver concrete and steel, and approximately 9,000 truck visits will be needed to deliver other materials. The estimated total number of truck deliveries is 24,000, at a rate of approximately 13 per day over the construction period. The peak number of private vehicles transporting personnel to the site is estimated to be 719 per day.

5.1.2.4 Shafts and Facilities Development

All of the repository shafts will be excavated using conventional drill-and-blast methods. Potential high ground-water inflows and unstable ground in the sediments above the salt will require pretreatment by freezing to allow shaft sinking through these sediments (Section 4.1.2.2.2).

Shaft linings will consist of concrete in the nonsalt rocks from the ground surface to a depth below the repository horizon. The linings will be cast in place behind the excavation as sinking progresses. Water seals will be placed where required to forestall interconnection between aquifers and to block ground water from passing downward along the shaft lining. For more detail of the shaft sinking process, see Section 4.1.2.

The scheduled sequence of shaft development will begin with the service shaft and ventilation supply shaft, allowing initial subsurface development to begin. The remaining three shafts will be completed concurrent with the initial subsurface development.

Individual shaft outfitting will immediately follow the shaft excavation and lining activities. Shaft outfitting will encompass the installation of the hoisting systems, utility conduit-runs, instrumentation, and all other equipment necessary for the shaft systems to operate properly. The parallel effort at the surface will be the construction of surface support facilities such as the shaft headframes, intake air filter buildings, exhaust air filter buildings, and related surface construction.

5.1.2.5 Subsurface Development

It is proposed that subsurface excavation be performed mechanically. The excavated salt will be transported by a haulage vehicle from the excavation face to a conveyer belt that will transport the salt to surge bins located near the service shaft. Conventional drill and blast excavation may be needed for the initial development of the shaft station areas. A feeder/breaker will be necessary to crush oversized rock prior to its placement on a conveyor system. Excavated salt in the surge bin will be loaded into the skips, which will then hoist the material to the surface. From the service shaft headframe, the excavated salt will be mechanically conveyed to either the salt stockpile area for longterm storage or to the railcar area for transport and eventual disposal off site as described in Section 5.1.3.

After an appropriate monitoring period, storage rooms will be backfilled after waste has been emplaced. Backfilling will be accomplished by mechanically compacting and pneumatically stowing salt as backfill material. Branch and main passageways will also be backfilled soon after the associated waste emplacement rooms are backfilled.

The initial development phase of the repository subsurface will begin when the service shaft and ventilation supply shaft are completed. The subsurface excavation to be performed in this initial development phase is shown in Figure 5-11 and will include:

- Excavation of passageways in the shaft pillar area
- Excavation of the five main passageways to access all panels necessary for the various waste types in the first year of emplacement
- Excavation of branch passageways, exhaust branch passageways and perimeter exhaust passageways necessary for the first two years of emplacement
- Excavation of storage rooms required for the first year of waste emplacement
- Completion of the remaining three shafts.

Table 5-5 summarizes estimated excavation, reexcavation (scaling), and backfill quantities for the repository subsurface. Reexcavation of passageways is necessary due to the slow closure that occurs because of the plastic flow of the salt.

5.1.3 Repository Operation Activities

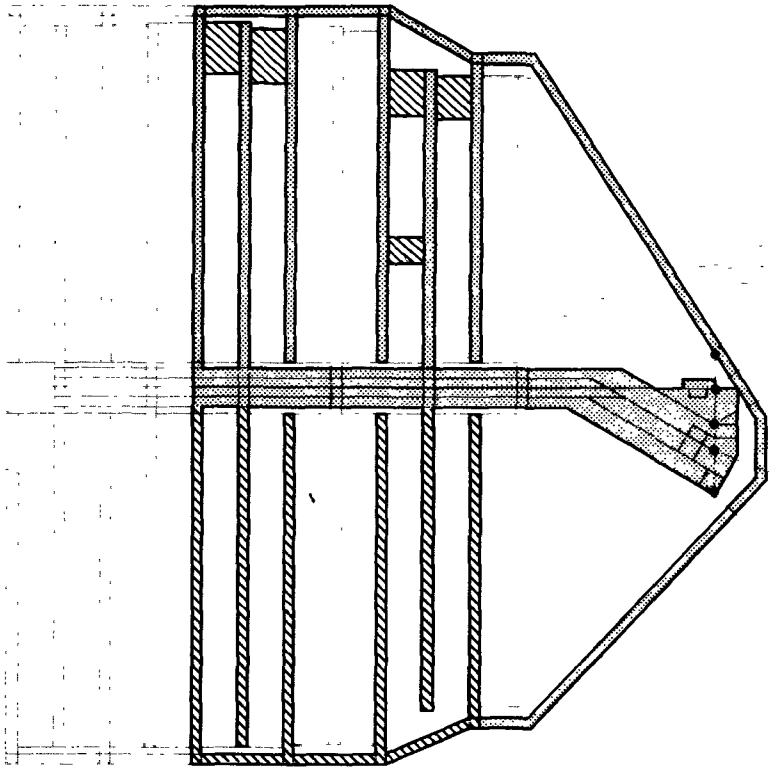
The start of repository operations will be marked by the granting of an operating license by the Nuclear Regulatory Commission (NRC) and initiating nuclear waste receipt, packaging, and emplacement activities. The estimated waste emplacement period of the repository will be approximately 26 years, during which the waste emplacement activities will be completed. The estimated operating life of the repository will be 50 years during which the nuclear waste will be retrievable. The number of employees required to operate the repository is shown in Table 5-2. Of this staff, approximately 20 percent will be directly involved with waste receiving, packaging, and emplacement operations, approximately 15 percent will be involved in underground mining operations, and the remaining 65 percent will be involved in administration, engineering, maintenance, security, and other support categories.

Estimated vehicular traffic during repository operation is given in Table 5-6. Upper limit shipping volumes for nuclear waste are based on the assumption that all shipments would be made by truck or rail in existing cask designs. However, it is expected that a large portion of the nuclear waste will come via rail and that future cask designs, both truck and rail, will have greater capacity. It is expected that both of these factors will markedly reduce the numbers of nuclear waste shipments.

In addition to the incoming nuclear waste, the repository facility will also receive waste packaging material and additional equipment and materials to service the facility.

The estimated quantity of excess salt to be disposed of over the operating period of the repository is given in Table 5-5. Disposal options are discussed in Section 5.1.3.4. A specific method for permanent disposal of excess salt has not been selected. This will be accomplished as part of the site-specific, conceptual design for a repository in salt. Several feasible candidate methods for salt disposal do exist and will be evaluated during conceptual design. These methods are discussed in Section 5.1.3.4, Salt Disposal; a representative disposal method is selected and its impacts evaluated in Section 5.3.5.

The Mine Safety and Health Administration (MSHA) is authorized to administer and enforce certain kinds of safety and health standards for protecting employees in the mining industry, pursuant to the Mine Safety and Health Act of 1977. The question of formal involvement of MSHA with the Civilian Radioactive Waste Management Program is not resolved at this stage.



UNDERGROUND STORAGE ROOM DEVELOPMENT INITIAL DEVELOPMENT PHASE		
PANEL	WASTE	NO. ROOMS
G	SF	10
F	SF	11
C	CHLW	7
C	DHLW	4
B	TRU	6

Explanation

PREVIOUSLY DEVELOPED
INITIAL DEVELOPMENT PHASE

Scale
0 1000 2000 Feet
0 300 600 Meters

Source: Adapted from SCC, 1984a.

Underground Activities
Last Year of Construction
Deaf Smith County

Figure 5-11

Table 5-5. Summary of Excavation Quantities
(all values in tons)

	Construction	Operation	Decommissioning	Total
Passageways	5,976,000	4,121,000	0	10,097,000
Storage Rooms	358,000	12,251,000	0	12,609,000
Shafts	485,000	0	0	485,000
Miscellaneous	69,000	0	0	69,000
Subtotal, Initial Excavation	6,888,000	16,372,000	0	23,260,000
Reexcavation (scaling)	0	309,000	0	309,000
Total Excavation	6,888,000	16,681,000	0	23,569,000
Tons Required for Backfill	-0	-8,557,000	-3,682,000	-12,239,000
Excess Mined Salt	6,888,000	8,124,000	-3,682,000	11,330,000

Table 5-6. Typical Vehicular Traffic Volumes During Repository Operations[a]

Vehicles	Frequency
Rail Cars	
Nuclear[b]	15/week
Salt	58/week
Supplies	4/week
Truck	
Nuclear	19/week
Salt	NONE
Supplies	270/week
Passenger vehicles	500/day

(a) Assume for design purposes; see Section 5.3 for analysis of transportation scenario.

(b) The majority of the nuclear waste material would be transported to the site by railcar. A total of approximately 15 railcars per week would make the trip using various rail routes to the site. The repository could also accommodate the processing of 19 truck loads of nuclear waste per week.

However, principal repository design, construction, and operating features would include provisions for worker protection by following the relevant requirements of 30 CFR Part 57, Health and Safety Standards - Metal and Non-Metallic Underground Mines.

Moreover, 10 CFR 60.131(b)(9) also states that to the extent the DOE is not subject to the Federal Mine Safety and Health Act of 1977, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions.

The repository design will therefore consider the relevant design requirements stated in 3 subchapters of 30 CFR Part 57, Chapter I, Mine Safety and Health Administration, Department of Labor:

- Subchapter D: electrical equipment, lamps, methane detectors; tests for permissibility; fees
- Subchapter E: mechanical equipment for mines; tests for permissibility and suitability; fees
- Subchapter N: metal and nonmetallic mine safety and health.

Specific areas of interest in maintaining occupational safety during mining include the following:

- Mining methods
- Fire prevention and control
- Working environment
- Ventilation systems
- Materials handling and storage
- Underground utility systems
- Occupational safety programs and personnel protection
- Emergency plans
- Inspection, testing, and maintenance.

The Occupational Safety and Health Administration (OSHA) administers the Occupational Safety and Health Act of 1970, as amended (29 CFR Part 1910). The purpose of OSHA is to establish standards with which industries are generally familiar, and to provide an opportunity for interested and affected persons to express their views on proposed standards before their adoption. Such standards are either (1) national consensus standards on whose adoption affected persons have reached substantial agreement, or (2) Federal standards already established by Federal statutes or regulations. The DOE will utilize, where practical, the OSHA regulations, in particular, Occupational Safety and Health Standards, 29 CFR Part 1910, and Safety and Health Regulations for Construction, 29 CFR Part 1926, as applicable.

Predictions of worker injury and fatality rates during salt mining operations at a repository are given in Section 4.1.2.2. Table 5-7 indicates possible injury and fatality rates to be expected during waste handling operations. Actual expected injuries cannot be predicted until repository designs are final.

5.1.3.1 Surface Waste Handling/Packaging Operations

The estimated nominal design capacity of the reference repository design is 72,000 metric tons of heavy metal (79,200 tons of heavy metal) in the form of spent fuel and CHLW. Additionally, the repository has been designed to accommodate 3,150 metric tons of heavy metal (MTHM) of defense high-level waste (DHLW). The waste receiving rates for each waste form contributing to this nominal capacity are plotted in Figure 5-12.

The anticipated sequence of repository operations will begin when the waste form has arrived at the repository by rail or truck in an approved, licensed shipping container.

Table 5-7. Atomic Energy Commission Injury and Fatality Incidence Rates: 1943-1975[a]

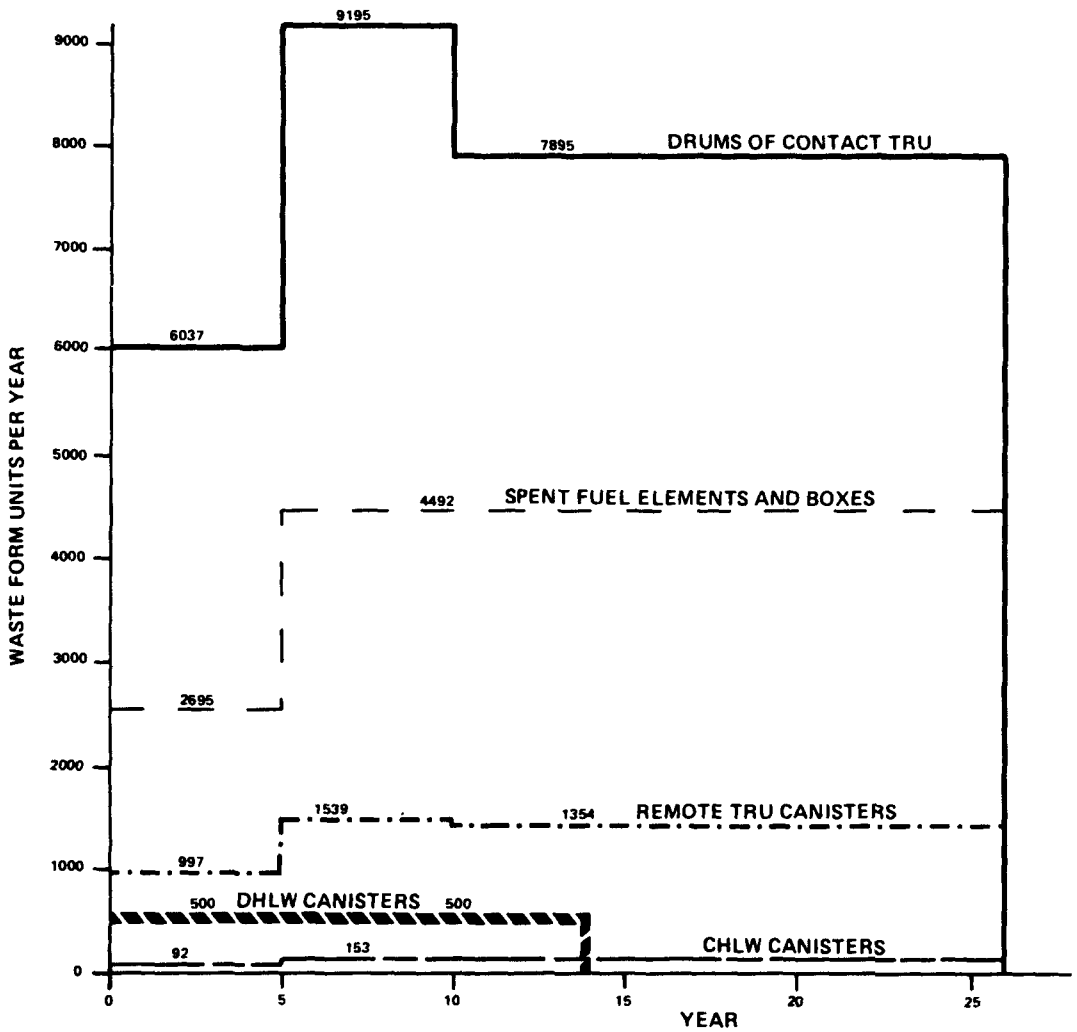
Lost-Time Injuries Per Million Work-Hours	
Construction	5.24
Operations	2.01
Overall[b]	2.75
Since 1958	2.2
Fatalities Per Million Work-Hours[c]	
Construction	0.117
Operations	0.024
Overall	0.046

(a) Total person hours for repository construction: 14,600,000
Total person hours for repository operation: 52,000,000.

(b) Overall = weighted average based on total number of work hours for each category.

(c) Derived from injury incidence rates by multiplying injury incidence rates by ratios of fatalities to injuries.

Source: AEC, 1975.



Input To Packaging Facility
Deaf Smith County

Source: Adapted from SCC, 1984a.

Figure 5-12

Notification of shipment will have been received and approved earlier so that receipt, handling, and emplacement operations for this waste shipment will have been integrated into the overall repository operations schedule.

At the repository security entrance, the shipment documents will be verified. Preliminary inspection of the shipping cask and carrier vehicle will then be performed. The shipping cask and carrier vehicle will then be moved into the repository facility area to the inspection station where they will be thoroughly checked for condition, including checking for sabotage, the structural condition, and the surface contamination level. Based on results of these inspections, the cask and vehicle will then be moved to either the isolation bunker or the waste handling and packaging facility (WHPF).

At the WHPF, the cask and vehicle will be moved to the cask cleaning and decontamination area where the exterior of the cask and vehicle will be cleaned to remove road dirt and any contamination. The cask and vehicle will then be moved into the receiving and packaging facility where the cask will be unloaded from the vehicle.

The shipping cask will then be moved to the cask preparation station to be prepared for the removal of the waste. The shipping cask will be positioned under the waste transfer port and the cask lid removed. The waste will then be removed from the cask, inspected, and transferred either to temporary storage or directly into the packaging hot cells. The cask lid will then be replaced and the shipping cask prepared for loading back onto the carrier vehicle. After loading, the cask and vehicle will be dispatched from the WHPF area to await movement off site.

The waste form will enter the hot cells either directly from the shipping cask or from the temporary storage area. Depending on the form of the waste, additional operations may be performed in the hot cells. For spent fuel, the waste form will move into the disassembly station where the fuel pins will be removed from the fuel assembly or box, consolidated, and placed into a waste package canister. This spent fuel waste package canister or the commercial high-level waste (CHLW) and DHLW canisters will then be moved to the packaging station where they will be placed inside of the thick-walled containter, and the container lid installed. The waste package will then move to the inspection station where the lid closure weld will be nondestructively examined, the surface contamination level checked, and appropriate identification numbers verified and recorded.

Remote TRU will be inspected without repackaging and passed through the hot cell to the transfer cask station. Contact TRU will be assembled onto 12-drum pallets, which will be loaded directly by forklift into the waste shaft hoist cage. At this point, it will be lowered to the repository subsurface level.

At the transfer cask station, the waste package will be loaded into the transfer cask (a heavy, shielded container similar to a shipping cask) through a transfer port with the transfer cask located outside the hot cell. The transfer cask containing the waste package will then be moved to the waste shaft hoist, loaded onto the hoist cage, lowered down to the repository subsurface level, and unloaded onto an underground transporter. At this point, subsurface operations will begin.

Requirements for waste storage on the surface are established in the Generic Requirements for a Mined Geologic Disposal System (DOE, 1984, DOE/NE/44301-1). A temporary storage capacity equivalent to three months waste receipts will be provided in order to minimize the effects of scheduled or unscheduled interruptions in repository operations. This requirement is subject to change if the monitored retrievable storage (MRS) facility is developed and will depend upon the established role of the MRS facility in the disposal scheme.

5.1.3.2 Subsurface Waste Handling Operations

Subsurface waste emplacement operations will begin upon completion of the initial development phase. During this first year of operation, the room excavation operations will be moved to the side of the main passageways opposite the emplacement operations.

Once the waste package transfer cask is unloaded from the hoist onto an underground transporter, the transporter will move the waste in the transfer cask to the designated storage room and position the cask over the vertical borehole in the storage room floor. This vertical borehole will have been performed before emplacement operations begin in that storage room. Once the transfer cask is over the borehole, the bottom will be opened and the waste package will be lowered into the borehole. The borehole then will be backfilled with crushed salt to storage room floor level. The transporter then will carry the empty transfer cask back to the hoist where the transfer cask will be loaded onto the empty hoist cage for transfer to the surface and reuse. The underground transporter then will be available to transport the next loaded transfer cask.

5.1.3.3 Retrievability

Section 122 of the NWPA mandates that the repository shall be designed and constructed to permit retrieval of any spent fuel emplaced in the repository during an appropriate period of operation of the facility. The reasons for such retrieval, as per the Act, may pertain to public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel.

The Civilian Radioactive Waste Management (CRWM) program's position on the issue of retrievability is that the repository be designed, constructed, and operated so that the capability to retrieve the previously emplaced waste packages is retained. This condition will be maintained until the satisfactory completion of a performance confirmation program as stipulated by NRC's 10 CFR 60.111 and decommissioning activities are authorized by the NRC.

In accordance with the NWPA and 10 CFR Part 60, the geologic repository operations area will be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a longer or shorter time period is specified by the Secretary (DOE) and approved by the NRC. For design purposes, it is assumed that the actual retrieval, if retrieval proves to be necessary, would take approximately as long as the period used for waste emplacement and repository construction. This length of time is consistent with the NRC's provision in 10 CFR 60.111, in which public health and safety considerations are of primary importance in any waste retrieval operation.

The capability to retrieve the waste packages would be demonstrated prior to a decision to backfill the waste package storage rooms and would be maintained regardless of whether the storage rooms have been backfilled. Therefore, the decision to backfill would be based on an evaluation of the advantages of early backfilling versus the disadvantages of increased difficulty of retrieval.

The DOE has, during the summer of 1985, developed a position on retrievability to describe and document all design, construction, operation, and maintenance equipment requirements associated with retrievability. An evaluation of the effects of these requirements on the repository design and the associated equipment needs has not been completed at this early stage in the repository design process. These retrieval effects will be analyzed and addressed during the site characterization period and subsequent design phases supporting the license application.

5.1.3.4 Salt Disposal

As the result of mining activities, approximately 10,280,000 metric tons (11,330,000 tons) of salt material will require disposal. The excess salt and salt-laden material brought to the surface during repository construction and operation could be disposed of in the following ways:

- Onsite disposal
- Commercial market
- Ocean disposal

- Mine disposal
- Offsite (surface) disposal.

Selection of the disposal option will be based on a comparative evaluation of the advantages and disadvantages of all options suitable for a given site. A principal factor in such an evaluation would be the potential for environmental impact. Knowledge gained from testing and experimentation during the site characterization phase will be incorporated in repository design, and will be applied to salt management during repository operations to limit impacts. The primary consideration will be assurance that the quality of the environment in the affected area during this and future generations will be adequately protected in accordance with the criteria set forth in the siting guidelines, especially 10 CFR 960.5-2-5, Environmental Quality. Transportation, with its potential impacts and costs, also would be a significant factor in the evaluation but would be given less weight than environmental impact.

While the repository program has not advanced to the point where the final selection of a disposal method can be made using data specific to the selected site, the significant impacts of the options at potential sites can be reliably anticipated at this time. The following sections summarize the salient features of each option.

5.1.3.4.1 Onsite Disposal. Onsite disposal would require the construction of a large surface storage area, underlain and covered by impervious materials. As discussed in Section 4.3.5.2, this option is relatively low in cost.

5.1.3.4.2 Commercial Market. Excavated salt would either be supplied through the General Services Administration to buyers or governmental agencies "as-is" or following some onsite processing. Because transportation costs may exceed the market price of the salt, the DOE may have to subsidize the sale. In addition, potentially adverse social and economic impacts are possible. Feasibility of this alternative has not been fully developed.

5.1.3.4.3 Ocean Disposal. The excess salt could be converted into brine and dispersed in ocean waters through outfalls. Transport of either the brine or the solid material from the site to the disposal point would be required.

5.1.3.4.4 Mine Disposal. Excess salt would be transported by rail to existing evaporite mines, transferred underground via a closed conveyor system, and packed into unused sections of the mines. There would be no expected long-term impacts associated with this option.

5.1.3.4.5 Offsite (Surface) Disposal. The disposed salt would be blended into a natural environment composed of evaporite materials very similar in composition to the material being disposed of.

5.1.3.4.6 Choice of Mine Disposal as Representative Method. Numerous evaporite mines were available (SCC, 1984b) with capacity to accept waste salt. This study provides assurance that many mines with sufficient capacity are available should this alternative be exercised. Tentative mine sites have been identified within a few hundred miles of the repository site. The resulting transportation costs are relatively modest. This option is the representative disposal option.

Impacts of the mine disposal option are transportation-related, and appear in Section 5.3.5, Salt Disposal.

5.1.3.4.7 Description of Salt-Handling Activities Related to the Mine Disposal Method. A general description follows of the physical activities likely to be performed at the repository site and at the disposal site if the salt disposal method selected were to be disposal in an existing mine. Several of these activities are general and would be applicable to other disposal methods.

Salt handling at the repository site. The excavated salt is brought to the surface by the skip hoisting system. The skips discharge into a surge bin near the headframe, and the salt is then conveyed from the surge bin to the site salt stockpile or, if excess salt, to the railroad loadout area.

The excess salt is loaded into railroad cars for shipment to the excess salt disposal site. The handling, loading, unloading, and transporting of salt at the repository and at the excess salt disposal site are performed in a manner to reduce air-borne particulates that avoids adverse impacts to surrounding environments. As far as practical, conveyors, transfer points, and loadout structures will be enclosed and equipped with dust collection equipment to minimize impacts on the environment.

Salt handling at the disposal site. A possible excess salt disposal location for the Deaf Smith County site is the Carlsbad area of New Mexico. The excess salt is dumped from the railroad cars into a track hopper and the salt is transported underground into an existing evaporite mine using one of several available conventional materials handling designs. The salt is placed as a backfill in the previously mined rooms.

5.1.3.5 Treatment and Disposal of Other Repository-Generated Wastes

Liquid and solid wastes generated by repository operations are collected and treated on site and disposed of in an appropriate manner. Treatment and disposal is in compliance with applicable local, state and federal regulations.

Sanitary wastes are collected and transferred to the wastewater treatment facilities by a site sanitary sewage system. The sanitary waste treatment facilities are a packaged system that utilizes both primary and secondary treatment to remove 85 to 95 percent of the 5-day biological oxygen demand (BOD) and a similar range of suspended solids. Following treatment, liquid effluents are discharged into the treatment wastewater pond.

Industrial wastes such as used lubricating oil, laboratory chemicals, and nonradioactive cleaning solutions will be collected at the source. Most or all of these wastes will be transported off site to commercial disposal sites or recycling centers. Hazardous industrial wastes will be disposed of at offsite commercial facilities specifically designed for the purpose.

Radiological wastes consist of items generated on site in the course of normal operations; for example, used high-efficiency particulate air (HEPA) filters, anti-contamination clothing, contamination test swipes, and solutions used to remove radioactive contamination. Solid radiological wastes are collected at the source, packaged as contact handled TRU, and disposed of in the repository. Liquid radiological wastes are collected at the source and taken to the wastewater treatment facility in a drain system that is entirely separated from the sanitary sewer system. Radioactive liquid and solid waste system quantities are listed in Table 5-1. All inaccessible radiological waste piping is double-walled to preclude undetected leaks. These waste liquids are solidified on site and packaged as contact handled TRU wastes.

All the ponds (storm-water detention, salt stockpile runoff and treated waste water) are designed to contain the inflow from a 100-year or greater, 24-hour storm event. The ponds, when full, will have spillways with the capacity to safely discharge a storm of greater magnitude without overtopping the embankment. All ponds will have an essentially impervious lining to prevent seepage of pond water into the subsurface aquifer. Each pond will contain facilities to monitor storm water and other effluents from the plant and evaluate them for radioactive and nonradioactive pollutants before being discharged to the existing natural surface drainage courses outside the repository. The total areas of the ponds are listed in Table 5-1.

5.1.4 Decommissioning and Decontamination

After the operational phase, the repository will be decommissioned and decontaminated (D&D). Detailed D&D plans will be developed and provided with the NRC construction application. Although future D&D requirements may differ from current requirements, the general philosophy is to reclaim the repository site to original site conditions as feasible and to complete backfill of the underground facilities to seal the drifts, haulageways, and shafts. During this period, the contaminated portions of the waste handling facilities could be cut up, packaged, and moved to the repository subsurface. The remaining open areas of the

repository subsurface will be backfilled and sealed using the originally excavated salt material stored on site. The surface facilities will be dismantled and the surface area restored as feasible to final reclamation grade. Shaft backfilling will include salt and selected materials with seal plugs at predesignated depths.

5.1.4.1 Surface Activities

Decommissioning operations will include decontaminating and dismantling the surface facilities and restoring the site area to the final reclamation grade, and seeding if appropriate. Mechanical and chemical decontamination methods will be used to remove radioactive contamination from the WPHF and its support facilities. Uncontaminated components from the demolition operations such as structural steel, and plate work will be removed and transported off site as scrap materials. Contaminated materials that cannot be decontaminated will be transferred to the subsurface drift areas for emplacement. A final radiation survey of the surface facilities will be performed to ensure that all areas are below radiation levels that allow for unrestricted public access.

Ponds used for containment of surface water runoff from the facility and process-water discharge will be surveyed for the presence of radioactive contamination. If radionuclide levels exceed acceptable limits, the material will be removed, packaged, and disposed of properly. If radionuclide levels in the pond water and sediments are within acceptable levels, the pond will be drained, backfilled, and graded consistent with the final reclamation topography.

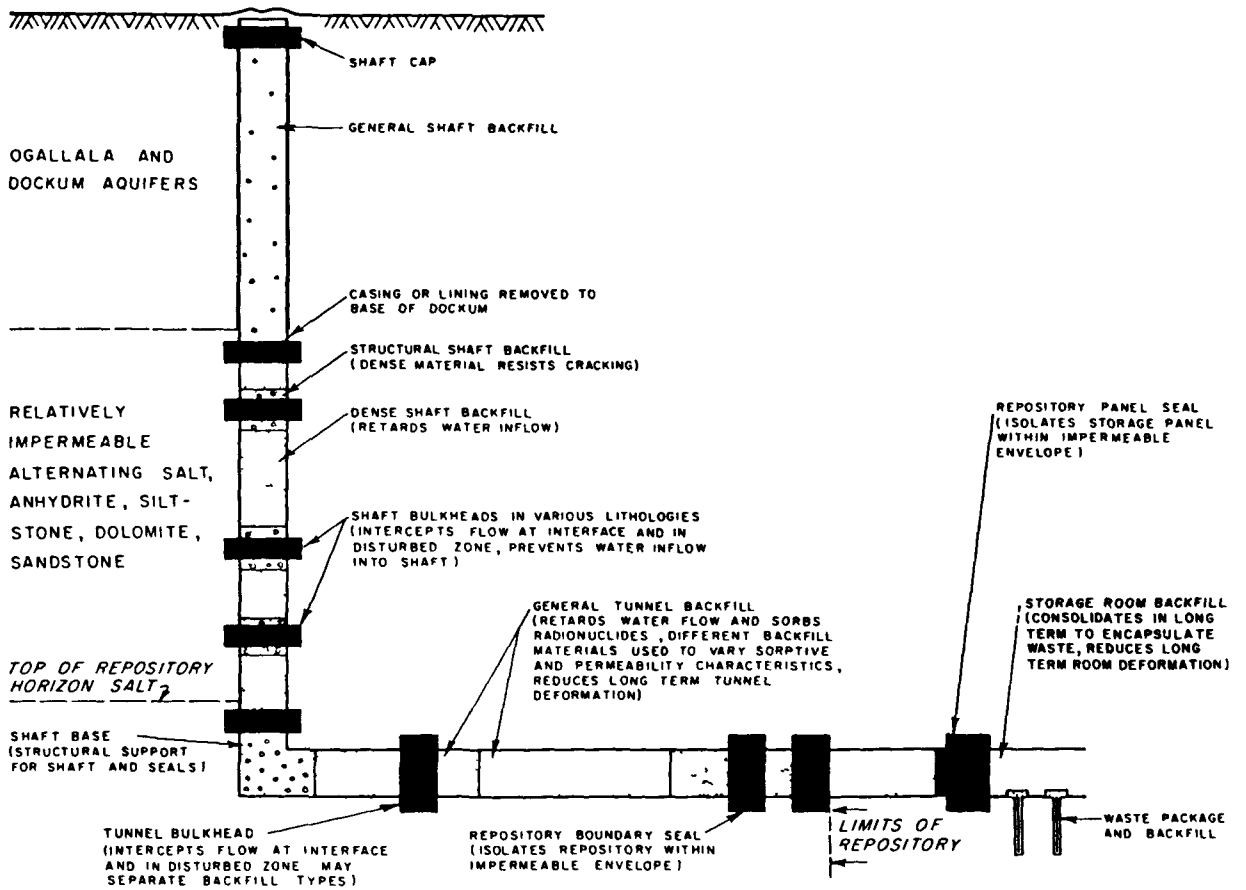
5.1.4.2 Subsurface Activities

After all contaminated materials from surface decommissioning and decontamination are emplaced under the surface, the repository subsurface facilities will be closed by installing a repository sealing system. The repository seals will consist of subsystems to seal the rooms, drifts and passageways; the shafts; and the boreholes. The repository sealing system components will be designed to withstand the effects of design basis seismic events, anticipated thermal conditions, and expected ground swell or subsidence without unacceptable loss of function. A schematic diagram of the sealing system is shown in Figure 5-13. A comprehensive description of the repository sealing system design and materials studies is contained in Kelsall et al. (1985, BMI/ONWI-564). The sealing system will meet or exceed any applicable state requirements for plugging mine shafts or wells.

5.1.4.2.1 Room, Drift, and Passageway Seals. The bulk of the horizontal openings will be filled with a crushed salt backfill, which under the stress and heat conditions will ultimately (tens to hundreds of years) reform into a solid mass of salt similar to the preemplacement conditions. Groups of rooms, referred to as panels, will be isolated with precompressed salt blocks installed as masonry walls to provide isolation while the crushed salt is compacting. In the passageways connecting the shafts to the main disposal area, multiple concrete bulkheads will be installed. Portions of the drift between concrete bulkheads will be backfilled with an earthen material to provide redundancy.

5.1.4.2.2 Shaft Seals. After the passageways connecting the shafts have been sealed, the base of the shaft will be filled with structural concrete to support the loads imposed by the shaft sealing materials. Most of the shaft volume will be backfilled with crushed salt, in salt horizons only; dense earthen material, a mixture of clay and locally available materials; or general backfill, locally available material such as that removed during shaft sinking. At selected locations along the shaft, bulkheads will be constructed as shown in Figure 5-14.

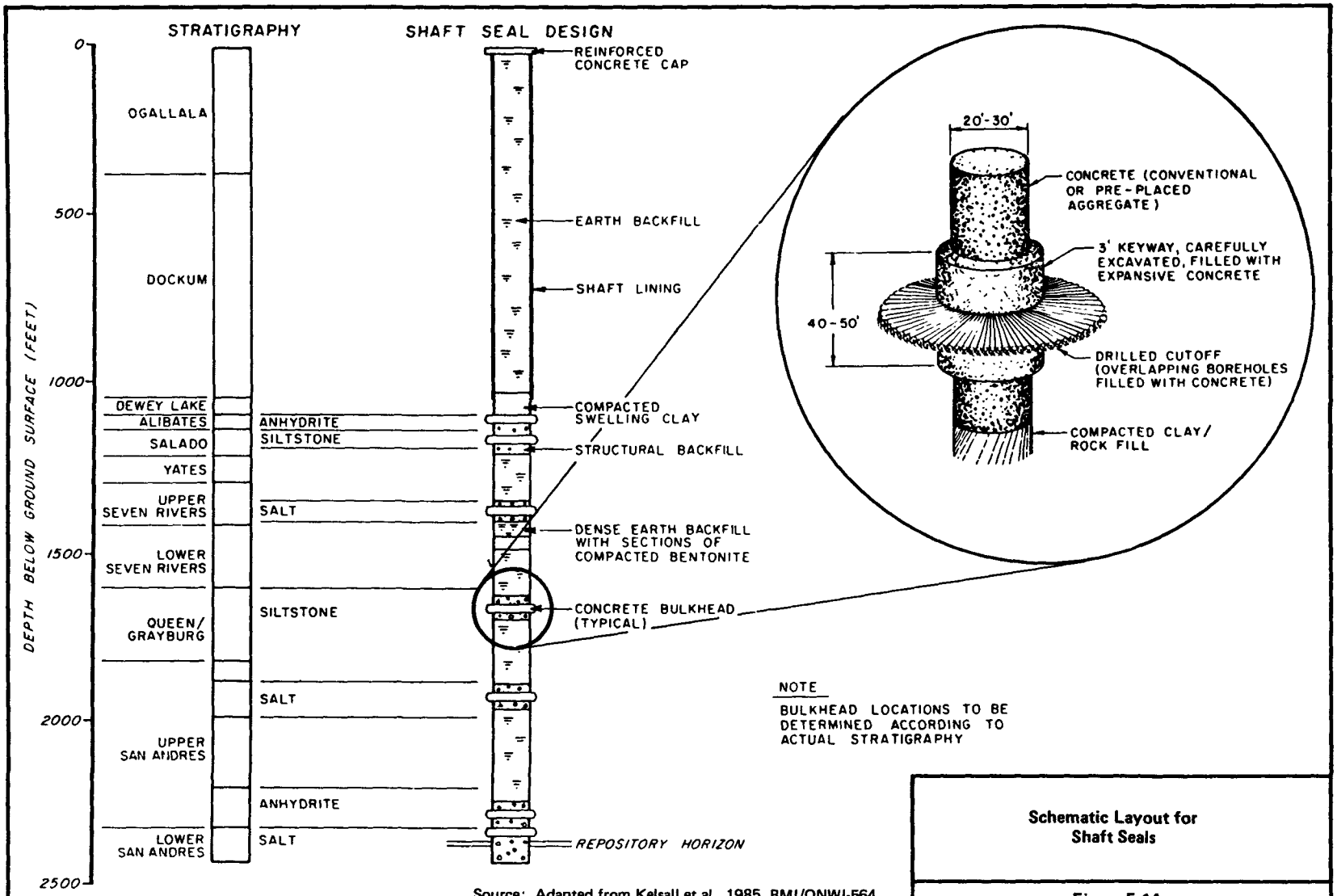
The shaft lining will be removed at the bulkhead locations. These bulkheads will extend into the rock around the shaft to intercept and seal any fracture areas created by the sinking of the shaft and prevent the transport of water outside of the sealed shaft. At the top of the shaft, a shaft cap of concrete will be placed.



Repository Sealing System Schematic Permian Basin Repository

Source Adapted from Kelsall et al, 1985, BMI/ONWI 564

Figure 5-13



Source: Adapted from Kelsall et al., 1985, BMI/ONWI-564.

Schematic Layout for Shaft Seals

Figure 5-14

5.1.4.2.3 Borehole Seals. Boreholes from the surface will be plugged as shown in Figure 5-15. Cement grout will be the primary constituent of the seal with a clay layer for material redundancy. Where necessary to seal behind the borehole casing, the casing can be perforated using oil field tools and grout squeezed through the holes into the formation.

5.1.4.3 Salt and Nonuclear Waste Disposal

Water in the salt pile retention pond will be allowed to evaporate, the liner and salt-contaminated materials will be removed, and the depression will be backfilled to final reclamation grade. Most of the salt contained in the surface stockpile will be used to backfill subsurface facilities. Salt remaining after this operation will be transported from the repository site and disposed of as excess salt.

5.1.4.4 Labor Force

Decommissioning activities will resemble those of the construction phase and require personnel for dismantling, backfilling, and ground-surface restoration procedures. The size of the decommissioning phase labor force will be smaller than the operations labor force, as shown in Table 5-2.

5.1.5 Postclosure Activities

Following the closure of the subsurface areas and decommissioning of the surface facilities, the repository will enter the postclosure phase. Generally, activities at the site will be those necessary for (1) active prevention against repository intrusion, (2) passive prevention against underground intrusion, and (3) possible active monitoring of repository conditions.

5.1.5.1 Active Prevention

After the time of repository closure, the DOE will own surface and subsurface title to approximately 2,331 hectares (5,760 acres). After closure, the DOE will maintain an institutional barrier into the foreseeable future. This arrangement will have provided active institutional barriers to subsurface exploration that has the potential for affecting the repository.

5.1.5.2 Passive Prevention

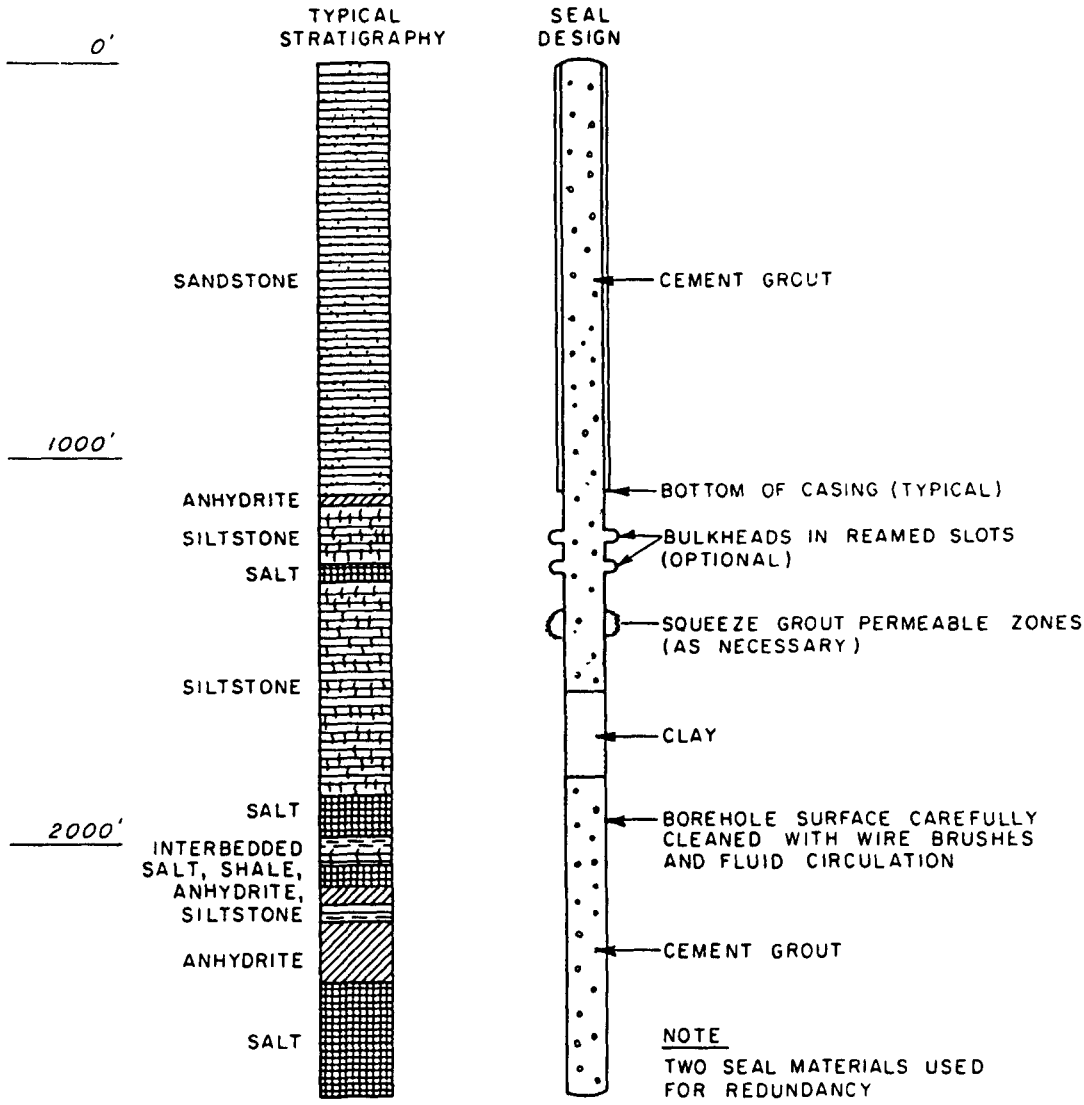
It is possible that institutional barriers and systems of recordkeeping and updating may fail in the future. For this reason, a passive barrier system will be used to notify future societies that have the technology to excavate or drill to the repository level about the hazards below the surface.

Numerous options for passive barriers are being considered by the DOE (Kaplan, 1982, ONWI-354; and Berry, 1983, ONWI-474). The options most likely to be implemented are various types of markers and records such as the following:

1. A set of 3- to 9-meter-high (10- to 30-foot-high) peripheral markers may be placed surrounding the outer control zone (the land owned by the DOE). These probably will be monolithic and shaped like tall pyramids. Simple warning symbols will be cast into each face. The markers probably will be spaced so a person standing at any point on the perimeter will be able to view two markers.

2. A monument may be created and located over the center of the repository area. This marker will probably by pyramidal and large enough to contain an internal area for accommodating details of the construction and hazards in the subsurface repository.

3. Earthworks of a size discernable by site visitors may be created. These probably will be constructed around the central monument in the form of warning symbols.



Schematic Design for Sealing Vertical Boreholes in the Permian Basin

Source. Adapted from Kelsall et al., 1985, BMI/ONWI-564.

Figure 5-15

4. A redundant set of warning symbols may be placed into the ground by tilling magnetite or some other site-anomalous material below the soil surface. These symbols, which may be quite large, will not be apparent to the eye but be detectable by simple instruments.

5.1.5.3 Active Monitoring

While postclosure monitoring requirements have not been established by the NRC, it is possible such requirements will be instituted. If postclosure monitoring is required, the DOE will probably retain a small technical staff and one of the small repository buildings.

5.2 EXPECTED EFFECTS ON THE PHYSICAL ENVIRONMENT

This section discusses the expected effects of repository development on (1) geologic conditions; (2) hydrology; (3) land use; (4) terrestrial and aquatic ecosystems; (5) air quality; (6) noise; (7) aesthetic conditions; and (8) archaeological, cultural, and historic resources. The effects are based on the engineering feasibility studies for constructing and operating a repository at candidate salt sites (SCC, 1984b). This design is currently undergoing revision (Section 5.5) and some impacts could change. However, as indicated in Section 5.5, it is not expected that these design modifications would significantly increase environmental impacts. Environmental effects of road and rail construction and upgrade, although discussed briefly in this section, are presented in greater detail in Sections 5.3.2 and 5.3.3.

5.2.1 Geologic Conditions

Potential effects identified are soil and topographic disturbances during site construction, removal from the public domain of potential mineral resources for an undetermined period into the postclosure phase, and minor subsidence or uplift of the surface over the repository. The effects are identified based on data presented in Section 3.2.2 and on the repository design described in Section 5.1.

5.2.1.1 Soils

This section summarizes the potential impacts resulting from repository construction, operation, and decommissioning and closure on the soils at the site.

5.2.1.1.1 Construction. In total, approximately 165 hectares (408 acres) of site and access-road soils will be disturbed, removed, stockpiled, or used as construction material. This is approximately 7 percent of the site and less than 1 percent of the prime farmland in the vicinity. Direct impacts to prime farmland in the area are expected to be insignificant. Additional areas of soil disturbance will occur from the construction of utility corridors.

Grading, cut and fill operations, topsoil stockpiling, and building construction will result in modification of the soils at the site. Top soil will be stripped from the site area and stockpiled by horizon off site until needed for reclamation at the end of decommissioning. The stockpiles will be seeded with suitable grasses and mulched and irrigated until the grass cover is established enough to prevent wind and water erosion. The natural soils will be removed, transported, compacted, and, in places, covered with concrete, asphalt, waste rock, salt, or gravel. Site preparation and repository construction will cause erosion and have the potential of producing a large amount of dust and sediment over the 7-year construction period. Sediment will be collected in the runoff ponds and will not move off site to surface waters. However, some dust will be carried off site by the wind and deposited elsewhere.

