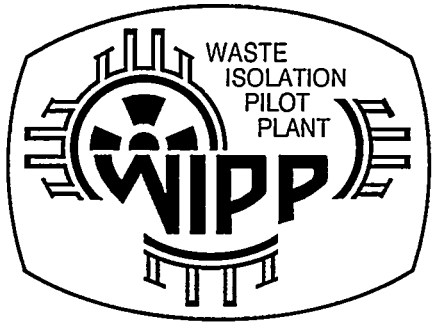
DOE/WIPP 91-005
Revision 5

Resource Conservation and Recovery Act Part B Permit Application

Volume VIII of X



Waste Isolation Pilot Plant
Carlsbad, New Mexico

APPENDIX D4

WASTE ISOLATION PILOT PLANT
ANNUAL SITE ENVIRONMENTAL REPORT
for Calender Year 1993

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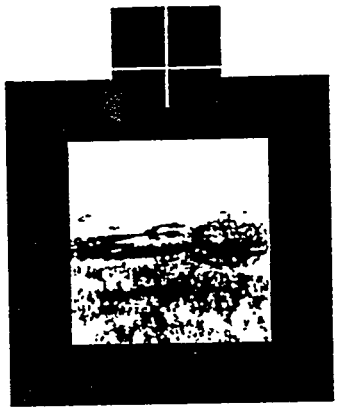

WIPP

ANNUAL

SITE

ENVIRONMENTAL

REPORT

FOR

CALENDAR

YEAR

1993

ISSUED SEPTEMBER 1994

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1993 WIPP Site Environmental Report
Table of Contents

Section		Page
Chapter 1	EXECUTIVE SUMMARY	1-1
1.1	Compliance Summary	1-1
1.2	Environmental Program Information	1-4
1.2.1	Environmental Monitoring Plan	1-4
1.2.2	Raptor Research Program	1-4
1.2.3	Reclamation of Distrubed Lands	1-5
1.3	Environmental Radiological Program Information	1-5
1.3.1	Airborne Particulate and Effluent Monitoring	1-5
1.3.2	Soil Sampling	1-6
1.3.3	Groundwater	1-6
1.3.4	Surface Water and Sediment Sampling	1-6
1.3.5	Game Animals and Fish Samples	1-6
1.4	Nonradiological Monitoring Information	1-6
1.4.1	Meteorology	1-7
1.4.2	Air Quality Monitoring	1-7
1.4.3	Wildlife Population Monitoring	1-7
1.4.4	Vegetation Monitoring	1-8
1.5	Quality Assurance	1-8
Chapter 2	INTRODUCTION	2-1
2.1	Description of the WIPP Project	2-2
2.2	Description of the Environment and Lands	2-3
Chapter 3	COMPLIANCE SUMMARY	3-1
3.1	Compliance Assessment for Calendar Year 1993	3-1

Table of Contents

Section			Page
3.2	Compliance Status		3-1
3.2.1	Atomic Energy Act of 1954 (AEA)		3-1
3.2.2	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)		3-2
3.2.3	Resource Conservation and Recovery Act (RCRA)		3-4
3.2.4	National Environmental Policy Act (NEPA)		3-4
3.2.5	Clean Air Act (CAA)		3-6
3.2.6	Clean Water Act (CWA)		3-8
3.2.7	Safe Drinking Water Act (SDWA)		3-9
3.2.8	Toxic Substances Control Act (TSCA)		3-10
3.2.9	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)		3-11
3.2.10	Endangered Species Act (ESA)		3-11
3.2.11	National Historic Preservation Act (NHPA)		3-11
3.2.12	Floodplain Management		3-13
3.2.13	Protection of Wetlands		3-13
3.2.14	Environmental Radiation Standards		3-13
3.2.15	Hazardous Material Transportation Act (HMTA)		3-15
3.2.16	Packaging and Transportation of Radioactive Materials		3-15
3.2.17	Department of Energy National Security and Military Application of Nuclear Energy Authorization Act of 1980		3-16
3.2.18	Waste Isolation Pilot Plant Land Withdrawal Act of 1991		3-16
	3.2.18.1	Federal Land Policy and Management Act	3-18
	3.2.18.2	Taylor Grazing Act	3-18
	3.2.18.3	Public Rangelands Improvement Act	3-19
	3.2.18.4	Executive Order 12548-Grazing Fees	3-19
	3.2.18.5	Material Act of 1947	3-19
	3.2.18.6	Federal Mine Safety and Health Act of 1977	3-19
3.2.19	Bald and Golden Eagle Protection Act		3-20
3.2.20	Migratory Bird Treaty Act		3-20
3.2.21	Noise Control Act of 1972		3-21
3.2.22	Occupational Safety and Health Administration (OSHA) Regulations		3-21
3.2.23	National Defense Authorization Act - Fiscal Year 1989		3-21
3.2.24	Protection and Enhancement of Environmental Quality		3-22
3.2.25	Federal Compliance with Pollution Control Standards		3-22
3.3	Other Significant Environmental Issues		3-24

Table of Contents

Section			Page
Chapter 4	ENVIRONMENTAL PROGRAM INFORMATION		4-1
4.1	Environmental Monitoring Plan		4-1
4.2	Baseline Data		4-1
4.3	Environmental Monitoring and Planning Activities		4-2
	4.3.1	Waste Minimization Committee	4-2
	4.3.2	Environmental Training	4-3
	4.3.3	WIPP Land Management Plan	4-3
Chapter 5	ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION		5-1
5.1	Radioactive Effluent Monitoring		5-1
5.2	Environmental Radioactivity Monitoring		5-1
	5.2.1	Atmospheric Radiation Baseline	5-2
	5.2.2	Ambient Radiation Baseline	5-2
	5.2.3	Radiological Soil Monitoring	5-3
	5.2.4	Hydrologic Radioactivity	5-3
	5.2.5	Biotic Radioactivity	5-4
5.3	Assessment of Potential Dose to the Public		5-4
Chapter 6	ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION		6-1
6.1	Meteorology		6-2
	6.1.1	Climatic Data Summary	6-2
	6.1.2	Wind Direction and Wind Speed	6-2
6.2	Environmental Photography		6-3
6.3	Air Quality Monitoring		6-3

Table of Contents

Section		Page
6.4	Wildlife Population Monitoring	6-4
6.4.1	Cooperative Raptor Research and Management Program	6-4
6.4.2	Breeding Bird Densities	6-5
6.4.3	Small Nocturnal Mammal Population Densities	6-6
6.5	Surface and Subsurface Soil Monitoring	6-7
6.6	Vegetation Monitoring	6-7
6.7	National Pollutant Discharge Elimination System Data	6-8
6.8	Volatile Organic Compounds Monitoring	6-9
6.9	Reclamation of Disturbed Lands	6-10
6.10	Seismic Activity	6-10
Chapter 7	GROUNDWATER SURVEILLANCE	7-1
7.1	Groundwater Quality	7-3
7.2	Groundwater Level Surveillance	7-4
Chapter 8	QUALITY ASSURANCE	8-1
8.1	Sample Collection Methodologies	8-2
8.2	Revision of Procedures	8-3
8.3	Interlaboratory Comparisons	8-3
8.4	Laboratory Quality Control	8-3
8.5	Record Keeping	8-4

Table of Contents

Section		Page
Chapter 9	REFERENCES	9-1
Chapter 10	REQUIRED DISTRIBUTION LIST	10-1
Appendix	GROSS ALPHA AND BETA CONCENTRATIONS REPORTED BY LOCATION	A-1

LIST OF TABLES

TABLE	TITLE	PAGE
3-1	Compliance Status with Major Environmental Regulations Applicable to the WIPP Project	3-25
3-2	DOE Orders and Agreements Affecting the WIPP Environmental Program	3-
3-3	Summary of Agreements Between DOE and the State of New Mexico that Affect the Environmental Program	3-
3-4	Active/Pending Permits for the Waste Isolation Pilot Plant During 1993	3-
5-1	Activity Concentrations in Quarterly Averages of the Low Volume Aerosol Filters	5
6-1	Summary of the 1993 Emlen Breeding Bird Density Measurements	6-
6-2	Observed Avifauna of Los Medanos and Surrounding Ecotones	6-
6-3	Summary of 1993 Small Nocturnal Mammal Densities	6-
6-4	Actual Captures of Nocturnal Mammals in 1993	6-
6-5	WIPP 1993 Fall Vegetation Report	6-
7-1	Parameters Analyzed During CY 93	7-
7-2	H-02c, Culebra Round 5, Comparison To Background Characterization	7-
7-3	H-03b3, Culebra Round 8, Comparison To Background Characterization	7-
7-4	H-04b, Culebra Round 8, Comparison To Background Characterization	7-
7-5	H-05b, Culebra Round 8, Comparison To Background Characterization	7-11

LIST OF TABLES
continued

TABLE	TITLE	PAGE
7-6	H-06b, Culebra Round 8, Comparison To Background Characterization	7-12
7-7	H-11b3, Culebra Round 7, Comparison To Background Characterization	7-13
7-8	H-14, Culebra Round 6, Comparison To Background Characterization	7-14
7-9	WIPP-19, Culebra Round 8, Comparison To Background Characterization	7-15
7-10	Barn Well, Dewey Lake Round 7, Comparison To Background Characterization	7-16
7-11	Ranch Well, Dewey Lake Round 8, Comparison To Background Characterization	7-17

LIST OF FIGURES

FIGURE	TITLE	PAGE
2-1	Location of the WIPP Site	2-5
5-1	Primary Pathways to Man for Radioactive Releases from the WIPP Site	5-8
5-2	Continuous Air Sampling Stations	
5-3	1993 Gross Alpha/Beta Concentration	
6-1	1993 Precipitation	6
6-2	1993 Annual Windrose	6
6-3	WIPP Seismograph Station Locations	6
7-1	Water Quality Sampling Program Sample Wells 1993	
7-2	Groundwater Level Surveillance Wells	7-18
7-3	Potentiometric Surface of the WIPP Site (Culebra)	7
7-4	Potentiometric Surface of the WIPP Site (Magenta)	

ACRONYMS AND ABBREVIATIONS

AEA	Atomic Energy Act
AIS	Air Intake Shaft
AMR	Annual Mitigation Report
AMS	Atmospheric Monitoring Station
ASER	Annual Site Environmental Report
BLM	U.S. Bureau of Land Management
BMP	Best Management Practices
Bq	Becquerel
CAA	Clean Air Act
C&C	Consultation and Cooperation
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (also known as Superfund)
CFR	Code of Federal Regulation
CH-TRU	Contact Handled Transuranic Waste
CT-1	Control 1
CT-2	Control 2
CWA	Clean Water Act
CX's	Categorical Exclusions
CY	Calendar Year
DOE	U.S. Department of Energy
DOE-EML	U.S. Department of Energy, Environmental Measurements Laboratory
DOL	U.S. Department of Labor
EA	Environmental Assessment
EC	Electrical Conductivity
EDF	Environmental Defense Fund

ACRONYMS AND ABBREVIATIONS
(Continued)

EEG	Environmental Evaluation Group
Eh	Oxidation-Reduction Potential
EIS	Environmental Impact Statement
EML	Environmental Measurement Laboratory
EMP	Ecological Monitoring Program
EO	Executive Order
EPA	U. S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESA	Endangered Species Act
FDA	Fluorescardiacetate Hydrolysis Assay
FEIS	Final Environmental Impact Statement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FLPMA	Federal Land Policy Management Act
FR	Federal Register
FSAR	Final Safety Analysis Report
FT	Feet
FWPCA	Federal Water Pollution Control Act
GSP	Groundwater Surveillance Program
HEPA	High Efficiency Particulate Air (filter)
HMTA	Hazardous Material Transportation Act
HSWA	Hazardous and Solid Waste Amendments
HW	Hazardous Waste
INEL	Idaho National Engineering Laboratory
LLCL	Low Level Counting Laboratory
LWA	Land Withdrawal Act
MOU	Memorandum of Understanding
MPS	Meters Per Second

ACRONYMS AND ABBREVIATIONS
(Continued)

MSHA	Mine Safety and Health Administration
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NES	Nonradiological Environmental Surveillance
NESHAPs	National Emissions Standard for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NM	New Mexico
NMD	No-Migration Determination
NMED	New Mexico Environment Department
NMGF	New Mexico Department of Game and Fish
NMIMT	New Mexico Institute of Mining and Technology
NOD	Notice of Deficiency
NPDES	National Pollution Discharge Elimination System
NRC	Nuclear Regulatory Commission
NW 2	Northwest 2
NWPA	National Waste Policy Act
OEMP	Operational Environmental Monitoring Plan
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyls
pH	Hydrogen-Ion Activity of a System
PRS	Project Records Services
QA	Quality Assurance
QAP	Quality Assurance Program
QC	Quality Control
RBP	Radiological Baseline Program
RCRA	Resource Conservation and Recovery Act
RES	Radiological Environmental Surveillance

ACRONYMS AND ABBREVIATIONS
(Continued)

ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SE-1	Southeast 1
SE-2	Southeast 2
SEIS	Supplement Environmental Impact Statement
SEN	Secretary of Energy Notice
SERC	State Emergency Response Commission
SHPO	State Historic Preservation Officer
SIC	Standard Industrial Code
SNL	Sandia National Laboratories
SPDV	Site Preliminary Design Validation
SWPPP	Storm Water Pollution Prevention Plan
TDS	Total Dissolved Solids
TRU	Transuranic
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facility
TSP	Total Suspended Particles
UIC	Underground Injection Control
USFWS	U.S. Fish and Wildlife Service
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds
WIPP	Waste Isolation Pilot Plant
WPSO	WIPP Project Site Office
WQSP	Water Quality Sampling Program

PREFACE

1993 WIPP Site Environmental Report
Preface

This is the tenth Annual Site Environmental Report (ASER), documenting the progress of environmental programs at the U.S. Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP). The most significant change affecting the WIPP facility in 1993 was the cancellation of the Test Phase. All activities pertaining to the Test Phase will now be conducted at the Idaho National Engineering laboratory.

Even though the cancellation of the Test Phase was a significant change in work scope for the WIPP, there are still numerous environmental monitoring and reporting activities that must be preformed as a routine part of daily operations. These activities, and the WIPP's ability to demonstrate compliance with both state and federal environmental compliance requirements, are documented in this report.

This report is a compilation and summarization of environmental data collected at the WIPP site. Should a reader of this report desire to obtain copies of the raw data used to generate this document, please write the U.S. Department of Energy, Manager of the Environment, Safety and Health Department, at P.O. Box 3090, Carlsbad, NM 88221.

CHAPTER 1

EXECUTIVE SUMMARY

Chapter 1
Executive Summary

The U.S. Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) Environmental Monitoring Plan (EMP) defines a comprehensive set of parameters that must be monitored to detect potential impacts to the environment and to establish baseline measurements for future environmental evaluations. Surface water and groundwater, air, soil, and biotics must be monitored for radiological and nonradiological activity levels. Nonradiological studies focus on the area immediately surrounding the WIPP site with emphasis on the salt storage pile. The baseline radiological surveillance covers a broader geographic area that expands to encompass nearby ranches, villages, and cities.

Since the WIPP is still in its preoperational phase (i.e., no waste has been received), certain operational requirements specified in DOE Orders 5400.1 and 5400.5, and in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T) are not yet relevant. Therefore this report does not discuss programs and activities that will be developed to meet future (operational requirements) such as those concerned with radionuclide emissions and effluents and their impact upon the public and the environment.

1.1 Compliance Summary

A summary of significant compliance-related issues and actions at the WIPP during Calendar Year (CY) 1993 presented in this section. The major environmental statutes and Executive Orders applicable to the WIPP, along with compliance status, and the significant issues, actions, and accomplishments at the WIPP facility in the CY 1993 as they relate to each statute, are described in Chapter 3 of this report.

Revision 3 of the Resource Conservation and Recovery Act (RCRA) Part B permit application was submitted to the New Mexico Environment Department (NMED) in January 1993. The NMED issued a test-phase draft permit for the WIPP facility in August 1993 for public comment. At the conclusion of the public comment period on January 15, 1994, the DOE requested from the New Mexico Environment Department (NMED) the opportunity to revise the Part B permit application, to reflect the October 1993 decision to redirect Test Phase activities from the WIPP to one of national laboratories, and thus, to more accurately describe the programmatic direction of the WIPP.

In addition, a report titled *No-Migration Determination Annual Report for the Period of September 1992 through August 1993* was submitted to the Environmental Protection Agency (EPA) Region VI

and to EPA Headquarters on November 9, 1993, to satisfy the annual reporting requirement of the No-Migration Determination (NMD).

The WIPP also validated the bin-case reports for the sixth and seventh bins of waste planned for shipment to the WIPP facility. The bin case addendum reports were validated for bins four, six, and seven. These reports contain the results of the waste analysis efforts conducted at the Idaho National Engineering Laboratory (INEL) for shipment to the WIPP site. After review of these reports, the WIPP concluded that the bins may be emplaced in the WIPP repository in compliance with the Waste Analysis Plan of the RCRA Part B permit application and the NMD.

On February 9, 1994, the WIPP submitted the *Emergency and Hazardous Chemical Inventory Report* for CY 1993 to the New Mexico (NM) State Emergency Response Commission, the Eddy County Local Emergency Planning Committee, and the local fire department with jurisdiction over the WIPP site, as required by Section 312 of the Superfund Amendments and Reauthorization Act (SARA) Title III. In March 1994 the WIPP submitted the Emergency and Hazardous Chemical Inventory Report for CY93 to all the appropriate organizations.

The WIPP National Environmental Policy Act (NEPA) Compliance Program has been developed to ensure the requirements of the NEPA are fulfilled at the WIPP site. The program specifies that those responsible for the planning, coordination, and performance of work follow the provisions of NEPA and that these provisions be applied appropriately for work performed at the WIPP. Furthermore, the NEPA Compliance Program details the actions taken in the evaluation of work documents for NEPA Compliance in accordance with DOE Order 5440.1E and Secretary of Energy Notice (SEN) 15-90.

In April 1993, Westinghouse Electric Corporation Waste Isolation Division (WID) completed the *WIPP Hazardous Air Pollutants (HAPs) Emission Inventory* (WP 02-15). The HAPs inventory was developed as a baseline document to calculate maximum potential hourly and annual emissions of both hazardous and criteria air pollutants. The HAPs inventory calculated emissions estimates for the three Carlsbad Area Office (CAO) locations. These locations include the WIPP site, the CAO located at Greene Street, and the WID Canal Street office. Emission estimates were used to determine if the WIPP is required to obtain an air permit under state or federal regulations.

On June 18, 1993, the DOE submitted an Air Quality Control Regulations (AQCR) 702 permit application for the WIPP back-up diesel generators. The New Mexico Air Quality Bureau issued Air Quality Permit 310-M-2 on December 7, 1993. On February 26, 1994, the WIPP completed the emission monitoring requirements established in the permit. With the submittal of the *Final*

Compliance Sampling Report on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit.

Section 402 of the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) program, establishes requirements for regulating industrial storm water runoff that has the potential to discharge into waters of the United States. The WIPP submitted a Notice of Intent to the EPA to obtain a NPDES Storm Water General Permit. On December 31, 1992, the EPA issued a New Mexico NPDES Storm Water General Permit (NMR00A021). The WIPP completed the WIPP *NPDES Storm Water Pollution Prevention Plan* (PPP) in March 1993. The NPDES Storm Water General Permit rules require that a PPP be developed for each facility covered under the permit by April 1, 1993. The PPP identifies and assesses potential pollutant sources, and describes all Best Management Practices (BMPs) that have been implemented to ensure that storm water runoff does not contact regulated pollutants.

The WIPP has applied for and received an approved Discharge Plan (DP-831) for the WIPP sewage facility. The Discharge Plan approves the construction, sampling, and management requirements for the facility. The expansion of the sewerage system was completed in April 1993. This expansion included the construction of a lined evaporation pond divided into two cells.

The WIPP continues to conduct a training program aimed at informing all WIPP personnel of their responsibilities under RCRA. The level of training provided under the program is contingent upon the employees' job titles and duties. All employees receive introductory RCRA training in the class *General Employee Training* at the WIPP.

On October 30, 1992, President Bush signed the Waste Isolation Pilot Plant Land Withdrawal Act (LWA) transferring land from the public domain for use by the DOE. The LWA establishes an extensive regulatory framework that governs the conduct of the WIPP Test Phase and, if all requirements are successfully met, the Disposal Phase.

The *Land Management Plan* has been prepared for the WIPP withdrawal area by the DOE in consultation with the U.S. Bureau of Land Management (BLM), and the State of New Mexico. The *Land Management Plan* was issued October 30, 1993. This plan encourages the public and local, state, and federal agencies to participate in the land use planning process.

A Memorandum of Understanding (MOU) between the DOE and the BLM is being prepared and should be issued by May 1994. This MOU outlines the responsibilities of each agency with regard to

land use management for the withdrawal area, and provides an additional mechanism to protect the withdrawal area from unallowable or inadvertent uses. The *Land Management Plan* and the MOU will serve to provide equitable and consistent administration of archaeological resources within the WIPP withdrawal area.

1.2 Environmental Program Information

The effort to establish environmental baseline conditions at the WIPP site before arrival of waste began in 1975. These studies are continuing to characterize the local environment both radiologically and nonradiologically until the WIPP site is operational. Once the site is operational, these programs will transition into the operational phase and the environment will be monitored constantly throughout the life of the project.

1.2.1 Environmental Monitoring Plan

The WIPP EMP provides schedules and guidelines for monitoring a comprehensive set of parameters in order to detect and quantify present or potential environmental impacts. Nonradiological portions of the program focus on the immediate area surrounding the WIPP site. The radiological surveillance generally covers a broader geographic area, one that includes nearby ranches, villages, and cities. Environmental Monitoring will continue at the WIPP site during project operations and throughout decommissioning activities. The sampling activities will continue to be performed at the monitoring locations established by the EMP. Monitoring parameters may need to be modified from time-to-time to ensure a technically sound program. None of these monitoring parameters will be changed, however, without the revision and approval of the EMP.

1.2.2 Raptor Research Program

In CY93 the Raptor Program focused on the impacts of human-related activities on four distinct groups of Harris' Hawks (*Parabuteo unicinctus*). During the course of the year, nest locations of the hawks were identified and nestlings were banded with U.S. Fish and Wildlife Service (USFWS) bands and with color bands with alpha numeric codes. These groups will serve as indicators for the data-sharing network between the WIPP and the BLM. Also, during the year nest locations of additional Harris Hawk groups and other

nesting species (e.g., Swainson's Hawks, Chihuahuan Ravens) were located. Nest locations were identified with Loran Navigators and these location were provided to the BLM for incorporation into their determinations per land use activities.

1.2.3 Reclamation of Disturbed Lands

Reclamation activities during CY93 consisted of constructing a fence around an existing reclamation site. The fence was constructed according to BLM specifications. Surface areas that retained water were hand seeded and minor erosion control measures were implemented. Additionally, a construction landfill area was capped and reseeded to bring the facility into compliance with NPDES stormwater discharge permit requirements.

1.3 Environmental Radiological Program Information

The following subsections present monitoring topics for the subprograms of the EMP. These programs are consistent with policies established in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, (DOE/EH-0173T).

DOE Order 5400.1 requires that a radiological baseline be established during the preoperational phase. Once a radiological baseline has been established, many of the radiological sampling programs can be redirected to collecting samples to archive for future analysis. As specifically outlined in the EMP, five subprograms are being conducted to document the background levels of potential radionuclide pathways leading from the WIPP to the environment and the public.

These five subprograms are presented in the *Statistical Summary of the Radiological Baseline Program (RBP) for the Waste Isolation Pilot Plant* (DOE/WIPP 92-037).

1.3.1 Airborne Particulate and Effluent Monitoring

WIPP began sampling airborne aerosol particulates in 1985 and this sampling activity continues to be an important subprogram of the EMP. The *Final Safety Analysis Report* (FSAR) (DOE, 1990) identifies the atmosphere pathway as the only pathway potentially capable of exposing the public to radiation. To monitor this pathway, particulate aerosol samplers continuously operate at eight locations: three within 1000 meters of the facility boundary, four at local ranches and communities, and one at a sample control site.

counted at the Low-Level Counting Laboratory at the WIPP site. The weekly filters are counted for gross alpha and beta activity. The data are then grouped into 13-week segments or calendar quarters and are presented as a calculated quarterly average. Table 5-1 lists the quarterly alpha and beta concentrations for each sampling location.

1.3.2 Soil Sampling

Soil samples were collected in CY93. However, due to discrepancies identified in the contract laboratory analytical contract, no radiological soil sampling data will be presented in the CY93 WIPP ASER. Two years of baseline soil analysis data were previously documented in DOE/WIPP 92-037.

1.3.3 Groundwater

Groundwater samples were collected in CY93. However, due to discrepancies identified in the contract laboratory analytical contract, no radiological groundwater sampling data will be presented in the CY93 WIPP ASER. Two years of baseline groundwater analysis data were previously documented in DOE/WIPP 92-037.

1.3.4 Surface Water and Sediment Sampling

There are no surface water and sediment samples were collected in CY93. However, due to discrepancies identified in the contract laboratory analytical contract, no radiological surface water and sediment sampling data will be presented in the CY93 WIPP ASER. Two years of baseline surface water and sediment analysis data were previously documented in DOE/WIPP 92-037.

1.3.5 Game Animals and Fish Samples

Game animals and fish samples were collected in CY93. However, due to discrepancies identified in the contract laboratory analytical contract, no radiological game animal and fish sampling data will be presented in the CY93 WIPP ASER. Two years of baseline game animal and fish analysis data were previously documented in DOE/WIPP 92-037.

1.4 Nonradiological Monitoring Information

Nonradiological environmental surveillance was also conducted in accordance with the EMP. This program was preceded by the WIPP Biology Program (1975-1982). Six universities participated in this surveillance program. An extensive baseline of information describing the major components of the Los Medanos ecosystem prior to the initiation of the WIPP site construction activities was developed.

A significant portion of the nonradiological surveillance was to document the effect fugitive salt dust generated by the surface stockpiling activities had on the surrounding ecosystem see (Reith et al., 1985). This study is described in the *Summary of the Salt Impact Studies at the Waste Isolation Pilot Plant 1984 to 1990* (DOE/WIPP 92-038).

1.4.1 Meteorology

The WIPP Nonradiological Environmental Surveillance (NES) includes a primary meteorological (MET) station that provides support for various programs at the WIPP. The primary MET function is to generate data to aid in modeling atmospheric conditions for Radiological Environmental Surveillance (RES). The data generated from the meteorological station are wind speed, wind direction, and temperatures at a radius of 3, 10, and 40 meters (10, 30, and 130 feet), respectively, with dew point and precipitation monitored at ground level. These parameters are measured continuously and the data are logged, at fifteen minute intervals, in the Central Monitoring Room.

The annual rate of precipitation at the WIPP site for 1993 was 24 cm (9.4 in), which is 18 cm (7 in) below last year's rate. The annual precipitation for 1993 was 43 percent less than that recorded for 1992.

In CY 1993, the data collected on wind direction in the WIPP area were consistent with data previously collected on wind direction. The wind direction at the WIPP site is predominately from the southeast.

1.4.2 Air Quality Monitoring

Seven pollutant gases are monitored at the WIPP site on a continuous basis. These gases are sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), hydrogen sulfide (H_2S), nitrous oxide (NO), nitrous dioxide (NO_2), and oxides of nitrogen (NO_x). In addition, weekly measurements of Total Suspended Particulates (TSP) are collected by the low-volume continuous air sampler at the far-field air sampling location.

1.4.3 Wildlife Population Monitoring

Population density measurements of birds and small nocturnal mammals are performed annually to assess the effects of WIPP activities on wildlife populations.

Bird Densities

Overall, distribution patterns of species living between WIPP transects and the control transects remain constant with the most significant changes occurring near the facility. More abundant food (i.e., insects drawn to the facility lights) and greater habitat diversity probably account for the increase in the number of species near the WIPP transects compared to those of the control transects. Insect dependant species such as barn swallows, ash-throated flycatchers, and king birds are the prominent species on the increase in the immediate vicinity of the facility. Rock doves, the common city pigeon, have been observed around the WIPP site.

Small Nocturnal Mammal Population Densities

Starting with the outbreak of Hanta virus in the spring of 1993, small nocturnal mammal censuses were conducted on two study plots rather than on the usual four. Midway through the census period there had been outbreaks of the virus in New Mexico and every state bordering New Mexico. The chief vector for the disease had been determined to be the deer mouse, *Peromyscus maniculatus*. To protect researchers from possible exposure, the censuses for Northwest (NW-2) and Control (CT-2) were cancelled. The two censuses that were conducted revealed that the Ord's kangaroo rats remains the most common species encountered in this area. Plains wood rats are the next most common species encountered. Other species encountered in this area are grasshopper mice, white-footed mice, deer mice, and silky pocket mice. A greater number of mammals were captured in the control 1 plot than in the WIPP plot.

1.4.4 Vegetation Monitoring

The CY 1993 vegetation monitoring data show a slight increase of perennial grasses with increasing proximity to the salt tailings. The total coverage of these grasses in all plots was relatively uniform over all distances from the tailings. Although densities of annuals and diversity of species were greater in the control plots, overall, these densities and diversities remained relatively uniform across all plots. A pattern observed from the 1989-1992 data which was also seen in the 1993 data is an increase in shrub cover with increasing proximity to the salt tailings. This increase is a common effect of secondary salination. However, differential effect resulting from salt-induced physiological stress near the salt tailings was not observed. The responses of these plots to higher rainfall in later years will reveal whether this pattern is reflecting the start of significant changes in the structure of the plant community or whether it is only a short-term effect caused by short-term weather conditions. During the study period weather conditions had a uniform effect on vegetation in all plots.

1.5 Quality Assurance

This document adheres to policies set forth by federal Quality Assurance (QA) regulations including: American Society of Mechanical Engineers (ASME) NQA-1, *Quality Assurance Program (QAP) Requirements for Nuclear Facilities* (ASME, 1989) and EPA, QAMS-005/80, *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA, 1980), and fulfills the requirements of the QA plans specified in DOE Orders 5400.1 (DOE, 1988d), 5400.3 (DOE, 1988e), 5700.6C (DOE, 1991) and the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T).

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CHAPTER 2

INTRODUCTION

Chapter 2
Introduction

This is the WIPP Annual Site Environmental Report (ASER) for CY93. The purpose of the WIPP as mandated by Public Law 96-164 is to provide a research and development facility to demonstrate the safe disposal of Transuranic (TRU) wastes generated by the defense activities of the U.S. Government. This document is prepared in accordance with the guidance contained in DOE Order 5400.1, *General Environmental Protection Program* (DOE, 1990); DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE, 1990); DOE/WIPP 91-054, *Environmental Protection Implementation Plan*, and DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. The above orders require DOE facilities to submit an ASER to the DOE Headquarters Office of the Assistant Secretary for Environment, Safety and Health.

This report provides a comprehensive description of environmental activities at the WIPP during CY93. The requirements and goals driving these activities are more fully described in the *Environmental Monitoring Plan for the Waste Isolation Pilot Plant* (DOE/WIPP 94-024). This plan defines the scope and extent of the WIPP effluent and environmental monitoring programs during the pre-operational and operational life of the site.

This ASER also discusses the QA and Quality Control (QC) programs, which ensure that samples collected and the analytical data obtained are representative of actual conditions at the WIPP site. The EMP is the guidance document that all environmental monitoring programs follow. This guidance document ensures that all appropriate sampling efforts are in place to establish the amount and type of naturally occurring radioactivity in the WIPP area before the WIPP site is operational and to provide data for comparisons between pre-operational and operational environmental conditions once the WIPP site is operating as a waste repository for TRU waste.

The EMP was prepared in accordance with the guidance contained in DOE Order 5400.1 and DOE Order 5400.5. Since waste has not been received, certain elements of DOE Order 5400.1 are not yet relevant to the WIPP environmental monitoring program (i.e., no discussion is included in this report of radionuclide emissions with subsequent calculation of doses to the public).

The EMP is reviewed and updated, as required by DOE Order 5400.1, to address general changes, improvements, and enhancements to be implemented due to experience gained from these monitoring programs.

2.1 Description of the WIPP Project

The WIPP is a project that was authorized by the DOE, National Security, and Military Applications of Nuclear Energy Authorization Act of 1980 (i.e., Public Law 96-164). Its legislative mandate is to demonstrate the safe disposal of radioactive waste resulting from national defense activities and programs. To fulfill this mandate, the WIPP has been designed to perform scientific investigations of the behavior of bedded salt and the interactions between the salt and radioactive wastes and to demonstrate safe and efficient handling, transport, and emplacement of transuranic (TRU) waste in a fully operational disposal site.

The first radioactive wastes will be emplaced once the bench-scale test have been completed at INEL. Once the tests have been successfully completed, wastes will be shipped over a 25-year period to the WIPP site from INEL, Rocky Flats Plant, Hanford Site, Savannah River Plant, Los Alamos National Laboratory, Oak Ridge National Laboratory, Mound Laboratory (operated by Monsanto Research Corporation), Nevada Test Site, Argonne National Laboratory, and Lawrence Livermore National Laboratory for permanent disposal. This TRU waste material is contaminated with alpha emitting radionuclides greater than 100 nCi/g.

Subsequent to a successful completion of the test phase, the WIPP site will be designated as an operational facility and TRU wastes will be transported from generator/storage sites throughout the United States to the WIPP site. This could not happen until the later years of this decade.

The TRU waste to be received from the generator sites will be transported to the WIPP site via tractor-trailer trucks. Each truck can haul up to three TRU Package Transporters (TRUPACT IIs), and each transporter may contain fourteen 55-gallon drums or two standard waste boxes. The TRUPACT II is a durable, reusable container that has been approved by the Nuclear Regulatory Commission (NRC) to transport contact-handled (waste containers that can be handled without shielding) transuranic waste to the WIPP.

Once the TRUPACT IIs have arrived at the WIPP and are transported into the Waste Handling Building, the waste containers will be removed from the TRUPACT IIs, placed on the waste handling hoist, and lowered to the repository level of 655 m (2150 feet) below the surface. During the disposal phase, waste containers will be removed from the hoist and emplaced in excavated storage rooms in the Salado formation, (i.e., a thick sequence of salt beds deposited approximately 250 million years ago in the Permian Age). After the storage areas have been filled, specially designed seals and plugs will be placed in the excavated storage rooms and in the shafts. The plastic

self-healing nature of the salt formation will result in a gradual creep closure, causing encapsulation and isolation of the waste within the Salado formation.

During site operations, the underground area will be ventilated with ambient air that enters the Air Intake Shaft, the Salt Handling Shaft, the Waste Handling Shaft, and exits through the Exhaust Shaft. In the event of an underground accident involving radioactivity, exhaust air can be circulated at a reduced flow rate through the Exhaust Filter Building. This building contains banks of High Efficiency Particulate Air (HEPA) filters that remove potentially contaminated particulates.

2.2 Description of the Environment and Lands

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 2-1). The WIPP site is approximately 40 kilometers (26 miles) east-southeast of Carlsbad, New Mexico, in an area known as Los Medanos (i.e., the dunes). This area is a sparsely inhabited plateau that has little water and limited land uses. Land uses in the surrounding areas include potash mining, oil and natural gas exploration, recreational uses (i.e., hunting, trapping, and birdwatching), and other uses permitted by the BLM.

The WIPP site boundary extends at least 1.6 kilometers or one mile beyond any of the WIPP underground developments and is defined on the surface by the 16-section (4,146 ha) Land Withdrawal Area. On October 30, 1992, the WIPP Land Withdrawal Act, Public Law 102-579, was signed by President Bush transferring the land from the Department of Interior (DOI) to the DOE. A WIPP land management plan, DOE/WIPP 93-004, was then prepared and submitted to Congress in October 1993.

The WIPP site consists of 16 sections (4,146 ha) of federal land in Township 22 South, Range 31 East. Except for the 2.59 square kilometers (one square mile) encompassing the facility known as the DOE exclusive use area, the surface land uses remain largely unchanged. Mining and drilling for purposes other than those which support the WIPP project are restricted within the 16-section (4,146 ha) area.

The WIPP site is divided into zones as represented in Figure 2-1. Zone I is surrounded by a chain-link fence that encompasses all major surface facilities. Zone II is the area that encloses the maximum extent of underground development. The WIPP site boundary provides a functional barrier of intact salt between the underground region defined by Zone II and the accessible environment.

The nearest residents to the WIPP site include eight individuals living at the Mills Ranch, 5.3 kilometers (3.5 miles) south-southwest of Zone 1 of the site, and two individuals living at the Smith Ranch, 11.3 kilometers (seven miles) west-northwest of Zone 1 of the site. Both ranches are continuously monitored as part of the environmental monitoring program. Also included in this monitoring program is the headquarters for the International Minerals and Chemical Corporation Potash Mine, located 14.5 kilometers (nine miles) west-northwest of Zone 1 of the site. Detailed demographic summaries and projections are listed in the *WIPP Final Environmental Impact Statement* (FEIS) (DOE, 1980), the *Final Supplement Environmental Impact Statement* (SEIS) (DOE, 1990), and the *WIPP Final Safety Analysis Report* (DOE, 1990).

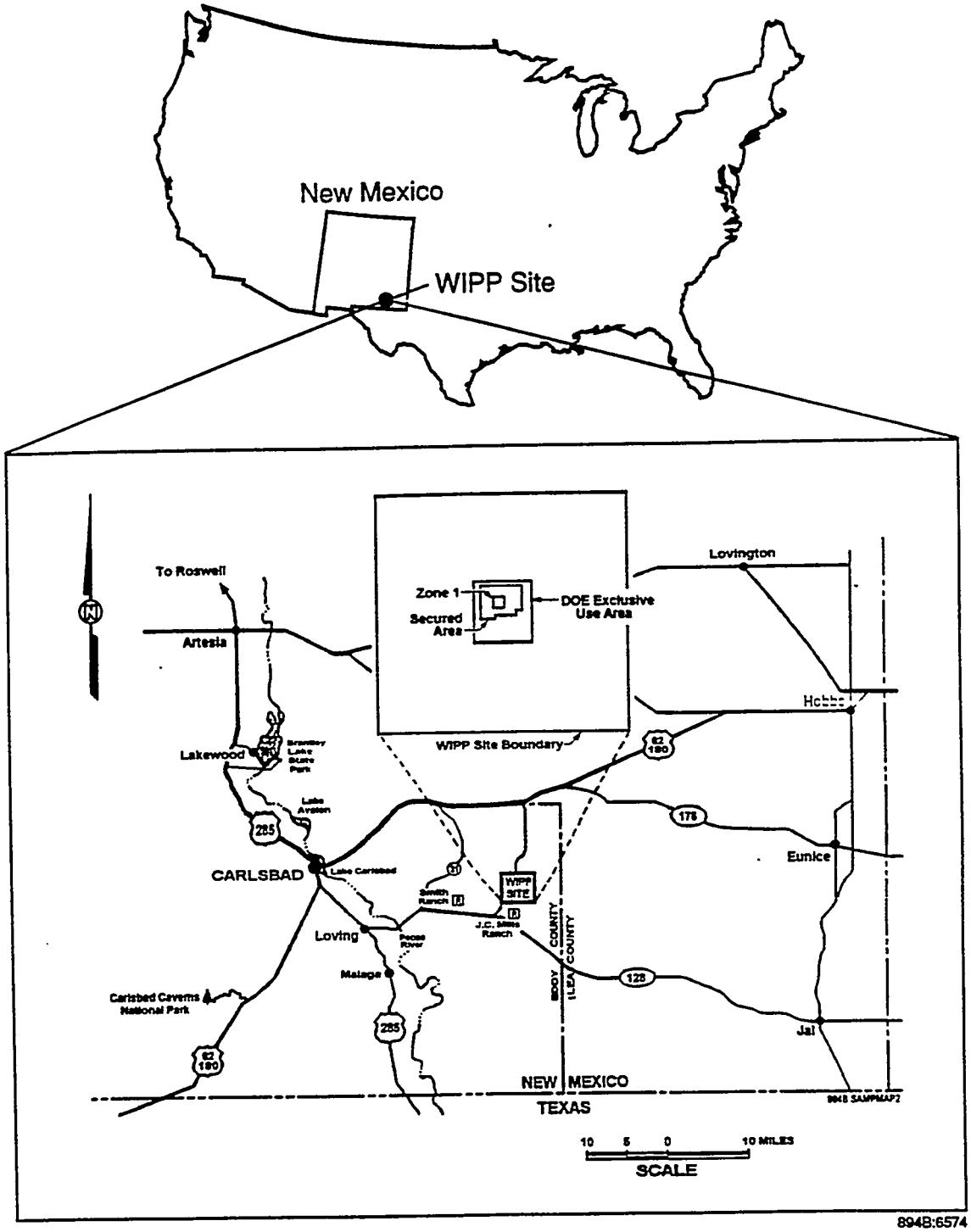

Figure 2-1
Location Of The WIPP Site

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CHAPTER 3

COMPLIANCE SUMMARY

Chapter 3
Compliance Summary

The WIPP is required to comply with all applicable DOE Orders and federal and state laws and regulations. Documentation of required federal and state permits, notifications, and approvals is maintained by the Environment, Safety, Health and Regulatory Compliance (ESH&RC) Department of the Management and Operating Contractor (MOC). Regulatory requirements are implemented by incorporating them into facility plans and procedures.

Table 3-1 provides a summary of the major federal and New Mexico statutes applicable to the WIPP Project. Table 3-2 presents DOE Orders and agreements affecting the WIPP environmental program. Table 3-3 is a summary of agreements between the DOE and the state of New Mexico that affect the environmental program. Table 3-4 details active environmental permits for the WIPP in CY93 and the first quarter of CY94.

3.1 Compliance Assessment for Calendar Year 1993

In 1993 the WIPP remained in compliance with applicable federal and state environmental regulations. Section 3.2 lists the compliance status of each major environmental statute and executive order applicable to the WIPP, including significant issues generated by, and actions and accomplishments driven by these statutes and orders. Section 3.3 describes other significant environmental issues, actions, and accomplishments at the WIPP facility in CY93.

3.2 Compliance Status

This section states the WIPP's status of compliance with the following regulatory requirements.

3.2.1 Atomic Energy Act of 1954 (AEA)
(42 U.S.C. sec. 2011 et seq.)

The AEA establishes a national program for research, development, and utilization of atomic energy for both national defense and domestic civilian purposes. Section 161 (i) (3) of the AEA provides that the Atomic Energy Commission (succeeded by the DOE for national defense purposes) is authorized to prescribe regulations and orders to

> Govern any activity authorized pursuant to this Act [the AEA], including standards and restrictions governing the design, location, and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life or property. . .

The authority of the DOE to develop policies, issue orders, and promulgate regulations (i.e., those addressing environment, safety and health protection aspects) regarding radioactive waste and nuclear materials is derived directly from the AEA. The EPA has also derived its authority to establish standards for the protection of the public and the environment from ionizing radiation from the AEA. The DOE, under the authority of the AEA and in accordance with various Executive Orders (EOs), uses a system of Orders, Notices, and Directives to carry out the mandate to implement effective and consistent programs to protect the public, the environment, and employees from adverse consequences resulting from the DOE operations. Implementation of those Orders, Notices, and Directives dealing with environmental monitoring and surveillance is addressed in the *Environmental Monitoring Plan for the WIPP*.

Most of the waste slated to be sent to the WIPP site is TRU waste. TRU waste contains radioactive components regulated by the AEA and hazardous components regulated by the RCRA. The RCRA contains qualifiying provisions that exclude activities or substances authorized by or regulated under the AEA. Two different sections of the RCRA address these exclusions:

The Solid Waste Exclusion. RCRA sec. 1004(27) defines a solid waste as a . . . *solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities. . .* This definition specifically excludes "source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended."

The Inconsistency Exclusion. RCRA sec. 1006(a) provides the following: "Nothing in this Act shall be construed to apply to (or to authorize any State, interstate, or local authority to regulate) any activity or substance which is subject to. . . the Atomic Energy Act of 1954. . . except to the extent that such application (or regulation) is not inconsistent with the requirements of such Acts." [Emphasis added.] Thus, although the WIPP is subject to dual regulation under the AEC and the RCRA, radioactive wastes are principally regulated by the AEC.

3.2.2 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

(42 U.S.C. sec. 9601 et seq.), including the Superfund Amendments and Reauthorization Act of 1986)

The CERCLA, or "Superfund," and the SARA establish a comprehensive federal strategy for responding to, and establishing liability for, releases of hazardous substances from a facility to the environment. Hazardous substance cleanup procedures are specified in the National Contingency Plan (NCP) in Title 40 Code of Federal Regulation (CFR), Part 300. No release sites have been identified at the WIPP that would require cleanup under the provisions of the CERCLA. Any spills of hazardous substances of

reportable quantities must be reported to the National Response Center (NRC) under the provisions of the CERCLA, section 103 and Title 40 CFR, Part 302.

Accidental Releases of Reportable Quantities of Hazardous Substances

During 1993 there were three spills of ethylene glycol in quantities that required reporting. Each spill was less than 1/2 gallon. The reportable quantity for ethylene glycol is one pound. One pound of ethylene glycol is equivalent to approximately one pint of liquid. All three spills were reported to the NRC, the State Emergency Response Commission (SERC), and the Local Emergency Planning Committee (LEPC). A follow-up written report was sent to the SERC and the LEPC. All the spills were immediately contained and cleaned up in accordance with the WIPP spill response procedures. All contaminated soils and spill containment pads were drummed, manifested, and transported to an off-site disposal facility.

The WIPP facility is required to report under Sections 311 and 312 of SARA Title III, also known as the Emergency Planning and Community Right-to-Know Act (EPCRA). Required reports under these two sections are submitted to the SERC, the LEPC, and the local fire department. The WIPP also submits Section 311 data and Section 312 Annual Reports to the Carlsbad Fire Department, the Hobbs Fire Department, and the Otis Fire Department. For emergency response purposes, the DOE maintains Memoranda of Understanding with each of these agencies.

The WIPP facility is currently exempt from reporting under Section 313 of the EPCRA. The items on the toxic chemical list mentioned in Section 313 that are currently in use at the WIPP in amounts meeting the reporting threshold level of 10,000 pounds are ethylene glycol, sulfuric acid, toluene, and xylene. These chemicals are exempted from reporting requirements at this time.

Waste Minimization and Pollution Prevention Awareness Plan

On March 2, 1993, the *WIPP Waste Minimization and Pollution Prevention Awareness Program Plan* was reviewed and accepted by the CAO. This plan will be reviewed annually and updated at least once every three years. Specific guidance for amending the plan will be provided periodically from the DOE; the changes for this year were received in March 1994. The new revision of the *WIPP Waste Minimization and Pollution Prevention Awareness Plan* was completed on May 31, 1994.

3.2.3 Resource Conservation and Recovery Act
(42 U.S.C. sec. 3251 et seq.)

The RCRA was enacted in 1976 and implementing regulations were promulgated in May 1980. This body of regulations ensures that hazardous wastes are managed and disposed of in an environmentally safe manner. Facilities that store, treat, or dispose of hazardous waste also must protect human health and the environment. The Hazardous and Solid Waste Amendments (HSWA) of 1984 restricts the land disposal of hazardous wastes unless certain treatment standards are satisfied. HSWA also places increased emphasis on waste minimization activities and serves as a mechanism to enforce cleanup.

Mixed-Waste Management Test Phase

On July 25, 1990, the state of New Mexico received final EPA authorization to regulate radioactive mixed waste. In a letter dated August 27, 1990, the state of New Mexico notified the WIPP that Parts A and B of the RCRA permit application for the WIPP were due by January 22 and February 28, 1991, respectively. On January 22, 1991, the Part A permit application was delivered to the state and to the EPA Region VI Office in Dallas, Texas (DOE, 1991b). The Part B permit application was delivered to the state on February 26 and to EPA Region VI on February 27, 1991. The DOE-CAO submitted Revision 1 in March 1992. Revision 2 was submitted to the NMED in segments beginning in August 1992. The third revision of the Part B permit application was submitted in January 1993.

The NMED issued a Test-Phase draft permit for the WIPP facility in August 1993 for public comment. In October 1993, the DOE made the decision not to conduct testing of radioactive wastes at the WIPP. Instead, the DOE decided to pursue an accelerated compliance approach in an effort to obtain the necessary permits for permanent waste disposal at the WIPP. At that time the DOE also requested an extension to the public comment period from the NMED. The public comment period was extended until January 15, 1994. The DOE submitted comments to the NMED prior to the January 15 deadline. On January 13, 1994, the DOE formally requested that the NMED allow the DOE to modify the RCRA permit application to reflect disposal, rather than Test-Phase operations.

3.2.4 National Environmental Policy Act
(42 U.S.C. sec. 4321 et seq.)

The NEPA was enacted to require the federal government to use all practicable means to consider potential environmental impacts as part of the decision-making process. The NEPA dictates that the public be allowed to review and comment on proposed projects that might have the potential to significantly affect the environment. The NEPA also directs the federal government to use all practicable means to improve and coordinate federal plans, functions, programs and resources. NEPA contains several "action-forcing" provisions such as:

> Utilizing an interdisciplinary approach in planning and decision making, ensuring appropriate consideration of unquantified environmental values, developing alternatives to proposals involving conflicts over use of resources, making environmental information generally available, and including a "detailed statement" on environmental impacts for "major federal actions significantly affecting the quality of the human environment."

NEPA procedural objectives and public involvement requirements are detailed in the Council on Environmental Quality regulations implementing NEPA in 40 CFR 1500-1508.

To satisfy NEPA requirements, the "Final Environmental Impact Statement" was issued in October 1980 (DOE, 1980), followed by the Record of Decision (ROD) to the FEIS (DOE, 1981), which was published in the *Federal Register* (FR) on January 28, 1981.

The ROD concluded that the Los Medanos (WIPP) site in southeastern New Mexico would be acceptable for the long-term disposal of TRU waste with "minimal risk of any release of radioactivity to the environment." The ROD noted the following:

> If significant new environmental data results [SIC] from the Site Preliminary and Design Validation (SPDV) program or other WIPP project activities, the FEIS will be supplemented as appropriate to reflect such data, and this decision to proceed with phased construction and operation of the WIPP facility will be reexamined in the light of that supplemental NEPA review.

Consistent with this commitment and to further the purposes of NEPA, the DOE issued the "Final Supplement Environmental Impact Statement" in January 1990 (DOE, 1990a) to address changes in the proposed action and the development of new geologic and hydrologic information. These changes included altering the composition of the waste inventory, transporting waste to the WIPP site, conducting a Test Phase, and managing TRU waste mixed with hazardous constituents. The DOE's ROD to proceed with the Test Phase was published on June 22, 1990 (DOE, 1990c).

In accordance with the commitments made in the ROD for the WIPP SEIS, the DOE will issue another SEIS prior to deciding whether to proceed with the Disposal Phase at the WIPP site.

The DOE released DOE Order 5440.1D, *National Environmental Policy Act Compliance Program,* on February 2, 1991. This revision combines a conservative interpretation of the NEPA with a number of new requirements to support direction provided in Secretary of Energy Notice (SEN)15-90. One new requirement was to develop a Mitigation Action Plan (MAP) "for implementation of any commitments

made in an Environmental I Act Statement (EIS)-ROD for mitigation of environmental impacts associated with an action" (DOE, 1991d, 7[a][23]]. A MAP was prepared based on both RODs and the final was submitted to DOE on July 10, 1991. The commitments described in the MAP will be tracked and reported annually as required by DOE Order 5440.1E (7[a][24]) and *WIPP Annual Mitigation Action Plan Report* (AMR).

DOE Order 5440.1E, *National Environmental Policy Act Compliance Program*, was issued on November 10, 1992, and was updated to meet the final DOE NEPA Rule codified in 10 CFR 1021. This rule revises the provisions of DOE's Guidelines for Implementing the Procedural Provisions of NEPA and consolidates changes required by certain policy initiatives instituted by the Secretary of Energy regarding participation of the public and affected states. The Rule also includes a revised and expanded list of Categorical Exclusions (CXs). CXs are classes of actions that normally do not require the preparation of either an environmental assessment or impact statement.