Soil structure will be altered, bulk densities increased, permeability reduced and texture altered by grading and cut-and-fill operations on site. Salt content in soils near the salt storage pile will probably be increased to some extent by deposition of windblown salt. All of the aforementioned impacts are considered long term. Natural structure, bulk density, and permeability similar to undisturbed soils will require years to become reestablished, depending on the condition of the soil at the site, the mitigation measures used, and the

amount of water penetrating the soil. Organic content will eventually be restored by new vegetation. Soil chemistry will be affected by the amount and quality of water penetrating the soil and the kinds of chemicals that may have been added, both before and after repository construction.

Salt deposited at predicted rates on the soil and absorbed by the plant roots will not result in reduced crop productivity (see Section 5.2.10). Blowing salt during repository construction activities will add less than 3 percent of the amount of salt in the irrigation water contribution to the soil. Cropland in the site vicinity is regarded as producing a high return in yields. Existing management practices are capable of alleviating the salt buildup incidental to irrigated farming and could be expected to negate the effect of any small additional increment from repository activities.

Areas used for routine vehicle and equipment maintenance may become oil- and grease-soaked. Soils in the fueling area may contain spilled gasoline, kerosene, and diesel fuel. Because soils contaminated by these activities will be removed during reclamation, such impacts are considered to be short term.

Soil-related impacts outside of the construction perimeter will result from construction of roads and a railroad spur, natural gas and water pipelines, and electric transmission lines. Permanent access roads will be paved; any new service roads for pipelines and transmission lines will remain unpaved and will be susceptible to erosion, although surface stabilizers and sealers will be used. Construction of the roads and other supporting services could possibly contribute sediment to surface waters off site. This would be an intermittent impact, as would any dust generated from unpaved surfaces.

In total, approximately 165 hectares (408 acres) of site and access road soils will be disturbed, removed, stockpiled, or used as a construction material. This is approximately seven percent of the site, indicating a small direct impact to farmland in the area. As noted, additional areas of soil disturbance will occur from construction of utility corridors.

5.2.1.1.2 Operation. Repository operation will create very few additional soil-related impacts beyond those expected during construction. The areas which have not been paved or sealed will continue to be exposed to wind and water erosion, resulting in loss of soil. This soil loss will contribute sediment to the storm water retention ponds, and add some dust to the site and surrounding area. Routine dust mitigation measures will be instituted to reduce this impact.

Topsoil, mined waste rock, and salt stockpiles will be stabilized, and erosion control measures, including revegetation for the topsoil piles, will be instituted. Separate salt pile runoff retention ponds will be maintained to isolate salt-contaminated runoff from off-site surface waters and soils. The effects of windborne salt are described in Section 5.3.5.

Paved access roads will create runoff to side ditches, producing some erosion and sedimentation. Unpaved access roads for utility corridors and pipelines will occasionally channel runoff into ruts, producing localized erosion and sedimentation. Compaction of unpaved surfaces by maintenance and inspection vehicles will continue during repository operation. These impacts are expected to be short term, localized, and insignificant.

5.2.1.1.3 Decommissioning and Closure. Repository closure will involve backfilling the underground workings and access shafts with salt from the onsite stockpile. This will produce considerable disturbance during loading and transport of the salt, and some wind-transported salt could potentially travel off site as well as accumulate on site. Salt transported by runoff will be collected and diverted to the salt pile runoff retention ponds. Some mixing of storm-water runoff with salt-contaminated runoff may be unavoidable at this stage, but it will be collected on site and should not produce any significant impact. When the salt stockpile is completely removed, the liner and soil layer covering will be removed and disposed of off site in a licensed landfill. The soil under the liner will require ripping to relieve compaction as a first step in reclamation. If the liner has been perforated, salt-contaminated soil will be removed and disposed of off site.

After dismantling the surface facilities, all foundations and paved surfaces other than permanent roads will be removed, exposing heavily compacted soil which has, in some cases, been mixed with rock, gravel, chemicals, and lubrication fluids. Onsite examinations will be made to determine whether these areas should be removed and replaced with new soil. All retention ponds will be drained, and sludge, sediment, and liners disposed of off site. The sediment collection pond may be retained for a period of time after reclamation has occurred on the rest of the site, or it may be a permanent installation that could be used as a stock water catchment. The site will undergo extensive preparation to relieve compaction before topsoil is replaced and seeded with appropriate ground cover.

Major long-term effects on soils from repository construction, operation, and closure should be limited to the soils that are actually subjected to physical admixture with nonsoil materials or disturbance. Soils used as construction materials will either be removed from the site and disposed of or treated to relieve compaction so that soil structure can begin to regenerate. These soils may require considerable admixture with stockpiled topsoil, mulches, and fertilizer (as discussed in Section 4.2.1.5) to prepare them for revegetation. Given these treatments, sufficient time, and maintenance of erosion-prevention practices, the repository site soils should return to a reasonably natural state. Reclamation activities will be designed and conducted to ensure that all soils will reestablish their structure and permeability as quickly as possible and to restore them to high productivity as prime farmland.

Long-term offsite impacts to soils are not expected. The maintenance of wind and water erosion control practices on site should make any contributions of dust and salt drift to offsite lands both minor and short-term. No major impact on soil chemistry or land productivity should occur.

5.2.1.2 Mineral Resources

The primary impact to mineral and hydrocarbon resources will be the exclusion of resource development within the 2,331-hectare (5,760-acre) controlled area. Surface and subsurface mineral rights in the area will be retained by the DOE throughout site construction, operation, and decommissioning. This will continue into the postclosure phase for an as-yet-undetermined period of time to prevent potential breach of the repository by future mineral exploration and development activities. The DOE will compensate affected mineral-rights owners for any mineral rights acquired.

Low resource potential was used as a condition for site selection during the site screening process and hence the local and regional effects of the restriction against development of mineral and hydrocarbon resources are expected to be minimal. Section 3.2.8 summarizes data on hydrocarbon production and mineral resource development and estimates the potential for undiscovered resources in the Palo Duro Basin. At this time, no production or development is occurring within the restricted area and no reserves are known. There may be sand, gravel, and caliche within the restricted area,, but these materials are not unique within the basin. The potential for undiscovered hydrocarbon and mineral resources is low.

5.2.1.3 Geologic Structure

Potential effects on the geologic structure are expected to be limited to local, minor subsidence or uplift of the surface over the repository, possibilities for increased microseismic activity, and salt dissolution. As discussed below, these effects should be within allowable limits and any resulting impacts should have acceptable environmental consequences. No other known or expected geologic conditions would be adversely affected by repository construction and operation. Impacts on the lithology and structure of the salt horizon and surrounding sediments are not expected. There will be no significant losses or modification of strata and rock other than the rock and salt actually removed in the process of underground development.

5.2.1.3.1 Surface Subsidence and Uplift. There are two principal mechanisms affecting movements within the rock mass and elevation changes of the ground surface above the repository. These are the following:

- Uplift caused by thermal expansion of the rock mass due to heating by the waste packages
- Subsidence caused by the creep of the salt into the subsurface workings.

In the preclosure period, cooling provided by ventilation of the repository tunnels will have a limited mitigating effect on the heating caused by the waste packages. In the postclosure period, uplift caused by thermal expansion will reach a maximum of about 0.5 meter (1.6 feet) approximately 1,000 years after waste emplacement (Wagner et at., 1985, BMI/ONWI-512). After this time, cooling by ground-surface convection and radiation will dominate and will act to return the ground surface to its original elevation.

Mining subsidence occurs in a time frame of tens of years (depending on salt characteristics, thermal load, room design and support system, and the amount and effectiveness of backfill), but its effects are relatively small and are masked by uplift due to thermal expansion. After some tens of thousands of years, when the repository has cooled down, the subsidence effect will result in a small amount of overall permanent subsidence of less than 1 meter (3.3 feet).

The DOE (1981, DOE/NWTS-147(2)) and Russell (1979) found that vertical uplift caused by heating of the repository could be as much as 3 meters (9.8 feet) and not cause environmental concerns. For example, Loken et al. (1984, Table 7-3) calculated a maximum surface uplift of 1 meter (3.3 feet). Note that this uplift is distributed gradually over the ground surface above the repository. This 1 meter (3.3 feet) does not represent a differential movement over a short distance that would cause significant shear distortion and cracking of the overburden. The finite element model used by Loken et al. (1984) accounted for stratigraphic heterogeneities of thermomechanical properties for repository region formations. Loken et al. (1984) ignored discontinuities such as joints and fissures not only because of a lack of data, but also because their omission would overpredict the thermomechanical response. The calculations of Loken et al. (1984) overpredict the thermomechanical responses in another way. Because Loken et al. (1984) made an elastic calculation, they ignored any stress relief due to creep closure of repository excavations and compaction of room backfill. Therefore, much of the stress driving uplift would dissipate in the creep closure of the repository rooms and consolidation of crushed salt backfill and it is concluded that repository-induced uplift or subsidence will be less than a few meters, will be distributed over the land surface, and will cause no environmental concerns. Because the uplift will be spread over thousands of years and progressively decrease after about 1,000 years, it should not significantly affect surface drainage gradients or ground-water flow patterns, nor should it cause major discontinuities in the bedded salt or overlying sediment that would provide possible pathways for ground-water intrusion.

5.2.1.3.2 Microseismic Activity. As addressed in Chapter 3, the probability of seismic activity in the site vicinity (Section 3.2.5.3) is low. Repository development is not expected to increase the occurrence of these geologic phenomena beyond present rates. Induced seismic events could occur at the site; however, current knowledge of stress conditions in the area (Section 3.2.6) suggests that the possibility is low. Information which can be used to completely evaluate the potential for microearthquake activity at the site due to repository-development activities is not presently available. Repository buildings that will contain radioactive materials are designated as Category I structures and will be designed to perform during and immediately following the Design Basis earthquake, yet to be established (Section 5.1). However, there is a possibility that repository development may induce microseismic activity in the site vicinity.

5.2.1.3.3 Salt Dissolution. Salt dissolution in the Palo Duro Basin is discussed in Section 3.2.3.3. Salt dissolution fronts of the repository salt horizon are 100 kilometers (62 miles) to the east of and 29.8 kilometers (18.5 miles) to the north of the geologic

repository operations area. No salt dissolution features are known at the site. Repository development could potentially cause or increase the natural rate of salt dissolution at the site by providing access pathways to the salt for ground or surface water. Such pathways would include shafts and boreholes and the induced structural discontinuities. As discussed above, the creation of major discontinuities is not likely. As discussed in Section 4.1.2.2, appropriate drilling techniques, seals, and plugs will be used to prevent vertical migration of water to the salt. Furthermore, as indicated in Sections 3.3.2 and 5.1, significant ground-water inflow is not anticipated to occur during construction of the shaft. Hence, the natural rate of salt dissolution should not be adversely affected by repository development.

In the absence of impurity stringers and heat, salt has negligible permeability. In the presence of heat, brine migration occurs. Within crystals, the most probable mechanism of brine migration is thermal-gradient-induced migration of brine inclusions, in which salt dissolves at the hot interface, diffuses through the inclusion, and precipitates at the cooler interface (Jenks and Claiborne, 1981, ORNL-5818). The brine moves up the temperature gradient and stops at the crystal boundary. With steep enough temperature gradients, large brine inclusions can move across crystal boundaries, but it is thought that repository temperature differentials will be too small to drive this type of migration. Consequently, any significant movement of liquid brine from crystal boundaries towards the emplacement hole must take place through connected pores and microcracks. Such movements could result from pressure gradients, temperature gradients, capillary action along previously unwetted surfaces, and water vapor moving under vapor pressure gradients.

Jenks and Claiborne (1981, ORNL-5818) calculated maximum rates of brine migration to be about 250 milliliters (0.07 gallons) per year for packages of CHLW in bedded salt, with the total amount of in-migration during the first 100 years after emplacement to be about 25 liters (6.6 gallons).

Providing care is taken to locate the emplacement holes in good quality salt that contains a minimum amount of brine, impurities, and interbeds, brine migration should be limited to the immediate vicinity of the waste canisters. Hence, brine migration is not expected to have any significant effect on the physical environment.

The above discussion on brine inclusions does not consider brine pockets, relatively large volumes of entrapped brine found in some salt deposits. They have been accumulating in the intergranular spaces since the formation of the deposit. If present, they will be detected during the site investigation phase.

5.2.2 Hydrology

Repository construction activities will span about 7 years, divided among onsite development, shaft and facilities development, and subsurface development (Figure 5-6). The shafts will be constructed using conventional mining methods. The waste emplacement activities will be completed over an estimated 26 years. After a caretaker period the repository will then be decommissioned. The potential impacts of repository construction, operation, and decommissioning on surface-water and ground-water resources are discussed in the following sections. Detailed descriptions of these resources are presented in Section 3.3, Hydrologic Conditions at the Deaf Smith County Site. Detailed descriptions of the repository construction and operation are presented in Section 5.1, The Repository.

5.2.2.1 Surface Water

If surface-water quality is affected by repository development and operation, provisions of the Clean Water Act and the Texas Water Quality Control Law will be applicable. As such, determinations of compliance requirements will be subject to consultations with the U.S. Environmental Protection Agency and the Texas Water Commission. Consultations with the U.S. Army Corps of Engineers will also be necessary with regard to effects on navigable waters and wetlands. Repository development is not expected to affect the surface-water quality of waters in the site vicinity.

5.2.2.1.1 Construction. Ways in which water quality in Palo Duro Creek and playas could be degraded during repository construction include contamination from runoff from the site, or from deposition of windblown salt and subsequent runoff from salt-contaminated soils. However, the impacts on surface-water quality are not expected to be significant because of the mitigation measures discussed below. There will be no impacts to surface-water supplies near the site because all water requirements will be supplied by ground water from onsite wells.

Construction activities will not take place in the 100-year or 500-year floodplains of Palo Duro Creek and its tributaries, or in playas. Limited activity may occur in the 100-year and 500-year floodplains of Palo Duro Creek as a result of railroad spur construction. The U.S. Fish and Wildlife Service has been consulted on the identification, location, and extent of wetlands and floodplains in the vicinity of the site that may be protected under Executive Order 11990, "Protection of Wetlands" and Executive Order 11988, "Protection of Floodplains" (Neff, 1984a, b; Johnson, 1984). An assessment of impacts on floodplains and wetlands is presented in Section 5.2.4.4.

The repository surface facilities have been planned to fit the natural land contours as closely as practical to minimize erosion. Site grading will be done in such a manner as to minimize changes to the natural drainage and to prevent concentration of runoff on adjacent properties. Non-salt-contaminated runoff from the topsoil stockpile area, perimeter roads, and other areas will be collected in storm-water detention ponds (see Figure 5-3) which are sized for zero discharge runoff from a 100-year, 24-hour storm. Discharges will be within applicable water quality standards. Permits for these facilities may be required under Section 402 of the Clean Water Act (33 USC Sections 1344) and the Texas Water Quality Control Law (Texas (Water) Code Annotated, Section 26.001 et. seq.).

Salt-contaminated runoff from the mined materials storage area, the salt loading area, and internal roads will be impounded in the salt runoff pond (see Figure 5-3). The impounded water will evaporate or, if necessary, be removed from the pond and transported to a licensed disposal facility. Salt-contaminated runoff will not be discharged to the environment. If necessary, additional control measures for fugitive salt dust could include the use of water sprays during loading and unloading of excavated salt, use of baghouses at conveyor belt transfer points, and wetting of excavated salt during distribution at the storage areas (SCC, 1984a).

Salt emission at the site will result from salt pile wind erosion and salt handling operations (see Section 5.2.10). The maximum salt deposition from repository operations at 840, 1,050, and 1,300 meters (0.5, 0.6, and 0.8 mile) from the site is estimated to be 3.8, 2.1, and 1.3 kilograms per hectare (3.4, 1.9, and 1.1 pounds per acre) per year, under average meteorological conditions. These data are also expected to be valid for the repository construction phase. By way of comparison, the natural salt burden associated with irrigated farming can be estimated from water quality data for water wells near the site. The average sodium concentration of water from 22 wells in the Ogallala aquifer is 33 milligrams per liter; the average concentration of water from a well in the Santa Rosa aquifer is 238 milligrams per liter (TNRIS, 1985). For the years 1958 through 1979, annual water use for irrigated farming in Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). The lower application rate (3,350 cubic meters per hectare [1.1 acre-feet per acre]) of Ogallala water will add about 110 kilograms per hectare (100 pounds per acre) of sodium per year to the soil; Santa Rosa water applied at that rate will add about 800 kilograms per hectare (710 pounds per acre) of sodium per year. A deposition of 3.8 kilograms per hectare (3.4 pounds per acre) of salt per year to the soil from the site represents about 1 percent of the sodium deposited by irrigation using the lower salinity Ogallala water, assuming the lower application rates. Since this percentage is both small and conservative, impacts are not expected to be significant.

The area of greatest annual windblown salt deposition extends to the northeast from the repository. Overland flow from this area drains predominantly to three playas, one to the north, one to the northeast, and one to the east (Figure 3-2). The concentration of salt in the playa lake water will vary over the course of a year, and from year to year, due to variation in the amount of rainfall, evaporation, and infiltration. A forecast of the precise

quantity of salt that will accumulate in playas and of the salt concentration in playa lake water requires the collection of site-specific data during site characterization and their use in a mathematical water-quality model. The site specific data needed for model verification are not yet available. However, impacts are not expected to be significant, since when compared with the salt loading due to irrigation, the windblown salt load is small.

5.2.2.1.2 Operation. Effects on surface-water quality and supplies will be similar to those for repository construction. There will be no effect on surface-water quantity near the site because all repository water requirements will be supplied using ground water from the Ogallala aquifer.

5.2.2.1.3 Decommissioning and Closure. Reclamation activities are not expected to affect the surface-water quality in Palo Duro Creek or nearby playa lakes. Abnormal conditions that occur during site restoration, such as flooding or high winds, could transport sediments to some of these water bodies. However, most transported sediment will be retained on site by the runoff and retention ponds, which are discussed in Section 5.1.1 and which will be maintained throughout site restoration. When all salt not needed for backfilling the repository has been removed from the site and grading of the site is completed, the remaining erosion-control structures will be backfilled, compacted, and graded to be nonimpounding, self-draining, mechanically stable, and consistent with the elevation and relief of the surrounding topography.

5.2.2.2 Ground Water

An assessment of ground-water impacts of repository activities is provided in the following sections. The potential impacts, which are expected to be insignificant, are discussed for each of the following phases of repository development: construction, operation, and decommissioning and closure. Because subsurface injection of wastewaters is not planned, there are no anticipated impacts due to this activity at any repository phase.

5.2.2.2.1 Construction. Potential impacts on ground-water availability and quality in the Ogallala and Santa Rose aquifers near the repository are discussed below.

The water used for repository construction activities will total about 6.81×10^8 liters (180 million gallons or 552 acre-feet) (Table 5-1). The first-year water use, most of the water used during repository construction, will total 6.53×10^8 liters (172.5 million gallons or 529 acre-feet). The remainder will be used over the next six years. The water will be supplied from onsite wells in the Ogallala Formation.* For the years 1958 through 1979, the annual water use for irrigated farming in Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). The first year's water consumption at the 165-hectare (408-acre) site will be comparable on an annual basis to that needed to irrigate 126 to 195 hectares (311 to 481 acres). Over the subsequent six years, average water consumption at the site will be comparable to that needed to irrigate 1.2 to 1.8 hectares (2.9 to 4.5 acres). Domestic water consumed by in-migrant workers and their families is addressed in Section 5.4.3.

Pumping the onsite wells will cause a drawdown in ground-water level in the surrounding area. Where pumping wells are spaced relatively close together, pumping one well will cause a drawdown in the others. Drawdowns are additive, so the total drawdown in a pumping well is equal to its own drawdown plus the drawdowns caused at its location by other pumping wells. The drawdown in pumping wells caused by withdrawals from other pumping wells is referred to as interference (Heath, 1983, p. 44).

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*Well yields of 25 to 57 liters per second (400 to 900 gallons per minute) have been reported for wells completed in the Dockum Group in Deaf Smith County (Duffin, 1984, p. 25, 16). Consequently, the Dockum will be evaluated during site characterization to determine its suitability as a supplementary water supply.

The interference caused by pumping the two onsite wells was estimated using a ground-water model developed by Prickett and Lonnquist (1971, p. 8-19, 27-29). Pumping from nearby privately owned wells was not included in the model due to the unavailability of data. The onsite wells were assumed to be in the Ogallala aquifer. By the year 2030 the saturated thickness within the site is projected to range from 6.1 to 30.5 meters (20 to 100 feet) (Knowles et al., 1984, p. 81); it was assumed to be 18 meters (60 feet). The hydraulic conductivity and specific yield were estimated to be 10 meters (34 feet) per day and 0.16, respectively (Knowles et al., 1984, pp. 141 and 145). For a pumping rate of 6.53×10^8 liters (529 acre-feet) per year for the first year and 6.20×10^6 liters (5 acre-feet) per year for the subsequent six years, the maximum interference to a well 2.4 kilometers (1.5 miles) from the onsite wells is estimated to be about 0.1 meter (0.3 feet). Given the assumed saturated thickness of the Ogallala aquifer (18 meters [60 feet]), this maximum interference represents a change in saturated thickness of 0.5 percent.

Salt-contaminated runoff from the mined-materials storage area, the shaft-loading area, and internal roads will be impounded in the salt runoff pond. The storage area, the pond, and the ditches that convey salt-contaminated runoff from the internal roads to the pond will be constructed to minimize leakage. The storage area and the pond will have two impermeable liners to prevent seepage of salt-contaminated water into the ground. Lining brine ponds is commonly practiced in the salt industry and has proven effective and reliable in preventing seepage of brine into the ground. A monitoring system will be installed to monitor the integrity of the liner system. A system of perforated pipes will be installed between the liners beneath the storage area and the pond, to detect and collect any salt seepage. Thus, no significant seepage of salt-contaminated water into the ground-water system is expected.

If the impermeable liner system under stockpiled materials should fail, the saline leachate will flow downward through the unsaturated zone to the water table at a rate dependent on the soil characteristics and the presence of clay or caliche aquicludes. Infiltration studies at irrigated sites (Knowles et al., 1984, p. 23-26) have shown that the percolation rate and the wetting front filtration rate are highly variable on the High Plains. For the six counties near the site with infiltration data (Oldham, Deaf Smith, Randall, Castro, Lamb, and Floyd), the wetting front infiltration rate varies from 0.24 to 2.65 meters (0.8 to 8.7 feet) per year with a mean rate of 0.83 meter (2.7 feet) per year. This slow rate of percolation will permit timely corrective actions to be taken. Such actions will protect the water quality of the Ogallala and Santa Rosa aquifers by limiting the volume of leachate that enters the unsaturated zone.

Infiltration followed by deep percolation is the pathway by which windblown salt could affect ground-water quality in the Ogallala and Santa Rosa aquifers. This assumes that salt deposited on the soil surface is dissolved by rainfall or irrigation water and percolates down through the surface soils to the underlying Ogallala or Santa Rosa aquifers.

Most of the area is a flat plateau covered by fine textured soils. Pullman clay loam is the predominant upland soil type. It is characterized by a slow infiltration rate, less than 0.25 centimeters per hour (0.10 inch per hour), and a zone of calcium carbonate accumulation, or caliche, 1 to 2 meters (3 to 6 feet) below the soil surface (NUS, 1984, BMI/ONWI-510, p. 40). The presence of a caliche layer suggests that percolation rarely moves beyond the first few meters of soil. Field measurements of deep soil moisture on the Southern High Plains have shown this to be the case. Klemt (1981, p. 1-29) found that, with few exceptions, fields that had been irrigated 25 years or more showed evidence of deep percolation only to depths ranging from 6 to 10 meters (20 to 30 feet). With the exception of basin irrigated fields, deep percolation was not detected through the Pleistocene sediments overlying the Ogallala aquifer (Aronovici and Schneider, 1972, p. 71-73). The results of these studies indicate that windblown salt is not likely to affect ground-water quality when present in water that infiltrates upland areas.

Wood and Osterkamp (1984, p. 337-349) agreed with Theis (1937, p. 564-568) that the overall recharge rate to the Ogallala aquifer from rainfall is less than 1.3 centimeters (0.5 inches) per year. However, they proposed that most recharge of the Ogallala is through the annular zones immediately surrounding the playa floor. Thus, salt-contaminated runoff

that collects in playa lakes near the site could adversely affect ground-water quality in the Ogallala. Due to the unavailability of data, it is not possible at this time to quantify this effect. However, impacts are not expected to be significant, because when compared with the salt loading due to irrigation, the windblown salt load is small. The hydraulic characteristics in the saturated and unsaturated zone underlying a playa will be determined during the site characterization program. These data will be used to simulate the potential changes in ground-water quality as a function of time, and to develop mitigation measures as required.

Shaft construction techniques will be similar to those for site characterization, and activities will be essentially isolated from contact with potable ground water, at first by the freeze wall and the temporary shaft lining as construction proceeds through the Ogallala and the Dockum, and eventually by the permanent shaft lining as construction proceeds into the lower formations. (See Section 4.1.2.2.2 for a discussion of shaft lining.) In addition, if any localized ground-water flow in the immediate vicinity of the shaft construction should take place, this flow will be into, not away from, the shaft. Thus, there is not expected to be any mechanism by which potential contaminants associated with shaft construction could be transported away from the shaft and adversely affect ground-water quality.

Upward vertical flow around the shaft of saline water from the lower formations into the Ogallala and Santa Rosa aquifers is not expected to occur, primarily because the predominant vertical gradient in potentiometric levels is downward from the shallow fresh water system (Section, 3.3.2.1.1, Regional Hydrostratigraphic Units). Thus, regardless of whether or not any preferential pathways for ground-water flow are temporarily created around the shaft, it will be impossible under conditions of normal ground-water movement for any flow to be vertically upward. In addition, before shaft construction proceeds below the base of the Dockum, the permanent shaft lining and sealing systems, including seals around the shaft at the base of the Ogallala and the Dockum, will be in place. The integrity of these systems will be continuously monitored and corrective action taken if potential problems develop.

5.2.2.2.2 Operation. Potential impacts on ground-water availability in the Ogallala and Santa Rosa aquifers could result from pumping ground-water to supply repository water requirements. Potential impacts on ground-water quality could result from infiltration of salt pile runoff and windblown salt into the oil. However, these impacts are not expected to be significant due to circumstances, engineering practices, and mitigation methods, as discussed below.

Repository operation will consume about 9.3×10^9 liters (2.45 billion gallons or 7,520 acre-feet) of water. The water will probably be supplied from the Ogallala aquifer with the Santa Rosa aquifer as a potential supplementary source. All demands on ground-water resources from irrigation, municipal, manufacturing, and the repository, as well as use trends, will have to be considered in determining whether there will be an adequate water supply for all uses during the time the repository will be in operation. Over the life of the repository, changes in agricultural practices, the development of artificial recharge methods, and secondary recovery of capillary water could have a profound effect on ground-water availability in the area, consequently minimizing the competition among water users.

The estimated annual water use at the repository during the 26-year emplacement phase is about 3.57×10^8 liters (94.2 million gallons or 289 acre-feet). For the years 1958 through 1979, the annual water use for irrigated farming in Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). On an annual basis, water consumption at the 165-hectare (408-acre) site will be comparable to that needed to irrigate 69 to 106 hectares (170 to 263 acres). Domestic water consumed by in-migrant workers and their families is addressed in Section 5.4.3.

The interference caused by pumping the onsite wells was estimated using the same model and aquifer properties used in the interference analysis for repository construction phase (Section 5.2.2.2.1). For a pumping rate of 3.57×10^8 liters (289 acre-feet) per year for 26 years, the maximum interference to wells 2.4 and 4.8 kilometers (1.5 and 3.0 miles) from the onsite wells is estimated to be 0.67 and 0.2 meters (2.2 and 0.7 feet), respectively.

Potential impacts on ground-water quality from repository operation could result from infiltration of salt-pile runoff and windblown salt into the soil. The impacts are expected to be on the same order as the impacts experienced during construction, and thus are not expected to be significant.

5.2.2.2.3 Decommissioning and Closure. The water requirements for decommissioning and closure activities have not been established at this time. It is anticipated that the water will be obtained from wells in the Ogallala aquifer. Impacts on ground-water availability and quality will be similar to those experienced during repository operation, and thus are not expected to be significant.

5.2.3 Land Use

The following sections describe the impacts on land use in the county, site, and vicinity, and on affected farmers as a result of repository construction, operation, and decommissioning. The site represents the 2,333 hectare (5,760-acre) area required for the repository and its controlled area. The site vicinity is the area within a 10-kilometer (6.2-mile) radius of the site center, or approximately 313 square kilometers (121 square miles).

5.2.3.1 Construction

The construction of a nuclear waste repository at the Deaf Smith County site will involve clearing and grading land for suitable facilities and installation of access roads and utilities (see Section 5.1.2). The surface facilities will occupy about 165 hectares (408 acres) of land. In addition, the DOE will acquire the surface and subsurface rights for 2,169 additional hectares (5,352 acres). A further description of land acquisition methods is presented in Section 5.1.1.5.

Repository construction and the establishment of a controlled area will affect agricultural use of the land, hybrid sorghum seed production, irrigation of adjacent lands, cattle grazing, management practices to prime agricultural soils, and may deposit wind-blown salt on adjacent lands.

5.2.3.1.1 Displacement of Agricultural Land. From a county perspective, the impact of removing 165 hectares (408 acres) of land from its present use is anticipated to be small. However, as stated above, additional land area around the surface facilities will be controlled. Within the 2,333-hectare (5,760-acre) repository site are approximately 2,093 hectares (5,168 acres) of active cropland and 217 hectares (536 acres) of rangeland. The remaining 23 hectares (56 acres) are associated with playas or residential or commercial structures.

Under regulations established by the Nuclear Regulatory Commission (NRC) (10 CFR Part 60.121(a)), the DOE is required to acquire and control the geologic repository operations area and the controlled area. This area must be held free and clear of all significant encumbrances. Because it cannot be determined that the NRC would allow the DOE to lease land outside the restricted area for farming or other purposes, for this assessment it has been assumed that all 2,093 hectares (5,168 acres) of active cropland will be displaced from irrigated use. This will represent less than 2 percent of the cropland in the county and approximately 9 percent of the cropland in the site vicinity (23,036 hectares [56,879 acres] of active cropland are within the site vicinity). The amount of cropland in the county varies by 1 to 2 percent per year. The land to be withdrawn represents less than the normal variation in year-to-year plantings. Some of this idle cropland may be able to be brought into production to partially alleviate the total reduction in cropland. However, the imposition of a controlled area may displace land currently used to grow hybrid sorghum seed. (See Sections 5.2.3.4 and 5.4.1.4 for more discussion of mitigation; also see Section 5.4.2.2 for a discussion of the socioeconomic agricultural impacts.)

5.2.3.1.2 Disruption of Irrigation. Several levels of impacts on land use could result from the restriction of irrigation practices within the controlled area around the surface facilities. Irrigated farmland may have to be converted to dryland agriculture, thus changing

the types of crops that can be grown on these farms. Wells that supply water for irrigation may have to be relocated. See Sections 5.2.3.4 and 5.4.1.4 on mitigation.

The amount of water used for repository construction is not expected to significantly affect irrigation on farmlands adjacent to the site. Drawdown from repository wells is also not expected to significantly affect nearby irrigation wells (see Section 5.2.2).

5.2.3.1.3 Cattle Grazing. Farmers graze cattle on harvested fields and areas of rangeland within the site and vicinity. Grazing will not be permitted within the restricted 165-hectare (408-acre) site and may be restricted within the controlled area.

5.2.3.1.4 Farm Management Practices. Farm management practices may be altered if the restricted area divides a particular farm. As stated previously, irrigation and cattle grazing will not be permitted in the restricted area. In addition, aerial application of pesticides outside the restricted area may have to be regulated in order to ensure repository worker health and safety. Sections 5.4.1.4 and 5.2.3.4 discuss mitigation measures to lessen the impact on farm management practices.

5.2.3.1.5 Disruption of Prime Agricultural Soils. As stated in Section 3.4.1, approximately 82 percent of the land on the site had been classified as prime agricultural land. If all surface uses are precluded on the entire 2,333 hectare (5,760-acre) protected area, a total of 1,902 hectares (4,696 acres) of prime agricultural land will be unavailable for agricultural use. This represents about 8 percent of the prime agricultural land within the site vicinity and less than 1 percent of the 263,231 hectares (649,917 acres) classified as prime agricultural land within the county. Prime farmland around the Deaf Smith County site that is not in agricultural use could help to offset any prime farmland that may be used for repository purposes. The DOE has filed Form AD 1006 with the Soil Conservation Service and has evaluated the effect of the repository on prime farmland in compliance with the Farmland Protection Policy Act (7 USC Sections 4201-4209). Soil-protection measures (Section 5.2.1.1) and reclamation activities will be undertaken to minimize impacts to prime agricultural lands (Section 5.2.3.4).

5.2.3.1.6 Salt Deposition. Salt stored on site during repository construction will be deposited by wind on adjacent croplands. However, based on the low predicted deposition rate of 3.8 kilograms per hectare (3.4 pounds per acre) per year presented in Section 5.2.5, no significant effects on crop productivity are anticipated. Section 5.4.2.2 discusses socioeconomic impacts on potential agricultural disruption.

In addition, based on examination of salt-management practices and results under a variety of conditions at the Retsoff Mine, Texasgulf's Potash Mine, Potash Corporation of America's Canadian Mine, as well as Project Gnome and WIPP (Parsons-Redpath, 1984), no apparent changes in offsite land use was found. It is reasonable to expect similar results in Deaf Smith County.

Transport of salt and salt-contaminated materials during rail transport is not expected to affect land use along the routes because various enclosures and dust collection equipment will be used to reduce airborne particulates (see Section 5.1.3.4). A further discussion of potential landfills that may accommodate waste salt and its impacts are presented in Sections 4.2.1.1.3 and 5.3.5.

5.2.3.1.7 Access and Utilities. Construction of a paved access road from FM 2587 will disrupt 3.7 hectares (9.1 acres) for every 1 kilometer (1.61 miles) of length. Most of this disturbance is expected to occur on agricultural land. In addition, existing roadways may have to be upgraded to handle increased loads (Section 5.3.2). This could result in disruptions to adjacent land users.

Six different rail corridors have been identified as potential rail alignments (see Section 5.3.2). These rail corridors have been selected to minimize disruption to land use. However, some disruption and displacement of agricultural land and rangeland may occur, particularly if any rail spur bisects a field.

Construction or installation of utilities will temporarily disrupt existing land uses. The disturbances will be short-term and confined to a relatively small area for the time necessary to dig a trench and bury the natural gas and water lines. An electric transmission line will also have to be installed; it will parallel the section lines and railroads, if possible. Attempts will be made to avoid any pivot irrigation systems in order to minimize disruption to land use.

5.2.3.1.8 Indirect Effects. The indirect or secondary effects of repository construction will extend beyond the site and Deaf Smith County. A maximum in-migrating population of about 2,520 people (including construction workers and family members) is expected. Most of these people (60 percent) are expected to settle in Amarillo; about 25 percent are expected to reside in Hereford (see Section 5.4.1 for further detail). This may result in an expansion of these urban areas and create additional nearby residential development, which will require the conversion of land now used for other purposes such as agriculture or rangeland.

5.2.3.2 Operation

The repository operation will occur for 50 years and will continue to preempt other land uses at the site and vicinity for that time. The surface facilities will occupy 165 hectares (408 acres), and no land use other than those associated with the repository will take place. If allowed by the NRC, the controlled area may be usable for agricultural purposes, including cattle grazing (see Section 5.4.2.4 on agricultural impacts).

The access road and railway will also continue to preempt land use during repository operations. This may also pose a barrier to cattle grazing and some farm management practices.

However, since no new land will be disturbed as a result of repository operations, the repository operation phase is not expected to disrupt land use and practices to the degree experienced by the repository construction phase.

Annual water consumption due to repository operation is estimated to be equivalent to the amount of water required to irrigate 69 to 106 hectares (170 to 263 acres) (Section 5.2.2.2.2). This is less than the amount of water that will be used if the site remained in irrigated agriculture.

Salt will be stored on site during repository operation. Salt storage and disposal are expected to have little impact on agricultural lands. Most salt deposition will occur within the restricted area. Using the description of salt deposition presented in Section 5.2.5, no significant alterations to the agricultural patterns are expected (See Section 5.4.2.4 for socioeconomic effects resulting from agricultural impacts).

As the repository begins and continues operation, it is expected that other industries and commercial establishments will locate in the region to support both the facility and the population increases in the nearby communities. Any increase in industrial and commercial activity will result in further population growth, which will necessitate the conversion of land from current to urban purposes. Section 5.4.1 discusses expected amounts and locations of residential expansion.

This may create land-use patterns in and around the urban areas that may not have occurred if the repository were not constructed and operated.

5.2.3.3 Decommissioning and Closure

Decommissioning the repository will involve dismantling the surface facilities, the railroad spur, and most access roads, and the construction of the permanent monuments and markers, as discussed in Sections 5.1.4 and 5.1.5. These activities will temporarily disrupt land use adjacent to the areas being decommissioned. Any disruption is expected to be less than that required for construction. A long-term plan will be developed to determine the types of land uses permissible following decommissioning. The site will be restored to as near original

conditions as is feasible. The land disturbed for repository surface facilities and access routes will be cleared, graded, and revegetated. The salt pile area will be reclaimed, with topsoil, and restored. Salt will be backfilled. Any salt waste not backfilled will be transported and disposed to a licensed landfill (see Section 4.2.1.1). Restrictions on subsurface activities in the controlled area will continue indefinitely.

5.2.3.4 Mitigation

The DOE will consult with land owners affected by repository construction, operation, and decommissioning to minimize, as far as practicable, disruption to their use of the land. In addition to compensating owners for land acquired for the repository, a mitigation plan will be developed to assist affected landowners and to minimize land impacts. Section 5.4.1.4 describes mitigation measures in more detail.

The DOE will consult with these landowners prior to ESF construction. The relatively long duration from ESF construction to repository construction will facilitate the development of an effective mitigation strategy.

The application of recognized procedures for reconditioning disturbed soils within the repository site is expected to return the affected acreage of prime agricultural land back to near its original agricultural status. Section 5.2.1.1 further discusses the impacts of soil disturbances.

A long-term monitoring program will be developed and initiated during repository construction and continue through decommissioning. This program will focus on identifying changes in land use in the site vicinity and any changes in soil salinity. Mitigation measures will be applied as appropriate.

5.2.3.5 Cumulative and Long-Term Impacts

Repository development should have relatively few cumulative or long-term effects on land use. Some amount of land may be indefinitely controlled by the DOE. Salt impacts on crop productivity are not expected to significantly alter the agricultural land-use patterns (also see Section 5.4.2.4). No subsurface activities will be allowed within the 2,333-hectare (5,760-acre) controlled area, precluding future resource development. Section 5.2.1.2 examines mineral impacts.

Land-use patterns in the area of the repository may be different from those that would have occurred if the repository had not been constructed. The growth that may result from the repository could result in the conversion of agricultural land to urban uses. In addition, urban land-use patterns may also be affected by the repository. Growth and expansion of urban areas near the site may occur more quickly than if the repository were not present. (Also see Section 5.4 on socioeconomic effects.)

5.2.4 Terrestrial and Aquatic Ecosystems

This section contains an evaluation of the potential effects of repository construction, operation, and decommissioning and closure on the terrestrial and aquatic ecosystems and associated biota of the proposed site. The analysis is based primarily on preliminary design, presented in Section 5.1, and on regional biological information, presented in Section 3.4.2. Results of future detailed site studies outlined in Section 4.1.3.1.2 will aid in the quantification of the effects described below.

5.2.4.1 Terrestrial Biota

The Deaf Smith County site is located in the Southern High Plains of the Texas Panhandle, a region largely devoted to intensive crop agriculture and cattle grazing. Natural ecosystems of the regions are generally confined to the Caprock Escarpment; unmodified playa wetlands; and ungrazed areas along drainageways, fencerows, shelterbelts, and prairie dog colonies. Construction of the surface facilities for the repository is expected to remove approximately

168 hectares (408 acres) of land from present use. In that part of the region containing the site, cropland, grazed rangeland, or ungrazed rangeland may be affected. Site layout will take into consideration the avoidance of impacts to sensitive ecosystems. With respect to the region, removal of cropland or rangeland for purposes of repository development will not be ecologically significant.

5.2.4.1.1 Construction. Ecological impacts of repository construction will depend on the types of vegetative cover and associated species of flora and fauna at each location. Important wildlife species found in the cropland and rangeland habitats of the site that are likely to be affected by repository construction include gamebirds such as mourning doves, ring-necked pheasants, and waterfowl using grain fields. Individuals of these species, which are protected under the Migratory Bird Treaty Act (16 USC 703-711), are more likely to be displaced than destroyed. Long-term impacts to populations will be insignificant because wetland habitats (which are more important to these species) will not be destroyed or adversely affected. Large areas of cropland, which is primarily feeding habitat, will remain unaffected by repository development.

Development of the repository in natural or seminatural areas will eliminate existing plant communities and wildlife habitat within the construction zone until the site is decommissioned and restored. Soil removal and grading will destroy most or all of the plant cover. Sedentary wildlife (primarily soil macrofauna, small mammals, and reptiles) will be destroyed, whereas mobile species (such as large mammals and birds) can relocate. Displaced wildlife will compete for resources with organisms in undisturbed areas, leading to additional ecological adjustments and potential mortality. Minor impacts, including potential behavioral changes, are expected from blowing dust, vehicle emissions, vehicle movements, loud and unexpected noises, lighting, and the general presence of humans. The biota affected will be primarily those remaining within close proximity to the construction sites.

Approximately 3.4 million metric tons (3.7 million tons) of salt will be generated and stored on site for up to 26 years. Windblown salt particles will be dispersed from the exhaust of subsurface mining operations and surface handling. The stabilized surface storage pile is not expected to contribute to windblown salt because of the rapid crusting characteristic of salt in the environment. Dispersion modeling of salt deposition suggests that maximum rates of deposition will be 3.8 kilograms per hectare (3.4 pounds per acre) less than 0.8 kilometers (0.5 miles) from the source. Deposition rates fall off rapidly from that point (see Section 5.2.10.2).

Although salt deposition will be practically unmeasurable beyond the 2,331-hectare (5,760-acre) controlled area, vegetation within this area may exhibit some symptoms of salt stress over the life of the repository. Plants exposed to elevated salt levels are affected by (1) osmotic inhibition of water absorption, (2) alteration of mineral nutritional balances in plant tissue, and (3) toxicity of specific ion concentrations, particularly sodium and chloride. Actual plant stress could be either cumulative or a combination of these mechanisms. Environmental conditions, including moisture, temperature, and time of day, also influence the effects of salt. Vegetation with a low tolerance for salt is most likely to be adversely affected. Maas and Hoffman (1977) show that, in general, grasses tend to be more tolerant than broad-leaved plants. This subject is discussed in more detail in Section 5.2.10.2.4.

Any potential loss of habitat through salt damage or other repository construction activities will be reviewed in consultation with the U.S. Fish and Wildlife Service (USFWS) under the Fish and Wildlife Coordination Act (16 USC 661-666c). The DOE will continue such consultations with the USFWS to develop appropriate measures for reducing or mitigating potential habitat loss. The DOE will also work with the USFWS to identify and mitigate any impacts to bald and golden eagles pursuant to the Bald and Golden Eagles Protection Act (16 USC 668-668d). The known range of these raptors is within the vicinity of the repository site.

Other impacts resulting from the development of linear corridors supporting site operations (railroad spur, transmission line, access road additions upgrades, and possible water and gas pipelines) may be anticipated. These are discussed in detail in Section 5.3.2.

5.2.4.1.2 Operation. The principal ecological impacts of repository operation are expected to be relatively minor and to occur throughout the 26-year lifetime of the facility. Possible impacts from deposition of windblown salt particles from salt transfer and handling will be similar to those experienced during the construction phase. These impacts will probably be measurable only on site, depending on deposition rate and susceptibility of species present. Some vehicle-wildlife collisions are expected throughout repository operation.

An influx of repository workers into the region will lead to an increase in demand on regional recreational resources, including game species. The USFWS will be included in discussions on development of mitigation measures to reduce impact on migratory birds. Since the majority of the region is privately owned, hunting opportunities may become more limited. Illegal shooting of wildlife could also increase, although education programs will likely reduce this potential. Increased demands will also occur on the nonconsumptive uses (e.g., observation) of wildlife at such places as Palo Duro Canyon State Park and Buffalo Lake National Wildlife Refuge. The refuge, which is 35 kilometers (22 miles) from the site, is the closest federal wildlife refuge to the repository site.

5.2.4.1.3 Decommissioning and Closure. Repository decommissioning will include site restoration and revegetation. The revegetation plan described for restoration of test facilities will also apply to the repository site (Thomas, 1984). Revegetation using native species may eventually result in a relatively natural shortgrass prairie ecosystem providing habitat for numerous species. Long-term protection of the site could provide similar protection of flora and fauna, which could become a valuable local natural resource.

Restoration of the access routes and facilities may result in a return to prerepository land uses. Protected rights-of-way that had become natural habitats during repository operation could either remain as such or be removed by the landowners for use as cropland or rangeland.

5.2.4.2 Aquatic Biota

5.2.4.2.1 Construction. As indicated in Section 3.4.2, aquatic resources found on or in the vicinity of the site consist of ephemeral streams and playa wetlands. Both features generally contain water only following precipitation. At such times, they become ecologically important to many species as temporary breeding grounds and sources of food and water.

Construction of the repository will have relatively little impact on aquatic biota, in that siting has been planned to avoid any areas, such as playas or floodplains, that may result in the repository flooding during major precipitation events. Reference site design indicates that all runoff from the construction site will be contained on site in runoff retention basins (Section 5.1.1). Thus, the potential sources for contaminated runoff or sediments will not be interconnected with any known surface water. Since ground water will be used to supply the estimated 681,300 cubic meters (180 million gallons) of water required for construction, existing surface water sources will not be affected.

Prior to construction of the repository, the USFWS and the Texas Parks and Wildlife Department will be further consulted under the Fish and Wildlife Coordination Act (16 USC 661-666c, 1979) to determine whether construction activities would adversely affect sensitive wetland habitat and associated biota. Playa lakes associated with the site may be affected by repository activities, and may be subject to terms of this act. In addition to consultations with the USFWS, wetland assessments will be performed, if necessary, to achieve compliance with 10 CFR Part 1022 (Floodplain/Wetlands Environmental Review Requirements). The DOE is prepared to perform other activities in order to comply with provisions of this act.

Construction of the corridors for the railroad spur, access roads, transmission lines, and pipelines may result in potentially adverse effects. It is likely that several of the corridors will cross stream valleys and encounter playas along the routes. The exact routes ultimately selected will have a direct bearing on the magnitude of any adverse impacts. Section 5.3.2 presents a description of several alternative corridors along with an assessment of the potential impacts of corridor development. Among the criteria for identifying a

corridor was the avoidance of ecologically important wetlands. During site characterization studies, several playa and riparian wetlands will be surveyed using established field techniques, for example, the USFWS Habitat Evaluation Procedures (See Section 4.1.3.1.2). Such studies may serve as a basis for conducting a floodplains-wetland assessment under 10 CFR Part 1022.

Depending on environmental conditions, local wetlands and aquatic habitats can be valuable to a wide variety of plants and wildlife (see Section 3.4.2). If unmodified by plowing or grazing, wetlands can be sources of native vegetation. They also provide food, water, and shelter for important wildlife such as waterfowl, upland gamebirds, raptors, and small game mammals. Site characterization studies, along with discussion with the USFWS and the Texas Parks and Wildlife Department under the Fish and Wildlife Coordination Act and the Migratory Bird Treaty Act, will be used to determine optimal times to schedule construction activities to avoid or minimize adverse effects.

Three types of retention ponds (for a total of six ponds) have been planned for the repository, including a treated wastewater holding pond, a basin to collect incidental salt pile runoff, and four storm-water retention ponds. All ponds are expected to be lined, which would minimize vegetation growth, and none of the ponds could support a population of fish. The ponds could, however, support periodic populations of invertebrates, making them potential sources of insect pests. It is conceivable that the storm-water retention pond could be attractive to wildlife, especially waterfowl, but the pond will get little use due to the lack of food sources and the general intensity of human activities on the site.

5.2.4.2.2 Operation. Because runoff will be controlled on site, no impacts to aquatic ecosystems are expected from either contaminated runoff or sedimentation. Airborne salt originating from the spoils pile could affect surface water in the vicinity, although projected deposition rates described in Section 5.2.10.2 will be practically unmeasurable at the nearest wetland or aquatic habitat to the repository site. Since ground water sources are expected to supply the estimated 9.3 million cubic meters (2.45 billion gallons) of water for repository operations, surface water sources will not be affected.

It is probable that operation of the repository will have a more indirect impact on aquatic ecosystems. Seeking recreational opportunities, repository workers and their families may contribute to the increasing demand for regionally important recreational fisheries, particularly at Lake Meredith, Lake MacKenzie, and various other reservoirs. Stocking programs conducted by the Texas Parks and Wildlife Department may attempt to meet such demand as long as both ecological and recreational carrying capacities of regional reservoirs are not exceeded.

5.2.4.2.3 Decommissioning and Closure. Repository decommissioning will involve site restoration and revegetation. Sediment basins will continue to be maintained during decommissioning to avoid offsite contamination. Due to the relatively flat terrain, such effects are not anticipated to be serious. Removing structures from the various corridors could also result in impacts on aquatic ecosystems at points of crossing. The timing of such restoration could be important in minimizing adverse impacts.

5.2.4.3 Threatened and Endangered Species

The presence of species protected under the Endangered Species Act of 1973 (16 USC 1531-1543) will be confirmed during site characterization studies (described in Section 4.1.3.1.2). If, in continuing discussions with the USFWS, it is determined that repository development may adversely affect a protected species, the DOE will initiate appropriate measures to avoid the impact.

5.2.4.3.1 Construction. No threatened or endangered species of flora or fauna are expected to be affected by repository construction, operation, or decommissioning because no preferred habitats exist within the site (see Section 5.2.4.3). No federally designated critical habitats exist either in the vicinity of the repository site or in the region (50 CFR Part 17.95).

Natural areas along the proposed linear corridors may provide suitable habitat for various species protected under the Endangered Species Act of 1973 (16 USC 1531-1543), the Bald and Golden Eagle Protection Act (16 USC 668-668d), and Endangered Species and Other Protected Wildlife (Texas Parks and Wildlife Code Annotated, 64.001 et seq., 68.001 et seq., and 88.001 et seq.). Although the probability of encountering such species is low, future site-specific ecological studies will confirm their presence and susceptibility to construction impacts. In the event protected species are encountered, the DOE will consult with the USFWS and the Texas Parks and Wildlife Department to develop appropriate measures for avoiding adverse impacts.

5.2.4.3.2 Operation. Any threatened or endangered species present in the vicinity of the site at various times of the year will be susceptible to repository impacts described in Section 5.2.4.1 above. Appropriate avoidance measures will be developed in consultation with the USFWS and the Texas Parks and Wildlife Department. Operation of the access and utility corridors will not adversely affect protected species.

5.2.4.3.3 Decommissioning and Closure. Any natural ecosystems that result from site restoration and revegetation and that will remain protected could provide habitat for threatened or endangered species that might be present at various times of the year. No adverse impacts are expected.

5.2.5 Air Quality

Repository construction, operation, and decommissioning and closure activities will affect air quality as a result of earthmoving equipment, stationary and portable diesel-powered equipment, a concrete batch plant, a natural gas-fired steam plant, mine ventilation exhausts, salt handling activities and windblown dust. This section makes an assessment of the potential air quality impacts by a comparison with the appropriate National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50). Project-related emissions analyzed are particulates, oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and carbon monoxide (CO). To determine compliance with the appropriate NAAQS, particulate and NO_x emissions and their impacts are examined in detail. Estimated concentrations of SO_2 and CO, based on maximum annual emissions for these pollutants, are small relative to the respective NAAQS (NUS, 1985b). Consequently, SO_2 and CO are not considered further.

5.2.5.1 Activities and Emissions

The repository project consists of three periods of activities: (1) construction, which includes the site clearing, surface construction, and underground development phases; (2) operations phase; and (3) decommissioning and closure. Summaries of particulate and NO_x emissions are presented in Tables 5-8 and 5-9, respectively, for the three construction phases and the operations phase (NUS, 1985b). These are the expected maximum annual emission rates based on available engineering descriptions (Sections 5.1.1 through 5.1.4). Source inventory has been changed since the modeling analysis discussed below was performed. The implications of these changes are evaluated in "Evaluation of Air Quality and Noise Impact Assessments - Deaf Smith County" (ONWI, 1986). Although small differences exist, conclusions remain as stated.

5.2.5.1.1 Construction. The primary source of particulate emissions during the three repository construction phases is earthmoving activity, which creates fugitive dust. Particulate emissions from engine exhaust are included in the earthmoving fugitive dust emissions rates. Maximum annual particulate emissions are 246 metric tons (271 tons) per year which occur during the site-clearing phase. As the repository site is developed, emissions from earthmoving activities become progressively less. At the same time, as shown in Table 5-8, other sources of particulate emissions become active. During the subsurface development phase, emissions of salt particulates occur from load-in and maintenance of the salt storage pile, and from two mine-vent exhausts. Particulate emissions due to wind erosion from disturbed areas of the site and from active areas of the salt storage pile are not included in Table 5-8 but are considered in estimating project-related impacts. The determination and application of these emissions is discussed further in Section 5.2.5.2.

Table 5-8. Maximum Repository Particulate Emission Rates (tons per year)

Source	Site Clearing[a]	Surface Construction[b]	Underground Development[c]	Operation[d]
Earthmoving fugitive dust	271	78	67	21
Concrete batch plant	0	15	10	0
Material handling	0	10	10	3
Salt handling[e]	0	0	15	15
Mine vent exhaust[f] (Salt)	0	0	1	9
Mine vent exhaust[f] (diesel)	0	0	0	1
Steam plant	0	0	7	7
Total	271	103	110	56

Note: Emissions from the concrete batch plant, the two mine vent exhausts, and the steam plant are considered to be point sources. All other sources are considered to be area sources.

(a) Maximum emission rate occurs during Year 1.

(b) Maximum emission rate ocurs during Year 3.

(c) Maximum emission rate occurs during Years 5, 6, and 7.

(d) Maximum emission rate occurs during Years 8 through 26.

(e) Estimate due to salt dumping and equipment working on the pile.

(f) Emissions presented are total mine vent exhaust emissions and are apportioned as follows: 36 percent of the emissions are from the confinement air exhaust stack; 64 percent are released from the unexposed air exhaust filter building.

Source: NUS, 1985b.

Table 5-9. Maximum Repository Oxides of Nitrogen Emission Rates (tons per year)

Source	Site Clearing[a]	Surface Construction[b]	Underground Development[c]	Operation[d]
Steam plant	0	0	100[e]	100[e]
Diesel Equipment, Vehicles	388	440	426	49
Mine vent exhaust[f]	0	0	0	20
Totals	388	440	526	169

Note: Emissions from the two mine vent exhausts and the steam plant are considered to be point sources. Vehicle emissions are considered to be an area source.

(a) Maximum emission rate occurs during Year 1.

(b) Maximum emission rate occurs during Year 3.

(c) Maximum emission rate occurs during Years 5, 6, and 7.

(d) Maximum emission rate occurs during Years 8 through 26.

(e) Calculated at 100 percent utilization and for conventional burners. Newer design burners would decrease emissions to about 50 tons per year; expected utilization will decrease emissions further, to about 20 tons per year.

(f) Emissions presented are total mine vent exhaust emissions and are apportioned as follows: 36 percent of the emissions are from the confinement air exhaust stack; 64 percent are released from the unexposed air exhaust filter building.

Source: NUS, 1985b.

Maximum erosion potential from disturbed areas is expected to occur during the site-clearing phase and decrease as the site is developed. During the underground development phase, wind erosion is expected to be minimal because of the presence of many surface structures and equipment laydown areas which would act as wind breaks. Furthermore, revegetation and paving of most of the remaining exposed areas is planned. Maximum erosion potential from the salt pile is expected from the actively developed areas of the pile, beginning during the underground development phase and lasting about 5 years. Wind erosion of the small salt pile remaining after site characterization is expected to be negligible because the pile will be covered.

NO_x emissions increase slightly during the three phases of repository construction due to increased vehicle and mobile equipment activity. Maximum annual NO_x emissions occur during the underground development phase with the initiation of steam plant operations (see Table 5-9).

5.2.5.1.2 Operation. Particulate emissions during the operations phase are similar to those of the underground development phase except that earthmoving equipment fugitives are minimal (see Table 5-8). Wind erosion of disturbed areas is expected to be negligible. Wind erosion will be reduced by the presence of many surface structures and equipment laydown areas which act as windbreaks. Furthermore, revegetation and paving of most remaining exposed areas is planned. Wind erosion from active areas of the salt pile would occur until the pile is filled to capacity, probably in the first year or two. The pile would be covered thereafter. NO_x emissions are noticeably less during this phase primarily due to decreased vehicle and mobile equipment activity (see Table 5-9).

5.2.5.1.3 Decommissioning and Closure. Particulate emissions during decommissioning will result from earthmoving equipment, stockpile removal, transport of salt, and fracturing of concrete structures and other facilities. Impacts from decommissioning activities are not modeled. Water sprays will be used to contain fugitive dust during decommissioning; disturbed areas will be reclaimed as described in Section 5.1.4.1. It is anticipated that these activities can be scheduled, and emissions controlled to the extent necessary to prevent exceedances of the NAAQS.

Particulate and NO_x emissions are expected to be insignificant during repository closure and they are not modeled.

5.2.5.1.4 Mitigation. The mitigation measures for fugitive dust and mobile NO_x emissions discussed in Section 4.2.1.3.1 will be utilized during the repository phases. For fugitive dust, the control program has a goal of 90 percent, to be accomplished primarily by the application of water and chemical suppressants to disturbed areas and haul roads. Additional controls may be applied such as speed controls on earthmoving vehicles and haul trucks, paving of haul roads, minimizing the size of disturbed areas, and covering of storage piles. Control of NO_x emissions from diesel exhaust will be as required of manufacturers by federal regulations. Inspection and maintenance of these controls by contractors will be a project requirement.

Mitigative measures are required to reduce the amount of particulate salt emissions associated with the salt storage pile. Salt will be conveyed from the service shaft to the pile in a totally enclosed conveyor transfer system. Salt pile load-in emissions will be reduced by using a wind guard to minimize the drop height of salt through the free air. Wind erosion emissions from the salt pile will be reduced by the natural crusting tendency of salt (Ver Planck, 1958). Crusting will be promoted by daily watering of the pile. Inactive areas of the salt pile will be covered (e.g., with dirt or asphalt). The application of these control measures is accounted for in the modeling of TSP and salt deposition impacts (NUS, 1985). After the salt pile is filled to design capacity, hauling of excess salt to offsite disposal areas will require load-in of railcars and trucks. These activities will occur in enclosed areas. Transport vehicles will be covered.

5.2.5.2 Methodology

The EPA Industrial Source Complex Dispersion Model (ISC) (Bowers et al., 1979) was used to predict the atmospheric concentrations of TSP and NO_2 and the deposition of salt particles around the site area. ISCST (short-term) was used to estimate 24-hour average TSP concentrations. ISCLT (long-term) was used to estimate annual average TSP and NO_2 concentrations and total annual salt deposition. The rationale for selecting this model, the meteorological input data, and the background TSP and NO_2 concentrations for determining air quality impacts (62 and 20 micrograms per cubic meter, respectively) are discussed in Section 4.2.1.3.2.

Emissions during the site-clearing and operations phases (Table 5-8), were used to model 24-hour and annual TSP impacts. Emissions during the subsurface development and operations phases (Table 5-9) were used to model annual NO_2 impacts. The site-clearing and subsurface development phases represent the periods of maximum expected impacts during the repository phases for TSP and NO_2, respectively.

Emissions during the operations phase (Table 5-8) were used to model annual salt deposition rates around the site area. Similar impacts are expected during the subsurface development phase as discussed below.

5.2.5.2.1 Construction. Particulate emissions during site clearing were modeled as area sources (NUS, 1985b). On a 24-hour basis, fugitive emissions due to earthmoving and related activities were assumed to occur over a disturbed area of 40 hectares (100 acres) on any given day (10 hectares [25 acres] are considered to be actively scraped and compacted; the remaining 30 hectares [75 acres] are less active with hauling and related equipment activities). For modeling purposes, a nominal repository site area of 163.8 hectares (405 acres) was represented by a square 1,280 meters (4,200 feet) on a side. Wind erosion emissions were assumed to occur over the entire repository site area, which implies the entire site had been previously disturbed. Wind erosion was assumed to occur only when the wind speed at the eroding surface exceeded the threshold of 19 kilometers (12 miles) per hour.

On an annual basis, both earthmoving and wind erosion fugitive particulate emissions were assumed to occur over the 163.8-hectare (405-acre) modeled area as site clearing activities progress during the year.

Wind erosion emissions from disturbed areas were calculated using a predictive emission factor equation (EPA, 1978). The emissions are a function of surface erodibility, soil silt content, precipitation - evaporation index, and wind speeds above the threshold value given above.

The ISC model requires input of a particle size distribution to account for the variable effects of deposition in estimating both concentrations and total deposition. The distribution used in these analyses is adapted from the results of fugitive dust measurements at western surface coal mines and is discussed in NUS (1985b). This distribution was used for all sources of particulate emissions (fugitive dust and salt).

Annual NO_x emissions from mobile sources were assumed to occur over the 163.8-hectare (405-acre) modeled site area during the subsurface development phase. The steam plant was modeled as a buoyant, elevated point source (NUS, 1985b).

5.2.5.2.2 Operation. Particulate emissions were modeled as a combination of area and point sources (NUS, 1985b). On a 24-hour basis, emissions due to vehicle movement and materials handling activities were assumed to occur over the 163.8-hectare (405-acre) modeled repository area. Salt handling emissions were modeled as an area source and assumed to occur over 10 percent of the total surface area of the salt pile (or about 2 hectares [5 acres]), on any given day. This represents a reasonable estimate of the active area over which freshly loaded salt may be moved as the pile is built and the area which would be subject to wind erosion. The remainder of the pile will be either covered or undeveloped. Mine vent exhausts from the confinement and unexposed air exhaust filter buildings were modeled as point sources. Salt and particulate emissions were combined and apportioned to each of the mine vent exhaust

points as discussed in Table 5-8. The steam plant was modeled as a buoyant, elevated point source.

Annual particulate emissions from these sources were modeled in the same manner except for salt handling and wind erosion of the active salt pile area. Emissions from these sources were assumed to occur over 20 percent of the total surface area of the salt pile; this represents one-fifth of the 5-year period required to fill the salt pile to capacity.

Wind erosion emissions from active areas of the salt pile were calculated using a predictive emission factor equation for active storage piles (EPA, 1983). The emissions are a function of silt content, the frequency of precipitation, and wind speeds above the threshold value of 19 kilometers (12 miles) per hour at the eroding surface.

Annual NO_x emissions from the steam plant and from mine vent exhausts were treated as point sources. Table 5-9 describes the apportionment of emissions between the two mine vent exhaust points. NO_x emissions from vehicle exhausts were assumed to occur over the 163.8-hectare (405-acre) modeled repository area (NUS, 1985b).

5.2.5.3 Air Quality Impacts

This section addresses the results of the air quality modeling analyses. Additional details appear in NUS, 1985b.

5.2.5.3.1 Regulatory Review. The primary criterion in determining Prevention of Significant Deterioration (PSD) applicability is whether a facility is a "major source" of criteria air pollutants. The sources of particulate and NO_x emissions discussed earlier are not included in the list of 28 major stationary sources subject to an emission limitation of 100 tons per year. To be considered a major source, project-related stationary source emissions would have to be greater than 227 metric tons (250 tons) per year (40 CFR 52.21[b][1]).

Stationary sources of particulate emissions during repository construction and operation include the concrete batch plant, the mine vent exhausts, and the steam plant. All other particulate emissions are from mobile sources or are fugitive emissions and are, therefore, not considered in the major source determination (see 40 CFR 52.2303 and 40 CFR 52.21[b][iii]).

Stationary sources of NO_x emissions during repository construction and operation include the steam plant and mine vent exhausts. All other NO_x emissions are due to mobile sources. Table 5-9 indicates that stationary emissions reach a maximum of 109 metric tons (120 tons) per year during repository operation and are less during all other phases.

The DOE concludes that the repository project is not subject to Federal PSD requirements because stationary source emissions do not exceed the threshold limit of 227 metric tons (250 tons) per year (40 CFR 52.21[b][1]).

In the interpretation of the modeling results presented below, air quality impacts are considered to be significant if the NAAQS are exceeded, i.e., those ambient concentrations which "... allowing an adequate margin of safety, are requisite to protect the public health" and those levels which "... are requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants in the ambient air" (EPA, 1971).

5.2.5.3.2 Uncertainities. Prior to discussing modeling results, it is important to point out that there are uncertainties in the air quality impact analysis associated with particulate emission rates. Emission factors, particle size distributions, and control factors used to estimate particulate emission rates are drawn from the published literature. While the DOE considers that these data are the best available for use in the impact analysis, the DOE recognizes that there are uncertainties inherent in their use. For example, fugitive dust emission factors are based on limited measurements at other locations and for other types of earth-moving activities where natural soil characteristics such as silt and moisture content are different from those existing at the site. Particle size distributions from

studies of western coal mines were used for both fugitive dust and salt emissions. Dust control efficiency values (50 percent using water application and vehicle speed limits, and 90 percent using chemical suppressant application and vehicle speed limits) can involve sizeable errors. The DOE believes the values used herein are achievable with a well designed and carefully conducted mitigation program. Uncertainties inherent in emission rate estimates have not been quantified; they could result in either higher or lower air quality impacts.

5.2.5.3.3 Estimated Concentrations. The highest and second-highest 24-hour TSP concentrations off site were estimated. The second-highest offsite values are reported as maximums for comparison with the 24-hour NAAQS, which are not to be exceeded more than once per year. The EPA recommends the use of the highest offsite 24-hour TSP concentrations for comparison with the applicable NAAQS standard whenever one year of meteorological data is used (as opposed to the second highest value when five years of data are employed). This comparison is presented in "Evaluation of Air Quality and Noise Impact Assessments - Deaf Smith County" (ONWI, 1986). It will be seen in that report that the conclusions presented here remain unchanged as a result of that comparison. The highest annual offsite concentrations of TSP and NO_2 are also reported. "Offsite" refers to points at or beyond the controlled area boundary (CAB), as presented in Figure 5-2.

Maximum offsite 24-hour TSP, and annual average TSP and NO_2 concentrations are summarized in Table 5-10. Total concentrations representing the sum of incremental concentrations plus background values identified in Section 3.4.3.1 are presented.

The results indicate that the primary and secondary 24-hour NAAQS for TSP, and the annual NAAQS for TSP and NO_2 will be met during repository construction, operation, and decommissioning and closure. On this basis, DOE concludes that the repository project will not have a significant impact on air quality.

5.2.5.3.4 Estimated Salt Deposition. Annual salt deposition rates were calculated using the ISCLT (long-term) code as discussed in Section 5.2.5.2. The results indicate that the higher deposition rates occur to the north and northeast of the repository site. The maximum annual deposition rate, 3.4 pounds per acre per year, occurs about 0.8 kilometer (0.5 mile) from the center of the repository site, just beyond the site boundary. Deposition values decrease to about 1.9 and 1.1 pounds per acre per year at distances of about 1.0 and 1.3 kilometers (0.6 and 0.8 mile) from the center of the site. Between 0.8 and 1.6 kilometers (0.5 to 1.0 mile), maximum deposition values decrease by a factor of 5. A similar decrease is observed between 1.6 and 3.2 kilometers (1.0 and 2.0 miles). Impacts resulting from these deposition rates are discussed in Section 5.2.10.

A qualitative evaluation has been made of the potential effects on the dispersion of salt from a tornado striking the salt storage pile. The amount of salt transported by a tornado would depend on the size, intensity, and speed of the tornado, state or condition of the salt pile, and threshold velocity at which salt aggregate would be lifted from the pile.

In the Deaf Smith County site area, the recurrence interval for a tornado striking any point is once in 7,400 years (see Section 3.4.3.3). Considering that the salt pile will be developed to capacity in about 5 years, and will be covered thereafter, the likelihood of a tornado damaging the pile is small. However, should such an event occur, maximum deposition may occur anywhere from 10 to 60 kilometers (about 6 to 37 miles) downwind of the site (BPNL, 1979, DOE/ET-0029). Point deposition values within this area may be significantly greater than the maximum annual deposition rate reported above for normal meteorological conditions.

5.2.6 Aesthetic Conditions

This section contains a discussion of the potential impacts on the visual character of the landscape from introduction of large structures and associated development in the Deaf Smith County site and vicinity. Potential project facilities affecting aesthetic conditions include waste-handling facilities, mine-support facilities (head frames, salt storage piles, ventilation exhaust, and supply buildings; utilities and utility-support facilities (see Section 5.1). A preliminary inventory of aesthetic resources has been conducted. However, a

Table 5-10. Air Quality Impacts During Repository Construction and Operation at the Deaf Smith County Site

Pollutant	Averaging Time	Location	Maximum Concentrations (micrograms per cubic meter) Construction	Operation	NAAQS (micrograms per cubic meter)
TSP	24-hour	CAB[a]	135[b]	74	260/150[d]
TSP	Annual	CAB	68[b]	63	75
NO_2	Annual	CAB	33[c]	22	100

Note: Background TSP value is 62 micrograms per cubic meter. Background NO_2 value is 20 micrograms per cubic meter.

(a) Controlled Area Boundary.

(b) Site Clearing Phase.

(c) Subsurface Development Phase.

(d) Primary standard/Secondary standard.

Sources: NUS, 1985b; 40 CFR Part 50.

detailed site-specific inventory of aesthetic resources will be conducted during site characterization to provide a basis for determining specific impacts of repository development. The inventory will be conducted using a combination of U.S. Forest Service and Bureau of Land Management methodologies.

5.2.6.1 Construction

Repository construction activities will involve excavating, grading, and storing materials and transporting workers, equipment, and supplies. Increased dust, storage piles, supply and equipment dumps, and construction traffic will have an impact on visual resources. A brief description of these activities and their degree of impact follows.

The storage pile for salt will cover 22.5 hectares (55.5 acres) to a height of 11.8 meters (38.6 feet). This pile will be visible within the site vicinity (the 10-kilometer [6.2-mile] radius surrounding the site) and from FM 2587. This visual disruption, however, is expected to be minor because the piles will not be visible beyond the 10-kilometer (6.2-mile) radius of the site and because few motorists travel FM 2587. Similarly, three engineered retention ponds, with a total area of about 16 hectares (39.3 acres), will cause only minor visual disruption to the area due to their low profile.

Visual intrusion from increased dust, construction of rail and utility lines to the site, and equipment and supply transport to the site will probably affect viewers over an area larger than site vicinity. These intrusions, however, will exist only for a short while.

5.2.6.2 Operation

The repository features will markedly contrast with the existing farmsteads and other elements of the agricultural landscape. Because of the size of some of the structures and the flat terrain, viewers within a few miles of the site will be affected. The waste packaging facility, for example, will be 262 meters (860 feet) long, 131 meters (430 feet) wide, and up to 21 meters (70 feet) high. Shaft head frames will range in height from 15 meters (50 feet) to 81 meters (265 feet). An FAA-approved safety light will be installed on structures with a height greater than 61 meters (200 feet). These facilities will be visible to motorists on I-40, U.S. 385, Texas Highway 214, and FM roads 2587 and 1412 as background objects on the horizon. Residents within the 10-kilometer (6.2 mile) radius of the site will also view these facilities as background (or larger) objects on the horizon.

The storage pile and ponds developed in the construction phase will remain on the site throughout the period of repository operation. Parking areas, access roads, and utility corridors will, however, be virtually unnoticeable. The new power lines are on 15-meter (50-foot) double poles spaced 152 meters (500 feet) apart (see Figure 4-8 for a typical power line). These power lines will cause some visual impact, appearing as dark lines on the horizon.

The operation of a railroad will intrude on the existing agricultural landscape. The rail corridor will be developed on open agricultural land and rangeland. It will parallel FM 1057 and may be elevated above the natural terrain. The railroad may be visible from at least 1.6 to 3.2 kilometers (1 to 2 miles), but the visual impact will be minimal and similar in nature to the landscape alteration of a new two-lane highway.

Plumes of steam associated with the small, industrial-type cooling towers are expected to be visible under certain atmospheric conditions. However, operating experience with wet mechanical-draft cooling towers of this type has shown that these plumes seldom persist for any great distance downwind. Thus, they should have minimal visual impact.

The visual impacts of night lighting will be determined from field studies. (See Section 4.1.3.1.7). Directional lighting will be used to minimize visibility of the light in the surrounding area. Impacts of lighting from perimeter fences will be minimized by using infrared lighting and television monitors.

Repository operation will have significant long-term visual impact on people within the 10-kilometer (6.2 mile) radius of the site. The impact on the larger populations outside that area, however, will be minor.

5.2.6.3 Decommissioning and Closure

After final emplacement of nuclear waste containers, the repository will be decommissioned and closed. All structures including meteorological towers and shaft-head frames will be dismantled and transported off site, and the landscape will be graded and revegetated to blend with the surrounding topography. Transportation and utility facilities may be decommissioned or converted to other uses.

The actual closure activities will be of short duration and thus have minimal visual impact. Postclosure features will include markers or monuments, and a small building to be used as a monitoring station (see Section 5.1.5). A monitoring station may have a minimal to moderate impact on the Deaf Smith County site, and the impact of the monument or marker will be dependent on the final design or method selected for the passive prevention barrier.

5.2.7 Noise

This section discusses noise impacts from repository construction, operation, decommissioning, and closure activities. Criteria selected for assessing noise impacts are discussed, followed by a summary of the noise modeling methodology, a description of potential construction and operation noise impacts, and possible mitigation measures.

5.2.7.1 Noise Criteria

As discussed in Section 4.2.1.6, two types of community-noise impact indicators are employed in this environmental assessment. The first indicator is energy-equivalent day/night sound level, L_{dn} (EPA, 1974). "Percent highly annoyed" is used as the second indicator (Schultz, 1978). More details concerning the application of these criteria and their interpretation are found in Section 4.2.1.6.1.

The EPA has not promulgated any community noise regulations pursuant to the Noise Control Act of 1972 as amended by the Quiet Communities Act of 1978 (42 USC Sections 4901-4918). The act requires Federal agencies to comply with State and local noise regulations. There are no local, State, or Federal regulations which specify limits for acceptable environmental sound levels at this site. In accordance with the EPA guidelines (1974) discussed in Section 4.2.1.6.1, noise levels are assumed to be acceptable when L_{dn} values are below 55 dBA at noise-sensitive receptors such as residences, schools, churches, and parks (see Section 3.4.4 for a description of L_{dn}). DOE believes this to be a conservative criterion since measured background L_{dn} values in Deaf Smith County exceed 40 dBA with levels between 40 and 50 dBA being typical (Section 3.4.4).

5.2.7.2 Methodology

Sound levels at nearby residences were estimated using a noise-level prediction model, SOCON-5 (NUS, 1985d). Details of the model and modeling assumptions are presented in Section 4.2.1.6. Source inventory, including traffic volume, has been changed since the modeling analysis discussed below was performed. The implications of these changes are discussed in "Evaluation of Air Quality and Noise Impact Assessments - Deaf Smith County" (ONWI, 1986). Although small differences exist, conclusions remain as stated. Sound-power levels for standard equipment without noitse control were adjusted to reflect the hours per day of operation and typical time of day at various loads. Although the locations of some equipment will vary during construction and operation, the movement of equipment was not modeled. Sources contained within buildings were not included in the estimated sound levels since the sound reduction effects of the buildings would be expected to reduce the contribution of these sources to below existing sound levels off site (NUS, 1985d). An ambient L_{eq} value of 35 dBA for daytime and nighttime periods, corresponding to an L_{dn} of 41 dBA, was assumed in the sound level calculations. In general, the analysis is expected to overestimate sound levels since

attenuation from vegetation, barriers, and engineered mitigation for the sources has not been considered.

Estimates of L_{dn} values for each traffic route were made using published methods (BBN, 1977, pp. C-29 through C-40). The existing ratio of trucks to cars on each route was estimated from traffic counts taken during the summer and winter sound-level surveys (NUS, 1984, BMI/ONWI-528, pp. 11-14; 1984, BMI/ONWI-526, pp. 10-16).

Estimates of L_{dn} values for rail operation were made using methods developed by Swing and Pies (1973, p. 3-24 through 3-42).

It is believed by the DOE that the noise modeling carried out in this section was based on the best available meteorological data, the latest literature on sound emission levels, and the state of the art of noise modeling techniques. However, uncertainties do exist in this modeling and are caused largely by the following:

- Uncertainties in sound emission levels to approximately $\pm$ 5 dB
- Consideration of wind and temperature gradient effects on noise propagation. Unfavorable gradients (when occurring) can significantly increase noise propagation toward a given receptor whereas favorable gradients can significantly reduce such impacts.

The accumulated effects of these uncertainties can be large at any point and at any time outside the site boundary.

5.2.7.3 Noise Impact

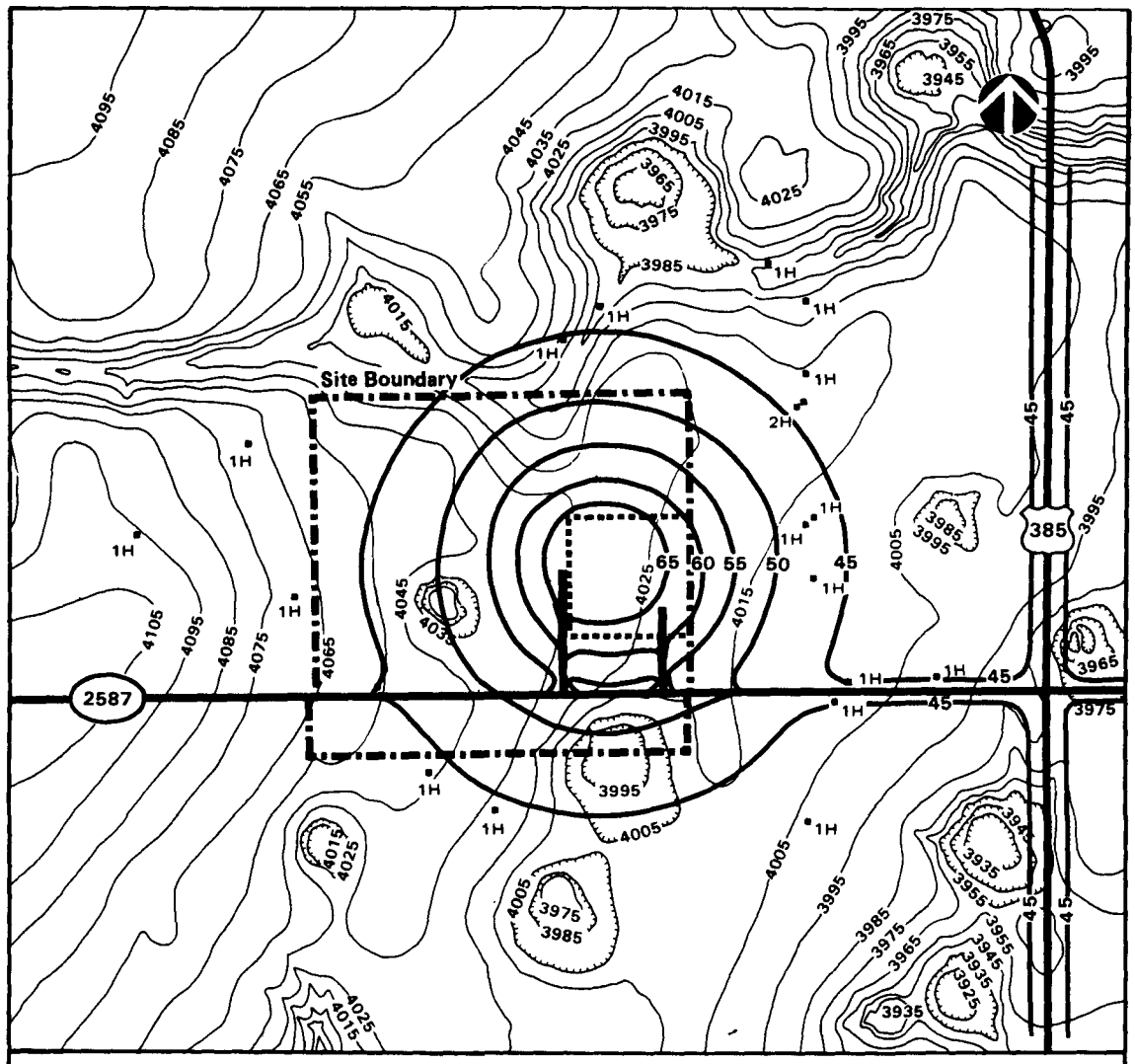
Potential noise impacts from repository construction, operation, and decommissioning and closure are discussed in this section. The discussion in Section 4.2.1.6 of impacts from tonal noise also applies to the repository.

5.2.7.3.1 Construction. Construction activities will occur in the following three phases: (1) site preparation, (2) surface and shaft construction, and (3) underground development. A schedule for these activities is shown in Figure 5-7. The noise impact of activities during surface and shaft construction was determined to have the greatest potential for causing noise impact during repository construction. Types of equipment used during repository construction are similar to those for exploratory-shaft construction (see Section 4.1.2). Estimated L_{dn} sound levels are shown in Figure 5-16. Residences located near the site constitute the only noise-sensitive land use likely to be affected by construction of the repository. The nearest residence to the repository site is located 2.8 kilometers (1.7 miles) east of the ventilation supply shaft shown in Figure 5-1. The estimated L_{dn} value at the nearest residence is 47 dBA (NUS, 1985d), which meets the EPA L_{dn} 55 dBA guideline for prevention of interference with outdoor activities for residential areas. No noise-sensitive receptors, such as schools and churches, lie within the L_{dn} 55 dBA contour.

Comparison of this predicted L_{dn} value with Schultz's (1978) correlation, or with percentages of the population highly annoyed, suggests that, although an increase in L_{dn} value of 6 dBA may be experienced, residents are not likely to be highly annoyed. In addition, estimated sound levels at the nearest residence for all phases of construction activity are below the L_{eq} 70 dBA EPA guideline for prevention of hearing loss.

Noise impacts from other repository construction phases will be less than those predicted for the surface construction phase modeled. The schedule for these activities is given in Figure 5-7.

The construction of the rail line will extend the area of activity beyond the site boundaries. Although noise levels from rail construction have not been modeled, an estimate of impacts may be made on the basis of the expected equipment inventory. The amount of equipment is less than that associated with site construction; therefore, the extent of the impact



Explanation

1H / 1T — Nearby Residence; H = House; T = Trailer

L_{dn} Sound Levels	Community Reaction "Percent Highly Annoyed"
L_{dn} = 45	0
L_{dn} = 50	0
L_{dn} = 55	3
L_{dn} = 60	8
L_{dn} = 65	15
L_{dn} = 70	24

Source: NUS, 1985d.

0 1 3 Kilometers

0 1 2 Miles

Deaf Smith County Repository Construction
L_{dn} Sound Levels (dBA)

Figure 5-16

is expected to be less. Areas exceeding L_{dn} 45 dBA are expected within 0.6 kilometer (0.4 mile) on either side of the rail construction. Areas exceeding L_{dn} 55 dBA are expected to extend less than 0.3 kilometer (0.2 mile) on either side of the rail construction.

Blasting will not be required for the first 8 to 15 meters (25 to 50 feet) of shaft sinking. Noise from blasting below this depth will be reduced by the sinking stage platform as shown in Figure 4-9. Blasting noise is not expected to be audible at nearby residences and cumulative adverse health effects to the general public due to impulsive noise are not anticipated. Perceptible ground vibration from blasting is not expected at nearby residences.

During surface construction, increases in sound levels from traffic will occur along access roads. Existing and expected traffic volumes during repository construction are discussed in Section 5.3.3 (see Table 5-23). As shown in Figure 5-16, a 1-dB increase over existing values of L_{dn} is expected within 120 meters (400 feet) of FM 2587 during this phase. During the construction phase when there is peak traffic activity a 2-dBA increase is expected in L_{dn} values at 120 meters (400 feet) from the road along FM 2587.

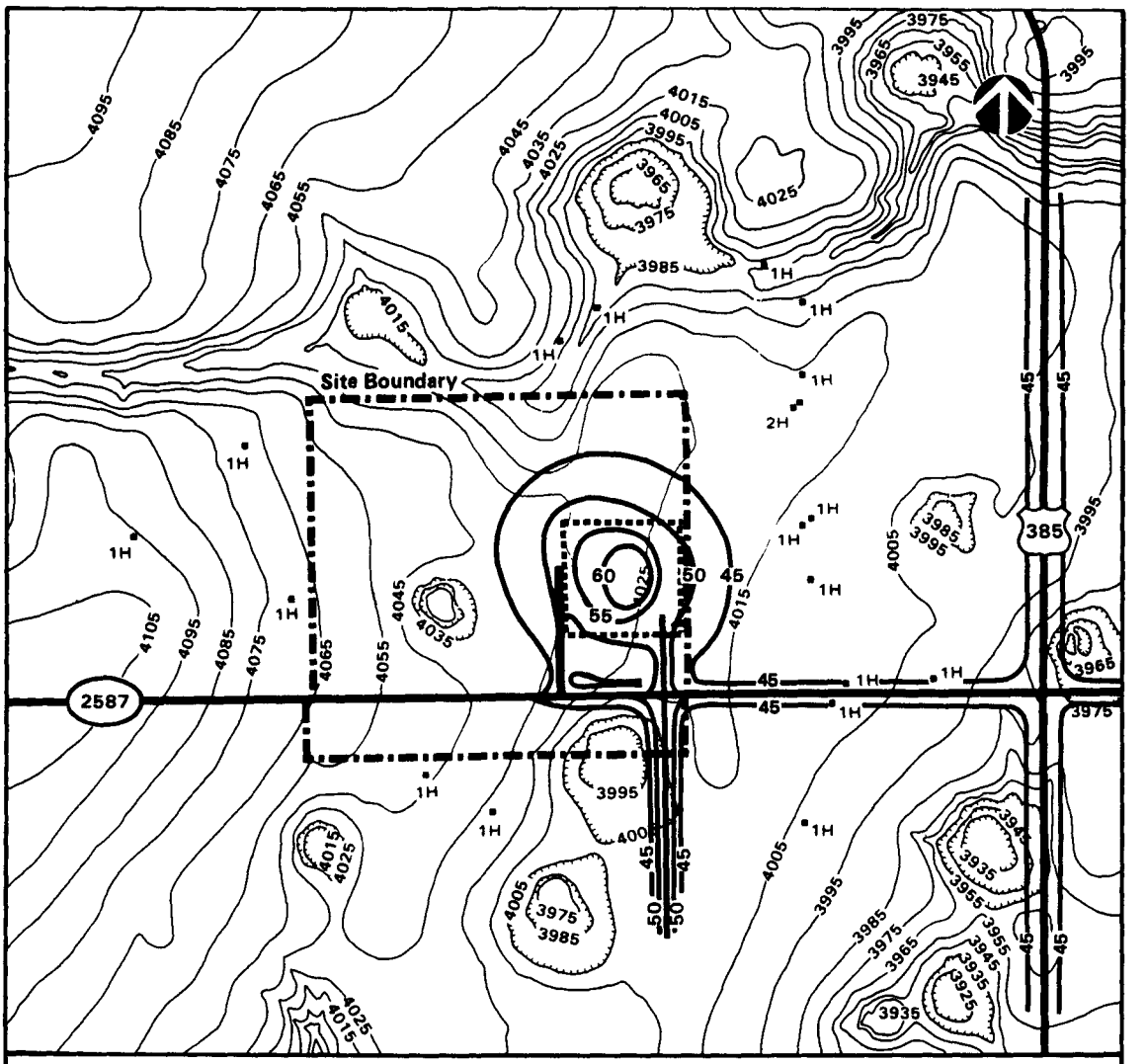
In summary, during repository construction there is a potential for noise impacts during the initial 3 years of surface construction when, for a short period, residents living within 0.3 kilometer (0.2 mile) of rail construction may be exposed to noise levels which exceed the EPA L_{dn} 55 dBA criterion. A few residents may be highly annoyed depending on the rail route chosen. Noticeable increases in sound levels will occur along the access roads during shift changes throughout repository construction. Noise impacts during other repository construction phases will be less than those for surface construction.

5.2.7.3.2 Operation. Equipment and activities modeled for repository operation are described in Section 5.1.3. These activities include onsite salt handling, railroad operations, project traffic along access roads and highways, and railroad operations along a representative rail corridor. Area sound levels near the repository, along access roads, and along the rail spur will increase during repository operation. Major noise sources are the steam plant, locomotives, cooling towers, and material-handling equipment.

Estimated energy-equivalent day and night sound level, L_{dn}, from repository operation is 42 dBA at the nearest residence (see Section 5.2.7.3.1). No sensitive receptors (such as schools and churches) lie within the L_{dn} 55 dBA contour. L_{dn} contours are shown in Figure 5-17 (NUS, 1985d). Estimated sound levels at nearby residences do not exceed either the EPA L_{eq} 70 dBA guideline for prevention of hearing loss or the L_{dn} 55 dBA EPA guideline for prevention of activity interference. There is little likelihood for residents to be highly annoyed by sound levels during repository operation.

Infrequent railcar coupling noise will result in maximum sound levels which are less than 45 dBA at the nearest residence. Except for occasional railyard operation, no impulsive noise sources are expected during repository operation.

Increases in sound-levels will occur along the access roads and the railroad spur during operation of the repository (Figure 5-17). Existing traffic volumes and the traffic volumes expected from repository operation are discussed in Section 5.3.3 (see Tables 5-26 and 5-27). A 1-dBA increase over existing L_{dn} values along FM 2587 at 122 meters (400 feet) is expected during repository operation. Noticeable increases in traffic noise at residences along the access road and FM 2587 can be expected during peak traffic periods (shift changes). Operation of two trains per day (four trips) along the railroad (see Table 5-26) will result in L_{dn} values of 55 dBA at 60 meters (200 feet) and 45 dBA at 250 meters (800 feet) from the railroad. Sound levels are shown for a representative rail route in Figure 5-17 and would be similar for other rail corridor options. Most rail corridors pass through sparsely populated rural areas although some pass through small communities (see Figure 5-9). Since neither the rail corridor nor the right-of-way within the 1.6-kilometer (1-mile)-wide corridor has been selected, no residences can be identified within the noise impact area. Actual impacts will depend on the rail corridor selected and the width of the right-of-way.



Explanation

1H / 1T	Nearby Residence H = House T = Trailer

L_{dn} Sound Levels	Community Reaction "Percent Highly Annoyed"
L_{dn} = 45	0
L_{dn} = 50	0
L_{dn} = 55	3
L_{dn} = 60	8
L_{dn} = 65	15
L_{dn} = 70	24

Source: NUS, 1985d.

0 1 3 Kilometers

0 1 2 Miles

Deaf Smith County Repository Operation
L_{dn} Sound Levels (dBA)

Figure 5-17

In summary, these are the potential noise impacts during repository operation:

- Minor increases in L_{dn} sound levels from traffic (less than 1 dBA increase beyond 122 meters [400 feet])
- Noticeable increases in sound levels along access roads during shift changes
- Noticeable increases in sound levels along the rail route when the train passes.

5.2.7.3.3 Decommissioning and Closure. Noise caused by decommissioning and closure of the repository has not been modeled. It is anticipated that these activities can be scheduled and sound power levels controlled such that the sound levels will not exceed those identified for repository construction.

5.2.7.4 Noise Impact Mitigation

The preceding noise analysis assumes that no special measures are used to mitigate noise impacts from repository construction and operation activities. Mitigation of noise is technically possible but is not considered necessary, since impacts from onsite activities are expected to be acceptable. Noise impacts from railroad construction can be mitigated, if necessary, by the use of "residential" grade exhaust silencers on construction equipment, resulting in a noise reduction of up to 10 dBA. Additional mitigative measures may include the following:

- Contract provisions which enforce the use of factory-equipped noise control equipment
- Selection of equipment which minimizes any audible tonal components
- Selection of right-of-ways and buffer zones along transportation corridors.

5.2.8 Archaeological, Cultural, and Historical Resources

This section assesses the impacts that construction, operation, and decommissioning and closure may have on cultural resources.

5.2.8.1 Construction

There are no recorded archaeological or historical sites within the site (NUS, 1984, BMI/ONWI-560); therefore, no direct impacts on recorded archaeological sites or historical locations and structures are anticipated as a result of repository construction. In addition, no direct impacts to Indian religious sites are expected as a result of repository construction (Section 4.2.1.8).