The WIPP NEPA Compliance Program (consisting of two procedures, a plan, and a training module) has been developed to ensure the requirements of the NEPA are fulfilled at the WIPP site. This program provides NEPA guidance for personnel responsible for the planning, coordination, and performance of work. Adherence to the program ensures that all work performed at the WIPP facility conforms to the provisions of the NEPA. The WIPP NEPA Compliance Program also details the actions taken to evaluate work documents for NEPA compliance in accordance with DOE Order 5440.1E and with 10 CFR 1021.

3.2.5 Clean Air Act (CAA)
(42 U.S.C. sec. 7401 et seq.)

The Clean Air Act provides for the preservation, protection, and enhancement of air quality, particularly in locations of special interest such as areas of natural, recreational, scenic, or historic value. Under Section 109 of the Clean Air Act, the EPA established the National Ambient Air Quality Standards (NAAQS) for six "criteria" pollutants: sulfur dioxide, total suspended particulates, carbon monoxide, ozone, nitrogen oxide, and lead. These standards establish primary and secondary standards for ambient air quality that the EPA judges are necessary to protect public health and welfare.

In 1993, Westinghouse Electric Corporation, Waste Isolation Division, completed the *WIPP Hazardous Air Pollutant (HAP) Emission Inventory* (WP 02-15). The HAPs inventory was developed as a baseline document to calculate maximum potential hourly and annual emissions of both hazardous and criteria air pollutants. The HAPs inventory calculated emissions estimates' for the three CAO locations. These locations include the WIPP site, the CAO located at Greene Street, and the WID Canal Street office.

Emission estimates were used to determine if the WIPP is required to obtain an air permit under state or federal regulations. The HAPs inventory was used to evaluate potential permitting requirements for the following regulations:

- § 112 Clean Air Act National Emission Standards for Hazardous Air Pollutants
- Part C Clean Air Act (Prevention of Significant Deterioration - Criteria Pollutants)
- New Mexico Air Quality Control Regulation 752
- New Mexico Air Quality Control Regulation 702.

Section 112 of the Clean Air Act establishes emission standards for Hazardous Air Pollutants. The 1990 Clean Air Act Amendments (CAAA) increased to 189 the number of hazardous air pollutants regulated under the CAA. Hazardous air pollutant emissions are regulated under 40 CFR [illegible] the National Emission Standards for Hazardous Air Pollutants (NESHAP). The NESHAP establishes permitting and reporting requirements for facilities that have the potential to emit hazardous air pollutants. At the WIPP, the majority of hazardous air pollutants are regulated in Subpart A of the NESHAP. Radionuclide emissions other than radon are regulated in Subpart H of the NESHAP.

Based on an agreement with EPA Region VI, the DOE has committed to comply with the requirements of 40 CFR 61, Subpart H, through the Disposal Phase of operations at the WIPP. A revised standard for Subpart H radionuclide emissions was promulgated by the EPA in a final rule published in the *Federal Register*, effective December 15, 1989 (54 FR 51654). In the *Final Safety Analysis Report* for the WIPP facility, the doses from future anticipated WIPP facility emissions were calculated to be less than 1 percent of the allowable effective dose equivalent of 10 millirem per year to any one member of the public. The DOE documented the expected emission levels in a data package. This original package was submitted to the EPA in 1990. Additional submittals will be submitted prior to waste receipt. An emissions monitoring system was installed to comply with NESHAPs and to meet periodic confirmatory monitoring compliance requirements. Emissions monitoring test results will be used to verify compliance.

Based on the HAPs inventory, WIPP operations do not exceed the 10 ton-per-year (tpy) emission limit for any individual HAP, or 25-tpy limit for combined HAPs emissions established in Subpart A. Thus, the WIPP does not have any NESHAP Subpart A permitting or reporting requirement at this time. However, 40 CFR 61, Subpart A, §61.09(a)(1), requires that the WIPP facility notify the EPA of its anticipated date of initial startup of the source not more than 60 days nor less than 30 days before that date. In addition, notification of the actual date of initial startup of the source must be made within 15 days after that date.

Based on emission estimates generated in the HAPs inventory, the WIPP site is not required to obtain any federal CAA permits. A federal permit is required if a facility emits 100 tpy of criteria pollutants, 10 tpy of a HAP, or 25 tpy of combined HAPs. In consultation with the NMED Air Quality Bureau, and in conjuction with data collected in the HAPs inventory, the WIPP was required to obtain a New Mexico Air Quality Control Regulation (AQCR) 702 Operating Permit for two back-up diesel generators. A state permit is required when criteria pollutants exceed the state threshold levels of 10 pounds per hour, or 25 tpy. The only emission points where the WIPP site exceeds state threshold criteria is the WIPP back-up diesel generators. On June 18, 1993, the DOE submitted an AQCR 702 permit application for the WIPP back-up diesel generators. The New Mexico Air Quality Bureau issued Air Quality Permit 310-M-2 on December 7, 1993. On February 26, 1994, the WIPP completed the emission monitoring requirements established in the permit. With the submittal of the "Final Compliance Sampling Report" on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit.

3.2.6 Clean Water Act (CWA)
(or Federal Water Pollution Control Act (FWPCA) of 1972) (33 U.S.C. sec. 1251 et seq.)

Section 402 of the Clean Water Act, the National Pollutant Discharge Elimination System program, establishes the requirements for regulating industrial storm water run off that has the potential to discharge into waters of the United States. The WIPP will demonstrate that the WIPP site prevents the discharge of contaminated storm water through the use of best management practices. These practices include engineering controls, storm water retention basins, the covering of materials storage areas, and the reclamation of disturbed zones.

The WIPP submitted a Notice of Intent to the EPA to obtain a NPDES Storm Water General Permit. On December 31, 1992, the EPA issued a New Mexico NPDES Storm Water General Permit (NMR00A021). As part of the Nationwide General Permit Program, the WIPP is included in the New Mexico General Permit.

The WIPP completed the *WIPP NPDES Storm Water PPP* in March 1993. The NPDES Storm Water Permit rules require that a PPP be developed for each facility covered under the permit by April 1, 1993. The PPP identifies and assesses potential pollutant sources and describes all BMPs that will be implemented to ensure that storm water run off does not contact regulated pollutants. Additionally, the WIPP outlined a schedule for the implementation of all BMPs required to demonstrate compliance with permit requirements.

Approximately 40,000 gallons of nonhazardous brine were generated at the WIPP site each month before the grouting of the Air Intake Shaft (AIS). These waters were generated by seepage between

stratigraphic formations in the ungrouted Air Intake Shaft and from the pumping of observation wells at the WIPP. The permanent disposal/prevention of site-generated brines has been accomplished by the expansion of the WIPP sewage treatment facility and by the grouting of the Air Intake Shaft. The grouting of the AIS began in May of 1993 and was completed in December 1993. This grouting reduced the volume of site-generated brine by approximately 90 percent.

The WIPP has applied for and received an approved Discharge Plan (DP-831) for the WIPP sewage facility. The approved Discharge Plan supersedes the emergency discharge permit of January 1992. Mine water is now collected in portable tanks and is hoisted to the surface where it is pumped to the WIPP site salt pile evaporation basin. Analytical studies have demonstrated that site-generated brines are nonhazardous and can be pumped to the main salt pile evaporation basin for disposal.

The Discharge Plan approves the construction, sampling, and management requirements for the facility. The expansion of the sewerage system was completed in April 1993. This expansion included the construction of a lined evaporation pond divided into two "cells."

The new evaporation pond is located down-gradient of the existing evaporation pond. The south cell of the new pond is used to evaporate sewage effluent only. The north cell is used to evaporate brine waters from mine dewatering and of well water mixed with sewage effluent. Brine waters are hauled to the north cell by water truck and then pumped from the water truck into the north cell. The existing evaporation basin was lined with a 30-mil synthetic liner after the two new cells were brought into operation. The system expansion was completed in April 1993.

3.2.7 Safe Drinking Water Act (SDWA)
(42 U.S.C. sec. 300f et seq.)

The SDWA of 1974 provides the regulatory strategy for protecting public water supply systems and underground sources of drinking water. The New Mexico Environment Department notified the WIPP in a September 9, 1992 letter that the WIPP Public Water Supply has been categorized as a non-transient, non-community system for reporting and testing requirements. The NMED determined that the WIPP is required to sample drinking water for total coliform bacteria, lead, copper, nitrate and nitrite, only.

The city of Carlsbad is contracted to provide raw drinking water to the WIPP from city wells located 31 miles north of the site. Because of this contractual agreement the city of Carlsbad completes the majority of SDWA compliance sampling for the WIPP water system. The city of Carlsbad is considered a community system and is subject to more comprehensive SDWA sampling requirements than WIPP's Non-Community, Non-Transient WIPP water system. WIPP compliance sampling

frequencies are the same as those listed in the table below with the exception of total coliform. Coliform sampling must only be completed quarterly. The sampling requirements for community systems are listed in the following table.

Contaminant	Ground Water
Nitrate	once per year
Nitrite	every three years
Asbestos	every nine years
Arsenic, Barium, Cadmium, Mercury, Chromium, Fluoride, Selenium	every three years
Lead and Copper (for water systems of 501 to 3,300 populations)	initial sampling requires 20 sample sites for two six-month periods beginning on July 1, 1993; requirements may be reduced when action levels are met for two consecutive sampling periods
Synthetic Organics	every three years
Volatile Organics	every three years
Radionuclides	every four years
Turbidity	not required
Total Coliform	once per month

3.2.8 Toxic Substances Control Act (TSCA)
(15 U.S.C. sec. 2601 et seq.)

The TSCA applies primarily to manufacturers, importers, and processors of toxic chemicals for commercial purposes. The WIPP site is not considered a manufacturer or processor of chemical products, and, therefore, most of the provisions of TSCA do not apply. The TSCA regulates the use of Poly-chlorinated Biphenyls (PCBs), asbestos, and materials containing PCBs and asbestos. DOE policy prohibits the use of PCB-containing materials in DOE-installed equipment at facilities like the WIPP site. Therefore, TSCA would not apply to DOE-installed equipment. At the present time, TSCA does not apply to the WIPP repository because there are no plans to ship PCB-contaminated wastes to the WIPP site. The WIPP site will comply with TSCA regulations contained in 40 CFR 761.60 and 761.65 with respect to any possible future storage or disposal of PCB-contaminated materials. Procurement of asbestos containing materials is also prohibited at the WIPP site.

3.2.9 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
(7 U.S.C. sec. 136 et seq).

The FIFRA authorizes the EPA to regulate the registration, certification, use, storage, disposal, transportation, and recall of pesticides. Recommended procedures for storage and disposal of pesticides and pesticide containers are contained in 40 CFR 165. The EPA at its discretion may exempt federal agencies from any FIFRA provisions if emergency conditions exist (40 CFR 166), FIFRA standards are considered mandatory for regular conditions at DOE facilities. DOE will continue to comply with the standards of FIFRA at the WIPP site.

3.2.10 Endangered Species Act (ESA)
(16 U.S.C. sec. 1531 et seq).

The ESA provides protection for threatened or endangered species of flora and fauna. Under Section 7 of the Act and its implementing regulations in 50 CFR 402, the EPA is prohibited from authorizing activities "likely to jeopardize the continued existence of any endangered species or threatened species or result in destruction or adverse modification of habitat of such species. . . The Section 7 process may involve a biological assessment and "formal consultation" followed by the issuance of a . . .*non biological opinion* by the U.S. Fish and Wildlife Service for any species that is determined to be in potential jeopardy. According to the WIPP FEIS (DOE, 1980) and the SEIS (DOE, 1990a), the U.S. Fish and Wildlife Service lists four threatened or endangered species of plants or animals that could occur at the WIPP site. The U.S. Fish and Wildlife Service has determined that WIPP facility activities will have no adverse impacts on these species (Stigman, 1979).

The New Mexico Department of Game and Fish (NMGF), and the U.S. Fish and Wildlife Service also lists 52 possible threatened and endangered species that habitate southeastern New Mexico. No critical habitat for terrestrial endangered species has been identified at the WIPP site (Stigman, 1979). As a result, the U.S. Fish and Wildlife service has not required the WIPP to complete a formal consultation or biological opinion processes under Section 7 of ESA.

3.2.11 National Historic Preservation Act (NHPA)
(16 U.S.C. sec. 470 et seq.)

The NHPA was enacted to protect the nation's cultural resources and to establish the National Register of Historic Places. Since 1976, cultural resources investigations have recorded 98 archeological sites and numerous isolated artifacts within the 16-square-mile area enclosed by the WIPP site boundary. Thirty-three sites are recorded within the central 4-square-mile area, including all of Zones I and II. The sites

are eligible for inclusion in the National Register as an archeological district. Investigations since 1980 have pin pointed an additional 14 individual sites outside the central 4-square-mile area that are considered eligible for inclusion in the National Register (DOE, 1990a). The average archeological site density on WIPP facility lands, according to the WIPP FEIS (DOE, 1980), is 7.5 sites per square mile. A mitigation plan describing the avoidance and/or excavation of sites was submitted to the New Mexico State Historic Preservation Officer (SHPO) (Hart and Brausch, 1980; DOE and BLM, 1983). A determination of "no adverse effect from WIPP facility activities" on cultural resources was made by the SHPO in May 1980 (Merlan, 1980). A similar plan was submitted to the National Advisory Council on Historic Preservation. The Council concurred that the WIPP Mitigation Plan is appropriate to protect cultural resources (National Advisory Council on Historic Preservation, 1981).

Other related legislation affecting WIPP facility lands include the Archeological Recovery Act, which was amended by the Archeological and Historic Preservation Act (AHPA) (16 U.S.C. sec. 469a et seq.). The AHPA requires the preservation of archaeological data affected as a result of any federal or federally related land modification activities. The Archaeological Resources Protection Act (16 U.S.C. 470aa-47011) created improved protection measures for archaeological resources on federal lands and established procedures for federal land managers to issue permits for authorized excavation and removal of archaeological resources.

In accordance with the *WIPP Mitigation Plan*, four archeological sites that could have been or that were actually disturbed by construction activities have been excavated. Avoidance of other archeological sites is carried out by DOE so there will be no adverse effects on known cultural resources from WIPP facility activities. No additional sites have been slated for excavation.

Under the WIPP Land Withdrawal Act, the jurisdiction for managing the cultural resources within the WIPP Site boundary have been transferred to the DOE. A land management plan has been prepared for the WIPP withdrawal area by the DOE in consultation with the BLM and the state of New Mexico. The *Land Management Plan* was issued October 30, 1993. The *Land Management Plan* provides opportunity for participation in the land use planning process by the public and local, state, and federal agencies.

A MOU between the DOE and the BLM is being prepared and should be issued by May 1994. This MOU outlines the responsibilities of each agency with regard to land use management for the withdrawal area, and provides an additional mechanism to protect the withdrawal area from unallowable or inadvertent uses. The *Land Management Plan* and the MOU will serve to provide equitable and consistent administration of archaeological resources within the WIPP withdrawal area.

Prior to disturbing any surface area, WIPP reviews archaeological surveys to determine if the area in question has received an archaeological clearance. If the area has not already received a clearance, a subcontract is issued to a firm providing archaeological resources consulting, and the necessary survey is completed. If archaeological resources are discovered, appropriate mitigating measures are taken.

3.2.12 Floodplain Management
(Executive Order 11988)

EO 11988 directs federal agencies to avoid making modifications that adversely impact floodplains, to consider alternatives to a proposed action, to provide early public review of proposed actions, and to propose mitigation measures for proposed actions within floodplains. Because the WIPP site is not located within a floodplain zone, EO 11988 does not apply to the WIPP facility.

3.2.13 Protection of Wetlands
(Executive Order 11990)

EO 11990 requires that federal agencies consider the effects of proposed actions in wetlands, determine whether wetlands are present, assess the impacts, consider alternatives to a proposed action, provide for early public review, and propose mitigation measures for proposed actions that could affect wetlands. The WIPP facility is neither located within nor will it impact a wetlands area; therefore, EO 11990 does not apply to the WIPP facility.

3.2.14 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes
(40 CFR 191)

The authority of the EPA to establish radiation protection standards for nuclear wastes is derived from the Atomic Energy Act, as amended; the Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act (NWPA) (Pub. L. 97-425). Since the mid-1970s, the EPA has been developing guidance and standards for the management and disposal of radioactive wastes. EPA's final rule, 40 CFR 191, was published on September 19, 1985 (50 FR 38066). In a challenge by a coalition of environmental organizations and states, the U.S. Court of Appeals for the First Circuit vacated and remanded 40 CFR 191 to the EPA. The Court found, among other things, that the EPA did not protect groundwater as stringently as provided under the SDWA underground injection provisions [NRDC v EPA 824 F.2d 1258 (1st cir. 1987)]. The Second Modification to the Agreement for Consultation and Cooperation between the DOE and the state of New Mexico dated August 4, 1987, specified that, although the standards were on remand status, the DOE would continue to guide its performance assessment planning efforts as though the vacated regulations were still in effect. In the WIPP Land

Withdrawal Act of 1992 (PL 102-579), Congress reinstated all of the 40 CFR 191, Subpart B regulations with the exception of those that were specifically questioned by the court (i.e., Sections 191.15, Individual Protection Requirements and 191.16, Ground Water Protection Requirements). Congress also required the EPA to issue final disposal regulations by April 30, 1993. On February 10, 1993, the EPA proposed revised disposal regulations under 40 CFR 191, Subpart B (58 FR 7924). On December 20, 1993, the EPA promulgated amendments to the final standard pertaining to individual and groundwater protection requirements (58 FR 66398). The standard applies to facilities regulated by the U.S. Nuclear Regulatory Commission and to facilities under the jurisdiction of the DOE that manage or dispose of spent nuclear fuel, high-level and TRU waste. The standard is divided into three subparts and these are described below.

Subpart A, *Environmental Standards for Management and Storage*, sets the operational term requirements limiting annual doses to members of the public from management and storage operations at disposal facilities. For facilities operated by the DOE and not regulated by the U.S. Nuclear Regulatory Commission, the DOE must provide reasonable assurance that the annual dose to the public in the general environment will not exceed 25 millirem (mrem) to the whole body and 75 mrem to any critical organ. In accordance with DOE policy as delineated in DOE Order 5400.5, the WIPP facility maintains compliance with 40 CFR 191, Subpart A requirements. In the Second Modification to the Agreement for Consultation and Cooperation, DOE agreed with the state of New Mexico that the WIPP facility will comply with the standards of Subpart A upon the initial and future receipt of waste.

Subpart B, *Environmental Standards for Disposal*, establishes several sets of long-term performance requirements for containment and individual protection and provides guidance for their implementation. Of particular significance to the WIPP are the containment provisions of 40 CFR 191.14, which require that radioactive waste disposal systems be designed to provide a reasonable expectation that cumulative releases of radionuclides from the repository over 10,000 years will not exceed levels specified in the standards. This degree of assurance is to be provided by a WIPP performance assessment conducted by the DOE.

Subpart C was established to provide a level of protection for underground sources of drinking water consistent with that provided by regulations implementing the SDWA. EPA believes that compliance with Subpart C of the standard will constitute compliance with the SDWA. Subpart C requires a demonstration that a prospective disposal system will comply for 10,000 years with the primary SDWA regulations for radionuclides. These are the maximum contaminant levels (MCLs) codified in 40 CFR 141.15 and 141.16 that were put into effect on January 19, 1994.

The LWA requires that the EPA must finalize criteria for certifying compliance with 40 CFR 191 by October 1984. These criteria will be codified as 40 CFR 194. Once the EPA establishes these criteria, the DOE will evaluate them as part of its compliance with the 40 CFR 191 disposal standards.

3.2.15 Hazardous Materials Transportation Act (HMTA)
(49 App. U.S.C. sec. 1801 et seq.; 49 CFR 106-179)

The HMTA provides for safe intra- and inter-state transportation of hazardous/nuclear materials. The HMTA allows states to regulate the transport of hazardous/nuclear materials if regulations are consistent with the HMTA or U.S. Department of Transportation (DOT) regulations. The DOT regulations for hazardous/radioactive materials are contained in 49 CFR 171-177. Specifications for the kinds and designs of packages to be used for the transport of various types of radionuclides are contained in 49 CFR 173, Subpart I (and parallel NRC regulations in 10 CFR 71). DOT regulations in 49 CFR 177 provide a routing and quantity rule for highway shipments of radioactive material; 49 CFR 174 contains segregation rules for shipment by rail. In the Second Modification to the Agreement for Consultation and Cooperation dated August 4, 1987, the DOE agreed to comply with all applicable DOT regulations and the corresponding NCR regulations.

3.2.16 Packaging and Transportation of Radioactive Materials
(10 CFR 71)

Regulations for shipping containers and the safe packaging and transportation of radioactive materials are under the authority of the NRC and the DOT. In the Second Modification to the Agreement for Consultation and Cooperation, the DOE agreed to comply with the applicable transportation regulations of the NRC. Packaging requirements for radioactive materials including the Type B packages to be used to transport waste to the WIPP facility are detailed in DOT regulations (49 CFR 173, Subpart I). This references the NRC regulations. The NRC regulations in 10 CFR 71 reference the DOT regulations in 49 CFR 173.

The NRC requirements for shipping containers apply to the certification of the TRUPACT-II shipping container, the container that will be used to transport radioactive waste to the WIPP facility. The TRUPACT-II container was certified by the NRC on August 30, 1989, after compliance with the 10 CFR 71 requirement for Type B packaging was demonstrated (NRC, 1990).

A container supplier inspection was conducted by NRC during the period of January 12-14, 1993. The scope of the audit was to determine whether procedures have been established, documented, and executed at DOE's WIPP facility that meet the quality assurance requirements of 10 CFR 71. The audit also determined whether packages were fabricated and maintained in accordance with the design

approved by the Commission. The NRC had no findings and stated that all quality assurance requirements of 10 CFR 71 were being followed.

3.2.17 Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
(Public Law 96-164)

This Act, which authorized the WIPP Project, provides as follows:

> Not withstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy . . . for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States. . . .

The statute provides for DOE consultation and cooperation with appropriate officials of the state of New Mexico with respect to public health and safety concerns. It also provides for a written agreement between the DOE and the appropriate officials of the state of New Mexico setting forth consultation and cooperation. In compliance, the DOE has entered into two agreements with the state of New Mexico: the Consultation and Cooperation (C&C) Agreement and the Working Agreement for the C&C Agreement. Both agreements have been modified several times (see Table 3-3). The most recent modification of the C&C Agreement is the Second Modification to the Consultation and Cooperation Agreement dated August 4, 1987. The Working Agreement for the C&C Agreement was last modified in March 1988. These agreements are implemented through the DOE and the New Mexico Radioactive Waste Consultation Task Force. In addition, the DOE interfaces regularly with the NMED and the New Mexico Legislature's Radioactive and Hazardous Waste Committee.

3.2.18 Waste Isolation Pilot Plant Land Withdrawal Act
(PL 102-579)

On October 30, 1992, President Bush signed the Waste Isolation Pilot Plant Land Withdrawal Act transferring land from the public domain for use by the Department of Energy (DOE) for the construction, experimentation, operation, maintenance, disposal, shutdown, monitoring, and decommissioning activities at the WIPP. The LWA establishes an extensive regulatory framework that governs the conduct of the WIPP Test Phase and, if all requirements are successfully met, the Disposal Phase.

As a result of the LWA, the Secretary of Energy is required to develop a management plan to provide for grazing, hunting and trapping; wildlife habitat; the disposal of salt tailings; and mining. The *WIPP Land Management Plan* was submitted to Congress in October 1993 and will be maintained throughout the life of the facility, including through decommissioning of the site.

Compliance with the following statutes or regulations is also required under the Act:

- Taylor Grazing Act
- Subchapter IV of the Federal Land Policy and Management Act
- Public Rangelands Improvement Act
- Materials Act of 1947
- Federal Mine Safety and Health Act of 1977
- Solid Waste Disposal Act
- 40 CFR 191
- 29 CFR 1910.120
- Clean Air Act
- Safe Drinking Water Act
- Toxic Substance Control Act
- Comprehensive Environmental Response, Compensation, and Liability Act
- All other applicable federal laws pertaining to public health and safety of the environment.

The law also requires the DOE and the EPA to conform to several requirements prior to initiating both the Test Phase and Disposal Phase, including the EPA's review and approval of key WIPP programmatic documents. Roles and responsibilities for the Department of Interior, the Department of Labor, the Environmental Evaluation Group, the National Academy of Sciences, and the state of New Mexico are defined in the law. A summary of the provisions of the act are as follows:

- The EPA must publish final radioactive waste disposal standards (40 CFR 191).
- The EPA must certify WIPP's compliance with 40 CFR 191, Subparts B and C.
- The EPA must determine that the DOE has complied with the terms and conditions of the NMD issued on November 14, 1990 (55 FR 47700).

- The federal Occupational Safety and Health Administration must certify that it has reviewed the DOE emergency response training programs and has concurred that such programs are in compliance with 29 CFR 1910.120.

NOTE: As defined in the *WIPP Land Management Plan*, the DOE will continue current land management practices and maintain all applicable permits with external organizations.

3.2.18.1 Federal Land Policy and Management Act
(43 U.S.C. secs. 1701-1782)

The Federal Land Policy and Management Act was enacted to ensure, among other things, that

> ". . .public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use. . ."

Under S. 1671, the Secretary of Energy is required to comply with Subchapter IV of the Federal La Policy and Management Act. Subchapter IV establishes the authority for grazing fees, range betterment funds, grazing permits, and grazing advisory boards. Under LWA, the Secretary of Energy is empowered to administer these programs.

3.2.18.2 Taylor Grazing Act
(43 U.S.C. sec. 315 et seq.)

This act is intended to prohibit injury to public grazing lands by preventing overgrazing and soil deterioration. The Act promotes the orderly use and/or improvement to public grazing lands by establishing grazing districts and a grazing permit system. As required by the LWA, the DOE must allow grazing to continue on WIPP facility land where grazing districts had been established prior to the date of enactment of the Land Withdrawal Act. The Department of Interior, in consultation with the DOE, will issue grazing permits on WIPP facility land.

3.2.18.3 Public Rangelands Improvement Act
(43 U.S.C. sec. 1901 et seq.)

The Public Rangelands Improvement Act establishes a national policy and commitment to

Inventory and identify current public rangeland conditions and trends.

Manage, maintain, and improve the condition of public rangelands in a manner that they become as productive as is feasible.

Continue the policy of protecting wild free-roaming horses and burros and of removing and disposing of those excess animals that pose a threat to themselves, their habitat, and other rangeland values.

As specified by the LWA, the DOE must administer WIPP facility lands as public rangelands.

3.2.18.4 Executive Order 12548 -- Grazing Fees

EO 12548 orders the establishment of fees for grazing of domestic livestock on public rangelands. The Department of Interior, in consultation with the DOE, will establish grazing fees for WIPP facility lands.

3.2.18.5 Materials Act of 1947
(30 U.S.C. 601 et seq.)

The Materials Act of 1947 pertains to the disposal of mineral materials (e.g., sand, stone, gravel, pumice, cinders, clay and etc.) on public lands. The disposal of vegetative materials (e.g., yucca, manzanita, mesquite, cactus, and timber or forest products) is also addressed. Under the LWA, the WIPP facility must dispose of those salt tailings not used for backfill, in accordance with the bidding, advertising, contract negotiation, and disposition of monies provisions (sections 602-603) of the Materials Act.

3.2.18.6 Federal Mine Safety and Health Act of 1977
(30 U.S.C. sec. 801 et seq.)

Under the Federal Mine Safety and Health Act of 1977, the U.S. Department of Labor (DOL) is responsible for developing and enforcing regulations and standards to protect mine workers. Under a memorandum of understanding between the DOE and the DOL effective July 9, 1987, the Mine

Safety and Health Administration (MSHA) conducts periodic health and safety compliance inspections of WIPP facility underground operations. When the WIPP Land Withdrawal Act was signed into law on July 10, 1993, MSHA became the agency responsible for conducting at least four surface and underground safety inspections per year at the WIPP.

MSHA conducted four inspections during 1993- in January, May, August, and December. The January and August inspections resulted in no surface or underground findings. One minor underground finding occurred during the May inspection, and eight minor surface findings were issued during the December inspection. All minor findings were abated before the MSHA inspector left the facility.

3.2.19 Bald and Golden Eagle Protection Act
(16 U.S.C. secs. 668-668d)

The Bald and Golden Eagle Protection Act makes it unlawful to capture, kill, molest, or disturb these eagles, their nests, or their eggs anywhere in the United States. A permit must be obtained from the U.S. Department of the Interior to relocate a nest that interferes with resource development or recovery operations. The Act potentially applies to the WIPP facility because there is a possibility that these birds could be present on WIPP facility lands.

However, surveys to identify raptor nests on WIPP facility lands since 1985 have thus for failed to locate any bald or golden eagle nests near operational activities. Through the Cooperative Raptor Research and Management Program at the WIPP facility the DOE will continue to monitor for raptor nests on WIPP lands and near operational buildings.

3.2.20 Migratory Bird Treaty Act
(16 U.S.C. sec. 703 et seq.)

The Migratory Bird Treaty Act is intended to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. The Act stipulates that it is unlawful to indiscriminately "kill . . . any migratory bird." It regulates the harvest of migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. Although the WIPP facility is not located within a major migration corridor, there are migratory birds present on WIPP facility lands. As required by the Migratory Bird Treaty Act, the DOE will consult annually with the U.S. Fish and Wildlife Service with respect to impacts on migratory birds from the hunting activities permitted on WIPP facility lands.

3.2.21 Noise Control Act of 1972
(42 U.S.C. sec. 4901 et seq.)

According to the Act's policy clause in section 2(a)(3), the primary responsibility for noise control is vested in state and local governments. Federal regulation is deemed essential only for commercial noise sources requiring national uniformity of treatment (e.g., aircraft noise). However, federal agencies are required to comply with federal, state, interstate, and local requirements respecting control and abatement of environmental noise "to the fullest extent consistent with their authority" [section 4[a] and [b][1], [2]).

DOE facilities are required to comply with the Occupational Safety and Health Administration (OSHA) standards in 29 CFR Part 1910, which include the Occupational Noise Exposure standards in 29 CFR 1910.95. Any WIPP facility noise sources that exceed these standards will be mitigated (e.g., noise dampers have been installed in the WIPP facility underground air exhaust fans). There are no noise sources at the WIPP facility that would affect the general public.

3.2.22 Occupational Safety and Health Administration Regulations
(29 CFR Parts 1900-1999)

Section 6(a) of the Williams-Steiger Occupational Safety and Health Act of 1970 provides that the Department of Labor (DOL) establish employee safety and health standards compatable with those that are commonly practiced in industry and that have been found to meet national consensus standards or established federal standards. DOE complies with OSHA standards and the OSHA safety and health management guidelines for all WIPP facility activities. In addition the WIPP facility has established safety procedures in accordance with DOE policy. The DOE-CAO recently submitted a Voluntary Protection Program (VPP) application to DOE Headquarters.

3.2.23 National Defense Authorization Act - Fiscal Year 1989

The DOE has contracted the New Mexico Institute of Mining and Technology to conduct independent reviews of the health and safety aspects of the design, construction, and operations of the WIPP facility, as required by the National Defense Authorization Act of 1989. The Environmental Evaluation Group (EEG) at the Institute performs the reviews. The DOE will cooperate, as appropriate, with the EEG reviews of health and safety practices at the WIPP facility.

3.2.24 Protection and Enhancement of Environmental Quality
(EO 11514, as amended by EO 11991)

EO 11514 directs federal agencies to

> Monitor, evaluate, and control their activities so as to protect and enhance the quality of the environment.
>
> Review their statutory authority, regulations, policies, and procedures in order to identify any deficiencies or inconsistencies that limit compliance with the NEPA.
>
> Develop procedures to ensure the public is informed of federal programs with environmental impact.
>
> Ensure that information regarding existing or potential environmental problems brought to light by research, development, demonstration, test, or evaluation activities is made available to federal agencies, states, counties, municipalities, institutions, and other appropriate entities.
>
> Comply their statutory authority, regulations, policies, and procedures in order to identify any deficiencies or inconsistencies that limit compliance with the NEPA.

The DOE complies with CEQ regulations and public disclosure requirements by preparing NEPA documentation on WIPP Project activities as necessary. The DOE also conducts continuing comprehensive environmental monitoring programs at the WIPP site.

3.2.25 Federal Compliance with Pollution Control Standards
(EO 12088)

The EO 12088 directs the head of each federal agency to ensure that all necessary actions are taken for the prevention, control, and abatement of environmental pollution. Each agency is responsible for compliance with applicable pollution control standards established by such statutes as the Clean Water Act, the Clean Air Act, the AEA of 1954, and others. Each agency must submit an annual plan for the control of environmental pollution at its facilities. This EO applies to the DOE in controlling pollution at the WIPP facility.

The *Waste Minimization and Pollution Prevention Awareness Plan* was approved by the DOE-WIPP Site Branch (WSB) on March 31, 1993. The plan will be reviewed annually and updated at least every three years. Pollution prevention awareness guidance is contained in the *Resource Conservation and Recovery Act Compliance Manual* (WP 02-6, 02-7) and its implementing procedures, and in the *Environmental Compliance Manual* (WP 02-5). These environmental compliance manuals are currently being revised to incorporate elements of the Waste Minimization and Pollution Prevention Awareness Program.

The WIPP has developed a central inventory database to track the type and quantity of hazardous materials on site. The software to be used for the inventory database was installed in December 1993. Inventory data are now being entered in the database. Once data entry is completed, the inventory will be performed on a monthly basis.

3.3 Other Significant Environmental Issues

An additional Environmental Management Assessment was conducted by EH-24 during the period from July 19 through July 30, 1993. The assessment areas covered and the subsequent WIPP findings are listed:

Organizational Structure	1
Environmental Commitment	None
Environmental Protection Programs	1
Formality of Environmental Programs	3
Internal and External Communications	None
Staff Resources, Training, and Development	1
Program Evaluation, Reporting, and Corrective Action	2
Environmental Planning and Risk Assessment	None
National Environmental Policy Act Programs	1
Total	**9**

Findings resulting from this audit have either been satisfactorily addressed or implementation plans have been developed to address all assessment findings.

Table 3-1
Compliance Status with Major Environmental Regulations
Applicable to the WIPP Project

Statute/Regulation	Status
Atomic Energy Act	No radioactive waste was received during CY93.
Clean Air Act	NESHAP data package and letter of notification submitted. No monitoring/reporting required until after receipt of waste.
Clean Water Act	Quarterly inspections of best management practices to comply with (stormwater retention basins) NPDB storm water general permit (NMR00A021)
Comprehensive Environmental Response, Compensation, and Liability Act/Superfund Amendments and Reauthorization Act	No Land Disposal Units (LDUs) exist at the site. No CERCLA site cleanup required. Reports filed as required under SARA for hazardous substances are maintained on site.
Endangered Species Act	Permits to collect biological samples and to band non-endangered species of raptors are obtained.
Federal Land Policy and Management Act	The Land Management Plan was issued October 30, 1993, as required by the WIPP Land Withdrawal Act. A MOU between the DOE and the BLM should be issued by May 1994. This MOU outlines the responsibilities the BLM and the DOE have with regard to land use management for the withdrawal area.
Federal Insecticide, Fungicide, and Rodenticide Act	All use of pesticides is approved by Industrial Safety and is performed by subcontractors.
Hazardous Materials Transportation Act	Hazardous wastes to be sent off site are reviewed to ensure compliance with HMTA.
National Environmental Policy Act (as supplemented by DOE Order 5440.1E, National Environmental Policy Act Compliance Program)	Mitigation Action Plan was prepared based on the RODs to the two WIPP EISs. Annual Mitigation Reports are prepared each year to status the commitments made in the RODs. All WIPP activities subject to the NEPA under DOE Order 5440.1E are reviewed and the appropriate NEPA documentation is filed with the DOE- CAO.
National Historic Preservation Act	See "New Mexico Cultural Properties Act."
*New Mexico Air Quality Control Act	New Mexico does not yet have primacy for NESHAP for radionuclide emissions from DOE facilities.

Table 3-1
(continued)
Compliance Status with Major Environmental Regulations
Applicable to the WIPP Project

Statute/Regulation	Status
New Mexico Hazardous Waste Management Regulations	See "Resource Conservation and Recovery Act." NMED does not yet have primacy for all areas by the RCRA.
New Mexico Radioactive Materials Act	No radioactive wastes had been received at the WIPP by the end of CY93.
*New Mexico Water Quality Act	The DOE submits quarterly discharge monitoring reports to the NMED Groundwater Quality Bureau to comply with the requirements of the WIPP Discharge Plan, DP-831.
New Mexico Wildlife Conservation Act	See "Endangered Species Act."
Resource Conservation and Recovery Act	*Hazardous-waste generator compliance:* All site-generated hazardous wastes were transported off-site within the 90-day accumulation period. *No-Migration Determination compliance:* The third annual report was submitted to EPA on November 9, 1993. *Mixed-waste management:* Revision 3 of the Part B permit applicatio was submitted to the NMED January 1993. The draft permit was issued by the NMED on August 24, 1993. *Underground Storage Tanks:* Annual registration fee paid. Maintenance of inventory control records continues.
Toxic Substances Control Act	Procurement of asbestos-/PCB-containing materials not allowed. Other portions of TSCA not applicable.

Table 3-2

DOE Orders and Agreements Affecting the WIPP Environmental Program

ORDER NO.	DATE	TITLE	ANNOTATION
DOE 5400.1	11/09/88 Change 1- 06/29/90	General Environmental Protection Program	Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for ensuring compliance with federal and state environmental protection laws and regulations, federal executive orders, and internal department policies.
DOE 5400.2A	01/31/89	Environmental Compliance Issue Coordination	Establishes DOE requirements for coordination of significant environmental compliance issues.
DOE 5400.3	02/22/89	Hazardous and Radioactive Mixed Waste Program	Establishes DOE hazardous and radioactive mixed waste policies and requirements for RCRA compliance.
DOE 5400.4	10/06/89	Comprehensive Environmental Response, Compensation, and Liability Act Requirements	Establishes basic requirements for implementation of the Superfund at DOE facilities.
DOE 5400.5	02/08/90 Change 2- 01/07/93	Radiation Protection of the Public and the Environment	Establishes standards and requirements for operations of the DOE and DOE contractors with respect to protection of the public and the environment against undue risk from radiation.
DOE 5440.1E	11/10/92	National Environmental Policy Act	Establishes DOE policy for implementation of the National Environmental Policy Act of 1969 (PL 91-190).
DOE 5480.1B	03/27/90 Change 5- 05/10/93	Environmental Protection, Safety and Health Protection Program for DOE Operations	Establishes and overall framework of program requirements for safety, environmental, and health protection.
DOE 5480.3	07/09/85	Safety Requirements for the Packaging of Fissile and Other Radioactive Materials	Establishes requirements for packaging and transportation of radioactive materials for DOE facilities.
DOE 5484.1	02/24/84 Change 7- 10/17/90	Environmental Protection, Safety, Health Protection Information Reporting Requirements	Establishes requirements and procedures for reporting information having environmental protection, safety, or health significance to DOE operations.
AL 5484.1	08/23/82 Change 1- 10/24/86	Environmental Protection, Safety and Health Protection Information Reporting Requirements	Albuquerque Operations Office implementation of 5484.1.

Table 3-2
(continued)

DOE Orders and Agreements Affecting the WIPP Environmental Program

ORDER NO.	DATE	TITLE	ANNOTATION
DOE 5480.23	04/30/92	Nuclear Safety Analysis Reports	To establish uniform requirements for the preparation and review of safety analyses of DOE operation,s which include the following: identification of hazards, their elimination or control, assessment of the risk, and documented management authorization of their operation.
DOE 5482.1B	9/23/86 Change-5 05/10/93	Environmental, Safety and Health Appraisal Program	To establish the Environmental Protection, Safety, and Health (ES&H) appraisal program for the DOE.
DOE 5500.3A	04/30/91 Change 1- 02/27/92	Planning, and Preparedness, for Operational Emergencies	To establish requirements for the development of DOE site-specific emergency plans and procedures for radiological emergencies occurring in existing or planned DOE reactors and non-reactor nuclear facilities. It also requires that comprehensive emergency actions are planned, coordinated, and implemented to respond effectively to the on-site and off-site consequences of a radiological emergency at these facilities, and it provides for appropriate coordination between DOE and off-site officials to ensure the protection of on-site personnel, public health and safety, and the environment.
DOE 5700.6C	08/21/91	Quality Assurance	To provide DOE policy, set forth principles, and assign responsibilities for establishing, implementing, and maintaining programs of plans and actions to ensure quality achievement in DOE programs.
DOE 5820.2A	09/26/88	Radioactive Waste Management	Establishes policies and guidelines by which DOE manages radioactive waste, waste byproducts, and radioactively contaminated surplus facilities.
DOE 6430.1A	04/06/89	General Design Criteria	To provide general design criteria for use in the acquisition of DOE facilities and to establish responsibilities and authorities for the development and maintenance of these criteria.

Table 3-3

Summary of Agreements Between the DOE and the State of New Mexico That Affect the WIPP Environmental Program

Stipulated Agreement on Civil Action No. 81-0363 JB - This agreement, approved by the U.S. District Court proceedings, held in abeyance in the lawsuit against the DOE by the state of New Mexico, was executed on July 1, 1981. The eight-page agreement assures that a binding, enforceable "consultation and cooperation" agreement will be entered into by the DOE and the state, and that the DOE will make a "good faith effort" to resolve certain state off-site concerns (which are covered in the Supplemental Stipulated Agreement). The Stipulated Agreement also addresses a number of additional studies and experiments to be conducted by the DOE for the Site Preliminary and Design Validation Phase of the WIPP facility. This agreement was signed by Jeff Bingaman (Attorney General, state of New Mexico) and Myles Flint (Attorney, U.S. Department of Justice), and was issued July 1, 1981, by Juan G. Burciaga (U.S. District Judge, District of New Mexico).

Agreement for Consultation and Cooperation – Usually referred to as the "C&C Agreement," this agreement is contained in Appendix A to the Stipulated Agreement. It affirms the intent of the Secretary of Energy to consult and cooperate with New Mexico with respect to state public health and safety concerns. It was signed in July 1981 by Bruce King (Governor, State of New Mexico) and James B. Edwards (Secretary, U.S. Department of Energy).

Working Agreement for Consultation and Cooperation, Appendix B, Article IV, Revision I – This agreement, Appendix B to the Stipulated Agreement, identifies in Article IV over 60 "key events" and "milestones" in the construction and operation of the WIPP facility that must be reviewed by the state before they are commenced. Many environmental items are included. It was signed in March 1983 by Robert McNeill (Chairman, Radioactive Waste Task Force), and R. G. Romotowski, (Manager, Albuquerque Operations Office, U.S. Department of Energy). (Article IV of the Working Agreement was revised on April 8, 1983).

Supplemental Stipulated Agreement Resolving Certain State Off-Site Concerns Over WIPP – This agreement dated December 27, 1982, addresses five state concerns including the need for state "verification" of the WIPP Environmental Monitoring Program. The concerns addressed are: state liability for a nuclear incident, emergency response preparedness, transportation monitoring of the WIPP facility waste, the WIPP facility environmental monitoring by the state, and upgrading of state highways. It was signed in December 1982 by Bruce King (Governor, State of New Mexico) et al., and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

First Modification to the July 1, 1981, Agreement for Consultation and Cooperation on WIPP by the State of New Mexico and the U.S. Department of Energy – This modification was signed November 30, 1984, wherein the DOE and the state agree to address certain concerns of the state regarding: (1) the specific mission of the WIPP Project, (2) a demonstration of retrievability prior to waste emplacement, (3) post-closure control and responsibility, (4) completion of certain additional scientific testing and reports, (5) compliance with applicable federal regulatory standards for waste repositories, and (6) a program for encouraging and reporting on the hiring of New Mexico residents at the WIPP Project. It was signed in November 1984 by Joseph Goldberg (Secretary, Health and Environment Department, State of New Mexico), and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Second Modification to the July 1, 1981, Agreement for Consultation and Cooperation on WIPP by the State of New Mexico and the U.S. Department of Energy – Signed August 4, 1987, wherein theDOE and the state agree to address certain concerns of the state regarding: (1) surface and subsurface mining and drilling after closure of the WIPP site, (2) the disposal of salt tailings at the WIPP site, and (3) compliance with U.S. Environmental Protection Agency, U.S. Department of Transportation, and U.S. Nuclear Regulatory Commission regulations. It was signed in August 1987 by Garrey Carruthers (Governor, State of New Mexico) et al., and R. G. Romotowski, (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Table 3-3
(continued)
Summary of Agreements Between the DOE and the State of New Mexico that Affect the WIPP Environmental Program

1988 Modification to the Working Agreement of the Consultation and Cooperation Agreement Between the U.S. Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant – This modification deleted the sorbing tracer test from the list of required reports and substituted additional tests. In addition, the state is allowed to operate a fixed-air sampler in the mine ventilation effluent air stream. It was signed in March 1988 by Kirkland Jones (Deputy Director, New Mexico Environmental Improvement Division, State of New Mexico) et al., and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Environmental Oversight and Monitoring Agreement – This agreement states that the DOE will provide additional technical and financial support for state activities in environmental oversight, monitoring, access, and emergency response to ensure compliance with applicable federal, state, and local laws at several DOE facilities including the WIPP facility. It was signed in October 1990 by Garrey Carruthers (Governor, State of New Mexico; Dennis Boyd (Secretary, Health and Environment Department), and Bruce G. Twining (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Site-Specific Protocol for Implementation of the Environmental Oversight and Monitoring Agreement – Signed October 23, 1992, this protocol describes the site-specific protocol for day-to-day activities involving NMED and DOE contract personnel stationed at the WIPP. This protocol is a result of the "Environmental Oversight and Monitoring Agreement of 1990" between the State of New Mexico and the DOE. It is designed within the context of the unique nature and purpose of the WIPP.

Table 3-4
Active/Pending Permits for the Waste Isolation Pilot Plant During 1993

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	Permit Status
Department of the Interior, Bureau of Land Management	Right-of-Way for Water Pipeline	NM53809	8/17/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for the North Access Road	NM55676	8/24/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Railroad	NM55699	9/27/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Dosimetry and Aerosol Sampling Sites	NM63136	7/31/86	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Seven Subsidence Monuments	NM65801	11/7/86	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Aerosol Sampling Site	NM77921	8/18/89	8/18/2019	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Ten Raptor Nesting Platforms	NM82212	9/12/89	12/13/2019	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Survey Monument Installation	NM82245	12/13/89	12/13/2019	Active
Department of the Interior, Bureau of Land Management	Approval to Drill 2 New Test Wells on Existing Pads at P-1 and P-2	None	9/18/86	None	Active
Department of the Interior, Bureau of Land Management	Free Use Permit for Caliche	NM-FU3-91183	8/18/93	8/18/94	Active
New Mexico Environment Department	Open Burning Permit to Train Fire Control Crews	None	5/3/93	5/3/94	Active
New Mexico Environment Department	Operating Permit for two Backup Generators	310-M-2	12/7/93	None	Active

Table 3-4
(continued)
Active/Pending Permits for the Waste Isolation Pilot Plant During 1993

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	Permit Status
New Mexico Environment Department	Submittal of Part B RCRA Permit Application		Submitted to the NMED and EPA Region VI on 2/26/92 and on 2/27/92. Revisions were delivered to the NMED on 3/4/92 and 1/27/93.		NMED declared permit administratively complete 7/22/92. Draft permit issued 8/24/93. Public comment period was held open to 7/14/94.
New Mexico Environment Department	Acknowledgement of Notification of Hazardous Waste Activity	NM48901 39088	1/88 Latest report delivered on 2/28/92	None - Contingent upon delivery of biennial report	Active
New Mexico Department of Game and Fish	Individual Banding	1961	4/2/93	3/31/94	Active
New Mexico Department of Game and Fish	Master Collecting	1894	4/1/93	3/31/94	Active
New Mexico Department of Game and Fish	Concurrence that WIPP construction activities will have no significant impact on State-listed threatened or endangered species	None	5/26/89	None	Active
U.S. Department of the Interior, Fish and Wildlife Service	Master Personal Banding	22478	5/19/93	6/30/95	Active
U.S. Department of the Interior, Fish and Wildlife Service	Concurrence that WIPP construction activities will have no significant impact on Federally-listed threatened or endangered species	None	5/29/80	None	Active

Table 3-4
(continued)
Active/Pending Permits for the Waste Isolation Pilot Plant During 1993

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	Permit Status
New Mexico Department of Finance and Administrative Planning Division, Historic Preservation Bureau	Concurrence that the DOE Archaeological Resources Protection Plan is adequate to mitigate any adverse impacts upon cultural resources resulting from construction of the WIPP facility	None	7/25/83	None	Active
U.S. Environmental Protection Agency	Notification of the presence of 2 Underground Storage Tanks	None	4/15/86	None	Active
U.S. Environmental Protection Agency	New Mexico NPDES Storm Water General Permit	NMR00 A021	12/31/92	12/31/97	Active
New Mexico Commissioner of Public Lands	Right-of-Way for High Volume Air Sampler	RW-22789	10/3/85	10/3/2020	Active

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CHAPTER 4

ENVIRONMENTAL PROGRAM INFORMATION

Chapter 4
Environmental Program Information

The WIPP's policy is to conduct its operations in a manner that complies with all applicable environmental laws and regulations.

4.1 Environmental Monitoring Plan

The WIPP Environmental Monitoring Plan outlines a program that monitors a comprehensive set of parameters that detect and quantify present and potential future environmental impacts. Nonradiological portions of the plan focus on the immediate area surrounding the site.

The goal of the EMP is to determine whether there are impacts during the preoperational phase of WIPP on the local ecosystem. Evaluation of the severity, geographic extent, and environmental significance of these impacts is important to future research and the mission of the facility. Although the WIPP has performed a detailed study of these impacts, additional samples will be collected and analyzed to investigate and explain trends or anomalies that may have a bearing on environmental impacts.

As recommended in DOE/EP-0023 (i.e., Corley et al. 1981) and DOE/EH-0173T, the EMP monitors levels of naturally occurring radionuclides. This surveillance includes the monitoring of world-wide fallout and those expected in the WIPP waste. The geographic scope of radiological sampling is based on projections of potential release pathways (see Figure 5-1, Primary Pathway Exposure) and those in WIPP waste. The surrounding population centers are also monitored as sampling devices.

As required by DOE Order 5400.1, the EMP is to be reviewed annually and updated every three years. The most recent EMP was updated in March 1994 (DOE/WIPP 94-024).

4.2 Baseline Data

Within the WIPP Environmental Monitoring section there are four programs currently in place, the NES, the RES, the Cooperative Raptor Research, and the WIPP Groundwater Surveillance Programs. Their purpose is to collect the data needed to detect and quantify possible impacts that construction and operational activities at the WIPP may have on the surrounding ecosystem.

Preliminary studies must be taken into effect when considering the WIPP environmental monitoring efforts because they contribute to the baseline data during the construction phase and are the predecessors to the long-term monitoring programs. These studies are:

- WIPP Site Characterization Program - instituted in 1976 by Sandia National Laboratories (SNL) to monitor air quality, background radiation levels, and groundwater quality (Pocalujka et al., 1979; 1980a, b, c; 1981a, b; Powers et al., 1978; Lappin, 1989).

- WIPP Biology Program - began in 1975 with baseline studies of climate, soils, vegetation, arthropods, and vertebrates (Best, 1980).

- Investigations of the site geohydrology - conducted by the U.S. Geological Survey (USGS) at the request of the DOE. In addition, the NRC issued a contract to Columbia University to perform a study of radionuclide mobility in the highly saline groundwaters of the Delaware Basin (USGS, 1983).

- Radiological monitoring of air, water, and biological media - conducted by the Atomic Energy Commission (ACE) before and after the Project Gnome nuclear detonation (U.S. AEC, 1962a, b, c, d).