The principal cultural resources that might be disturbed during repository construction are those archaeological and historical resources that are not recorded, but which may be located where construction activities take place. Sensitive areas include playa dunes, stream slopes, and bottom lands. The site and access corridors encompass some of these sensitive areas. The site is also located in an area thought to be a major trail used by Comancheros, Ciboleros, and Pueblo traders. Ground disturbances associated with construction activities could disrupt any unrecorded archaeological site located within the 165-hectare (408-acre) area designated for surface facilities. Any construction activity that would occur in the surrounding area could also disrupt unrecorded archaeological resources. This includes construction of access roads and the installation of utility lines.

Surveys will be performed in consultation with the State Historic Preservation Office (SHPO) to identify all unrecorded sites within the repository surface area. A qualified archaeologist will monitor construction activities to assure that no unexpected resources are disturbed until their significance can be determined. Mitigative measures, including excavation, salvage operations, and avoidance, may be required for any resources identified in the intensive survey.

Indirect or secondary impacts to cultural resources will result primarily from increased visitation to historic sites and community activity centers. Increased traffic along existing roads and through the towns of Hereford and Vega could result in additional noise and restricted access in the vicinities of these sites and centers.

5.2.8.2 Operation

No additional land areas will be disturbed during repository operations, and therefore, no direct impacts to cultural, historic, or archaeological resources are anticipated. However, indirect impacts to cultural resources could result from increases in traffic, population growth, and commercial activity. These indirect impacts would be identical to those discussed in Section 5.2.8.1, except that anticipated growth would fluctuate less during the project's operational phase.

5.2.8.3 Decommissioning and Closure

Although the existence of significant cultural resources is unlikely, decommissioning and closure of the repository have the potential to adversely impact cultural resources if a new area is disturbed. Direct impacts may result from placing peripheral markers around the perimeter of the controlled area, creating earthworks, and placing redundant warning symbols in the soil around the repository. Before land-altering activities are started outside the restricted area, surveys will be conducted to locate and evaluate cultural resources in areas of potential impact.

Potential indirect impacts associated with the number of decommissioning personnel involved are similar to those for construction and operation. Possible adverse impacts can be mitigated through the use of an employee education program or other site protection measures.

Because the 165-hectare (408-acre) area designated for repository surface facilities would already have undergone ground disturbances associated with construction, direct impacts to cultural, historic and archaeological resources associated with repository decommissioning are not expected.

5.2.9 Radiological

As with exploratory shaft development (see Section 4.2.1.9), repository construction and operation will result in releases of radon and daughter products to the environment. The rate of release and attendant level of impact would depend principally on the rate at which salt was mined from the repository, and the content of radioactive elements in the salt. During site characterization, the radioactive content of the salt formation will be precisely measured, and an estimate of radon impact on the environment will be made.

The dose consequences of operational releases are assessed in Section 6.4.1. No repository-associated radon impacts are expected during repository closure and decommissioning, because no additional salt will be mined.

5.2.10 Impacts of Salt Management and Disposal

This section summarizes the potential environmental impacts associated with the management of salt and salt-laden rock during repository construction, operation, and decommissioning, as well as measures for mitigating those impacts. The discussion is presented in three parts: (1) the management practices are described in the context of their potential for releasing salt to the environment; (2) measures for mitigating the impacts from these sources are discussed, and the basis for assessing the impacts are described; (3) the options for permanently disposing of the excess salt are identified and described.

5.2.10.1 Salt Management and Control

The repository development will involve mining, handling, transport, onsite storage, reuse and disposal of salt and salt-laden rock (see Section 5.1.3). The discrete elements of

this salt management process, each element's potential contribution to an overall salt emission, and likely mitigation measures for each source point are illustrated in Figure 5-18.

Repository development requires the excavation of corridors and waste emplacement rooms within the salt deposits. Salt excavated during repository construction will be brought to the surface for both immediate offsite disposal and stockpiling for backfilling during decommissioning. Salt excavated during repository operation will be transferred from the development area directly to the emplacement area for use as backfill. Excess salt will be hauled to the surface for offsite disposal. The quantities of excess salt produced during construction, operation, and decommissioning are presented in Table 5-5.

Mined salt is lifted to the surface via a skip and transferred by covered conveyors either to the railcar loading facilities for transfer off site or to the salt storage pile. Emissions of salt to the atmosphere occur at the outlet of the mine ventilation system and at the point of transfer of the mined salt to the surface transport vehicle. Saline water, from either the salt control devices or as storm runoff, will be collected and conveyed to the evaporation and retention pond.

Although the surface transfer systems will be covered, small losses may occur along the haulage route. These will be collected as saline runoff and moved to the evaporation and retention pond.

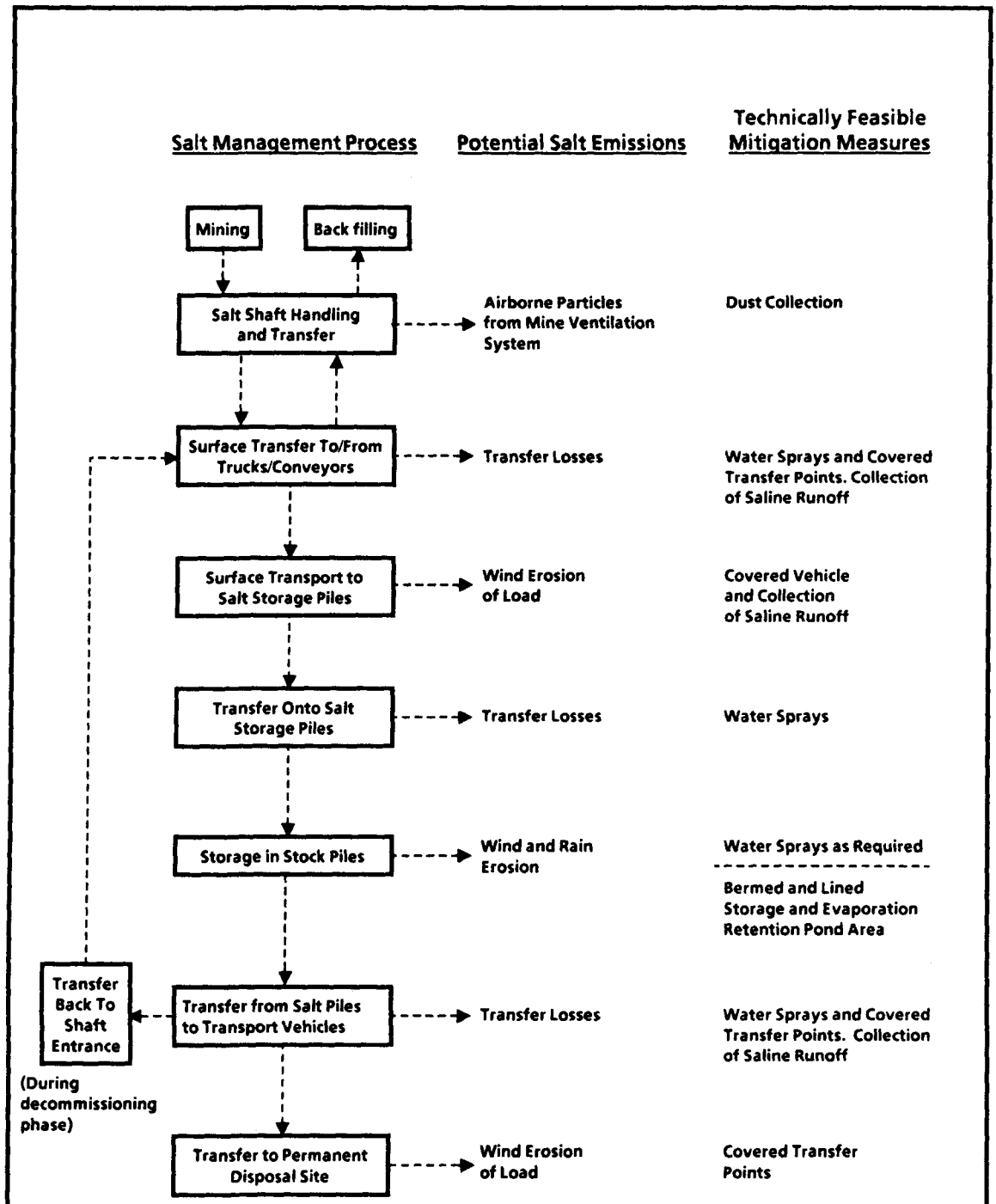
When salt is exposed to the weather or another source of moisture, a hard surface crust which tends to shed rain water forms in a few days (Ver Planck, 1958; DOE, 1983, WIPP-DOE-161; Section 5.1.2.3). According to the experience of the salt industry, stockpiled salt is not a source of windblown particles, and crusting can be accelerated by wetting the pile (Parsons-Redpath, 1984). The active areas of the salt storage pile will be kept moist as required to accelerate crust formation. Once the crust is established, further watering will not be necessary.

Possible leaching of brine from the evaporation and retention pond into the ground will be prevented by a double liner. These can be made of natural clays or synthetic materials (polyvinyl chloride, polyethylene, or polypropyl). A leachate collection system will be installed between the liners to monitor their integrity. The existing topsoil overburden will be stripped before emplacement of the liner and an engineered, sound subbase established. If a synthetic liner is used, an additional layer of compacted backfill material will be placed on top of the liner so that it can accommodate heavy equipment (Section 5.1.2.3).

Three major retention ponds will collect runoff from the shaft area, haul roads, and mined material stockpiles. In addition, water collected in the shafts sumps will be periodically pumped to the evaporation and retention pond. The salt-pile-runoff evaporation and retention pond will be designed for a operational volume equivalent to 100 percent of the rainfall volume from a 100-year, 24-hour storm falling on the areas which drain to the evaporation and retention pond (Section 5.1.2.3).

Project GNOME and the Waste Isolation Pilot Plant (WIPP) involved salt management practices similar to those that will be employed at the repository. The knowledge gained from those two projects, therefore, will be considered wherever appropriate (INTERA, 1978).

Activities associated with the December 1961 Project GNOME underground nuclear test resulted in a substantial volume of sodium chloride salt being excavated and stored on the site. The storage facility for the salt is an area of approximately 1.2 hectares (3 acres) enclosed by a dike and fence. The salt pile is stored inside the dike and fence but is otherwise open and exposed to the elements of the environment. The project GNOME test site is located approximately 48 kilometers (30 miles) southeast of Carlsbad, New Mexico. Soil samples and ecology surveys indicate that insignificant wind erosion and dispersion is occurring at the Project GNOME salt pile, and that there is little, if any, attendant adverse impact on the immediate surrounding environment due to salt dispersion by wind (INTERA, 1978).



Salt Management Flow Diagram

Figure 5-18

The Waste Isolation Pilot Plant (WIPP), presently under construction approximately 40 kilometers (25 miles) east of Carlsbad, New Mexico, will test the feasibility of storing nuclear defense wastes in salt. Excavated salt has been stored in an uncovered, unlined pile holding about 136,170 metric tons (150,000 tons) of salt. The pile is surrounded by a bermed ditch which collects and evaporates the precipitation which falls on the pile (average rainfall: 23 centimeters [9 inches] per year). The salt is crusted over, and rainfall does not penetrate the pile. No problems with wind dispersion of the stored salt have been experienced (DOE, 1980, DOE/EIS-0026; 1983, WIPP-DOE-161).

5.2.10.2 Impacts of Salt Management

Soil productivity, water quality, ecosystems, and land use can be affected by salt transported through air and water pathways. Assessment of the potential impacts requires identification and quantification of the various factors involved. For example, airborne salt can affect crop productivity through root uptake by the plants and through foliar deposition. In these cases, not only must deposition rates be estimated, but also irrigation rates, rainfall patterns, and the like must be considered. The airborne particulate deposition rates for the repository are predicted to be 3.8, 2.1, and 1.3 kilograms per hectare (3.4, 1.9, and 1.1 pounds per acre) per year at 840, 1,050, and 1,300 meters (0.5, 0.6, and 0.8 mile), respectively (Section 5.2.5). The highest deposition rate per unit area would occur within the fenced area and DOE-controlled areas.

The amount of salt dispersed by a tornado would be limited by the crustation and reconsolidation of the salt storage pile and, therefore, would affect only the working face of the pile. The probability of a tornado strike to the site is addressed in Section 5.2.5.

In the following sections, factors are identified for each category of impact, and numerical values are provided to the degree that current information allows. Knowledge gained during characterization will be used in repository design and the planning of operating procedures.

5.2.10.2.1 Impacts on Soils. Soils on site and in the site vicinity are generally rated as Prime Native by the Texas State Office of the Soil Conservation Service (Williams, 1984). This implies that they have the physical and chemical properties necessary to produce consistently high yields of those crops suited to the climate of the area. The agriculturally important soils in the area are described as moderate- to fine-textured, deep, moderately to slowly permeable, and having a high volume of calcium carbonate in the subsoil. The subsoils are generally fine-textured and limit drainage. Soil salinity that affects crop yields is a combination of many factors, including the ratios of cations such as sodium, calcium, and magnesium to each other, the mineralogy of the clays in the soil, the amounts and ratios of soluble salts in irrigation water, soil drainage related to soil structure and permeability, and the nature of the anions present in both soil and irrigation water (Allison, 1964). Plant responses to salinity can also be significantly affected by tillage, irrigation practices, growth stage, varietal factors, and the nature of the climate related to temperature, humidity, and amount of the ozone present (Maas and Hoffman, 1977).

Effective salinity in the plant root zone is controlled by the quantity and quality of irrigation water and the timing of its application. Plants can tolerate water containing a considerable amount of soluble salts if that water passes freely through the soil. If the roots are not long in contact with the water, no adverse osmotic gradient is established. The roots will only withdraw the water and the ions needed to maintain growth. If drainage is restricted, either by poor soil structure or a high water table, and some portion of the roots cannot access water of better quality, then salinity effects may be seen in reduced transpiration (Lunin and Gallatin, 1965), reduced ratio of top growth to roots (Eaton, 1942; Maas and Hoffman, 1977), and generally reduced yields (Allison, 1964; Shannon, 1984). Barley, cotton, and sugar beets have a high range of salt tolerance; alfalfa, corn, oats, rye, soybeans, sunflowers, and wheat have a medium tolerance; and field beans have a low tolerance (SCS, 1971).

The natural salt burden associated with irrigated farming can be drawn from information available on water quality for irrigation wells near the site. The natural sodium

concentration in 22 wells pumping irrigation water from the Ogallala aquifer averages 33 milligrams per liter (33 parts per million) of sodium (TNRIS, 1985). For the years 1958 through 1979, annual water use for irrigated farming for Deaf Smith County ranged from 3,350 to 5,180 cubic meters per hectare (1.1 to 1.7 acre-feet per acre) (TDWR, 1981, p. 252). Irrigation with the high-quality Ogallala water adds 110 tc 170 kilograms per hectare (100 to 155 pounds per acre) per year of sodium to the soil. Use of Santa Rosa aquifer water adds 800 to 1,225 kilograms per hectare (710 to 1,120 pounds per acre) per year of sodium to the soil. Use of both sources of water in combination results in a sodium addition somewhere in between.

The high return in crop yields in the site vicinity is evidence that the existing farming practices do not cause harmful salt buildup and could be expected to negate the effect of an additional increment resulting from repository construction and operation (no more than 3.8 kilograms per hectare (3.4 pounds per acre) per year; that is, less than the difference between wells in the high-quality Ogallala aquifer).

5.2.10.2.2 Impact on Surface-Water Quality. Salt-laden runoff will not be discharged to the environment. Runoff from the mined materials storage area, the shaft loading area, and internal roads will be impounded in the evaporation and retention pond, which is designed to retain runoff from a single-event 100-year, 24-hour storm with a 0.6-meter (2-foot) freeboard. The impounded water will be disposed of by evaporation or, if needed, by removal from the pond and transported to a licensed disposal facility (Section 5.1.2.3).

Given the direction of the prevailing winds, the area of greatest potential for windblown salt deposition extends to the northeast from the repository operations area. Overland flow from this area drains predominantly to three playas, one to the north, one to the northeast, and one to the east. The quantity of salt that will accumulate in the playas and the salt concentration in playa water will be predicted using a model verified during site characterization. This model takes into account that the concentration of salt in the playa water will vary over the course of a year and from year to year due to variation in the amount of rainfall, evaporation, and infiltration.

The amount of salt deposited in the soil from repository development and operation will be very small, less than 0.4 to 3.0 percent of the sodium added annually by irrigation. This amount is smaller than the variation of salt concentrations among individual wells. As discussed in Section 5.2.10.2.1, the natural salt burden associated with irrigated farming in Texas using lower water application will add about 110 kilograms per hectare (100 pounds per acre) and 800 kilograms per hectare (710 pounds per acre) of sodium per year to the soil from Ogallala and Santa Rosa water, respectively. The confidence level at which the deposition rate can be predicted will be improved by monitoring actual deposition during site characterization. A deposition of 3.8 kilograms per hectare (3.4 pounds per acre) of salt per year to the soil from the repository (Section 5.2.10.2) represents 0.4 to 3.0 percent of the annual sodium contribution by irrigation waters.

5.2.10.2.3 Impact on Ground-Water Quality. Any area that is used for storage and handling of salt-contaminated material will be constructed with two impermeable liners to prevent seepage of salt-laden runoff into the ground. Lining brine ponds is commonly practiced in the salt industry and has proven effective and reliable in preventing brine seepage into the ground. A system will be installed to monitor the integrity of the liner system. A system of perforated pipes will be installed between the liners beneath the storage area, the pond, and the drainage ditches to detect and collect any salt seepage. Thus, no significant seepage of salt-laden runoff into the ground is expected.

If the impermeable liner system under the stockpiled materials should fail, saline leachate will flow downward through the unsaturated zone to the water table at a rate dependent on the soil characteristics and the presence of clay or caliche aquicludes. Infiltration studies at irrigated sites (Knowles et al., 1984, pp. 23-26) have shown that the percolation rate and the wetting front filtration rate are highly variable on the High Plains. For the six counties near the site with infiltration data (Oldham, Deaf Smith, Randall, Castro, Lamb, and Floyd), the wetting front infiltration rate varies from 0.24 to 2.65 meters (0.8 to 8.7 feet) per year, with a mean rate of 0.83 meter (2.7 feet) per year. This slow rate of percolation

will permit such timely corrective action as restoring the integrity of the liner and leachate collection system and pumping leakage back to the surface. Such action will protect the quality of the Ogallala aquifer by limiting the volume of leachate that may enter the unsaturated zone.

Infiltration followed by deep percolation is the pathway by which windblown salt could affect ground-water quality in the Ogallala and Santa Rosa aquifers. This assumes that salt deposited on the soil surface is dissolved by rainfall or irrigation water and percolates down through the surface soils to the underlying Ogallala.

Most of the area is a flat plateau covered by fine-textured soils. Pullman clay loam, the predominant upland soil type, is characterized by a slow infiltration rate, less than 0.25 centimeter (0.10 inch) per hour, and a zone of calcium carbonate accumulation, or caliche, 1 to 2 meters (3 to 6 feet) below the soil surface (NUS, 1984, BMI/ONWI-510, p. 40). The presence of a caliche layer suggests that percolation rarely moves beyond the first few meters of soil. Field measurements of deep soil moisture on the southern High Plains have shown this to be the case. Klemt (1981, pp. 1-29) found that, with few exceptions, fields that had been irrigated for 25 years or more showed evidence of deep percolation only to depths ranging from 6 to 10 meters (20 to 30 feet). With the exception of basin-irrigated fields, deep percolation was not detected through the Pleistocene sediment overlying the Ogallala aquifer (Aronovici and Schneider, 1972, pp. 71-73). The results of these studies indicate that windblown salt is not likely to affect ground-water quality when present in water that infiltrates upland areas.

Wood and Osterkamp (1984, pp. 337-349) agreed with Theis (1937, pp. 564-568) that the overall recharge rate to the Ogallala aquifer from rainfall is less than 1.3 centimeters (0.5 inch) per year. They proposed that most recharge of the Ogallala is through the annular zones immediately surrounding the playa floor; thus, the salt-laden runoff that collects in playa lakes near the site could be a part of that recharge. However, impacts are not expected to be significant since the salt contributed by the repository activities to this recharge zone will be less than 0.4 to 3.0 percent of that from good-quality irrigation water.

5.2.10.2.4 Effects on Ecosystems. Any impact on the terrestrial ecosystem will be small and highly localized because of the low rate and extent of the deposition. There will be little deposition in aquatic environments; however, as noted in Section 5.2.10.2.3, some of the deposited salt will be carried into playa environments by the runoff of precipitation. The amount is a small fraction of that contributed by relatively good-quality irrigation water; therefore, the impact will be negligible.

The ions present in common salt, sodium, and chloride, are universal components in plant materials. However, excessive amounts of these ions deposited on vegetation or present in the soil are harmful to plant growth. The major toxic effect is osmotic inhibition of water absorption; a common symptom is leaf-tip burn. Salinity levels (generally expressed as electrical conductivity) at which a definite reduction occurs have been reported (Wadleigh and Sherman, 1978; Bernstein and Howard, 1958).

5.2.10.2.5 Effects on Land Use. Salt deposited at predicted rates on the soil and absorbed by the plant roots will not result in reduced crop productivity. As noted earlier, the natural sodium content in the water used for irrigation in the area is adding 110 to 175 kilograms per hectare (100 to 155 pounds per acre) per year of sodium to the soil (see Section 5.2.10.2.1), and blowing salt during repository construction and operation will add less than 3 percent of the contribution of irrigation water to the soil. Crop productivity is high and the repository addition is insignificant in comparison to the amount added by current irrigation practices; therefore, no impact is expected from the additional increment.

Gratten et al. (1981) has shown that foliar deposition (salt deposited on leaf surfaces) does not cause leaf injury unless high humidity conditions exist (greater than 70 percent) and deposition rates exceed 65 kilograms per hectare (58 pounds per acre) per year. Salt deposition from repository development and operation is predicted to be lower than 5 percent of this amount at the point of highest deposition. Therefore, no reduction in productivity is

expected as a result of foliar deposition, even if it is assumed that all of the salt is deposited on the leaf surface.

Soil salinity and vegetation effects will be monitored during site characterization activities. If the data suggest that harmful levels of salt could be approached during repository construction and operation, impacts will be mitigated. If poor soil conditions exist, management practices can be instituted to cope with these conditions. They consist of installing artificial drainage at a suitable soil depth, occasionally flushing the soil with irrigation water containing cations which are in the proper ratio to leach harmful buildups of salts below the root zone, and adding soil amendments such as gypsum, calcium chloride, or sulfuric acid to alleviate salt buildups if irrigation water quality cannot be changed (Rhoades, 1982).

Such practices are common when producing crops in arid and semi-arid regions where evapotranspiration exceeds natural precipitation. Under these conditions, salts naturally increase in the soils since the soils are seldom saturated to the point where they drain freely. Also, water applied for irrigation naturally contains salts of some kind, which adds to the salt burden, and crops never remove more than a small percentage of these additions (Hoffman and Meyer, 1982).

5.2.10.3 Salt Disposal and Impacts

The development of a mined geologic repository in subsurface salt deposits will involve excavating large-diameter shafts from the surface to the subsurface geologic formation and tunneling drifts in which the waste packages will be placed. More than half the excavated material will be used to backfill the mined areas after the emplacement of the wastes. The backfill material will be stored on the site, and the excess (10.3 million metric tons [11.3 million tons]) will be permanently disposed of.

5.2.10.3.1 Disposal Options. The excess salt and salt-laden material brought to the surface during repository construction and operation could be disposed of in the following ways (Section 5.1.3.4):

- Onsite disposal
- Commercial market
- Ocean disposal
- Offsite (surface) disposal
- Mine disposal.

Selection of the disposal option will be based on a comparative evaluation of the advantages and disadvantages of all options suitable for a given site. A principal factor in such an evaluation will be the potential for environmental impact. The primary consideration will be assurance that the quality of the environment in the affected area during this and future generations will be adequately protected in accordance with the criteria set forth in the siting guidelines, especially 10 CFR 960.5-2-5, Environmental Quality. Transportation, with its potential impacts and costs, also will be a significant factor in the evaluation.

The potential environmental impacts of each option have been identified and evaluated (D'Appolonia, 1976; BGI, 1983, ONWI-453; NUS, 1984a; Scheriff, 1983; Langill, 1983; SCC, 1984) and the results of these works provide a basis for comparing the advantages and disadvantages of each option. While the repository program has not advanced to the point where the final selection of a disposal method can be made using data specific to the selected site, the significant impacts of the options at potential sites can be reliably anticipated at this time. The following sections summarize the salient features of each option. (See also Section 5.1.3.4.)

Onsite Disposal. Onsite disposal will require the construction of a large surface storage area, approximately 81 hectares (200 acres) in area and 7.5 meters (25 feet) high, underlain and covered by impervious materials. As discussed in Section 4.3.4.2, this option is relatively low in cost and has few immediate environmental impacts. Problems ensuring long-term landfill integrity raise questions about long-term environmental impacts.

Commercial Market. Excavated salt will be supplied either through the General Services Administration to buyers or governmental agencies "as-is" or following some onsite processing. Because the salt would be removed from the repository site, there will be no potential for long-term impacts. Potential for short-term impacts will be limited to the duration of the repository operating period and to the magnitude of those of a commercial salt production facility.

If transportation costs exceed the market price of the salt, a subsidy might be required. Feasibility of this alternative has not been fully explored.

Ocean Disposal. The excess salt could be converted into brine and dispersed in ocean waters through outfalls. Transport of either the brine or the solid material from the site to the disposal point will be required.

As discussed in Section 4.3.4.2, such disposal techniques employed in the Gulf of Mexico have caused negligible impacts on marine biota. A concern remains regarding the potential for long-term irreversible changes that have not yet been observed in the short term.

Offsite (Surface) Disposal. The potential for impact of this option would depend heavily on the environment chosen for disposal. Alkali flats and dried saline lake beds present the least potential for impact since the salt to be disposed of will be blended into a natural environment composed of evaporite materials very similar in composition.

Short-term impacts would occur from transporting and leveling the salt over the lake beds; long-term impacts are not expected.

Mine Disposal. Excess salt will be transported by rail to existing evaporite mines, transferred under the surface via a closed conveyor system, and packed into unused sections of the mines. The principal impacts of this option will occur during transportation from the repository site to the disposal site. Those impacts would occur only during the operation of the repository and, therefore, would be short term.

No long-term impacts are expected from this option.

The supporting studies for the preceding sections identify mine disposal as being environmentally benign and technically feasible. Numerous mine operations were contacted (Scheriff, 1983) to locate evaporite mines with the capacity to accept waste salt; many mines with sufficient capacity are available.

Tentative mine sites have been identified within 650 to 800 kilometers (400 to 500 miles) of the repository site in Colorado, Kansas, New Mexico, and Texas. The resulting transportation impacts, both environmental and economic, are relatively modest. This tentative choice could be modified, if warranted, on the basis of any new information obtained during the characterization phase.

Disposal in such a mine would eliminate the need to isolate the excess salt from the surrounding environment. Any mine selected as a candidate to receive excess salt would be subjected to detailed geotechnical, hydrological, and mine engineering evaluation to determine its suitability for that purpose.

Reference Disposal. The reference disposal method (Section 5.3.5) is to transport the salt by rail from the site to the abandoned potash mines near Carlsbad, New Mexico. The Atchison, Topeka, and Santa Fe rail line is the only system which connects the site with Carlsbad. Rail line distance is approximately 443 kilometers (275 miles). The route passes through the New Mexico towns of Fanwell, Clovis, Roswell, and Carlsbad. Information concerning route characteristics and possible impacts will be collected during site characterization activities. Anticipated impacts from salt spillage during transport are discussed in Section 4.2.1.11.3.

5.2.10.3.2 Impacts of Disposal. For any selected disposal option, the excess salt will be loaded into hopper-type railroad cars and shipped to the disposal site. If the reference disposal option is chosen, the excess salt will be shipped to an evaporite mine near Carlsbad, New Mexico. The salt will then be fed to skip loaders and transported down into the mine for backfilling. Conveyors will be covered and loadout structures enclosed as much as practicable with dust collection and suppression equipment to reduce escape of salt dust. Thus, every effort will be made to limit additions of salt dust to the environment, although the Carlsbad area is already heavily affected by salt from natural sources and from the potash mining industry (NUS, 1985c). Ecological effects from repository salt disposal are expected to be insignificant. Water quality is generally poor and yield is low. Potable water is usually piped in from sources 30 to 45 kilometers (20 to 30 miles) away. Soil, vegetation, and wildlife have adjusted to the saline conditions intensified by low rainfall (33 centimeters [13 inches] per year). Land use will not be adversely affected by using existing or abandoned mines, and air quality will be protected from further degradation by use of dust collection and suppression devices during unloading.

In the event of an accidental spillage of salt during transportation potential, the extent of impacts will depend on several factors:

- Location and quantities involved
- Proximity to water bodies
- Cleanup response time
- Weather conditions during that period.

Impacts resulting from accidental transportation spills on land will be localized and short-term. Spills occurring during precipitation could lead to infiltration of saline runoff which will adversely affect soils in a limited area by drastically altering the cation ratios, thus producing sodic conditions, which, in turn, will lead to dispersion of soil aggregates and loss of soil permeability. Reclamation would consist of containing the area within a berm and flooding it with water to which amendments such as calcium chloride have been added (Hoffman and Meyer, 1982; Rhoades, 1982). The amendments would restore permeability as the water penetrates the soil, and the leachate would be collected by drains and disposed of properly.

During dry conditions, a small plume of dust would be generated at the accident site, settling out within a short distance. Some vegetation that is not otherwise crushed or broken by either the vehicle or its load may demonstrate symptoms of salt stress after prolonged exposure to salt drift or runoff if the site is not rapidly cleaned up. Procedures will be established to reload the salt into another vehicle, test soils for elevated salt concentrations, reclaim soil, and remove and replace soil or vegetation as necessary.

Accidental spillage into a body of water is a lesser probability; its mitigation will be more difficult and time dependent. If effective mitigation is not feasible, precautions are possible that will reduce the probability even lower, e.g., route selection and train speed control.

5.3 EXPECTED EFFECTS OF TRANSPORTATION AND UTILITIES

This section identifies and describes the potential impacts of repository construction, operation, and decommissioning and closure on the existing transportation network and on utilities serving the study area. Nuclear transportation impacts are discussed in Section 5.3.1, environmental impacts of improvements to transportation corridors and facilities are described in Section 5.3.2, nonnuclear transportation impacts are discussed in Section 3.3.3, and utilities are discussed in Section 5.3.4.

5.3.1 Nuclear Waste Transportation

This section presents information about the costs and risks of nuclear waste transport to the Deaf Smith County site. Impacts specific to the region around the Deaf Smith County as well as those that apply nationally are addressed. The concerns that are generic to all sites

are addressed in Appendix A. There are also institutional issues related to transportation, both in the vicinity of the site and nationally. For discussion of these issues the reader is referred to Appendix A and to the Mission Plan (DOE, 1985, DOE/RW-0005, Vol. 1, p. 98) titled "The Institutional Development of the Transportation Systems."

The nuclear waste which will be disposed of in a deep-mined geologic repository arises from a variety of sources across the United States. Wastes being considered for disposal include spent nuclear fuel, spent fuel consolidated at a monitored retrievable storage (MRS) facility and the associated wastes generated from consolidation, defense wastes, and high-level waste from the cleanup of the West Valley, New York facility.

Two alternative waste-acceptance systems are presented Appendix A. One is called the authorized system, and the other is called the improved performance system. The impacts of both these systems on waste transport to the repository are presented in this section.

The authorized system is based on DOE's reference waste-management plan and includes the receipt of waste shipped directly from the point of generation to the Deaf Smith County candidate repository site. Under the authorized system, 62,000 metric tons uranium (MTU) of spent fuel from commercial nuclear power plants is received.

Additional waste sources considered within the authorized system include high-level waste from the cleanup of the commercial reprocessing plant at West Valley, New York and from defense-related reprocessing activities at Savannah River, South Carolina, Idaho Falls, Idaho, and Hanford, Washington. The Mission Plan discusses the receipt of the equivalent of 8,000 MTU of defense and West Valley high-level waste (DHLW and WVHLW), making the evaluation consistent with the NWPA, which states that the total capacity of the first repository shall be limited to 70,000 MTU of high-level waste until the second repository is in operation. Based on evaluations documented in Appendix A, the waste equivalent of 11,425 MTU of DWLW and 400 MTU of WVHLW may be available for disposal. To be conservative this section of the EA considers the impacts of transporting 62,000 MTU of spent fuel plus the equivalent of 11,825 MTU of HLW to the repository site.

The improved performance system considers the receipt of consolidated spent fuel from an MRS facility. Generally, no spent fuel would be shipped directly from a reactor to the repository. Spent fuel is first shipped to the MRS for consolidation and storage (detailed description of the MRS scenarios is presented in Section 5.3.1.1). Then all the consolidated spent fuel (along with additional wastes generated during the consolidation process) is shipped directly from the MRS facility to the Deaf Smith County Site via dedicated trains. The total quantity of consolidated spent fuel shipped from the MRS is 62,000 MTU. The improved performance system also considers the same additional waste sources as were considered in the authorized system, that is, wastes from cleanup of the West Valley, New York facility and from three defense-related reprocessing activities (see Table 5-11). For the purposes of this analysis, it is assumed that these waste forms are shipped directly to the repository under both the authorized and the improved performance systems.

The following subsections discuss the waste-transport activities, the costs of such activities, the radiological and nonradiological risks associated with nuclear waste transport, and regional risks of nuclear waste transport.

5.3.1.1 Waste Transportation Activities

The introduction to this section briefly described the basis for the transportation impact assessment. In order to describe the nuclear waste transportation activities, it is necessary to specify the geographic distribution of waste sources and the quantity of waste from each source location.

For the authorized system, the transportation analyses consider the shipment of spent fuel from each reactor to the Deaf Smith County candidate site. The reactor sites considered, the quantity of waste shipped from each site, and the distance from each of the reactor sites to the Deaf Smith County site by highway and railroad are included in the analysis. Because

Table 5-11. Lifetime Nuclear Waste Shipment Requirements to the Repository

Waste Receipts	Number of Packages	100 Percent Truck Payload[b]	100 Percent Truck Number of Shipments	100 Percent Rail Payload[b]	100 Percent Rail Number of Shipments	Shipment Miles (Millions)[f] 100% Truck	Shipment Miles (Millions)[f] 100% Train
Component 1: Spent Fuel Direct to Repository							
PWR[a]	--	2	43,611	14	6,190		
BWR	--	5	26,942	36	3,737		
Total	--		70,553		9,927	94.4	15.4
Component 2: Defense[e] & West Valley Wastes							
SRP	11,600	1	11,600	5	2,320		
INEL	9,000	1	9,000	5	1,800		
Hanford	2,250	1	2,250	5	450		
Total DHLW	22,850		22,850		4,570	26.0	6.1
WV-HLW	800	1	800	7	115		
Total	23,650		23,650		4,685	1.0	0.2
Component 3: Spent Fuel to MRS							
PWR	--	2	44,222	14	6,267		
BWR	--	5	26,346	36	3,667		
Total	--		70,568		9,934	48.8	8.0
Component 4: Consolidated SF and Secondary Waste from MRS							
Consolidated SF	--		2 PWR/1 BWR[g]		8,074		
Hardware	5,455	--	--	4	1,364		
High Activity Waste	5,084	--	--	4	1,270		
CH-TRU (HAW) 36 Drums/PKG	11,400	--	--	72[c]	159		
Total					10,867	15.3[d]	15.3[d]
Authorized System (Component 1 & 2 direct to Repository)							
Spent Fuel	--	--	70,553	--	9,927		
Defense & West Valley HLW	--	--	23,650	--	4,685		
Total	--	--	94,203	--	14,612	121.4	21.7
Improved Performance System (Components 2, 3, & 4)							
Spent Fuel to MRS	--	--	70,568	--	9,934		
Consolidated SF to Repository	--	--	(d)	--	10,867		
Defense & West Valley HLW	--	--	23,650	--	4,685		
Total	--	--	94,218	--	25,486	91.1	29.6

(a) PWR - pressurized water reactor; BWR - boiling water reactor.
(b) Payload refers to number of fuel assemblies, canisters, waste packages or drums per transport package.
(c) Two packages per railcar.
(d) All shipments from MRS to repository via dedicated trains.
(e) SRP = Savanah River Plant; INEL = Idaho National Engineering Laboratory.
(f) One-way-loaded miles.
(g) 100-ton casks, 24 PWR assemblies in two ready-to-emplace waste packages on 30 BWR assemblies in one ready-to-emplace waste package. This is the most conservative case.

of uncertainty in the combination of truck and rail transport, both 100-percent-rail transport and 100-percent-truck transport are presented.

The second case considered is the improved performance system. For this system, truck and rail transport is considered from the reactor sites to the MRS facility, but only rail transport of consolidated spent fuel is considered from the MRS facility to the Deaf Smith County site. The point of origin for the consolidated spent fuel shipments is taken as Oak Ridge, Tennessee.

In Appendix A, the transportation impacts of four cases involving the MRS operations are presented. The first case ships 62,000 MTU of spent fuel to the MRS, consolidates and overpacks the spent fuel so that it is ready to emplace upon arrival at the repository. This case used a 91-MT rail cask to ship the consolidated spent fuel to the repository. The 91-MT cask is also used to transport the hardware and high-activity wastes generated during the consolidation operation. The next case is similar to the first with the exceptions that a 136-MT rail cask is used in place of the 91-MT cask and the consolidated spent fuel is not overpacked before shipment.

The third case takes all the spent fuel generated west of longitude 100 degrees and ships it directly to the repository. Longitude 100 degrees passes through the Texas Panhandle and about 7.5 percent of the waste is generated west of this longitude. The remaining 92.5 percent of the spent fuel is shipped to the MRS. The fuel shipped from the MRS to the repository is transported in 91-MTU rail casks as ready-to-emplace waste packages. The fourth case is similar to Case 3, except that the larger transportation cask is used and the consolidated fuel is not overpacked at the MRS.

For purposes of the EA, a conservative approach to impacts was taken. A comparison of the four cases in Appendix A shows that Case 1 (overpacked fuel in a 91-MTU cask) is the most conservative MRS case and Case 4 is the most optimistic. In the impact sections that follow, Case 1 results will be shown in all the tables. The text will discuss the percentage improvements that might occur if other transport systems had been utilized.

5.3.1.1.1 Required Shipments. Authorized and improved performance systems contain common elements. Thus it is convenient to divide the analyses into four components which can then be combined to fully characterize the authorized and improved performance systems. These four components are as follows: Component 1, the transport of 62,000 MTU of spent fuel from the reactors directly to the repository via 100 percent truck transport or 100 percent rail transport; Component 2, the transport of 22,850 canisters of defense HLW and 800 canisters of West Valley HLW from their points of origin to the repository using 100 percent truck transport or 100 percent rail transport; Component 3, the transport of 62,000 MTU of spent fuel from the reactor sites to the MRS facility near Oak Ridge, Tennessee, via either 100 percent truck or 100 percent rail; and Component 4, the transport of consolidated spent fuel and secondary wastes from Oak Ridge, Tennessee to the Deaf Smith County site via dedicated train.

The estimated number of truck and rail shipments required for nuclear waste transport for the four components for all waste types is shown in Table 5-11. Also shown in the table are the cask capacities used for each of the packagings. These capacities are based on using current waste package data and packaging technology discussed in Appendix A.

For the spent-fuel-to-repository component, it is estimated that approximately 71,000 shipments would be required for 100-percent-truck transport. Approximately 10,000 shipments would be required for 100-percent-rail transport of spent fuel.

The defense and West Valley HLW component results in approximately 23,700 shipments for 100 percent truck transport or 4,700 shipments for the 100 percent rail transport. The breakdown of shipments among the waste sources is presented in Table 5-11.

The third component considers shipment of 62,000 MTU of spent fuel to the MRS by truck or rail. The number of shipments is approximately the same as the numbers required if the shipments had been sent directly to the repository. Approximately 10,000 rail shipments and

71,000 truck shipments are required. The numbers differ slightly because of shipping-schedule differences.

The final component considers shipment from the MRS facility to the repository of 62,000 MTU of consolidated spent fuel and the resultant waste from the consolidation. The consolidated spent fuel, shipped as ready-to-emplace waste packages, requires approximately 8,100 cask loads or approximately 1,600 dedicated train shipments over the lifetime of the repository. It is estimated that another 2,800 casks containing wastes produced from the consolidation operation will also be shipped in the dedicated trains over the lifetime of thee repository.

From these four components, it is possible to construct the shipment requirements, costs, and risks associated with both the authorized system and the improved performance system. The authorized system includes Components 1 and 2, the improved performance system includes Components 2 through 4. The shipment data for these two transport systems are shown at the bottom of Table 5-11.

5.3.1.1.2 Waste Transportation Costs. The shipment information in Table 5-11 has been used with the source distribution data to estimate the total cost of transporting nuclear waste to the site. These costs were developed using data and techniques summarized in Appendix A. The total life cycle costs for the two Mission Plan transportation systems are shown in Table 5-12. The costs shown are the projected total transport cost for the repository shipping lifetime (approximately 25 years) expressed in undiscounted 1985 dollars.

The costs consider fleet capital, fleet servicing and maintenance, and shipping charges. Fleet capital costs were based on transportation system characteristics and comparisons with costs of existing transportation systems. Servicing and maintenance costs were estimated by taking a fraction of the unit capital cost per year multiplied by the operation fleet size. It was also assumed in the capital cost estimate that the fleet would be replaced for any shipment schedule that exceeded 15 years. Based on the shipment schedule shown in Appendix A, the cask fleet was completely replaced for spent fuel, West Valley HLW, and defense waste shipped from the Savannah River Plant. The cask fleet was not replaced for Idaho Falls and Hanford shipments.

Freight charges were based on published tariffs, where available. If no tariffs have been published, estimates were based on spent fuel shipments. Charges for physical security in transit were based on current spent fuel escorting experience. These costs were applied to all waste forms. This is believed to be conservative because current regulations do not include such requirements for HDW, HAW and CH-TRU waste shipments from the MRS.

5.3.1.2 Radiological and Nonradiological Effects Associated With Radioactive Waste Transport

The measure used for estimating the radiological and nonradiological effects of nuclear waste transport to the Deaf Smith County site is the risk of several categories of health effects to the general population. The categories are broadly divided into nonradiological and radiological health effects.

The nonradiological health effects include injuries and fatalities associated with transport vehicular accidents, as well as pollution health effects caused by truck and train emissions (primarily in urban areas). Accident-rate experience using transportation accident-rate statistics was used in estimating the number of nonradiological injuries and fatalities is described in Appendix A. Pollution health-effect estimates were based on analysis methods and data developed by the Transportation Technology Center (TTC) at Sandia National Laboratories and are summarized in Appendix A. These analyses conclude that essentially all pollution health effects from transportation occur while vehicles are travelling through urban areas. Appendix A provides estimates of the fractions of travel through urban areas for shipments to the repository sites. These estimates are used to estimate the pollutant health effects shown in Table 5-13.

Table 5-12. Total Life Cycle Nuclear Waste Transport Costs[a]
(Millions of 1985 Dollars)

Receipt Type	100 Percent Truck Transport	100 Percent Rail Transport
Authorized System		
Spent Fuel	922	832
West Valley HLW	8	10
Defense HLW	195	279
Total	1,127[e]	1,122[e]
Improved Performance System[b]		
Spent Fuel Shipments to MRS	600	593
Consolidated Spent Fuel from MRS	638[c]	638
HAW/HDW from MRS[d]	124[c]	124
CHTRU from MRS[d]	9[c]	9
West Valley HLW	8	10
Defense HLW	195	279
Total	1,576[e]	1,654[e]

(a) From Appendix A.

(b) Ready-for-emplacement waste packages in 100-ton casks, the most conservative MRS case.

(c) Dedicated train cost of consolidated spent fuel and associated wastes included to completely describe system using truck transport for spent fuel to MRS and for defense and West Valley wastes to the repository.

(d) HAW = High Activity Waste; HDW = Hardware; CH-TRU = Contact Handled Transuranic Waste.

(e) Sum of component values shown may not add up to total because of round off.

Table 5-13. Total Risk of Nuclear Waste Transport to the Deaf Smith County Site[a][b] During the Operational Period

Risk Measure	Waste Transport Mode	
	100% Rail	100% Truck
Authorized System		
Nonradiological		
Number of Injuries	21	310
Number of Fatalities	1.9	24
Pollutant Health Effects	0.2	0.3
Radiological[d]		
LCFs from Normal Transport	0.2	7.9
LCFs from Accidents[c]	0.02	0.03
Improved Performance System[f]		(e)
Nonradiological		
Number of Injuries	170	350
Number of Fatalities	16	30
Pollutant Health Effects[c]	0.3	0.4
Radiological[d]		
LCF from Normal Transport	0.3	5.4
LCF from Accidents	0.04	0.05

(a) From Appendix A.

(b) Includes DHLW and WVHLW shipments.

(c) Calculated latent cancer fatalities from vehicle emissions to present and future generations.

(d) Calculated latent cancer fatalities from radiation exposure to present and future generations.

(e) Truck shipment risks includes rail shipment risks from dedicated trains from MRS to repository.

(f) Ready-for-emplacement waste packages in 100-ton casks, the most conservative MRS case.

The radiological impact analysis included health effects associated with both normal transport and very infrequent accidents severe enough to release some of the radioactive material being carried. Health effects also include both acute fatalities and latent cancer fatalities to both the present and future generations. To make the estimates, a computer code, RADTRAN-II (described in Appendix A) was used. RADTRAN-II models both incident-free radiological exposure and the consequence of radiological releases following severe accidents. The results depend on such factors as transport mode, population density, distance, cask capacity, and accident rates.

The results of past analyses show that no acute radiation fatalities are projected as a result of radioactive material releases from any postulated accidents. Thus, only latent cancer fatalities (LCFs) have been included in the results tables shown in this section.

Table 5-13 summarizes the nonradiological and radiological risk measures for transporting waste to the Deaf Smith County site. As stated previously, an upper-bound estimate of the risks associated with waste transport is desired. To obtain this estimate, the authorized system and the improved performance system have been evaluated. The purpose of the analysis is to bound the impacts and not compare the two transportation systems. The more important fact to recognize is that the risks, even for the bounding case, are very small compared to other risks. This perspective is discussed in Section 5.3.1.2.3.

Based on the values in Table 5-13 the limited impacts over the shipping lifetime are as follows: the maximum number of injuries projected to occur from traffic accidents are 170 for rail and 350 for truck; the maximum number of fatalities projected to occur from traffic accidents are less than 16 for rail and 30 for truck; and radiation exposure resulting from normal transport is estimated to result in less than 1 latent cancer fatality to present and future generations for rail, and approximately 8 for truck transport.

5.3.1.2.3 Risk Perspectives. The previous paragraphs have presented an analysis of the maximum risks of nuclear material transport to the Deaf Smith County candidate repository sites. It is important to place these values in perspective. All the results have been based on a shipping period of 25 years. During this period, using the same models and data as this analysis, which are based on data and methods reported by the Committee on the Biological Effects of Ionizing Radiation (CBEIR, 1980), 113,000 LCFs from background radiation would be predicted in the nation. Based on the accident data for 1983 (National Safety Council, 1984, p. 56) 112,500 individuals would be predicted to die during a 25-year period as a result of accidents involving truck tractors and semi-trailers. For freight transport by rail, using the 1983 accident data (National Safety Council, 1984, p. 78), 27,000 individuals would be projected to die during a 25-year period. Based on these values, the fatalities resulting from accidents, and not the radiological nature of the cargo, are less than 0.03 percent of the fatalities attributed to the transport of commercial freight. The latent cancer fatality estimates are less than 0.01 percent of those attributable to natural background radiation. Thus, all the national risks resulting from nuclear waste transport are extremely small relative to other comparable risks. This conclusion is valid for both the authorized and improved performance systems.

5.3.1.3 Access Routes and Modes of Transport

The most visible impact on the region around the repository would be the regular transport of waste materials into the region. The frequency of shipments will depend on the mix of truck and rail transport. The estimates for the authorized and improved performance transport systems are shown in Table 5-14. For the authorized system, the receipt rate is 16 trucks per day for the 100-percent-truck transport and 3 rail cars per day for 100-percent-rail transport. As shown in Table 5-14, the number of shipments decrease to no more than 4 per day for the improved performance system. It should also be pointed out that the payload of the casks and a mix of rail and truck shipments has a large effect on the daily receipt rates. The estimate of 16 trucks per day is not expected to be exceeded during normal conditions.

The exact route of transport to the site from the many waste-generation and storage points is difficult to project for rail transport because the routes may depend on contractual

Table 5-14. Average Daily Receipts for Authorized and Improved Performance Systems

Receipt Form	Transport Mode	
	100 Percent Truck	100 Percent Rail
Authorized System	12	2
Spent Fuel[a]		
Defense & West Valley Waste[b]	4	1
Total	16	3
Improved Performance System		
Consolidated SF and associated waste[a]	(c)	2[d]
Defense and West Valley Waste	4	1
Total	4	3

(a) Assuming receipts of 3,000 metric tons/year of Spent Fuel during 50 weeks/year, 6 days/week.

(b) Based on peak receipt rate of 1,190 canisters/year during 50 weeks/year, 6 days/week.

(c) Consolidated Spent Fuel - rail only.

(d) Receipts will occur via dedicated train, approximately one train every five days.

agreements between the DOE and waste carriers. For highway transport, local routes are also uncertain because the State of Texas may designate preferred alternative routings in accordance with the Department of Transportation (DOT) guidelines. Thus, the analyses of regional impacts presented here are based on routes judged to be reasonable by the DOE.

The region, as defined for this regional analysis, is a circle with a radius of 200 kilometers (125 miles) centered on the site. The 200-kilometer (125-mile) radius was selected to include the major railroad interchange locations that may be used to bring waste to the site. For highways the major consideration is site access from the national interstate highway system. The 200-kilometer (125-mile) radius is expected to include all the major interstate highways and rail lines in the area as shown in Figure 5-19. The following discussion will consider first the regional impacts of highway transport, then the impacts of rail transport. This is followed by a brief discussion of barge transport.

The described routes will be used as a basis for assessing the impacts associated with nuclear waste transport to the Deaf Smith County site. Prior to selection of actual routes, a detailed study and evaluation will be required. If other routes are proposed representative routes, the impacts associated with such alternatives are not expected to be significantly different.

5.3.1.3.1 Highway Transport. The east-west access to the Texas Panhandle is Interstate 40. For this analysis, it was assumed that all waste traffic comes into this region on I-40 because of DOT highway routing regulations (49 CFR 177.825). These routing regulations allow a state to designate a preferred alternative routing. However, such a designation is not anticipated at this time, so two highway approaches are evaluated below for the Deaf Smith County site.

1. I-40 West - U.S. 385 South. Traffic from the eastern United States could travel west on I-40 through Amarillo to the interchange with U.S. 385 at Vega, about 55 kilometers (34 miles) west of Amarillo. I-40 through Amarillo is in excellent condition. It is a typical interstate highway design including concrete pavement, limited access, and a concrete barrier as a median.

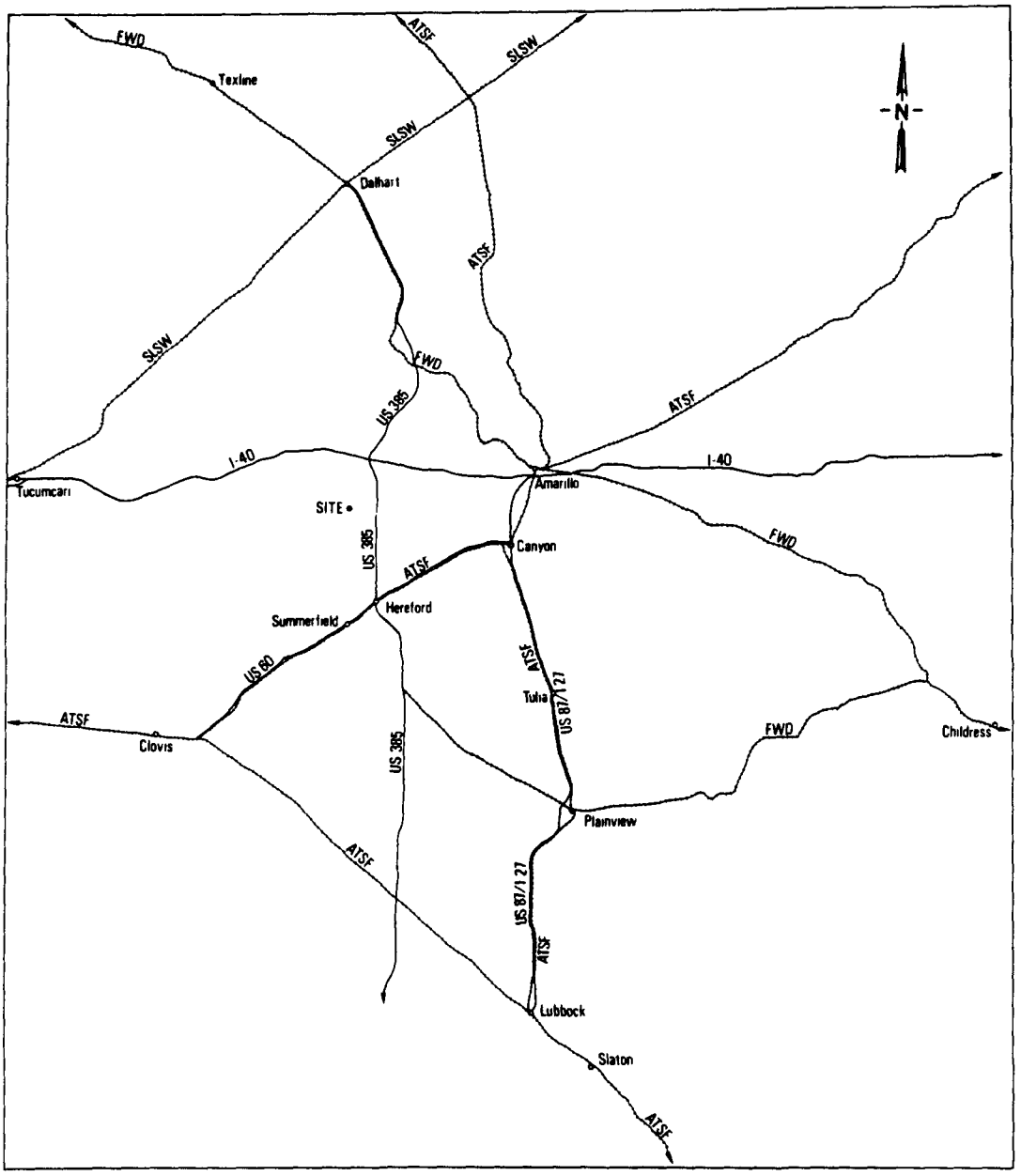
   Carriers would exit the interstate at Vega and turn south on U.S. 385. U.S. 385 is flat and straight and in good condition. It consists of two 3.7-meter (12-foot) lanes with no median and 1.8-meter (6-foot) shoulders. Traffic could proceed about 16 kilometers (10 miles) before turning west on FM 2587 to the repository access road.

2. I-40 East - U.S. 385 South. Traffic from the western United States would enter the region traveling east on I-40 to the interchange with U.S. 385 in Vega. Carriers would then follow the same route described above to the repository access road.

Research has identified factors which influence the risk and cost of transporting radioactive materials and a methodology has been developed for estimating cost and risk on a generic basis (Appendix A). This methodology has been applied on a national basis and the cost and risk estimates are shown in Tables 5-12 and 5-13 respectively.

In the following paragraphs, the national risk estimating methodology will be applied to the region to make a preliminary evaluation of the regional impact. It should be pointed out at this time that many of the parameters used in a national evaluation may not apply locally because of site-specific conditions or characteristics. At this time, available data have not permitted a thorough enough evaluation to establish the validity of using the national techniques in a regional analysis. Therefore, this analysis should be considered preliminary.

The regional risk calculation assumes that the maximum number of shipments under the authorized system or the improved performance system will be shipped on each route. Since the goal of this calculation is to present a conservative evaluation, these assumptions are adequate.



Scale

0 10 20 30 40 Km

0 5 10 15 20 25 Mi

Explanation

ATSF	Atchison, Topeka and Santa Fe
FWD	Fort Worth and Denver (a subsidiary of Burlington Northern)
SLSW	St. Louis and Southwestern

Major Regional Railroads and Highways — Deaf Smith County Site

Figure 5-19

The risk calculation requires several regional parameters, including the population density along the routes, the fraction of travel along each route, and the total route length. In addition, the total number of shipments made along the route is needed.

Route-specific population density estimates are preliminary. They were obtained from data in the County-City Data Book (Bureau of the Census, 1983, pp. 368, 522, 875, 912). To characterize the population density along the route, three population classifications were considered. They have been termed urban, suburban, and rural for these analyses but should not be confused with definitions of urban and suburban being used in socioeconomic evaluations. These terms for the regional transport analyses are defined in the following paragraph.

The surburban density was estimated by taking all towns and cities of between 2,500 and 100,000 population within a 200-kilometer (125-mile) radius of the Deaf Smith County site and calculating their average population density. This value was used as the suburban density for all routes in the regional analyses. The rural density was based on a route-specific evaluation. For each route a weighted rural density was calculated as follows. The distance through each county was estimated. Then the rural density in the county was calculated by taking the county population and land area and subtracting the population and land area of any towns and cities. The average rural density along a route was then calculated by weighting the county data by the fraction of rural travel through the county and summing the weighted values. The mean urban density was assumed to be 3,861 people per square kilometer (10,000 people per square mile). This density has been used in national analyses in Appendix A. The estimated land area occupied by urban zones was obtained by taking the density of large cities with more than 100,000 inhabitants and finding the number of square miles of urban area that would be needed so that the remaining suburban area population density matches the region average surburban value. If the density of the large cities is not significantly different from the suburban value, the city is classed as suburban in spite of its population in excess of 100,000 inhabitants. Based on this criterion, Amarillo is classed as suburban. The results of this calculation for the Deaf Smith County site are shown in Table 5-15 in the section of the table labeled "Population Density."

The next step in the regional calculation was to estimate the fraction of travel for waste transport through each of the population zones on a route-specific basis. The route fraction estimates are shown in the second section in Table 5-15 under the heading "Fraction through Population Zones." RADTRAN-II was used to obtain the unit risk factors. The unit risk factors were then multiplied by the appropriate vehicle mileage traveled in the region to get the impacts in Table 5-15.

The purpose of the regional risk calculation is to estimate the risk to the people in the vicinity of the site should the site be chosen as a first repository for high-level nuclear waste. The values presented in Table 5-15 are not presented for the purpose of comparing routes but rather to estimate the spectrum of risks that are projected. The size of the risk number and not the variation caused by using different routes is of interest. Based on the size of the numbers, the incremental risk associated with regional transport is very small compared with other risks to the same population.

5.3.1.3.2 Railroad Transport. It is too early to predict exact rail routes. Competing carriers potentially offering service from the many points of origin to the repository will need to be evaluated by the DOE on the basis of service, reliability, safety, and cost before repository start-up. In addition, several access-route corridors are being considered (see Section 5.1.2.2).

Three Class 1 railroads serve the 200-kilometer (125-mile) region surrounding the Deaf Smith County site. These railroads, shown in Figure 5-19, are the Atchison, Topeka & Santa Fe (AT&SF); the Burlington Northern (BN) system, which includes the Fort Worth and Denver (FWD) system; and the Southern Pacific (SP) system, which includes the St. Louis Southwestern (SLSW) or Cotton Belt) railroad. In addition to these rail lines, a fourth railway line running east-west through Amarillo is a former mainline route of the Chicago, Rock Island and Pacific Railroad. The Rock Island maintained service between Tucumcari, New Mexico, and Memphis, Tennessee, on this line before Rock Island declared bankruptcy. The segment of the Rock

Table 5-15. Regional Risk Calculation (Highway)

Route Characteristics	I-40 West U.S. 385 South	I-40 East U.S. 385 South
Distance (kilometers)	230	247
Fraction in Population Zones (percent)		
Urban	0.0	0.0
Suburban	7.4	1.9
Rural	92.6	98.1
Population Density (persons per square kilometer)		
Urban	3,861[a]	3,861
Suburban	732	732
Rural	1.3	0.6
Risk Parameters		
Authorized System		
Nonradiological		
Fatalities	2.8	3.1
Injuries	35	38
Radiological LCFs[c]		
Normal Transport	0.7	0.8
Accidents	0.001	0.0003
Risk Parameters		
Improved Performance System[b]		
Nonradiological		
Fatalities	2.5	2.6
Injuries	27	28
Radiological LCFs[c]		
Normal Transport	0.2	0.2
Accidents	0.001	0.001

(a) 10,000 people per square mile.

(b) Includes risk of dedicated rail transport on ATSF line through Pampa, Texas, from the MRS.

(c) LCF = latent cancer fatalities.

Island line from Amarillo to Bushland is active and is being serviced by the Burlington Northern system.

When the number of potential access routes is combined with the number of potential interchange points within a 200-kilometer (125-mile) radius of the site, the number of routes to be analyzed exceeds 40. Because the purpose of the assessment is to bound impacts and not compare routes, only four of the routes were analyzed. Three will provide repository access from the AT&SF mainline between Amarillo and Clovis through Hereford. The fourth will build the repository access from the abandoned Rock Island right-of-way through Bushland and Vega. By analyzing these four routes it is felt that the regional rail impacts will have been bounded. The cases are as follows:

1. Traffic from the eastern part of the United States could arrive in the vicinity of the site on the AT&SF mainline track through Pampa, Texas, into the AT&SF terminal in Amarillo. From Amarillo, the rail cars would be switched for local service between Amarillo, Texas, and Clovis, New Mexico, and be dropped off at the repository siding. From there, the repository railroad would deliver the cars to the Deaf Smith County site. Summerfield is used as the repository access point.

2. Traffic from the east and southeast could arrive in the vicinity of the site on the BN mainline track from Fort Worth to Denver passing through Amarillo. At Fort Worth, which is outside the 200-kilometer (125-mile) region, traffic from the east and southeast on lines such as the Union Pacific-Missouri Pacific (UP-MP) could be switched to the BN-FWD mainline. The cars containing nuclear waste would arrive in the BN yards, be sorted for interchange with the AT&SF, transferred to the AT&SF yards in Amarillo, and sorted for local train service on the Amarillo to Clovis segment of the AT&SF mainline. A local train would then drop off the cars at the repository siding. From there, the repository railroad would deliver the cars to the Deaf Smith County site. Summerfield is the repository access-point used in this case.

3. Traffic from the western part of the United States could arrive in the vicinity of the site via the AT&SF mainline through Clovis, Hereford, Canyon, and Amarillo, Texas. At Clovis, cars would be switched for local service and dropped off at the repository siding. From there, the repository railroad would deliver the cars to the Deaf Smith site. Summerfield is the repository access-point used in this case.

4. This last case is a variation of Case 1. Traffic arriving in the vicinity of the site on the AT&SF mainline track through Pampa, Texas is interchanged with BN at the Amarillo railyard for local service on the Bushland line. For this analysis it was assumed that the abandoned Rock Island right-of-way through Vega would be reconstructed and provide service to the repository as discussed in Section 5.1.2.2.

The regional risk for rail shipment to the site was evaluated by assuming that each of the routes is used to ship all waste to the repository. Table 5-16 shows the results of the calculations using the risk factors and population densities applicable to the routes. The first seven lines provide a summary of the characteristics of the route, expressed in terms of distance traveled in the 200-kilometer (125-mile) radius; the fraction traveled through urban, suburban, and rural routes; and the population density in those regions.

As was the case with highway risks, of concern is the magnitude of the risk value rather than the risk differences among routes. Based on the magnitude of these numbers, the risk of nuclear waste transport in the region is very small.

5.3.1.3.3 Barge Transport of Spent Fuel. Up to this point, the entire discussion of the costs and risks of waste transportation to the repository site has considered truck or rail transport. In addition, barge transport is discussed in Appendix A. If barge transport were used, intermodal transport would be required. As currently envisioned, casks would be transferred to railcars from the barge. The most likely points of debarkation may be Memphis, Tennessee or Houston, Texas.

Table 5-16. Regional Risk Calculation (Rail)

Route Characteristic	Route #1	Route #2	Route #3	Route #4
Point of Entry	AT&SF through Pampa	BN-FWD from Fort Worth	AT&SF from Clovis	B&N through Bushland
Distance (kilometers)	278	297	259	226
Fraction through Population Zones				
Urban	0.0	0.0	0.0	0.0
Suburban	11.0	10.0	6.5	8.9
Rural	89.0	90.0	93.5	91.1
Population Density (per square kilometer)				
Urban	3,861[a]	3,861	3,861	3,861
Suburban	732	732	732	732
Rural	1.7	1.5	1.6	1.1
Risk Parameters				
Authorized System				
Nonradiological				
Fatalities	0.23	0.25	0.21	0.19
Injuries	2.4	2.6	2.3	2.0
Radiological LCFs[b]				
Nonaccidental	0.05	0.05	0.05	0.04
Accidents	0.0009	0.0009	0.0005	0.0005
Risk Parameters				
Improved Performance System				
Nonradiological				
Fatalities	1.8	1.8	1.8	1.8
Injuries	20	20	20	20
Radiological				
Nonaccidental	0.02	0.02	0.02	0.02
Accidents	0.001	0.001	0.001	0.001

(a) 10,000 people per square mile.
(b) LCF = latent cancer fatalities.
(c) Includes MRS dedicated train shipment on ATSF line through Pampa, Texas.

The DOE plans further national logistics, economics, and risk studies of barge transport. These studies will be coordinated with site-specific studies (Section 4.1.3.1.10) during site characterization. However, since shipments via barge will require rail transport locally, the results already presented in Section 5.3.1.3.2 are adequate for purposes of this EA.

5.3.1.4 Additional Regional Concerns

Concerns have been expressed about the radiation exposure to individuals under normal conditions of transport, the cumulative exposure to people in the vicinity of the site because one individual may see many shipments, and the consequences of releases from severe transport accidents.

Radiation Exposure to Individuals From Normal Transport. The previous risk analyses aggregate the radiation exposure and in turn, the health effects to the national and regional population from all nuclear waste transportation activities. This section identifies several activities and routine operations in which individual workers are exposed to radiation. Also included are exposures to individuals in the public domain under conditions which may occur during normal transportation operations. These exposures are summarized in Tables 5-17 and 5-18. Further description of these activities and assumptions made in the calculations of radiation exposure are given in the references cited in Appendix A.

It should be noted that the likelihood of repeated exposures to individuals in the public domain in the vicinity of the repository, where such exposures could conceivably occur, is low (except as noted in the next paragraph) but has not yet been quantified. This will be done during site characterization activities (Section 4.1.3.1.10). Repeated exposure to service personnel or other transportation workers will also be examined, and necessary procedures and equipment developed, if required to limit occupational exposure to acceptance levels.

Cumulative Exposure. As waste shipments approach the repository, more waste travels along fewer routes. Thus, one concern to individuals in the region is the cumulative exposure realized by an individual. This exposure is commonly termed the maximum individual dose and is given in the last entry on Table 5-17.

The range of estimates for the maximum individual dose assumes the individual is 30 meters (100 feet) from all shipments and the transport vehicle (truck or rail) moves past the individual at 24 kilometers per hour (15 miles per hour). Over the 25-year repository shipping period, the cumulative individual dose received would range from 49 to 203 millirem.

Annually, the maximum individual exposure values range from 2 to 8 millirem. Assuming the average individual dose is 95 millirem per year from natural background (Section 3.4.7), the maximally exposed individuals would receive an increase above background ranging from 2 to 8 percent as a result of waste transport. Additional data on traffic patterns through regional highway and rail systems are needed for more precise analyses of the maximum individual dose in the region. The values given here are believed to be very conservative and actual exposures are expected to be significantly lower.

Radiation Exposure to Individuals and Population Groups Under Accident Conditions. The previous risk analyses aggregate the radiation exposure from accidents and, in turn, the health effects to the national and regional population into the overall risk analyses which includes both normal and accident exposures. This section identifies several classes of severe accidents which could occur, and summarizes the resulting exposures to individuals and population groups in the vicinity of the postulated accidents. Only accidents involving a rail cask are analyzed because it is assumed that the accident severity and isotopic releases in a truck accident are bounded by the rail accident. Further detail on description of the accident scenarios, assumptions used in the calculations, and resulting radiation dose distribution and pathways to man are given in the references cited in Appendix A.

The accident classes listed are considered to include credible but extremely severe and unlikely rail accidents. In the extreme case, the rail cask and its air-cooled spent fuel assemblies are assumed to suffer impact rupture, or both impact and burst rupture, or a

Table 5-17. Estimated Radiological Radiation Exposure to an Individual in the Public Sector From a Single Shipment Under Selected Normal Conditions of Transport[a]

Activity Description	Mean Distance from Center of Cask (Meters)	Exposure[b] Time (Minutes)	Approximate Dose (mrem)
Truck Transport			
Caravan			
Passengers in vehicles traveling in adjacent lanes in the same direction as cask vehicle	10	30	1
Traffic Obstruction			
Passengers in stopped vehicles in lanes adjacent to the cask vehicle which have stopped due to traffic obstruction	5	30	3
Residents and Pedestrians			
Slow transit (due to traffic control devices through area with pedestrians)	6	6	0.4
Truck stop for driver's rest. Exposures to residents and passers-by.	40	480[c]	3
Slow transit through area with residents (homes, businesses, etc.)	15	6	0.1
Resident exposed to 100% of shipments	30	25 years	203
Rail Transport			
Caravan			
Passengers in rail cars or highway vehicles traveling in same direction and vicinity as cask vehicle	20	10	3
Traffic Obstruction			
Exposures to persons in vicinity of stopped/slowed cask vehicles due to rail traffic obstruction	6	25	2
Residents and Pedestrians			
Slow transit (through station or due to traffic control devices) through area with pedestrians	8	10	0.7
Slow transit through area with residents (homes, businesses, etc.)	20	10	0.2
Train stop for crew's personal needs (food, crew change, first aid, etc.)	50	120	0.7
Resident exposured to 100% of shipments	30	25 years	40

(a) From Appendix A - Authorized System.
(b) Minutes, except as noted.
(c) Assumes overnight stay.

Table 5-18. Estimated Radiological Radiation Exposure to an Individual Worker for a Single Shipment During Selected Activities Under Normal Conditions of Transport[a]

Activity Description	Mean Distance from Center of Cask (Meters)	Exposure[b] Time (Minutes)	Approximate Dose (mrem)
Truck Servicing and Monitoring			
Refueling (100 gallon capacity)	7	40	2
Tire change or repair to cask trailer	5	50	5
Load inspection/enforcement	3	12	2
State weight scales	5	2	0.2
Train Servicing			
Engine refueling, car changes, train maintenance, etc.	10	120	5
Cask car coupler inspection/maintenance	9	20	1
Axle, wheel or brake inspection/ lubrication/maintenance on cask car	7	30	3
Cask inspection/enforcement by train, state or federal officials	3	10	2

(a) From Appendix A - Authorized System.

combined impact and burst rupture accompanied by increased release due to spent fuel oxidation. This is assumed to result from severe mechanical disruption and intense heating from a fire fueled by petroleum or other highly flammable materials. Spent-fuel assemblies which are five years or older (i.e., have been out of the reactor core for five years or more) do not produce sufficient self-heating from radioactive decay to support a rapid oxidation process. Therefore, a large external source of heat, similar to a burning rail-tank car of fuel, is needed to create any substantial increase in release above that from impact and burst rupture.

Accident consequences in terms of dose and LCFs to individuals and population groups are given in Tables 5-19 through 5-21 for atmospheric release and land and water contamination. Isotopes considered and pathways to man assumed are discussed in Appendix A.

The probability of accidents of the severity assumed in the analysis is very low, and the likelihood of releases from a cask in such accidents is even lower. The doses calculated and, in turn, the health effects in terms of latent cancer fatalities (LCFs) are considered to be very conservative upper bounds to the consequences of extremely severe accidents in both urban and rural settings. No attempt has been made to examine accident scenarios peculiar to a specific site. Such scenarios will be developed and analyzed during site characterization activities (Section 4.1.3.1.10) if not bounded by the analyses presented in this EA.

5.3.2 Environmental Effects of Improvements to Transportation Corridors

The following section provides an overview of the expected improvements to transportation corridors in the site vicinity and a discussion of the potential environmental effects. The route in this analysis are used for environmental evaluation; no selection of the preferred routes will be made prior to site characterization (see Section 5.1.2.2).

5.3.2.1 Roadways

The highway route to the site leaves Interstate 40 at Vega and follows U.S. 385 south for approximately 16 kilometers (10 miles) before turning westward on FM 2587 for 6 kilometers (4 miles) to the vicinity of the site. The total length of the highway access route is approximately 24 kilometers (15 miles) (Section 5.1.2.2). A new access route 1.6 kilometers (1 mile) long will be constructed to the surface facilities.

A number of alternative rail corridors varying in length from 39 to 56 kilometers (25 to 35 miles) are being considered as described in 5.1.2.2. Environmental effects from construction of any of these corridors are discussed in qualitative terms in Section 5.3.2.2.

Roadway access to the site uses existing paved highways over most of the route. Upgrading some highway sections to handle increased loads is anticipated. A new access road will have to be constructed from FM 2587 to the exploratory shaft site.

5.3.2.1.1 Construction. Upgrading existing roadways or constructing entirely new roads will be required to ensure adequate site access for workers and for transport of construction materials. Additional access roads will also be needed during the construction of the railroad spur, electrical transmission line, and gas pipeline as such facilities are required. Construction of a paved road will require approximately 3.7 hectares (9.1 acres) of land for every kilometer of length, or 5.9 hectare (14.5 acres) for every mile of length. Land use disturbances can be expected because the land will be removed from agricultural production or grazing use. However, no residences are expected to be affected significantly by access road development.

Engineering considerations for placement of roads or other access routes usually involve selecting routes that involve the fewest cut-and-fill operations for grade reduction. Surface terrain features such as playas and stream crossings would be avoided, if possible, both on this basis and to avoid drainage problems associated with clayey materials.

Table 5-19. Maximum Individual Radiation Dose Estimates for Rail Cask Accident Involving Release to the Atmosphere[a]

Accident Class	Dose (mrem)[b]			
	Inhalation	Plume Gamma	Ground Gamma	Dust Inhalation
Impact	180	11	12	0.0001
Impact and Burst	6,100	71	91	0.004
Impact, Burst, and Oxidation	9,000	550	710	0.0006

(a) From Appendix A.

(b) Maximum individual dose occurs 70 meters (230 feet) downwind of the release point.

Table 5-20. Fifty-Year Population Dose Estimates for Rail Cask Accidents Involving Land Contamination[a]

Accident Class	Urban Area (3,851 people/km^2)				Rural Area (6 people/km^2)			
	Inhalation	Plume Gamma	Ground Gamma	Total	Inhalation	Plume Gamma	Ground Gamma	Total
Impact								
Dose (man-rem)	3	0.33	940	940	0.005	0.0005	1.4	1.4
Latent Cancer Fatalities[b]				0.2				0.0003
Impact and Burst								
Dose (man-rem)	110	2.2	13,000	13,000	0.2	0.003	21	21
Latent Cancer Fatalities[b]				3				0.004
Impact, Burst, and Oxidation								
Dose (man-rem)	150	17	110,000	110,000	0.2	0.03	170	170
Latent Cancer Fatalities[b]				22				0.04

Note: The ground dose is what would be received if each member of the population stayed at the same location for 50 years. The inhalation dose is a 50-year dose commitment from inhalation of the passing plume. Doses are for the population within 80 kilometers (50 miles) of the release point. Cleanup occupational dose not included.

(a) From Appendix A.

(b) Based on 1 man-rem = 0.0002 latent cancer fatalities (relates to early fatalities plus first and second generation genetic effects).

Table 5-21. Fifty-Year Population Radiation Exposure from a Drinking Water Reservoir Contamination from a Rail Cask Accident[a,b]

Accident Class	Effects	Population-Dose from Water Ingestion[c]
Impact		180 man-rem 0.04 LCF[d]
Impact and Burst		6,900 man-rem 1.4 LCF[d]
Impact, Burst, and Oxidation		63,000 man-rem 13 LCF[d]

(a) From Appendix A.

(b) The noble gas Kr-85 is omitted because of its negligible uptake by a surface water body.

(c) A 100-acre/one-billion-gallon urban reservoir is assumed which supplies domestic/agricultural/industrial needs to the surrounding population. Radioactive decay, settling or water filtration is not assumed.

(d) Latent cancer fatality (LCF) estimates are based upon 1 man-rem = 2×10^{-4} LCF.

The bulk of the soils in the area are located on nearly level to gentle slopes. Most such soils rated as prime farmland. Locating roads on these soils would remove them from production until the access corridors are removed and reclaimed.

Soil texture in the area are predominantly silty or clayey. Once disturbed, they erode easily and would contribute sediment to surface runoff. Areas where vegetation is removed during construction and not subsequently covered with some type of hard surface to prevent wind and water erosion would require revegetation or some other type of protection, on either a temporary or permanent basis. Silty soils are also less desirable for road subgrade due to poor bearing strength and a high shrink-swell potential.

Construction and upgrade of access roads could decrease the surface water quality through erosion and sedimentation, particularly at stream or playa crossings. However, due to the ephemeral nature of these features, the effects on water quality would occur only during precipitation events. In addition, with rapid infiltration and evaporation following such events, the effects are not expected to extend far from their points of origin.

Expected effects of upgrading and paving existing roads include decreased dust and noise from vehicles, but increased speeds with a higher probability of vehicle-wildlife collisions. Building entirely new roads would result in loss of habitats and destruction of biota. In general, the magnitude of any disturbances is expected to be proportional to the length of the road constructed; therefore, the construction of a shorter repository access road is desirable.

Increases in air pollution will occur along the access road from construction activities. Construction air pollutants will include gaseous emissions from construction equipment and windblown particulates from grading and materials handling.

Increases in sound levels will occur along the access road corridor during construction. Construction noise impacts will occur in the immediate area of the corridor from the operation of construction equipment. Detailed analyses of construction impacts along the selected road will be made during site characterization.

Any cultural resources encountered will be reported to the State Historic Preservation Officer for a determination of significance. If sites are determined to be eligible for inclusion in the National Register of Historic Places, appropriate actions will be taken to safeguard the sites.

5.3.2.1.2 Operation. Once the access road is in operation, few additional impacts to land use, soils, or cultural resources are anticipated. Runoff from highway surfaces may result in temporary and very local decreases in water quality at stream crossings, playa wetlands, and roadside ditches. Minor ecological effects could result from collisions with wildlife. Highway noises may be disruptive to some species at various times of the year.

Air pollution during operation will occur due to gaseous emissions from vehicles and particulates suspended by passing vehicles. Increased air pollutant concentrations for the access road have not been evaluated.

Traffic along the access road will result in temporary increases in sound levels along the road during construction and operation of the repository. Based on estimated truck and auto traffic occurring mostly during daytime shift changes, 1 dBA increase over existing values is expected within 122 meters (400 feet) during repository operation.

5.3.2.1.3 Decommissioning and Closure. The effects of closing the repository and restoring the land area to a level compatible with surrounding conditions could closely resemble construction effects. Reclamation activities will involve dismantling surface facilities and removing them from the site, as well as regrading and revegetating the surface. It is assumed that the road access corridor will be maintained for some time during postclosure. A decision concerning the final disposition of the access corridor (pavement, right-of-way, and revegetation) will be made during the decommissioning of the facility.

5.3.2.2 Railroads

A number of alternative rail-access corridors have been investigated to determine the types of impacts which would result from construction and operation of a rail access line (NUS, 1985a). These corridors are illustrated in Section 5.1. Further investigation of the siting of rail-access corridors will occur during site characterization studies. The corridors evaluated thus far are 1.6 kilometers (1 mile) wide. The inventory of anticipated impacts reveals the types of detailed studies required for corridor selection and final route alignment within the selected corridor.

Corridors were sited to avoid, as much as possible, populated areas, recreational sites, surface hydrologic features, potentially sensitive ecosystems, cultural features, and areas of slope or other features which would require increased construction costs.

The predominant land use in the region is agriculture. To minimize disruption of this land use, an attempt was made to site corridors along straight lines to coincide with property boundaries, or along existing utility, highway, and abandoned railroad rights-of-way. The feasibility and actual advantages of doing this need to be further investigated during site characterization. However, some land will be removed from productive agricultural use which may also entail the disruption of pivot irrigation systems.

Stream crossings occur on all the potential corridors. Streams and their floodplains may contain ecologically valuable habitats and may be in areas particularly susceptible to erosion, thus increased sedimentation, during construction.

Siting a rail line within a 1.6-kilometer (1-mile) wide corridor will allow the flexibility of avoiding playas and selecting the best location for stream crossing. Playas are considered particularly sensitive environmental features because they are likely to contain important habitats, are associated with cultural features, and require filling and compacting during construction. Detailed studies such as archaeological and ecological surveys will be performed within selected 1.6-kilometer (1-mile)-wide corridors to assist in guiding final route alignment in an attempt to minimize impacts.

Corridors 1, 2, and 3 all take partial advantage of the abandoned Chicago, Rock Island and Pacific railine right-of-way which begins in Bushland and extends westward. The use of this right-of-way and existing rail bed is assumed to facilitate property acquisition and minimize land-use disruptions.

Corridor 1 uses approximately 8 kilometers (5 miles) of the right-of-way before turning southwest and then west across range and farmland. While requiring a relatively large amount of agricultural land and rangeland, this route avoids the communities of Wildorado and Vega that lie further west on this abandoned rail line.

Corridor 2 disrupts less agriculture and rangeland by using more of the existing rail bed, yet it passes through Wildorado, thus affecting that community.

Corridor 3 uses the longest extent of the rail bed, thus avoiding disruption of agriculture and rangeland to the greatest extent. However, this route would require construction of a rail line through Wildorado and Vega.

Corridor 4 departs the AT&SF line between Amarillo and Canyon. Though it is the longest of the five alternatives presented here, it takes extensive advantage of an existing transmission line right-of-way and highway rights-of-way and avoids populated areas once it leaves the area between Amarillo and Canyon.

Corridor 5 is a relatively short route which follows several utility rights-of-way, avoids residential and urban areas, and crosses only one stream. It departs the AT&SF line northeast of Hereford.

Corridor 6, the shortest and most direct route, requires two stream crossings and the disruption of a high percentage of prime agricultural land. Though it is one of the least expensive rail lines to develop, it has a high number of at-grade road crossings and disrupts irrigation systems. This route departs the AT&SF line in Summerfield.

These corridors were sited as a series of alternatives to illustrate the types of impacts which may be encountered and to help understand the issues which will require further study. One or more preferred corridors will be chosen for more detailed study of the potential impacts from rail line construction and operation within that corridor.

5.3.2.2.1 Construction. The extent of construction required to upgrade rail lines in the site vicinity will be investigated during site characterization. The impacts from such construction, if required, are expected to be short term and localized along selected corridors. New construction of rail to the site or to salt disposal areas involving earth movement and excavation can be expected to temporarily disrupt soil structure, surface-water quality (due to wind and water erosion), and drainage patterns. Erosion and sedimentation control measures will be applied, especially at drainage or stream crossings. Impacts to soils are discussed in Section 5.3.2.1.1.

A standard 18-meter (60-foot) railroad right-of-way will remove approximately 7.4 hectare (17.3 acres) of habitat for each kilometer of length, or 3 hectares (7 acres) of habitat for each mile of length. This may result in the permanent alteration of existing habitat to a potentially greater degree than development of the repository because the rail spur will have a greater probability of encountering sensitive ecosystems such as streams, playa wetlands, or natural prairie communities requiring either avoidance in routing or mitigation of impacts at crossings. If the right-of-way is protected from farming or grazing, it may revert to a more natural prairie condition, creating habitat as well as a corridor for biological dispersion. Conversely, protecting the right-of-way with security fencing will create a barrier for some species which may require construction of underpasses for animals. Railroad noises may create temporary disturbances depending on the time of day or year and the species present.

Although increased air pollutant concentrations for rail construction have not been evaluated, increases in air pollution will occur along the rail corridor from construction activities. Construction air pollutants will include gaseous emissions from construction equipment and windblown particulates from grading and materials handling. Activities will move along the corridor during the construction of the rail line, resulting in only temporary increases in air pollution at any location.

Increases in sound levels will occur along the rail corridor during construction. Because construction activities will move along the corridor with different activities occurring over a period of time, the sound level increases during construction will be temporary for a particular area. Increased noise levels will occur in the immediate area of the corridor from the operation of construction equipment. The average L_{dn} value at 0.6 kilometer (0.4 mile) of the rail construction activities is estimated to be 45 dBA.

Any cultural resources encountered will be reported to the State Historic Preservation Officer for a determination of significance. If determined to be eligible for inclusion in the National Register of Historic Places, appropriate actions will be taken to safeguard the site.

5.3.2.2.2 Operation. Once the railroad is in operation and prior to repository operation, few additional impacts to land use, soils, surface water resources, or cultural resources are anticipated. Minor ecological effects could result from collisions with wildlife, railroad noises may be disruptive to some species, and any security fencing may present barriers to wildlife movement.

Although increased air pollutant concentrations for rail operation have not been evaluated, air pollution during operation will result from locomotives operating along the corridor. Temporary increases in air pollution along the rail line will occur during operation due to the intermittent passage of trains. Particulate emissions from transport of salt during

repository construction and operation could be controlled by using enclosed or covered rail cars.

Operation of the rail line will result in temporary increases in sound levels along the corridor with the passage of each train. The average day and night weighted sound level (L_{dn}) at 246 meters (800 feet) from the rail line is estimated to be 45 decibels (dBA) from passage of two trains per day (four trips). It is anticipated that use of this rail line for transport of materials and possibly workers will reduce the number of project-related vehicles and highway impacts.

5.3.2.2.3 Decommissioning and Closure. The effects of closing the repository and restoring the land area to a level compatible with surrounding conditions could closely resemble construction effects. Reclamation activities will involve dismantling surface facilities and removing them from the site, as well as surface regrading and revegetation. A decision concerning the final disposition of the rail line will be made during the decommissioning of the facility.

5.3.2.3 Airports

No significant improvements to nearby airports or significant increases in operations are expected, and hence, no environmental effects are expected.

5.3.2.4 Waterways

Since a water transport alternative would still involve rail shipments to the repository, no additional impacts beyond those discussed for rail operations are expected.

5.3.3 Effects on Transportation Infrastructure in the Local Area and Region

This section discusses the impacts of transportation of workers, materials, and supplies to and from the site, and transportation of excess salt from the site. Nuclear waste transportation impacts are discussed in Section 5.3.1.

Two types of direct transportation impacts from repository activities are expected to occur: impacts on the transportation network itself and impacts on current route users in terms of traffic and safety. During site characterization, these impacts and potential mitigative measures will be studied in greater detail, as described in Section 4.1.3.1.10.

5.3.3.1 Roadways

5.3.3.1.1 Construction. The sixth-year peak employment period of repository construction (Table 5-2) is expected to generate the peak number of vehicles shown in Table 5-22. It is anticipated that the main supply route for steel and other supplies and equipment will be from Amarillo via I-40 (U.S. 66), U.S. 385, and FM 2587. Increases in private vehicle trips on individual route segments were calculated by distributing the total vehicle trips among the communities in and around which workers are likely to reside (Section 5.4.1) and assuming that workers would take the most direct routes to the repository site.

Some small percentage of workers are likely to use alternative routes to the site, although it is currently not possible to predict this percentage. However, it is expected that this would reduce impacts on primary routes considered in this analysis.

Potential traffic increases by route segment are enumerated in Table 5-23 and are summarized in Table 5-24. The latter describes impacts in terms of percent of maximum service volume under ideal conditions. These service volumes are specified in Table 3-52. It should be noted that construction-related traffic has been added to current (1981) traffic. The current traffic load on these routes is likely to increase somewhat prior to repository construction, so that actual daily and peak traffic levels may be somewhat higher than those indicated in Tables 5-23 and 5-24. At the same time, the relative contribution of site-related traffic to the total traffic load will actually be smaller.

Table 5-22. Vehicular Traffic During Repository Construction

	Vehicles/Day	One-Way Trips/Day[b]
Trucks[a]	13	26
Passenger Vehicles[c]	753	1,506

(a) From Section 5.1.2.3, average for construction period.

(b) Each vehicle makes one trip to the site and one trip from the site per day.

(c) Assumes 2 passengers per vehicle and peak work force in Table 5-2.

Source: Section 5.1.2.3 and Table 5-2.

Table 5-23. Expected Traffic Increases Resulting From Repository Construction, Deaf Smith County Site

Route Segment	Current Traffic,[a] Daily (peak hour)	Expected Daily Increase in Passenger Vehicle Trips[b]	Expected Daily Increase in Truck Trips[c]	Total Expected Traffic Daily (peak hour)[d]
I-40 (U.S. 66) (Amarillo-U.S. 66 Business)	9,100-58,000 (1,092-6,960)	900	26	10,026-58,926 (1,555-7,423)
I-40 (U.S. 66) (U.S. 66 Business-Vega)	7,700-9,500 (924-1,140)	900	26	8,626-10,426 (1,387-1,603)
U.S. 60 (Canyon-Hereford)	4,200-7,400 (504-888)	97	0	4,297-7,497 (553-937)[e]
U.S. 385 (Vega-FM 2587)	1,450 (174)	959	26	2,435 (666)
U.S. 385 (Hereford-FM 1062)	1,500-6,000 (180-720)	446	0	1,946-6,446 (403-943)
U.S. 385 (FM 1062-FM 2487)	1150 (138)	543	0	1,693 (409)
FM 1062 (U.S. 60-U.S. 385)	230-400 (28-48)	97	0	327-97 (76-97)
FM 2587 (U.S. 385-site boundary)	110-220 (13-26)	1,502	26	1,638-1,748 (777-790)
FM 214 (I-40 (U.S. 66)-FM 2587)	110-180 (13-22)	4	0	114-184 (15-23)

(a) From Table 3-52.

(b) Calculated using methodology described in Section 4.2.1.10.2.

(c) From Table 5-22. Assumes, as a worst case, all trucks routed through Amarillo.

(d) Calculated by adding current traffic to expected increase. Peak hour assumes that 50 percent of passenger vehicle trips and 50 percent of truck trips coincide with peak hour traffic.

(e) Occurs between Canyon and FM 1062.

Table 5-24. Comparison of Roadway Use Prior to and During Repository Construction and Operation, Deaf Smith County Site

Road Segment	Percent of Maximum Daily Service Volume for Ideal Conditions			Percent of Maximum Hourly Service for Ideal Conditions		
	Current[a]	Construction[b]	Operation[c]	Current[a]	Construction[b]	Operation[c]
I-40 (U.S. 66) (Amarillo-U.S. 66 Business)	14-86	15-88	15-87	39-249	56-265	51-261
I-40 (U.S. 66) (U.S. 66 Business-Vega)	11-14	13-16	12-15	33-41	50-57	45-53
U.S. 60 (Canyon-Hereford)	6-11	6-11	6-11	18-32	20-33	19-33
U.S. 385 (Vega-FM 2587)	15	25	23	44	167	133
U.S. 385 (Hereford-FM 1062)	16-63	20-67	19-66	45-180	101-236	82-217
U.S. 395 (FM 1062-FM 2587)	12	18	16	35	102	80
FM 1062 (U.S. 60-U.S. 385)	2-4	3-5	3-5	7-12	19-24	15-20
FM 2587 (U.S. 385-site boundary)	1-2	17-18	12-13	3-7	194-198	138-141
FM 214 (I-40/U.S. 66-FM 2587)	1-2	1-2	1-2	3-5	4-6	4-6

(a) From Table 3-52.

(b) Calculated from total expected traffic daily (peak hour) in Table 5-23 and maximum service volume in Table 3-52.

(c) Calculated from total expected traffic daily (peak hour) in Table 5-27 and maximum service volume in Table 3-52.

Table 5-24 indicates that traffic impacts are not evenly distributed and during construction probably will be most noticeable on FM 2587 and on U.S. 385. Impacts resulting from increased traffic will be greatest during peak hours. U.S. 385 north of FM 2587 will be carrying more than 650 vehicles per peak hour. Near Hereford, U.S. 385 will carry more than 900 vehicles during peak hours, and between FM 2587 and FM 1062 over 400 vehicles during peak hours. FM 2587 between U.S. 385 and the site access road will carry nearly 800 vehicles per hour during peak periods (Table 5-23). At these levels, drivers will experience some loss of maneuverability, although driving speeds will not be substantially diminished where the flow of traffic is uninterrupted. The major interruption on U.S. 385 would be the convergence of traffic onto FM 2587 from two directions. Other interruptions may be caused by slow-moving or turning vehicles on U.S. 385.