4.3 Environmental Monitoring and Planning Activities

This section addresses significant environmental activities that occurred during CY93.

4.3.1 Waste Minimization Committee

A Waste Minimization Committee was formed of representatives from groups generating or working with hazardous and/or large volumes of waste. The Committee prepared a Waste Minimization Charter, which outlines the Committee's responsibilities.

The Waste Minimization Committee began a white bond paper and aluminum can recycling project on December 1, 1993. Various employee incentives are being used to promote these recycling programs. The WIPP site has been recycling approximately 3 tons of paper and 50 pounds of cans per month since this project began.

Other waste minimization activities for 1993 include:

- Off-site recycling of approximately 2,100 gallons of waste oil
- Reuse of cold-degreasing solvents at 6 solvent stations used for cleaning parts
- Off-site reclamation of 600 gallons of cold-degreasing solvents
- Substitution of nonhazardous for hazardous materials
- Exclusive use of recycled janitorial paper products
- Off-site recycling of approximately 150 lead-acid batteries

On February 18, 1993, the WIPP completed the annual waste reduction report required by DOE Order 5400.1 and SEN 37-92. This report delineates waste reduction activities conducted at the WIPP in CY93.

4.3.2 Environmental Training

Environmental training was provided to those personnel associated with environmental operations at the WIPP. Training courses ranged in content from technical topics (e.g., the RCRA), to basic ES&H training. These courses were conducted both on-site by WIPP personnel and off-site by various contractors. Four people attended a six-week in-depth study of environmental compliance issues relevant to the DOE at the Environmental School of Excellence.

4.3.3 WIPP Land Management Plan

On October 30, 1992, WIPP Land Withdrawal Act (i.e., Public Law 102-579) was signed into law. The WIPP Land Withdrawal Area is comprised of 10,240 acres that have been transferred from the Department of Interior to the Department of Energy.

One requirement of the Act is the preparation of a land management plan. The WIPP site *Land Management Plan* completed in October 1993 fulfills this requirement. This plan has been drafted by the DOE and the BLM in consultation with the state of New Mexico. This land management plan assures that future management of the withdrawal area will be consistent with the Federal Land Policy Management Act (FLPMA), the WIPP Land Withdrawal Act, and other applicable laws. The term of this land management plan is through the decommissioning phase of the WIPP facility. A separate plan for the post-commissioning phase is required by the Act and will be prepared at a later date.

Management Goal

The goal of the Land Management Plan is to manage the withdrawal area as it has been traditionally managed and to avoid, whenever possible, placing restriction on land use. It is not the intent of the

DOE to make the withdrawal area an exclusive-use area. However, some restrictions are needed to protect the long-term integrity of the WIPP repository. During operations, the safety and security of the facility must be maintained. The Act gives the DOE the authority to restrict activities in the withdrawal area to whatever extent it deems necessary to ensure the protection of the facility, the staff, and the public.

As a complement to this land use plan, a MOU shall be executed between the DOE and the BLM as required by the Act. This MOU will outline responsibilities of each agency with regard to requests for the use of the withdrawal area. This MOU will also define the consultation role of other land management agencies adjacent to and in the vicinity of the withdrawal, (including the state of New Mexico and other federal agencies).

CHAPTER 5

ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

Chapter 5
Environmental Radiological Program Information

The following subsections provide a description of the various radiological programs constituting the EMP at the WIPP. The media that are analyzed radiologically are airborne particulates, soil, surface water, groundwater, and biotics. Parameters analyzed are in the primary pathway exposure model which could possibly influence the dose to man.

5.1 Radioactive Effluent Monitoring

The Radioactive Effluent Monitoring Program is described in the EMP. This plan defines the scope of the WIPP effluent and environmental monitoring programs during the operational life of the facility as indicated in Figure 5-1, Primary Pathways To Man For Radioactive Releases From The WIPP Site.

The Environmental Regulatory Guide for Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T), (DOE, 1991), requires that monitoring of liquid waste effluent streams be adequate to demonstrate compliance with dose limits in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE, 1990). This order also requires that potential sources of contaminated airborne emissions be monitored. In CY93 no radioactive waste was received at the WIPP site, so no effluent sampling or release data are reported in this document.

5.2 Environmental Radioactivity Monitoring

The following subsections present the monitoring results of the EMP for CY93. These results include those for monitored subprograms such as aerosols, ambient radiation, terrestrial radioactivity, hydrologic radioactivity, and biotic radioactivity. It should be noted that in this report no off-site radiological analytical data are presented. The contract laboratory that was awarded the 1993 radiological analytical contract was unable to meet the terms of the contract. Upon a review of the data submitted and an evaluation of the laboratory's performance, the WIPP decided to cancel the contract. Thus, no data concerning subprogram monitoring will be included in this report. Aggressive steps have been taken at the WIPP to issue another contract for radiological analytical services. It is expected that all environmental media sampled in 1994 will have associated data presented in the WIPP 1994 ASER. However, it should be noted that gross alpha and beta analysis of the air filters was conducted at the WIPP Low Level Counting Lab.

The *Statistical Summary of the Radiological Baseline Program for the WIPP* (DOE/WIPP 92-037) provides an in-depth analysis of radiological data collected to meet the requirements of DOE Order 5400.1.

5.2.1 Atmospheric Radiation Baseline

Continuous particulate aerosol samplers operate at eight locations, three within 1000 meters of the facility, four at local ranches and communities, and one as a sample control site (Figure 5-2). The continuous aerosol samplers presently in use maintain a regulated flow rate of approximately 950 milliliters per second (two cubic feet per minute) of air through a 47-millimeter (1.9-inch) glass fiber filter. Table 5-1 lists the 1993 quarterly average concentrations of the alpha and beta activity on the low-volume aerosol filters from each location.

Airborne particulate sampling was initiated in July 1985 at a few locations. Routine weekly filter collections and subsequent radiochemical analyses began in early 1986, except for in the Far Field location where data collection began in October 1986. Particulate filters were collected weekly at all locations in CY93. These filters were analyzed at the Environmental Low-Level Counting Lab at the WIPP where a weekly gross alpha and beta count of each filter was completed.

Figure 5-3 shows the mean gross alpha concentrations for all eight sampling locations. The mean gross alpha concentrations in Figure 5-3 show limited fluctuation throughout the year and range from 1.26 E-10 to 5.22 E-10 Bq/ml. These fluctuations appeared to be consistent among all sampling locations.

The mean gross beta concentrations in Figure 5-3 fluctuate throughout the year within the range of 1.23 E-09 to 9.74 E-10 Bq/ml. The individual gross alpha and beta concentrations reported for each location are documented in Appendix 1.

Gross alpha and beta measurements provide an indication of naturally occurring radionuclide concentrations or changes in a specific radionuclide concentration. These measurements are screened to ensure that important radionuclides are not overlooked when measurements are performed.

5.2.2 Ambient Radiation Baseline

A Reuter-Stokes High Pressure Ionization Chamber designed to monitor low levels of gamma radiation in the environment was put into operation in May 1986. This unit is located at the WIPP far field location, which is 1000 meters northwest of the site. The detector used to measure low levels of gamma radiation, a pressurized ion chamber, measures levels of radiation from 1 to

100 microroentgen per hour (μR/hr). Using the average rate of 7.4 μR/hr, the estimated annual dose is approximately 65 millirem. The fluctuations noted are primarily due to calibration of the system and meteorological events (e.g., the high intensity thunderstorms that frequent this area in late summer).

A seasonal drop in ambient radiation has been observed in the first and fourth quarters of each year. As stated in previous reports, this fluctuation may be due to variations in the emission and dispersion of Radon-222 from the soil around the WIPP site. These variations can be caused by meteorological conditions, (i.e., inversions), which would slow the rate of dispersion of radon and its progeny.

5.2.3 Radiological Soil Monitoring

Soil samples were collected in CY93. However, due to the contract laboratory's failure to meet the conditions of the contract (see section 5.2), no radiological soil sampling data will be presented in this report. Two years of baseline soil analysis data were previously documented in DOE/WIPP 92-037. A substantial baseline of soil analysis data that meets the requirements of DOE Order 5400.1 is available in the Statistical Summary of the Radiological Baseline Program for the WIPP, (DOE/WIPP 92-037).

5.2.4 Hydrologic Radioactivity

The hydrologic radioactivity subprogram is designed to establish characteristic radioactivity levels in surface water bodies, bottom sediments, and groundwater. The following discussion of the hydrologic program includes sampling locations, data collected, and time these data were collected during 1993. It also details refinements made to the program since the publication of the *Radiological Baseline Program Sampling Plan* (Reith and Daer, 1985).

Radiological Surface Water and Sediment Monitoring

There were no radiological surface water or sediment samples collected in 1993. A substantial baseline of surface water and sediment analyses, one that meets the requirements of DOE Order 5400.1, is available in the Statistical Summary of the Radiological Baseline Program for the WIPP (DOE/WIPP 92-037).

Radiological Groundwater Characterization

Groundwater samples were collected in accordance with the Water Quality Sampling Program (WQSP). The primary objective of the WQSP is to obtain using rigorous field and laboratory procedures and protocols, representative groundwater data from selected wells. At each well site, the well is purged and the groundwater serially analyzed for specific field parameters. Once the field

parameters have stabilized denoting a chemical steady state with respect to those parameters analyzed, a final groundwater sample is collected and analyzed for radionuclides. The controlling document for the WQSP is the *WIPP Water Quality Sampling Plan and Procedures Manual* (WP 02-1, Rev 2).

The primary water bearing units being evaluated by the WQSP are the Culebra and Magenta Dolomite members of the Rustler Formation. In 1993 groundwater data were gathered at 10 well locations. Data were collected at eight locations completed in the Culebra dolomite. Water quality data were also collected from two privately owned wells in the area near the WIPP site. These two private wells provide water for area livestock. An in-depth discussion of groundwater hydrology and a figure showing well locations is presented in Chapter 7.0, Groundwater Surveillance.

5.2.5 Biotic Radioactivity

Biotic samples were collected in CY93. However, due to the aforementioned problems concerning the laboratory contract, no radiological biotic sampling data will be presented in this report. Two years of baseline biotic analysis data were previously documented in DOE/WIPP 92-037.

5.3 Assessment of Potential Dose to the Public

In 1993 no waste was received at the WIPP. Therefore, the public could not be exposed to radiation due to WIPP operations. Documentation of naturally occurring background radiation is discussed in Chapters 5 and 7 of this report.

Table 5-1

Activity Concentrations in Quarterly Averages of Low Volume Aerosol Filters

(Bq/ml)

FIRST QUARTER 1993

LOCATION	ALPHA	BETA
Carlsbad	5.22 E-10	7.23 E-10
Smith Ranch	4.75 E-10	9.64 E-10
Mills Ranch	4.97 E-10	9.35 E-10
WIPP Far Field	4.86 E-10	9.24 E-10
WIPP South	5.07 E-10	9.61 E-10
WIPP East (1)	5.26 E-10	9.47 E-10
Eunice	5.32 E-10	9.74 E-10
South East Control	5.04 E-10	9.74 E-10

SECOND QUARTER 1993

LOCATION	ALPHA	BETA
Carlsbad	2.62 E-10	7.02 E-10
Smith Ranch	2.26 E-10	7.11 E-10
Mills Ranch	2.64 E-10	6.13 E-10
WIPP Far Field	2.57 E-10	6.01 E-10
WIPP South	2.54 E-10	6.22 E-10
WIPP East (1)	2.56 E-10	6.01 E-10
Eunice	2.78 E-10	6.46 E-10
South East Control	2.51 E-10	5.74 E-10

THIRD QUARTER 1993

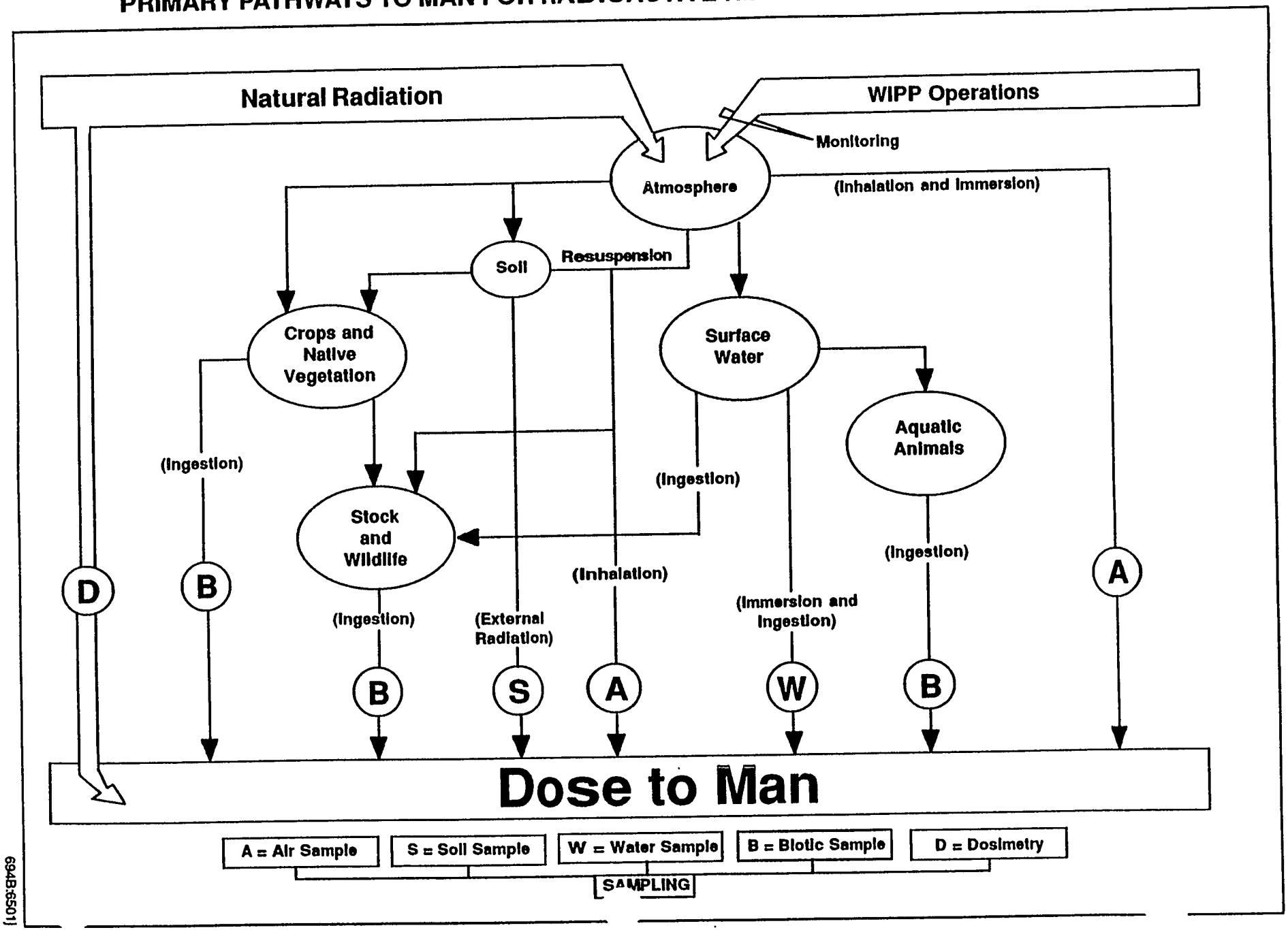
LOCATION	ALPHA	BETA
Carlsbad	2.89 E-10	8.84 E-10
Smith Ranch	2.45 E-10	8.54 E-10
Mills Ranch	2.82 E-10	8.12 E-10
WIPP Far Field	2.87 E-10	8.51 E-10
WIPP South	2.82 E-10	6.81 E-10
WIPP East (1)	3.20 E-10	8.30 E-10
Eunice	3.04 E-10	9.39 E-10
South East Control	2.50 E-10	7.94 E-10

FOURTH QUARTER 1993

LOCATION	ALPHA	BETA
Carlsbad	2.52 E-10	1.60 E-09
Smith Ranch	2.33 E-10	1.39 E-09
Mills Ranch	2.77 E-10	1.29 E-09
WIPP Far Field	1.26 E-10	1.51 E-09
WIPP South	2.11 E-10	1.47 E-09
WIPP East (1)	2.89 E-10	1.32 E-09
Eunice	2.93 E-10	1.27 E-09
South East Control	2.23 E-10	1.23 E-09

Figure 5-1

PRIMARY PATHWAYS TO MAN FOR RADIOACTIVE RELEASES FROM THE WIPP SITE



694B:5501j

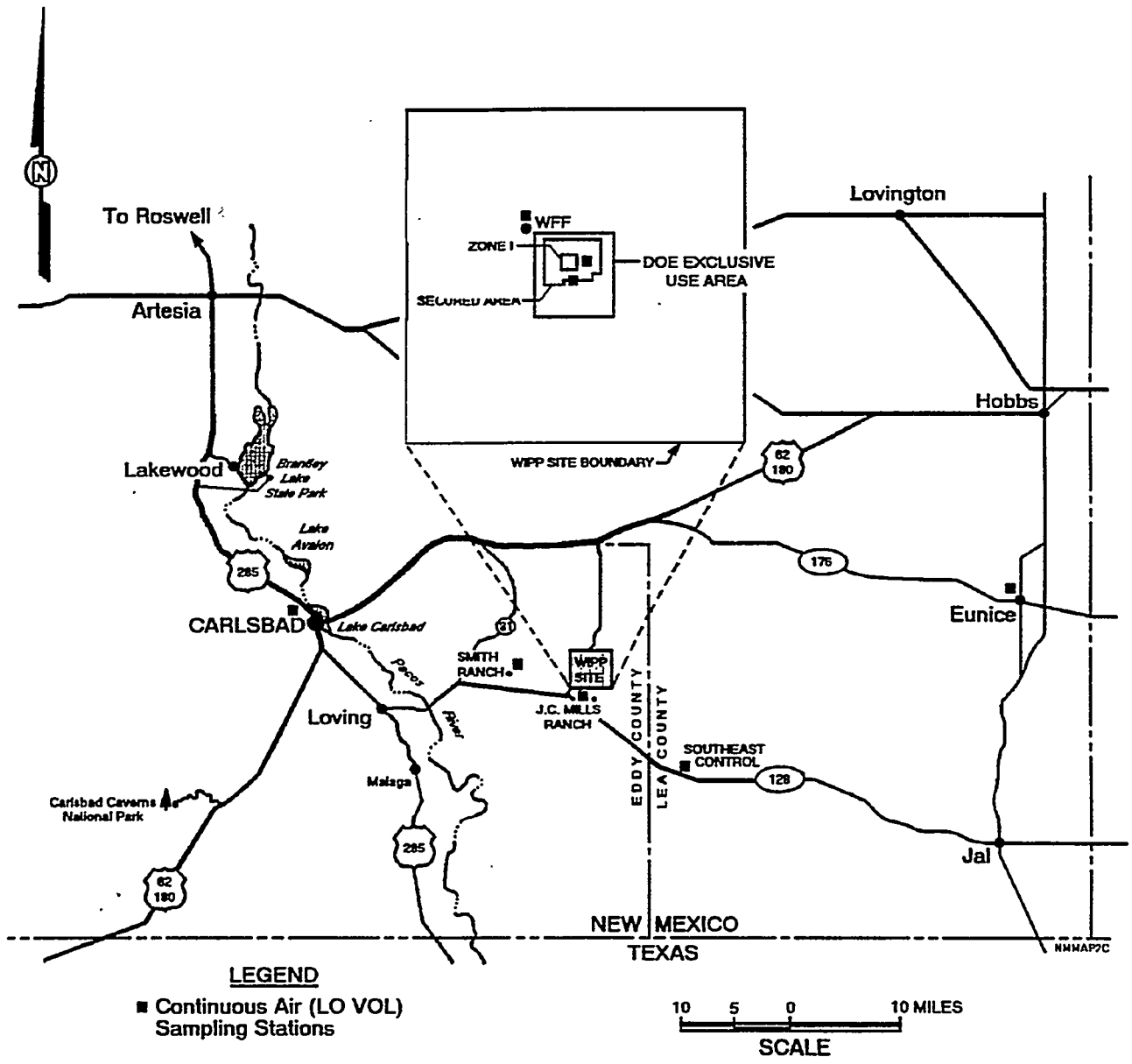


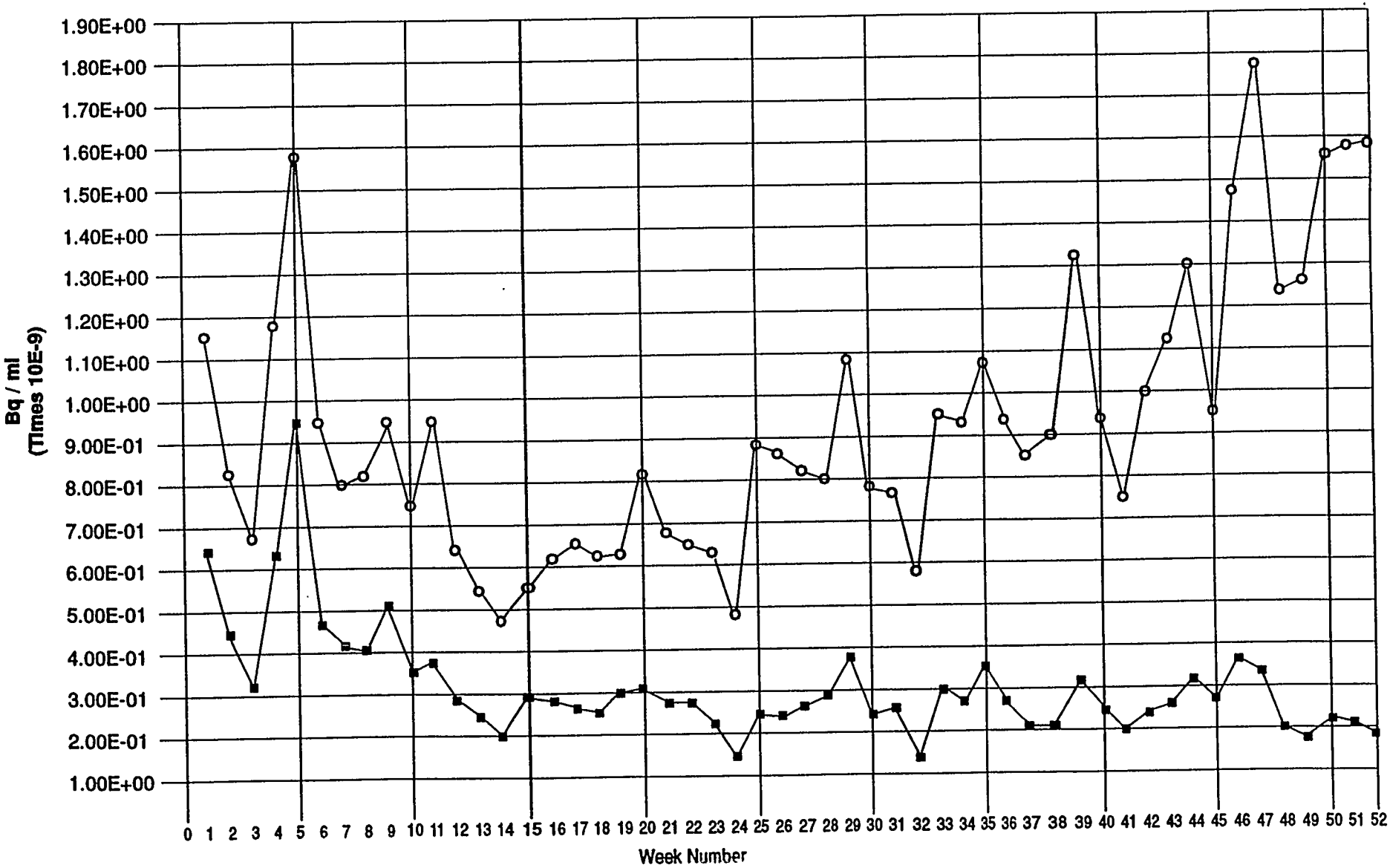
Figure 5-2
Continuous Air Sampling Stations

694B:6501a

Figure 5-3

1993 Gross Alpha / Gross Beta Concentration

Average of all locations



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CHAPTER 6

ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

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Chapter 6
Environmental Nonradiological Program Information

The EMP (DOE/WIPP 94-024) for the WIPP defines the scope and extent of the WIPP effluent and environmental monitoring programs and quality assurance and the quality control programs during the operational life of the facility. The monitoring program is divided into two segments - radiological and nonradiological monitoring. Nonradiological Environmental Surveillance, discussed in this chapter, is conducted by the Environmental Monitoring Section of the Environmental, Safety and Health Department.

The principal functions of the NES are to:

Detect and quantify the impacts of construction and operational activities at the WIPP on the surrounding ecosystem

Continue the development of the ecological database for the Los Medanos Area that was initiated by the WIPP Biology Program

Investigate unusual or unexpected elements in the ecological databases

Provide environmental data that are important to the mission of the WIPP project, but which have not or will not be acquired by other programs

This Chapter of the ASER presents and discusses data collected between January 1, 1993, and December 31, 1993, as part of the NES. Ecological monitoring at the WIPP include the following six subprograms: meteorological monitoring, air quality monitoring, wildlife population monitoring, surface disturbance and soil monitoring, vegetation monitoring, and water quality monitoring. In addition to the NES programs, Volatile Organic Compound are monitored as part of the air requirement for the NMD. The results of the environmental monitoring activities and discussions of significant findings are presented in this report.

6.1 Meteorology

An important component of the NES is a meteorological station located 600 meters northeast of the site. The primary function of the MET is to generate data to use for modeling atmospheric conditions. The data generated from the meteorological station are wind speed, wind direction, and temperatures at 3, 10, and 40 meters (10, 30, and 130 feet), with dew point and precipitation monitored at ground level. These parameters are measured continuously and the data are logged at fifteen-minute intervals.

In addition to the primary meteorological station, the Atmospheric Monitoring Station (AMS) is located 1000 meters northwest of the site. At the AMS a secondary meteorological station measures and records temperature and barometric pressure at ground level and wind speed and wind direction at 10 meters (30 feet).

6.1.1 Climatic Data

The mean annual temperature for the WIPP area in 1993 was 18°C (64°F). The mean monthly temperatures for the WIPP area ranged from 7°C (45°F) during January to 29.6°C (86°F) in June. Generally, maximum temperatures occur in June through September, while minimum temperatures occur in December through February.

The last freezing day of the 1993-94 winter season was April 28, with a temperature of 0°C (32°F). The first freezing day of the 1993-94 winter season occurred October 27, with -1°C (30°F). The maximum temperature recorded was 43°C (109°F) on July 7.

The annual precipitation at the WIPP site for 1993 was 24 cm (9.4 in), which is 18 cm (7 in) below 1992 precipitation. In other words, the annual precipitation for 1993 was 43 percent less than that recorded for 1992. The average precipitation for the period 1989 through 1993 was 3 percent less than the previous 5-year period (36.8 cm [14.4 in]). Figure 6-1 displays the monthly precipitation at the WIPP.

6.1.2 Wind Direction and Wind Speed

The predominate wind direction in the WIPP area was from the southeast sector (135°). However, winds occurring in late spring were primarily from the west. Various storm systems move through this area that briefly alter the predominate southeasterly winds. Wind speed noted as calm (less than 0.5 meters per second [mps]) occurred seven percent of the time. Winds of 1.4 through 2.7 mps were

the most prevalent over 1993, accounting for 37.2% of the time. Figure 6-2 displays the annual wind data at the WIPP for CY 1993.

6.2 Environmental Photography

Surface photography has been conducted at seven ecological study plots since 1984. Photographs are used to document year-to-year surface impacts at the study plots and are archived for future reference. Although some paths are noticeable in some plots due to foot traffic, very little surface disturbance was noted in the 1993 photographs.

6.3 Air Quality Monitoring

Five classes of pollutant gases are monitored 1000 meters (0.6 mile) northwest of the exhaust shaft at the WIPP site on a continuous basis. These are sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), hydrogen sulfide (H_2S), and oxides of nitrogen (NO, NO_2, NO_x). The data generated by the analyzers showed these gases to be at the lower limit of detection, that is below the baseline concentrations set by the state of New Mexico. The permissible New Mexico state standard for the gases monitored at the WIPP are listed below:

SO_2	0.02 ppm	annual average
	0.10 ppm	24-hour average
CO	8.70	per eight-hour average
O_3	0.06 ppm	per one hour average
H_2S	0.10 ppm	per one half hour average
NO_2	0.10 ppm	24-hour average

The ambient gas monitors are extremely sensitive instruments that require semiannual recertification by a factory engineer. During CY93 the H_2S, SO_2 and NO_x analyzers were replaced with analyzers incorporating more modern technology. These instruments were installed late in CY93 and a long-term evaluation of the data generated by these instruments is unavailable at this time. However, initial indications show H_2S, SO_2, and NO_x data values at or below the lower level of detection for these analyzers. These data are consistent with data gathered by the previous analyzers.

In addition, weekly measurements of Total Suspended Particulates (micrograms per cubic meter) are made from the particulates collected by the low-volume continuous air sampler at the Far-Field air sampling location. These filters can load with dust particles due to the arid climate of this area; however, this poses no health concern.

6.4 Wildlife Population Monitoring

Population density measurements of breeding birds and small nocturnal mammals are performed annually to assess the effects of WIPP activities on wildlife populations. Two permanent study plots adjacent to the WIPP facility are used for each of these two classes of wildlife. The data are compared to the data from two control sites for each class. Trap grids are used to measure small mammal populations, and 2,500-foot-long Emlen transects are used to measure bird population densities.

6.4.1 Cooperative Raptor Research and Management Program

In CY93 the Raptor Program focused on the impacts of human-related activities on four distinct groups of Harris' Hawks (*Parabuteo unicinctus*). During the course of the year, nest locations of the hawks were identified and nestlings were banded (in accordance with federal banding permit #22476 and state banding permit #1961) with U.S. Fish and Wildlife bands and anodized aluminum color bands inscribed with alpha numeric codes. These groups will serve as indicators for the data-sharing network between the WIPP and the BLM. Moreover, nest locations of supplementary groups of Harris' Hawks, in addition to nest sites of divergent species (e.g., Swainson's Hawks, Chihuahuan Raven) were located. Nest locations were identified with Loran Navigators and provided to the BLM for incorporation into its land use determinations (e.g., oil and gas activities).

In previous years, several oil wells that had been scheduled to be drilled in close proximity to active nest sites were relocated. Had the information from the wildlife monitoring program been unavailable to the BLM, the nests would have been disturbed.

In 1994, the WIPP proposes to continue these activities in addition to examining the subtle territorial behaviors in the color-marked groups of Harris' Hawks.

Guidance and assistance is welcomed from the local BLM office, the New Mexico Department of Game & Fish, and the U.S. Fish & Wildlife Service. In addition, WIPP will solicit program recommendations from University of Arizona raptor specialists.

6.4.2 Breeding Bird Densities

The densities and distributions of breeding birds between the WIPP transects and the control transects conformed to patterns reported in previous years (Table 6-1). A greater number of species and a higher total density of birds were found in the Southeast 1 (SE-1) and the Northwest 2 (NW-2) transects, with an overall percentage increase of 0.23% and 32.3% respectively. The Control 1 (CT-1) plot showed similar increases of 29.6%. The CT-1, SE-1 and NW-2 plots showed a substantial increase in densities of birds - 14 new species were observed. This increase is possibly due to major oil field activity north, south, east, and west of the 16-section land withdrawal area. Noise levels are markedly higher in areas with oil production activity and loss of habitat in these areas is apparent, possibly forcing the birds away from these areas toward the 16-section land withdrawal area. New oil field activity southwest of the site has, as predicted, resulted in an 11.1% decline of bird activity in the CT-2 transect. A new well was drilled just yards north of the existing CT-2 Emlen line.

Insect dependant species continue to be more abundant near the site than in previous years. For example, there is a greater number of flycatchers. Populations of nesting barn swallows are also on the rise. A new seed eater species, pigeon, has been seen flying over the site but, to date, no nests have been found. A nest count was conducted on-site in June. The most common nester is the barn swallow. Forty-two active broods were located. Other on-site nesters include Western king birds (21 nests); house finches (2 nests); and house sparrow, Say's phoebe, killdeer, northern (Bullock's) oriole, and cactus wren (1 nest each).

The monitoring of the 21.5-mile-line transect, begun in September of 1991, was conducted monthly to assess which species utilize this region year-round or as a fly-way during migration (Table 6-2). As most birds are migratory, the possibility of seeing rare, threatened, or endangered species during the Emlen transects is minute. Examples of these species include the Peregrine and Aplomado Falcons. Although never seen during the Emlen transects, these state and federally endangered falcons have been documented within range of the 21.5-mile transect and, indeed, are species WIPP activities could possibly affect.

The 1993 observations on the 21.5-mile transect listed no threatened or endangered species; however, sightings which would be considered significant for this area are sandhill crane, Bewick's wren, pine siskin, cliff swallow, rock wren, mountain bluebird and blue-gray gnatcatcher.

From 1984 through 1993, WIPP avian surveys have identified 98 species that inhabit or migrate through the areas. Extensive avian studies in southeastern New Mexico suggest that there could be u to 300 species on-site.

6.4.3 Small Nocturnal Mammal Population Densities

Starting with the outbreak of Hanta virus in the spring of 1993, small nocturnal mammal censuses were conducted on two study plots rather than on the usual four. Midway through the census period there had been outbreaks of the virus in New Mexico and every state bordering New Mexico. The chief vector for the disease had been determined to be the deer mouse, *Peromyscus maniculatus*, a mammal encountered on all four transects. To protect researchers from possible exposure, the remaining 1993 censuses for NW-2 and CT-2 and all future censuses were cancelled until precautionary controls could be implemented. Recommendations from the New Mexico Environment Department, the Centers for Disease Control, and Los Alamos National Laboratories will be addressed and satisfied prior to reestablishment of this program in 1994. In addition to establishing safety procedures, blood serum samples will be extracted and analyzed for the presence of Hanta virus in specimens collected from southeastern New Mexico.

Tables 6-3 and 6-4 summarize the results of the 1993 small mammal surveys i the Control 1 (Ct1) and WIPP Southeast 2 (SE2) trap grids. Grids are composed of 100 traps set in a 150m x 150m grid with traps spaced 15 meters apart. Trapping sessions began June 15, 1993, and ended June 24, 1993. Mammals were trapped using Sherman live traps baited with milo.

Mammals were trapped and released for two weeks, three successive nights per week. Larger mammals, such as kangaroo rats, pains wood and hispid cotton rats, deer mice, and grasshopper mice were tagged with numbered ear tags. Silky pocket mice were marked with a stain on their side or head. Grid location of trapped individuals as well as genus, species, new or recapture, tag number or location of stain, sex, and weight were logged on Small Mammal Data sheets. From this data, population densities, actual numbers of captures for each genus, and travel distances for recaptured individuals were calculated.

Population densities were calculated using the Schnabel Method (Tanner, 1978) for mark and recapture mammal trappings. Kangaroo rats were the most common species encountered. Tables 6-3 and 6-4 list the actual number of captures rather than statistical populations for each plot.

Within each grid, each rodent occupies a certain territory or range. By plotting data on recaptured animals, grid locations, and the total distance each animal traveled within the grids during the two

trapping sessions was determined. Of the 27 kangaroo rats surveyed, 5 were recaptured each night in the same trap location, whereas 13 out of 24 plains woodrats were captured in the same location. These figures show the woodrat is more likely to stay in its home range. Several Ord's kangaroo rats were recaptured 30 to 85 meters from their original capture locations, while those recaptured ventured 49 meters from their original capture locations. According to these calculations, the Ords were more active in 1993 than in 1992 by an average of 30 meters. 1993 marked a decline for woodrat captures. Twenty-four individuals were captured and tagged. The average distance traveled by woodrats was 9 meters.

Females of both species were dominant in CT1; whereas males dominated in both species in SE2. Densities dropped significantly for the kangaroo rats in both grids sampled. A total of 24 wood rats were trapped in both plots for CY93. This is a moderate decline in total captures of woodrats in 1993 and a moderate decrease in the 1985 to 1992 average. The overall decline in nocturnal rodent population may be attributed to the droughty conditions that prevailed in 1993. Rodents were more abundant in the control grids than in the WIPP grids; however, no grasshopper mice or silky pocket mice were captured.

6.5 Surface and Subsurface Soil Monitoring

Surface and subsurface soil monitoring was temporarily discontinued in CY92. Substantial analysis of soil was performed from 1984 to 1990. A detailed discussion of the non-radiological soil monitoring program is available in the report titled *Summary of the Salt Impact Studies at the WIPP, 1984 to 1990* (DOE/WIPP 92-038). This program could be reinstated if, in the future, elevated salt levels were suspected in the topsoil adjacent to the salt storage piles.

6.6 Vegetation Monitoring

Vegetation in each of the seven ecological monitoring plots was measured in the fall to assess the effect of the salt tailings on the proximal plant community structures. In each plot, foliage of each species and species diversity were measured using the methods described in Reith, et al, 1985. The frequency of a species is defined as the proportion (percent) of the quadrats containing that species. The 1993 fall vegetation summaries are presented in Table 6-5. Species listed in the table with zero data values were not encountered during the 1993 survey; however, these species are known to exist in the WIPP ecological monitoring plots.

The total CY93 precipitation rate of 23.88 cm. (9.4 in.) was a dramatic decrease over the 1992 total precipitation rate of 42.11 cm (16.58 in). Drought conditions persisted from February through May

and improved as precipitation began to increase in April. However, relatively little precipitation fell throughout the summer, resulting in stressed plants and drought conditions by the end of September.

The CY93 vegetation monitoring data showed an increase, for the first time since 1989, of perennial grasses with their increasing proximity to the salt tailings. The total coverage of these grasses in all plots was relatively uniform over all distances from the tailings. Although densities of annuals and species richness were slightly greater in the nearfield plots, overall, species remained relatively uniform across all plots. A pattern observed from the 1989 through 1992 data, which was also seen in the 1993 data, is an increase in shrub cover with increasing proximity to the salt tailings. A departure from the 1989 through 1992 data was an approximately equal richness, overall, in the perennial grass cover as opposed to the decline observed in the past. This common effect of secondary salination may be declining as the salt tailings become more solidified through time. The responses of these plots to higher rainfall in later years will reveal whether adverse effects of salination will prevail or begin to abate in the structure of the plant community or whether these responses are only a short-term effect caused by short-term weather conditions. Weather conditions had a uniform effect on vegetation in all plots. Prodigious differential effects resulting from salt-induced physiological stress near the salt tailings was not observed.

The mine tailings may not be having great negative effects on the surrounding plant communities in the form of eolian salt deposition. The nature of the salt is to become compacted and solidified by the heavy machinery and moisture. Run-off is collected in the catchment basin where it is evaporated to the atmosphere and absorbed into the soil. Any resulting salt crust is then weathered and partially dispersed to the surrounding area. This represents only a minimal deposit. Interestingly, wildlife has been observed using the salt tailings as a source of salt, similar to cattle using salt licks.

6.7 National Pollutant Discharge Elimination System Data

The WIPP completed the WIPP NPDES Storm Water Pollution Prevention Plan (PPP) in March 1993. The NPDES Storm Water Permit rules require that a PPP be developed for each facility covered under the permit by April 1, 1993. The PPP identifies and assesses potential pollutant sources and describes all Best Management Practices that will be implemented to ensure that storm water runoff does not contact regulated pollutants. Additionally, the WIPP outlined a schedule for the implementation of all BMPs required to demonstrate compliance with all permit requirements.

The completion of Best Management Practices identified in the WIPP NPDES Storm Water Pollution Prevention Plan include: 1) the construction of storm water retention basins to collect all Zone 1 storm water discharges; 2) the covering of all material storage areas to prevent contact with

precipitation runoff; 3) the covering of the Sandia Diesel generators; 4) construction of berms around all material storage areas outside of Zone 1; and 5) the storage of all recycled batteries in the Excess Storage Area on spill containment devices. Additionally, disturbed areas that are no longer in use are being reclaimed. Reclamation of the unused portions of the Construction Landfill has been completed.

The NPDES Storm Water Pollution Prevention Plan establishes a preliminary schedule for the initiation of reclamation activities for all but 16 of the Solid Waste Management Units (SWMUs) located within the WIPP Land Withdrawal Area. The schedule for the completion of reclamation activities for these 16 SWMUs is contingent upon negotiation with EPA Region VI. The DOE does not anticipate that the assessment, remediation, and reclamation of these 16 SWMUs will be initiated until a Disposal Phase RCRA/HSWA permit is issued for the WIPP.

6.8 Volatile Organic Compounds Monitoring

As stated in Section 3.2.3, the WIPP has developed and implemented a Volatile Organic Compound (VOC) monitoring program to satisfy the air monitoring requirements of the NMD for the WIPP (55 FR 47700). The data resulting from this program are reported in the NMD annual reports submitted to the EPA. As stated in Section 3.2.3, the most recent report titled, *Waste Isolation Pilot Plant No-Migration Determination Annual Report for the period of October 1991 through August 1992* (DOE/WIPP 92-057), was submitted to the EPA on November 11, 1992.

Unlike the other programs listed in this chapter, the WIPP VOC Monitoring Program is not included in the EMP for the WIPP (DOE/WIPP 88-025) and is not implemented by the Environmental Monitoring Section. Rather, the WIPP VOC Monitoring Program is implemented by the Dosimetry and Analytical Technology Section of the Environment, Safety and Health Department, and the implementing documents are specific to the program. These include *VOC Monitoring Plan for Bin-Room Tests* (WP 12-6) and *Volatile Organic Compounds Monitoring Quality Assurance Program Plan* (WP 12-7).

6.9 Reclamation of Disturbed Lands

During CY93, the WIPP adopted contemporary reclamation techniques more conducive to a desert environment. Rather than using prescribed techniques involving deep ripping and tillage, WIPP used a shallow tillage reclamation drill. The use of this type of drill allows for the retention of critical sub-moisture while distributing seed rates at determined intervals and desired depths.

Reclamation activities during CY93 consisted of fence construction around an existing reclamation site. The fence was constructed according to BLM specifications. Surface areas comprising a retention basin for water were hand seeded and minor erosion control measures were taken. Additionally, a construction landfill area was capped and reseeded in order to comply with NPDES stormwater discharge permit requirements.

Due to the lack of precipitation during 1993, seed germination on reclamation sites was negligible. Success or failure of shallow-tillage reclamation techniques is contingent on precipitation.

6.10 Seismic Activity

There were a total of 76 earthquakes located within 300 kilometers of WIPP in 1993. Major readings on the Richter Scale were: 3.2 (Ruidoso, December 22, 1994), 3.1 (Presidio, July 15, 1994), 2.8 (Odessa, June 23, 1994), and 2.5 (Hobbs, August 26, 1994). From June through December there was increased activity along the Central Basin Platform south of Odessa with 19 seismic events with readings ranging from 1.2 to 2.8. There were two events, 1.1 and 1.2, which were located near the Rattlesnake Canyon earthquake epicenter of January 2, 1992.

Historically, the seismic information for the WIPP facility region before 1962 is based on chronicles of the effects of those tremors on people, structures, and land forms (called macroseismic evidence). Since 1962 virtually all seismic information is based on instrumental data recorded at various seismograph stations. Currently, seismicity is being monitored at the New Mexico Institute of Mining and Technology (NMIMT), Socorro, using data from a seven-station network centered on the WIPP (Figure 6-3). The stations are telemetered to the NMIMT Seismological Observatory. Seismicity is also being monitored from other New Mexico stations and from bordering states.

Pre-1962 seismicity reported in New Mexico occurred in the Rio Grande Valley area between Albuquerque and Socorro and is associated with a structure known as the Rio Grande Rift. These earthquakes had intensities of Modified Mercalli V or greater as based upon the perceptions of people experiencing these quakes. More recently, from January 1, 1962 through November 28, 1974, seismicity near the site has been registered with readings as great as 3.8 in magnitude.

Geologic structures and tectonism of the Permian Basin are associated with large-scale basin, inter-basin, and basin-margin subsidence or emergence that occurred during the Paleozoic era. The WIPP facility is about 60 miles from the western margin of the Permian Basin. The basin is a broad structural feature made up of a series of Paleozoic sedimentary basins whose last episodes of major subsidence occurred during late Permian time. The area today is characterized by the basin filled with

thick evaporite layers and bordered by the Amarillo uplift to the north, the Marathon thrust belt to the south, and the Diablo Platform, Sacramento and Guadalupe Mountain orogenies to the west. All major tectonic elements of the Permian Basin were completely formed before deposition of the Permian salt-bearing rocks, and the region has been relatively stable since that time. Deep-seated faults are rare except along the west margin of the basin and no indications of younger deep-seated faults are noted.

Central Basin Platform related seismicity may not be entirely tectonic, but instead, may be related to water injection and withdrawal for secondary recovery operations in oil fields. Similar evidence suggests that the June 16, 1978 event near Snyder, Texas, may have been induced by secondary oil recovery operations. The depth of the earthquake closely approximates the bottom of drillholes located in this gas producing area.

There is little indication that significant magnitude events are likely to occur in the WIPP facility zone. There is no Quaternary fault offset, and seismic activity is low. Analysis of risk for the WIPP facility source zone suggests that in the event of 4.5 magnitude would have been the maximum historical event near the site of tectonic origin plus about one magnitude unit and an event of 5.5 as the maximum event recorded anywhere within the Permian Basin subregion, plus about one magnitude unit.

Figure 6-1
1993 Precipitation

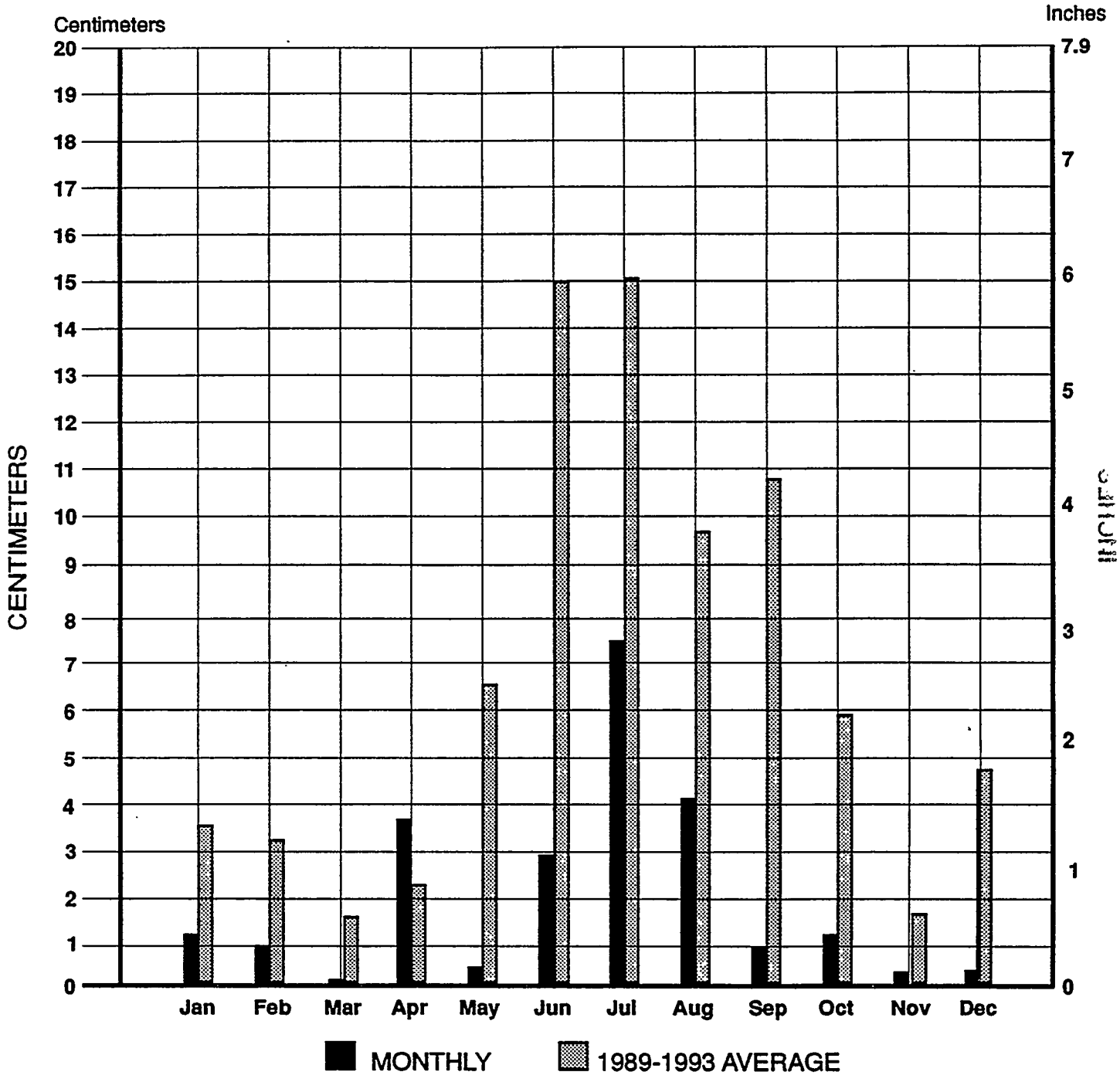

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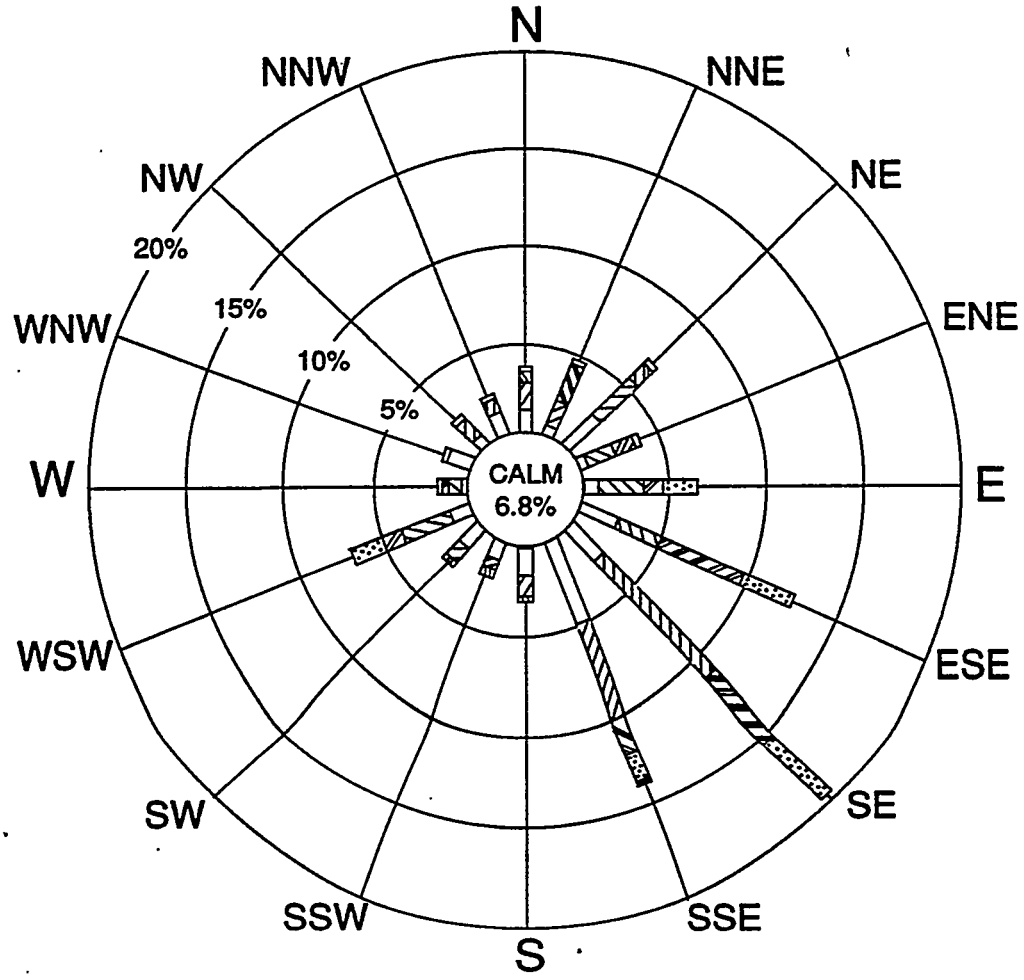
Figure 6-2

ANNUAL WINDROSE 1993



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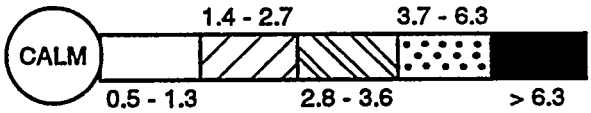


WIND VELOCITY IN METERS PER SECOND

Table 6 - 1

Summary of the 1993 EMLEN Breeding Bird Density Measurements in Birds per 40 ha.