Congestion currently occurs on I-40 (U.S. 66) in the vicinity of Amarillo and on U.S. 385 near Hereford during peak use periods. Site-related traffic will contribute to these problems, although on I-40 (U.S. 66) overall driving conditions are not expected to be markedly worse because the repository-related traffic is a small fraction of total traffic.

Traffic generated by repository construction, especially large construction-related vehicles and trailers, will degrade road surfaces, although a quantitative assessment of this impact cannot be performed without more detailed study. This impact will be investigated during detailed site characterization.

Based on accident rates from Table 3-52, the average repository construction traffic over 7 years may increase the number of accidents on I-40 within Amarillo by 6.6 accidents per year. From 1978 through 1982, an average of 288 accidents per year occurred on this highway segment. From the western edge of Amarillo to Vega on I-40, accidents may increase by 3.4 per year; between 1978 and 1982, the average was 41 accidents per year on this section. Site-related traffic on U.S. 385 between Hereford and FM 1062 may cause an additional 4.3 accidents per year. This highway segment averaged 46 accidents per year during the 1978-through-1982 period (TSDHPT, 1978-1982). Accidents on other route segments under consideration may increase by no more than 1.5 per year as a result of repository construction (Table 5-25). The predicted number of accidents may decrease on those routes that are upgraded or improved. A detailed analysis of accident data will be made if this site is considered further for the repository.

The State of Texas had a statewide highway fatality rate in 1982 of 3.5 per 100 million vehicle miles (National Safety Council, 1983). By applying this rate to the total vehicle miles per year of repository construction, a statistical value of 0.7 fatality per year of construction activity is predicted over all route segments considered.

In addition to impacts related to site development, traffic impacts are likely to result from offsite development activities, such as constructing or upgrading roads and railroads and moving workers and supplies to these sites. Road improvements may be required for those portions of FM 2587 and U.S. 385 that will be used for site access. These routes will be most congested during peak use periods (shift changes). Obstructions caused by roadway improvement activities will temporarily aggravate the congestion that will occur during repository construction.

Construction of a rail spur will entail a grade-separated crossing and many at-grade crossings on three farm-to-market and numerous unpaved roads. These roads will not be noticeably affected by other site-related traffic. Rail construction will cause short-term congestion, obstructions, or temporary rerouting of vehicles that would normally use these roads.

5.3.3.1.2 Operation. Repository operation is expected to generate the volume of traffic indicated in Table 5-26. These values are average figures for the expected 26 years of operation. Expected impacts on traffic are enumerated in Table 5-27. The methodology for calculating impacts on individual route segments is discussed in Section 4.2.1.10. Table 5-24 summarizes traffic impacts during repository operation and allows a comparison with current roadway use and with impacts during repository construction.

Table 5-25. Expected Traffic Accidents per Year of Repository Construction Resulting from Transport to and from the Deaf Smith County Site

Route Segment	Accident Rate per Million Vehicle-Miles[a]	Site-Related Trips per Day[b]	Site-Related DVM[c]	Offsite Accidents per Year of Construction[d]
I-40 (U.S. 66) (Amarillo-U.S. 66 Business)	3.27	646	5,555	6.6
I-40 (U.S. 66) (U.S. 66 Business-Vega)	0.56	646	16,538	3.4
U.S. 60[e] (Canyon-Hereford)	1.22	68	306	0.1
U.S. 385 (Vega-FM 2587)	0.57	687	7,145	1.5
U.S. 385 (Hereford-FM 1062)	3.20	311	3,670	4.3
U.S. 385 (FM 1062-FM 2587)	0.43	379	3,108	0.5
FM 1062 (U.S. 60-U.S. 385)	1.13	68	1,578	0.7
FM 2587 (U.S. 385-site boundary)	0.26	1,066	3,091	0.3
FM 214 (I-40/U.S. 66-FM 2587)	0.21	3	35	0

(a) From Table 3-52.
(b) Private vehicles plus trucks (off site only), averaged over 7-year construction period.
(c) Daily vehicle-miles (offsite), calculated by multiplying route segment length (Table 3-52) by trips per day.
(d) Associated only with travel to and from the site. DVM x 365 x accident rate ÷ million.
(e) Site-related traffic will use 7.2 kilometers (4.5 miles) of this segment.

Table 5-26. Estimated Average Vehicular Traffic During Repository Operation, Deaf Smith County Site

Mode	Cargo	Round Trips per Week[b]	Average Trips per Day[c]
Passenger Vehicles	Workers	3,500	1,000
Trucks[a,d]	Supplies	270	78
Rail Cars	Salt, Supplies and and Nuclear Waste[d]	Average of One Train Per Day - 10 to 30 Cars Per Train	

(a) Does not include nuclear waste shipments.

(b) From Table 5-6.

(c) One-way trips. Assumes 7 days of operation per week, each vehicle making 2 trips (one to and one from the site).

(d) See Section 5.3.1 for discussion.

Table 5-27. Expected Traffic Increases Resulting from Repository Operation, Deaf Smith County Site

Route Segment	Expected Daily Increase in Passenger Vehicle Trips[a]	Expected Daily Increase in Truck Trips[b]	Total Expected Traffic[c] daily (peak hour[d])
I-40 (U.S. 66) (Amarillo-U.S. 66 Business)	598	78	9,776-58,676 (1,430-7,298)
I-40 (U.S. 66) (U.S. 66 Business-Vega)	598	78	8,376-10,176 (1,262-1,478)
U.S. 60 (Canyon-Hereford)	64	0	4,264-7,464 (536-920)
U.S. 385 (Vega-FM 2587)	637	78	2,165 (531)
U.S. 385 (Hereford-FM 1062)	296	0	1,796-6,296 (328-868)
U.S. 385 (FM 1062-FM 2587)	361	0	1,511 (318)
FM 1062 (U.S. 60-U.S. 385)	64	0	294-464 (60-80)
FM 2587 (U.S. 385-site boundary)	997	78	1,185-1,295 (551-564)
FM 214 (I-40 (U.S. 66)-FM 2487)	3	0	113-183 (15-23)

(a) From Table 5-6. See Section 5.3.3.1.2 for discussion.

(b) From Table 5-6. Assumes all trucks routed through Amarillo. Nuclear waste not included. See Section 5.3.1 for discussion.

(c) Obtained by adding expected increases to 1981 traffic counts, Table 3-52. Actual totals are likely to be higher than indicated due to the probable increase in traffic over time.

(d) Assumes 50 percent of passenger vehicle trips and 50 percent of truck trips coincide with peak hour traffic.

On a daily basis, traffic density on all routes considered will be comparable to that occurring during repository construction (Table 5-24). The proportion of truck traffic during repository operation will be higher with an average of 78 one-way truck trips per day carrying nonnuclear materials (Table 5-26). These trucks will have a greater impact on road users than smaller vehicles. Congestion will occur during peak hours on FM 2587 and on U.S. 385. Congestion may also occur in the vicinity of slow-moving or turning vehicles, as discussed in the immediately preceding section.

Repository operation is predicted to cause an increase in accidents (Table 5-28), due to the increase in miles travelled on affected roads, in addition to those that would occur without repository operation. Total expected accidents (Table 5-28) are based on current accident rates as calculated from Texas Department of Highways and Public Transportation data (TSDHPT, 1978-1982). A more detailed analysis of accidents by accident and vehicle type (i.e., accidents resulting in fatalities, injuries, or property damage only) will be conducted during site characterization. Site-related traffic on I-40 (U.S. 66) from Amarillo to the U.S. 66 business route intersection may cause an additional 6.9 accidents per year during repository operation; from 1978 through 1982 this segment averaged 288 accidents per year. From the U.S. 66 business route intersection to Vega on I-40, accidents may increase by 3.5 per year over the 41-per-year average between 1978 and 1982. On U.S. 385 between Hereford and FM 1062, an additional 4.1 accidents per year are estimated; an average of 46 accidents per year occurred on this segment between 1978 and 1982 (TSDHPT, 1978-1982). The number of additional predicted accidents per year on all other routes will be no more than two. The estimated off-site highway fatality rate for repository operation over all routes considered is 0.5 fatality per year of operation (see Section 5.3.3.1.1 for discussion).

The use of trains to transport materials to and from the site during repository operation is expected to affect road users. At-grade crossings will present the limited potential for delays to road users and for collisions between trains and road users. Rail cars to the site probably can be organized into one train per day although scheduling details and train assembly location are not yet known. These trains would be used to transport supplies, nuclear waste, and empty salt disposal cars to the repository. A quantitative assessment of the impact of these trains will be conducted during detailed site characterization (Section 4.1.3.1.10).

5.3.3.1.3 Decommissioning and Closure. Fewer workers will be employed during repository decommissioning and closure than during repository construction or operation (Section 5.1); therefore, impacts resulting from worker trips are expected to be proportionally smaller, although similar in type. Both trucks and rail will probably be used to remove surface equipment to disposal or reuse sites, although the number of trips is not known. The preceding section more completely discusses potential types of impacts.

5.3.3.2 Railroads

5.3.3.2.1 Construction. During repository construction, a new rail line will be constructed to connect the repository with the existing railroad infrastructure. A number of alternative locations (Section 5.1.2.2) will be investigated during site characterization activities (Section 4.1.3.1.10).

Prior to the completion of the rail access route, it is anticipated that some repository construction materials will be shipped by rail to Amarillo and then by truck to the repository site. This anticipated use will not have a significant impact on existing users or on the rail infrastructure.

Once the rail access route to the site is completed, it can be used for transport of materials and possibly workers to the repository during the construction phase. This could reduce repository-related traffic on the highways, and thus help to minimize adverse impacts of such traffic.

Table 5-28. Expected Traffic Accidents per Year Due to Repository Operation, Deaf Smith County Site

Route Segment	Accident Rate per Million Vehicle-Miles[a]	Site-Related Average Daily Traffic[b]	Site-Related Accidents per Year of Operation[c]
I-40 (U.S. 66) (Amarillo-U.S. 66 Business)	3.27	676	6.9
I-40 (U.S. 66) (U.S. 66 Business-Vega)	0.56	676	3.5
U.S. 60 (Canyon-Hereford)	1.22	64	0.1[d]
U.S. 385 (Vega-FM 2587)	0.57	715	1.6
U.S. 385 (Hereford-FM 1062)	3.20	296	4.1
U.S. 385 (FM 1062-FM 2587)	0.43	361	0.5
FM 1062 (U.S. 60 U.S. 385)	1.13	64	0.6
FM 2587 (U.S. 385-site boundary)	0.26	1,075	0.3
FM 214 (I-40 (U.S. 66)-FM 2587)	0.21	3	0.0

(a) From Table 3-52.

(b) Passenger vehicles plus trucks (off site only), from Table 5-27.

(c) Associated with travel to and from the site. DVM x 365 x accident rate ÷ million.

(d) Site-related traffic will use 7.2 kilometers (4.5 miles) of this segment.

5.3.3.2.2 Operation. Repository operation is expected to generate the amount of rail traffic shown in Table 5-26. Impacts of repository rail transport on existing rail users will depend on the number and frequency of trains. Materials coming into the repository probably will have been shipped from a variety of directions on different routes.* Considering this light traffic load, negative impacts on current users are likely to be minimal. The precise nature of railroad conditions and impacts will be evaluated in more detail during site characterization (Section 4.1.3.1.10).

The rail yard where trains to the repository are assembled is another area that will be affected by rail transport of materials to the repository. A detailed study of such rail yards will be conducted to evaluate the logistics and to assess the impacts on rail yard activities.

5.3.3.2.3 Salt Transportation. Excess salt to be disposed of could be transported via either truck or rail car. Because of the much greater payload capacity of rail cars (82 to 91 metric tons [90 to 100 tons] versus 21 to 25 metric tons [23 to 27 tons] for trucks), rail transportation would have a much lesser impact in terms of number of loads transported. In addition, because of the large amount involved (suggesting possible use of lower unit-cost train-load quantities), rail transport may also be more economical. Because salt is typically transported in covered hopper cars, rail shipment poses virtually no threat of fugitive salt loss enroute during normal conditions.

At a conservatively estimated average payload per car of 82 metric tons (90 tons),** approximately 130,000 carloads would be required, or about 5,000 per year. For this traffic volume, improvements to any existing rail carrier trackage are probably not needed although further investigation will be necessary to confirm this.

The salt disposal method (Section 5.2.10) requires the use of the AT&SF rail line to transport salt from the repository to the potash mines in the Carlsbad, New Mexico, area, a distance of approximately 440 kilometers (275 miles). Salt disposal will require approximately 100 rail cars per week.

It may be necessary to construct new rail sidings or schedule salt disposal train trips so that current track users are not adversely affected. Additional information on rail conditions and rail use characteristics for the AT&SF rail line to the Carlsbad area will be collected during site characterization (Section 4.1.3.1.10).

The AT&SF Railroad system had an accident rate of 3.64 accidents per million train miles in 1984 (DOT, 1985), calculated from all derailments, collisions, and other accidents in which more than $4500 in damages were incurred. Assuming that a 100-car train will make the 880-kilometer (550-mile) round trip once per week to Carlsbad for salt disposal, 2.6 rail accidents involving these trains are estimated during the period required for salt disposal.

This estimate is based on train-miles rather than rail-car miles. A change in the number of rail cars per train or in the total number of trains required would alter the accident estimate. Environmental impacts of salt, which may escape from a railroad car in an accident, are discussed in Section 5.2.10.

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*However, materials and supplies going to and from the repository probably can be organized into one train per day.

**Most covered hopper rail cars manufactured in recent years have payload capacities of between 86 and 96 metric tons (95 and 105 tons). Older cars in the present U.S. fleet have lower capacities.

5.3.3.2.4 Decommissioning and Closure. Both trucks and railroads will probably be needed to remove surface equipment to disposal sites, although the number of trips is not known. Impacts on the rail network and rail users will be similar in type to impacts during repository operation.

5.3.3.3 Airports

Air transportation is not expected to contribute substantially to the daily movement of people and materials associated with repository construction, operation, and decommissioning.

Therefore, no significant impacts on nearby airports as a result of daily activities at the repository site are expected. However, the site will be visited by technical personnel, representatives of governing bodies, and other individuals, many of whom will travel via the Amarillo International Airport. Others may use the Hereford Municipal Airport. The amount of air travel generated by the repository is not known at this time. The potential for these airports to accommodate additional air traffic to the site will be assessed during site characterization.

5.3.3.4 Waterways

The DOE is studying the operational safety and economics of transporting nuclear waste casks by barge from ports on the East Coast and Great Lakes to ports on the Gulf Coast and Mississippi River (Appendix A). From the Mississippi River and Gulf Coast ports, the waste would be moved to the repository by rail. Since this alternative would still involve rail shipments to the repository, no additional impacts beyond those discussed for rail operations are expected. However, this alternative will be further studied during site characterization (Section 4.1.3.1.10 and Appendix A).

5.3.4 Utilities

Utility requirements for repository construction, operation, and decommissioning are discussed in Section 5.1. It is expected that electric power for construction, operation, and decommissioning at the site will be supplied by a power line from the existing substation at U.S. 385/FM 2587 (Figure 3-84). If this supply proves inadequate, an existing substation located at Bushland would be used because it currently has the capacity to serve repository needs. In general, electric capacity exceeds demand in the county (NUS, 1984, BMI/ONWI-509) so that such a connection is not expected to have an adverse impact on that utility. Natural gas requirements for all phases of the repository project may be supplied by tapping one of the pipelines located near the site (Figure 5-10). A more detailed study of potential utility services will be conducted during detailed site characterization. This study will include an assessment of the capability of existing commercial power sources to meet the energy requirements of the repository.

It is anticipated that the water supply for the repository will be obtained from an onsite well or well field (see Section 3.3). The effects of repository water supply on ground water are discussed in Section 5.2.2.2. There will be an onsite treatment plant for sewage and waste water (see Section 5.1). Therefore, there will be no impact on existing municipal waste treatment facilities during construction, operation, or decommissioning. Sludge remaining after treatment will be transported to an offsite location for appropriate disposal.

5.4 EXPECTED EFFECTS ON SOCIOECONOMIC CONDITIONS

Baseline demographic, economic, public service, fiscal, and social conditions were discussed in Section 3.6; this chapter addresses expected changes to these conditions due to the repository. The ONWI in-migration model described below was used to assess probable demographic impacts. A population allocation model was used to determine distribution of expected population effects. Sections 5.4.2 through 5.4.6 discuss demographic impacts as well as possible effects on the economic conditions, public services, social structure, and governments of the host communities.

Project-related impacts were estimated using the ONWI Population In-migration Computer Model (Goldsmith, 1984). This model is a linear program that estimates the number of people who will relocate to an area as a result of repository construction and operation. The definitions of terminology used in the model are shown on Table 5-29. Figure 5-20 illustrates the model operations and logic chart; the input and multipliers used in the model and the basis for each appear in Table 5-30. The model calculates the following items for repository construction and operation:

- Direct and indirect in-migration
- Direct and indirect school-age children
- Direct and indirect household heads
- Single-worker in-migration
- Total direct and indirect in-migrating employment.

Direct in-migrants are repository workers and their families. Indirect in-migrants are repository- and consumer-related service workers and their families.

The key variables determining in-migration include the following:

- The number of repository workers needed each year
- Indirect employment multipliers
- Percent of direct and indirect workers expected to in-migrate
- Direct and indirect family size multipliers (calculates school-age children)
- Repository and indirect worker spouses employed in indirect jobs.

These variables were adjusted so that a range of impacts could be established for the site. The various multipliers and percentages were chosen on the basis of references listed in Table 5-30, which reflect research conducted for other large-scale developments in rural settings. The model incorporates information on local labor availability based on existing local employment in construction and mining and total study area population and labor force. Also, the level of economic activity in the study area was evaluated to establish realistic, conservative indirect multipliers (Section 3.6).

The changes in inputs and multiplier values for the operations phase are based on the research literature referenced. This literature indicates that during the longer operation phase of a project (1) more workers will relocate with family members, (2) the families which relocate tend to be larger, (3) more local hires are attracted to the long-term job opportunities, and (4) indirect multipliers are higher because of an expanded economy and long-term business opportunities.

The model was designed to project a range of in-migration within which actual in-migration values would lie. The analysis presented here reflects a realistic, conservative case. It assumes no mitigation measures to limit repository-related in-migration, and references worker and worker-family characteristics that tend to raise in-migration.

The model was validated using the documented impacts resulting from two energy projects. These projects were selected because they were similar in nature to the repository program and because adequate detail was provided in the project-monitoring reports on model variables to perform the validation process (Goldsmith, 1984). The model was validated for peak-year projection; projections for years other than the peak are not as accurate. Variable sensitivity analysis, scenario hypotheses testing, and testing with historical data from actual facility-monitoring reports were completed as part of the model's validation and verification.

The repository-related populations were allocated to communities on the basis of a population location (gravity) model. This model assumes that relocation decisions are made in direct proportion to community population and in inverse proportion to distance to work. The model results for the Deaf Smith County site are shown in Tables 5-31 and 5-32.

Table 5-29. Definitions of Terms Used in In-Migration Model

Direct Work Force - The work force hired for jobs at the repository facilities.

Indirect Work Force - The work force hired for jobs that are available because of the repository location but that are not at the facilities, such as jobs with repository suppliers, town services, or retail business.
Note: To avoid double counting, spouses of repository workers who are in the indirect work force are counted only as direct in-migrants.

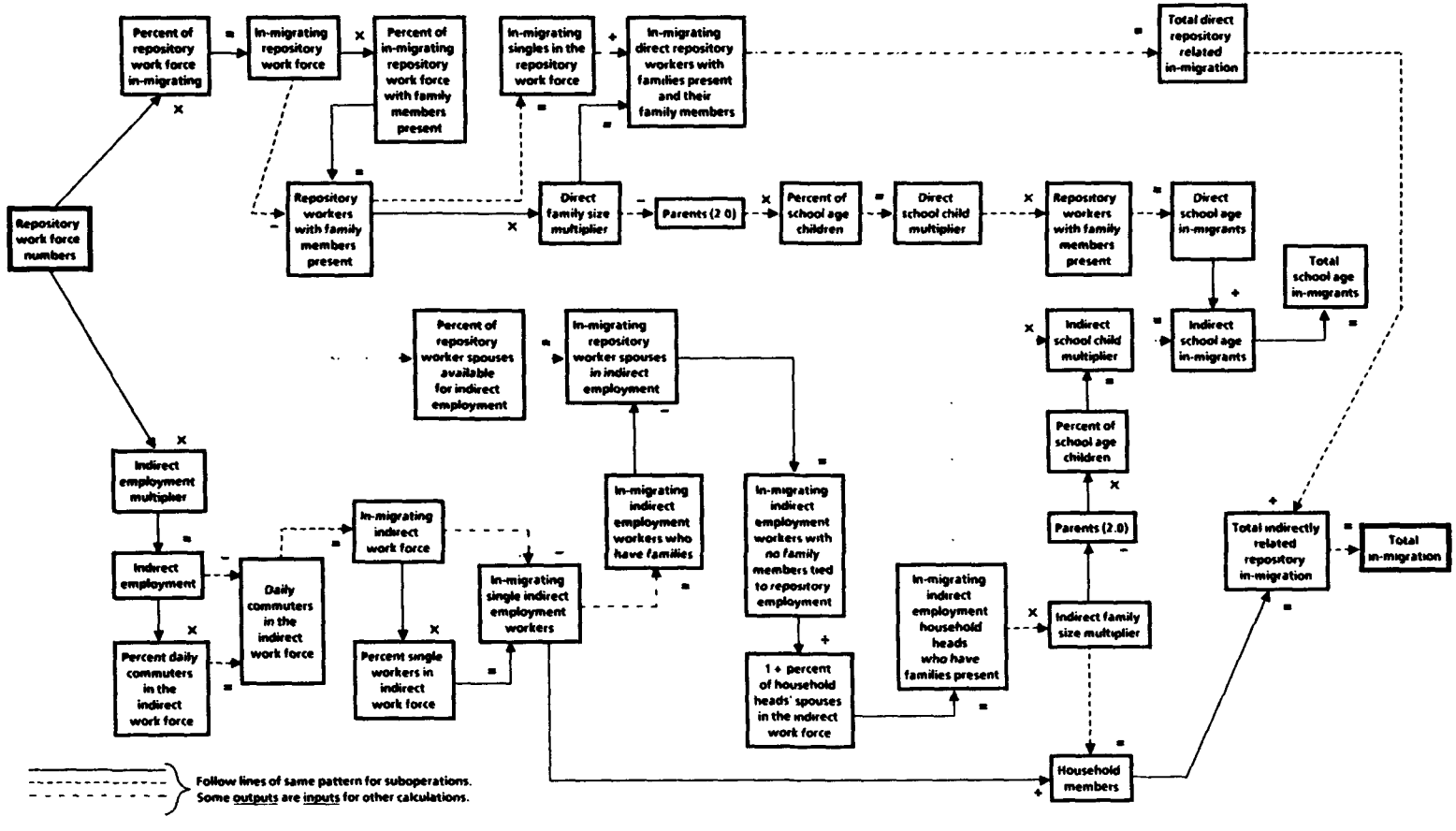
Local Hires - The local workers who are hired for direct or indirect jobs. These workers currently reside in surrounding communities.

In-Migrants - These workers and their families will relocate on a permanent or temporary basis to communities adjacent to the site. These workers and families are considered to be in-migrants during the construction and operation phase, for as long as they are present. It will be necessary to plan for the housing and service needs of these relocating workers.

Household Heads - The in-migrating workers who will be seeking housing for themselves and their families, if present.

Baseline Projections - Future estimates of the population, employment, and other elements of a community or larger jurisdiction based on conditions without the planned project.

Source: Goldsmith, 1984.



Source: Goldsmith, 1984.

In-Migration Model Logic of Calculations

Figure 5-20

Table 5-30. Inputs and Multipliers for the ONWI In-Migration Computer Model

	Construction	Operation
Direct In-Migration		
Percent of repository work force in-migrating - Available labor force within commuting distance (Section 3.6) - Skills of available labor force (Section 3.6)	50.0	45.0
Percent of in-migrating direct work force with family members present[1,2]	75.0	80.0
Percent of direct worker spouses available for indirect employment[3]	20.0	40.0
Family-size multipliers[4]	3.6	3.8
Percent of school-age children[5]	65.0	65.0
Indirect In-Migration		
Indirect employment multiplier[1] - Available labor force within commuting distance (Section 3.6) - Economic activities in the study area (Section 3.6)	0.5	1.0
Percent of local hires for the indirect work force - Assumed to be 10% higher than the direct work force	60.0	65.0
Percent of single workers in the indirect in-migrating work force[6]	35.0	35.0
Percent of indirect worker spouses indirect work force[5]	40.0	40.0
Family-size multipliers[5]	3.3	3.3
Percent of school-age children - same as direct work force	65.0	65.0

Sources:
(1) Murdock and Leistritz, 1979.
(2) TVA, Yellow Creek, 1980.
(3) Halstead and Leistritz, 1983.
(4) DOE, 1978.
(5) Bureau of the Census, 1982.
(6) Bureau of Labor Statistics, 1980.

Table 5-31. Population Location Results During Construction Peak

City	Population In-Migration Percentage[a]	Peak In-Migrant Population (1997)	Percent Change in 1997 Baseline Population[b]
Amarillo	60	1,510	1
Hereford	25	630	3
Canyon	6	150	1
Vega	4	100	8

Note: The formula for the gravity model is as follows:

$$Ii = \frac{\dfrac{Pi}{Dij^{bj}}}{\sum_{i=1}^{n} \dfrac{Pi}{Dij^{bj}}}$$

where: Ii = in-migration percent to community i
Pi = population of community i
Dij = distance between the work site and community i
bj = distance elasticity with respect to job location and bj = 2 (Krueckeberg and Silvers, 1974)
n = number of communities.

(a) Five percent of the in-migration population is expected to locate in rural areas.

(b) Baseline population numbers are presented in Section 3.6.

Table 5-32. Population Location Results During Operation

City	Population In-Migration Percentage[a]	Peak In-Migrant Population (2005)	Percent Change in 2005 Baseline Population[b]
Amarillo	60	1,230	1
Hereford	25	510	2
Canyon	6	120	1
Vega	4	80	5

Note: The formula for the gravity model is as follows:

$$Ii = \frac{\frac{Pi}{Dij^{bj}}}{\sum_{i=1}^{n} \frac{Pi}{Dij^{bj}}}$$

where:
- Ii = in-migration percent to community i
- Pi = population of community i
- Dij = distance between the work site and community i
- bj = distance elasticity with respect to job location and bj = 2 (Krueckeberg and Silvers, 1974)
- n = number of communities.

(a) Five percent of the in-migration population is expected to locate in rural areas.

(b) Baseline population numbers are presented in Section 3.6.

Baseline population projections (Section 3.6) were added to project-related in-migration to determine total population and service demands. Community service requirements and fiscal impacts on communities were determined based on data presented on existing service capacity in Section 3.6. Potential changes in service capacities (e.g., water, sewer, etc.) and service standards (e.g., police-to-population ratios) resulting from projected baseline project-related growth were assessed. Impacts on local revenues and expenditures are addressed similarly. Additional sources of revenue and mitigation measures are discussed.

The four communities expected to receive the majority of the in-migrating work force (approximately 95 percent) are Amarillo, Hereford, Canyon, and Vega. Therefore, the following impact evaluation focuses on these communities.

5.4.1 Population Distribution and Displacement

Figure 5-21 shows project work force requirements. Table 5-33 gives direct, indirect, and total in-migration of families and singles that is projected to be generated by the project during the construction phase. Cumulative in-migration will peak in the sixth year of construction. The projected change in population within commuting distance from the site is approximately 0.9 percent of the current population during the peak repository construction period. This figure does not include changes in the baseline population. By this time a total of approximately 2,520 people will have moved into the area. During the last three years of the construction phase, the work force will decline and some out-migration will occur.

As shown in Table 5-34 and Figure 5-22, during the first few years of repository operations, changes in the work force and population supporting the facility will occur. An average of 1,000 workers is expected throughout operations. The peak number of workers is 1,150 and occurs in years 14 to 17 of the project. A higher proportion of the operations workers moving into the area are assumed to be married and accompanied by their families. During the peak operation years, cumulative in-migration will be approximately 2,040 people.

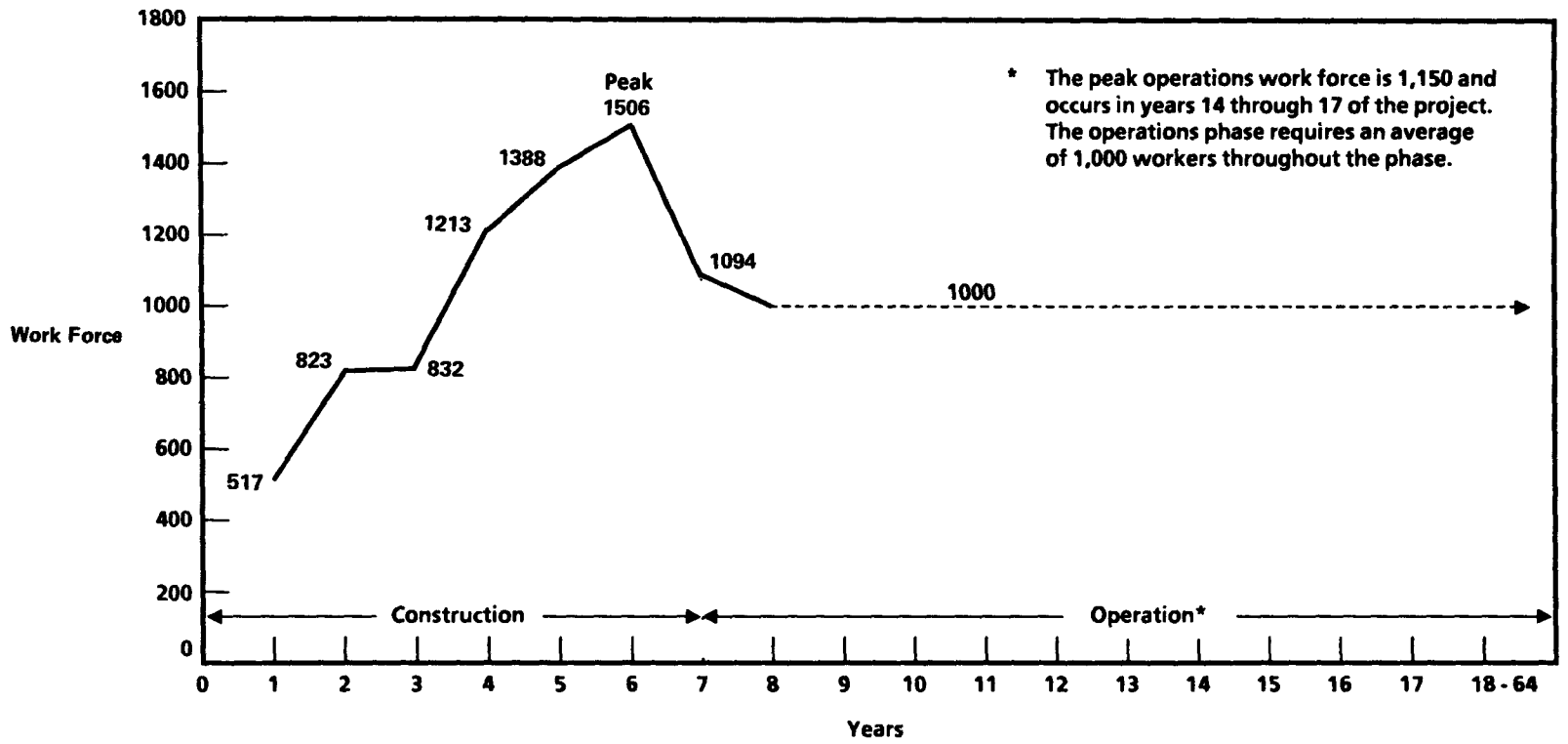
5.4.1.1 Construction

The estimated in-migrating population is allocated to local communities on the basis of the results of the population allocation model. The model estimates the percentage of in-migrants likely to settle in each community, based on the distance from the site to the community and the population of the community. The calculated percentages for the four affected communities are: Vega, 4 percent; Amarillo, 60 percent; Hereford, 25 percent; and Canyon, 6 percent. The population relocating to these communities represents approximately 95 percent of the expected project-related in-migration. The remaining 5 percent is anticipated to settle in other communities and rural areas of the nine-county study area.

By year 6, which is the peak year in terms of cumulative in-migration, approximately 1,510 people will have relocated to Amarillo. That number is equivalent to approximately 1 percent of the population of 184,746 projected for Amarillo in the year 1997 without the project (Table 5-31). The analogous figures for the other cities are Hereford, 3 percent; Canyon, 1 percent; and Vega, 8 percent. The population allocation model predicts that Vega will have the greatest proportional impact because of its relative size and proximity to the site. The other communities will experience less of an impact in comparison with baseline projections because they are further from the site and have significantly larger baseline populations. The communities of Hereford, Canyon, and Vega will receive 630, 150, and 100 new residents, respectively, in the peak construction year.

5.4.1.2 Operation

The estimated number of people in-migrating to Amarillo, Hereford, Canyon, Vega, and the surrounding area during the peak of the operations phase of the repository is provided in Table 5-32. The percentages of in-migrants relocating to each community are Amarillo, 60 percent; Hereford, 25 percent; Canyon, 6 percent; and Vega, 4 percent. The greatest annual population increases will occur in the seventh year of operation (project year 14) and will be



Repository Work Force Requirements

Figure 5-21

Table 5-33. Estimated Direct, Indirect, and Total In-Migration During Repository Construction[a]

Year	Direct			Indirect[b]			Total Annual Increment	Cumulative Increase
	Single Workers	Married Workers	Families	Single Workers	Married Workers	Families		
1	70	190	500	40	20	50	870	870
2	30	120	300	20	10	30	510	1,380
3	0	0	10	0	0	0	10	1,390
4	50	150	360	30	20	30	640	2,030
5	20	60	170	10	10	20	290	2,320
6[c]	20	50	100	(10)	0	20	200	2,520
7	(50)	(160)	(390)	(30)	(20)	(40)	(690)	1,830

(a) Values presented are approximate; results of models and calculations have been rounded to the nearest 10.

(b) Indirect work-force numbers are based on the assumption that a percentage of the spouses of married workers in the direct (20 percent) and indirect (40 percent) work forces are available for indirect employment.

(c) Parentheses indicate decrease in work force resulting in out-migration.

Source: Hines, 1985. ONWI In-Migration Model Outputs.

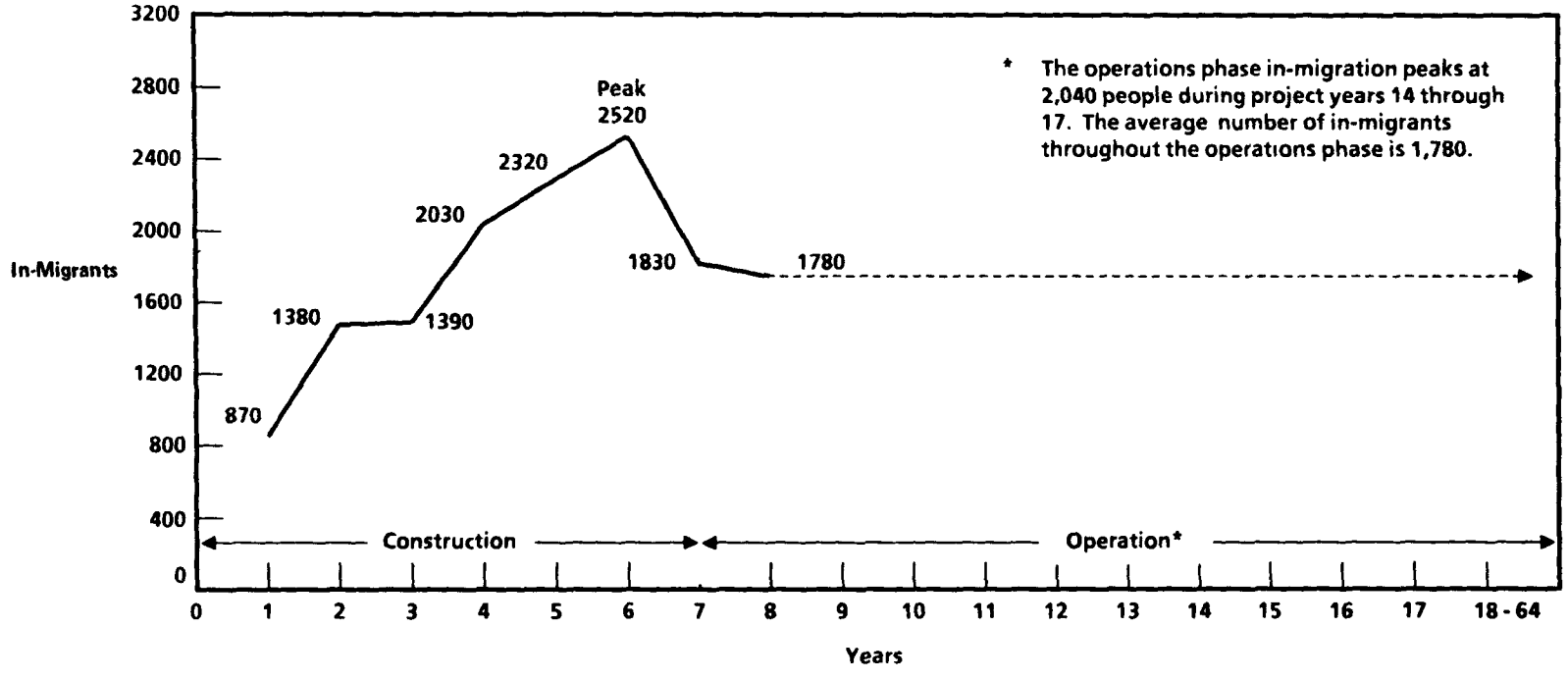
Table 5-34. Direct, Indirect, and Total In-migration During Peak Repository Operation[a]

Year	Direct			Indirect[b]			Total Annual Increment[e]	Cumulative Increase
	Single Workers	Married Workers	Families	Single Workers	Married Workers	Families		
14-17	100	410	1,160	140	70	160	2,040	2,040

(a) Parentheses indicate decrease in work force resulting in out-migration. Values presented are approximate; results of models and calculations have been rounded to the nearest 10.

(b) Assumption: 40 percent of the spouses of married workers in the direct and indirect work forces are available for indirect employment.

Source: Hines, 1986. ONWI In-Migration Model Output.



Total Cumulative In-Migration

Figure 5-22

approximately 1,230 in Amarillo, 510 in Hereford, 120 in Canyon, and 80 in Vega. In comparison to the year 2005 projected baseline population, the project-related increase would be 1 percent for Amarillo; 2 percent for Hereford; 1 percent for Canyon; and 5 percent for Vega.

5.4.1.3 Decommissioning and Closure

The size of the work force will decrease during the 23-year caretaker period. An average of 230 workers will be required during this phase. Some job displacement will occur at this stage, creating some unemployment and possibly out-migration. Out-migration may also initiate a decline in some indirect employment opportunities. The caretaker period is followed by a 5-year decommissioning phase. The decommissioning workforce will average about 930 workers. Many of the decommissioning jobs are expected to be short-term so that the majority of the workforce in-migrating for jobs at this stage would not be in-migrating permanently. At the end of decommissioning, some unemployment and out-migration is likely to occur. However, growth in the local economy is expected to have created alternative opportunities for some of the workers who will no longer be employed at the repository.

5.4.1.4 Displacement of Residents

In addition to contributing new people to the communities near the site, the construction of the repository will also necessitate the relocation of all residents currently living within the 23.3-square-kilometer (9-square-mile) site. Based on the distribution of residences within the site and the average number of persons per household in Deaf Smith County, it is likely that as many as 27 people will require relocation. In addition, displacement of residences may occur along access roads constructed to serve the facility. Under the Uniform Relocation Assistance and Real Property Acquisitions Act of 1970 (42 USC 4601 et seq.), the DOE will compensate individuals, partnerships, corporations, and associations who are to be displaced because the Federal government has acquired their property. Under this Act, the acquiring agency must offer fair market value for the property. The Act encourages Federal departments such as the DOE to make every reasonable effort to acquire real property expeditiously by negotiation or by offering just compensation, which must be at least as much as the DOE's approved appraisal of fair market value of the property.

5.4.2 Economic Conditions

5.4.2.1 Employment

5.4.2.1.1 Construction. The proposed repository would provide a substantial number of jobs to the local area. Table 5-35 summarizes anticipated employment opportunities for the construction phase, including the expected number of jobs that would be provided to local residents. The project would require many types of skilled workers, including carpenters, electricians, ironworkers, laborers, engineers, pipefitters, and teamsters. Amarillo, Hereford, and Canyon are expected to be the major suppliers of such skills, but the availability of training programs would allow persons from all communities to attain necessary skills for repository employment. As Table 5-35 indicates, the number of workers will increase during the first 6 years and then decline slightly.

While the increased employment would tend to provide higher incomes for the workers, it may also reduce labor supplies for other sectors of the local economy and increase the cost of living in the area. It is not unusual for rents and food prices to increase in such affected communities in response to project-generated demand pressures. As a result, farmers and small business owners may find that their labor costs increase, and people on fixed incomes, such as the elderly and the poor, may find it difficult to pay for needed services. In addition, if growth is substantial, local business interests may have difficulty in competing with any new large-volume stores that may be attracted to the area. This impact can be reduced by providing technical planning assistance and improvement loans or grants to the community so that the economic benefits of development also accrue to local businesses.

If site contractors hired local residents, impacts would be reduced. This would reduce the number of workers and families relocating to an area. This would also increase the

Table 5-35. Employment Generated by Repository Construction[a]

Year	Direct Employment				Indirect Employment				Total Cumulative Employment
	In-Migrating	Local	Yearly Increment	Cumulative Direct Employment	In-Migrating	Local	Yearly Increment	Cumulative Indirect Employment	
1[b]	260	260	520	520	100	160	260	260	780
2	150	150	300	820	70	80	150	410	1,230
3	10	0	10	830	0	10	10	420	1,250
4	190	190	380	1,210	70	120	190	610	1,820
5	90	90	180	1,390	40	40	80	690	2,080
6	60	60	120	1,510	20	40	60	750	2,260
7[c]	(210)	(210)	(420)	1,090	(80)	(120)	(200)	550	1,640

(a) Numbers are rounded to nearest 10.
(b) Assumes that 50 percent of the repository work force will be hired locally and 50 percent will in-migrate.
(c) Parentheses indicate decrease in work force resulting in out-migration.

Source: Hines, 1986.

economic benefit to the region by increasing local employment opportunities for existing residents. In addition, the amount of wages spent outside the region are likely to be less for existing residents than for in-migrants who may be there for a shorter period of time.

5.4.2.1.2 Operation. The amount of in-migrating and local employment that can be expected from repository operations is shown in Table 5-36. The operations figures are larger than in the construction phase because the indirect employment multiplier is higher for the operating phase. The percentage of local hires is also assumed to be greater for the operations phase. Local labor is assumed to account for approximately 65 percent of the peak repository-related work force during the operations phase. Some short-term unemployment may occur in the period of transition between construction and operation, depending upon the skill requirements for each phase and the degree to which construction personnel seek operations employment.

During the operations peak approximately 1,380 local workers could be employed in repository-related jobs. Amarillo is the largest city near the site and has the greatest diversity of skilled workers; therefore, it is expected to provide many of the local workers during these years. Hereford and Canyon can also be expected to provide a substantial number of workers. Training programs should help prepare local workers to fill positions on the project.

5.4.2.1.3 Decommissioning and Closure. During the caretaker period, an increase in area unemployment may result from reduced employment at the repository pending replacement of jobs by other regional economic activity. The decommissioning phase will provide some additional job opportunities but they are expected to be short term. Following the decommissioning phase, area unemployment and out-migration is expected to occur. Some communities may experience greater unemployment than others. Levels of unemployment will depend on the diversity of a community's economic base and the percentage of its labor force employed at the repository. The unemployment effects can be mitigated through economic development programs. The effectiveness of such programs will depend upon the timing of programs relative to decommissioning activities and the resources available for other such economic opportunities.

5.4.2.2 Economic Activity

5.4.2.2.1 Construction. Business activity in the area is expected to increase due to purchases related to repository development and purchases by the work force for personal needs such as food, clothing, housing, and entertainment. Increases in trade, government, and the services section of the economy are anticipated. Increases in demand, particularly for consumer goods and housing, may result in inflationary pressures on prices, causing adverse effects on local residents, particularly those on fixed incomes. Most consumer purchases will occur in the communities of Amarillo, Canyon, Hereford, and Vega where workers reside.

Farmland values in the study area between 1974 and 1982 have increased but at a slower rate than statewide farmland values (see Section 3.6.2). The construction of the repository may have some effect on the marketability and value of land close to the site, including an initial decline in value, although there are presently no data to substantiate the extent of land value changes adjacent to the construction site. Conversely, residential property values in surrounding communities may increase as the in-migrating population places additional demands on the housing market. The extent of these effects has not been estimated at this time.

Direct purchases of materials during construction are estimated to be about 11.3 million dollars per year (1983 dollars). Approximately 10 percent of the material purchases are expected to be made in the local area. Using an economic base multiplier of 1.5, these local purchases are estimated to amount to about 16.9 million dollars per year during construction. This represents an annual increase of about 0.6 percent in local sales during construction.

5.4.2.2.2 Operation. Direct local purchases of materials during operations are expected to average about 3 million dollars per year. Repository purchases of goods and services will contribute to the regional economy. It is expected that most large-volume goods suppliers are located in Amarillo, as are major service suppliers, and that many local purchases would be made there.

Table 5-36. Employment Generated by Repository Operations[a]

Year	Direct Employment				Indirect Employment				Total Cumulative Employment
	In-Migrating	Local	Yearly Increment	Cumulative Increase	In-Migrating	Local	Increment	Cumulative Increase	
14-17[b]	520	630	1150	1150	400	750	1150	1150	2300

(a) Numbers are rounded to nearest 10.
(b) Assumes that 65 percent of the repository work force will be hired locally and 35 percent will in-migrate.

Source: Hines, 1986. ONWI Population In-Migration Model Outputs.

The indirect output multiplier effect should increase local economic activity. The Texas Department of Water Resources input/output model indicates that the mining multiplier is 1.3 and the construction multiplier is 1.6 in the High Plains area. A multiplier of 1.5 was applied to project purchases in the region. Total purchases in the region, then, during operations will be about $4.5 million per year. The project will also have an impact on the local economy due to purchases by work force for personal goods and services in surrounding communities where workers reside.

The potential inflationary effect of the project and its effects on local residents with fixed incomes is covered in the discussion of construction impacts. During the operation phase, this effect should diminish somewhat as the number of employees and the income generated by the project begins to stabilize.

5.4.2.2.3 Decommissioning and Closure. The decline in employment during the caretaker phase will result in secondary effects such as a decrease in consumer spending. As consumer spending decreases, demand for secondary goods and services will decline. Spending will increase during the decommissioning phase and will decline once again after decommissioning. Reduced levels of repository demand may be offset by other economic development in the area.

5.4.2.3 Displacement of Economic Activity

The economic impact on the county from the removal of 2,331 hectares (5,760 acres) of land from either rangeland or cropland use is anticipated to be relatively small, as this land requirement represents less than 0.6 percent of the total land in Deaf Smith County. Farmers whose land is taken out of production for a repository will be compensated at fair market value. Any displacement will occur during the construction phase; no new displacement is expected during operation.

Although the DOE does not pay property taxes for its facilities, it does pay grants equal to taxes. These payments are discussed in Section 5.4.5.

By the time operations begin, any previous effect on land values adjacent to the repository should have normalized to the prevailing market levels. Property values in surrounding communities should remain at about the level they reach during the construction phase unless they are further influenced by increases in the work force stimulating other new development. In addition, changes in residential property values may result if the type of housing required by the operations work force differs from the construction work force requirements.

No additional economic activity will be displaced during decommissioning unless highly specialized business activities dependent primarily on repository operations lose their market and cease operations as the result of decommissioning. The decline in employment may result in housing vacancies which may depress residential property values.

5.4.2.4 Agricultural Impacts

The potential agricultural impacts related to a nuclear waste repository stem from the land and water requirements of the facility and the effects of the repository on real property and product values. The following summary section is based on the calculations provided in Sections 5.4.2.4.1 and 5.4.2.4.2.

The removal of land from agricultural production is expected to result in an annual loss in the socioeconomic study area of over $1.6 million in crop and livestock revenues at peak construction and about $1.7 million at peak operation. This loss represents about 0.12 percent of total anticipated crop and livestock revenues in the region in 1997. With the construction of the repository, 148 hectares (365 acres) of productive cropland will be lost to housing and other residential services due to in-migrating persons. During peak operation the need for land will decrease to 117 hectares (288 acres). Water demands of the repository and in-migrants have been measured in terms of equivalent requirements for irrigating land. During peak construction (1997) there will be a net gain of water available to irrigate 1,959 hectares (4,839 acres), and during peak operation (2005) water to irrigate

1,940 hectares (4,792 acres) will be available. All of the net gain in water will occur in Deaf Smith County. For those areas where a reduction in available water will be experienced due to in-migrating population, the impact is anticipated to be minimal.

5.4.2.4.1 Potential Agricultural Impacts of Repository Land and Water Requirements. The high-level nuclear waste repository will require approximately 165 hectares (408 acres) for surface facilities. The site will also consist of the geologic repository underground operations area of approximately 906 hectares (2,240 acres). An additional area of about 1,425 hectares (3,120 acres) is required to assure control of human activities at the proposed site for the purpose of preserving the integrity of the site. Construction of support facilities will disrupt land use as well. A relatively small area will be disturbed for the construction or installation of a water line and a gas line, but only for the short time necessary to dig a trench and bury the line. Installation of access roads and a railroad spur could disrupt farming operations adjacent to the roads or rail line (Section 5.1.1).

Repository development and related municipal needs for in-migrants will result in demands on ground-water sources. The total water use at the site during the seven-year construction phase is 681,300 cubic meters (180 million gallons) (Section 5.2.2.2). In 1997, the year of peak construction activity, average annual water use is expected to be 98,410 cubic meters (26 million gallons). In 1980, water use for irrigated farming in Deaf Smith County was approximately 3,963 cubic meters per hectare (1.3 acre-feet per acre) (NUS, 1985, BMI/ONWI-557; 1984, ONWI-461). At peak construction, water consumption at the site will be about the same as the amount used to irrigate 25 hectares (61 acres).

The total water use at the site during repository operation is 9.3 million cubic meters (7,520 acre-feet). Average annual water use is about 163,000 cubic meters (132 acre-feet). Assuming water use for irrigated farming of 3,963 cubic meters per hectare (1.3 acre-feet per acre), it is estimated that annual water use at the site during operations will be about the same as the amount used to irrigate 41 hectares (102 acres).

Ground water will also be used by the repository-related population in-migrating to the region. Additional municipal water needs in Amarillo, Hereford, Canyon, and Vega are identified in Table 5-37. These water needs have been translated into equivalent water needs for irrigating farmland by assuming that the cubic meters of water per irrigated hectare (acre-feet of water per irrigated acre) are 1,220 (0.4), 6,100 (2.0), and 3,050 (1.0) in Oldham, Potter, and Randall counties, respectively (NUS, 1984, ONWI-461). It is estimated that in 1997 repository in-migrants will use water that would be sufficient to irrigate 108 hectares (268 acres) of cropland. Expected water use at peak operation is greater due to the larger direct and indirect work force requirements. Estimated water use by repository in-migrants in the year 2005 would be sufficient to irrigate 105 hectares (259 acres) of cropland.

5.4.2.4.2 Agricultural Impacts Resulting from Repository-Related Population Growth. The cumulative in-migration (direct and indirect workers and their families) at the peak of construction and operation activity is estimated to be 2,520 persons and 2,040 persons, respectively (Tables 5-31 and 5-32). The majority of the population is expected to locate in Amarillo, Hereford, Canyon, and Vega. Residential land requirements associated with in-migrating persons have been estimated by comparing the number of additional housing units required to maintain existing vacancy rates with the average amount of land required to support those additional units. Because the demand for specific types of housing is not known, the following assumptions have been made: (1) 30 housing units will be needed for every 100 persons, and (2) the units will be provided in the following mix: 18 units at 4 units per acre, 10 units at 8 units per acre, and 2 units at 15 units per acre (Murray and Lamont, 1978). This results in a land requirement of 5 hectares (12.64 acres) for 30 housing units and associated services such as utilities, roads, and other services or 0.17 hectares (0.42 acres) per household (Mountain West Research, 1979).

For impact assessment purposes it is necessary to make an assumption about the land these additional units will consume. Although it is likely that some housing units will be constructed on vacant land within urban areas, it has not been determined how much vacant land is available and suitable for residential development. Therefore, it has been assumed that all

Table 5-37. Repository and Municipal Water Needs Due to Repository Construction, Operation, and In-Migrating Population, Deaf Smith County Region

		Municipal[a]				
	Repository	Amarillo	Hereford	Canyon	Vega	Total Municipal Use
1997 Water Needs, Acre-Feet	80	224	101	22	22	370
1997 Equivalent Acres of Irrigated Land[a]	61	112	78	22	56	268
2005 Water Needs, Acre-Feet	132	224	90	22	22	358
2005 Equivalent Acres of Irrigated Land	102	112	69	22	56	259

(a) Municipal water needs were calculated from Tables 5-52 and 5-53.

land needed for residential construction will be consumed from agricultural lands near urban areas. As a consequence, urban land area will increase and rural acreage will decrease, with resultant loss of productive farmland. The amount of additional land required by in-migrants during the peak construction year will be Amarillo, 94 hectares (231 acres); Hereford, 39 hectares (95 acres); Canyon, 9 hectares (23 acres); and Vega, 6 hectares (15 acres), for a total of 148 hectares (365 acres). During operations, the peak land requirements will be Amarillo, 74 hectares (182 acres); Hereford, 31 hectares (76 acres); Canyon, 7 hectares (18 acres); and Vega, 5 hectares (12 acres), for a total of 117 hectares (288 acres).

Effects on Crop Agriculture. Loss of productive acreage due to the repository and residential construction needs ranges from 100 percent of productive land on the site to 0.61 percent of Deaf Smith County land area, to 0.13 percent of the land area of the seven Texas counties included in the impact area for the repository, as shown in Table 5-38.

Approximate current use of the 2,331-hectare (5,760-acre) Deaf Smith County site is as follows:

217 hectares	(536 acres)	rangeland
2,091 hectares	(5,168 acres)	cropland
23 hectares	(56 acres)	residential, commercial, or playas
2,331 hectares	(5,760 acres)	total site

In approximating cropland use, a realistic, conservative-case assumption is made that all cropland in the site and vicinity is irrigated.

As construction, operation, and closure will result in the removal of land from production, there will be a direct effect on site, county, and regional crop production. The direct economic loss from a reduction in crop agriculture is measured in terms of loss of crop receipts for 1997 and 2005, the years of peak construction and operation.

Estimation of the loss in crop production from removal of 2,092 hectares (5,168 acres) of irrigated land is based on the assumption that the types of crops grown on the site are in the same proportion as those grown on irrigated cropland throughout the county. Corn, upland cotton, grain sorghum, wheat and sugar beets are the major irrigated crops. The proportion that each comprises of total harvested irrigated acres for the County, and the estimates for the site, are shown in Table 5-39.

As described in Section 3.6.2, another important component of the agricultural industry in this area is the seed production industry. Hybrid seeds are produced in the Deaf Smith County site area and these seeds are used in commercial farming (Gustafson, 1984). Table 5-40 shows the number of acres producing certified, registered, and foundation seed by county for the Deaf Smith County study area. The number of acres producing certified, registered, and foundation seed was up to 0.4 percent of the total amount of cropland in the study area between 1982 and 1984.

In Deaf Smith County, in 1984, this type of seed production was occurring on 0.8 percent of the County's cropland. Although the land area is rather limited, the value of seed may be slightly higher than the average value of other crops. The Texas Department of Agriculture estimated that the average value of seed is 60 cents per pound in this area (TDA, 1985). This compares to a value of 81 cents per pound for cottonseed, 39 cents per pound for hay, 25 cents per pound for peanuts, 59 cents per pound for upland cotton, and $1.13 per pound for American-Pima cotton (TDA, 1985). Thus, seed value is within the range of other crop values. Since the value of seed is similar to that for other crops, the value of crop loss resulting from repository development is estimated using the crop production average values in Table 5-41. As shown in Table 5-41, average crop values per acre are highest for irrigated sugarbeets. Because crop values are extremely complex due to their susceptibility to external influences such as technology, world economic policies, and domestic and foreign supply and demand, attempts to project future crop values would be speculative. Therefore, to measure the impact of repository program land requirements on crop values, it has been assumed that their values will remain constant at 1982 levels. As Table 5-41 indicates, the estimated annual value of

Table 5-38. Productive Acreage Lost as a Result of the Repository and In-Migrant Population

	Size (acres)	Productive Land Lost (acres)		Productive Land Lost (% of total)	
		Peak Construction	Peak Operation	Peak Construction	Peak Operation
Site	5,760	5,760	5,760	100.00	100.00
County (inclusive of site)	966,000	5,856	5,836	0.61	0.61
Region[a] (inclusive of site and county)	4,758,000	6,125	6,048	0.13	0.13

(a) Does not include the two New Mexico counties considered to be in the nine-county Deaf Smith County region.

Sources: NUS, 1984, BMI/ONWI-509 and Section 5.4.1.

Table 5-39. Crops Grown on Harvested Irrigated Acreage, Deaf Smith County and Site

	Harvested Acres for Deaf Smith County			Proportion of Total Harvested (Acres)	Estimated Crop Cover on Deaf Smith Site (Acres)
	1981	1982	1981-82 Average		
Irrigated Crops:					
Corn	27,100	24,000	25,550	14.0	724
Upland Cotton	10,400	5,700	8,050	4.0	207
Grain Sorghum	51,100	54,500	52,800	28.0	1,447
Sugarbeets	9,900	11,700	10,800	6.0	310
Wheat	90,500	77,200	83,850	44.0	2,273
Vegetables and Other	5,000	8,600	6,800	4.0	207
Total	194,000	181,700	187,850	100.0	5,168

Source: Texas Crop and Livestock Reporting Service, 1982.

Table 5-40. Acres in Certified, Registered, and Foundation[a] Seed Production, Deaf Smith County Study Region

	1982	1983	1984
Castro	1,410	1,078	963
Deaf Smith	2,085	1,966	3,382
Oldham	400	1,000	822
Parmer	850	307	1,123
Randall	85	406	132
Swisher	2,070	2,159	2,878
Potter	N/A	N/A	N/A
Total Seed Producing Acres for Counties	6,900	6,916	9,300
Total Cropland in Counties (1981-82 Average)	2,125,000	2,125,000	2,125,000
Seed Production as a Percentage of Total Acreage	0.4	0.3	0.3

(a) Four classes of seed are recognized in seed certification: breeder, foundation, registered, and certified. Foundation seed is the progeny of breeder seed (source for the production of seed of the certified classes) or foundation seed which is handled to maintain specific genetic purity and identity. Production must be acceptable to the certifying agency. Registered seed is the progreny of breeder or foundation seed handled to maintain satisfactory genetic purity and identity. This class is suitable for the production of certified seed. Certification is a voluntary process whereby inspections are made only for those firms/individuals who choosed to quality and are in a position to qualify. Seed certification is a method for keeping pedigree records on approved crop varieties to ensure their purity (TDA, Texas Seed Certification Directory, 1984, preface). Acres used for non-certified seed production are not included in these estimates.

Source: Texas Department of Agriculture, Computer Printouts of Certified, Registered, and Foundation Seed by county, Feb., 1985.

Table 5-41. Estimated Annual Value of Lost Crop Production Due to Repository and In-Migrant Land Requirements, Deaf Smith County Site

	Value per Acre			Estimated Average Crop Value/Acre		Estimated Annual Value of Lost Crop Production
	1980	1981	1982	1980-1982	Crop Acreage	(1982)
Irrigated Crops:						
Corn	390	433	390	404	724	$292,496
Upland Cotton	272	204	135	204	207	42,228
Grain Sorghum	225	225	236	229	1,447	331,363
Sugarbeets	734	713	(a)	724	310	224,440
Wheat	149	163	168	160	2,273	363,680
Vegetables and Others	(a)	(a)	(a)	344[b]	207	71,208
Total					5,168	1,325,415

(a) Information not available.
(b) Assumed average value of all crops for this category since data were not available.

Sources: Texas Crop and Livestock Reporting Service, 1980, 1981, 1982.
USDA, 1980, 1981, 1982.

lost crop production due to repository activities will be approximately $1,325,415. For compensation purposes, land values (which include crop/livestock value) will be measured at the time land is acquired.

The estimated effects on crop agriculture for Deaf Smith County and the region are based on the assumption that land use in both will not change significantly through the year 2005. The development of land-use projections, based, for example, on a ratio of irrigated to non-irrigated farmland, could result in slight modifications to this analysis and the results.

Analysis of the Deaf Smith County site focused on crops grown on irrigated land; however, the specific characterization of the land to be taken out of production in the County and the region is uncertain. It is assumed that residential development will encroach on farmland (crop/pasture/rangeland), but not on more capital intensive agricultural activities, such as feedlots and grain or seed storage operations. To characterize the land that will be taken out of farming, acreage dedicated to cropland, irrigated land, and pasture and rangeland in 1981 and 1982 was averaged for Deaf Smith County and the seven-county region, as follows:

	Deaf Smith County	Seven-County Region
Total cropland, pasture/rangeland (acres)	832,000	4,365,000
Average of 1981-1982 cropland planted (acres)	438,000	2,125,000
Average of 1981-1982 irrigated land (acres)	249,000	1,277,000
Average of 1981-1982 pasture/rangeland (acres)	394,000	2,240,000
Irrigated land as percentage of cropland planted	57 percent	60 percent

Source: U.S. Department of Agriculture, 1981, 1982, 1983.

Of the total cropland, pastureland, and rangeland in the county, 53 percent of the land is cropland and 47 percent is rangeland. From this characterization it was assumed that 53 percent of the land taken out of production in Deaf Smith County will be cropland and 47 percent will be pasture/rangeland. Irrigated land comprises 57 percent of the cropland in the county that will be removed from production for urban uses.

The regional characterization is only slightly different. The land removed from production in the seven-county region is assumed to be 49 percent cropland and 51 percent pasture and rangeland, with irrigated land comprising 60 percent of the cropland.

The factors on which estimates of the effects on county and regional crop agriculture are based are cash receipts from crops and acres harvested. These are examined over a 3-year period to moderate the influence of variances that occur from year to year based on price expectations and weather patterns.

The average crop receipts per acre for 1980 through 1982 were $168 for Deaf Smith County and $190 for the region. Crop receipts have been projected to 1997 and 2005 (in 1982 dollars) as shown in Table 5-42. The basis for the projection is an expected annual increase of 2 percent per year in crop receipts per acre.

The effect on Deaf Smith County and the region of the loss of productive cropland is shown in Table 5-43. It is expected that in Deaf Smith County, 39 hectares (95 acres) will be removed from production to accommodate housing and infrastructure needs during peak repository construction activity. Based on the current characterization of the land as discussed earlier, 20 hectares (50 acres) are assumed to be cropland and 18 hectares (45 acres) pasture and rangeland. This results in an estimated loss, in addition to the loss from the site itself, of $11,550 in crop receipts. The regional loss (which includes Deaf Smith County, but not the site) is estimated to be $50,373 in crop revenues, during the year of peak construction.

The crop revenue loss at peak operation of the repository is expected to be slightly smaller. Estimated crop revenues lost are $10,800 and $46,665 for the County and the region, respectively, during the year of peak operation.

Table 5-42. Projected Crop Receipts, Deaf Smith County and Region

	1980-1982 Average Receipts From Crops	1980-1982 Average Acres Harvested	1980-1982 Average Crop Receipts Per Acre	1997 Projected[a] Crop Receipts Per Acre	2005 Projected[a] Crop Receipts Per Acre
Deaf Smith County	$ 60,824,000	362,000	$168	$231	$270
Deaf Smith Region	$332,669,000	1,754,000	$190	$261	$306

(a) Assumes 2 percent annual increase in crop receipts since 1981 based on historical trends.

Source: Texas Crop and Livestock Reporting Service, 1973-1982.

Table 5-43. Projected Crop Revenues Lost at Peak Construction and Operation Due to In-Migrant Land Requirements, Deaf Smith County and Region

	Acres Removed From Production	Acres of Cropland	Projected Crop Receipts Per Acre	Crop Revenues Lost
Peak Construction (1997):				
Deaf Smith County (not including site)	95	50	$231	$11,550
Deaf Smith Region (not including site but including D.S. County)	365	193	$261	$50,373
Peak Operation (2005):				
Deaf Smith County (not including site)	76	40	$270	$10,800
Deaf Smith Region (not including site but including D.S. County)	288	153	$305	$46,665

The effects of competing demands for water on crop agriculture will be felt most acutely if repository-related water requirements result in the displacement of water that might otherwise be used for irrigation. Thus, this analysis will be based on evaluating the reduction in crop production that could occur if the amount of land under irrigation declines due to the water requirements of the repository and repository-related in-migrants.

Evaluation of water impacts on crop agriculture is based on the assumption that repository water use, as well as municipal water needs associated with in-migrating population, will displace water that would otherwise be used for irrigation purposes. It is estimated that there are 2,092 hectares (5,168 acres) of irrigated land on the Deaf Smith County site. Because this land would be removed from agricultural production, the water used to irrigate it would become available for other uses. At the peak of construction, repository water needs will approximate that consumed to irrigate 25 hectares (61 acres). In addition, water needs related to in-migrating population in Hereford, Amarillo, Vega, and Canyon will approximate that consumed to irrigate 108 hectares (268 acres) (see Table 5-37). The total requirement will result in a net gain in water in the peak year of construction equivalent to that consumed to irrigate 1,959 hectares (4,839 acres). In the year of peak operation, repository and in-migrant water needs will be about the equivalent of irrigating 152 hectares (376 acres), resulting in a net gain of water available to irrigate 1,940 hectares (4,792 acres).

The availability of additional water for irrigation could result in increased land values. The 1983 average land value per acre of irrigated cropland in Texas was $966, as opposed to a value of $763 per acre for nonirrigated cropland (USDA, 1983), a difference in value of $203 per acre.

This analysis is based on 1980 water use levels. Because of declining water levels in the High Plains aquifer and changing patterns of irrigation practices, the net gain or loss in water due to repository activities may vary significantly in the future (see Section 3.3.3 for description of baseline and projected water conditions).

Effects on Animal Agriculture. Cattle feedlots are the primary determinant of cash receipts from livestock in Deaf Smith County and other counties in the region. However, loss of pasture and rangeland now used for grazing cattle on the site may necessitate removing these cattle.

Raising cattle on pasture and rangeland requires extensive grazing area per head of cattle. For example, during the late 1960s, the average size of cattle ranches located in Arizona, New Mexico, and western Texas was 7,174 hectares (17,720 acres), with an average of 304 cows and heifers 2 years old and over per ranch (Gray et al., 1971). The average amount of ranchland per head of cattle was approximately 28 hectares (68 acres).

Even if current stocking rates are twice as intensive as that reported by Gray et al. (1971), probably less than 200 cattle are being grazed within the 2,331-hectare (5,760-acre) area of the site. This number of cattle is a negligible proportion (less than 0.1 percent) of the total number of cattle in Deaf Smith County. While these cattle would be removed, there would not be any foreseeable impact on the overall Texas Panhandle cattle feeding industry.

Feedlots are the primary determinant of the cash receipts from livestock in a county. However, loss of pasture and rangeland now used for grazing on the site may reduce the number of cattle that can be supported. To estimate the possible effects on individual cattle ranchers, the cash receipts from livestock per acre of pasture and rangeland for the Deaf Smith County region was calculated. This calculation was made on a regional rather than county basis because the uneven distribution of feedlots among counties would significantly skew the results. Average cash receipts from livestock and acres in pasture and rangeland in 1981 and 1982 were used as a basis for the forecast of the loss in livestock production. The average livestock receipts per acre for 1981-1982 are estimated at $207. This average has been inflated at 4 percent a year, the expected increase in livestock receipts, to develop estimates of $939 and $1,285 per hectare ($380 and $520 per acre) (in 1982 dollars) for the peak years of construction and operation. With the estimated loss of 217 hectares (536 acres)

of pasture and rangeland of grazing, losses of $203,680 and $278,720 in livestock receipt are projected for 1997 and 2005, respectively, as shown in Table 5-44.

The effect on Deaf Smith County and the region of the loss of pasture and rangeland is shown in Table 5-45. As stated earlier, 39 hectares (95 acres) are expected to be removed from production in Deaf Smith County to accommodate housing and infrastructure needs during peak repository construction activity. Based on the current characterization of the land, 18 hectares (45 acres) are assumed to be pasture and rangeland. This results in an estimated loss, in addition to the loss from the site itself, of $17,100 in county livestock receipts at peak construction. The regional loss is estimated to be $64,980 in livestock revenues.

The animal agriculture revenue loss at peak operation of the repository is expected to be slightly smaller. Livestock revenues lost are estimated to be $18,720 in the county and $70,200 in the region at peak operation.

The water requirements for animal agriculture are small relative to crop agriculture. Livestock water use in Deaf Smith County was only 1.9 percent of total agricultural water uses in 1980. This is slightly higher than the Deaf Smith Region where 1.3 percent of agricultural water is used for livestock. A comparison with similar results can be made between livestock water use and total water use (Table 5-46).

For this portion of the assessment it has been assumed that all farming activity on the Deaf Smith site will be prohibited. Therefore, there will be no further effects on animal agriculture from competing water demands at the site.

The effects on animal agriculture in Deaf Smith County and the region are expected to be slight. The greatest impact on Deaf Smith County animal agriculture would be if all water needs of the repository and its associated in-migrants are met by diverting water that would otherwise be used for livestock. Water use during peak construction is estimated to be 98,700 cubic meters (80 acre-feet) on the Deaf Smith County site and 124,600 cubic meters (101 acre-feet) in Hereford (Table 5-37). The total annual repository-related water use in Deaf Smith County of 229,500 cubic meters (181 acre-feet) is 3.0 percent of livestock water use. However, because 2,092 hectares (5,168 acres) of irrigated land will be acquired for the repository, water previously used to irrigate that land will be available. Thus, because of the net gain in water from construction and operation of the repository, no water effects on animal agriculture are anticipated.

Summary of Effects on Cropland and Animal Agriculture. Table 5-47 gives a summary of the direct effects on crop and animal agriculture of the loss of productive land on the site, county, and region. It is important to recall that this estimate does not include the impacts of competing water demands.

The indirect agricultural effects of the site, county, and region are best observed on a regional basis because of the presumed high level of agricultural trade between the seven counties included in the regional definition. Crop and livestock revenues for the entire region have been projected based on 1981-1982 average acreage in pasture and rangeland, 1980-1982 average acreage harvested for the entire region, and projected crop and livestock receipts per acre for 1997 and 2005. When compared with estimates of regional crop and livestock revenues lost, the actual decrease in crop and animal agriculture is 0.12 percent at the peak of construction and 0.10 percent at the peak of operation as shown in Table 5-48.

The indirect effects are defined as the change in livestock and poultry purchased; feed for livestock and poultry; animal health costs; seeds, fertilizers, and agriculture chemicals; labor, customwork, and machine hire; and energy and petroleum products. The sum of this business activity for the Deaf Smith region is shown in Table 5-49.

Total estimated production inputs are projected to 1997 and 2005 based on the assumption that these costs will increase an average of 4 percent per year through 2005. The indirect effect of the decrease in crop and animal agriculture production is estimated by assuming there will be a decrease in total estimated production inputs that is equivalent to the loss

Table 5-44. Projected Loss of Livestock Receipts Due to Repository and In-Migrant Land Requirements, Deaf Smith County Site

1981-1982 Average Receipts from Livestock ($1000) for Deaf Smith Region	$462,948
1981-1982 Average Acres in Pasture and Rangeland (1000 acres) for Deaf Smith Region	2,239
1981-1982 Average Receipt per Acre	$ 207
1997 Projected Receipts[a] per Acre (1982 dollars)	$ 380
2005 Projected Receipts[a] per Acre (1982 dollars)	$ 520
1997 and 2005 Acres Removed from Grazing on Deaf Smith Site	536
1997 Projected Livestock Receipts Lost on Deaf Smith Site (1982 dollars)	$203,680
2005 Projected Livestock Receipts Lost on Deaf Smith Site (1982 dollars)	$278,720

(a) Assumes 4 percent annual increase since 1981 in livestock prices.

Source: Texas Crop and Livestock Reporting Service, 1973-1982.

Table 5-45. Projected Livestock Revenues Lost at Peak Construction and Operation Due to In-Migrant Land Requirements, Deaf Smith County and Region

	Total Acres Removed From Production	Acres of Pasture and Rangeland Removed	Projected Livestock Receipts per Acre	Livestock Revenues Lost
Peak Construction (1997):				
Deaf Smith County (not including site)	95	45	$380	$17,100
Deaf Smith Region (not including site but including D.S. County)	365	171	$380	$64,980
Peak Operation (2005):				
Deaf Smith County (not including site)	76	36	$520	$18,720
Deaf Smith Region (not including site but including D.S. County)	288	135	$520	$70,200

Table 5-46. Livestock Water Use in 1980 in Deaf Smith County and Region (acre-feet)

	Livestock Water Use	Total Agricultural Water Use	Livestock Use as Percentage of Total Agricultural Use	Total Water Use For All Purposes	Livestock Use as Percentage of Total Use
Deaf Smith	6,113	315,306	1.9%	322,163	1.9%
Region	20,286	1,494,379	1.4%	1,562,539	1.3%

Source: NUS, 1984, BMI/ONWI-509.

Table 5-47. Estimated Direct Effects on Crop and Animal Agriculture, Deaf Smith Site, County, and Region (in 1984 Dollars)

	Estimated Crop Revenues Lost (1997)	Estimated Live-Stock Revenues Lost (1997)	Total Crop and Livestock Revenues Lost (1997)	Estimated Crop Revenues Lost (2005)	Estimated Live-Stock Revenues Lost (2005)	Total Crop and Livestock Revenues Lost (2005)
Deaf Smith Site	$1,325,415	$203,680	$1,529,095	$1,325,415	$278,720	$1,604,135
Deaf Smith County (including site)	$1,336,965	$220,780	$1,557,745	$1,336,215	$297,440	$1,633,655
Deaf Smith Region (including D.S. County and site)	$1,375,788	$273,880	$1,649,668	$1,372,080	$348,920	$1,721,000

Table 5-48. Regional Crop and Animal Agriculture Production Lost, Deaf Smith County Region

Year	Projected Crop Revenues	Projected Livestock Revenues	Projected Total Crop and Livestock Revenues	Estimated Crop and Livestock Revenues Lost	Revenues Lost As Percent of Total
1997	$490,875,000	$851,200,000	$1,342,075,000	$1,649,668	0.12
2005	$554,625,000	$1,164,800,000	$1,719,425,000	$1,721,000	0.10

Table 5-49. Selected Farm Production Inputs, Deaf Smith County Socioeconomic Region, 1982
(in Millions of Dollars)

	Livestock and Poultry Purchased	Feed for Livestock and Poultry	Animal Health Costs[a]	Seed, Fertilizer, and Agriculture Chemical	Labor Custom-work and Machine Hire	Energy and Petroleum Products	Total Estimated Production Inputs
Deaf Smith County	307.5	115.3	2.9	10.0	11.2	16.7	463.6
Deaf Smith Region	725.0	298.7[b]	12.6	48.4	45.0	78.3	1208.0

(a) Not reported in 1984 Census; therefore estimate based on 1.77 percent average annual increase in other farm production inputs from 1978 to 1982.

(b) Not reported for Randall County in 1984 Census; therefore estimate based on average of 0.49 percent average annual decrease in feed inputs experienced by other counties in Permian Basin Region.

Source: Bureau of the Census, 1984.

in crop and livestock production. This results in an estimated decrease in agricultural business activity of $2.5 million in 1997 and $3.0 million in 2005 as shown in Table 5-50.

The indirect effects of competing demands for water are worthy of consideration because of the uncertainty surrounding the anticipated direct effects. Possible indirect effects on crop agriculture include changes in the types of agricultural activities as well as implementation of irrigation methods that conserve more water. As discussed previously, there is extensive use of irrigation in crop agriculture. If water competition increases, farmers may switch from crops such as corn that are highly water intensive to other crops such as wheat, milo, or grasses, that require less water and irrigation. Alternatively, they may convert their cropland to pasture land and increase their livestock herds.

Although furrow irrigation is the most commonly practiced method of irrigation in the Deaf Smith region, the amount of land under sprinkler irrigation increased by over 6,000 percent in Deaf Smith County alone between 1964 and 1979 (Section 3.4.1.1). Greater competition for scarce water could encourage farmers to implement irrigation methods that better conserve water such as drip or trickle irrigation.

Indirect effects of repository-related demands for water may be experienced in the animal agriculture sector as well. If dryland farming activity increases as a result of decreased water availability for crop irrigation, productivity will decrease and prices for locally obtained feed such as corn and grain sorghum will increase.

As with the indirect effects of repository-related demand for land, there may also be effects on other farm production expenses (livestock and poultry purchased; feed for livestock and poultry; animal health costs; seeds, fertilizers, and agriculture chemicals; labor, custom work, and machine hire; and energy and petroleum products). Because these indirect effects of the repository are expected to be very slight, resultant impacts on employment are expected to be negligible.

The total number of paid employees in agricultural services establishments in 1978 in the Deaf Smith region was 2,869 (Bureau of the Census, 1981). If employment drops proportionally to the drop in agricultural business activity, approximately five jobs in agricultural services will be lost across the region for both 1997 and 2005. This is not expected to lead to a substantial change in agricultural employment.

Effects on Food Processors. The losses in crop and livestock production may affect food processors in Deaf Smith County and region if supplies previously relied upon are limited or no longer available. As food processors are assumed to receive agricultural product inputs from several farmers in a multicounty area, it is most useful to examine the effects on food processors from a regional perspective.

The crop and livestock revenues lost to farmers were discussed previously and, as shown in Table 5-48, are estimated to be 0 12 percent and 0.10 percent of projected regional crop and livestock revenues in the years of peak construction and operation. This implies an equal decline in availability of agricultural product inputs to food processors in the region. Of greatest significance is the removal of the Deaf Smith County site itself from production, an area of high yield due to the widespread use of irrigation. In comparison, relatively few acres are expected to be removed from production to accommodate residential expansion.

Decline in supply may have several possible effects on food processors. The reduced supply could result in a lower level of production for an individual processor, if a new source of supply is not available. Alternatively, processors may be able to find new suppliers and experience no change in level of production.

Even if production is maintained, there may be greater competition for local crops and livestock, resulting in potentially higher prices to processors. Processors may also incur higher transportation costs if they are forced to purchase supplies from sources farther away from their processing facility.

Table 5-50. Indirect Effects of Lost Crop and Animal Agriculture, Deaf Smith County Region (in Millions of Dollars)

Year	Total Estimated Production Inputs	Lost Crop and Livestock Production	Decrease in Total Estimated Indirect Agricultural Business Activity
1982	$1,208		
1996[a]	$2,091.9	0.12 percent	$2.5
2005[a]	$2,977.4	0.10 percent	$3.0

(a) Based on assumed average annual increase in expenses of 4 percent.

Reduced production levels can diminish economies of scale that have previously been achieved for a particular food processor, resulting in higher per unit costs. Increased costs of inputs, due to higher agriculture product prices or transportation costs, may also result in higher per unit costs. Possible consequences are decreased profit margins to the food processor, or reduced competitiveness as output prices are raised to offset costs. These effects are not expected to be widespread.

Partial or total curtailment of operations by a food processor, either as a result of unavailability of supply or reduced competitiveness, will affect regional employment. The extent of effects on employment levels will depend on the extent to which processor operations are curtailed.

Impacts on water resources may affect food processors in Deaf Smith County and the region if the cost of water increases or if the repository-related water requirements result in a decreased availability of water to the processors. However, water use in manufacturing is less than 1 percent of total water use in the region (NUS, 1984, BMI/ONWI-557); therefore, food processing needs are not expected to be a major factor in the competing demand for water.

Water requirements of food processors vary. In some operations the primary water need may be for cooling equipment. Higher quality, and increased quantities of water are required for food processing activities such as meat processing. Should competition for water occur due to repository-related activity, some processors may experience increased production costs or decreased production levels.

Possible indirect effects of the water impacts include changes in the availability of agricultural product inputs to food processors in the region. Decreased availability of water could result in lower crop yields and hence a decrease in crop product inputs as well as an increase in their cost. Alternatively, if water for irrigation becomes less available, some farmers may increase their livestock operations, resulting in greater availability of inputs to meat processors.

Curtailment of operations by a food processor due to repository-related demands for water is unlikely; however, should curtailment occur, employment in the food processing industry may be affected.

Potential Effect of Perceived Contamination on Agricultural Products. As indicated elsewhere in this report, on the basis of either concentration/maximum permissible concentration ratios or repository to background-related radionuclide ingestion ratios, the actual repository contribution to potential radiological contamination of agricultural products in the Texas Panhandle is miniscule (Section 6.4). There is some public concern relative to agricultural impacts of nuclear waste disposal facility siting, as evidenced by comments in the hearings. Part of this public concern is due to perceptions that agricultural commodities and processed food products could become radiologically contaminated. A public perception that products might be contaminated, even if they are completely safe to consume, could affect the actions of some agricultural commodity purchasers. If these commodity purchasers (such as meat packers and grain processors) decided to seek alternative supply sources, farm sales of agricultural products could decline, along with commodity prices. This, in turn, could exert downward pressure on land values. Both effects would hurt the area's economy, which is closely tied to agriculture.

As long as there is no actual food product contamination during repository operations, the perception that contamination exists may be a "short-term" impact of greatest significance during the first few years of waste emplacement. Monitoring activities (such as soil- and water-sample testing) will be conducted during this time to determine if soils or water contain contaminants.

In this preliminary assessment, literature was identified that quantitatively measures business or individual consumer reactions when faced with the perception that food products may be radiologically contaminated. In studies of the Three Mile Island, a case in which an actual radiological incident occurred, the Pennsylvania Department of Health indicated that

effects on agricultural sales were limited to the week following the accident (Flynn and Chalmers, 1979, NUREG/CR-1215, p. 60). The only other food-related decline was in recreational fishing in the Susquehanna River. Fishing was restricted for a period by the NRC, but the decline did not affect total-year fish catch (Hickey, 1981, NUREG-0754).

Using a realistic, conservative case, several potential effects related to a perceived threat of radiological contamination of agricultural products are possible. These include the following:

- Local concerns regarding agricultural products contamination
- Potential for food processors or consumers to reduce consumption of agricultural products purchased near the site, or potential for food processors to leave the area
- Economic multiplier effects of the potential exit of food processors from the area
- Potential effect of reduced crop yields per acre
- Potential for reduced market prices for agricultural commodities and processed products
- Potential effects on farm supply organization and sales.

In evaluating the impacts of perceived contamination on agricultural products grown near a repository, the following factors were considered:

- The type of product and how it is identified by the consumer: is the product identified with the specific area in which it is grown?
- The marketing, distribution, and consumption of the products: is the product consumed locally or sold outside the region?
- Form in which the product is purchased: is the product purchased directly by a consumer or is it an ingredient in other products?

It is assumed that three conditions must be present to negatively affect consumer purchases of agricultural products grown near a repository: (1) the consumer must be able to clearly identify the product with the locality in which it was grown, (2) the consumer must be aware that a nuclear repository is located in the region where the product is grown, and (3) the consumer must identify the existence of a repository with a health hazard that is transmitted through the food chain.

Several conditions should be considered in evaluating the marketability of products grown near a repository. Food products that are labeled with a regional identification can be more easily associated with a particular area than products with more generic labels. In addition, consumers who live within the region are more likely to know whether they are purchasing goods grown in that region than consumers who live outside the region. People who live within the region are likely to be more cognizant of the repository's location than people located outside the region. If a consumer is unaware of a product's origin and the repository location, purchasing decisions concerning agricultural products will not be affected. On the other hand, if the consumer knows where certain products are grown and where a repository is located, individual purchasing decisions may be affected by concern about possible contamination.

Food processors are important users of agricultural products. They perform various important value-added functions and serve as the link between farmers and individual consumers. Their behavior is substantially influenced by consumer demand. If decisions to relocate or to discontinue purchasing locally produced agricultural products were made by

particular businesses, the economic disruption of relocation and finding new suppliers would have to be considered. These businesses may wait for some real indication of changing demand associated with a repository before deciding to relocate or find new suppliers. If consumer purchases of processed agricultural products grown near a repository declined, food processors and farmers would be negatively affected. Conversely, it is assumed that if consumer purchases remain constant, there would be no economic incentive for food processors to either relocate or find new suppliers. To evaluate a repository's effect on farmers and food processors in the region, this analysis will focus on the types of agricultural businesses in the region and the potential for change in consumer demand.

Table 5-51 identifies the assumptions and evaluation scheme in which changes to consumer demand are assessed. The primary assumptions in this scheme are that consumers know where their purchased products are grown and where the repository is located.

The following discussion refers to a 12-county region that includes both Deaf Smith and Swisher Counties. The analysis does not differentiate between the Deaf Smith and Swisher socioeconomic study areas because the effects are qualitative and similar for both site areas.

The number of food processing employees in 1981 was estimated to be more than 75,500, with Potter County accounting for nearly 40 percent of the employment. Many were employed in meat slaughtering and processing operations. Food processing employment is estimated to account for between 45 and 50 percent of the total number of employees engaged in manufacturing operations, and between 6 and 11 percent of all employees, excluding government, railroad, and self-employed persons in the 12-county region (Bureau of the Census, 1977; 1981).

The largest food processing industry in the region is meat packing and processing. Using data obtained from the U.S. Department of Census, it was estimated that the total value of shipments from meat packing probably amounts to more than $1.1 billion, of the total food processing shipments of $1.56 billion. There are a number of meat packing or meat processing facilities within the region. The facilities range in size from small local firms to a large firm with national distribution and employment of approximately 1,000 persons (Dun and Bradstreet, 1984). Processed meats are currently suffering an image problem because of saturated fat content and the use of nitrates for preservation purposes. Consumer perception that a certain brand or brands of meat products may be contaminated with nuclear waste materials could compound this problem for processors located within the area of perceived contamination. In most cases, however, meat products are final products and are not labeled with a regional identification. The meat products from this area are probably consumed within the region and sold nationally as well. Thus, sales for such products have a fairly low potential for being affected by a repository.

In addition to meat packing and processing, sugar refining, wet corn milling, soft drinks, bottled water, and dairy products are other important food processing categories. Within the region there are large bakeries and two confectionary companies. These products are probably sold both locally and in other parts of the southwestern United States. All of their raw materials are obtained outside the area of concern, with the exception of sugar and corn sweeteners that might be purchased from local suppliers. These products are final products and some of them may have a regional identification. The majority of the products, however, are likely to have a more general label and should not be affected by a repository site in the area.

Within the region, there are also firms making ground-corn products (such as tortillas and tacos) and a wet-corn milling facility. Both kinds of firms distribute products nationally. There are at least several smaller companies within the region that produce tortilla-type products from ground corn. Presently it is not known how dependent these companies are on local corn supplies. A wet-corn milling facility in the area produces cornstarch, corn syrups, and high fructose corn syrups (HFCS) (Dun and Bradstreet, 1984; Bureau of Business Research, 1984). The primary market for a wet-corn miller is the food processor rather than the consumer. Much of the HFCS produced is used as an ingredient to sweeten soft drinks.

Table 5-51. Qualitative Basis for Evaluating Impacts on Agricultural Sector of Economy

Type of Product[a]	Market Distribution	Marketability of Agricultural Products if Repository Were Located in Region[b]
Health food products with specific regional identity (e.g., health food producers, bottled water)	National	Medium potential for some effect on sales
	Regional	High potential for some effect on sales
Health food products without specific regional identity (e.g., health food producers, bottled water)	National	Low potential
	Regional	Medium potential
Foodstuffs that are ingredients to a final product (e.g., wet and dry corn milling, sugarbeets processing)	National	Low potential
	Regional	Low potential
Agricultural products produced in area near repository that would also be final food or feed products (e.g., meat products, vegetables, sugar beets, cottonseed/soybean/sunflower seed oil)	National	Low potential
	Regional	Medium potential

(a) Some types of products are listed in more than one category since packaging and destination of specific food items within these businesses will vary.

(b) This analysis assumes that potential consumers are (1) able to identify the geographic source of the product, (2) aware that a high level waste repository is sited in the vicinity of the product source, and (3) associating the existence of a repository with a food chain-induced health hazard.

There is one beet-sugar processing facility in the area. As in the case with the wet-corn miller, the majority of the sugar is sold to food processors rather than the public. Molasses and beet-pulp by-products of the sugar is sold to food processors rather than the public. Molasses and beet-pulp by-products of the sugar processing facility are sold as a cattle feed. Most of the molasses and beet pulp produced is sold to local feed lots for feed mixes. For 0.9 metric ton (1 ton) of beets, approximately 13 percent would be sugar sold to grocers and food processors, 5 percent would be a molasses by-product and 5 percent would be a beet-pulp by-product (McGinnis, 1971). Goods from the beet sugar processing facility, then, are both ingredients in other products and final products. They are likely to be sold both within and outside of the region. Only sales for the final sugar products consumed locally could be affected by a repository.

At least two companies process cottonseed and sunflower seed to oil and meal. Undoubtedly these companies depend on locally grown raw materials. These are also primarily final products consumed both inside and outside the region.

There are health food processors, two nationally recognized bottling facilities, and a bottled water company in Amarillo (Bureau of Business Research, 1984). National soft drink bottling facilities are franchised operations, and often the franchise owns several processing facilities. Bottled water is sold as a health food product. Consumers of health food products are likely to be interested in and aware of a product's origin. In addition, some health foods are labeled with an indication of the area in which they were produced. The location of a nuclear waste repository might cause some consumer skepticsm regarding the perceived contamination of bottled water and other health food products. Sales for such products could decline, particularly if the product's origin is indicated. This may be particularly important for bottled water, if the source of water for processing operations is the Ogallala aquifer. Perceived contamination of the Ogallala aquifer could influence sales of all bottled water using the Ogallala label (since the aquifer extends over several states) under such circumstances.

In addition to food processing facilities, it is important to note that the Texas Panhandle Region is the major hybrid grain sorghum and forage sorghum seed producer (Gustafson, 1984). The reasons for the importance of the Texas Panhandle as a seed producing region are the optimum growing conditions, which include low humidity, low disease problems, cool summer nights, water for irrigation, and abundant sunshine. If buyers of sorghum seed in the United States and other countries perceived that the seed might be radiologically contaminated, their alternatives would be: (1) to continue to purchase seed, (2) to seek alternative sources of seed grown in other locations (few alternatives are currently available), or (3) to discontinue sorghum seed purchases entirely, in which case some alternative crops might be grown, depending on the location. Concerns over potential contamination could be alleviated through monitoring activities such as soil-and water-sample testing. This testing can be done both by project personnel and through independent testing.

In general, sales for most agricultural products grown near a repository should not be affected. For particular manufacturers (such as bottled water, specialized health foods, and hybrid seeds) identified within the region, there could be some decline in sales. Given the evidence from the actual accident scenario at Three Mile Island, perceived effects are likely to be short term (Flynn and Chalmers, 1979, NUREG/CR-1215, p. 60; Hickey, 1981, NUREG 0754). As the repository operations are monitored and the public is reassured of its safety, these markets should stabilize.

5.4.3 Community Services

The number of individuals and families moving into the area during repository construction, operation, and decommissioning are discussed in Section 5.4.1. They will require housing and must also be provided with community services such as education, police, water, sewerage, medical, and creation. Public service impacts are expected to occur primarily in Amarillo, Hereford, Canyon, and Vega. Project-related impacts are estimated for these cities for the peak in-migration years. Project-related population increases include both direct and indirect workers and their families.

Increases in the current population (baseline) will have occurred by the time repository activities begin. The service demands of the additional baseline and project-related populations are presented in this section. They were calculated using the national service standards or averages discussed in Section 3.6. The projected baseline population service demands were estimated by applying the 1997 and 2005 projected population increases for each city (Table 3-56) to the appropriate standards or averages. Similarly, the projected number of project-related in-migrants were applied to these service standards or averages to determine project-related service demands.

Even though national service standards or averages were used in all calculations except housing needs, such levels (ratio of service per capita) may or may not be suitable for an individual community. National service levels are used in this analysis so that a comparison from site to site can be made. Local service levels vary, as shown in Section 3.6.3, and a local level of service may be preferred by a specific community. The use of a particular service level affects the amount of excess capacity that would be absorbed by the baseline growth.

The excess service capacity identified in Section 3.6.3 is not considered in the new service demand estimates for baseline and project-related growth. However, a comparison between estimated baseline and project service needs and the 1980 excess capacity levels is made where possible.