PLOTS:	CT1	CT2	1993 AVERAGES	84-93 AVERAGES	NW2	SE1	1993 AVERAGES	84-93 AVERAGES
BIRD SPECIES								
CATTLE EGRET	0.0	0.0	0.0	0.0	6.5	0.0	3.2	0.2
SANDHILL CRANE	8.6	0.0	4.3	0.2	0.0	0.0	0.0	0.0
KILLDEER	0.0	4.3	2.1	0.1	0.0	7.3	3.7	5.3
WILSON'S PHALAROPE	0.0	0.0	0.0	0.0	8.6	0.0	4.3	0.2
TURKEY VULTURE	0.0	0.0	0.0	0.0	8.6	0.0	4.3	0.2
NORTHERN HARRIER	0.0	0.0	0.0	0.6	0.0	0.0	0.0	2.1
SWAINSON'S HAWK	2.8	0.0	1.4	0.1	8.6	4.3	6.4	3.3
HARRIS' HAWK	0.0	4.3	2.1	1.1	0.0	0.0	0.0	0.0
OSPREY	2.1	0.0	1.1	0.1	0.0	0.0	0.0	0.0
NORTHERN BOBWHITE	13.4	17.2	15.3	10.9	14.3	11.7	13.0	10.3
SCALED QUAIL	3.2	25.8	14.5	11.4	34.5	0.0	17.2	10.9
ROCK DOVE	0.0	0.0	0.0	0.0	5.3	0.0	2.6	0.1
MOURNING DOVE	12.9	4.3	8.6	10.9	7.3	3.7	5.5	6.3
GREATER ROADRUNNER	0.0	0.0	0.0	0.0	17.2	8.6	12.9	8.2
COMMON BARN-OWL	0.0	0.0	0.0	0.0	0.0	8.6	4.3	0.2
GREAT HORNED OWL	12.2	0.0	6.1	6.0	0.0	0.0	0.0	0.1
BURROWING OWL	0.0	0.0	0.0	0.0	0.0	8.6	4.3	0.2
COMMON POORWILL	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1
COMMON NIGHTHAWK	0.0	8.6	4.3	2.8	10.7	17.2	13.9	7.5
LADDER-BACKED WOODPECKER	0.0	0.0	0.0	2.4	9.3	8.6	8.9	7.1
WESTERN KINGBIRD	11.3	11.8	11.5	9.4	18.8	15.6	17.2	15.8
SCISSOR-TAILED FLYCATCHER	0.0	0.0	0.0	0.2	3.2	34.5	18.8	11.7
ASH-THROATED FLYCATCHER	11.2	8.6	9.9	7.3	12.0	12.0	12.0	10.9
SAY'S PHOEBE	8.6	0.0	4.3	2.7	0.0	17.2	8.6	0.5
BARN SWALLOW	17.2	0.0	8.6	0.5	7.9	31.0	19.4	18.0
CHIHUAHUAN RAVEN	15.8	4.8	10.3	7.4	5.1	4.8	4.9	5.8
VERDIN	0.0	0.0	0.0	0.0	17.2	0.0	8.6	0.5
CACTUS WREN	11.1	17.2	14.1	12.6	12.9	16.1	14.5	13.1
LOGGERHEAD SHRIKE	7.7	7.9	7.8	9.1	9.1	5.4	7.2	5.2
NORTHERN MOCKINGBIRD	15.3	14.0	14.6	12.4	14.0	15.0	14.5	12.8
SAGE THRASHER	3.2	0.0	1.6	0.1	0.0	2.1	1.0	0.1
CURVE-BILLED THRASHER	3.6	6.5	5.0	0.3	8.6	17.2	12.9	0.7
CRISSAL THRASHER	17.2	0.0	8.6	5.3	0.0	8.6	4.3	4.7
BELL'S VIREO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
YELLOW-RUMPED WARBLER	0.0	0.0	0.0	0.0	17.2	34.4	25.8	1.4
YELLOW WARBLER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
PYRRHULOXIA	12.9	18.8	15.8	17.7	28.5	21.2	24.8	22.6
RUFOUS-SIDED TOWHEE	0.0	0.0	0.0	0.0	0.0	17.2	8.6	2.1
GRASSHOPPER SPARROW	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
LARK SPARROW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
BLACK-THROATED SPARROW	35.5	53.8	44.6	36.9	44.1	53.8	48.9	40.6
SAGE SPARROW	17.2	0.0	8.6	0.5	17.2	20.1	18.6	1.0
CASSIN'S SPARROW	28.3	0.0	14.1	11.7	55.9	34.4	45.1	30.4
RUFOUS-CROWNED SPARROW	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
CHIPPING SPARROW	17.2	8.6	12.9	0.7	17.2	0.0	8.6	0.5
BREWER'S SPARROW	17.2	17.2	17.2	8.7	14.3	8.6	11.4	7.4
WHITE-CROWNED SPARROW	0.0	0.0	0.0	0.0	17.2	0.0	8.6	12.9
YELLOW-HEADED BLACKBIRD	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1
RED-WINGED BLACKBIRD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
BREWER'S BLACKBIRD	0.0	17.2	8.6	4.8	60.2	0.0	30.1	18.7
BROWN-HEADED COWBIRD	10.7	7.2	8.9	8.2	4.31	8.0	6.1	7.5
LARK BUNTING	19.9	0.0	9.9	8.8	0.0	21.5	10.7	11.9
MEADOWLARK	11.8	9.7	10.7	9.7	11.3	9.2	10.2	8.3
NORTHERN ORIOLE	8.6	0.0	4.3	3.2	18.6	0.0	9.3	6.6
HOUSE SPARROW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
AMERICAN GOLDFINCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
LESSER GOLDFINCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
HOUSE FINCH	0.0	0.0	0.0	0.01	0.0	17.2	8.6	6.9
TOTAL DENSITY IN 1993 PER 40ha.	356.7	267.8	311.6	232.9	555.2	487.1	520.2	349.6
AVERAGE AVIAN DENSITY PER 40ha (1992-93)	303.9	284.5	294.3	208.9	465.6	486.5	476.0	308.6
NUMBER OF SPECIES 1993	28	20	32	40	35	31	41	53
TOTAL SPECIES OBSERVED1984-93	58							

Species in italics are considered threatened or endangered federally and/or by New Mexico.

Table 6 - 2
Observed Avifauna of Los Medanos and Surrounding Ecotones
1993

MONTH OBSERVED	J	F	M	A	M	J	J	A	S	O	N	D	SPECIES TOTALS
BIRD SPECIES													
BLACK-CROWNED NIGHT-HERON	0	0	0	>525	209	26	0	0	0	0	0	0	>525
SNOWY EGRET	0	0	0	0	66	42	8	0	0	0	0	0	66
GREAT BLUE HERON	0	0	0	0	0	0	0	0	0	0	0	0	0
SANDHILL CRANE	3	0	0	0	0	0	0	0	0	0	0	0	3
BLUE-WINGED TEAL	0	0	0	0	0	0	0	0	0	0	0	0	0
AMERICAN COOT	0	0	0	0	0	0	0	0	0	0	0	0	0
SNOWY PLOVER	0	0	0	0	0	1	0	0	0	0	0	0	1
BLACK-NECKED STILT	0	0	0	1	0	0	0	0	0	0	0	0	1
KILLDEER	0	0	0	1	1	0	0	0	1	0	0	0	3
SEMIPALMATED SANDPIPER	0	0	0	0	0	0	0	0	0	0	0	0	0
LEAST SANDPIPER	0	0	0	0	0	0	0	0	0	0	0	0	0
RING-BILLED GULL	0	0	0	0	0	0	0	0	0	0	0	0	0
TURKEY VULTURE	0	0	1	1	16	17	4	16	10	0	0	0	65
GOLDEN EAGLE	0	0	0	0	0	0	0	0	0	0	0	0	0
NORTHERN HARRIER	5	4	8	10	0	0	0	1	4	7	1	9	49
SHARP-SHINNED HAWK	0	0	0	0	0	0	0	0	0	0	0	0	0
RED-TAILED HAWK	11	6	3	9	1	4	2	3	3	3	5	7	46
SWAINSON'S HAWK	0	0	0	14	5	7	8	14	9	1	0	0	58
ROUGH-LEGGED HAWK	0	0	0	0	0	0	0	0	0	0	0	0	0
FERRUGINOUS HAWK	0	0	1	1	0	0	0	0	0	0	1	1	3
HARRIS' HAWK	0	0	0	6	5	3	1	1	1	1	6	6	30
AMERICAN KESTREL	0	0	0	1	0	0	0	1	5	0	0	0	7
MERLIN	0	0	0	0	0	0	0	0	1	1	0	0	2
PRAIRIE FALCON	1	0	0	0	0	0	0	0	0	0	0	0	1
NORTHERN BOBWHITE	0	0	0	0	4	6	12	0	9	1	2	0	34
SCALED QUAIL	0	1	1	9	3	4	3	9	6	10	0	8	54
MOURNING DOVE	0	2	3	4	20	4	10	9	1	2	0	0	55
GREATER ROADRUNNER	0	0	1	1	0	0	2	2	1	1	1	0	9
GREAT HORNED OWL	0	0	1	3	1	0	0	0	0	0	0	0	5
BURROWING OWL	0	0	0	0	1	5	1	0	0	0	0	0	7
COMMON NIGHTHAWK	0	0	0	0	4	1	13	1	1	0	0	0	20
LESSER NIGHTHAWK	0	0	0	0	0	0	0	0	0	0	0	0	0
RED-SHAFTED NORTHERN FLICKER	0	0	0	0	0	0	0	0	0	0	0	0	0
LADDER-BACKED WOODPECKER	2	0	1	2	0	5	0	0	2	1	0	1	14
WESTERN KINGBIRD	0	0	0	6	14	14	17	1	1	0	0	0	53
SCISSOR-TAILED FLYCATCHER	0	0	0	9	3	2	1	8	11	0	0	0	34
ASH-THROATED FLYCATCHER	0	0	0	0	7	12	5	2	0	0	0	0	26
SAY'S PHOEBE	0	0	2	0	0	0	0	0	1	0	0	0	3
HORNED LARK	0	0	0	0	2	0	0	3	4	0	0	0	9
CLIFF SWALLOW	0	0	0	3	0	0	0	0	0	0	0	0	3
BARN SWALLOW	0	0	0	4	0	0	2	0	1	0	0	0	7
CHIHUAHUAN RAVEN	0	0	11	30	46	30	16	6	0	0	0	0	139
VERDIN	0	0	0	2	2	0	2	0	0	0	0	0	6
BEWICK'S WREN	1	0	0	0	0	0	0	0	0	0	0	0	1
ROCK WREN	0	0	0	0	0	0	0	0	4	1	0	0	5
CACTUS WREN	5	6	24	7	23	7	27	23	16	20	1	7	166
OBSERVED MONTHLY SUBTOTALS	28	19	57	>649	433	190	134	100	92	49	17	37	
OBSERVED SPECIES SUBTOTALS	7	5	12	22	20	18	18	16	21	12	7	7	

Table 6 - 2
(Continued)
Observed Avifauna of Los Medanos and Surrounding Ecotones
1993

MONTH OBSERVED	J	F	M	A	M	J	J	A	S	O	N	D	SPECIES TOTALS
BIRD SPECIES													
RUBY-CROWNED KINGLET	0	0	0	0	0	0	0	0	0	0	1	0	1
BLUE-GRAY GNATCATCHER	0	0	0	0	0	0	0	0	0	0	0	1	1
MOUNTAIN BLUEBIRD	0	0	0	0	0	0	0	0	0	6	0	0	6
HERMIT THRUSH	0	0	0	0	0	0	0	0	0	0	0	0	0
LOGGERHEAD SHRIKE	4	2	12	4	6	2	10	26	9	9	3	14	101
NORTHERN MOCKINGBIRD	0	0	0	3	34	46	35	6	2	8	0	0	134
SAGE THRASHER	0	0	0	1	2	1	2	0	3	1	0	0	10
CURVE-BILLED THRASHER	0	0	0	1	0	0	0	0	0	0	0	0	1
CRISSAL THRASHER	1	0	1	0	0	0	2	0	0	0	0	1	5
AMERICAN PIPIT	0	0	0	0	0	0	0	0	0	0	0	0	0
WILSON'S WARBLER	0	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW-RUMPED WARBLER	0	0	0	0	0	0	0	0	0	0	0	0	0
MACGILLIVRAY'S WARBLER	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRRHULOXIA	23	11	15	26	46	77	94	15	12	2	0	1	322
BLUE GROSBEAK	0	0	0	0	3	1	1	0	0	0	0	0	5
LAZULI BUNTING	0	0	0	0	0	0	0	0	0	0	0	0	0
GREEN-TAILED TOWHEE	0	0	0	0	0	0	0	0	0	0	0	0	0
RUFOUS-SIDED TOWHEE	0	0	0	0	0	0	0	0	0	0	0	0	0
CANYON TOWHEE	3	0	0	0	2	0	0	0	1	1	0	0	7
GRASSHOPPER SPARROW	0	0	0	0	0	0	0	0	0	0	0	0	0
VESPER SPARROW	0	0	0	0	0	0	0	0	0	0	0	0	0
SONG SPARROW	0	0	0	0	0	0	0	0	0	0	0	0	0
LARK SPARROW	0	0	0	0	0	0	0	0	0	0	0	0	0
BLACK-THROATED SPARROW	53	23	29	38	69	79	69	14	11	7	1	2	395
SAGE SPARROW	4	0	17	2	0	0	0	0	0	7	0	0	30
CASSIN'S SPARROW	0	0	71	84	62	77	48	1	0	3	0	0	346
CHIPPING SPARROW	0	0	0	0	4	0	0	7	0	0	0	0	11
BREWER'S SPARROW	0	0	0	0	2	2	2	0	1	0	0	3	10
DARK-EYED JUNCO	0	0	0	0	0	0	0	0	0	0	1	0	1
WHITE-CROWNED SPARROW	10	0	1	0	0	0	0	0	0	0	0	0	11
YELLOW-HEADED BLACKBIRD	0	0	0	0	2	0	0	1	0	0	0	0	3
RED-WINGED BLACKBIRD	0	0	0	0	0	0	0	0	0	0	0	0	0
BREWER'S BLACKBIRD	0	0	0	39	0	0	0	0	0	0	0	0	39
BROWN-HEADED COWBIRD	0	0	0	0	3	2	6	3	0	0	0	0	14
LARK BUNTING	125	52	80	212	2	0	0	41	18	3	0	0	533
MEADOWLARK	18	13	57	25	24	53	53	7	8	33	4	0	295
SCOTT'S ORIOLE	0	0	0	0	0	0	0	0	0	0	0	0	0
NORTHERN ORIOLE	0	0	0	0	0	5	1	6	2	0	0	0	14
PINE SISKIN	0	0	14	29	1	0	0	0	0	0	0	0	44
AMERICAN GOLDFINCH	0	0	14	95	0	0	0	0	0	0	0	0	109
LESSER GOLDFINCH	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUSE FINCH	38	0	0	0	0	0	0	0	0	0	0	0	38
OBSERVED MONTHLY SUBTOTALS	279	101	311	559	262	345	323	127	67	80	10	22	TOTAL
OBSERVED SPECIES SUBTOTALS	10	5	11	13	15	11	12	11	10	11	5	6	SPECIES OBSERVED
1993 MONTHLY TOTALS	307	120	368	120	695	535	457	227	159	129	27	59	62
1993 SPECIES TOTALS	17	10	23	35	35	29	30	27	31	23	12	13	
1992-93 MONTHLY AVERAGES	1243.0	571.0	579.5	948.5	693.5	570.0	565.5	328.0	240.5	211.0	138.5	171.0	
1992-93 SPECIES AVERAGES	20.0	17.5	26.0	39.5	37.5	28.5	31.5	26.0	29.5	24.0	17.0	20.0	

Note: Species without data were observed in previous years but not in 1993.

Table 6-3
Summary of 1993 Small Nocturnal Mammal Densities

MEASUREMENTS ARE INDIVIDUALS PER 150M X 150M TRAP GRID

	CONTROL GRIDS				WIPP GRIDS			
	CT1	CT2	AVE 1993	AVE 85-92	NW2	SE2	AVE 1993	AVE 85-92
ORD'S KANGAROO RAT	20	NA	NA	25	NA	11	NA	19
SILKY POCKET MOUSE	0	NA	NA	11	NA	0	NA	4
NORTHERN GRASSHOPPER MOUSE	0	NA	NA	7	NA	0	NA	7
PLAINS WOODRAT	21	NA	NA	12	NA	21	NA	6
WHITE-FOOTED MOUSE AND DEER MOUSE	4	NA	NA	.25	NA	4	NA	2
TOTAL DENSITY	45	NA	NA	55	NA	36	NA	38

Table 6 - 4
Actual Captures of Nocturnal Mammals in 1993

	CT1	CT2	AVE 1993	AVE 91-92	NW2	SE2	AVE 1993	AVE 91-92
ORD'S KANGAROO RAT	18	NA	NA	34	NA	10	NA	27
WHITE FOOTED/DEER MOUSE	4	NA	NA	.25	NA	4	NA	3
PLAINS POCKET MOUSE	0	NA	NA	6	NA	0	NA	3
GRASSHOPPER MOUSE	0	NA	NA	5	NA	0	NA	3
PLAINS WOOD RAT	12	NA	NA	9	NA	15	NA	6
HISPID COTTON RAT	0	NA	NA	2	NA	0	NA	4

NOTE: 1993 AVERAGES ARE NOT INCLUDED AS THE DATA SET IS INCOMPLETE.

Table 6-5
WIPP 1993 Fall Vegetation Report

TREE, SHRUB, CACTI, YUCCA	ACRO	* CONTROL 1 COVER	FREQ	DENS	* CONTROL 2 COVER	FREQ	DENS
WESTERN SOAPBERRY	SASA	0.00	0.00	0.00	0.06	0.26	0.00
HONEY MESQUITE	PRGL	0.54	1.72	0.00	2.06	8.86	0.00
SHINNERY OAK	QUHA	6.59	21.03	0.00	8.00	34.41	0.00
THREAD-LEAF SAGE WORT	ARFI	1.66	5.30	0.00	0.00	0.00	0.00
SOUTHWEST RABBITBRUSH	CHPU	0.00	0.00	0.00	0.00	0.00	0.00
PLAINS YUCCA	YUCA	1.61	5.14	0.00	0.45	1.93	0.00
PERENNIAL FORBS							
DUNE FLATSEDGE	CYON	0.49	1.56	0.00	0.00	0.00	0.00
PRAIRIE SPIDER-WORT	TROC	0.10	0.32	0.00	0.00	0.00	0.00
LEATHER-WEED CROTON	CRPO	2.22	7.09	0.00	0.00	0.00	0.00
SMOOTH OXYBAPHUS	OXGL	0.26	0.83	0.00	0.16	0.69	0.00
WOOLLY DALEA	DALA	0.12	0.38	0.00	0.56	2.41	0.00
CUTLEAF GOLDENWEED	MAPI	0.14	0.45	0.00	0.00	0.00	0.00
PLAINS BLACKFOOT	MELE	0.90	2.87	0.00	0.00	0.00	0.00
PERENNIAL GRASSES							
SANDBUR	CEIN	2.39	7.63	0.00	1.04	4.47	0.00
FALL WITCHGRASS	LECO	2.26	7.21	0.00	3.15	13.55	0.00
MESA DROPSEED	SPFL	0.00	0.00	0.00	0.49	2.11	0.00
GIANT DROPSEED	SPGI	0.22	0.70	0.00	1.41	6.06	0.00
SAND PASPALUM	PAST	1.01	3.22	0.00	0.86	3.70	0.00
PURPLE THREE-AWN	ARPU	8.70	27.77	0.00	2.30	9.89	0.00
LOVEGRASS (SESSILISPICA)	ERSE	0.16	0.51	0.00	1.05	4.52	0.00
RED LOVEGRASS	EROX	0.72	2.30	0.00	0.00	0.00	0.00
GRASS COTYLEDON		0.04	0.13	0.00	0.00	0.00	0.00
ANNUAL FORBS							
TEXAS CROTON	CRTE	0.19	0.61	0.05	1.31	5.63	0.25
PRAIRIE SPURGE	EUMI	0.31	0.99	0.20	0.00	0.00	0.00
RIDGE-SEED SPURGE	EUGL	0.04	0.13	0.05	0.00	0.00	0.00
BINDWEED HELIOTROPE	HECO	0.00	0.00	0.00	0.22	0.95	0.15
ANNUAL WILD-BUCKWHEAT	ERAN	0.06	0.19	0.05	0.00	0.00	0.00
YELLOW WOOLLY-WHITE (BIENNL)	HYFL	0.12	0.38	0.05	0.00	0.00	0.00
ANNUAL SUNFLOWER	HEAN	0.42	1.34	0.05	0.06	0.26	0.05
GOLDEN CROWNBEARD	VEEN	0.06	0.19	0.05	0.00	0.00	0.00
ANNUAL GRASS							
FALSE BUFFALO GRASS	MUSQ	0.00	0.00	0.00	0.07	0.30	0.10

* ACRONYM: 4 letter abbreviation of the scientific name COVER: Foliar cover in percent FREQUENCY: Percent of sample DENSITY: Annual plants per square meter

TREE, SHRUB, CACTI, YUCCA	ACRO	* NORTHWEST 1 COVER	FREQ	DENS	COVER	* NORTHWEST 2 FREQ	DENS
HONEY MESQUITE	PRGL	0.00	0.00	0.00	0.02	0.06	0.00
SHINNERY OAK	QUHA	7.16	24.17	0.00	9.42	28.90	0.00
THREAD-LEAF SAGE WORT	ARFI	3.41	11.51	0.00	3.59	11.01	0.00
SOUTHWEST RABBITBRUSH	CHPU	0.16	0.54	0.00	0.12	0.37	0.00
YELLOW EVENING PRIMROSE	CASE	0.12	0.40	0.00	0.12	0.37	0.00
PLAINS YUCCA	YUCA	0.00	0.00	0.00	0.94	2.88	0.00
PLAINS PRICKLYPEAR	OPPO	0.00	0.00	0.00	0.04	0.12	0.00
PERENNIAL FORBS							
DUNE FLATSEDGE	CYON	0.00	0.00	0.00	0.12	0.37	0.00
SMOOTH OXYBAPHUS	OXGL	0.00	0.00	0.00	0.10	0.31	0.00
WOOLLY DALEA	DALA	0.00	0.00	0.00	0.30	0.92	0.00
THREADLEAF SENECIO	SELO	0.00	2.00	0.00	0.25	0.77	0.00
RIDDELL SENECIO	SESP	0.80	2.70	0.00	0.00	0.00	0.00
PERENNIAL GRASSES							
SANDBUR	CEIN	6.40	21.60	0.00	2.92	8.96	0.00
FALL WITCHGRASS	LECO	3.11	10.50	0.00	5.60	17.18	0.00
MESA DROPSEED	SPFL	0.12	0.40	0.00	0.00	0.00	0.00
GIANT DROPSEED	SPGI	2.87	9.69	0.00	1.19	3.65	0.00
LITTLE BLUESTEM	ANSC	0.00	0.00	0.00	1.87	5.74	0.00
SAND PASPALUM	PAST	1.04	3.51	0.00	1.20	3.68	0.00
PURPLE THREE-AWN	ARPU	4.50	15.19	0.00	1.94	5.95	0.00
BLACK GRAMA	BOER	0.00	0.00	0.00	0.57	1.75	0.00
LEHMANNS' LOVEGRASS	ERLE	0.00	0.00	0.00	0.30	0.92	0.00
LOVEGRASS (SESSILISPICA)	ERSE	0.06	0.20	0.00	0.00	0.00	0.00
GRASS COTYLEDON		0.00	0.00	0.00	0.02	0.06	0.00
ANNUAL FORBS							
TEXAS CROTON	CRTE	0.06	0.20	0.05	0.25	0.77	0.20
PRAIRIE SPURGE	EUMI	0.16	0.54	0.05	0.71	2.18	0.65
RIDGE-SEED SPURGE	EUGL	0.06	0.20	0.05	0.74	2.27	1.75
BINDWEED HELIOTROPE	HECO	0.12	0.40	0.05	0.00	0.00	0.00
ANNUAL WILD-BUCKWHEAT	ERAN	0.00	0.00	0.00	0.12	0.37	0.10
NEALLEY BEE-BLOSSOM	GASU	0.00	0.00	0.00	0.19	0.58	0.05
LIMONCILLO	PETE	0.19	0.64	0.05	0.00	0.00	0.00
ANNUAL GRASS							
FALSE BUFFALO GRASS	MUSQ	0.00	0.00	0.00	0.07	0.21	0.15

* ACRONYM: 4 letter abbreviation of the scientific name COVER: Foliar cover in percent FREQUENCY: Percent of sample DENSITY: Annual plants per square meter

Table 6-5
(Continued)
WIPP 1993 Fall Vegetation Report

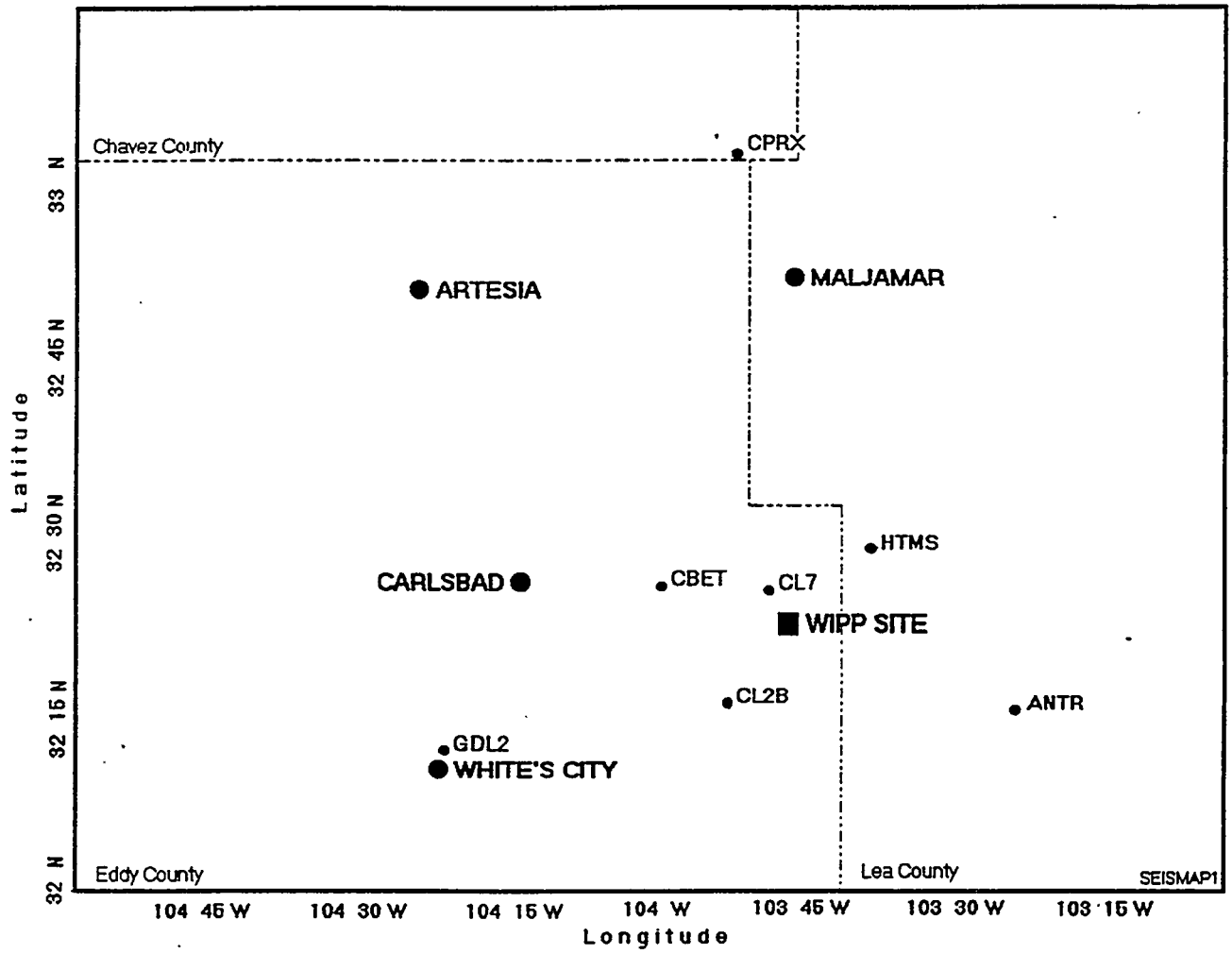
TREE, SHRUB, CACTI, YUCCA	ACRO	* SOUTHEAST 1 COVER	FREQ	DENS	COVER	* SOUTHEAST 2 FREQ	DENS
HONEY MESQUITE	PRGL	5.75	20.17	0.00	0.81	3.07	0.00
SHINNERY OAK	QUHA	7.44	28.10	0.00	7.96	30.16	0.00
THREAD-LEAF SAGE WORT	ARFI	2.97	10.42	0.00	3.54	13.41	0.00
PLAINS YUCCA	YUCA	0.00	0.00	0.00	1.79	6.78	0.00
PERENNIAL FORBS							
LEATHER-WEED CROTON	CRPO	0.06	0.21	0.00	0.00	0.00	0.00
SMOOTH OXYBAPHUS	OXGL	0.06	0.21	0.00	0.00	0.00	0.00
WOOLLY DALEA	DALA	0.06	0.21	0.00	0.19	0.72	0.00
SLENDER GREENTHREAD	THSI	0.19	0.67	0.00	0.00	0.00	0.00
THREADLEAF SENECIO	SELO	0.00	0.00	0.00	0.12	0.46	0.00
PERENNIAL GRASSES							
SANDBUR	CEIN	1.94	6.80	0.00	1.57	5.95	0.00
FALL WITCHGRASS	LECO	0.06	0.21	0.00	3.77	14.29	0.00
MESA DROPSEED	SPFL	1.56	5.47	0.00	0.00	0.00	0.00
GIANT DROPSEED	SPGI	0.44	1.54	0.00	1.10	4.17	0.00
LITTLE BLUESTEM	ANSC	0.56	1.96	0.00	0.00	0.00	0.00
SAND PASPALUM	PAST	0.35	1.23	0.00	0.70	2.65	0.00
PURPLE THREE-AWN	ARPU	3.70	12.96	0.00	3.10	11.75	0.00
BLACK GRAMA	BOER	0.00	0.00	0.00	0.22	0.83	0.00
LEHMANNS' LOVEGRASS	ERLE	0.04	0.14	0.00	0.00	0.00	0.00
LOVEGRASS (SESSILISPICA)	ERSE	0.06	0.21	0.00	0.00	0.00	0.00
RED LOVEGRASS	EROX	0.85	2.98	0.00	0.12	0.46	0.00
ANNUAL FORBS							
TEXAS CROTON	CRTE	0.25	0.88	0.05	0.06	0.23	0.05
PRAIRIE SPURGE	EUMI	0.42	1.47	0.20	0.25	0.95	0.10
RIDGE-SEED SPURGE	EUGL	1.30	4.56	2.25	0.35	1.33	0.30
BINDWEED HELIOTROPE	HECO	0.00	0.00	0.00	0.06	0.23	0.05
ANNUAL WILD-BUCKWHEAT	ERAN	0.00	0.00	0.00	0.40	1.52	0.25
WINGED PIGWEED	CYAT	0.19	0.67	0.05	0.00	0.00	0.00
NEALLEY BEE-BLOSSOM	GASU	0.00	0.00	0.00	0.06	0.23	0.05
LIMONCILLO	PETE	0.22	0.77	0.30	0.00	0.00	0.00
ANNUAL GRASS							
FALSE BUFFALO GRASS	MUSQ	0.04	0.14	0.05	0.22	0.83	0.10

* ACRONYM: 4 letter abbreviation of the scientific name COVER: Foliar cover in percent FREQUENCY: Percent of sample DENSITY: Annual plants per square meter

TREE, SHRUB, CACTI, YUCCA	ACRO	* EAST 1 COVER	FREQ	DENS
HONEY MESQUITE	PRGL	5.75	21.66	0.00
SHINNERY OAK	QUHA	5.90	22.43	0.00
THREAD-LEAF SAGE WORT	ARFI	1.75	6.65	0.00
PLAINS YUCCA	YUCA	3.03	11.52	0.00
PERENNIAL FORBS				
LEATHER-WEED CROTON	CRPO	0.41	1.56	0.00
WOOLLY DALEA	DALA	0.56	2.13	0.00
PLAINS BLACKFOOT	MELE	0.44	1.67	0.00
THREAD-LEAF BROOMWEED	XAMI	1.69	6.42	0.00
PERENNIAL GRASSES				
SANDBUR	CEIN	1.36	5.17	0.00
FALL WITCHGRASS	LECO	0.41	1.56	0.00
MESA DROPSEED	SPFL	0.62	2.36	0.00
SAND PASPALUM	PAST	0.54	2.05	0.00
PURPLE THREE-AWN	ARPU	3.22	12.24	0.00
HAIRY GRAMA	BOHI	0.12	0.46	0.00
PLAINS BRISTLEGRASS	SEMA	0.25	0.95	0.00
ANNUAL FORBS				
TEXAS CROTON	CRTE	0.06	0.23	0.05
PRAIRIE SPURGE	EUMI	0.16	0.61	0.15
RIDGE-SEED SPURGE	EUGL	0.04	0.15	0.05
ANNUAL GRASS				

* ACRONYM: 4 letter abbreviation of the scientific name COVER: Foliar cover in percent FREQUENCY: Percent of sample DENSITY: Annual plants per square meter

Figure 6-3
WIPP Seismograph Station Locations



Definitions of Acronyms

ANTR - Antelope Ridge
CBET - Carlsbad East Tower
CL2B - Carlsbad Station 2B
CL7 - Carlsbad Station 7
CPRX - Caprock
GDL2 - Guadalupe Mountains
HTMS - Hat Mesa

CHAPTER 7

GROUNDWATER SURVEILLANCE

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Chapter 7
Groundwater Surveillance

Current groundwater surveillance activities at the WIPP are outlined in the WIPP groundwater *Monitoring Program Plan and Procedure Manual* (WP 02-1, Rev 2). WP 02-1, Rev. 2, is a Quality Assurance document that contains program plans for each of the activities performed by groundwater surveillance personnel. Detailed procedures for performing specific activities such as pumping system installations, field parameter analysis, and document and QA records management are also contained in WP 02-1, Rev 2. Groundwater surveillance activities are also defined in the EMP.

The objective of the Groundwater Surveillance Program (GSP) is to determine the physical and chemical characteristics and maintain surveillance of groundwater levels of the groundwater surrounding the WIPP facility, both before and throughout the operational lifetime of the facility. The GSP also fulfills the requirements set forth in DOE Order 5400.1.

Background water quality data were collected from the 1985 through the 1990 sampling period. DOE/WIPP 92-013, "Background Water Quality Characterization Report for the Waste Isolation Pilot Plant," evaluates the background water quality data from the 1985 through the 1990 sampling period. This background data will be compared to water quality data collected throughout the operational life of the facility. Pre-operational data will be gathered in the interim period and utilized to strengthen the background data and to evaluate the need to make adjustments to comparison criteria. Data generated by groundwater surveillance programs are also useful in determining future regulatory needs and land use decisions, and in updating information for site documents such as the EMP.

The data obtained by the Water Quality Sampling Program (WQSP) in 1993 supported three major programs at the WIPP: (1) site characterization; (2) performance assessment (in compliance with 40 CFR 191); and (3) the EMP. Each of these programs requires a unique set of analyses and data, but overlap of analytical needs does occur. Particular sample needs are defined by each program. In addition to the characterization of groundwater the WQSP supported radionuclide monitoring for the Environmental Analysis and Compliance section of the WID. Results of radionuclide sampling are discussed in chapter 5 of this report. The NMED was on hand at each sampling event to collect samples for independent evaluation.

The WIPP is located within the Pecos Valley section of the Southern Great Plains physiographic province (Powers et al., 1978). The primary industries in the area that could contribute to pollution of the groundwater are local potash mining, gas and oil drilling, and cattle ranching. Geologic and lithologic descriptions of the area surrounding the WIPP site can be found in documents such as the

EMP, DOE/WIPP 90-008, *Groundwater Protection Management Program Plan*, or USGS 83-4016 (Mercer, 1983).

The rock units that were sampled in 1993 are in descending order; the Dewey Lake Redbeds and the Culebra dolomite. Fluids from these rock units have been collected either from wells at the WIPP or from privately owned wells (windmills). Groundwater sampling at WIPP focuses on the Culebra dolomite Member of the Rustler Formation. The Culebra dolomite is the most significant water bearing unit within the vicinity of the WIPP. No known hydrologic connection exists between the repository horizon and the Culebra dolomite. Surveillance of the characteristics of the water contained in the Culebra dolomite is beneficial to the WIPP because it provides data that can be used to determine if the characteristics of water in the Culebra are changing. It also provides additional data for use in hydrologic models designed to predict long-term performance of the repository (i.e., the Performance Assessment).

Groundwater surveillance activities during 1993 consisted of two separate programs: groundwater quality sampling and groundwater level measurements. Groundwater surveillance programs utilize 58 well bores to gather data. Six of these well bores are equipped with production inflated packers that allow groundwater to be sampled from more than one producing zone through the same well bore.

Groundwater quality data were gathered from 10 well locations. Data were collected at eight locations completed in the Culebra dolomite and from two privately owned wells in the vicinity of the WIPP that are completed in the Dewey Lake Redbeds.

The water quality sampling process has been developed around the logistics of using groundwater wells that were originally constructed for characterization and not for groundwater monitoring activities. The WIPP site has been given a conditional No-Migration Determination and is not required to have a monitoring program in compliance with the RCRA. The original wells are therefore being used for surveillance. Most of the wells are constructed with J-55 or K-55 iron casing In order to decrease the sampling bias created by well construction deficiencies, combined with the low transmissibilities of the formations involved, a labor intensive sampling process has been initiated. Because of the time required to collect representative samples and because of the number of wells to be sampled, wells are sampled only once per year. A sampling episode is referred to as a "sampling round." Each yearly sampling round consists of the collection of two types of samples: serial samples and final samples. Serial samples are taken periodically, while the well is being purged. Data on key physical and chemical parameters (known as field parameters) are collected and compared to past serial sampling data until it is determined that a chemical steady state has been

reached. A chemical steady state is usually defined as +\- 5% of the average of the three to five preceding parameter measurements on the final day of serial sampling from previous sampling rounds. Stabilization of these field parameters is a function of purging and is used as an indicator to determine if the groundwater is representative of the zone being sampled. A final sample is collected once it has been determined that the pumped groundwater has achieved a representative state. This sample is sent off-site to a contract laboratory for analysis.

7.1 Groundwater Quality

Sampling for groundwater quality was performed at 10 well locations including two privately owned well sites during 1993 (Figure 7-1). With the exception of the two privately owned wells, each well was purged a minimum of 24 hours prior to the commencement of the serial sampling phase of the purging process. Field analyses for Oxidation Reduction Potential (Eh), pH, Specific Gravity, Specific Conductance, Alkalinity, Chloride, Divalent Cations, and Total Iron were performed on a periodic basis during serial sampling. These field parameters were used as indicators, during the purging process to better determine when the formation water being pumped had reached a representative state. Normally this process required seven to ten days to complete. Following the field analysis of the final serial sample, samples were collected and shipped to an independent, contract laboratory for analysis. Parameters of analyzed by the contract laboratory are listed in Table 7-1.

The total gallons of water removed from the Culebra dolomite member of the Rustler Formation during 1993 as a result of groundwater surveillance activity was approximately 22,732 gallons. The data from the final sample analyses show relative consistency when compared to background data. Tables 7-2 through 7-9 contain average results of data collected from the Culebra dolomite during 1993 as compared to background data for major constituents of the background matrix. None of the waste stream Volatile Organic Compounds for which analyses were run showed any detectable concentrations.

Water quality of the Culebra in the vicinity of the WIPP is naturally poor and the waters are not suitable for human consumption or for agricultural purposes. The waters contain naturally high concentrations of total dissolved solids and mineral constituents, primarily chloride, calcium, magnesium, sodium and potassium (Mercer, 1983). Although a number of wells within the vicinity of WIPP contain less than 10,000 mg/l Total Dissolved Solids (TDS) the chloride and sulfate concentrations in these wells are well above limits set by water quality standards. The generally poor quality of the waters has historically posed a problem when it comes to analyzing these waters because it tends to interfere with the performance of standard laboratory equipment such as the Atomic Absorption or the Inductive Coupled Atomic Plasma, causing detection limits to be inconsistent.

The only usable water in the area of the WIPP is from wells completed in the Dewey Lake Redbeds, which produce water from discontinuous saturated zones of thin lenticular sands that are believed to be locally recharged (Mercer 1983). The water quality of the Dewey Lake Redbeds are generally considered to be fresh water, suitable for agricultural purposes and marginal for human consumption. Two wells were sampled in the Dewey Lake Redbeds, these were: Ranch well, located approximately 3 and 2 tenths miles south of the WIPP site, and Barn well, located approximately 3 and 4 tenths miles south of the WIPP site. Each of these wells showed elevated levels of nitrate in the groundwater analysis. Ranch well showed the highest average concentration (16.9 mg/l) and the Barn well concentration was 10.5 mg/l. The most probable source of these nitrate concentrations are the large numbers of livestock that utilize these wells for drinking water. A comparison of 1993 analytical data results to background data are presented in Tables 7-10 and 7-11 for data collected from the Dewey Lake formation.

7.2 Groundwater Level Surveillance

In October 1988, WID was tasked with conducting a groundwater level surveillance program in the area of the WIPP site. Fifty-eight well bores were used to sample six water bearing zones in the WIPP area. The two zones of primary interest were the Culebra dolomite and Magenta dolomite members of the Rustler Formation: forty-six measurements were taken in the Culebra dolomite and 11 measurements were taken in the Magenta dolomite. Two measurements were taken in the Rustler/Salado contact and Dewey Lake formation; one measurement each was taken in the Bell Canyon, the Forty-niner and the Unnamed Lower Member. Locations of groundwater-level surveillance sites are pictured in Figure 7-2.

Groundwater elevation measurements in the Culebra dolomite indicate that the generalized directional flow of groundwater is north to south in the vicinity of WIPP (Figure 7-3). However, caution should be used when making assumptions based on groundwater-level data alone; studies in the Culebra dolomite have shown that fluid density variations in the Culebra dolomite can affect flow direction (Crawley, 1988 and Davies, 1989). One should also be aware that the fractured media of the Culebra dolomite coupled with variable fluid densities can cause localized flow patterns to have little or no relationship to general flow patterns (Mercer, 1983 and Crawley, 1988).

Groundwater flow directions in the Magenta dolomite appear to be generally from an east to west direction across the WIPP site (Figure 7-4). Studies have not been performed to determine spacial variations in the fluid densities in the Magenta dolomite to the same magnitude as those the Culebra dolomite. It is very possible if not likely that density variations do occur in the Magenta dolomite. Therefore, the potential may exist that to some extent flow patterns in the Magenta dolomite may be

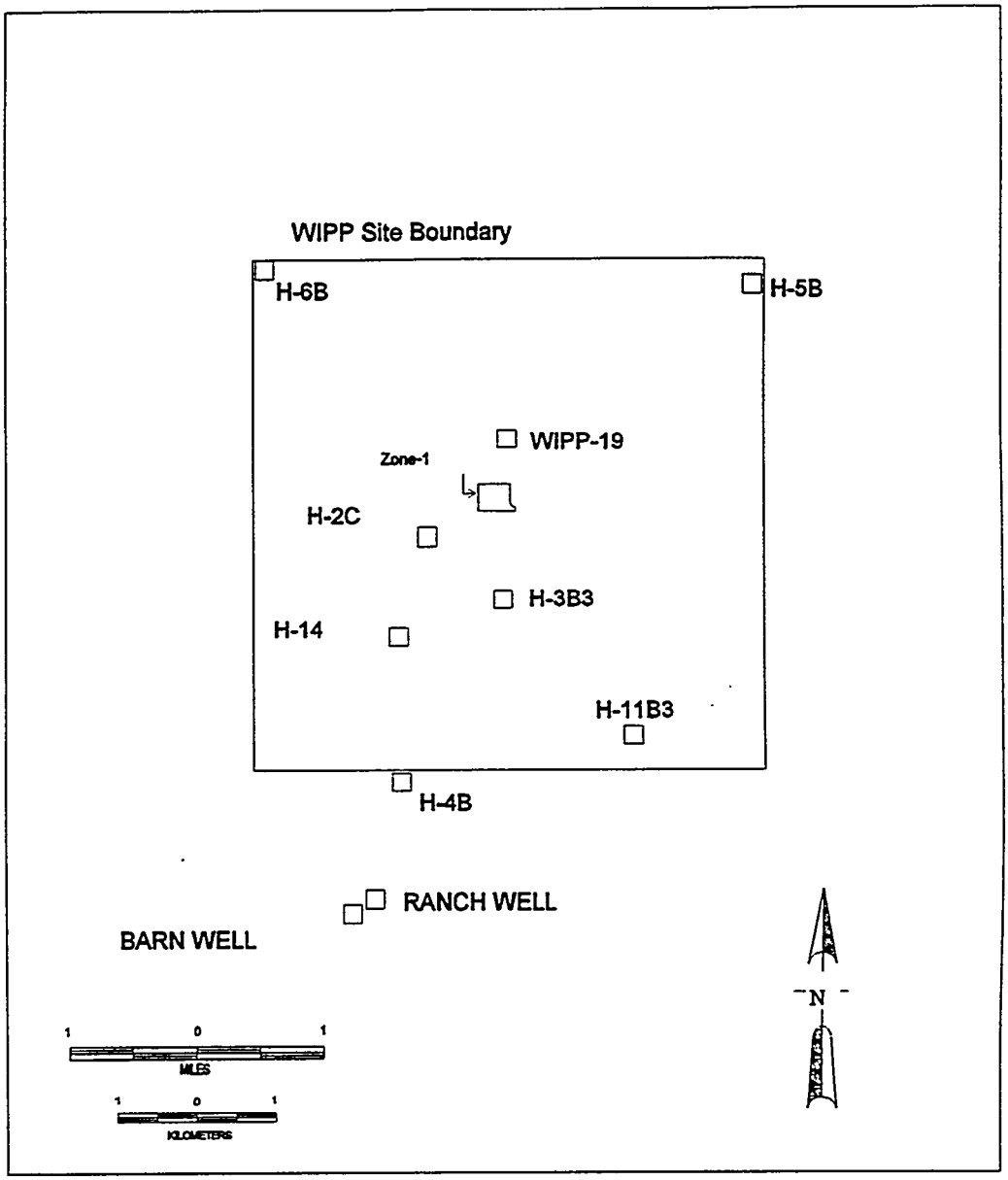
affected by variations in fluid density. Also flow through the fractured media of the Magenta dolomite may well dictate the behavior of localized flow patterns.

Groundwater level measurements taken in 1993 show a general trend toward rising water levels. The increase in water levels may be attributed to the natural recovery of water bearing formations near the WIPP to levels near those noted by Mercer in 1983. Mercer's 1983 report was produced prior to the onset of large-scale pumping tests that removed huge volumes of water from the Magenta and Culebra members of the Rustler Formation from 1984 through 1988. Also, the grouting of the four shafts that provide access to the WIPP underground has recently been completed, sealing off the inflow of water from these formations into the shaft area. Significant recovery of the Magenta and Culebra members in the immediate vicinity of the WIPP will probably occur in CY 1994 due to the completion of the grouting process.

Table 7-1

Parameters Analyzed During Calendar Year 1993

Specific Conductance	Boron
Sulfate	Cadmium
Total Dissolved Solids	Calcium
Total Suspended Solids	Chromium
Density	Iron
pH	Lead
Alkalinity	Lithium
Bromide	Magnesium
Chloride	Mercury
Fluoride	Potassium
Iodide	Selenium
Nitrogen, NO_3 (AS N)	Silica
Total Organic Carbon	Silver
Total Organic Halogens	Sodium
Phenol, Total	Carbon Tetrachloride
Orthophosphate (AS P)	Methylene Chloride
Arsenic	Trichloroethylene
Barium	1,1,1-Trichloroethane
Beryllium	Freon-113



WATER QUALITY SAMPLING PROGRAM

FIGURE 7-1 SAMPLE WELLS 1993

Table 7-2
H-02c, Culebra
Round 5 Comparison To Background Characterization

Parameter	1993 Average Concentration (mg/l)	Background Concentration Interval (mg/l)
Boron	9.75	9-12
Calcium	603	589-841
Iron	0.37	0-1.9
Lithium	0.229	0.26-0.72
Magnesium	185	152-181
Potassium	86	86-119
Sodium	1,775	0-5,270
Alkalinity	45.2	52-60
Bromide	9.17	0-5
Chloride	3,060	2,396-6,737
Fluoride	2.21	2.1-2.2
pH	7.38	7.38-8.04
Sulfate	2,700	2,061-3,806
Total Dissolved Solids	9,285	7,612-15,689
Arsenic	<0.003	≤0.014
Barium	0.006	<0.05
Beryllium	<0.0025	<0.05
Cadmium	<0.0025	≤0.08
Chromium	<0.01	≤0.4
Lead	<0.025	≤0.5
Mercury	<0.002	<0.0002
Selenium	<0.002	<0.05
Silica	12	6.1-14
Silver	<0.025	≤0.20
Iodide	<1.0	1-9
Nitrate as (N)	<0.10	≤0.30
Phenolics	<0.1	≤0.097
Phosphate AS (P)	<0.02	≤0.03
Total Organic Carbon	1.26	5-7
Total Organic Halogen	0.0166	≤0.14

Table 7-3
H-03b3, Culebra
Round 8 Comparison To Background Characterization

Parameter	1993 Average Concentration (mg/l)	Background Concentration Interval (mg/l)
Boron	22.5	19-32
Calcium	1,210	1,193-1,527
Iron	0.36	0.14-0.47
Lithium	0.54	0.15-0.82
Magnesium	621	710-826
Potassium	448	372-534
Sodium	12,100	16,140-17,900
Alkalinity	41	46-54
Bromide	26.6	7-41
Chloride	27,600	26,742-30,838
Fluoride	1.27	1.5-1.6
pH	7.32	6.85-7.66
Sulfate	5,275	4,537-4,823
Total Dissolved Solids	52,500	53,130-55,170
Arsenic	<0.003	<0.10
Barium	<0.005	≤0.06
Beryllium	<0.028	≤0.15
Cadmium	0.002	≤0.07
Chromium	<0.005	0.007-0.4
Lead	<0.016	≤0.50
Mercury	<0.0002	<0.001
Selenium	<0.003	<0.50
Silica	9.83	4.5-13
Silver	<0.013	≤0.10
Iodide	<1.0	<2.0
Nitrate as (N)	<0.10	<0.20
Phenolics	<0.10	≤0.033
Phosphate AS (P)	<0.02	≤0.06
Total Organic Carbon	0.70	≤2.0
Total Organic Halogen	0.048	0.14-0.42

Table 7-4
H-04b, CULEBRA
Round 8 Comparison To Background Characterization

Parameter	1993 Average Concentration (mg/l)l	Background Concentration Interval (mg/l)
Boron	14.2	14-21
Calcium	669	604-741
Iron	<1.00	0.40-0.55
Lithium	0.398	0.25-0.58
Magnesium	339	385-468
Potassium	173.5	179-261
Sodium	5,270	5,625-6,255
Alkalinity	49.4	51-72
Bromide	40.3	31-83
Chloride	7,350	1,968-12,099
Fluoride	1.82	1.7-2.2
pH	7.27	6.30-7.82
Sulfate	6,300	4,447-6,513
Total Dissolved Solids	20,600	17,010-23,050
Arsenic	<0.003	<0.10
Barium	<0.02	<0.10
Beryllium	<0.01	<0.05
Cadmium	0.0045	<0.005
Chromium	<0.01	<0.30
Lead	0.0278	<0.05
Mercury	<0.0002	<0.0017
Selenium	<0.005	<0.05
Silica	11.6	5.6-14
Silver	0.11	<0.10
Iodide	<1.14	<2.0
Nitrate AS (N)	<0.20	<0.10
Phenolics	<0.10	<0.026
Phosphate AS (P)	<0.02	<0.03
Total Organic Carbon	0.59	3.0-5.0
Total Organic Halgen	0.0198	0.06-0.64

TABLE 7-5
H-05b, CULEBRA
Round 8 Comparison To Background Characterization

Parameter	1993 Average Concentration (mg/l)	Background Concentration Interval (mg/l)
Boron	27.1	28-35
Calcium	1,305	1,205-1,875
Iron	1.38	1.8-3.2
Lithium	0.84	0.6-1.3
Magnesium	1,670	1,586-2,094
Potassium	883	1,014-1,362
Sodium	41,200	44,526-55,955
Alkalinity	30.9	39-47
Bromide	68.1	24-99
Chloride	84,500	84,085-91,835
Fluoride	0.77	0.7-1.2
pH	7.08	6.88-7.11
Sulfate	8,595	5,914-7,646
Total Dissolved Solids	149,500	142,508-164,093
Arsenic	<0.006	<0.1
Barium	<0.02	<0.5
Beryllium	<0.01	<0.05
Cadmium	<0.0006	<0.11
Chromium	<0.0025	<0.3
Lead	0.009	<1.0
Mercury	<0.002	<0.0005
Selenium	<0.006	<7.3
Silica	5.99	<21
Silver	<0.0063	<0.1
Iodide	3.61	<2.0
Nitrate AS (N)	0.10	<0.4
Phenolics	<0.10	<0.51
Phosphate AS (P)	<0.02	<0.13
Total Organic Carbon	3.79	<4.0
Total Organic Halogen	0.059	<7.6

Table 7-6
H-06b, Culebra
Round 8 Comparison To Background Characterization

Parameter	1993 Average Concentration (mg/l)	Background Concentration Interval (mg/l)
Boron	11.4	7.7-10.7
Calcium	2,140	1,702-2,138
Iron	<2.40	0.2-0.6
Lithium	<0.68	0.3-0.7
Magnesium	1,009	791-1,085
Potassium	356	330-556
Sodium	17,450	14,230-17,710
Alkalinity	80	91-101
Bromide	36.7	12-62
Chloride	31,550	28,816-34,462
Fluoride	1.28	1.2-1.5
pH	6.87	6.18-7.37
Sulfate	5,220	3,093-3,527
Total Dissolved Solids	61,450	56,831-64,569
Aresenic	<0.005	<0.5
Barium	<0.09	<0.1
Beryllium	<0.055	0.05
Cadmium	<0.002	<0.05
Chromium	<0.003	0.22-0.45
Lead	<0.01	<0.83
Mercury	<0.001	<0.0012
Selenium	<0.005	<1.3
Silica	17.4	8.3-25
Silver	<0.004	<0.1
Iodide	<1.0	<2.0
Nitrate AS (N)	<0.25	<0.2
Phenolics	<0.10	0.004-0.016
Phosphate AS (P)	<0.02	<0.02
Total Organic Carbon	1.94	<7.0
Total Organic Halogen	0.29	0.16-3.0

Table 7-7
H-11b3, Culebra
Round 7 Comparison To Backround Characterization

Parameter	1993 Average Concentration (mg/l)	Background Concentration Interval (mg/l)
Boron	27.1	29-31
Calcium	1,145	1,329-1,655
Iron	1.41	<1.0
Lithium	0.979	0.5-0.6
Magnesium	848	1,038-1,272
Potassium	1,010	654-990
Sodium	28,650	35,169-45,432
Alkalinity	42.6	44-58
Bromide	48.4	18-90
Chloride	64,000	57,063-72,497
Fluoride	<.50	1.0-1.2
pH	7.39	6.95-7.22
Sulfate	7,405	5,843-7,397
Total Dissolved Solids	114,500	113,705-123,095
Arsenic	<0.003	<0.15
Barium	0.014	<0.10
Beryllium	0.004	<0.05
Cadmium	<0.0013	0.06-0.09
Chromium	<0.005	0.32-.40
Lead	0.018	<0.60
Mercury	<0.002	<0.0004
Selenium	<0.003	<0.50
Silica	5.84	4.1-15
Silver	0.019	0.1-0.2
Iodide	1.15	<2.0
Nitrate AS (N)	<1.0	<0.30
Phenolics	<0.10	<0.02
Phosphate AS (P)	<0.02	<0.04
Total Organic Carbon	1.63	<3.0
Total Organic Halogen	0.069	<1.5

Table 7-8
H-14, Culebra
Round 6 Comparison To Background Characterization

Parameter	1993 Average Concentration mg/l	Background Concentration Interval mg/l
Boron	9.06	11
Calcium	1,655	1,504-2,129
Iron	1.56	0.1-0.8
Lithium	0.396	.039-0.56
Magnesium	515	451-613
Potassium	211	233-257
Sodium	2,955	2,750-4,184
Alkalinity	28.2	35-43
Bromide	13.6	9-18
Chloride	9,050	6,954-9,779
Fluoride	2.22	0.1-2.6
pH	7.53	5.89-8.50
Sulfate	2,025	1,209-2,291
Total Dissolved Solids	18,100	14,066-19,867
Arsenic	<0.003	<0.05
Barium	0.012	<0.05
Beryllium	<0.0027	<0.05
Cadmium	0.0015	<0.06
Chromium	<0.005	0.2-0.4
Lead	<0.0132	<0.5
Mercury	<0.002	<0.0004
Selenium	<0.003	<0.05
Silica	10.95	5.5-14
Silver	<0.013	<0.1
Iodide	1.67	<2.0
Nitrate as (N)	< .20	<0.40
Phenolics	<0.10	0.068-0.14
Phosphate AS (P)	<0.02	<0.05
Total Organic Carbon	1.07	<2.0
Total Organic Halogen	0328	0.08-1.1

Table 7-9
WIPP-19, Culebra
Round 8 Comparison To Background Characterization

PARAMETER	1993 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
Boron	27.8	27-34
Calcium	1,385	1,441-1,919
Iron	1.95	<2.0
Lithium	0.45	0.3-1.1
Magnesium	917	961-2,239
Potassium	508	565-913
Sodium	22,900	23,962-32,658
Alkalinity	46.0	51-70
Bromide	41.1	22-126
Chloride	41,850	33,201-54,520
Fluoride	1.04	0.8-1.1
pH	7.05	6.75-7.33
Sulfate	5,560	5,097-5,763
Total Dissolved Solids	75,650	68,389-103,151
Arsenic	<0.003	<0.5
Barium	<0.02	<0.50
Beryllium	<0.01	<0.50
Cadmium	<0.001	<0.50
Chromium	<0.003	<2.0
Lead	<0.01	<5.0
Mercury	<0.05	<0.002
Selenium	<0.003	<0.50
Silica	8.18	<4.40
Silver	<0.01	<1.0
Iodide	2.06	<2.0
Nitrate AS (N)	<0.25	<0.12
Phenolics	<0.1	<0.019
Phosphate AS (P)	<0.02	<0.03
Total Organic Carbon	2.64	2-7
Total Organic Halogen	133	0.57-3.2

Table 7-10
Barn Well, Dewey Lake
Round 7 Comparison To Background Characterization

Parameter	1993 Average Concentration mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
Calcium	52.4	47-85
Manganese	<0.13	<0.015
Sodium	80.9	74-142
Alkalinity	200	262-291
Chloride	36.0	32-49
Fluoride	1.87	2.5-2.7
pH	7.10	6.37-8.17
Sulfate	141	167-246
Total Dissolved Solids	545	606-729
Aresnic	<.003	<0.05
Barium	0.026	<0.2
Cadmium	<0.006	<0.005
Chromium	<0.01	≤0.02
Copper	<0.025	≤0.03
Lead	<0.25	<0.05
Mercury	<0.002	<0.0002
Selenium	<0.002	<0.05
Silver	0.0275	<0.01
Zinc	<0.05	≤0.03
Nitrate AS (N)	10.45	7.1-9.6
Phenolics	<0.10	<0.008
Total Organic Carbon	0.865	≤4.0
Total Organic Halogen	0.08	≤0.15

Table 7-11
Ranch Well, Dewey Lake
Round 8 Comparison To Background Characterization

Parameter	1993 Average Concentration mg/l	Background Concentration Interval mg/l
Calcium	601	283-397
Magnesium	<0.013	<0.015
Sodium	182	115-270
Alkalinity	143	215-256
Chloride	268	318-470
Fluoride	1.17	0.7-1.5
pH	7.31	6.75-7.58
Sulfate	1575	700-1299
Total Dissolved Solids	3580	2818-3302
Arsenic	<0.003	<0.01
Barium	0.0060	<0.20
Cadmium	0.003	≤0.01
Chromium	<0.01	≤0.07
Copper	<0.025	<0.025
Lead	<0.026	≤0.08
Mercury	<0.002	≤0.0008
Selenium	<0.002	≤0.079
Silver	<0.025	≤0.02
Zinc	<0.05	0.02-0.16
Nitrate AS (N)	16.9	110-120
Phenolics	<0.1	≤0.022
Total Organic Carbon	0.19	3-4
Total Organic Halogen	0.045	≤0.4

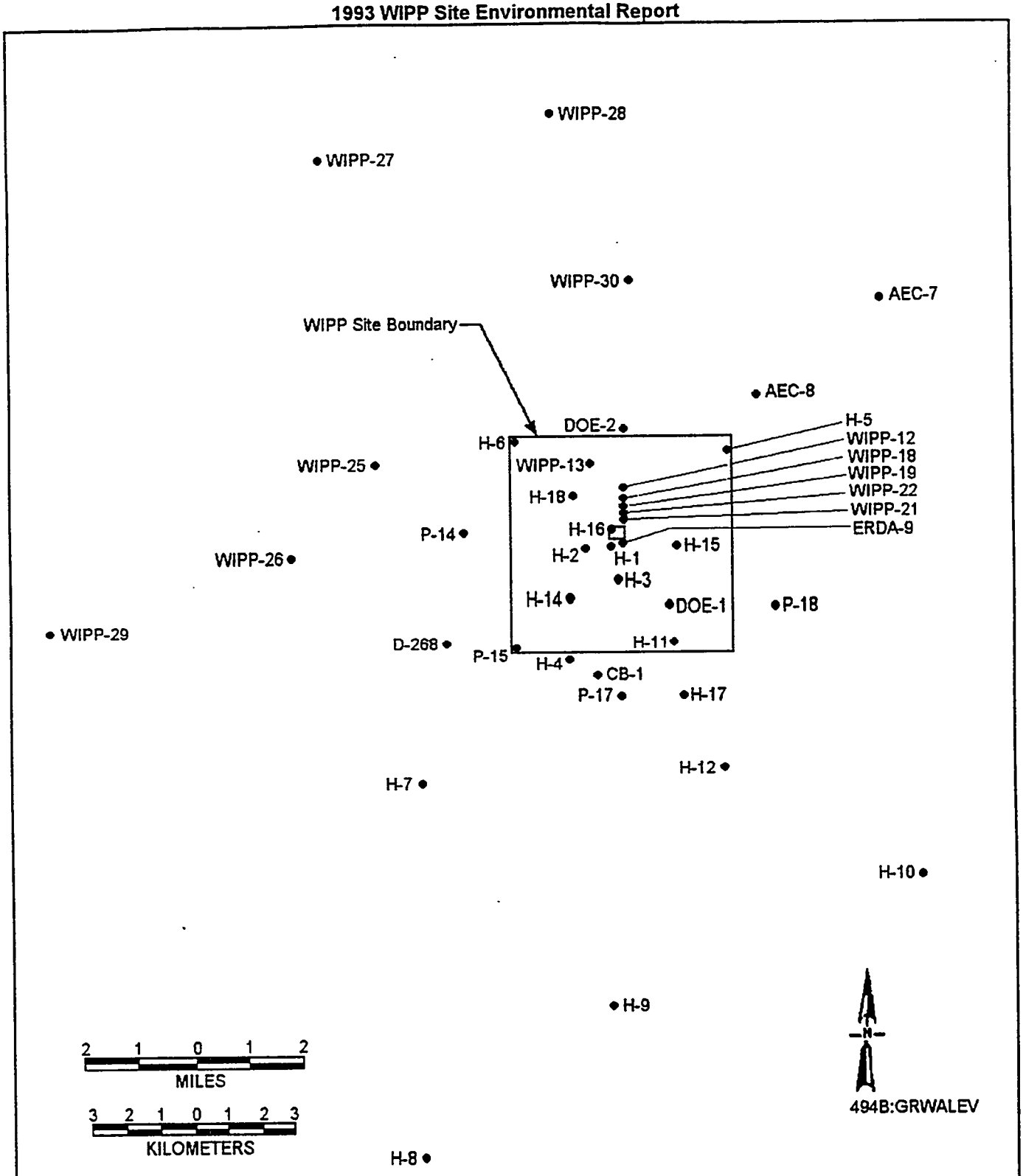


Figure 7-2
Ground Water Level Surveillance Wells

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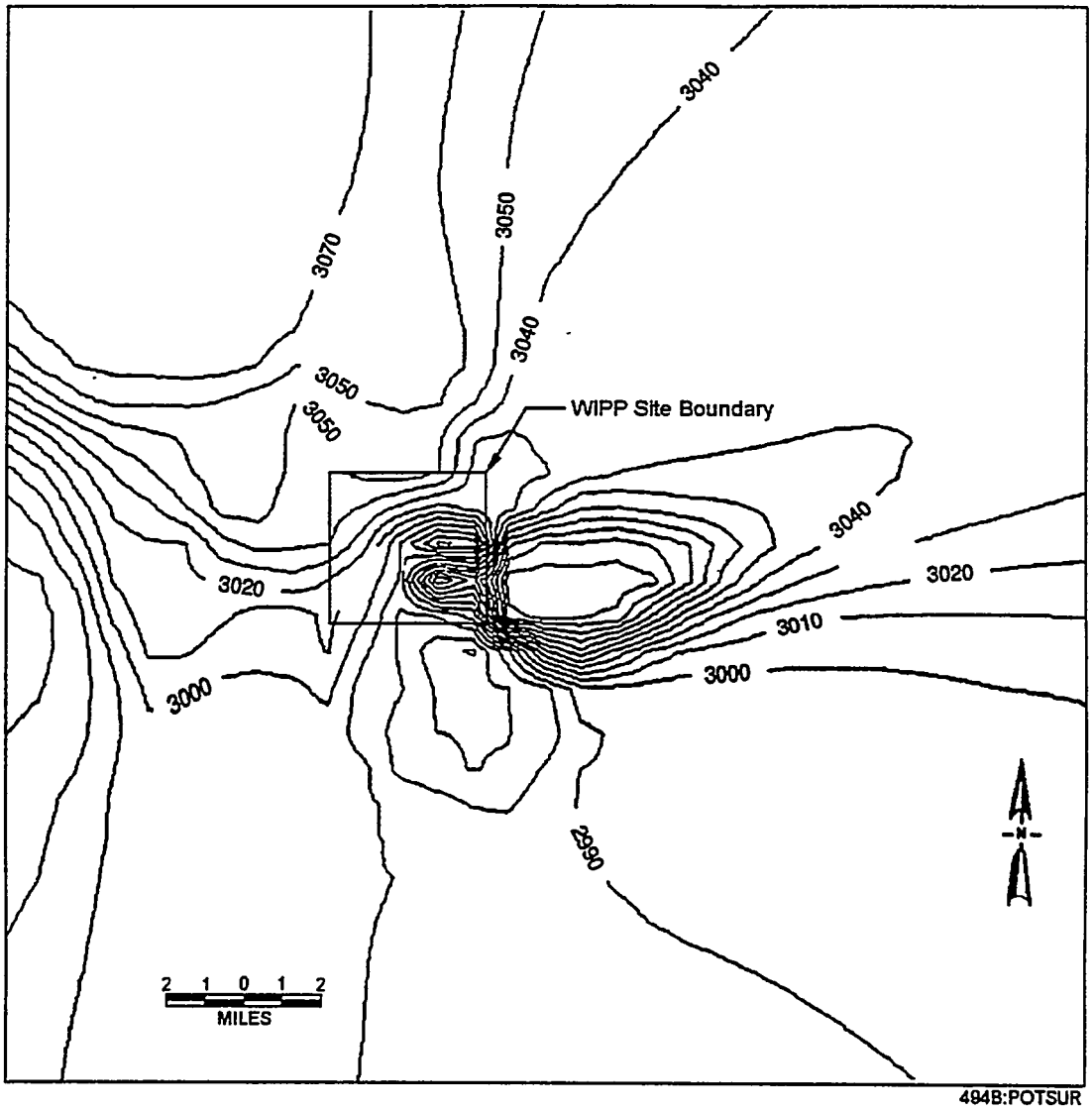

Figure 7-3
Potentiometric Surface of the Culebra Dolomite Member
of the Rustler Formation near the WIPP Site

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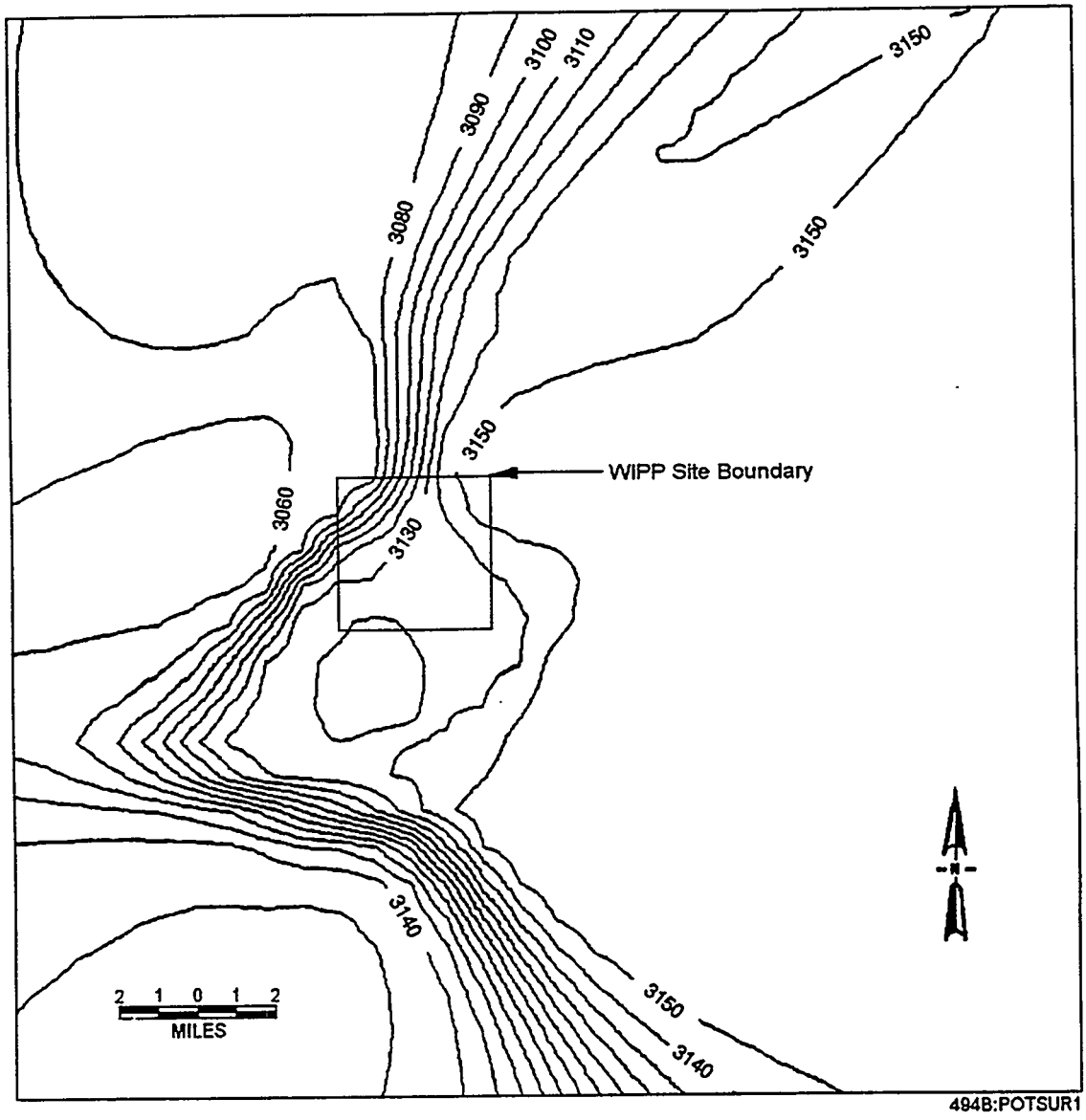

Figure 7-4
Potentiometric Surface of the Magenta Dolomite Member
of the Rustler Formation near the WIPP Site as of 12-93

CHAPTER 8

QUALITY ASSURANCE

Chapter 8
Quality Assurance

This chapter outlines the Quality Assurance/Quality Control goals and procedures for the radiological and nonradiological monitoring programs at the WID and at the off-site subcontractor laboratories. The purpose of the program is to monitor the reliability, accuracy, and precision of all data, and to detect and correct problems in the sample collection, preparation, analysis, and the data evaluation phases.

QA comprises all of the planned and programmed events undertaken to ensure the validity of the results of the monitoring program. Included in the QA Program is the QC task specific and provides a context for assessing the performance of equipment, instruments, and procedures. The QA/QC program for the WIPP environmental programs is established within the framework of the overall *Quality Assurance Program Manual* of the Westinghouse Electric Corporation, Waste Isolation Division.

A comprehensive QA program has been implemented to ensure that the data collected reflect actual concentrations in the environment and have been obtained prior to commencement of operations. In other words, these data must provide a sound baseline for comparison with operational-phase data that reflect potential impacts of the WIPP. The focus of this program includes:

Collect samples at all locations according to procedures based on accepted practices and widely recognized methodologies and criteria

Review and revise procedures as appropriate to minimize uncertainty due to sampling error while maintaining comparability and continuity between past and future data

Verify data through a continuing program of analytical laboratory quality control, including the performance of inter-laboratory cross-checks, duplicate sample/split radiological analysis, and sample splits provided to the EEG, and NMED.

Adherence to policies set forth by federal QA regulations include the following: ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME, 1989); EPA; QAMS-005/80, *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA, 1980); DOE Orders 5400.1 (DOE, 1990d), 5400.3 (DOE, 1989), 5700.6C (DOE, 1991); and the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T, 1991).

8.1 Sample Collection Methodologies

Written procedures are important because they not only provide guidance to field personnel for samples collected in the field but also form the basis of an auditable program. To ensure compliance with the written procedures, the QA Department periodically conducts surveillance, inspection, and internal audits. An inspection report surveys personnel performance in one activity. A surveillance assesses a procedure according to specifications and standards described in WP 13-011. An internal audit, which is a more comprehensive investigation, evaluates the adequacy and effectiveness of the QA program's implementation, related procedure's, and practices. An audit may include review of procedures, file management, and test equipment. Audits are conducted according to WP 13-005.

Sampling procedures are contained in the following documents:

WIPP Groundwater Monitoring Program Plan and Procedure Manual (WP 02-1)
WIPP Environmental Procedures Manual (WP 02-3)
WID Quality Assurance Program Description (WP 13-1, Rev. 14)

Sampling procedures describe the methods for determining sample location, the timing of collection, equipment calibration, shipment method, and the specific steps to be taken for sample collection, analysis, and shipment. The sampling procedures also provide program requirements for data entry, sample tracking, and record-keeping. These procedures ensure that the data collected and entered accurately reflect conditions at the WIPP site. Standard sample location codes are used for reporting results for all environmental programs.

The current guiding document provides details on the sampling procedures and cites the document containing those procedures. Chapter 11 of the EMP defines the policies and practices that are followed to ensure the data are accurate, complete, representation, and comparable.

The data collected in the NES monitoring programs are analyzed as stated in DOE/EH-0023 (Corley et al., 1981). Section 8.0 of the EMP discusses at length the statistical procedures used to analyze the data.

Following the policies and procedures outlined in the various documents above, the WIPP conducted one internal audit and seven QA surveillances in 1993 on the environmental programs at the WIPP. These evaluations resulted in seven program deficiency reports (PDRs) being issued. To date, six of the PDRs have been closed out and the final PDR will be closed out in September 1994.

8.2 Revision of Procedures

One of the responsibilities of data collection personnel is to assess collection and analysis methodologies. Field procedures, analytical procedures, and laboratory methodologies are periodically scrutinized for adequacy. Procedures and methodologies that require modification are modified according to the criteria set forth in WP 15-101. Additionally, radiological samples are split with the EEG and the NMED to act as a check that procedures are adequate and that data results are comparable among the WIPP, the EEG, and the NMED samples. All procedure manuals are reviewed regularly, updated, and expanded as necessary.

8.3 Interlaboratory Comparisons

The WIPP Low-Level Counting Laboratory (LLCL) participated in the DOE Environmental Measurements Laboratory (EML) Quality Assessment Program (QAP). The DOE-EML QAP not only provides an external method of ensuring the quality of LLCL analysis, but also provides a method for demonstrating the LLCL's analytical capabilities.

The EML measures its performance as the ratio of a laboratory's reported results to its results. Results are categorized as falling within the accepted ratio range of 0.8-1.2, 0.5-1.5 and, outside the accepted ratio range (0.5-1.5). The LLCL fell within the accepted 0.8-1.2 range for all analytical results reported.

Only analysis of water and air filters for gamma emitting nuclides was performed due to the lack of sample preparation facilities at the WIPP site. The WIPP is in the process of obtaining a modular sample preparation laboratory. Once the laboratory is installed the WIPP will have the on-site capability to perform actinide analysis and preparation of sample matrix other than water and air filters. The WIPP anticipates participation in the DOE-EML QAP for more variety of sample matrices will further demonstrate the analytical abilities of the LLCL.

The WIPP was accepted for participation in the Environmental Protection Agency Intercomparison Program in the fall of 1993. This program will serve as an additional method of ensuring the quality of the analyses performed by the LLCL.

8.4 Laboratory Quality Control

During CY93 the WIPP extended contracts to the following analytical laboratories:
Ross Analytical Services Inc. in Strongsville, Ohio, and Accu-Labs. in Golden, Colorado.

These laboratories must adhere to and provide evidence of the following compliance with the ASME NQA-1:

Routine calibration of instruments

- Frequent source and background counts (as appropriate)
- Routine yield determinations of radiochemical procedures
- Replicate/duplicate, and blank analyses to check precision
- Analyses of reagents to ensure chemical purity that could affect the results of the analytical process
- Each laboratory will have a written and implemented QA program that utilizes standard analysis methods for each parameter studied.
- Participation in interlaboratory cross-checks can reveal outdated, previously acceptable lab procedures that are currently unsuitable or inadequate. Steps are then taken to find updated methodologies. The laboratories providing chemical analytical services for the WIPP are required to participate in interlaboratory cross-checks conducted by the EPA.

8.5 Record Keeping

Records generated in support of the EMP are controlled and maintained in accordance with DOE Order 1324.2A, *Records Description* (DOE, 1992), and *WIPP Records Management Procedure* (WP 15-030). All original records are maintained in fire resistant file cabinets until they are transmitted to the WIPP Project Records Services (PRS) for permanent filing (WP 15-030). All records including raw data, calculations, computer programs, or other data manipulation media are subject to review and verification under the WIPP Quality Assurance Program. The Environmental Monitoring Section is responsible for validating of these records before transmitting them to the PRS center in accordance with the Records Inventory Disposition Schedule.

Records (i.e., reports of analyses and sample receipt forms transmitted by contract analytical laboratories) are dated upon receipt and a copy made for QC review as specified in *NES/RES QA/QC Implementation Procedures* (WP 02-302). Specific record and data management procedures including those referencing data manipulations are implemented according to the WIPP Groundwater

Monitoring Program Plan and Procedures Manual, "RES Data Management Procedure" (WP 02-305), and *NES Data Management Procedure* (WP 02-334).

The WIPP complies with record-keeping requirements issued under 40 CFR Part 61, Subpart H (EPA, 1985B), which pertain to atmospheric radionuclide emissions (WP 02-301). In addition unless regulations are amended in the future, records development pursuant to these criteria (i.e., Medical, Health and Safety Records) will be maintained at least 30 years as specified in DOE 1324.2A (DOE, 1992), Chapter V, Attachment 1, Schedule 25.

Consistent record-keeping in all aspects of the Environmental Monitoring Programs are a part of QA requirements. Section 10 of the EMP lists of the required records and reports and the laws, regulations, or DOE Orders that contain the requirements. Records are maintained in accordance with WP 15-030, Records Management.

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CHAPTER 9

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Chapter 9
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CHAPTER 10

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Carlsbad, NM 88220

APPENDIX

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Appendix 1

Gross Alpha and Beta Concentrations Reported by Location

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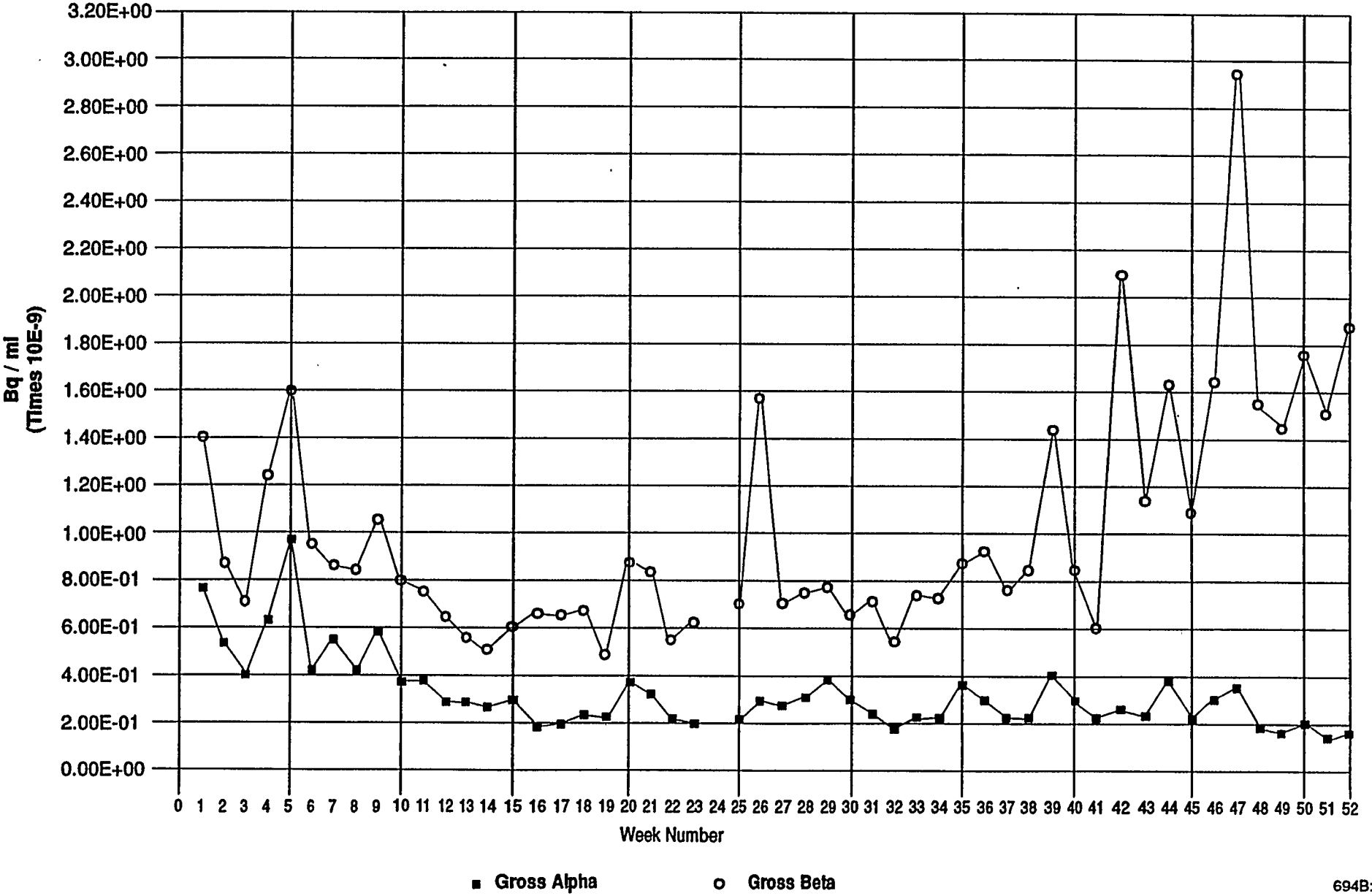
Carlsbad

1993 Gross Alpha / Gross Beta



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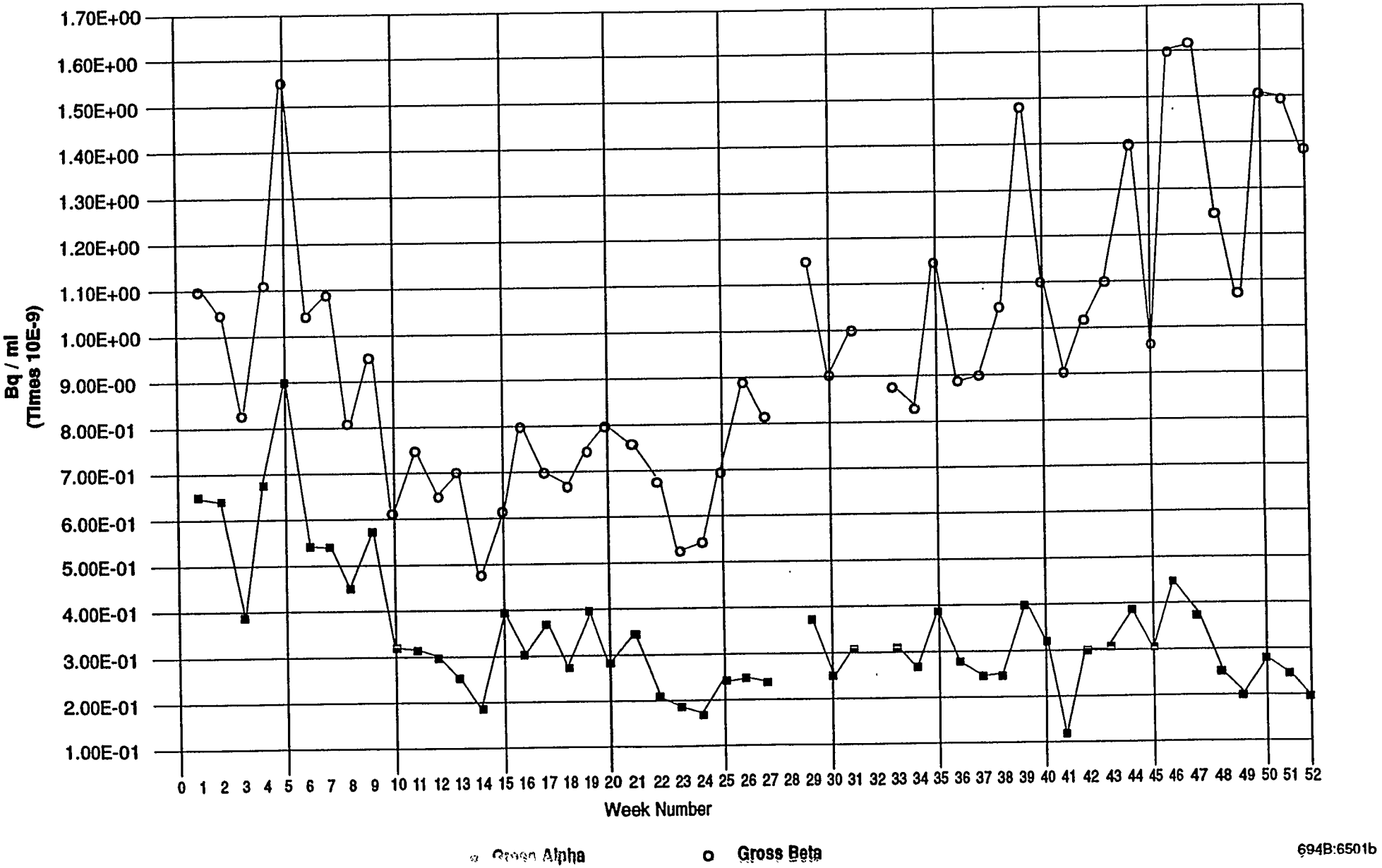
Eunice

1993 Gross Alpha / Gross Beta



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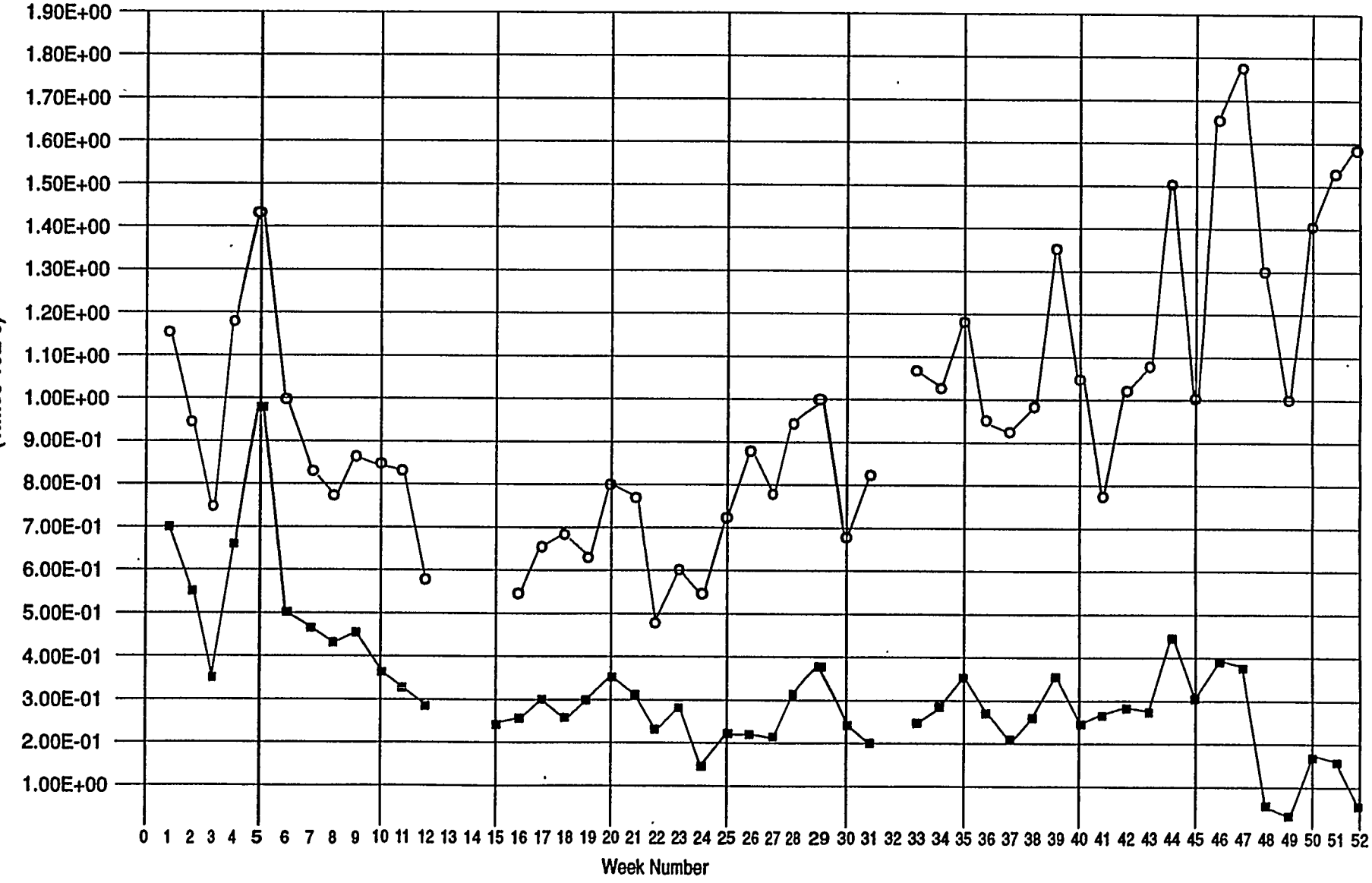
Mills Ranch

1993 Gross Alpha / Gross Beta



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Smith Ranch

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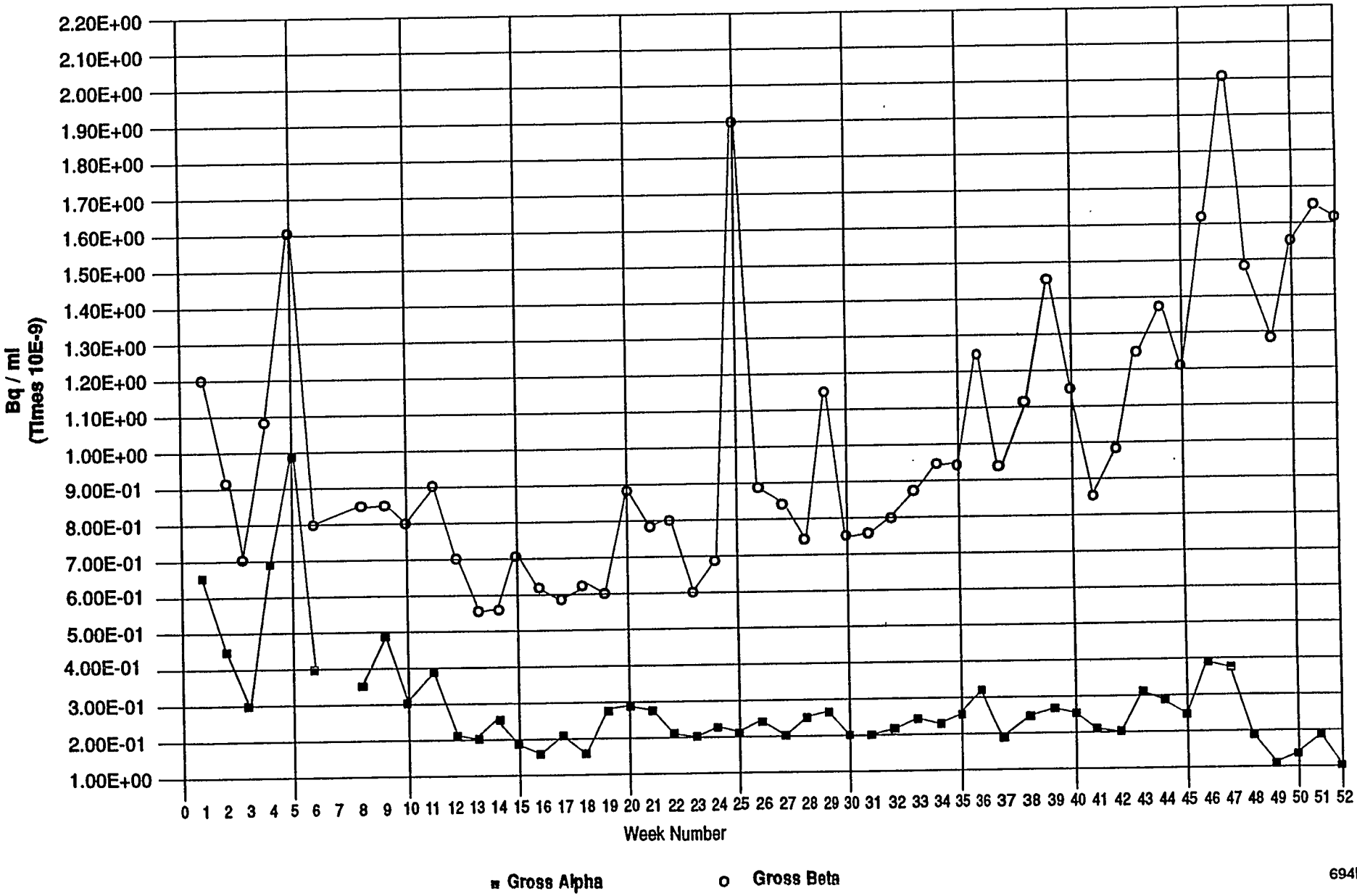

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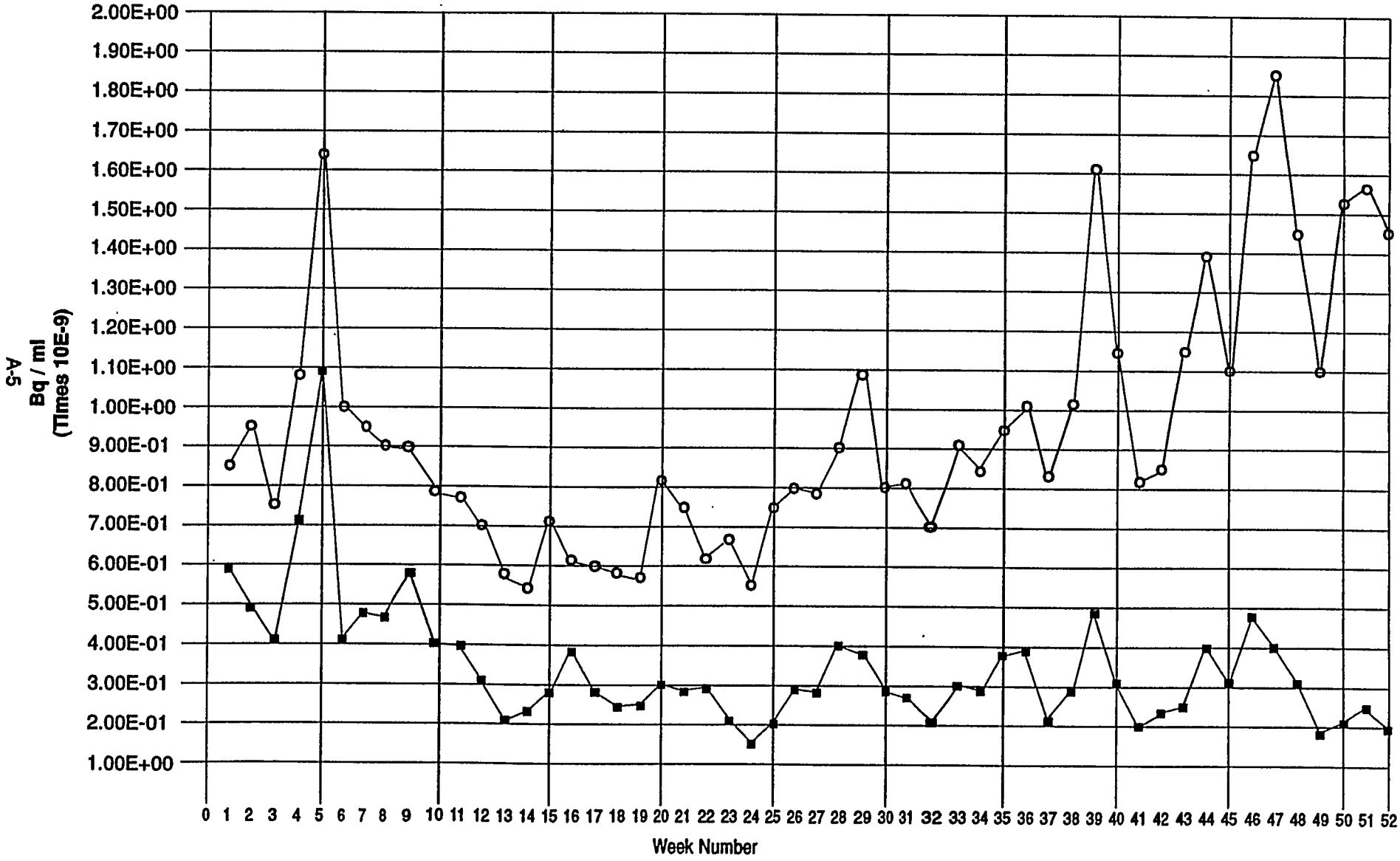
WIPP East

1993 Gross Alpha / Gross Beta



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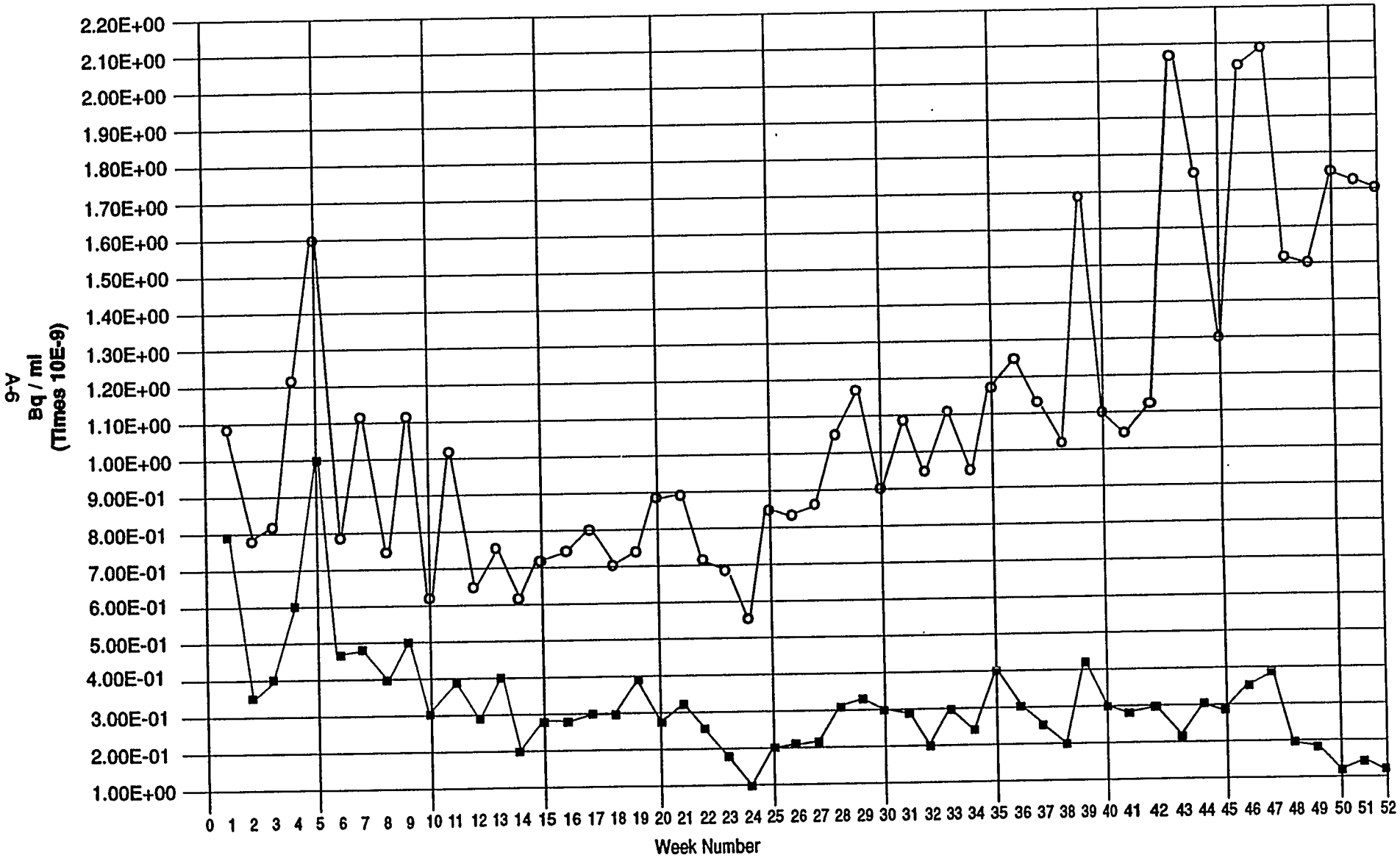
WIPP Far Field