5.4.3.1 Housing

5.4.3.1.1 Construction. Housing needs of in-migrating persons are an important community concern. Table 5-52 presents the additional housing units required to meet the baseline and project-related population increases in 1997. In addition to the demand presented, some housing units may be needed in order to maintain some flexibility in the housing market. The types of housing available to meet the increased demands could be expected to include single- and multiple-family housing units and temporary housing. Accommodations for families or individuals may include houses, mobile homes, apartments, and motel rooms. It is anticipated that mobile homes will provide housing accommodations for many workers during the repository construction phase, thereby reducing the need to build a large number of new housing units.

5.4.3.1.2 Operation. Table 5-53 presents estimated increases in housing and service needs for baseline and project-related needs in 2005. During the peak period of project operations, the projected need for additional housing units is Amarillo, 439; Canyon, 43; Hereford, 182; and Vega, 29.

5.4.3.1.3 Decommissioning and Closure. The decline in repository employment during the caretaker phase could cause a decline in population and an excess of housing if the unemployed emigrate from the region. It is assumed, however, that economic development efforts by the communities will result in new employment opportunities that will allow some repository workers to remain in the area. These efforts may reduce any excess supply of housing and municipal services that may result from the caretaker phase. During decommissioning, there will be some additional demand for housing resulting from the larger work force requirements. Since many of the jobs are short term, temporary housing such as hotel and motel space and trailer facilities may be required. This phase is several decades into the future and it is difficult to predict whether the excess capacity present at the end of the operation phase will be present and capable of handling the additional housing demands created by the decommissioning phase. If not, additional mitigation may be required to assist affected communities in providing housing and other necessary services. After decommissioning, a decline in population will probably occur and there will again be some excess housing. Other economic development in the area, however, will assuage this problem.

After decommissioning, repository employment will continue to decline. The effects on housing and community services will be minimal due to the limited numbers of workers involved.

Table 5-52. Projected Baseline and Project-Related Service Requirements for Affected Communities During Repository Construction

Service	Amarillo		Canyon		Hereford		Vega	
	Baseline 1997	Project-Related 1997	Baseline 1997	Project-Related 1997	Baseline 1997	Project-Related 1997	Baseline 1997	Project-Related 1997
Additional population	35,516	1,510	3,731	150	4,175	630	315	100
Additional housing required[a]	12,684	540	1,333	54	1,491	225	113	36
EDUCATION								
Additional school-age children[b]	7,458	384	784	38	1,086	160	110	26
Additional teachers required	438	20	46	2	64	8	6	1
PROTECTIVE SERVICES								
Additional municipal police officers required	71	3	7	0	8	1	1	0
Additional paid firefighters required	25	1	3	0	3	0	0	0
HEALTH								
Additional physicians required	35	1	4	0	4	1	0	0
Additional hospital beds required	142	6	15	1	16	3	1	0
WATER								
Additional municipal water needs, MGD	5.3	0.2	0.6	0.02	0.6	0.09	0.05	0.02
SEWAGE								
Additional effluent, MGD	3.6	0.2	0.4	0.02	0.4	0.06	0.03	0.01
RECREATION								
Additional developed acres required	35	1	4	0	4	1	0	0

Note: MGD = Million gallons per day.

(a) Population was divided by an average household size of 2.8 in order to estimate housing requirements.

(b) Baseline calculations use proportion of school-age students to population in 1980: Amarillo, 21 percent; Canyon, 21 percent; Hereford, 26 percent; and Vega, 35 percent.

Source for 1980 figures used as base: NUS, 1984, ONWI-461. Additional services for 1997 are in comparison with 1980. Figures are obtained by applying national service ratios (see Section 4.2.2) to demographic projections.

Table 5-53. Projected Baseline and Project-Related Service Requirements for Affected Communities During Repository Operation

Service	Amarillo		Canyon		Hereford		Vega	
	Baseline 2005	Project-Related 2005	Baseline 2005	Project-Related 2005	Baseline 2005	Project-Related 2005	Baseline 2005	Project-Related 2005
Additional population	49,250	1,230	5,790	120	6,020	510	570	80
Additional housing required[a]	17,589	439	2,068	43	2,150	182	204	29
EDUCATION								
Additional school age children[b]	10,342	324	1,215	32	1,565	135	199	22
Additional teachers required	608	19	71	2	92	7	12	1
PROTECTIVE SERVICES								
Additional municipal police officers required	98	3	12	0	12	1	1	0
Additional paid firefighters required	35	1	4	0	4	0	0	0
HEALTH								
Additional physicians required	49	1	6	0	6	1	1	0
Additional hospital beds required	197	5	23	0	24	2	2	0
WATER								
Additional municipal water needs, MGD	7.4	0.2	0.9	0.02	0.9	0.08	0.09	0.02
SEWAGE								
Additional effluent, MGD	4.9	0.1	0.6	0.01	0.6	0.05	0.06	0.008
RECREATION								
Additional developed acres required	49	1	6	0	6	1	1	0

Note: MGD = Million gallons per day.

(a) Population was divided by an average household size of 2.8 in order to estimate housing requirements.

(b) Baseline proportion of school-age students to population in 1980 for communities was used for calculation: Amarillo, 21 percent; Canyon, 21 percent; Hereford, 26 percent; and Vega, 35 percent.

Source for 1980 figures used as base: NUS, 1984, ONWI-461. Additional services for 2005 are in comparison with 1980. Figures are obtained by applying national service ratios to demographic projections.

5.4.3.2 Education

5.4.3.2.1 Construction. The projections shown in Table 5-52 for education are for the school districts located in or near the four communities, as explained in Section 3.6.3.2. Although changes in population age characteristics and birth rates may result in somewhat different proportions, the assumption has been made that the number of students in each school district will change by 1997 in the same proportion as the overall population. Baseline and project-related increases in students and teachers are shown in Table 5-52.

Comparison of the existing capacity and projected baseline demand figures for 1997 indicates that the Amarillo school district may have adequate space for all projected students in 1997; however, the school facilities in the Canyon, Vega, and Hereford districts would require expansion. All school districts may have to provide additional classrooms depending on where growth occurs within the school district. The Texas legislature recently enacted legislation specifying student/teacher ratios for school districts. In some districts additional teachers will be required to meet both the baseline and project-related demand (Merriman and Barber, 1985).

5.4.3.2.2 Operation. By 2005, the number of additional students anticipated as a result of the project in each school district is as follows: Amarillo, 324; Canyon, 32; Hereford, 135; and Vega, 22. Using the 1981-82 national average student/teacher ratio of 17:1, the numbers of additional teachers that will be needed are Amarillo, 19; Canyon, 2; Hereford, 7; and Vega, 1.

5.4.3.2.3 Decommissioning and Closure. An excess supply of classroom space and teachers could occur in the city school districts during the caretaker phase if the population decreased. Additional demand will be placed on the school districts during decommissioning but the demand will diminish after this phase. Some excess supply of classroom space and teachers may again be present. However, economic development efforts could mitigate population losses and subsequently assist in maintaining the level of educational facilities needed.

5.4.3.3 Protective Services

5.4.3.3.1 Police Services. Construction. A national service standard ratio of two municipal police officers per 1,000 population has been assumed to determine baseline and project needs in Table 5-52. Project-related growth will require three additional municipal police officers in Amarillo and a maximum of one in Hereford by 1997. County police officers also assist in each community and it would be expected that the number of these officers would also increase in the future.

Operation. Baseline service demands are shown in Table 5-53. A maximum of three officers in Amarillo and one in Hereford will be required to serve the projected population increases during the operation phase. Canyon and Vega will not require additional officers. Additional staff needs may be identified in an emergency preparedness plan that will be prepared for the repository project.

Decommissioning and Closure. The level of police protection should remain proportional to the population throughout repository decommissioning.

5.4.3.3.2 Fire Services. Construction. A national service standard ratio of two firefighters per 1,000 dwelling units was used to determine fire protection service needs. The additional firefighters needed in 1997 to meet project demand include one additional firefighter in Amarillo.

Operation. Baseline service needs are shown in Table 5-53. One firefighter will be required in Amarillo as the result of project-related population increases during the operation phase.

Decommissioning and Closure. The level of firefighting protection is not expected to be significantly affected with the relatively small population change occurring during these periods.

5.4.3.3.3 Health Services. Construction. The number of physicians and licensed hospital beds were the baseline medical needs calculated for the cities. The semi-rural area national averages of 0.99 physician per 1,000 population (1977) and five hospital beds per 1,000 (1976) were used in the calculations. Project-related growth will require the addition of one physician in Amarillo and one in Hereford. The number of hospital beds needed to serve population increases associated with the project are as follows: Amarillo, six; Canyon, one; and Hereford, three.

Operation. Baseline service needs are shown in Table 5-53. Amarillo will require a maximum of one additional physician and Hereford will require one as a result of project operation during the peak year. The other communities would not require any additional physicians. To accommodate the project-related population expected to locate in each city in 2005, the number of additional hospital beds needed will be Amarillo, five and Hereford, two. Additional staff needs may be identified in an emergency preparedness plan that will be prepared for the repository project.

Decommissioning and Closure. The fluctuation in work force during this phase should not significantly affect services in the region. Any additional hospital facilities added as the result of repository construction are expected to remain as part of the community infrastructure and serve future population health care needs. The number of doctors needed to serve the communities should not be greatly affected as few additional physicians would have been required as the result of project-related in-migration.

5.4.3.3.4 Water Supply. The Ogallala aquifer and Lake Meredith are the major sources of water for residents of the four communities. The water table in the Ogallala aquifer is declining and the communities are exploring other sources of water. The repository and related work force would place an additional burden on the water sources in this area.

Construction. The magnitude of the repository's effect on the aquifer is relatively small in comparison to both current and projected rates of use. Projected baseline water demand for 1990 is 355 million cubic meters (287,867 acre-feet). The annual repository requirements during construction would peak at approximately 230,000 cubic meters (180 acre-feet) in 1997. This includes repository construction needs as well as water required for in-migrants locating in Deaf Smith County. The annual repository-related water needs during construction represent approximately 0.06 percent of the projected water demand from the Ogallala aquifer in Deaf Smith County in 1990. It represents 0.06 percent of the projected annual supply for Deaf Smith County in 1990 (see Section 6.2.1.7.3). Thus, while the repository will place additional demands on the Ogallala, existing use is a major problem for the entire region. The strain from the repository could be mitigated by using water sources other than the Ogallala.

Water needs for in-migrants have been projected using the national service standard usage rate of 0.568 cubic meters (150 gallons) per day per capita. The average daily water use in 1997 by project-related in-migrants is expected to be: Amarillo, 760; Canyon, 80; Hereford, 390; and Vega, less than 80 cubic meters (or 200,000, 20,000, 90,000, and 20,000 gallons, respectively) per day.

The additional domestic water demand is only a small percentage of total municipal water requirements for the study area. However, such additional demand may have a significant impact on smaller municipal water systems which may face water shortages in 1990 and beyond (Knowles et al., 1984, pp. 130-132). While municipal demand theoretically has first priority on available supplies, in fact, the smaller communities may face supply shortages because of infrastructure limitations or because of drawdown from adjacent large consumers (irrigation). Water projections and a description of Texas water rights laws are provided in Section 3.3.3.

Operation. The annual repository requirements during operations would peak at approximately 500,000 cubic meters (375 acre-feet) in 2005. This includes repository operations needs as well as water required for in-migrants locating Deaf Smith County. The annual repository-related water needs during operations represent approximately 0.08 percent of the projected water demand from the Ogallala aquifer in Deaf Smith County in 2005. It represents

0.12 percent of the projected annual supply for Deaf Smith County in 2005 (see Section 6.2.1.7.3). Baseline service needs are shown in Table 5-53. The estimated amount of additional municipal water needed for project-related populations (in cubic meters per day) is: Amarillo, 800; Canyon, 70; Hereford, 300; and Vega, 80 (or 200,000, 20,000, 80,000, and 20,000 gallons per day, respectively).

Decommissioning and Closure. No substantial adverse impacts on municipal water supply facilities will occur as the result of repository decommissioning and the caretaker phase. If decreases in populations occur during the caretaker phase, average and peak daily water-use levels may decrease in some cities. During decommissioning, demands may increase somewhat and then decline during closure.

5.4.3.3.5 Sewage and Solid Waste. Construction. Sewer capacity needs have been determined by using the national service standard for effluent production of 0.38 cubic meters (100 gallons) per day per capita. Service requirements are shown in Table 5-52. For project-related populations, the sewage effluent produced is (in cubic meters per day): Amarillo, 800; Canyon, 80; Hereford, 190; and Vega, 40 (or 100,000, 20,000, 60,000, and 10,000 gallons per day, respectively).

The current capacity to dispose of solid waste should be adequate in the communities until some time after 2000. The landfill in Canyon will be full at that time. The landfill in Amarillo, which has a 50- to 60-year lifespan, will probably be in use for a longer time.

Operation. Service needs are shown in Table 5-53. For project-related population, the sewage effluent produced is (in cubic meters per day): Amarillo, 400; Canyon, 40; Hereford, 200; and Vega, 30 (or 100,000, 10,000, 50,000, and 8,000 gallons per day, respectively).

Solid waste disposal facilities in each city except Amarillo may require expansion or alteration by 2005. The landfill in Amarillo should have a somewhat longer lifespan.

Decommissioning and Closure. Municipal sewage treatment facilities, including those expanded to serve project-related population increases, will remain as part of community infrastructure during repository caretaker and decommissioning phases. Landfills and other solid waste disposal facilities will also remain in service, during these phases. Demand for these services will decrease during the caretaker phase, increase during decommissioning and decline thereafter.

5.4.3.3.6 Recreational Facilities. Construction. The national service standard for neighborhood parks of 0.4 hectare (1 acre) per 1,000 population was used to determine how many acres will be needed in the future (see Table 5-52). Project-related growth will require a maximum of 0.4 hectare (1 acre) in Amarillo and 0.4 hectare (1 acre) in Hereford. There may be some increase in visitation to the Palo Duro State Park as a result of the population in-migration.

Operation. Baseline service needs are shown in Table 5-52. As the result of project operation, 0.4 hectare (1 acre) of parkland will be needed in Amarillo and a maximum of 0.4 hectare (1 acre) will be needed in Hereford.

Decommissioning and Closure. Parkland developed to serve the recreation needs of project-related in-migrants can be expected to remain as part of each community's acreage during the caretaker and decommissioning phases. The changes in demand during these phases should not significantly affect recreation facilities.

5.4.4 Social Conditions

Predictions of probable social impacts are qualitative in nature, based on expectations of social interaction and behavior. Generally, local social impacts can be expected to result from rapid and significant changes in population in individual communities. Regional impacts occur when most or all communities in an area experience rapid change. The degree of local or regional impact is influenced by lifestyle differences or similarities between the composition

of entering, exiting, and existing population groups and associated changes to the economic and community service sectors.

5.4.4.1 Construction

Social problems are associated with sudden population growth and are generally assumed to be in proportion to the study area's ability to absorb change. The annual growth rate for the nine-county socioeconomic study area has been 0.76 percent. The additional annual growth rate with a repository located in the area would be about 0.15 percent. The additional repository growth then represents a small proportion of the existing growth in the region.

In case studies where changes in social conditions have been documented, community populations have increased by 100 percent or more within a 5-year period (Gilmore and Duff, 1975; Kohrs, 1974; Little, 1977; Davenport and Davenport, 1979; and Finsterbusch, 1980).

The largest increases in population associated with this project will occur in the nearby communities during the first few years of repository construction (Section 5.4.2.1). Amarillo and Canyon will receive a one percent change above the baseline population projection in the fifth year of the project. Vega will receive an eight percent increase above baseline and Hereford a three percent increase above its projected baseline population.

Impacts on social structure and quality of life are related largely to the population change in a community and to its existing culture. Vega's social structure should not be significantly altered as a result of the relatively small number of in-migrants compared to the local residents. This is significantly below the 100 percent increases evaluated in boom town scenarios. There may, however, be some conflict between the newcomers and existing residents. Research has indicated that these conflicts focus on differences in lifestyle, political philosophy, economic interests, and moral values (Finsterbusch, 1980). These conflicts are expected to be quite limited for Vega since the peak change in population will be approximately 8 percent.

Large population in-migration is often considered to be the impetus for changes in community lifestyles. A measure of the community's propensity to accommodate population in-migrations is the relationship between the level of the native population base and the in-migrating population level. The native population base is defined as those persons residing in a community who were born within the state of their residence. For example, the native population base of Amarillo is the number of persons residing in Amarillo who were born in Texas.

It is not anticipated that any of the communities within the region will experience any major reduction in their native population base as a result of the project. It is estimated that the native popoulation base of Vega could be reduced from a baseline of 68 percent to 63 percent during peak construction and to 64 percent during peak operation. That of Amarillo is estimated to be reduced from 65 percent (baseline) to 64 percent (peak construction) and to remain at 65 percent (during peak operation); Canyon is estimated to drop from 65 percent (baseline) to 64 percent (peak construction and peak operation); while the native population base of Hereford is estimated to decline from 73 percent (baseline) to 71 percent (peak construction and peak operation). These compare to the state average of 72.2 percent and a national average of 68.2 percent.

Because of the temporary nature of some of the construction tasks, some differences in lifestyle can be anticipated between the long-term resident population and workers temporarily relocating to the area. Experience at large-scale energy development projects in the western United States has shown that many construction workers will chose to live in mobile homes or temporary housing for the duration of their jobs, often creating new mobile home parks to accommodate this new but temporary population. Given the relatively stable farm-based population in the project area, there could be some difference in values and attitudes between the old and new populations that will affect their interaction.

Social programs can be developed to promote interaction between new and long-time residents and to help reduce initial conflict. Better access to social services and aid for the disadvantaged, such as elderly and low income housing, could be a primary goal of the NWPA-negotiated local mitigation measures.

Construction personnel expecting to be employed for the entire duration of the construction period will be more likely to find permanent housing and establish lifestyles in keeping with the existing regional lifestyle. Temporary construction personnel would be less likely to work at adapting to local attitudes and customs. Any contrast in lifestyles will be similar to that experienced by Amarillo when it contained a military population with continuous turnover.

5.4.4.2 Operation

Operation activities, despite associated new population growth in the early years, are not expected to result in significant effects on social conditions, except in Vega, where the expected increase will be 4 percent above the projected baseline population. By the time the repository begins operation, it will be well established as an element of the community, and associated population change at the beginning of operation will be less drastic than that experienced with construction activities. Because of the long-term nature of the facility, any new project-related residents are likely to be long term as well and therefore are also likely to better assimilate with existing established lifestyles.

Population allocation model projections indicate growth patterns similar to those experienced during construction. Persons choosing to relocate to the area for jobs at the repository will choose to do so in part because the area and its lifestyle make it attractive.

5.4.4.3 Decommissioning and Closure

Although the caretaker phase will result in a loss of jobs to the region, this project phase is relatively long term. As a consequence, no sudden impacts to the social structure are expected in terms of rapid population or economic changes. Workers displaced during this phase will either find new employment elsewhere in the region or leave the area to seek employment; however, any out-migration is expected to occur over several years and be relatively small, not severely disrupting the local economy or social structure. The local economy is sufficiently diverse so that other economic activities could take the place of the repository, preserving the continuity of the area communities. During decommissioning, there may be some social affects resulting from the temporary in-migration related to work force requirements after decommissioning; the repository workers will again either find new employment elsewhere in the region or leave the area to seek employment.

5.4.5 Fiscal Conditions and Government Structure

5.4.5.1 Fiscal Conditions

5.4.5.1.1 Construction. Revenues can come from a variety of sources, including property taxes, sales taxes, user fees and charges, intergovernmental transfer of funds, and miscellaneous income. The jurisdictions also have authority to issue bonds, which usually are used for construction of capital facilities (NUS, 1984, ONWI-461, pp. 195-199).

The trends in the per capita revenue for the local jurisdictions for 1967, 1972, and 1977 are presented in Section 3.6. The trends are for the combination of all city, county, and special district revenues in each of the counties. Construction of the repository will result in an increase in revenue from property taxes, sales taxes, and user fees. Intergovernmental transfers may increase, depending on the formulas for calculating the amount of the transfer and the impact of project-related growth on the formulas. Revenue from bonds will vary depending on capital funding requirements, ability to get bonds approved by the voters, if necessary, and dollar amount of bonding capability available.

Additional intergovernmental transfers related to repository development will be designed to offset any negative impacts on property tax and provide assistance to affected State and local jurisdictions. The NWPA provides for grants in lieu of tax payments to State and general units of local governments in which a candidate site for characterization is approved by the President. Payments will be made during (1) site characterization, (2) repository construction, and (3) repository operation. These payments will continue until activities at the site are terminated. These funds are not earmarked for specific community projects (see Section 4.2.2).

The DOE shall provide additional grants to the State to (1) review activities and determine economic, social, public health and safety, or environmental impacts; (2) develop impact assistance requests; (3) monitor, test, or evaluate site characterization activities; (4) inform residents of activities; and (5) request information and make comments to the Secretary of the DOE. The States are required to submit their analyses of the impacts of a repository to the Secretary of the DOE when site characterization activities are completed and before a site is recommended to the President for a repository. The analysis will then serve as a basis for the State's impact assistance requests.

Technical and financial assistance will be provided to any host State requesting such assistance within six months following issuance of a construction authorization from the U.S. Nuclear Regulatory Commission. The DOE must seek to enter into an agreement with the State on the amount of financial and technical impact assistance to be provided and procedures to be followed in providing such assistance. As stated earlier, in order to receive these payments, the State must submit an evaluation of the likely social, economic, public health and safety, and environmental impacts to the Secretary of the DOE.

The DOE's technical assistance efforts can aid local planning activities. This assistance could be used to develop job training programs for local residents, programs for worker transportation, and any other mitigation measures which require coordination between the DOE, the State, and the local governments. The DOE technical assistance could also be used to help local governments form an impact management committee and it could be used in the development and implementation of a comprehensive impact monitoring program. Such a monitoring program will be established during site characterization so that types of impacts can be identified, projections made of these impacts, and appropriate mitigation measures recommended.

Cities, counties, and special districts have authority to levy and collect property taxes. Property tax revenue will increase in those jurisdictions where workers choose to settle and residential and commercial real estate development occurs, thus increasing the amount of taxable property. Per capita revenue may increase depending on the value of the property added to the tax base (NUS, 1984, ONWI-461, p. 195).

Cities have the option of levying a 1 percent sales tax. The construction of the repository will increase the income and, therefore, consumer purchases in the area, resulting in greater revenues from this source. Sales tax revenues will also increase if some repository construction supplies are purchased locally (NUS, 1984 ONWI-461, p. 198).

User fees are related to specific services such as water supply or wastewater collection and treatment and, therefore, the revenue collected will depend on the demand for these services. If demand increases proportionally with population growth, then total revenues will increase, but fee per capita will not. Variances between demand for services and population growth will cause different changes in the total revenue and fee per capita (NUS, 1984 ONWI-461, p. 198).

A major problem for local governments facing rapid development is the front-end financing of new capital projects. Although new service demands will arise immediately during construction, many of the revenues necessary to meet those costs may not be available for one or more years. Taxes from project-related in-migration typically are not available at the same time costs are incurred by the local governments, creating a revenue-cost squeeze.

Cities, counties, and special districts have the power to issue bonds for capital projects, subject to certain limitations on tax rates and total amount of indebtedness. This is an effective front-end financing arrangement for those circumstances where expansion needs and revenue returns are certain. The types of bonds include tax bonds, if a majority of the voters approve; bonds secured by the operating revenues of the facility constructed with the bond proceeds; and certificates of obligation to pay for the construction of public works. Certificates of obligation may be repaid by taxes, revenues, or a combination thereof (Texas Legislative Council, 1980, Art. 3, Sect. 52).

In the near term, grants equal to tax payments and DOE grants to the States may reduce revenue-cost problems and assume bond obligations. Over the long term, however, revenues will increase due to additional sales taxes, property taxes, and user fees.

Changes in expenditures resulting from normal growth and construction of the repository are influenced by increases or decreases in population and the spatial distributions of growth.

Section 5.4.3 presents the service requirements that result from the population changes. The changes in service requirements will result in increased governmental operations expenditures equivalent to the population growth times the per capita costs. The percent distribution discussed in Chapter 3 will not be significantly affected. Changes in capital expenditures will fluctuate since expanding or constructing new facilities may be necessary. The timing and impact of new public facility construction is related to need and follows population increases, but due to the need to build for future years, capacity costs per capita will vary significantly.

5.4.5.1.2 Operation. Governmental revenue sources will be influenced by the same factors that influenced them during repository construction, although the magnitude of the changes may be different. Property tax revenues will increase due to the projected increase in home ownership. These revenues will fluctuate in the transition from construction to operations because of work force size and characteristic changes. Other factors discussed under construction impacts will probably remain the same. The DOE grants equal to tax payments will continue and may increase revenues depending on how the repository is assessed.

User fees are related to specific services and will fluctuate as the population fluctuates. The same factors discussed under construction impacts will influence user fees during repository operations.

Bonding requirements will probably drop, since most of the demand for new facilities will have been met during the construction period. There will be replacement requirements as the useful life of the various facilities is exhausted.

Changes in expenditures are subject to the same factors discussed for repository construction. Service requirements will fluctuate with changes in total population and in the demographic characteristics. This may result in periods of over- or under-utilized capacity. Since the peak operational work force is greater than peak construction, expenditures may be higher. The differences between construction and operational work force family characteristics may require expansion of some services, such as water and sewer lines and schools.

5.4.5.1.3 Decommissioning and Closure. Revenues to State and local governments will decrease as operations phase out and the repository is permanently closed. The DOE grants equal to tax payments will continue during the caretaker and decommissioning phase. Outmigration of unemployed repository workers during the caretaker phase may create a greater than normal housing vacancy rate, resulting in a reduction of new home construction.

City sales tax revenue may decline during the caretaker phase if unemployed repository workers cannot find other job opportunities in the area. Revenues will increase during decommissioning and decline again during closure.

User fees are related to specific services. Per capita costs may increase if repository workers leave during the caretaker phase, since fixed costs will have to be paid by fewer users. These costs may decrease during decommissioning with additional workers and increase again during closure.

Bonding requirements will drop, since excess facility capacity will result from out-migration during the caretaker phase. There will be replacement requirements as the useful life of the various facilities is exhausted.

Changes in expenditures are subject to the same factors discussed for repository construction. Service requirements will decline if unemployed depository workers leave the area. The decline periods may result in excess capacity and reductions in expenditures to reduce capacity.

5.4.5.2 Government Structure

The different local governmental organizations responsible for providing services are discussed in Chapter 3. Construction of the repository will not change this organizational structure. Cities have the authority to annex additional territory and may decide to do so if community growth resulting from repository construction is concentrated in an area adjacent to a city and it is advantageous for such annexation to occur.

5.4.5.2.1 Construction. The larger and more populated city of Amarillo, counties of Potter and Randall, and the Amarillo Independent School District are expected to have sufficient administrative staffing to manage repository-related community growth and additional work tasks associated with the growth. The less populated communities, counties, and school districts have limited administrative staff for community impact planning. Additional technical staffing may be required in these communities.

5.4.5.2.2 Operation. The State and local governments concerned with the repository will shift some emphasis from planning and program implementation to program management, evaluation, and support. The skills required will be different, resulting in retraining needs. The change in staff will also vary from agency to agency, depending on how that agency's functions are used. The larger, more populated cities and counties generally have larger staffs; thus, they have more flexibility to address the changes.

5.4.5.2.3 Decommissioning and Closure. The State and local governments will change emphasis from program management, evaluation and support, to economic development and planning designed to replace the lost repository jobs during the caretaker and closure phase. The skills required will be different, resulting in retraining of staff. The larger, more populated cities and counties generally have larger staffs, and, therefore, greater flexibility to plan for the changes.

5.5 SUMMARY TABLE

Repository development activities, including repository construction, operation, and decommissioning and closure, have the potential to cause various levels of repository development impacts. The following Table 5-54 is a summary of such impacts, drawn from the text of Chapter 5. Impacts are discussed in terms of their duration or intensity or significance. The use of mitigation measures is noted in determining intensity of the impact. As applicable, location of the impact is also indentified.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site

I. Repository Construction

Primary activities are as follows:

development of offsite utility and transportation access corridors, development of onsite transportation and utility infrastructure, establishment of a water supply, site preparation and grading, construction/erection of repository surface facilities, development of shafts and underground facilities, storage of mined materials, transport of personnel and subsurface use restrictions, and population in-migration.

Summary of Impacts

1. Soils (Section 5.2.1.1.1)

   a. About 165 hectares (408 acres) of soil will be modified in chemistry and structure, covered by facilities and roads, or eroded by wind and water. Additional areas of soil disturbance will occur from construction of utility corridors.

   b. Salt deposited at predicted rates on the soil and adsorbed by the plant roots will not result in reduced crop productivity (Section 5.2.10).

2. Mineral Resources (Section 5.2.1.2)

   Mineral and hydrocarbon resources development will be excluded from the 2,331-hectare (5,760-acre) controlled area.

3. Surface Water (Section 5.2.2.1.1)

   a. No impacts to surface-water quantity are expected because sedimentation of surface waters will be controlled.

   b. Impacts due to surface-water transfer of deposited salt into nearby playas will be insignificant.

4. Ground Water (Section 5.2.2.2.1)

   a. Minimal drawdown interference to nearby wells will occur; the maximum interference to wells 2.4 kilometers (1.5 miles) from the onsite wells is expected to be approximately 0.1 meters (0.4 feet).

   b. No significant seepage from onsite retention pond of salt-contaminated water into ground water is expected because ponds will be double-lined and the monitoring/recovery system will be installed.

   c. Impacts to ground water due to wind-deposited salt entering playas will be insignificant.

   d. Since proper engineering practices will prevent shaft leakage, no impacts due to shaft leakage are expected. Because the prominent vertical gradient of the aquifer is downward, and the shaft will be isolated from ground water, minimal impacts to potable water are expected.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
(Page 2 of 14)

I. Repository Construction

5. Land Use (Section 5.2.3.1)

a. About 165 hectares (408 acres) of land will be converted for use for surface facilities.

b. An additional 2,169 hectares (5,352 acres) will be a controlled area. The DOE may restrict current land uses such as residences, irrigation of crops, and hybrid sorgum production.

c. Land withdrawn for surface facilities and controlled area may potentially remove up to 8 percent of the prime farmland within the site vicinity but less than 1 percent within the county.

d. Withdrawal of agricultural land at the site and controlled area is equal to less than 2 percent of the cropland in Deaf Smith County and 9 percent in the site vicinity.

e. No significant impact to soil productivity is expected from windblown salt deposition.

f. Installation of access road and a railroad spur will eliminate current land uses and could disrupt current farming practices on adjacent lands.

6. Terrestrial Biota (Section 5.2.4.1.1)

a. Some natural or seminatural plant communities may be eliminated in the area required for surface facilities and access corridors until the site is decommissioned and restored.

b. Some mortality and disturbances to local wildlife can be expected; however, changes to wildlife populations will be insignificant from a regional standpoint.

c. Vegetation within the 2,331-hectare (5,760-acre) controlled area may exhibit some symptoms of salt stress. Salt deposition will be practically unmeasurable beyond the controlled area.

7. Aquatic Biota (Section 5.2.4.2.1)

a. Construction of the repository, corridors for the railroad spur, access roads, transmission lines, and pipelines will have little impact on aquatic biota. Repository siting has been planned to avoid any playas or floodplains. Engineered control measures to minimize sedimentation at stream crossings have been incorporated in the design.

b. Potential sources of contaminated runoff or sediments will not be discharged off site. Runoff will be contained on site in evaporation or sedimentation retention basins.

c. Because aquifers will supply the water for repository construction, existing surface-water sources will not be affected.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
(Page 3 of 14)

I. Repository Construction

8. Threatened and Endangered Species (Section 5.2.4.3.1)

Although threatened or endangered species are unlikely to be present on site or along the proposed linear corridors, any of these terrestrial species that might be in the general area or use the site during migration would be subject to the impacts described for terrestrial biota (see Section 5.2.4.1.1).

9. Air Quality (Section 5.2.5)

Estimated offsite concentrations of particulate and gaseous NO_x emissions from stationary fugitive and mobile sources will meet NAAQS standards.

10. Aesthetics (Section 5.2.6.1)

Within the site vicinity, visual impacts of storage piles for mined material, retention ponds, increased dust, and traffic from construction activities will be minor due to their low profile; taller structures will be visible for up to 10 miles.

11. Noise (Section 5.2.7)

a. Sound levels of 55 dBA L_{dn} which may be disruptive of outdoor activities will not be exceeded at nearby residences.

b. Temporary increases in sound levels of greater than 55 dBA L_{dn} will be limited to within 0.3 kilometers (0.2 miles) on either side of railroad corridor.

12. Archaeological, Cultural, and Historic Resources (Section 5.2.8.1)

a. No direct impacts to recorded archaeological or historic resources are anticipated.

b. Impacts to unrecorded sites--if discovered--will be mitigated in consultation with the State Historic Preservation Officer.

13. Transportation (Section 5.3.3)

a. Traffic impacts would be most noticeable on FM 2587 and U.S. 385 during peak hours. Driving speeds would not be substantially diminished, although congestion may be experienced at the intersection of these two roads.

b. Up to 18 additional highway accidents and less than one fatality per year are estimated to result from traffic increases over all routes considered.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
(Page 4 of 14)

I. Repository Construction

14. Utilities (Section 5.3.4)

    a. Existing utilities will be sufficient to handle construction needs.

    b. No impacts on waste treatment facilities are expected because waste treatment will be handled on site.

15. Population (Section 5.4.1.1)

    a. By the peak year of construction, 1,510 people will have relocated to Amarillo, 630 people will have relocated to Hereford, 150 to Canyon, and 100 to Vega (Section 5.4.2.2.1).

16. Employment (Section 5.4.2.1.1)

    a. Labor supplies for other sectors of the local economy may be reduced.

    b. Local cost of living may increase.

17. Economic Activities (Section 5.4.2.2.1)

    a. Business activity in the local area is expected to increase. Local purchases related to construction of the repository are estimated at $16.9 million per year.

    b. Property values near the site and in surrounding communities may change.

18. Community Services (Section 5.4.3)

    a. Population in-migration will require additional community services, including housing, schools, fire and police protection, medical services, water supply, and recreation.

19. Social Conditions (Section 5.4.4.1)

    a. Vega may experience social changes as a result of its relatively high projected population increase (8 percent of projected 1997 population).

20. Fiscal Conditions (Section 5.4.5.1.1)

    a. Revenue from property taxes, sales taxes, and user fees will increase.

    b. Changes in service requirements (Section 5.4.3) will result in increased governmental operations expenditures.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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I. Repository Construction
21. Salt Management and Disposal (Section 5.2.10)
a. Windblown salt deposition expected to be no more than 3.8 kilograms per hectare (3.4 pounds per acre) at 840 meters (0.5 mile), which is within the controlled area.
b. No significant impact to soil productivity expected from windblown salt deposition, because the majority of any salt deposition will be within the controlled area.
c. Minimal impact to surface and ground water quality due to controls placed on surface handling of salt.
d. Adverse impacts on terrestrial ecosystems will be minimal and localized because the majority of any salt deposition will be within the controlled area.
e. Impacts resulting from accidental transportation spills of salt on land expected to be localized and short-term due to implementation of emergency cleanup procedures.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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II. Repository Operation

Primary activities are as follows:

transport and handling of nuclear wastes, other surface facilities operations, salt storage, water and energy use, transport of personnel and nonwaste materials to and at the site, surface and subsurface use restrictions, population in-migration.

Summary of Impacts

1. Soils (Section 5.2.1.1.2)

   a. Repository operations will create few additional soil related impacts beyond those expected during construction.

   b. Wind and water erosion will result in insignificant soil losses.

2. Mineral Resources (Section 5.2.1.2)

   Mineral and hydrocarbon resource development will be excluded from the 2,331-hectare (5,760-acre) controlled area.

3. Surface Water (Section 5.2.2.1.2)

   a. No impacts to surface-water quantity expected because sedimentation of surface waters will be controlled on site.

   b. Impacts due to surface-water transport of deposited salt into nearby playas will be insignificant.

4. Ground Water (Section 5.2.2.2.2)

   a. Minimal drawdown interference to nearby wells; the maximum interference to wells 2.4 kilometers (1.5 miles) from the onsite wells is expected to be approximately 0.1 meter (0.4 foot).

   b. No significant seepage from onsite retention pond of salt-contaminated water into ground water is expected because of double-lined ponds and the monitoring/recovery system to be installed.

   c. Insignificant impacts to ground water due to wind-deposited salt entering playas.

   d. Since proper engineering practices will prevent shaft leakage, no impacts due to shaft leakage are expected.

   e. Because the prominent vertical gradient of the aquifer is downward, and the shaft will be isolated from ground water, minimal impacts to potable water are expected.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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II. Repository Operation

5. Land Use (Section 5.2.3.2)

The DOE will control land uses within the controlled area, for the 50 years of repository operation.

6. Terrestrial Biota (Section 5.2.4.1.2)

a. Vegetation within the 2,331-hectare (5,760-acre) controlled area may exhibit some symptoms of salt stress. Salt deposition from salt transfer and handling will be practically unmeasurable beyond the controlled area.

b. The influx of repository workers will increase the hunting of wildlife and will increase use of parks and wildlife refuges in the region.

7. Aquatic Biota (Section 5.2.4.2.2)

a. No impacts to aquatic ecosystems are expected from either contaminated runoff or sedimentation because runoff will be controlled on site.

b. Windblown salt will not reach the nearest wetland/aquatic habitat to the repository site in measurable amounts.

c. Since ground-water sources are expected to supply the water for repository operations, surface-water sources and associated aquatic biota will not be affected.

d. Repository workers and their families will create an increased demand for recreational fisheries.

8. Threatened and Endangered Species (Section 5.2.4.3.2)

a. Any threatened or endangered species present in the vicinity of the site will be susceptible to loss of habitat or any disturbances.

b. Operation of the access and utility corridors will not adversely affect protected species.

9. Air Quality (Section 5.2.5)

Estimated offsite concentrations of particulate and gaseous NO_x emissions will meet the NAAQS.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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II. Repository Operation

10. Aesthetics (Section 5.2.6.2)

a. Visual intrusion of the repository surface facilities will range from significant within the 10-kilometer radius of the site to minor on the larger populations outside that area.

b. Cooling tower plumes are expected to have minimal visual impact under certain short-term atmospheric conditions.

11. Noise (Section 5.2.7.2)

a. L_{dn} of 55 dBA, which could be disruptive of outdoor activities, will not be exceeded at nearby residences.

b. Noticeable increase in traffic noise at residences on FM 2587 can be expected during peak periods.

c. Sound levels of 55 dBA L_{dn} will not be exceeded beyond 61 meters (200 feet) of the center of the railroad access corridor.

12. Archaeological, Cultural, and Historic Resources (Section 5.2.8.2)

No direct impacts are anticipated.

13. Nuclear Waste Transport (Section 5.3.1)

a. Estimated radiological health effects from nuclear waste transport are expected to result in 8 (assumes 100-percent-truck transport) to less than one (assumes 100-percent-rail transport) latent cancer fatalities to present and future generations.

b. Estimated nonradiological fatalities resulting from traffic accidents range from 16 (100 percent rail) to 30 (100 percent truck).

c. The regional maximum individual exposure values range from 1 to 4 millirem per year, or about 1 to 4 percent of background.

14. Transportation (Section 5.3.3)

a. Traffic impacts during operation will include increased traffic on FM 2587 and U.S. 385, with increased congestion at their intersection during peak hours. Although truck traffic is expected to be significant, driving speeds on local routes will not be substantially diminished.

b. Up to 18 additional highway accidents and less than one fatality per year are estimated to result from the traffic increase over all routes considered.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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II. Repository Operation

15. Utilities (Section 5.3.4)

    Operation of any transmission lines and pipelines will result in minimal adverse impacts to local ecosystems, land use, and air quality (5.3.2).

16. Population (Section 5.4.1.2)

    The peak operation phase population increase would occur in project years 14 through 17 of operation and would cause increases in Amarillo (1,230 people); Hereford (510 people); Canyon (120 people); Vega (100 people) (Section 5.4.2.2.2).

17. Employment (Section 5.4.2.1.2)

    a. By the peak operation year, repository operations will generate 1,150 direct and 1,150 indirect employment opportunities.

    b. During project years 14 to 17, approximately 1,380 local workers could be employed in repository-related jobs.

18. Economic Activities (Section 5.4.2.2.2)

    a. Local economic activity would increase from purchases by the work force for personal goods and services.

    b. Inflationary effect should diminish as the number of employers and income generated begins to stabilize.

    c. Some repository purchases will be made in the Texas Panhandle during operations.

19. Community Services (Section 5.4.3)

    Population in-migration will require increases in community services such as housing, schools, police and fire protection, medical services, water supply, and recreation.

20. Social Conditions (Section 5.4.4.2)

    a. Operations activities are not likely to have significant effects on social conditions. The operation work force will become a long-term part of the community and, therefore, will probably integrate into existing established lifestyles.

    b. Vega will experience the greatest growth due to the operations work force (4 percent above the projected population for year 2005).

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
(Page 10 of 14)

II. Repository Operation

21. Fiscal Conditions (Section 5.4.5.1.2)

    a. Grants equal to taxes would continue.

    b. User fees related to specific services would fluctuate as population fluctuates.

    c. Bonding requirements would probably decrease, since most of the demand for new facilities would have been met during the construction phase.

    d. Changes in service requirements may require increased expenditures.

22. Government Structure (Section 5.4.5.2.2)

    Government agency staffing requirements may shift from planning and program implementation to program management, evaluation, and support.

23. Salt Management and Disposal (Section 5.2.10)

    a. Windblown salt deposition expected to be 3.8 kilograms per hectare (3.4 pounds per acre) at 840 meters (0.5 mile), which is within the controlled area.

    b. No significant impact to soil productivity is expected from windblown salt deposition, because the greater part of any salt deposition will be within the controlled area.

    c. Minimal impact to surface and ground-water quality due to controls placed on surface handling of salt.

    d. Adverse impacts on terrestrial ecosystems will be minimal and localized because the majority of any salt deposition will be within the controlled area.

    e. Impacts resulting from accidental transportation spills of salt on land are expected to be localized and short-term due to implementation of emergency cleanup procedures.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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III. Repository Decommissioning/Closure

Primary activities are as follows:

dismantling of surface facilities, shaft backfilling, site regrading and revegetation, transport of personnel and materials to, from, and at the site, and population out-migration.

Summary of Impacts

1. Soils (Section 5.2.1.1.3)

   a. Deposition of wind-blown salt on soils on and off site may occur during loading and transport of salt.

   b. No long-term impacts are anticipated after soils are treated and revegetated.

2. Mineral Resources (Section 5.2.1.2)

   Mineral and hydrocarbon resource development will be excluded from the 2,331-hectare (5,760-acre) controlled area.

3. Surface Water (Section 5.2.2.1.3)

   No significant impacts are expected.

4. Ground Water (Section 5.2.2.2.3)

   No significant impacts are expected.

5. Land Use (Section 5.2.3.3)

   Long-term land use of the Federal land after decommissioning has not been determined; restrictions on surface uses and subsurface uses will continue.

6. Terrestrial Biota (Section 5.2.4.1.3)

   a. Revegetation of the site using native vegetation may eventually result in a relatively natural shortgrass prairie ecosystem.

   b. Restoration of access routes and facilities may result in a return to pre-repository land uses.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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III. Repository Decommissioning/Closure

7. Aquatic Biota (Section 5.2.4.2.3)

Aquatic biota will be protected by sediment basins will be maintained during decommissioning to avoid offsite contamination.

8. Threatened or Endangered Species (Section 5.2.4.3.3)

No adverse impacts are expected because revegetated areas that remain protected could provide appropriate habitat for threatened or endangered species present at various times of the year.

9. Air Quality (Section 5.2.5)

a. Temporary increase is expected in suspended particulate and gaseous contaminant concentrations.

b. Impacts are not expected to exceed those modeled for construction and operation phases.

10. Aesthetics (Section 5.2.6.3)

Closure activities will be of short duration and thus should have minimal visual impact.

11. Noise (Section 5.2.7.3.3)

Sound levels from closure activities are expected to be less than those for construction, although activities will be similar.

12. Archaeological, Cultural, and Historic Resources (Section 5.2.8.3)

No direct impacts are expected.

13. Transportation (Section 5.3.3)

Some traffic congestion will occur on FM 2587 and U.S. 385; however, this is expected to be less than that during construction.

14. Utilities (Section 5.3.4)

No additional impacts are expected.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
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III. Repository Decommissioning/Closure

15. Population (Section 5.4.1.3)

    Size of repository work force will decline during the caretaker phase, increase during decommissioning and decline thereafter; potential for out-migration will be greater during the work force reduction and may initiate a decline in some indirect employment opportunities.

16. Employment (Section 5.4.2.1.3)

    A short-term increase in area unemployment may result during the caretaker phase and after decommissioning.

17. Economic Activities (Section 5.4.2.2.3)

    Demand for secondary goods and services may decline as repository employment declines.

18. Community Services (Section 5.4.3)

    a. Out-migration due to a decline in repository employment may result in excess housing and community services capacities.

    b. Average and peak daily water use levels may decrease in some cities.

19. Social Conditions (Section 5.4.4.3)

    No significant changes to social structure are expected.

20. Fiscal Conditions (Section 5.4.5.1.3)

    a. Revenues to State and local governments will decrease.

    b. Sales tax revenues may decline because of out-migration.

    c. As service requirements decline, government expenditures will also be reduced.

21. Government Structure (Section 5.4.5.2.3)

    Government staffing emphasis will change from program management to economic development and planning.

Table 5-54. Summary of Repository Impacts, Deaf Smith County Site
(Page 14 of 14)

III. Repository Decommissioning/Closure
22. Salt Management and Disposal (Section 5.2.10) a. Windblown salt deposition is expected to be no more than 3.8 kilograms per hectare (3.4 pounds per acre) at 0.8 kilometers (0.5 mile), which is within the controlled area. b. No significant impact to soil productivity is expected from windblown salt deposition, because the greater part of any salt deposition will be within the controlled area. c. Minimal impact to surface- and ground-water quality is expected due to controls placed on surface handling of salt. d. Adverse impacts on terrestrial ecosystems will be minimal and localized because the greater part of any salt deposition will be within the controlled area. e. Impacts resulting from accidental transportation spills of salt on land are expected to be localized and short-term due to implementation of emergency cleanup procedures.

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5.6.2 Federal Statues and Regulations and Executive Orders

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10 CFR Part 960, Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines.

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5.6.3 Texas Statutes and Regulations

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