1993 Gross Alpha / Gross Beta



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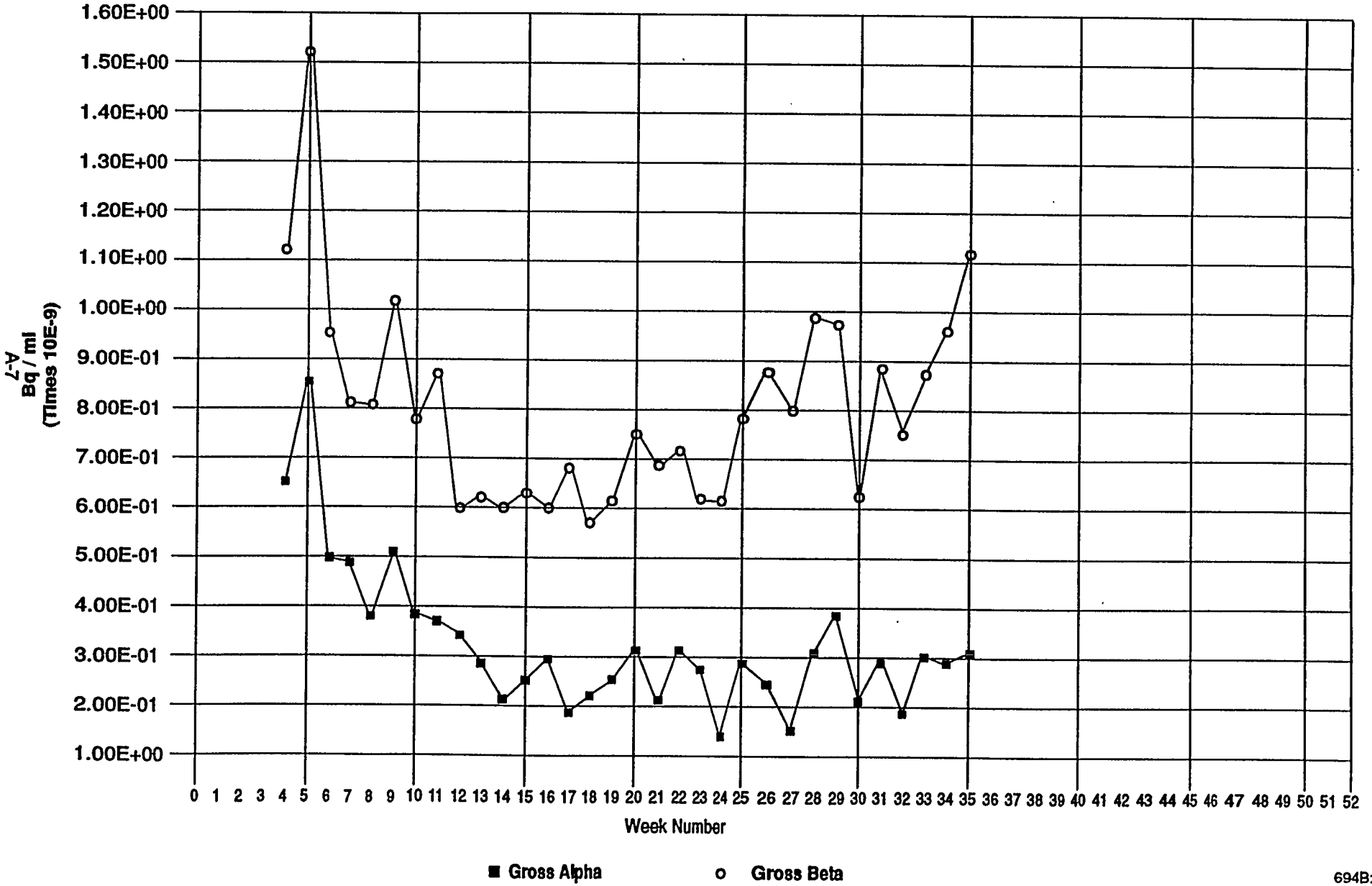
WIPP South

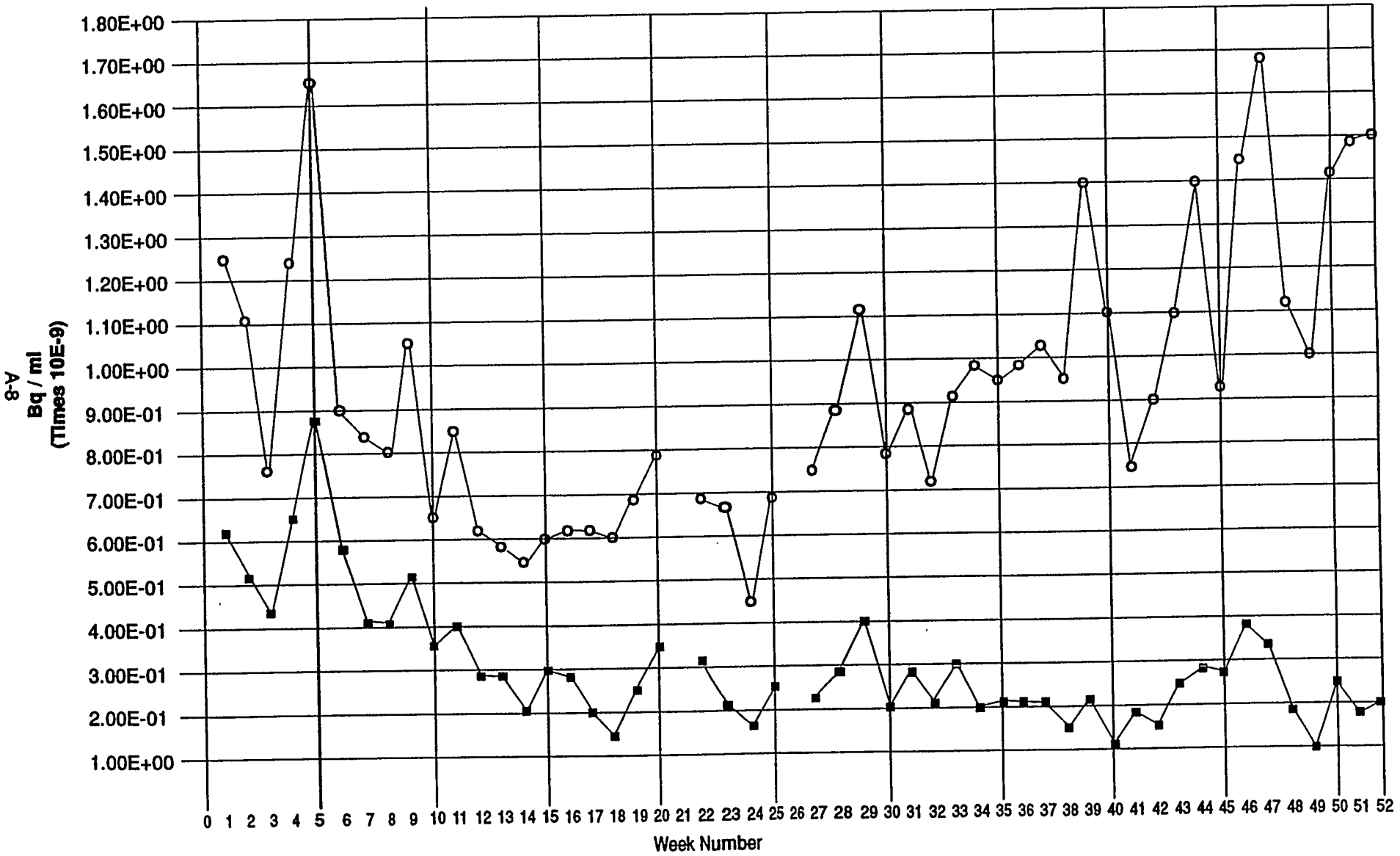
1993 Gross Alpha / Gross Beta



694B:6501

South East Control

1993 Gross Alpha / Gross Beta



694B:6501c

METRIC FRACTIONS

Multiple	Decimal Equivalent	Prefix	Symbol
10^6	1,000,000	mega-	M
10^3	1,000	kilo-	k
10^2	100	hecto-	h
10	10	deka-	da
10^{-1}	0.1	deci-	d
10^{-2}	0.01	centi-	c
10^{-3}	0.001	milli-	m
10^{-6}	0.000001	micro-	µ
10^{-9}	0.000000001	nano-	n
10^{-12}	0.000000000001	pico-	p
10^{-15}	0.000000000000001	femto-	f
10^{-18}	0.000000000000000001	atto-	a

METRIC CONVERSION TABLE

Multiply	By	Equals	Multiply	By	Equals
in.	2.54	cm	cm	0.394	in.
ft	0.305	m	m	3.28	ft
ac	0.404	ha	ha	2.47	ac
mi	1.61	km	km	0.621	mi
lb	0.4536	kg	kg	2.205	lb
liq. qt. - U.S.	0.946	l	l	1.057	liq. qt. - U.S.
ft^2	0.093	m^2	m^2	10.764	ft^2
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.31	ft^3
d/m	0.450	pCi	pCi	2.22	d/m
pCi/l (water)	10^{-9}	µCi/ml (water)	µCi/ml (water)	10^9	pCi/l (water)
pCi/m^3 (air)	10^{-12}	µCi/cc (air)	µCi/cc (air)	10^{12}	pCi/m^3 (air)

TRADITIONAL AND INTERNATIONAL SYSTEMS OF RADIOLOGICAL UNITS

(Traditional units are in parentheses.)

Quantity	Name	Symbol	Expression in Terms of Other Units
absorbed dose	Gray	Gy	J/Kg^{-1}
	(rad)	rad	10^{-2} Gy
activity	Becquerel	Bq	1 dps
	(curie)	Ci	3.7×10^{10} Bq
dose equivalent	Sievert	Sv	J/Kg^{-1}
	(rem)	rem	10^{-2} Sv
exposure	Coulomb per kilogram		C/Kg^{-1}
	(roentgen)	R	2.58×10^{-4} C/Kg-1

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APPENDIX D5
ENVIRONMENTAL MONITORING PLAN AT THE
WASTE ISOLATION PILOT PLANT

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DOE/WIPP 94-024

WASTE ISOLATION PILOT PLANT

Environmental Monitoring Plan

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This document is issued by Westinghouse Electric Corporation, Waste Isolation Division, as the Management and Operating Contractor for the Department of Energy, Waste Isolation Pilot Plant, Carlsbad, New Mexico, 88221.

DOE CONTRACT NUMBER: DE-AC04-86AL31950

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TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

2.0 PROJECT DESCRIPTION 2-1

3.0 SITE CHARACTERISTICS 3-1
3.1 GEOGRAPHY 3-1
3.2 GEOLOGY 3-1
3.3 CLIMATOLOGY 3-1
3.4 HYDROLOGY 3-2
3.5 ECOLOGY 3-2
3.6 DEMOGRAPHY 3-3

4.0 DOSE CALCULATIONS 4-1
4.1 GENERAL 4-1
4.2 PATHWAY ANALYSIS 4-2
4.2.1 Exposure Pathways 4-2
4.3 CONSEQUENCE ANALYSIS 4-3
4.3.1 Overview of CAP88-PC 4-3
4.3.2 Stack Effluent Monitoring and Modeling 4-4
4.3.3 Meteorological Modeling 4-4
4.3.4 Dispersion Modeling 4-4
4.3.5 Terrestrial Modeling 4-5
4.3.6 Dose Modeling 4-5
4.3.7 Regulatory Compliance 4-6
4.3.8 Release and Dose Consequence Assessment 4-6

5.0 ENVIRONMENTAL MONITORING PROGRAM 5-1
5.1 GUIDELINES 5-1
5.2 SITE CHARACTERIZATION 5-3
5.2.1 WIPP Biology Program 5-3
5.2.2 United States Geological Survey (USGS) Studies 5-3
5.2.3 Project Gnome 5-4
5.3 RADIOLOGICAL ENVIRONMENTAL MONITORING 5-4
5.3.1 Effluent Monitoring - Liquid Releases 5-4
5.3.2 Effluent Monitoring - Airborne Emissions 5-6
5.3.3 External Radiation 5-6
5.3.4 Airborne Particulates 5-7
5.3.5 Vegetation 5-9
5.3.6 Beef 5-9
5.3.7 Game Animals 5-9
5.3.8 Soil Sampling 5-9
5.3.9 Surface/Drinking Water 5-9

TABLE OF CONTENTS
(CONTINUED)

5.3.10 Groundwater 5-10
5.3.11 Aquatic Foodstuffs 5-11
5.3.12 Sediment Sampling 5-11
5.4 NONRADIOLOGICAL ENVIRONMENTAL MONITORING 5-11
5.4.1 Meteorological Monitoring 5-12
5.4.2 Volatile Organic Compound Monitoring Program 5-12
5.4.3 Airborne Gases 5-14
5.4.4 Ecological Monitoring Plot Selection 5-14
5.4.5 Aerial Photography 5-15
5.4.6 Salt Impact Studies 5-15
5.4.6.1 Surface Photography 5-15
5.4.6.2 Soil Chemistry 5-16
5.4.6.3 Vegetation Survey 5-16
5.4.6.4 Vertebrate Census 5-16

6.0 SAMPLE HANDLING AND LABORATORY PROCEDURES 6-1
6.1 SAMPLE HANDLING 6-1
6.2 RADIOLOGICAL ENVIRONMENTAL SURVEILLANCE 6-2
6.3 NONRADIOLOGICAL ENVIRONMENTAL MONITORING 6-3

7.0 DATA ANALYSES 7-1
7.1 ACCURACY 7-1
7.2 TEMPORAL AND SPATIAL ANALYSIS 7-2
7.3 DISTRIBUTIONS AND DESCRIPTIVE STATISTICS 7-3
7.4 DATA ANOMALIES 7-3
7.5 COMPARISONS AND REPORTING 7-4

8.0 QUALITY ASSURANCE 8-1
8.1 INTRODUCTION 8-1
8.2 GOAL 8-1
8.3 PROGRAM ELEMENTS/CRITERIA 8-3
8.3.1 Program 8-3
8.3.2 Personal Training and Qualification 8-4
8.3.3 Quality Improvement 8-4
8.3.4 Documents and Records 8-4
8.3.5 Work Processes 8-4
8.3.6 Design 8-6
8.3.7 Procurement 8-6
8.3.8 Inspection and Acceptance Testing 8-7
8.3.9 Management Assessment 8-7
8.3.10 Independent Assessment 8-7

TABLE OF CONTENTS
(CONTINUED)

9.0 REQUIRED RECORDS AND REPORTS 9-1
9.1 RECORD KEEPING 9-1
9.2 REPORTING 9-1

10.0 REFERENCES 10-1

LIST OF TABLES

TABLE NO.	TITLE	
4-1	PROJECTED ANNUAL RADIOACTIVITY RELEASED AS A RESULT OF NORMAL CH AND RH OPERATIONS	4-8
4-2	STACK INFORMATION	4-9
4-3	METEOROLOGICAL DATA	4-10
4-4	FREQUENCY OF ATMOSPHERIC STABILITY CLASSES FOR EACH DIRECTION	4-11
4-5	FREQUENCIES OF WIND DIRECTIONS AND TRUE-AVERAGE WIND SPEEDS	4-12
4-6	FREQUENCIES OF WIND DIRECTIONS AND RECIPROCAL-AVERAGE WIND SPEEDS	4-13
4-7	CAP88-PC DEFAULT VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS TABLE A	4-14
4-8	CAP88-PC DEFAULT VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS TABLE B	4-15
4-9	CAP88-PC DEFAULT VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS TABLE C	4-16
4-10	POPULATION DATA	4-17
4-11	NUMBER OF BEEF CATTLE	4-18
4-12	NUMBER OF MILK CATTLE	4-19
4-13	AREA OF VEGETABLE CROP PRODUCTION	4-20
4-14	CAP88-PC DEFAULT VALUES FOR RADIONUCLIDE-INDEPENDENT PARAMETERS	4-21
5-1	EMP SAMPLING SCHEDULE	5-18
5-2	EMP ANALYTICAL ARRAY	5-19
8-1	DOE 5700.6C CROSS REFERENCE TO ASME NQA-1 AND EPA QAMS-005/80	8-2

LIST OF FIGURES

FIGURE NO.	TITLE	
3-1	LOCATION OF THE WIPP SITE	3-4
3-2	PLAT OF WIPP SITE	3-5
3-3	GENERAL STRATIGRAPHY OF THE WIPP SITE	3-6
5-1	EMP EFFLUENT DISCHARGE AND METEOROLOGICAL MONITORING LOCATIONS	5-21
5-2	EMP AIRBORNE PARTICULATE SAMPLING STATIONS	5-22
5-3	EMP VEGETATION SAMPLING STATIONS FOR RADIOANALYSIS	5-23
5-4	EMP RADIOLOGICAL SOIL SAMPLING SITES	5-24
5-5	EMP RADIOLOGICAL SURFACE WATER SAMPLING SITES	5-25
5-6	EMP GROUNDWATER SAMPLING LOCATIONS	5-26
5-7	EMP SEDIMENT SAMPLING LOCATIONS	5-27
5-8	ECOLOGICAL IMPACTS OF WIPP	5-28
5-9	LOCATIONS OF EMP ECOLOGICAL MONITORING PLOTS	5-29

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
AIBS	American Institute of Biological Scientists
ANSI	American National Standards Institute
ASER	Annual Site Environmental Report
ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
CAM	continuous air monitor
CAP88-PC	Clean Air Act Associated Package, 1988
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CH	contact-handled
CMS	Central Monitoring System
DOE	Department of Energy
DOE/AL	DOE Albuquerque Operations Office
DOT	Department of Transportation
EC	electrical conductivity
EDE	effective dose equivalent
EEG	Environmental Evaluation Group
EMP	Environmental Monitoring Plan
EPA	Environmental Protection Agency
FAS	fixed air sampler
FEIS	Final Environmental Impact Statement

LIST OF ACRONYMS
(CONTINUED)

FSAR	Final Safety Analysis Report
HEPA	high efficiency particulate air
HPIC	high pressure ionization chamber
ICRP	International Commission on Radiological Protection
LD	limit of detection
LoVol	low volume air sampler
LWA	Land Withdrawal Act
NBS	National Bureau of Standards
NCR	Nonconformance Report
NCRP	National Commission on Radiation Protection and Measurements
NES	Nonradiological Environmental Surveillance
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Testing
NMD	No-Migration Determination
NMED	New Mexico Environment Department
NMVP	No-Migration Variance Petition
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OEMP	Operational Environmental Monitoring Plan
PDR	Program Deficiency Rep[illegible]
QA/QC	Quality Assurance/Qu[illegible] Control
RBP	Radiological Baseline Program

LIST OF ACRONYMS
(CONTINUED)

RCA	Request for Corrective Action
RCRA	Resource Conservation and Recovery Act
RES	Radiological Environmental Surveillance
RH	remote-handled
SEIS	Final Supplement Environmental Impact Statement
SES	storage exhaust shaft
SNL	Sandia National Laboratories
SOP	standard operating procedure
STAR	Stability and Array File
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TKN	total kjeldahl nitrogen
TLD	thermoluminescent dosimeter
TRU	transuranic
TRUPACT	Transuranic Package Transporters
TSP	total suspended particulates
TSS	total suspended solids
USBM	United States Bureau of Mines
USGS	United States Geological Survey
VOC	volatile organic compound
WHB	Waste Handling Building

LIST OF ACRONYMS
(CONTINUED)

WID	Westinghouse, Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
WSB	WIPP Site Branch
WQSP	Water Quality Sampling Program

PREFACE

DOE Order 5400.1 (1990) requires each DOE site to prepare an Environmental Monitoring Plan (EMP). This document is to be reviewed annually and updated every three years. This is the first update of the EMP, formally known as the Operational Environmental Monitoring Plan (OEMP) (DOE/WIPP 88-025).

There is significant discussion throughout this EMP in reference to established environmental baselines that are the results of OEMP activities initiated in 1985. These baselines are noted below:

DOE/WIPP 92-037
Statistical Summary of the Radiological Baseline for the WIPP, 1992

DOE/WIPP 92-038
Summary of the Salt Impact Studies at the WIPP, 1984 to 1990, and 1992

DOE/WIPP 92-039
A Study of Disturbed Land Reclamation Techniques for the WIPP, 1992

DOE/WIPP 92-013
Background Water Quality Characterization Report for the WIPP, 1992

These documents may be obtained by referring to the DOE/WIPP number, or they may be found as attachments to the Annual Site Environmental Report for the WIPP for Calendar Year 1991, DOE/WIPP 92-007, 1992.

This EMP will be reviewed annually and will document any proposed changes in the environmental monitoring program. Changes to the environmental monitoring program may be necessary to allow the use of advanced technology and new data collection techniques.

The fundamental purpose of this document is to describe the programs established to evaluate long term effects of the WIPP on the environment. This plan should not be evaluated from the standpoint that monitoring is being conducted for release detection from the WIPP facility, but rather, for recorded historical trends.

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1.0 INTRODUCTION

U.S. Department of Energy (DOE) Order 5400.1, General Environmental Protection Program Requirements (DOE, 1990a), requires each DOE facility to prepare an Environmental Monitoring Plan (EMP). This document is prepared for the Waste Isolation Pilot Plant (WIPP) in accordance with the guidance contained in DOE Order 5400.1 (DOE, 1990a); DOE Order 5400.5, Radiation Protection of the Public and Environment (DOE, 1990b); and the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T, 1991). The WIPP project is operated by Westinghouse Electric Corporation, Waste Isolation Division (WID), for the DOE.

This plan defines the extent and scope of the WIPP effluent and environmental monitoring programs during the facility's preoperational and operational life. This document also discusses the WIPP's quality assurance/quality control programs.

This plan provides a comprehensive description of environmental activities at WIPP including:

- A summary of environmental programs including the status of environmental permits and monitoring activities (Section 1.0);
- A description of the WIPP project and its mission (Section 2.0);
- A description of the local environment including demographics (Section 3.0);
- An overview of the methodology used to assess radiological consequences to the public including brief discussions of potential exposure pathways, routine and accidental releases, and their consequences (Section 4.0);
- A summary of preoperational environmental monitoring and assessment activities (Section 5.0); and
- Responses to the requirements described in the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T).

This document extensively references DOE Orders and other federal and state regulations affecting effluent and environmental monitoring programs at the site. WIPP procedure manuals, which implement the requirements of this program plan, are also referenced.

The DOE regulates its own activities for radiation protection of the public under the authority of the Atomic Energy Act of 1954, as amended. The effluent and environmental monitoring activities prescribed by DOE Order 5400.5 and the DOE/EH-0173T guidance manual are designed to ensure that DOE facilities collect the information required to estimate potential and actual radiation doses to site personnel and the surrounding population. Effluent and environmental monitoring also provide the data necessary to demonstrate compliance with applicable environmental protection regulations.

Other federal agencies, such as the U.S. Environmental Protection Agency (EPA), are empowered through specific legislation to regulate certain aspects of DOE activities potentially affecting public health and safety or the environment. Presidential Executive Order 12088, "Federal Compliance with Pollution Control Standards," requires the heads of executive agencies to ensure that all federal facilities and activities comply with applicable pollution control standards and to take all necessary actions for the prevention, control, and abatement of environmental pollution.

deposition and precipitation scavenging. Radionuclides are depleted from the plume by precipitation scavenging, dry deposition, and radionuclide decay.

Dry deposition is the process by which particles deposit on grass, leaves, and other surfaces by impingement, electrostatic deposition, chemical reactions, or chemical reactions with surface components. The rate of deposition on earth surfaces is proportional to the ground-level concentrations of the radionuclides in air:

$$R_d = V_d x$$

where:

R_d = Surface deposition rate, pCi/cm^2-s,
x = Ground level concentration in air, pCi/cm^3, and
V_d = Deposition velocity, cm/s.

Defaults for deposition velocity used by CAP88-PC are 1.8E-03 m/sec for particulates, and zero for gases.

The rate of deposition by scavenging is a function of the precipitation rate and is principally a mechanism of washout of particles from a plume by rain or snow. The scavenging coefficient is an average value for the entire year and includes all periods without rain or snowfall; i.e., the model treats scavenging as a continuous depletion, at a constant rate, of contaminants from the plume over the entire year. The scavenging coefficient has units of s^{-1}. The scavenging rate (R_s), in pCi/cm^2-s, is:

$$R_s = r x_{ave} L$$

where:

r = Scavenging coefficient, s^{-1}
x_{ave} = Average concentration of nuclide in a column of air to the lid height, pCi/cm^3
L = Height of the lid, cm.

The scavenging coefficient is calculated in CAP88-PC by multiplying the rainfall rate by 1E-07 yr/cm-s. Refer to Tables 4-7, 4-8, and 4-9 for values for radionuclide-dependent parameters used by CAP88-PC.

4.3.5 Terrestrial Modeling

As previously discussed, the area surrounding the WIPP site is modeled as an 80-kilometer (50-mile) radius circular grid system with the site located at the center. WIPP-specific data for population are used and are summarized in Table 4-10. Beef and dairy cattle, and vegetable crop productivity data used in the dose assessment is CAP88-PC default for the State of New Mexico and are summarized in Tables 4-11, 4-12, and 4-13. Table 4-14 summarizes radionuclide-independent default data used by CAP88-PC.

4.3.6 Dose Modeling

Radiation dose is calculated by multiplying radioactivity concentrations in air and water or on contaminated ground surfaces, by assumed human intake rates (for internal exposure) or exposure times (for external exposure to penetrating radiation), and then by the appropriate radiation dose conversion factors. That is:

Radiation Dose = (Radioactivity Concentration) x (Intake Rate/Exposure Time) x (Dose Conversion Factor)

WIPP must also comply with specified permitting and approval requirements of several federal and state regulating agencies. A database is maintained of all required permits, notices, and approvals which apply to the WIPP project. This database enables environmental personnel to anticipate commitments such as renewal dates, fee payments, and reclamation requirements. This database is updated annually and is available in the Annual Site Environmental Report (ASER) produced for the WIPP. The latest issued permit matrix is listed in the Site Environmental Report for the WIPP for Calendar Year 1991 (DOE/WIPP 92-007).

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2.0 PROJECT DESCRIPTION

The purpose of WIPP is to provide a research and development facility to demonstrate the safe disposal of TRU waste generated by the defense activities of the U.S. Government. The preoperational radiological and ecological environmental monitoring programs were detailed in earlier documents entitled: "Radiological Baseline Program for the Waste Isolation Pilot Plant" (Reith and Daer, 1985) and "Ecological Monitoring Program for the Waste Isolation Pilot Plant, Semi-annual Report" (Reith et al., 1985). A summary of those programs is presented in Section 5.0 of this document. The environmental monitoring program continues the established preoperational environmental monitoring efforts as appropriate and adds monitoring of the airborne and liquid effluent discharges. Details regarding the design and operation of the WIPP facility are in the Final Safety Analysis Report (FSAR) (DOE, 1990c).

Both contact handled (CH) and remote handled (RH) waste will be received and stored at the WIPP facility. CH waste consists of transuranic (TRU) waste that has a relatively low surface dose rate and therefore lends itself to direct handling. RH waste is TRU waste that, due to higher levels of penetrating radiation, must be shielded and handled remotely. Waste will be classed as CH or RH based on whether surface dose rates are less than or greater than 200 mrem/hr, respectively. TRU waste is radioactive waste that, without regard to source or form, is contaminated with alpha-emitting TRU radionuclides having atomic numbers larger than 92 and half-lives longer than 20 years in concentrations greater than 100 nanocuries per gram of waste. The CH and RH waste contain both alpha and beta-gamma emitting nuclides. Isotopes of plutonium, americium, and curium will be the predominant radionuclides contaminating the TRU waste. The waste will be in a variety of forms such as concrete stabilized sludges, decommissioned machine tools, glove boxes, etc. All wastes received by the WIPP will be restricted according to specific Waste Acceptance Criteria (WAC Rev. 4, 1991) which prohibit pressurized gases and explosives, and limits free liquids to less than one percent of the volume of each container. General criteria defining the various categories of radioactive waste, including TRU waste, appear in DOE Order 5820.2A and DOE/AL Order 5820.2. A portion of the waste that will be emplaced will also be contaminated with hazardous materials. The hazardous waste component is subject to regulation by the Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA), and consists largely of toxicity characteristic metals, halogenated organic compounds, and nonhalogenated organic compounds.

Waste will be delivered to the WIPP Waste Handling Building (WHB) via semi-trailer trucks. CH wastes will arrive in shipping containers known as TRUPACT IIs (TRansUranic PACkage Transporters). TRUPACT IIs are durable, Type B, Department of Transportation certified (DOT) transport containers, designed to accommodate both waste boxes and drums. The DOE has received a certificate of compliance from the Nuclear Regulatory Commission (NRC) for use of the TRUPACT II. Remote-handled transuranic (RH TRU) wastes will be packaged in waste canisters and shipped to WIPP in special transportation casks. The remote-handled casks are awaiting NRC approval.

The storage rooms prepared for the waste have been excavated from the Salado Formation, a thick sequence of salt beds deposited 250 million years ago (Permian age). The emplacement horizon is located at a depth of 655 meters (2,150 feet). The waste containers within the WHB will be removed from their shipping containers, placed on the waste-handling hoist, and lowered to the emplacement horizon. Waste containers will then be removed from the hoist and emplaced within the storage rooms. Eventually, specially designed seals and plugs will be placed in the excavated drifts and in the shafts. Geologic pressures and the plasticity of the salt will result in the excavation's gradual closure due to creep. This closure will encapsulate and isolate any waste within the Salado.

The underground area is ventilated by air entering via the Salt Handling, Air Intake, and Waste Handling Shafts and exiting through the Exhaust Shaft. In the event of an accident involving waste in the underground, air from the Exhaust Shaft will be directed, at a reduced flow rate, through the Exhaust Filter Building containing banks of high efficiency particulate air (HEPA) filters in order to remove potentially contaminated particulates. Exhaust ventilation from the WHB is continuously HEPA filtered and is not expected to represent a significant release point. Effluent monitoring is discussed in Section 5.3.2.

3.0 SITE CHARACTERISTICS

3.1 GEOGRAPHY

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 3-1) within the Pecos Valley section of the southern Great Plains physiographic province (Powers et al., 1978). The site is 42 km (26 miles) east of Carlsbad in an area known as Los Medanos (the dunes). Los Medanos is a relatively flat, sparsely inhabited plateau with little water and limited land uses.

The WIPP site (Figure 3-2) consists of 16 sections of federal land in Township 22 South, Range 31 East. The 16 sections of federal land were withdrawn from the application of public land laws by the WIPP Land Withdrawal Act (LWA), Public Law 102-579, that was signed on October 30, 1992. The LWA transferred the responsibility for the administration of the 16 sections from the Department of Interior, Bureau of Land Management, to the Department of Energy. This law specified that mining and drilling for purposes other than support of the WIPP project are restricted within this 16 section area with the exception of Section 31. Oil and gas activities are restricted in Section 31 from the surface down to 6,000 feet.

3.2 GEOLOGY

Los Medanos soils are sandy and well drained with a well developed caliche layer occurring below one meter. There are no integrated natural surface drainage features at the site. Scattered throughout the local area are numerous livestock watering ponds (tanks) and seasonally wet, shallow lakes (playas) which are located approximately 6 miles southeast of the site. Geologically, the site is located in the northern portion of the Delaware Basin, one of the westernmost sedimentary basins known collectively as the Permian Basin. Approximately 3,960 meters (13,000 feet) of strata are present in the Delaware Basin (Bachman, 1984) including hundreds of meters of evaporite sequences composed in part of halite, anhydrite, and gypsum. Figure 3-3 illustrates the local stratigraphy.

3.3 CLIMATOLOGY

Regional climate is semi-arid with generally warm temperatures. Approximately half the average annual precipitation, about 31 centimeters (12 inches), is received from summer thunderstorms during June through September. Daytime summer temperatures consistently exceed 32°C (90°F) and occasionally rise above 38°C (100°F). Winter temperatures often rise as high as 21°C (70°F) during the afternoon. Night time lows during winter average near -5°C (23°F), occasionally dipping below -10°C (14°F). Prevailing winds are from the southeast; however, strong winds are common and can blow from any direction creating potentially violent windstorms which carry large volumes of dust and sand. The wind test data have remained essentially the same from year to year. Detailed compilations of climatic data have appeared in the Ecological Monitoring Reports (Fischer et al., 1985; 1987) and in the Annual Site Environmental Reports for calendar years 1988, 1989, 1990, 1991, and 1992 (DOE/WIPP 89-005, DOE/WIPP 90-003, DOE/WIPP 91-008, DOE/WIPP 92-007, DOE/WIPP 93-017, respectively). Additional climatic information appears in the Final Environmental Impact Statement (FEIS) (DOE, 1980), Final Supplement Environmental Impact Statement (SEIS) (DOE, 1990d), and the FSAR (DOE, 1990c).

3.4 HYDROLOGY

Surface water is absent at the WIPP site. The nearest large surface water body, Laguna Grande de la Sal, is located approximately 13 kilometers (8 miles) west-southwest of the WIPP site in Nash Draw where shallow brine ponds occur. The Pecos River is located 22.4 kilometers (14 miles) southwest of the WIPP site.

Several water-bearing zones have been studied near the WIPP. The most significant are the Culebra and Magenta Dolomite Members of the Rustler Formation, which consist of interbedded anhydride, dolomite, siltstone, and halitic claystone. The dolomite units produce brackish to saline water. Limited amounts of potable water are found in the Dewey Lake Redbeds and the overlying Triassic Dockum Group. Another saline water-bearing zone identified is the Rustler-Salado contact, which contains very little water at the WIPP site. It was exposed during shaft construction and produced only small brine seepages. Other water bearing zones that have been evaluated as part of site characterization include the Bell Canyon and Castile Formations.

The Dewey Lake Formation is comprised of alternating thin, even beds of siltstone and mudstone with lenticular interbeds of fine-grained sandstone. Exploratory drilling during site hydrogeologic evaluation did not identify a continuous zone of saturation within the Dewey Lake. The few Dewey Lake wells yielding water for domestic and stock purposes are believed to be completed in the thin, discontinuous lenticular sands where favorable groundwater recharge occurs (Mercer, 1983). A more complete discussion of both the regional and site-specific groundwater hydrology is contained in the WIPP FSAR.

3.5 ECOLOGY

The biota of Los Medanos represent a transition between the northern Chihuahuan Desert and the southern Great Plains. The soils at the site include sandy surface soils with wind-blown particles, a thin soil crust, and a layer of moist subsoil. These sandy soils form stabilized coppice dunes interspersed with swales.

Shrubs and grasses are the most prominent components of the local flora. The development of specific plant communities is dependent on such factors as the infiltration rate of the surface soil, depth to a restrictive layer (e.g., caliche), and the extent to which the surface soil has been reworked by wind or water erosion. The area is dominated by the shinnery oak, mesquite, sand sage, and perennial grasses. Typical grassland and shrubland species dominate the fauna of the area. The primary mammals found at the site include the lagomorphs (rabbits and hares), desert dwelling rodent species, and carnivore species such as the coyote, gray fox, badger, and striped skunk.

A large variety of bird species are also found in the region. The following avian species are present in greatest densities: scaled quail, mourning dove, mocking bird, loggerhead shrike, pyrrhuloxia, black-throated sparrow, wester meadowlark, the lark bunting, vesper sparrow, Cassin's sparrow, and the white-crowned sparrow. The Harris hawk, the Chihuahuan raven, Swainson's hawk, the Northern Harrier, and the American kestrel are also found at the site.

Twenty-nine species of amphibians and reptiles are observed in the site vicinity. Characteristic reptiles in the region include the western box turtle, side-blotched lizard, western whiptail, bullsnake, and western rattlesnake. The primary amphibians are the tiger salamander, green toad, and plain's spadefoot.

A brief summary of the ecological baseline surveys appears in Appendix H of the FEIS (DOE, 1980). If there are any changes observed in the area ecology they will be noted in the WIPP ASERs.

3.6 DEMOGRAPHY

The distribution of the local 1990 population within 50 miles of the WIPP site is provided in Table 4-10. The nearest residents to the site include eight individuals living at the Mills Ranch, 5.8 km (3.5 miles) south-southwest of the center of the site, and two individuals living at the Smith Ranch, 10 km (6 miles) west-northwest of the center of the site (DOE/WIPP 93-017). Both neighboring ranches have been and will continue to be monitored as part of WIPP's environmental surveillance program. Detailed demographic summaries and projections are in the WIPP SEIS (DOE, 1990d) and WIPP FSAR (DOE, 1990c).

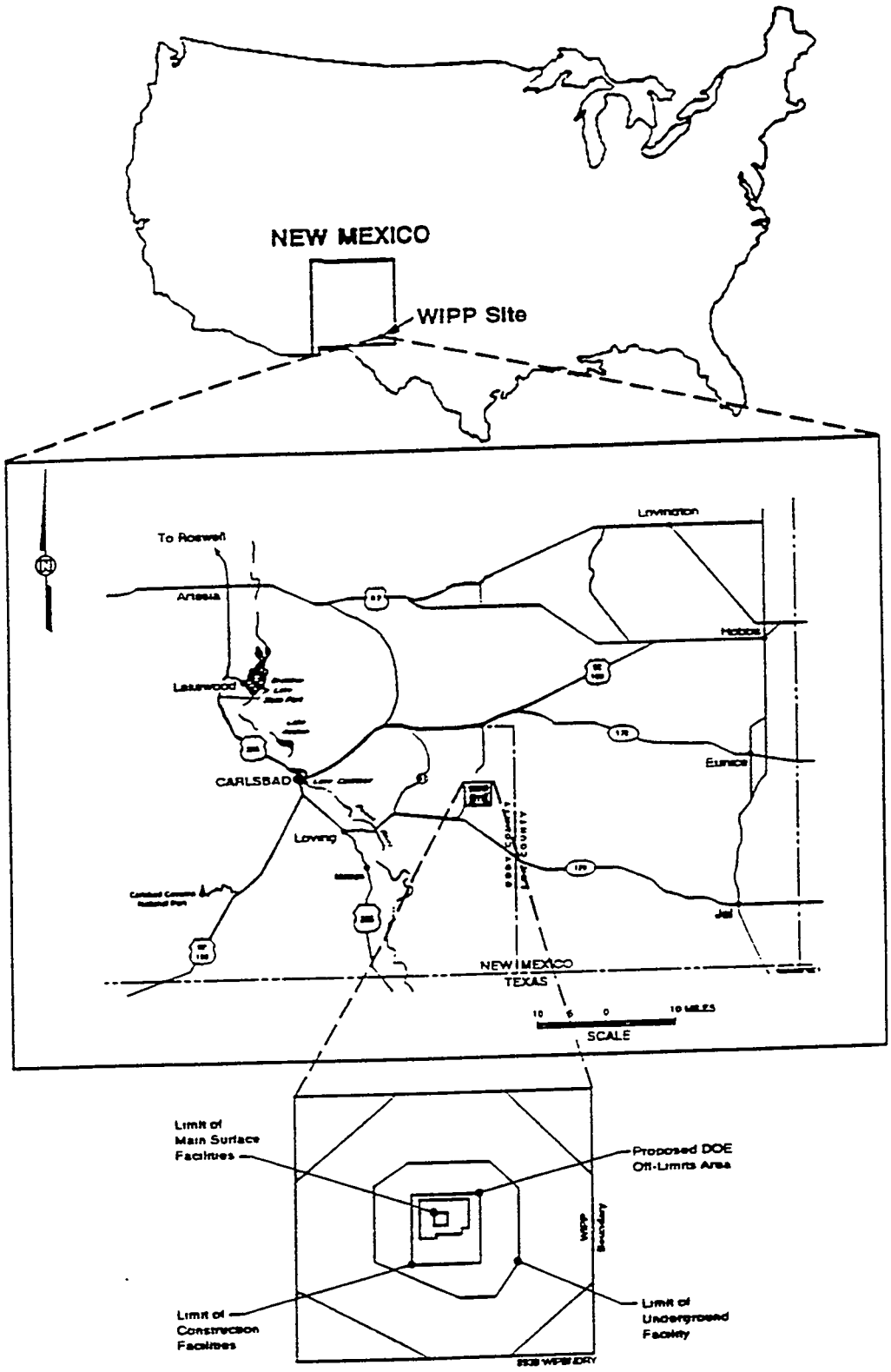

Figure 3-1 Location of the WIPP Site

APPENDIX D6
SITE CHARACTERIZATION

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APPENDIX D6
TABLE OF CONTENTS

List of Tables D6-iii
List of Figures D6-iv
Introduction D6-1
D6-1 Geology D6-2
D6-1a Data Sources D6-2
D6-1b Geologic History D6-3
D6-1c Stratigraphy and Lithology in the Vicinity of the WIPP Site D6-4
D6-1c(1) General Stratigraphy and Lithology below the Bell Canyon Formation D6-4
D6-1c(2) The Bell Canyon Formation D6-6
D6-1c(3) The Castile Formation D6-7
D6-1c(4) The Salado Formation D6-8
D6-1c(5) Rustler Formation D6-11
D6-1c(6) The Dewey Lake D6-16
D6-1c(7) The Santa Rosa D6-17
D6-1c(8) The Gatuña Formation D6-17
D6-1c(9) The Mescalero Caliche D6-18
D6-1c(10) Surficial Sediments D6-19
D6-1d Physiography and Geomorphology D6-20
D6-1d(1) Regional Physiography and Geomorphology D6-20
D6-1d(2) Site Physiography and Geomorphology D6-21
D6-1e Tectonic Setting and Site Structural Features D6-22
D6-1e(1) Basin Tilting D6-22
D6-1e(2) Faulting D6-23
D6-1e(3) Igneous Activity D6-24
D6-1e(4) Loading and Unloading D6-24
D6-1f Nontectonic Processes and Features D6-25
D6-1f(1) Evaporite Deformation D6-25
D6-1f(2) Evaporite Dissolution D6-36
D6-2 Surface-Water and Groundwater Hydrology D6-40
D6-2a Groundwater Hydrology D6-42
D6-2a(1) Hydrology of the Capitan Limestone D6-42
D6-2a(2) Hydrology of the Delaware Mountain Group D6-43
D6-2a(3) Hydrology of the Salado and Castile Formations D6-43
D6-2a(4) Hydrology of the Rustler-Salado Contact Zone D6-46
D6-2a(5) Hydrology of the Rustler Formation D6-48
D6-2a(6) Hydrology of the Supra-Rustler Rocks (the Dewey Lake and the Santa Rosa) D6-51
D6-2a(7) Groundwater Elevation Measurements in 1991 ..... D6-52
D6-2b Surface-Water Hydrology D6-53
D6-2c Groundwater Discharge and Recharge D6-54
D6-2d Water Quality D6-56

TABLE OF CONTENTS *(CONTINUED)*

D6-2d(1) Groundwater Quality D6-56
D6-2d(2) Surface-Water Quality D6-57
D6-3 Resources D6-58
D6-3a Extractable Resources D6-59
D6-3a(1) Potash Resources at the WIPP Site D6-59
D6-3a(2) Hydrocarbon Resources at the WIPP Site D6-60
D6-3b Cultural and Economic Resources D6-60
D6-3b(1) Demographics D6-60
D6-3b(2) Land Use D6-61
D6-3b(3) History and Archaeology D6-62
D6-4 Seismicity D6-65
D6-5 Rock Geochemistry D6-66
References D6-68
Bibliography D6-77

List of Tables

Table	Title	Page
D6-1	Culebra Thickness Data Sets	D6-114
D6-2	Hydrologic Characteristics of Rock Units at the WIPP Site	D6-114
D6-3	Capacities of Reservoirs in the Pecos River Drainage	D6-115
D6-4	Current Estimates of Potash Resources at the WIPP Site	D6-115
D6-5	In-Place Oil within Study Area	D6-116
D6-6	In-Place Gas within Study Area	D6-116
D6-7	Chemical Formulas, Distributions, and Relative Abundances of Minerals in Delaware Basin Evaporites	D6-117

List of Figures

Figure	Title	Page
D6-1	WIPP Site Location in Southeastern New Mexico	D6-118
D6-2	Borehole Location Map	D6-119
D6-3	Major Geologic Events—Southeast New Mexico Region	D6-120
D6-4	Site Geological Column	D6-121
D6-5	Cross Section from Delaware Basin (Southeast) Through Marginal Reef Rocks to Back-Reef Facies	D6-122
D6-6	Generalized Stratigraphic Cross Section above the Bell Canyon at WIPP Site	D6-123
D6-7	Salado Stratigraphy	D6-124
D6-8	Rustler Stratigraphy	D6-125
D6-9	Halite Margins in the Rustler	D6-126
D6-10	Isopach Map of the Entire Rustler	D6-127
D6-11	Percentage of Natural Fractures in the Culebra Filled with Gypsum	D6-128
D6-12	Log Character of the Rustler Showing Mudstone-Halite Lateral Relationships	D6-129
D6-13	Isopach of the Dewey Lake	D6-130
D6-14	Isopach of the Santa Rosa	D6-131
D6-15	Physiographic Provinces and Sections	D6-132
D6-16	Site Topographic Map	D6-133
D6-17	Structural Provinces of the Permian Basin Region	D6-134
D6-18	Depth to Base of the Culebra	D6-135
D6-19	Location of Main Stratigraphic Drill Holes	D6-136
D6-20	Seismic Time Structure of the Middle Castile	D6-137
D6-21	Fence Diagram Using DOE-2 and Adjacent Holes	D6-138
D6-22	Isopach from the Top of the Vaca Triste to the Top of the Salad	D6-139
D6-23	Isopach from the Base of Marker Bed 103 to the Top of the Salado	D6-140
D6-24	Isopach from the Base of Marker Bed 123/124 to the Base of the Vaca Triste	D6-141
D6-25	Structure Contour Map of the Culebra	D6-142
D6-26	Drainage Pattern in the Vicinity of the WIPP Facility	D6-143
D6-27	Schematic West-East Cross Section through the Northern Delaware Basin	D6-144
D6-28	Schematic North-South Cross Section through the Northern Delaware Basin	D6-145
D6-29	Potentiometric Surface Map (composite) of the Delaware Mountain Group and Capitan Aquifer	D6-146

List of Figures *(Continued)*

D6-30	Measured Water Levels and Estimated Freshwater Heads of the Unnamed Lower Member and Rustler/Salado Contact Zone	D6-147	1 2
D6-31	The Transient Calibrated Log_{10} Transmissivities	D6-148	3
D6-32	Water Levels and Estimated Freshwater Heads in the Magenta (Holt et al., 1989)	D6-149	4 5
D6-33	Location of Reservoirs and Gauging Stations in the Pecos River Basin	D6-150	6 7
D6-34	Culebra Freshwater-Head Contour Surface	D6-151	8
D6-35	Mariah Study Archaeological Sites	D6-152	9
D6-36	Regional Earthquake Epicenters Occurring after 1961	D6-153	10

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APPENDIX D6
SITE CHARACTERIZATION

Introduction

This appendix describes the Waste Isolation Pilot Plant (WIPP) site in terms of its geology, hydrology, climatology, air quality, ecology, and cultural and natural resources. The purpose of this appendix is to provide information on the disposal system's natural characteristics that are relevant to the assessment of the WIPP site as a potential repository for transuranic (TRU) and TRU mixed waste and to establish the favorable characteristics of the site and background environmental quality. The U.S. Department of Energy (DOE) is developing the WIPP as a deep geologic repository for disposal of TRU waste from government defense installations across the country. In order for the DOE to formulate a reasonable expectation of site conditions far into the future, the DOE has characterized the site in detail to provide basic data for a variety of geologic and hydrologic parameters. The DOE uses these parameters in computational models to predict the likelihood and possible consequences of various scenarios expected to apply to the WIPP site over a 10,000-year period

The DOE located the WIPP site 26 miles (mi) (41.8 kilometers [km]) east of Carlsbad, New Mexico, in Eddy County (Figure D6-1). The region surrounding the WIPP site has been under study for many years, and exploration of both potash and hydrocarbon deposits has provided extensive knowledge of the geology of the region. Two exploratory holes were drilled by the federal government during 1974 at a location northeast of the present site; that location was abandoned in 1975 as a possible repository site after a well, U.S. Energy Research and Development Administration (ERDA)-6, was drilled, and unacceptable structure and pressurized brine were encountered. The results of these investigations were reported by Powers et al. (1988, pp. 2-6). During late 1975 and early 1976, the ERDA identified the present site, and an initial exploratory hole (ERDA-9) was drilled. By the time an initial phase of site characterization was completed in August 1978, 47 holes had been drilled or were in progress for hydrologic and various geologic purposes. Geophysical techniques were modified to address local geology and WIPP needs and provided significant support as screening techniques for specific geologic anomalies. Since 1978 the DOE has drilled additional holes to support hydrologic programs, geologic programs, and facility design. Geophysical logs, cores, basic data reports, geochemical sampling and testing, and hydrological testing and analyses are reported by the DOE and its scientific advisor, Sandia National Laboratories (SNL), in numerous documents and are maintained in reference libraries that are available to the public, such as the Sandia WIPP Central File (in Albuquerque, New Mexico). Where necessary, specific references from these documents are cited to reinforce the statements being made. Additional sources of information on the various topics in this section are listed in a bibliography at the end of the chapter.

Biological studies of the site began in 1975 to gather information for the Environmental Impact Statement. Meteorological studies began in 1976, and economic studies were initiated during

1977. Baseline environmental data were initially reported in 1987 and are now updated annually by the DOE.

The DOE selected the WIPP disposal horizon to be located within a rock-salt deposit known as the Salado Formation (hereafter referred to as the Salado) at a depth of 2,150 feet (ft) (650 meters [m]) below the ground surface. The Salado is regionally extensive; includes continuous beds of salt without complicated structure; is deep enough for waste isolation, reducing the potential for dissolution; and is near enough to the surface to make access reasonable. Particular site-selection criteria narrowed the choices when the present site was located during 1975–76.

D6-1 Geology

Geological data have been collected from the WIPP site and surrounding area for use in evaluating the site's suitability as a radioactive waste repository. These data have been collected principally by the DOE and its predecessor agencies, the United States Geological Survey (USGS), the New Mexico Bureau of Mines and Mineral Resources (NMBMMR), and private organizations engaged in natural resource exploration and extraction. The DOE has analyzed the data provided in the following discussion and believes it supports the DOE's position that the WIPP site is suitable for the long-term isolation of radioactive waste. Numerous questions have been raised and subsequently discussed, investigated, and resolved in order for the DOE to reach the conclusion that the site is suitable. The DOE discusses these questions in the following with emphasis on the resolution of the issues.

D6-1a Data Sources

The geology of southeastern New Mexico has been of great interest for more than a century. The Guadalupe Mountains have become a common visiting and research point for geologists because of the spectacular exposures of Permian-age reef rocks and related facies. Some historical references included in the Bibliography are Shumard (1858), Crandall (1929), Newell et al. (1953), and Dunham (1972). Because of intense interest in both hydrocarbon and potash resources in the region, there exists a large volume of data as potential background for the WIPP site, though some data are proprietary. Finally, there is the geological information developed directly and indirectly by studies sponsored by WIPP; it ranges from raw data to interpretive reports.

Elements of the geology of southeastern New Mexico have been discussed or described in professional journals or technical documents from many different sources. These types of articles are an important source of information, and where there is no contrary evidence, the information in these articles is included through reference where subject material is relevant. Implicit rules of professional conduct of research and reporting are assumed to have been applied, and journal/editorial review has normally been applied. Certain elements of the geology presented in such sources have been deemed critical to the WIPP and have been the subject of specific WIPP-sponsored studies.

Geological data have been developed by the DOE through a variety of WIPP-sponsored studies using drilling, mapping, or other direct observation; geophysical techniques; and laboratory work. Most of the techniques and statistics of data acquisition will be incorporated by specific discussion. Boreholes are, however, a major source of geological data for the WIPP and surrounding area. From boreholes come raw data (e.g., depth measurements, amount of core, and geophysical logs) that provide the basis for point data and interpreted data sets. These data serve as the base for computing other useful elements such as structure maps for selected stratigraphic horizons or isopachs (thickness) of selected stratigraphic intervals.

The borehole data set in Sub-Appendix BH to this appendix is considered the usable reference information. Figure D6-2 provides a map of some borehole locations in this data set used in this chapter.

D6-1b Geologic History

This section summarizes the more important points of the geologic history within about 200 mi (321.9 km) of the WIPP site, with emphasis on more recent or nearby events. Major elements of the geological history from the end of the Precambrian in the vicinity of the WIPP site were compiled in graphic form (Figure D6-3). The geologic time scale that the DOE uses for the WIPP is based on a compilation by Palmer (1983, pp. 503-504) for *The Decade of North American Geology* (DNAG). There are several compiled sources of chronologic data related to different reference sections or methods (see, for example, Harland et al. [1982] and Salvador [1985] in the bibliography). Although most of these sources show generally similar ages for chronostratigraphic boundaries, there is no consensus on either reference boundaries or most-representative ages. The DNAG scale is accepted by the DOE as a standard that is useful and sufficient for WIPP purposes, as no known critical parameters require more accurate or precise dates.

The geologic history in this region can conveniently be subdivided into three general phases:

- A Precambrian period, represented by metamorphic and igneous rocks, ranging in age from about 1.5 to 1.0 billion years old
- A period principally of erosion from about 1.0 to 0.5 billion years ago, as there is not known to be any rock record from this time
- An interval from 0.5 billion years to the present represented by a more complex set of mainly sedimentary rocks and shorter periods of erosion and dissolution.

This latter phase is the main subject of the DOE's detailed discussion of this text.

Precambrian crystalline rocks have been penetrated in only a few deep boreholes in the vicinity of the WIPP, and therefore relatively little petrological information is available. Foster (1974, Fig. 3) extrapolated the elevation of the Precambrian surface under the area of the WIPP site as being between 14,500 ft (4.42 km) and 15,000 ft (4.57 km) below sea level; the site surface at

the WIPP is about 3,400 ft (1,036 m) above sea level. Keesey (1977, Vol. I, Exhibit No. 2) projected a depth to the top of Precambrian rocks of 18,191 ft (5.55 km) based on the geology of a nearby borehole in Section 15, T22S, R31E.

Precambrian rocks of a variety of types crop out in the following locations: the Sacramento Mountains northwest of the WIPP; around the Sierra Diablo and Baylor Mountains near Van Horn, Texas; west of the Guadalupe Mountains at Pump Station Hills; and in the Franklin Mountains near El Paso, Texas. East of the WIPP, a relatively large number of boreholes on the Central Basin Platform have penetrated the top of the Precambrian (Foster, 1974, Fig. 3). As summarized by Foster (1974, p. 10), Precambrian rocks in the area considered similar to those in the vicinity of the site range in age from about 1.14 to 1.35 billion years.

For a period of about 500 million years (1.1 to 0.6 billion years ago), there is no certain rock record in the region around the WIPP site. The most likely rock record for this period may be the Van Horn sandstone, but there is no conclusive evidence that it represents part of this time period. The region is generally interpreted to have been subject to erosion for much of the period, until the Bliss sandstone began to accumulate during the Cambrian.

D6-1c Stratigraphy and Lithology in the Vicinity of the WIPP Site

This section presents the stratigraphy and lithology of the Paleozoic and younger rocks underlying the WIPP site and vicinity (Figure D6-4), emphasizing the units nearer the surface. Details begin with the Permian (Guadalupian) Bell Canyon Formation (hereafter referred to as the Bell Canyon)—the upper unit of the Delaware Mountain Group—because this is the uppermost water-bearing formation below the evaporites. The principal stratigraphic data are the chronologic sequence, age, and extent of rock units, including some of the nearby relevant facies changes. Characteristics such as thickness and depth are summarized here from published sources for deeper rocks and are mainly based on data sets presented in Sub-Appendix BH for shallower rocks (above the Bell Canyon). The main lithologies for upper formations and members of some formations are described; some of the major stratigraphic divisions (e.g., Jurassic) are not described because they do not occur at or near the WIPP site.

D6-1c(1) General Stratigraphy and Lithology below the Bell Canyon Formation

As stated previously, the Precambrian basement near the site is projected to be about 18,200 ft (5,545 m) below the surface (Keesey, 1977 , Vol. II, Exhibit No. 2), consistent with information presented by Foster in 1974. Ages of similar rock suites in the region range from about 1.14 to 1.35 billion years.

The basal units overlying Precambrian rocks are clastic rocks commonly attributed either to the Bliss sandstone or the Ellenberger Group (Foster, 1974, p. 10*ff*), considered most likely to be Ordovician in age in this area. The Ordovician system comprises the Ellenberger, Simpson, and Montoya groups in the northern Delaware Basin. Carbonates are predominant in these groups,

with sandstones and shales common in the Simpson group. Foster (1974, p. 12) reported 975 ft (297 m) of Ordovician north of the site area and extrapolated a thicker section of about 1,300 ft (396 m) at the present site (p. 17). Keesey (1977, Vol. II, Exhibit No. 2) projected a thickness of 1,200 ft (366 m) within the site boundaries.

Silurian-Devonian rocks in the Delaware Basin are not stratigraphically well defined, and there are various notions for extending nomenclature into the basin. Common drilling practice is not to differentiate, although the Upper Devonian Woodford shale at the top of the sequence is frequently distinguished from the underlying dolomite and limestone (Foster, 1974, p. 18). Foster (1974, p. 21) showed a reference thickness of 1,260 ft and 160 ft (384 m and 49 m) for the carbonates and the Woodford shale, respectively; he estimated thickness contours for the present WIPP site of about 1,150 ft (351 m) and 170 ft (52 m), respectively. Keesey (1977, Vol. II, Exhibit No. 2) projected 1,250 ft (381 m) of carbonate and showed 82 ft (25 m) of the Woodford shale.

The Mississippian system in the northern Delaware Basin is commonly attributed to "Mississippian limestone" and the overlying Barnett shale (Foster, 1974, p. 24), but the nomenclature is not well settled. At the reference well used by Foster (1974, p. 25), the limestone is 540 ft (165 m) thick and the shale is 80 ft (24 m) thick; isopachs at the WIPP are 480 ft (146 m) and less than 200 ft (61 m). Keesey (1977, Vol. II, Exhibit No. 2) indicates 511 ft (156 m) and 164 ft (50 m), respectively, within the site boundaries.

The nomenclature of the Pennsylvanian system applied within the Delaware Basin is both varied and commonly inconsistent with accepted stratigraphic rules. Chronostratigraphic, or time-stratigraphic, names are applied to these lithologic units: the Morrow, the Atoka, and the Strawn, from base to top (Foster, 1974, p. 31). Foster (1974, p. 34) extrapolated thicknesses of about 2,200 ft (671 m) for the Pennsylvanian at the WIPP site. Keesey (1977, Vol. II, Exhibit No. 2) reports 2,088 ft (636 m) for these units. The Pennsylvanian rocks in this area are mixed clastics and carbonates, with carbonates more abundant in the upper half of the sequence.

The Permian system in the northern Delaware Basin is the thickest system in the northern Delaware Basin, and it is divided into four series from the base to top: the Wolfcampian, the Leonardian, the Guadalupian, and the Ochoan. According to Keesey (1977, Vol. II, Exhibit No. 2), the three lower series total 8,684 ft (2,647 m) near the site. Foster (1974, p. 35*ff*) indicates a total thickness for the lower three series of 7,665 ft (2,336 m) for a reference well north of WIPP. Foster's 1974 isopach maps of these series indicate about 8,500 ft (2,591 m) for the WIPP site area. The Ochoan series at the top of the Permian is considered in more detail later, because the formations host and surround the WIPP repository horizon. Its thickness at DOE-2, about 2 mi (3.2 km) north of the site center, is 3,938 ft (1,200 m) according to Mercer et al. (1987, pp. 23-24).

The Wolfcampian series is also referred to as the Wolfcamp Formation (hereafter referred to as the Wolfcamp) in the Delaware Basin. In the site area, the lower part of the Wolfcamp is

dominantly shale, with carbonate and some sandstone according to Foster (1974, p. 38); carbonate increases to the north. Clastics increase to the east toward the margin of the Central Basin Platform. Keesey (1977, Vol. II, Exhibit No. 2) reports the Wolfcamp to be 1,493 ft (455 m) thick at a well near the WIPP site. The Leonardian Series is represented by the Bone Spring Formation (hereafter referred to as the Bone Spring) (erroneously called the Bone Spring Limestone in many publications). According to Foster (1974, p. 39) the lower part of the formation is commonly interbedded carbonate, sandstone, and some shale, while the upper part is dominantly carbonate. Near the site, the Bone Spring is 3,247 ft (990 m) thick according to Keesey (1977, Vol. II, Exhibit No. 2).

The Guadalupian series is represented in the general area of the site by a number of formations exhibiting complex facies relationships (Figure D6-5). The Guadalupian series is known in considerable detail west of the site from outcrops in the Guadalupe Mountains, where numerous outcrops and subsurface studies have been undertaken. (See for example P. B. King [1948], Newell et al. [1953], and Dunham [1972] in the Bibliography.) According to Garber et al. (1989, p. 36), similar facies relationships are expected from the site to the north (Figure D6-5).

Within the Delaware Basin, the Guadalupian series comprises three formations: the Brushy Canyon, the Cherry Canyon, and the Bell Canyon, from base to top. These formations are dominated by submarine channel sandstones with interbedded limestone and some shale. A limestone (Lamar) generally tops the series, immediately underneath the Castile Formation (hereafter referred to as the Castile). Around the margin of the Delaware Basin, reefs developed during the same time the Cherry Canyon and the Bell Canyon were being deposited. These massive reef limestones, the Goat Seep and Capitan limestones, are equivalent in time to these basin sandstone formations but were developed much higher topographically around the basin margin. A complex set of limestone to sandstone and evaporite beds was deposited further away from the basin behind the reef limestones. The Capitan reef limestones are well known because the Carlsbad Caverns are partially developed in these rocks.

D6-1c(2) The Bell Canyon Formation

The Bell Canyon is known from outcrops on the west side of the Delaware Basin and from subsurface intercepts for oil and gas drilling. Several informal lithologic units are commonly named during such drilling. Mercer et al. (1987, p. 28) stated that DOE-2 penetrated the Lamar limestone, the Ramsey sand, the Ford shale, the Olds sand, and the Hays sand. This informal nomenclature is used for the Bell Canyon in other WIPP reports.

The Clayton Williams Badger Federal borehole near the WIPP site (Section 15, T22S, R31E) intercepted 961 ft (293 m) of the Bell Canyon, including the Lamar limestone, according to Keesey (1977, Vol. II, Exhibit No. 2). Reservoir sandstones of the Bell Canyon were deposited in channels that are straight to slightly sinuous. Density currents flowed from shelf regions, cutting channels and depositing the sands that are identified in Harms and Williamson (1988, pp. 299-317).

Within the basin, the Bell Canyon (Lamar limestone)/Castile contact is distinctive on geophysical logs because of the contrast in low natural gamma of the basal Castile anhydrite compared to the underlying limestone. Density or acoustic logs are also distinctive because of the massive and uniform lithology of the anhydrite compared to the underlying beds. In cores, the transition is sharp, as described by Mercer et al. (1987, p. 312) for DOE-2.

D6-1c(3) The Castile Formation

The Castile is the lowermost lithostratigraphic unit of the Late Permian Ochoan series (Figure D6-6). It was originally named by Richardson for outcrops in Culberson County, Texas. The Castile crops out along a lengthy area along the western side of the Delaware Basin. The two distinctive lithologic sequences, now known as the Castile and the Salado, were separated into the upper and lower Castile by Cartwright in 1930. Lang, in 1939, clarified the nomenclature by restricting the Castile to the lower unit and naming the upper unit the Salado. By defining an anhydrite resting on the marginal Capitan limestone as part of the Salado, Lang, in 1939, effectively restricted the Castile to the Delaware Basin inside the ancient reef rocks.

Through detailed studies of the Castile, Anderson et al. (1972, pp. 59-86) introduced an informal system of names that are widely used and included in many WIPP reports. They named the units, beginning at the base, as anhydrite 1 (A1), halite 1 (H1), anhydrite 2 (A2), etc. The informal nomenclature varies throughout the basin upwards from A3 because of the complexity of the depositional system. The Castile consists almost entirely of thick beds of two lithologies: (1) interlaminated carbonate and anhydrite and (2) high-purity halite. The interlaminated carbonate and anhydrite are well known as possible examples of annual layering or varves.

In the eastern part of the Delaware Basin, the Castile is commonly 1,400 to 1,500 ft thick (427 to 457 m) (derived from Borns and Shaffer, 1985, Figs. 9, 11, and 16). At DOE-2, the Castile is 989 ft (301 m) thick. The Castile is thinner in the western part of the Delaware Basin, and it lacks halite units. Anderson et al. (1978, Figs. 1, 3, 4, and 5) correlated geophysical logs, interpreting thin zones equivalent to halite units as dissolution residues. Anderson further interpreted the lack of halite in the basin as having been removed by dissolution.

For borehole DOE-2, a primary objective was to ascertain whether a series of depressions in the Salado, 2 mi (3.3 km) north of the site, was due to dissolution in the Castile as proposed by Davies in his doctoral thesis in 1984. Studies have suggested that these depressions were not due to dissolution but to halokinesis in the Castile (for example, see Borns [1987] and Chaturvedi [1987] in the Bibliography). Robinson and Powers (1987, pp. 69-79) analyzed one such unit as partly due to synsedimentary, gravity-driven clastic deposition and suggested that the extent of dissolution may be overestimated. No Castile dissolution is known to be present in the immediate vicinity of the WIPP site. The process of dissolution and the resulting features are further discussed later in this appendix.

In Culberson County, Texas, the Castile hosts major native sulfur deposits. The outcrops of the Castile on the Gypsum Plain south of White's City, New Mexico, have been explored for native sulfur without success, and there is no reported indicator of native sulfur anywhere in the vicinity of the WIPP.

In a portion of the area around the WIPP, the Castile has been significantly deformed, and there are pressurized brines associated with the deformed areas; borehole ERDA-6 encountered both. WIPP-12, 1 mi (1.6 km) north of the WIPP site center, revealed lesser Castile structure, but it also encountered a zone of pressurized brine within the Castile. The Castile deformation is described and discussed later in Section 1.1.5 (structural features), and pressurized brines are described in Section 1.2, which details the area's hydrology.

The Castile continues to be an object of research interest unrelated to the WIPP program as an example of evaporites supposedly deposited in "deep water." Anderson (1993, pp. 12-13) discusses alternatives and contradictory evidence. Similar discussions may eventually affect concepts of the Castile deposition and dissolution; however, this issue is largely of academic interest and bears no impact on the suitability of the Los Medaños region for the WIPP site.

D6-1c(4) The Salado Formation

The Salado is dominated by halite, in contrast to the underlying Castile, and extends well beyond the Delaware Basin. Lowenstein (1988, pp. 592-608) has termed the Salado a "saline giant." The Fletcher Anhydrite Member, which is deposited on the Capitan reef rocks, is defined by Lang (1939, pp. 1569-1572; 1942, pp. 63-79) as the base of the Salado. Some investigators believe the Fletcher Anhydrite Member may interfinger with anhydrites normally considered part of the Castile. The Castile/Salado contact is not uniform across the basin, and whether it is conformable is still under consideration. Around the WIPP site, the Castile/Salado contact is commonly placed at the top of a thick anhydrite informally designated as A3; the overlying halite is called the infra-Cowden salt and is included within the Salado. Bodine (1978, pp. 28-29) suggests that the clay mineralogy of the infra-Cowden in ERDA-9 cores changes at about 15 ft (4.6 m) above the lowermost Salado and that the lowermost clays are more like the Castile clays. The top of the thick anhydrite remains the local contact for differentiating the Salado from the Castile, and there is no known significance to the WIPP from these differences.

The Salado in the northern Delaware Basin is broadly divided into three informal members. (Figure D6-7 details the Salado's stratigraphy.) The middle member is known locally as the McNutt potash zone, and it includes 11 defined potash zones, 10 of which are of economic significance in the Carlsbad Potash District. The lower and upper members remain unnamed. The WIPP repository level is located below the McNutt Potash Zone in the lower member.

Within the Delaware Basin, a system is used for numbering the more significant sulfate beds in the Salado, designating these beds as marker beds from Marker Bed 100 (near the top of the formation) to Marker Bed 144 (near the base). The system is generally used within the Carlsbad

Potash District as well as at and around the WIPP site. The facility horizon is located between Marker Bed 139 and Marker Bed 138.

In the central and eastern part of the Delaware Basin, the Salado is at its thickest, ranging up to about 2,000 ft (about 600 m) thick and consisting mainly of interbeds of sulfate minerals and halite, with halite dominating. The thinnest portions of the Salado consist of a brecciated residue of insoluble material a few tens of feet thick and crop out in parts of the western Delaware Basin. The common sulfate minerals are anhydrite ($CaSO_4$), gypsum ($CaSO_4 \cdot 2H_2O$) near the surface, and polyhalite ($K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$). The sulfate minerals form beds and are also found along boundaries between halite crystals.

Early investigators of the Salado recognized a repetitious vertical succession, or cycle, of beds in the Salado: clay-anhydrite-polyhalite-halite and minor polyhalite-halite. Later investigators described the cyclical units as clay-magnesite-anhydrite, polyhalite or glauberite-halite-argillaceous halite capped by mudstone. Lowenstein (1988, pp. 592-608) defined a depositional cycle (Type I) consisting of: (1) basal mixed siliciclastic and carbonate (magnesite) mudstone, (2) laminated to massive anhydrite or polyhalite, (3) halite, and (4) halite with mud. Lowenstein in 1988 also recognized repetitious sequences of halite and halite with mud as incomplete Type I cycles and termed them Type II cycles. Lowenstein (1988, pp. 592-608) interpreted the Type I cycles as having formed in a shallowing upward, desiccating basin beginning with a perennial lake or lagoon of marine origin and evaporating to saline lagoon and saltpan environments.

Type II cycles are differentiated because they do not exhibit features of prolonged subaqueous deposition and also have more siliciclastic influx than do Type I cycles.

From detailed mapping of the Salado in the Air Intake Shaft at WIPP, Holt and Powers (1990, pp. 45-72) constructed a more detailed sedimentological analysis of the Salado depositional cycles, similar in broad aspects to the Type I cycle defined by Lowenstein in 1988. The details available from the shaft demonstrated the important role of syndepositional water level to water-table changes that created solution pits and pipes within the halitic beds while they were at the surface. Holt and Powers (1990, App. F, pp. 3-26) concluded that passive halite cements filled the pits and pipes, as well as less dramatic voids, as the water table rose. Early diagenetic to synsedimentary cements filled the porosity early and rather completely, reducing the porosity to a very small volume according to Casas and Lowenstein in 1989. These void-filling halites are commonly clear and coarsely crystalline and might be mistaken for recrystallization textures. Although Holt and Powers did not find it in their 1988 study, other investigators have found much evidence for halite recrystallization (or halite diagenesis) in the Salado.

The effects of water-rock interactions resulting in evaporite dissolution in the Salado are observable near the surface in the Nash Draw and other localities where gypsum karst is developed and where overlying units, such as the Rustler, the Dewey Lake, and the post-Permian rocks, have subsided. Physical evidence of water-rock interaction (e.g., post-depositional accumulation of insoluble residues, brecciation from differential collapse, and mass removal) in

the Salado is less apparent, especially where it is buried at depths greater than 984 ft (300 m). However, given the susceptibility of evaporite minerals to dissolution by circulating groundwater, geochronological investigations provide a means of determining the approximation time of latest episode of regional recrystallization of the evaporite minerals, which can be inferred as the approximate time of the latest episode of freely circulating groundwater. Radiometric dates for minerals of the Salado are available from several sources (Register and Brookins, 1980, pp. 29-31; Brookins, 1980, pp. 29-31; Brookins et al., 1980, pp. 635-637; Brookins 1981, pp. 147-152; Brookins and Lambert, 1987, pp. 147-152). The distribution of dates shows that rubidium-strontium (Rb-Sr) isochron determinations on evaporite minerals, largely sylvite (179-229 million years ago [Ma]), are in good agreement with potassium-argon (K-Ar) determinations on pure polyhalites (195-216 Ma).

The only recrystallization event found younger than Early Jurassic (200 Ma) was known to be a contact phenomenon associated with emplacement of an Oligocene lamprophyre dike (21 Ma for polyhalite versus 32-34 Ma for the dike; see Calzia and Hiss, 1978, pp. 39-45). Clay minerals have both Rb-Sr isochron and K-Ar ages significantly older (390 ± 77 Ma) than the evaporites.

It has been known that sylvite yields significantly younger K-Ar ages than Rb-Sr ages. This has been explained as loss of radiogenic Ar. Radiogenic Sr, as a solid, and dating by the Rb-Sr isochron method is not considered as likely to give spurious results, especially if the isochron is well defined. The results of radiometric determinations argue for the absence of pervasive recrystallization of the evaporites in the Salado in the last 200 Ma. The number of replicate determinations, the wide distribution of dated minerals throughout the Delaware Basin, and the concordance of dates obtained by various radiometric methods all indicate that this conclusion is supportable based on generally accepted interpretations.

Argillaceous halites and halitic mudstone at the top of many depositional cycles were interpreted by Holt and Powers (1990, pp. 45-78) in terms of modern features, such as those at the Devil's Golf Course at Death Valley National Monument, California. The evaporative basin was desiccated, and varying amounts of insoluble residues collected on the surface through surficial dissolution, eolian sedimentation, and some clastic sedimentation from temporary flooding caused by runoff from surrounding areas. The surface developed local relief that could be mapped in some cycles, while the action of continuing desiccation and exposure increasingly concentrated insoluble residues. Flooding, most commonly from marine sources, reset the sedimentary cycle by depositing a sulfate bed.

Within the Nash Draw, Robinson and Lang (1938, pp. 2-64 to 2-67) recognized a zone equivalent to the upper Salado but lacking halite. Test wells in the southern Nash Draw produced brine from this interval, and it has become known as the brine aquifer. Robinson and Lang in 1938 considered this zone a residuum from dissolution of Salado halite. Jones et al. (1960, p. 25) remarked that the residuum should be considered part of the Salado, though geophysical log signatures may resemble the lower Rustler.

At the center of the site, Holt and Powers in their 1984 report recognized clasts of fossil fragments and mapped channeling in siltstones and mudstones above halite; they considered these beds to be a normal part of the transition from shallow evaporative lagoons and desiccated salt pans of the Salado to the saline lagoon of the lower Rustler. Although the Salado salt may have been dissolved prior to deposition of the Rustler clastics, the process is detached from the concept of subsurface removal of salt from the Salado in more recent time to develop a residuum and associated "brine aquifer."

Based on the Salado isopachs, thickness begins to change significantly near Livingston Ridge, the eastern margin of the Nash Draw. That should be the approximate eastward limit to the residuum and "brine aquifer," although the normal sedimentary sequence may yield limited fluids east of this margin.

The DOE believes the Salado is of primary importance to the containment of waste. As the principal natural barrier, many of the properties of the Salado have been characterized, and numerical codes were developed to simulate the natural processes within the Salado that affect the disposal system performance.

D6-1c(5) Rustler Formation

The Rustler Formation (hereafter referred to as the Rustler) is the youngest evaporite-bearing formation in the Delaware Basin. It was originally named by Richardson for outcrops in the Rustler Hills of Culberson County, Texas. Adams (1944, p. 1614) first used the names "Culebra member" and "Magenta member" to describe the two carbonates in the formation, indicating that W. B. Lang favored the names, although Lang did not use these names in his most recent publication. Vine in his 1963 work described extensively the Rustler in the Nash Draw and proposed the four formal names and one informal term for the stratigraphic subdivisions still used for the Rustler (from the base): the unnamed lower member, the Culebra member, the Tamarisk member, the Magenta member, and the Forty-niner member (Figure D6-8). (The Culebra member, the Tamarisk member, the Magenta member, and the Forty-niner member are hereafter referred to as the Culebra, the Tamarisk, the Magenta, and the Forty-niner.) Although some investigators suggest that the unnamed lower member might be referred to as the Los Medaños member, the nomenclature has not been formalized.

An additional system of informal subdivisions was contributed by Holt and Powers (1988, Fig. 3.2), based on more detailed lithologic units of the noncarbonate members (Figure D6-8). These subdivisions have partially been related to hydrostratigraphic units for the Rustler.

Two studies of the Rustler since Vine's 1963 work contribute important information about the stratigraphy, sedimentology, and regional relationships while examining more local details as well. Eager (1983, pp. 273-283) reported on relationships of the Rustler observed in the southern Delaware Basin as part of sulfur exploration in the area. Holt and Powers (1988, Chapter 5.0)

reported the details of sedimentologic and stratigraphic studies of WIPP shafts and cores as well as of geophysical logs from about 600 boreholes in southeastern New Mexico.

The Rustler is regionally extensive (a similar unit in the Texas panhandle is also called the Rustler). Within the area around the WIPP site, evaporite units of the Rustler are interbedded with significant siliciclastic beds and carbonates. Both the Magenta and the Culebra extend regionally beyond areas of direct interest to the WIPP. In the general area of the WIPP, both the Tamarisk and the Forty-Niner have similar lithologies: lower and upper sulfate beds and a middle unit that varies principally from mudstone to halite from west to east (Figure D6-8).

In a general sense, halite in the unnamed lower member broadly persists to the west of the WIPP site, and halite is found east of the center of the WIPP in the Tamarisk and the Forty-Niner (Figure D6-9). (Additional detail on the lithologies of these members follow.) Two differing depositional models have been generally used, either implicitly or explicitly, to account for the halite distribution. A longstanding and implicit model in many earlier documents is that halite was originally deposited relatively uniformly in the noncarbonate members across southeastern New Mexico, including the WIPP site area. The modern distribution is caused by dissolution of the Rustler halite to the west and progressing toward the east. As shown by Holt and Powers (1988), sedimentary features and textures within WIPP shafts and cores that led them to propose an explicit model of depositional facies for the mudstone-halite units; halite was dissolved syndepositionally from mud-flat facies, especially to the west, and was redeposited in a halite pan to the east. The Culebra transmissivity shows about six orders of magnitude variation across the area around the site, and the changes have commonly been attributed to post-depositional dissolution of the Rustler halite.

In the region around the WIPP, the Rustler reaches a maximum thickness of more than 500 ft (152 m) (Figure D6-10), while it is about 300 to 350 ft (91 to 107 m) thick within most of the WIPP site. Much of the difference in the Rustler thickness can be attributed to variations in the amount of halite contained in the formation from place to place. The Tamarisk accounts for a larger part of thickness changes than do either the unnamed lower member or the Forty-Niner. Much project-specific information about the Rustler is contained in Holt and Powers (1988). The WIPP shafts were a crucial element in their study, exposing features not previously reported. Cores were available from several WIPP boreholes, and their lithologies were matched to geophysical log signatures to extend the interpretation throughout a larger area in southeastern New Mexico.

D6-1c(5)(a) The Unnamed Lower Member

The unnamed lower member rests on the Salado with apparent conformity at the WIPP site. It consists of significant proportions of bedded and burrowed siliciclastic sedimentary rocks with cross bedding and fossil remains. These beds record the transition from strongly evaporative environments of the Salado to saline lagoonal environments. The upper part of the unnamed lower member includes halitic and sulfitic beds within clastics. Holt and Powers (1988, p. 9-1*ff*) interpret these as facies changes within a saline playa environment. The implied model from

earlier descriptions is that the nonhalitic areas of the upper unnamed lower member are dissolution residues from post-depositional dissolution.

As shown in Holt and Powers (1988, Fig. 4.7), the unnamed lower member ranges in thickness from about 96 to 126 ft (29 to 38 m) within the site boundaries. The maximum thickness recorded during that study was 208 ft (63 m) southeast of the WIPP site. Halite extends west of most of the site area in this unit (see Figure D6-9 for an illustration of the halite margins). Cross sections based on geophysical log interpretations in Holt and Powers (1988) show the relationship between the thickness of the unit and the presence of halite.

D6-1c(5)(b) The Culebra Member

The Culebra rests with apparent conformity on the unnamed lower member, though the underlying unit ranges from claystone to its lateral halitic equivalent in the site area. West of the WIPP site, in the Nash Draw, the Culebra is disrupted in response to dissolution of underlying halite. Holt and Powers (1988, pp. 6-12, 6-13, 8-14*ff*) attribute this principally to dissolution of the Salado halite, while Snyder (1985, p. 6) indicates that salt was dissolved post-depositionally from the unnamed lower member. These alternative models provide the basis for differing explanations of how the existing Rustler hydrologic system developed and might continue to develop.

The Culebra was described by Robinson and Lang in 1938 as a dolomite 35 ft (11 m) in thickness; Adams (1944, p. 78) noted that oölites are present in some outcrops as well. The Culebra is generally brown, finely crystalline, locally argillaceous and arenaceous dolomite, with rare to abundant vugs with variable gypsum and anhydrite filling. Holt and Powers (1988) describe the Culebra features in detail, noting that most of the Culebra is microlaminated to thinly laminated, while some zones display no depositional fabric. Holt and Powers (1984) described an upper interval of the Culebra consisting of waxy, golden-brown carbonate, dark organic claystone, and some coarser siltstone of probable algal origin. Because of the unique organic composition of this thin layer, Holt and Powers (1984) did not include it in the Culebra for thickness computations, and this will be factored into discussions of Culebra thickness. Based on core descriptions from the WIPP Project, Holt and Powers (1988, p. 5-11) concluded that there is very little variation of depositional sedimentary features throughout the Culebra.

Vugs are an important part of Culebra porosity. They are commonly zoned parallel to bedding. In outcrop, vugs are commonly empty. In the subsurface, vugs may be filled with anhydrite or gypsum, or they may have some clay lining. Lowenstein (1988, pp. 20-21) noted similar features. Holt and Powers (1988) attribute vugs partly to syndepositional growth as nodules and partly, later, as replacive textures. Lowenstein (1988, pp. 592-608) also described textures related to later replacement and alteration of sulfates. Vugs or pore fillings vary across the WIPP site and contribute to the porosity structure of the Culebra. Natural fractures filled with gypsum are common east of the WIPP site center and in a smaller area west of the site center (Figure D6-11).

After dolomite, Sewards et al. (1991, p. IX-1) report that clay is the most abundant mineral of the Culebra. Clay minerals include corrensite, illite, serpentine, and chlorite. Clay occurs in bulk rock and in fracture surfaces.

In the WIPP site area, the Culebra varies in thickness. Different data sources provide varying estimates (Table D6-1). Holt and Powers (1988, pp. 4-7) considered the organic-rich layer at the Culebra/Tamarisk contact separately from the Culebra in interpreting geophysical logs.

Comparing data sets, Holt and Powers (1988) typically interpret the Culebra as being about 3 ft (about 1 m) thinner than have other sources. In general, this reflects the difference between including or excluding the unit at the Culebra/Tamarisk contact. Each data set shows areal differences in thickness of the Culebra when it is examined township by township.

LaVenue et al. (1988) calculated a mean thickness of 25 ft (7.7 m) for the Culebra based on 78 boreholes. This mean thickness has been used uniformly for the Culebra in PA calculations. Many of the boreholes represented multiple drilling location (points) at individual hydrology drill pads H-2 through H-11. The multiple points at each drillhead normally would be considered a single location for statistical purposes. If each data point is considered to be distinct, the implication is that thickness varies significantly over the distances between these closely spaced boreholes, and it may not be consistent for calculations to use averaging thickness as a parameter. Mercer (1983, Table 1) reported a data set similar to LaVenue et al. (1988), but without statistics.

The borehole database in Sub-Appendix BH makes it possible to defend choices of the Culebra thicknesses for the area being modeled. If repository performance is insensitive to Culebra thickness, defining the specific thickness of the Culebra is not important.

D6-1c(5)(c) The Tamarisk Member

Vine (1963, p. B15) named the Tamarisk for outcrops near Tamarisk Flat in the Nash Draw. Outcrops of the Tamarisk are distorted, and subsurface information was used to establish member characteristics. Vine reported two sulfate units separated by a siltstone, about 5 ft (1.5 m) thick, interpreted by Jones et al. (1960) as a dissolution residue.

The Tamarisk is generally conformable with the underlying Culebra. The transition is marked by an organic-rich unit interpreted as being present over most of southeastern New Mexico. The Tamarisk around the site area consists of lower and upper sulfate units separated by a unit that varies from mudstone (generally to the west) to mainly halite (to the east). Near the center of the WIPP site, the lower anhydrite was partially eroded during deposition of the middle mudstone unit, as observed by in the WIPP Waste Shaft and the WIPP Exhaust Shaft. The lower anhydrite was completely eroded at WIPP-19. Before shaft exposures were available, the lack of the lower Tamarisk anhydrite at WIPP-19 was interpreted as the result of solution, and the mudstone was considered a cave filling.

Jones et al. (1960) interpreted halite to be present east of the center of the WIPP site based on geophysical logs and drill cuttings. Based mainly on cores and cuttings records from the WIPP potash drilling program, Snyder prepared a map in 1985 showing the halitic areas of each of the noncarbonate Rustler members. A very similar map based on geophysical log characteristics was prepared independently by Powers in 1984 (see Figure D6-9).

Holt and Powers (1988) describe the mudstones and halitic facies in the middle of the Tamarisk, and they interpreted the unit as formed in a salt pan to mud-flat system. They cited sedimentary features and the lateral relationships as evidence of syndepositional dissolution of halite in the marginal mud-flat areas. In contrast, other investigators interpreted the lateral decrease in thickness and absence of halite to the west as evidence of post-depositional dissolution (see for example Jones et al. [1960], Jones [1978], and Snyder [1985] in the bibliography). The differing concepts for halite distribution in the Rustler, and particularly the Tamarisk, have been used in explaining the large changes in hydrologic properties of the Culebra, as described in later sections.

The Tamarisk thickness varies greatly in southeastern New Mexico, principally as a function of the thickness of halite in the middle unit. Within T22S, R31E, Holt and Powers (1988) show a range from 84 to 184 ft (26 to 56 m) for the entire Tamarisk and a range from 6 to 110 ft (2 to 34 m) for the interval of mudstone-halite between lower and upper anhydrites. Expanded geophysical logs with corresponding lithology illustrate some of the lateral relationships for this interval (Figure D6-12).

D6-1c(5)(d) The Magenta Member

Adams (1944, p. 1614) attributes the name "Magenta member" to W. B. Lang, based on a feature north of Laguna Grande de la Sal named Magenta Point. According to Holt and Powers (1988, p. 5-22*ff*), the Magenta is a gypsiferous dolomite with abundant primary sedimentary structures and well-developed algal features. It does not vary greatly in sedimentary features across the site area.

Holt and Powers (1988, p. 5-22) reported that the Magenta varies from 23 to 28 ft (7.0 to 8.5 m); they did not contour the thickness because of limited changes.

D6-1c(5)(e) The Forty-niner Member

J. D. Vine named the Forty-Niner for outcrops at Forty-Niner Ridge in the eastern Nash Draw, but the outcrops of the Forty-Niner are poorly exposed. In the subsurface around the WIPP, the Forty-niner consists of basal and upper sulfates separated by a mudstone. It is conformable with the underlying Magenta. As with other members of the Rustler, geophysical log characteristics can be correlated with core and shaft descriptions to extend geological inferences across a large area.

The Forty-Niner ranges from 43 to 77 ft (13 to 23 m) thick within T22S, R31E. East and southeast of the WIPP, the Forty-Niner exceeds 80 ft (24 m), and some of the geophysical logs from this area indicate halite is present in the beds between the sulfates.

Within the Waste Shaft, the Forty-Niner mudstone displays sedimentary features and bedding relationships indicating sedimentary transport. The mudstone has been commonly interpreted as a residue from the dissolution of halitic beds because it is thinner where there is no halite. These beds have not been described in detail prior to mapping in the Waste Shaft at the WIPP. The features found in the shaft led Holt and Powers (1988, p. i, ii) to reexamine the available evidence for and interpretations of dissolution of halite in the Rustler units.

D6-1c(6) The Dewey Lake

The nomenclature for rocks included in the Dewey Lake was introduced during the 1960s to clarify relationships between these rocks assigned to the Upper Permian and the Cenozoic Gatuña Formation (hereafter referred to as the Gatuña).

There are three main sources of data about the Dewey Lake in the area around the WIPP. Miller reported the petrology of the unit in 1955 and 1966. Schiel described outcrops in the Nash Draw areas and interpreted geophysical logs of the unit in southeastern New Mexico and west Texas to infer the depositional environments and stratigraphic relationships in 1988 and 1994. Holt and Powers (1990) were able to describe the Dewey Lake in detail at the Air Intake Shaft for the WIPP in 1990, confirming much of Schiel's information and adding data regarding the lower Dewey Lake.

The Dewey Lake overlies the Rustler conformably though local examples of the contact (e.g., the Air Intake Shaft described by Holt and Powers [1990]) show minor disruption by dissolution of some of the upper Rustler sulfate). The formation is predominantly reddish-brown fine sandstone to siltstone or silty claystone with greenish-gray reduction spots. Thin bedding, ripple cross-bedding, and larger channeling are common features in outcrops, and additional soft sediment deformation features and early fracturing are described from the lower part of the formation by Holt and Powers (1990). Schiel (1988; 1994, p. 5-13) attributed the Dewey Lake to deposition on "a large, arid fluvial plain subject to ephemeral flood events."

There is little direct faunal or radiometric evidence of the age of the Dewey Lake. It is assigned to the Ochoan series of late Permian age, and it is regionally correlated with units of similar lithology and stratigraphic position. Schiel in both 1988 and 1994 reviewed the limited radiometric data from lithologically similar rocks (Quartermaster Formation) and concluded that much of the unit could be early Triassic in age.

Near the center of the WIPP site, Holt and Powers (1990, Fig. 5) mapped 498 ft (152 m) of the Dewey Lake (Figure D6-13). The formation is thicker to the east (Schiel, 1994, p. 6) of the WIPP site, in part because western areas were eroded before the overlying Triassic rocks were deposited.

The Dewey Lake is extensively fractured, and both cements and fracture fillings have been further examined to ascertain the possible contributions of surface infiltration to underlying units. Holt and Powers (1990, p. 3-8*ff*) described the Dewey Lake as cemented by carbonate above 164.5 ft (50 m) in the Air Intake Shaft; some fractures in the lower part of this interval were also filled with carbonate, and the entire interval surface was commonly moist. Below this point, the cement is harder (probably anhydrite), the shaft is dry, and fractures are filled with gypsum. Holt and Powers (1990, pp. 3-11, Fig. 16) suggested the cement change might be related to infiltration of meteoric water. They also determined that some of the gypsum-filled fractures are syndepositional. The Dewey Lake fractures include horizontal to subvertical trends, some of which were mapped in detail (Holt and Powers, 1986, Figs. 6–8).

Lambert (1991, pp. 5-65) analyzed the deuterium/hydrogen (D/H) ratios of gypsum in the Rustler and gypsum veins in the Dewey Lake and suggests that none of the gypsum formed from evaporitic fluid, such as Permian seawater. Rather, they formed from meteoric water. Lambert (1991, pp. 5-66) infers that the gypsum D/H is not consistent with modern meteoric water, but it may be consistent with earlier meteoric fluids. There is no obvious correlation with depth indicating infiltration. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) indicate no intermixing or homogenization of fluids between the Rustler and the Dewey Lake, but there may be lateral movement of water within the Dewey Lake. The Dewey Lake carbonate vein material shows a broader range of strontium ratios than does surface caliche, and the ratios barely overlap.

D6-1c(7) The Santa Rosa

There have been different approaches to the nomenclature of rocks of the Triassic age in southeastern New Mexico. Bachman generally described the units in 1974 as "Triassic, undivided" or as the Dockum Group. Vine in 1963 used the term "Santa Rosa Sandstone." "The Santa Rosa" has become common usage. Lucas and Anderson in 1993 imported other formation names that are unlikely to be useful for WIPP.

The Santa Rosa is disconformable over the Dewey Lake (Vine, 1963, p. B25). The rocks of the Santa Rosa have more variegated hues than the underlying uniformly colored Dewey Lake. Coarse-grained rocks, including conglomerates are common, and the formation includes a variety of cross-bedding and sedimentary features (Lucas and Anderson, 1993, pp. 231-235).

Within the WIPP site boundary, the Santa Rosa is relatively thin to absent (Figure D6-14). At the Air Intake Shaft, Holt and Powers (1990, Fig. 5) attributed about 2 ft (0.6 m) of rock to the Santa Rosa. The Santa Rosa is a maximum of 255 ft (78 m) thick in potash holes drilled for WIPP east of the site boundary. The Santa Rosa is thicker to the east.

D6-1c(8) The Gatuña Formation

Lang in 1938 named the Gatuña for outcrops in the vicinity of the Gatuña Canyon in the Clayton Basin. Rocks now attributed to the Gatuña in Pierce Canyon were once included in the "Pierce

Canyon Formation," along with rocks now assigned to the Dewey Lake. The formation has been mapped from the Santa Rosa, New Mexico, area south to the vicinity of Pecos, Texas. It unconformably overlies different substrates.

Vine in 1963 and Bachman in 1974 provided some limited description of the Gatuña. The DOE's most comprehensive study of the Gatuña is based on WIPP investigations and landfill studies for Carlsbad and Eddy County. Much of the formation is colored light reddish-brown. It is broadly similar to the Dewey Lake and the Santa Rosa, though the older units have more intense hues. The formation is highly variable, ranging from coarse conglomerates to claystones with some highly gypsiferous sections. Sedimentary structures are abundant. Analysis of lithofacies indicates that the formation is dominantly fluvial in origin with areas of low-energy deposits and evaporitic minerals. It was deposited in part over areas actively subsiding in response to dissolution.

The thickness of the Gatuña is not very consistent regionally. Thicknesses range up to about 300 ft (91 m) at the Pierce Canyon, with thicker areas generally subparallel to the Pecos River. To the east, the Gatuña is thin or absent. Holt and Powers (1990) reported about 9 ft (2.7 m) of undisturbed Gatuña in the Air Intake Shaft at the WIPP.

The Gatuña has been considered to be Pleistocene in age based on a volcanic glass in the upper Gatuña that has been identified as the Lava Creek B ash dated at 0.6 million years by Izett and Wilcox (1982). An additional volcanic ash from the Gatuña in Texas yields consistent K-Ar and geochemical data, indicating it is about 13 million years (Powers and Holt 1993, p. 272). Thus the Gatuña ranges in age over a period of time that may be greater than the Ogallala Formation on the High Plains east of the WIPP.

D6-1c(9) The Mescalero Caliche

The Mescalero caliche (hereafter referred to as the Mescalero) is an informal stratigraphic unit first explicitly used by Bachman in 1974, although in 1973, Bachman described the "caliche on the Mescalero Plain" (Bachman, 1973, p. 17). He differentiated the Mescalero from the older, widespread Ogallala caliche or caprock on the basis of textures, noting that breccia and pisolitic textures are much more common in the Ogallala caliche. The Mescalero has been noted over significant areas in the Pecos drainage, including the WIPP site area, and it has been formed over a variety of substrates.

In 1974, Bachman described the Mescalero as a two-part unit: (1) an upper dense laminar caprock and (2) a basal, earthy to firm, nodular calcareous deposit. Machette (1985, p. 5) classified the Mescalero as having Stage V morphologies of a calcic soil (the more mature Ogallala caprock reaches Stage VI).

Bachman (1976, p. 148) provided structure contours on the Mescalero for a large area of southeastern New Mexico, including the WIPP site. From the contours and Bachman's (1976)

discussion of the Mescalero as a soil, it is clear that the Mescalero is expected to be continuous over large areas. Explicit WIPP data are limited mainly to boreholes, though some borehole reports do not mention the Mescalero. The unit may be as much as 10 ft (3 m) thick.

The Mescalero was inferred by Bachman (1974) on basic stratigraphic and climatic grounds as having accumulated during the early to middle Pleistocene. Bachman (1974) also reported finding a volcanic ash in the upper Gatuña along Livingston Ridge and underlying the Mescalero. His original report that this was the Pearlette "O" ash, but the report was superseded when Izett and Wilcox (1982) reported the ash as being Lava Creek B and about 0.6 million years old. The Mescalero must, therefore, be younger. Samples of the Mescalero from the vicinity of the WIPP were studied using uranium-trend methods. Based on early written communication from Rosholt, Bachman (1985, p. 20) reports that the basal Mescalero began to form about 510,000 years ago and that the upper part began to form about 410,000 years ago; these ages are commonly cited in WIPP literature. The samples are interpreted by Rosholt and McKinney in 1980 in the formal report as indicating ages of 570,000 ± 110,000 years for the lower part of the Mescalero and 420,000 ± 60,000 years for the upper part.

Based on morphology of caliche along part of the southern rim of Pierce Canyon, some of the caliche within the Delaware Basin may be Ogallala caliche instead of Mescalero. This issue has not been further addressed.

According to Bachman (1985, p. 19), the Mescalero soil is an indicator of stability or integrity of the WIPP site surface. Bachman (1985, p. 27) considered the Mescalero as an impediment to erosion; the discussion by Bachman indicates that the Mescalero is an indicator of surface stability over the last 500,000 years. The conclusions reached about stability of the WIPP site based on the presence of Mescalero and radiometric data are fundamentally sound.

D6-1c(10) Surficial Sediments

Soils of the region have developed mainly from Quaternary and Permian parent material. Parent material from the Quaternary system is represented by alluvial deposits of major streams, dune sand, and other surface deposits. These are mostly loamy and sandy sediments containing some coarse fragments. Parent material from the Permian system is represented by limestone, dolomite, and gypsum bedrock. Soils of the region have developed in a semiarid, continental climate with abundant sunshine, low relative humidity, erratic and low rainfall, and a wide variation in daily and seasonal temperatures. Subsoil colors normally are light brown to reddish brown but are often mixed with lime accumulations (caliche) that result from limited, erratic rainfall and insufficient leaching. A soil association is a landscape with a distinctive pattern of soil types (series). It normally consists of one or more major soils and at least one minor soil. There are three soil associations within 5 mi (8.3 km) of the WIPP site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit. Of these three associations, only the Kermit-Berino have been mapped across the WIPP site (by Chugg et al. [1952, Sheet No. 113]). These are sandy soils developed on eolian material. The Kermit-Berino include active dune areas. The

Berino soil has a sandy A horizon; the B horizons include more argillaceous material and weak to moderate soil structures. A and B horizons are described as noncalcareous, and the underlying C horizon is commonly caliche. Bachman in 1980 interpreted the Berino soil as a paleosol that is a remnant B horizon of the underlying Mescalero.

Generally, the Berino which covers about 50 percent of the site, consists of deep, noncalcareous, yellow-red to red sandy soils that developed in wind-worked material of mixed origin. These soils are described as undulating to hummocky and gently sloping (ranging from 0 to 3 percent slopes). The soils are the most extensive of the deep, sandy soils in the Eddy County area. The Berino is subject to continuing wind and water erosion. If the vegetative cover is seriously depleted, the water-erosion potential is slight, but the wind-erosion potential is very high. These soils are particularly sensitive to wind erosion in the months of March, April, and May, when rainfall is minimal and winds are highest.

The Kermit consists of deep, light-colored, noncalcareous, excessively drained loose sands, typically yellowish-red fine sand. The surface is undulating to billowy (from 0 to 3 percent slopes) and consists mostly of stabilized sand dunes. The Kermit is slightly to moderately eroded. Permeability is very high, and if vegetative cover is removed, the water-erosion potential is slight, but the wind-erosion potential is very high. In 1980, Rosholt and McKinney applied uranium-trend methods to samples of the Berino from the WIPP site area. They interpreted the age of formation of the Berino as 330,000 ± 75,000 years.

D6-1d Physiography and Geomorphology

In this section, the DOE presents a discussion of the physiography and geomorphology of the WIPP site and surrounding area.

D6-1d(1) Regional Physiography and Geomorphology

The WIPP site is in the Pecos Valley section of the southern Great Plains physiographic province (Figure D6-15), a broad highland belt sloping gently eastward from the Rocky Mountains and the Basin and Range Province to the Central Lowlands Province. The Pecos Valley section itself is dominated by the Pecos River Valley, a long north-south trough that is from 5 to 30 mi (8.3 to 50 km) wide and as much as 1,000 ft (305 m) deep in the north. The Pecos River system has evolved from the south, cutting headward through the Ogallala sediments and becoming entrenched some time after the middle Pleistocene. It receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent because of the semiarid climate. The surface locally has a karst terrain containing superficial sinkholes, dolines, and solution-subsidence troughs from both surface erosion and subsurface dissolution. The valley has an uneven rock- and alluvium-covered floor with widespread solution-subsidence features, the result of dissolution in the underlying Upper Permian rocks. The terrain varies from plains and lowlands to rugged canyonlands, including such erosional features as scarps, cuestas, terraces,

and mesas. The surface slopes gently eastward, reflecting the underlying rock strata. Elevations range from more than 6,000 ft (1,829 m) in the northwest to about 2,000 ft (610 m) in the south.

The Pecos Valley section is bordered on the east by the Llano Estacado, a virtually uneroded plain formed by river action. The Llano Estacado is part of the High Plains section of the Great Plains physiographic province and is a poorly drained, eastward-sloping surface covered by gravels, wind-blown sand, and caliche that has developed since early to middle Pleistocene time. Few and minor topographic features are present in the High Plains section, formed when more than 500 ft (152 m) of Tertiary silts, gravels, and sands were laid down in alluvial fans by streams draining the Rocky Mountains. In many areas, the nearly flat surface is cemented by a hard caliche layer.

To the west of the Pecos Valley section are the Sacramento Mountains and the Guadalupe Mountains, part of the Sacramento section of the Basin and Range Province. The Capitan Escarpment along the southeastern side of the Guadalupe Mountains marks the boundary between the Basin and Range and the Great Plains Provinces. The Sacramento section has large basinal areas and a series of intervening mountain ranges.

D6-1d(2) Site Physiography and Geomorphology

The land surface in the area of the WIPP site is a semiarid, wind-blown plain sloping gently to the west and southwest and is hummocky with sand ridges and dunes. A hard caliche layer (Mescalero caliche) is typically present beneath the sand blanket and on the surface of the underlying Pleistocene Gatuña. Figure D6-16 is a topographic map of the area. Elevations at the site range from 3,570 ft (1,088 m) in the east to 3,250 ft (990 m) in the west. The average east-to-west slope is 50 ft per mi (9.4 m per km).

The Livingston Ridge is the most prominent physiographic feature near the site. It is a west-facing escarpment that has about 75 ft (23 m) of topographic relief and marks the eastern edge of the Nash Draw, the drainage course nearest to the site. The Nash Draw is a shallow 5-mile-wide (8-km-wide) basin, 200 to 300 ft (61 to 91 m) deep and open to the southwest. It was caused, at least in part, by subsurface dissolution and the accompanying subsidence of overlying sediments. The Livingston Ridge is the approximate boundary between terrain that has undergone erosion and/or solution collapse and terrain that has been affected very little.

About 15 mi (24 km) east of the site is the southeast-trending San Simon Swale, a depression due, at least in part, to subsurface dissolution. Between San Simon Swale and the site is a broad, low mesa named "the Divide." Lying about 6 mi (9.7 km) east of the site and about 100 ft (30 m) above the surrounding terrain, the Divide is a boundary between southwestern drainage toward the Nash Draw and southeastern drainage toward the San Simon Swale. The Divide is capped by the Ogallala Formation (hereafter referred to as the Ogallala) and the overlying caliche, upon which have formed small, elongated depressions similar to those in the adjacent High Plains section to the east.

Surface drainage is intermittent; the nearest perennial stream is the Pecos River, 12 mi (19 km) southwest of the WIPP site boundary. The site's location near a natural divide protects it from flooding and serious erosion caused by heavy runoff. Should the climate become more humid, any perennial streams should follow the present basins, and the Nash Draw and the San Simon Swale would be the most eroded, leaving the area of the Divide relatively intact.

Dissolution-caused subsidence in the Nash Draw and elsewhere in the Delaware Basin has caused a search for geomorphic indications of subsidence near the site. One feature that has attracted some attention is a very shallow sink about 2 mi (3 km) north of the center of the site. It is very subdued, about 1,000 ft (305 m) in diameter, and about 30 ft (9 m) deep. Resistivity studies indicate a very shallow surficial fill within this sink and no disturbance of underlying beds, implying a surface, rather than subsurface, origin. Resistivity surveys in the site area showed an anomaly in Section 17 within the WIPP site boundary. It resembles the pattern over a known sink, a so-called breccia pipe, but drilling showed a normal subsurface structure without breccia, and the geophysical anomaly is assumed to be caused by low-resistivity rock in the Dewey Lake.

D6-1e Tectonic Setting and Site Structural Features

The processes and features included in this section are those more traditionally considered part of tectonics, broad-scale processes that develop the features of the earth. Salt dissolution is a different process that can develop some features resembling those of tectonics.

Broad-scale structural elements of the area around the WIPP developed over geological time, and most formed during the late Paleozoic. There is little historical or recent geological evidence of significant tectonic activity in the vicinity. More recently, the entire region has tilted, and activity related to Basin and Range tectonics formed major structures southwest of the area. Seismic activity is specifically addressed in Section D6-4.

Broad subsidence began in the area as early as the Ordovician, developing a sag called the Tabosa Basin. By late Pennsylvanian to early Permian time, the Central Basin Platform developed (Figure D6-17), separating the Tabosa Basin into two parts: the Delaware Basin to the west and the Midland Basin to the east. The Permian Basin refers to the collective set of depositional basins in the area during the Permian period. Southwest of the Delaware Basin, the Diablo Platform began developing either late in the Pennsylvanian or early Permian. The Marathon Uplift and Ouachita tectonic belt limited the southern extent of the Delaware Basin. Most of these broader scale features surrounding the Delaware Basin formed during the late Paleozoic and have remained relatively constant in their relationships since.

D6-1e(1) Basin Tilting

According to Brokaw et al. (1972, p. 30) pre-Ochoan sedimentary rocks in the Delaware Basin show evidence of gentle downwarping during deposition, while Ochoan and younger rocks do not. A relatively simple eastward tilt generally from about 75 to 100 ft per mi (14 to 19 m per km) has

been superimposed on the sedimentary sequence. P. B. King (1948, p. 108) generally attributes the uplift of the Guadalupe and Delaware mountains along the west side of the Delaware Basin to later Cenozoic, though he also notes that some faults along the west margin of the Guadalupe Mountains have displaced Quaternary gravels.

P. B. King (1948, p. 144) also infers that the uplift is related to the Pliocene-age deposits of the Llano Estacado. Subsequent studies of the Ogallala of the Llano Estacado show that it ranges in age from Miocene (about 12 million years before present) to Pliocene. This is the most likely range for uplift of the Guadalupes and broad tilting to the east of the Delaware Basin sequence.

D6-1e(2) Faulting

Fault zones are well known along the Central Basin Platform, east of the WIPP, from extensive drilling for oil and gas as reported by Hills (1984, pp. 250-267). Holt and Powers performed a more recent analysis in 1988 of geophysical logs to examine regional geology for the Rustler that showed these faults displaced, at least, the Rustler rocks of late Permian age. The overlying Dewey Lake shows marked thinning along the same trend as the fault line or zone according to Schiel (1988, Fig. 21), but the structure contours of the top of the Dewey Lake are not clearly offset. Schiel (1988) concluded that the fault was probably reactivated during Dewey Lake deposition, but movement ceased at least by the time the Santa Rosa was deposited. No surface displacement or fault has been reported along this trend, indicating movement has not been significant enough to rupture the overlying materials since Permian time.

Within the Delaware Basin, there are few examples of faults that may offset part of the evaporite section. At the northern end of the WIPP site, Snyder in Borns et al. (1983, p. 17*ff*) drew structure contours on the top of the basal A1 of the Castile for boreholes WIPP-11, WIPP-12, and WIPP-13. Northeast-southwest-trending faults were interpreted to displace this unit both north and south of WIPP-11 (Borns et al., 1983). Snyder inferred that the Bell Canyon/Castile contact is also faulted and displaced along the same trend. Barrows in Borns et al. (1983, pp. 58-60) interpreted seismic reflection data to indicate, with varying confidence, faults within Castile rocks but not in underlying units.

The faults interpreted by Snyder (Borns et al., 1983) around WIPP-11 depend on the correct identification of the basal Castile anhydrite (A1) in that borehole. The evaporite structure is complex, and some of the upper units of the Castile and the lower Salado differ from surrounding boreholes. The diagnostic Castile/Bell Canyon contact was not reached by this borehole, and the faults inferred for the Castile/Bell Canyon contact also depend on correct identification of A1 and projection of A1 thickness by Snyder (Borns et al., 1983). Inferred connections with the underlying Bell Canyon or deeper units could signify circulation of fluids to the evaporite section within the site boundaries. This is unlikely, given the Castile geology within boreholes WIPP-13 and DOE-2 near the trend of the inferred fault. Drilling for hydrocarbon exploration has been extensive around the northern and western boundaries of the site since the mid-1980s.

Muehlberger et al. (1978, pp. 337-340) have mapped quaternary fault scarps along the Salt Basin graben west of both the Guadalupe and the Delaware Mountains. These are the nearest known Quaternary faults of tectonic origin to the WIPP. Kelley in 1971 inferred the Carlsbad and Barrera faults along the eastern escarpment of the Guadalupe Mountains based mainly on vegetative linaments. Hayes and Bachman reexamined the field evidence for these faults in 1979 and concluded that they were nonexistent.

On a national basis, Howard et al. (1971, Sheets 1-2) assessed the location and potential for activity of young faults. For the region around the WIPP site, Howard et al. (1971, Sheet 1) located faults along the western escarpment of the Delaware and the Guadalupe mountains trend. These faults were judged to be late Quaternary (approximately the last 500,000 years) or older.

In summary, there are no known Quaternary or Holocene faults of tectonic origin offsetting rocks at the surface nearer to the site than the western escarpment of the Guadalupe Mountains. A significant part of the tilt of basin rocks is attributed to a mid-Miocene to Pliocene uplift along the Guadalupe/Sacramento mountains trend that is inferred on the basis of High Plains sediments of the Ogallala. Seismic activity is low and is commonly associated with secondary oil recovery along the Central Basin Platform.

D6-1e(3) Igneous Activity

Within the Delaware Basin, only one feature of igneous origin is known to have formed since the Precambrian. An igneous dike or series of echelon dikes occurs along a linear trace about 75 mi (120 km) long from the Yeso Hills south of White's City, New Mexico, to the northeast. At its closest, the dike trend passes about 8 mi (13 km) northwest of the WIPP site center. Evidence for the extent of the dike range from outcroppings at Yeso Hills to subsurface intercepts in boreholes and mines to airborne magnetic responses.

An early radiometric determination by Urry (1936, pp. 35-40) for the dike yielded an age of 30 ± 1.5 million years. More recent work by Calzia and Hiss (1978, pp. 39-45) on dike samples are consistent with early work, indicating an age of 34.8 ± 0.8 million years. Work by Brookins et al. (1980, pp. 28-31) on dike samples in contact with polyhalite indicated an age of about 21.4 million years.

Volcanic ashes found in the Gatuña were airborne from distant sources such as Yellowstone and represent no volcanic activity at the WIPP.

D6-1e(4) Loading and Unloading

Tectonic forces, working with environmental factors, produce conditions by which sediments can be deposited (causing loading of the underlying rocks) or eroded (causing unloading). The loading and unloading history of the site and surrounding areas may be considered a factor in the development of the hydrological system, including the Culebra, at the WIPP site.

The depth to the base of the Culebra in the area (Figure D6-18) indicates the current state of loading for the unit. This depth is a function of regional dip, erosion, and dissolution/subsidence. Regional geology information has been used to construct a broader view of the loading and unloading history at the site for the Culebra.

D6-1f Nontectonic Processes and Features

Halite in evaporite sequences is relatively plastic, which can lead to the process of deformation; it is also highly soluble, which can lead to the process of dissolution. Both processes (deformation and dissolution) can develop structural features similar to those developed by tectonic processes. The features developed by dissolution and deformation can be distinguished from similar-looking tectonic features where the underlying units do not reflect the same feature as do the evaporites. As an example, the evaporite deformation can commonly be shown not to affect the underlying Bell Canyon. The deformation also tends to die out in overlying units, and the Rustler or the Dewey Lake may show little, if any, of the effects of the deformed evaporites. Beds underlying areas of dissolved salt are not affected, but overlying units to the surface may be affected.

D6-1f(1) Evaporite Deformation

The most recent review of evaporite deformation in the northern Delaware Basin and original work to evaluate deformation is summarized here.

D6-1f(1)(a) Basic WIPP History of Deformation Investigations

Gravity-Driven Structure in the Castile Formation

This document describes the structural features in the Castile that are commonly attributed to gravity-driven deformation. In order to properly present this subject, the data will first be presented in a general historical overview. The known extent of deformation in the Castile, how these structures are likely to develop in the future, how well they can be predicted, and the potential impact law act of these structures on the WIPP will also be discussed. Apart from the general geological impact, the performance of the WIPP as it might be affected by such structures is not specifically assessed here.

Background Information

Parts of the Castile have been known for a number of years to be deformed. Cross sections of the basin geology through its margins have shown some evidence of deformation. Jones et al. (1973) provided a map of the isopachs of part of the Castile that clearly show much thicker portions in some of the areas along the northwestern to northern Delaware Basin, just inside the margin of the Capitan reef. Very little information was collated concerning deformation within the Delaware Basin prior to studies of the basin as a possible site for radioactive waste disposal.

Jones et al. (1973) is probably the most lucid early presentation of this information, although a dissertation by Snider (1966) and a paper by Anderson et al. (1972) also reflect thicker sections in some Castile units adjacent to the reef.

In 1975, SNL drilled a borehole ERDA-6 at a site (Figure D6-19) that had been partially investigated by Oak Ridge National Laboratories (ORNL) during 1974. Two boreholes (AEC-7 and AEC-8) had been drilled in 1974 by ORNL . Formation boundaries and marker beds in ERDA-6 were structurally high compared to AEC-7 and 8, and the degree of deformation increased downward. At about the 2,711-ft (826-m) depth, ERDA-6 began to produce pressurized brine and gas. The hole was eventually tested extensively to determine the nature and origin of the brine. Beds within the Castile were displaced structurally upward, apparently by hundreds of feet (Jones, 1981; Anderson and Powers, 1978), and some of the lower units may have actually pierced upper units (Anderson and Powers, 1978). Because of the desire for structurally uncomplicated units to simplify mining for a repository, the site under investigation at ERDA-6 was abandoned in 1975. In 1975-76 the current site was initially selected, and investigations were begun (Powers et al., 1978). As part of the selection criteria, a zone about 6 mi (10 km) wide inside the Capitan reef was avoided because it included known deformed Castile and Salado (Griswold, 1977). This is the first instance in which the site investigations were directly influenced by discovery of deformation in the Castile and the lower Salado.

The present site for the WIPP was selected and initially investigated in 1976 to determine if the desired characteristics for the preliminary site selection were present (Griswold, 1977; Powers et al.,1978). As the general criteria appeared to be met during this phase, the site and surrounding areas were characterized much more extensively and intensively beginning in 1977. Extensive new seismic reflection data were collected in 1977 and 1978 that began to reveal the deformed Castile north of the center of the site (Figure D6-20). Because the principal effect was that the good quality Castile reflectors from the area south of the site center were "disturbed," the area to the north was dubbed the "disturbed zone" (DZ). It also became known as "the area of anomalous seismic reflectors," or the "zone of anomalous seismic reelection data." The boundary of the DZ was variously described as being from about 0.5 to 1 mi (0.8 to 1.6 km) north of the center of the site, depending on the criteria to define the DZ. Powers et al. (1978) generally defined the DZ as beginning about 1 mi (1.6 km) north of the site center, where the seismic reflector character was poor to uninterpretable or "anomalous" (Borns et al., 1983). About 0.5 mi (0.8 km) north of the site center, it appeared that beds within the Castile began to steepen in gradient, dipping to the south from a higher area to the north. The Environmental Evaluation Group summarized various map limits to the DZ, including the area where the Castile dip begins to steepen (Neill et al., 1983). Borns et al. (1983) included two separate areas south of the site as part of the DZ based seismic character.

The first new drillhole within the area encompassed by the DZ was WIPP-11, and it was located about 3 mi (5 km) north of the center of the WIPP site (Figure D6-19). Long and Associates (1977) examined proprietary petroleum company data in 1976, and they identified anomalous areas around the WIPP site, including the structural anomaly at the WIPP-11 location. Seismic

reelection data acquired in 1977 indicated possible salt flowage within the Castile and a structure that could be similar to that at ERDA-6 (SNL and USGS, 1979). WIPP-11 was drilled early in 1978, demonstrating the extensive deformation within the Castile and extending upward into the Salado. WIPP-11 did not encounter any brine or gas flows.

Seismic reflection data acquired in 1977 not only showed a zone of steepened dip of the Castile north of the site center, it also showed a possible fault offsetting parts of the Salado and the Rustler. A series of five boreholes were planned to provide detailed information on the structure of the Rustler/Salado contact. Four boreholes (WIPP 18,19, 21, and 22) were required to demonstrate that there was no detectable offset on that contact in the area interpreted from 1977 seismic reflection data (Figure D6-19). Later epochs (1978 and 1979) of seismic data in the same area, along with the drilling, continued to show generally poor resolution or uninterpretable data in the area of the DZ. These studies generally showed that the acoustic velocity of the upper section changes laterally, complicating further the interpretation of the deeper Castile structure. Through the WIPP 18-22 drilling program, the upper Salado and the Rustler were determined to be fundamentally undisturbed over the southern margin of the disturbed zone where the Castile appears to dip to the south (SNL and USGS, 1979).

The upper part of the Castile about 1 mi (1.6 km) north of the WIPP site center was interpreted to range from about 250 ft to as much as 400 ft (100 to 120 m) (SNL and D'Appolonia Consulting Engineers, 1982a) above the elevation of the top of the Castile at about the center of the WIPP site. WIPP-12 was located approximately 1 mi (1.6 km) north of the site center to test the amount the Castile was elevated (Figures D6-19 and D6-20). It was drilled late in 1978 to the top of the Castile and detected approximately 160 ft (50 m) of structural elevation compared to ERDA-9 and the center of the site (SNL and D'Appolonia Consulting Engineers, 1982a). The amount of disturbance of the Salado was not considered to be an impediment to underground development, although the underground storage facility was later reoriented from this northern area to an area south of the site center. From drilling WIPP-12 and the WIPP 18-22 series, the southern margin of the DZ was considered to be much more gentle in structure, while the seismic character and WIPP-11 indicated much more severe deformation of the Castile further to the north.

Two additional phases of seismic reflection data were acquired in 1978 and 1979. These data mainly concerned the immediate site area (about 4 square mi [10 square km]) and the southern edge of the DZ. They indicated much the same problems and margins associated with the DZ from the 1977 data. The latest seismic data (1979) were principally acquired to facilitate construction and Site and Preliminary Design Validation (SPDV) activities. As the project moved into SPDV activities, the DZ was little investigated directly during the period from about late 1979 until mid-1981.

A microgravity survey of the site area was conducted to determine if the structure within the DZ could be partially resolved (Barrows et al., 1983; Barrows and Fett, 1985). The large differences in density of halite and anhydrite could cause detectable differences in the gravity field locally if the units were displaced and/or thickened relative to the surrounding areas. The microgravity

survey covered an area of "normal" stratigraphy from south of the WIPP site center to the area of WIPP-11 (Figure D6-21). As interpreted (Barrows et al., 1983), the microgravity does not resolve the larger scale deformation within the Castile. Based on the interpretation of probable shallow disturbance of the gravity field, WIPP-14 and WIPP-34 were drilled about 2 mi (3 km) north and about 0.5 mi (0.8 km) east of the site center (Figure D6-19). These boreholes encountered normal stratigraphy within the Rustler and upper Salado (SNL and D'Appolonia Consulting Engineers, 1982b; SNL and USGS, 1981), with some slight structural depression made apparent mainly by the deformation northeast of this area around ERDA-6 (Holt and Powers, 1988). Barrows et al. (1983) attributed the gravity anomaly around WIPP-14 to decreased density within parts of the Rustler, mainly from the difference in density due to anhydrite versus gypsum in WIPP-14. The overall difference in mass was attributed to karst processes by Barrows et al. (1983) rather than to deformation of any of the units associated with the DZ.

During the mapping of the first shaft drilled at the WIPP site (the Salt Handling Shaft), Marker Bed 139 was observed to have a few inches of relief on the basal contact and 2 to 3 ft (0.6 to 0.9 m) of relief on the upper surface. Jarolimek et al. (1983) interpreted the internal structure on these high points of Marker Bed 139 as showing a radial structure due apparently to gypsum growth textures and subsequent crushing, indicating a fundamentally depositional origin to the relief rather than any structural disturbance related to the DZ. Borns and Shaffer (1985) conducted an investigation of additional cores and holes drilled through Marker Bed 139, as there was concern on the part of the EEG that the apparent structure was related to the DZ. Borns and Shaffer (1985) also concluded that the relief was not due to structural deformation, but instead, was due mainly to erosional processes that carved part of the relief found on the top of the Marker Bed. From either point of view, the difference in relief on the upper and basal contacts of Marker Bed 139, in such a thin unit, were convincing evidence that a form of tectonic deformation was not involved.

In late 1981, WIPP-12 was deepened to test for the possible presence of brine and/or pressurized gas within the structure in the Castile (D'Appolonia Consulting Engineers, 1982). The probability of producing brine/gas from WIPP-12 was considered reasonably low at the time, because most known pressurized brine/gas was associated with much more deformed units in the Castile at WIPP-12. Fractured anhydrite in the upper Castile did begin to yield pressurized brine and gas when intercepted late in 1981, and WIPP-12 and ERDA-6 were further tested. Later geophysical work (Earth Technology Corporation, 1987) suggests that the brine may underlie part of the WIPP facility, beyond the area usually included in the DZ. Though the DOE and the EEG agreed that the structure did not constitute a threat to health and safety, the proposed underground facilities were reoriented south of the site center, avoiding longer haulage and the slight structure encountered at the facility horizon. As a consequence of the deepening and testing of WIPP-12, the link between structure and pressurized brine and gas was strengthened.

The last direct investigation of the DZ was a by-product of another investigation. DOE-2 was drilled approximately 2 mi (3.2 km) north of the center of the WIPP site to investigate the origin

of a modest depression on Marker Bed 124 (Griswold, 1977; Powers et al., 1978) that was detected in a core hole drilled by a potash company. DOE-2 was principally a test of the hypothesis that the depression was caused by ductile flow of halite in response to deep dissolution of halite by water from the Bell Canyon (Mercer et al., 1987). Halite layers in the lower Salado were thicker than usual, indicating that part of the sequence had not been dissolved, and the Castile was very deformed. The Castile stratigraphy was not normal; the second halite was apparently squeezed out of the area during deformation. The stratigraphy in DOE-2 is apparently the result of processes which caused the DZ and is not the result of any dissolution (Borns, 1987; Mercer et al., 1987).

The preceding paragraphs describe most of the direct investigations of the disturbed zone and place them in their historical context. In the following text, more of the specific features of the DZ will be described, interpreted, and discussed to indicate the significance of the structures and processes of formation for the WIPP.

Specific Features of the Disturbed Zone

The first specific feature of the DZ is its boundary. As discussed above, the different concepts of the boundary depend on ideas of where the Castile began to change and steepen its dip (about one-half mi [0.8 km] north of the site center) or where the seismic data became unreliable to uninterpretable. Borns et al. (1983) present one diagram (Figure D6-20) of the seismic time structure for the top of the Castile that illustrates the variously defined boundaries. The principal part of the disturbed zone is defined by a lobate area (Figure D6-20) shown as an "area of complex structure" where the seismic data are considered "ambiguous." The structurally deformed area clearly includes an area about halfway between boreholes WIPP-12 and ERDA-9, as well as a larger area to the northeast. The two-way travel time contoured on the map is a function of depth; as the reflector is nearer the surface, the travel time to the reflector and back to the surface decreases. Thus, the areas enclosed with contours of smaller values should be interpreted as structurally higher. (The top of the Castile in WIPP-12 was 160 ft [50 m] higher than it is in ERDA-9.) The map was not directly converted to depth because the seismic reflection and borehole geophysical logging programs clearly demonstrate that there are also lateral velocity variations within the upper part of the rock section, especially within the Rustler and the Dewey Lake. These velocity variations cannot be extracted from the travel times adequately to permit converting the travel time to depth. Nonetheless, the map demonstrates the general best information about the extent of the DZ. The central and southern parts of the WIPP site area display relatively uniform seismic travel time structure, and nothing within the geological data contradicts that information to date.

The broad forms of the structures within the DZ are generally anticlinal and synclinal (Borns, 1987), although they are not necessarily regular shapes. The best known shape for part of the DZ is between WIPP-12 and ERDA-9, where seismic information and several drillholes constrain part of the interpretation of the stratigraphy. There the structure tends to be a gently dipping limb of an anticlinal structure. Most of the remaining shapes attributed to the Castile

within the DZ or related areas are based more on one drill hole or a few drill holes that somewhat constrain the interpretation of the structure. WIPP-11, WIPP-13, DOE-1, and ERDA-6 are all examples. A generalized cross section of the structure at ERDA-6 (Anderson and Powers, 1978) shows a piercement structure and a regular shape; the piercement is based on stratigraphic inferences, but the shape is fundamentally uncontrolled by closely spaced data. WIPP-11 and WIPP-12 are both believed to penetrate anticlinal forms, though the structure is only partially known from drilling and seismic reflection data. DOE-2 is believed to lie in a synclinal structure, and contacts on various units show a nested series of depressions in the upper Salado (Borns, 1987). There are too few drill holes into the Castile to reconstruct the detailed shapes of Castile structures. The seismic data are not well enough constrained to calculate depths to reflectors, and most reflectors are too "disturbed" to interpret in this area. The specific shapes of individual structures are unlikely to be defined in the near future.

Anderson and Powers (1978) contoured several structures within the Delaware Basin, including structures at Poker Lake at least grossly similar to ERDA-6. Borns and Shaffer (1985) reexamined the information from Poker Lake and concluded that the actual shape is poorly constrained. Outside of the area on the north side of the current WIPP site, the information available is too sparse to define the individual shapes of structural features on borehole data.

It is important to note that, to date, none of the structures are demonstrably associated with comparable structure on the underlying Delaware Mountain Group. Snyder (in Borns et al., 1983) does show an upthrown block (horst) through WIPP-11 on the top of the Bell Canyon that is based on his projection of the thickness of the lower Castile; WIPP-11 did not penetrate the complete Castile section. Other areas, such as the Poker Lake structures, may display some relief on the top of the Delaware Mountain Group, but Borns and Shaffer (1985) do not attribute the relief to faulting. They believe the relief existed before and during deposition of the overlying Castile units. The underlying units to the Castile are, for the most part, uninvolved in the structures displayed by the Castile.

Structure contour and isopach maps of the Salado and the Rustler over areas of the complicated Castile structure also show that the overlying units are successively less involved in the structure (e.g., Borns and Shaffer, 1985; Borns et al., 1983; Holt and Powers, 1988). Lower units that are thicker and deformed are overlain by units that are thinner and less structurally involved in the deformation. Under normal geological circumstances, e.g., dealing with a rock sequence of carbonates or siliciclastics, the deformation would be considered to be completed by the time of deposition of the lowermost undeformed rock unit. Here, within a much more plastic set of rocks, the same geological reasoning is of less value, as the rocks may compensate laterally for late deformation effects and produce the same results.

Borns (1983; 1987; Borns et al., 1983) has extensively examined the macroscopic to microscopic features from cores taken within the structurally deformed areas. These studies follow earlier, broader studies of macroscopic features from the "state line outcrop" (Kirkland and Anderson, 1970) and ERDA-6 (Anderson and Powers, 1978). Kirkland and Anderson (1970) reported that

small-scale folding within the Castile outcrops is oriented consistently along the general north-south strike of beds in the Delaware Basin. From this they concluded that the deformation was related to tilt of the basin, generally believed to be Cenozoic in age (e.g., Anderson, 1978; King, 1948; Borns et al., 1983), although authors differ in opinions on when this took place by tens of millions of years. Anderson and Powers (1978) used this apparent relationship to estimate that folding at ERDA-6 took place after the tilt of the basin. Jones (1981) estimated that deformation took place before the Ogallala was deposited because that unit is undeformed at the location of ERDA-6. Bachman (1980) and Madsen and Raup (1988) are among investigators who interpret angular relationships between various formations of the Ochoan Series, beginning with the Castile/Salado contact. These relationships require tilting of the existing beds to the east, as the angular unconformities are always placed on the western side of the basin. Tilting of the basin may well have occurred through much of the time when the Ochoan Series was being deposited, as Holt and Powers (1988) present evidence that the depocenter for the Rustler was displaced eastward from the Castile and the Salado patterns and overlies part of the Capitan reef on the northeastern side of the Delaware Basin. The Delaware Basin appears to have tilted at various times from the late Permian to at least the Cenozoic, and the conditions for deformation may well have existed since the late Permian. Direct evidence of the time of affirmation has been difficult to obtain, and tilting of the basin, as a condition for the deformation, appears to have occurred at times beginning in the late Permian. Jones (1981) argues that the structure at ERDA-6 must be in part younger than Triassic because Triassic rocks are also deformed over the deformed evaporates, and that the structure must be older than late Cenozoic because the Ogallala over part of the structure is undeformed and erosionally truncates the upper part of the Triassic rocks. This may be the most conclusive age relationship demonstrated for any of these related structures. Conventional relationships with beds overlying deformed evaporites, such as that cited by Jones (1981) for the Ogallala, are suspect if the deformation ends or dies out vertically within the evaporites because of the potential for compensating deformation in evaporates (e.g., Borns, 1983).

Borns (1983, 1987) reexamined the "state line outcrop" as well as the cores from various boreholes and concluded that the styles of deformation present in these cores indicate a very complicated history, including episodes of deformation that are probably synsedimentary. The folding may, for example, display disharmonic or opposing styles that would not normally be attributed to a single episode of strain in a pervasive stress field. If the deformation all occurred in response to a single event such as the tilting of the Delaware Basin, the folds and other strain indicators should all have a common orientation. Isoclinal folding may occur very early, while asymmetric folding is often penetrative, indicating later time of origin. Fractures in more brittle units such as the Castile anhydrites are often very high-angle to vertical and are considered one of the late deformation features in cores. These fractures in the larger anticlinal structures of the DZ are apparently the proximate source of pressurized brines and gases. Borns (Borns and Shaffer, 1985; Borns, 1987) recognized that tilting of the basin, among other possible sources of stress, may have occurred at several different times and is not limited to a single Cenozoic event.

Hypotheses of Formation of Deformation in Castile

Several hypotheses have been advanced for the formation of the Castile structures in the DZ and other parts of the Delaware Basin (Borns et al., 1983). The five principal processes hypothesized as causes of the DZ are gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes (Borns et al., 1983). Each of these hypotheses will be briefly summarized, though gravity foundering due to density differences between halite and anhydrite is considered the leading hypothesis (Borns, 1987).

Gravity foundering is based on the fact that anhydrite (about 181 pounds per cubic ft [lb/ft^3], or 2.9 grams per cubic centimeter [gm/cc]) is much more dense than halite (about 134 lb/ft^3 [2.15 gm/cc]). When anhydrite beds overlie halite, there is considerable potential for the anhydrite to sink and for the halite to rise. This potential exists throughout much of the Delaware Basin in the Castile. Mathematical and centrifuge models of similar systems confirm the potential for such deformation and even suggest that the rate of deformation is about 0.02 inch (in)/year (yr) (0.05 centimeters [cm]/yr) (Borns et al., 1983). At such a rate, the DZ could be inferred to develop over about 700,000 years (Borns et al., 1983). The principal difficulty with this hypothesis is that there are large areas of the Delaware Basin that remain undeformed, though the stratigraphy is similar to that within the DZ. The potential for gravity foundering exists over most of the basin, yet only a small part actually manifests such deformation. A special condition, such as a localized higher water content or an anomalous distribution of water, is hypothesized to explain why deformation is localized despite the pervasive density inversion (Borns et al., 1983). The presence of pressurized brine and gas associated with some of these structures is at least consistent with this explanation.

Halite could potentially be removed from the evaporite section by dissolution and change the form of the evaporites. The density structure could be changed by removing salt near the surface, causing collapse and fill with sediment that is more dense than the removed salt (Anderson and Powers, 1978). Borns et al. (1983) reviewed some of the evidence that evaporites were deformed near surficial sinks and concluded that there was certainly some association but that the pattern of deformation did not match the shallow dissolution. If salt is dissolved from the lower Salado or the Castile, then overlying beds should deform in response to the removal of mass. DOE-2 was drilled to test that hypothesis. Recrystallized halite has been offered as evidence of the passage of fluids, but there appears to be no unique relationship between recrystallized halite and deformation. In addition, certain halite sections appear much overthickened, which is clearly not directly due to halite removal. These features indicate generally that the halite can be squeezed and will "move" laterally. The fact that the Rustler shows no discernable overall structural lowering over the DZ (Holt and Powers, 1988) suggests that neither the dissolution of the lower Salado nor the Castile is the origin of the deformation. The one area in which the Rustler is structurally affected is around ERDA-6, and there it is warped upward as noted by Jones (1981). Borns et al. (1983) do not believe that the Bell Canyon has been a source for brines in the Castile because of the chemistry (Lambert, 1978; 1983a) and the small volume.

Gravity sliding in the Delaware Basin could be driven by two physical situations: the general eastward dip and the dip off the Capitan reef and forereef into the basin. In contrast to the gravity

foundering mechanism, where movement is dominantly vertical, gravity would result in sliding blocks moving mainly laterally as well as downslope in this mechanism. Some of the deformation is adjacent to the reef (Jones et al., 1973), lending some substance to the hypothesis that the reef-forereef slope and facies changes could cause such sliding. Some deformation is in somewhat isolated portions of the basin (e.g. Poker Lake) (Anderson and Powers, 1978; Borns and Shaffer, 1985), and these structures were originally interpreted to align along the strike of the basin (Anderson and Powers, 1978). Borns and Shaffer (1985) conclude that the data do not uniquely support that interpretation, and these structures may or may not support the concept of gravity sliding within the basin. Borns et al. (1983) also concluded that the timing of the various structures is an important factor in evaluating this hypothesis. As discussed above, neither the age of the various structures nor the timing of the basin tilt are well constrained. If tilting of the basin is an important event in forming these structures, the various macro to microstructures should probably be consistently related. As in gravity foundering, much of the basin area has not reacted to what appears to be widespread similar stresses. Special circumstances, such as an anomalous distribution of water, may be necessary to overcome a threshold for deformation to occur.

In general, as temperature and pressure increase, gypsum dehydrates to form anhydrite and release free water. Borns et al. (1983) discuss the effects this process has in experiments in that weaken the anhydrite. Borns et al. (1983) suggest, however, that a major difficulty with this hypothesis is that there should remain relics of the original gypsum within the sedimentary column; these are not observed. Borns et al. (1983) suggest that mostly anhydrite was deposited in the Castile, and as a consequence, the dehydration hypothesis has little observable support. More recently pseudomorphs after gypsum have been recorded in every major anhydrite of the Castile (Harwood and Kendall, 1988; Hovorka, 1988; Powers, unpublished data; SNL and D'Appolonia Consulting Engineers, 1982c). Gypsum certainly has been present in the Castile, though anhydrite cannot be dismissed as possibly an important primary mineral. Delicate forms of original gypsum crystals are sometimes preserved and pseudomorphed by anhydrite or halite. Each requires volume-for-volume replacement, probably through dissolution and crystallizing the replacement mineral. There are no observed fluid escape paths, and the gypsum may have been replaced very early in the sedimentary history. The additional major drawback to this hypothesis is that the process should be pervasive, while the deformation is localized. Special pleading for an additional factor is necessary in this process as in some other hypotheses.

Depositional or syndepositional processes have been invoked for some of the deformation in the Castile. Borns et al. (1983) list four main mechanisms that have been suggested: penecontemporaneous folding, resedimentation, slump blocks off of reef margins, and sedimentation on inclined surfaces. Penecontemporaneous folding requires consolidation of the units over relatively short times. Borns et al. (1983) also cite the lack of observed features that indicate the rocks were reexposed. Evaporite units in the Mediterranean contain resedimented material: turbidities, slumping, and mud flows with other clastic sediment. Borns et al. (1983) report that "the units of the WIPP area show little chaotic or clastic structures." They also apply

the same argument of Kirkland and Anderson (1970) that the deformed units would have to be consolidated by the time of resedimentation.

In a more recent study of cores from the western part of the Delaware Basin, Robinson and Powers (1987) report a lobate unit of the resedimented Castile anhydrite clasts overlying both the lower anhydrite and halite of the Castile and underlying the second anhydrite. The apparently unconformable contact with both anhydrite 1 and halite 1 lies across the extension of the Huapache monocline, which appears to have been still active during the time part of the Castile was deposited. Polyclasts within some beds of this unit demonstrate that the original anhydrite was partially consolidated and that a unit of clasts was also at least partially consolidated to provide the polyclasts. These units were consolidated early between the time halite 1 was deposited and anhydrite began to be deposited.

In the rest of the basin there is no apparent interval between the end of the halite and beginning of the anhydrite deposition. The relationship clearly indicates that the western margin was an area of sulfate clast formation, deposition, and lithification over a very short interval of geologic time. Hovorka (1988) indicates that similar clastic deposits occur in cores from nearer the eastern margin of the Delaware Basin. Snider (1966) proposed much earlier that sedimentation caused anomalous thickness of Castile units near the basin margin, and Billo (1986) presented a similar conclusion. Neither reported any textural evidence to support their conclusions.

Clearly, Castile rock has been resedimented, but in the area where textural data are available, only modest deformation appears to be present (Robinson and Powers, 1987). At this time, there is little to suggest that such sedimentation resulted in the deformation in the DZ. There is also no direct evidence from the WIPP area that suggests slump blocks off of the reef margin moved into the area, causing deformation. The high inferred slopes of some of these structures argues strongly against sedimentation on inclined surfaces (Borns et al., 1983).

The concept that deformation was syndepositional or penecontemporaneous with deposition appears to mainly be driven by the fact that deformation decreases upward through successive units. Normal geologic reasoning would support penecontemporaneous deformation but does not take into account the rather plastic behavior of halite, allowing flow from over high areas to move halite into low areas. Overlying units, such as the Rustler, are made of much less plastic material and do not respond as the Salado does. The deformation appears to be compensated in overlying units through deposition.

Overall, both gravity-driven mechanisms require some special additional conditions restricting deformation to small areas though most of the basin appears to be equally susceptible. Dissolution permits a more localized effect, but there does not appear to be an overall loss of mass in these areas, and the chemistry of the fluids and hydrology of the units do not readily support the concept. Most of the syndepositional processes have no evidence to support them in the area of the DZ. The most favored hypothesis at the moment is gravity foundering, with a

yet undetected anomalous distribution of fluid lowering the viscosity of halite locally to permit deformation.

Timing of Deformation

Most of the arguments about timing of deformation have already been discussed. Standard geologic arguments about relative timing, based on involvement of the overlying units, is unlikely to hold for the evaporite units. Jones (1981) notes that uplifted and arched Triassic rocks near the ERDA-6 borehole are truncated by the flat-lying, undeformed Pliocene Ogallala. This was interpreted as an indication that salt movement was complete before deposition of the Ogallala (Jones, 1981). However, he does not explain either how the Triassic structure relates to the deeper DZ or how it is distinguished from near surface dissolution effects (Borns et al., 1983). The Castile rocks may have been deformed during any time period from Permian to the present. More to the point, for some hypotheses, the general conditions thought necessary to deform the Castile and the Salado are still present, and mechanisms such as gravity foundering are potentially active (Borns et al., 1983).

An additional piece of data is relevant. Brines from ERDA-6 and WIPP-12 were analyzed, and the brines were calculated to last have moved after about 800,000 years ago (Lambert and Carter, 1984; Barr et al., 1979). One set of reasonable assumptions about brine chemistry and interactions with the rock leads to calculated residence times of about 25,000 to 50,000 years for these brines. This may relate to the last time deformation was active on this structure, although it is not uniquely an indicator of deformation. The interaction between rock and water may have been strictly hydrologically driven and may not require deformation at that time.

The second point of interest is that some modelling calculations indicate, as stated above, that the kinds of structures observed in the DZ may require periods on the order of 700,000 years to form. There is no indication when the structures formed by this calculation, but it is relevant to timing and assessing how these structures might affect the WIPP.

Importance to the WIPP

The structures interpreted from core retrieved from WIPP-12 and ERDA-6 serve as possible analogs to effects of deformation on the WIPP. The DOE and the EEG have analyzed the effects of brine and structure at WIPP-12 and the southern portion of the site and have concluded that the geologic conditions represent no threat to health and safety. In addition, both boreholes encountered brine only within the anhydrite units, and that is the experience of all other encounters of these larger brine inflows (Popielak et al., 1983). Anhydrite supports the fractures that provide porosity for the brine, and the anhydrite/halite units form an effective seal, as the pressurized brines and gas did not escape upward. The principal concern for isolation would be that the deformation, and its associated phenomena such as pressurized brine and gas could cause breaching of the repository and provide or make a pathway for the escape of the waste constituents. The period of time expected for development of the structure (700,000 years) is well

beyond periods of regulatory concern. In addition, the evidence of the pressurized brine and gas occurrences is that they are confined to these Castile anhydrite layers and do not breach the lower Salado to reach the stratigraphic level of the repository. There is nothing at present to indicate that these features will form in the time period of concern or that they can directly cause a breach of the repository.

D6-1f(2) Evaporite Dissolution

Because evaporites are much more soluble than most other rocks, project investigators have considered it important to understand the dissolution processes and rates that take place within the site considered for long-term isolation. These dissolution processes and rates constitute the limiting factor in any evaluation of the site. Over the course of the WIPP Project, extensive resources have been committed to identify and study a variety of features in southeastern New Mexico interpreted to have been caused by dissolution. The subsurface distribution of halite for various units has been mapped. Several different kinds of surface features have been attributed to dissolution of salt or karst formation. The processes proposed or identified include point-source (brecciation), "deep" dissolution, "shallow" dissolution, and karst. The categories are not well defined. Nonetheless, as discussed in the following sections, dissolution is not considered a threat to isolation of waste at the WIPP.

D6-1f(2)(a) Brief History of Project Studies

Well before the WIPP Project, several geologists recognized that dissolution is an important process in southeastern New Mexico and that it contributed to the subsurface distribution of halite and to the surficial features. A number of these are listed in the Bibliography to this appendix, including Lee (1925, pp. 107-121), Maley and Huffington (1953, pp. 539-546), and Olive (1957, pp. 351-358). Robinson and Lang identified an area in 1938 under the Nash Draw where brine occurred at about the stratigraphic position of the upper Salado/basal Rustler and considered that salt had been dissolved to produce a dissolution residue. Vine mapped the Nash Draw and surrounding areas, reporting in 1963 on various dissolution features. Vine (1963) reported surficial domal structures later called "breccia pipes" and identified as deep-seated dissolution and collapse features.

As the USGS and ORNL began to survey southeastern New Mexico as an area in which to locate a repository site in salt, Brokaw et al. in 1972 prepared a summary of the geology that included solution and subsidence as significant processes in creating the features of southeastern New Mexico. Brokaw et al. (1972) recognized a solution residue at the top of salt in the Salado, and the unit commonly became known as the "brine aquifer" because it yielded brine in the Nash Draw area. Brokaw et al. (1972) interpreted the east-west decrease in thickness of the Rustler to be a consequence of removal of halite and other soluble minerals from the formation by dissolution.

During the early 1970s, the basic ideas about shallow dissolution of salt (generally from higher stratigraphic units and within a few hundred feet of the surface) were set out in a series of reports by Bachman, Jones, and collaborators. Piper independently evaluated the geological survey data for ORNL. Claiborne and Gera concluded that salt was being dissolved too slowly from the near-surface units to affect a repository for several million years, at least.

By 1978, shallower drilling around the WIPP site to evaluate potash resources was interpreted by Jones (1978, p. 9), who felt the Rustler included "dissolution debris, convergence of beds, and structural evidence for subsidence." Halite in the Rustler has been reevaluated by the DOE, but there are only minor differences in distribution among the various investigators, and these investigators have different explanations about how this distribution occurred (see previous section on the Rustler stratigraphy): through dissolution of the Rustler's halite after the Rustler was deposited or through syndepositional dissolution of halite from saline mud flat environments during the Rustler deposition.

Under contract to SNL, Anderson, in work reported in 1978, reevaluated halite distribution in deeper units, especially the Castile and the Salado. He identified local anomalies proposed as features developed after dissolution of halite by water circulating upward from the underlying Bell Canyon. In response to Anderson's developing concepts, ERDA-10 was drilled south of the WIPP area during the latter part of 1977. ERDA-10 is interpreted to have intercepted a stratigraphic sequence without evidence of solution residues in the upper Castile. Anderson mapped geophysical log signatures of the Castile and interpreted lateral thinning and change from halite to nonhalite lithology as evidence of lateral dissolution of deeper units (part of "deep dissolution"). Anderson (1978) considered that deep dissolution might threaten the WIPP site.

A set of annular or ring fractures is evident in the surface around the San Simon Sink, about 18 mi (30 km) east of the WIPP site. Nicholson and Clebsch (1961, p. 14) suggested that San Simon Sink developed as a result of deep-seated collapse. WIPP-15 was drilled at about the center of the sink to a depth of about 811 ft (245 m) to obtain samples for paleoclimatic data and stratigraphic data to interpret collapse. Anderson and Bachman both interpret San Simon Sink as dissolution and collapse features, and the annular fractures are not considered evidence of tectonic activity.

Following the work by Anderson, Bachman mapped surficial features in the Pecos Valley, especially at the Nash Draw, and differentiated between those surface features in the basin that were formed by karst and deep collapse features over the Capitan reef. WIPP-32, WIPP-33, and two boreholes over the Capitan reef were eventually drilled. Their data, which demonstrated the concepts proposed by Bachman, are documented in Snyder and Gard (1982, p. 65).

A final program concerning dissolution and karst was initiated following a microgravity survey of a portion of the site during 1980. Based on localized low-gravity anomalies, Barrows et al. in 1983 interpreted several areas within the site as locations of karst. WIPP-14 was drilled during 1981 at a low-gravity anomaly. It revealed normal stratigraphy through the zones previously

alleged to be affected by karst. As a followup in 1985, Bachman also reexamined surface features around the WIPP and concluded there was no evidence for active karst within the WIPP site. The nearest karst feature is northwest of the site boundaries at WIPP-33 and is considered inactive.

D6-1f(2)(b) Extent of Dissolution

Within members of the Rustler, the margins of halite have been mapped by differing methods and summarized by Beauheim (1987). There are few differences, despite the difference in methods (Figure D6-9). Lower members of the Rustler are halitic west of the site, and higher members generally show halite only further east. Snyder interprets these margins as a consequence of post-depositional dissolution of halite. Holt and Powers (1988, pp. 6-8 to 6-9) interpret sedimentary structures within the Rustler mudstone as being equivalents to halite in order to indicate that most halite was removed during the depositional process and redeposited in a salt pan in the eastern part of the depositional basin.

Upper intervals of the Salado thin dramatically west and south of the WIPP site (Figures D6-22 and D6-23) compared to deeper Salado intervals (Figure D6-24). There are no cores for further consideration of possible depositional variations. As a consequence, this margin is interpreted as the edge of dissolution of the upper Salado.

General margins of halite for the Castile are well west of the WIPP site and are generally accepted. Although Robinson and Powers (1987, pp. 69-79) question the volume of salt that may have been dissolved from the Castile, the general boundaries are not disputed.

D6-1f(2)(c) Timing of Dissolution

The dissolution of Ochoan-Epoch evaporites through the near-surface processes of weathering and groundwater recharge has been studied extensively (Anderson, 1981, pp. 133-145; Lambert, 1983a; Lambert, 1983b, pp. 291-298; Bachman, 1984, pp. 1-22; see also Holt and Powers, 1988) The work of Lambert (1983a) was specifically mandated by the DOE's agreement with the State of New Mexico in order to evaluate, in detail, the conceptual models of evaporite dissolution proposed by Anderson (1981, pp. 133-145). There was no clear consensus of the volume of rock salt removed. Hence, estimates of the instantaneous rate of dissolution vary significantly. Dissolution may have taken place as early as the Ochoan, during or shortly after deposition. For the Delaware Basin as a whole, Anderson (1981, pp. 133-145) proposed that up to 40 percent of the rock salt in the Castile and the Salado was dissolved during the past 600 thousand years ago (ka). Lambert (1983b, pp. 291-298) suggested that in many places the variations in salt-bed thicknesses inferred from borehole geophysical logs that were the basis for Anderson's (1981) calculation were depositional in origin, compensated by thickening of adjacent nonhalite beds, and were not associated with the characteristic dissolution residues. Borns and Shaffer also suggested in 1985 a depositional origin for many apparent structural features attributed to dissolution.

Snyder (1985, pp. 85-229), as do earlier workers (e.g., Vine, 1963; Lambert, 1983b, pp. 291-298; Bachman, 1984, pp. 1-22), attributes the variations in thickness in the Rustler, which crops out in the Nash Draw, to post-depositional evaporite dissolution. Holt and Powers (1988, pp. 7-1 to 7-27) have challenged this view and attribute the east-to-west thinning of salt beds in the Rustler to depositional facies variability rather than postdepositional dissolution. Bachman (1974, pp. 74-194; 1976, pp. 135-144; 1980, pp. 80-109) envisioned several episodes of dissolution since the Triassic, each dominated by greater degrees of evaporite exhumation and a wetter climate, interspersed with episodes of evaporite burial and/or a drier climate. Evidence for dissolution after deposition of the Salado and before deposition of the Rustler along the western part of the Basin was cited by Adams (1944, pp. 1596-1625). Others have argued that the evaporites in the Delaware Basin were above sea level and therefore subject to dissolution during the Triassic, Jurassic, Tertiary, and Quaternary periods. Because of discontinuous deposition, not all of these times are separable in the geological record of southeastern New Mexico. Bachman (1984) contends that dissolution was episodic during the past 225 ma as a function of regional base level, climate, and overburden.

Some investigators have reasoned that wetter climate accelerated the dissolution. Various estimates of middle Pleistocene climatic conditions have indicated that climate was more moist during the time of the Gatuña than during the Holocene. An example of evidence of mass loss from dissolution since Mescalero time (approximately 500 thousand years ago [ka]) is found in displacements of the Mescalero caliche as large as 180 ft (55 m) in collapse features in the Nash Draw. However, given the variations in Pleistocene climate, it is unrealistic to apply a calculated average rate of dissolution, determined over 500 ka, to shorter periods, much less extrapolate such a rate into the geological future.

There have been several attempts to estimate the rates of dissolution in the basin. Bachman provided initial estimates of dissolution rates in 1974 based on a reconstruction of the Nash Draw relationships. Although these rates do not pose a threat to the WIPP, Bachman later reconsidered the Nash Draw relationships and concluded that pre-Cenozoic dissolution had also contributed to salt removal. Thus the initial estimated rates were too high. Anderson concluded in 1978 that the integrity of the WIPP to isolate radioactive waste would not be jeopardized by dissolution within about 1 million years. Anderson and Kirkland (1980, pp. 66-69) expanded on the concept of brine-density flow proposed by Anderson in 1978 as a means of dissolving evaporites at a point by circulating water from the underlying Bell Canyon. Wood et al. (1982) examined the mechanism and concluded that, while it was physically feasible, it would not be effective enough in removing salt to threaten the ability of the WIPP to isolate TRU waste.

There is local evidence of Cenozoic dissolution taking place at the same time that part of the Gatuña was being deposited in the Pierce Canyon area. Nonetheless, there is no indicator that the rates of dissolution in the Delaware Basin are sufficient to affect the ability of the WIPP to isolate TRU waste.

D6-1f(2)(d) Features Related to Dissolution

Bachman (1980, p. 97) separated breccia pipes, formed over the Capitan reef by dissolution and collapse of a cylindrical mass of rock, from evaporite karst features that appear similar to breccia pipes. There are surficial features, including sinks and caves, in large areas of the basin. The Nash Draw is the result of combined dissolution and erosion. Within the site boundaries, there are no known surficial features due to dissolution or karst.

South of the WIPP site, there is a clear relationship between a subsurface structure on the Culebra (Figure D6-25) and dissolution. Salt has been removed from the underlying Salado to create a general anticline from near the Laguna Grande de la Sal to the southeast. Beds generally dip to the east, and salt removed to the west created the other limb of the structure. Units below the evaporites do not apparently show the same structure.

D6-2 Surface-Water and Groundwater Hydrology

The DOE believes the hydrological characteristics of the disposal system require evaluation to determine if contaminant transport via fluid flow is a pathway of concern. At the WIPP site, one of the DOE's selection criteria was to choose a location that would minimize fluid-related impacts. This was accomplished when the DOE selected (1) a disposal medium that is essentially devoid of groundwater, (2) a location where the effects of groundwater circulation are minimal and predictable, (3) an area where groundwater use is virtually nonexistent, (4) an area where there are no surface waters, (5) an area where future groundwater use is unlikely, and (6) a repository host rock that will not likely be affected by anticipated long-term climate changes possible within 10,000 years.

The following discussion summarizes the characteristics of the groundwater and surface water at and around the WIPP site. This summary is based on data-collection programs that were initiated at the inception of the WIPP program and which continue to some extent today. These programs have several purposes as follows:

- To provide sufficient information to develop predictive models of the groundwater movement within the vicinity of the WIPP site
- To collect data to evaluate the predictive models and to adapt them to the specific conditions of the WIPP site
- To develop an understanding of the surface water characteristics and the interaction between surface waters and groundwater
- To develop predictive models of the interaction between surface water and groundwater during reasonably expected climate changes.

In order to provide a comprehensive understanding of the impact of groundwater and surface water on the disposal system, the following relevant factors have been evaluated:

- Groundwater

- General flow direction
- Flow type
- Horizontal and vertical flow velocities
- Hydraulic interconnectivity between rock units
- General groundwater use
- Chemistry (including, but not limited to, salinity, mineralization, age, Eh, and pH)

• Surface Water

- Regional precipitation and evapotranspiration rates
- Location and size of surface-water bodies
- Water volume, flow rate, and direction
- Drainage network
- Hydraulic connection with groundwater
- Soil hydraulic properties (infiltration)
- General water chemistry and use.

For the purposes of groundwater modeling, the hydrological system is divided into three segments. These are (1) the Salado, which for the most part concerns the undisturbed performance of the disposal system; (2) the non-Salado rock units, which essentially are impacted by the disturbed (human intrusion) performance of the disposal system; and (3) the surface waters, which are impacted by the natural variability of the climate.

The WIPP site lies within the Pecos River drainage area (Figure D6-26). The climate is semiarid, with a mean annual precipitation of about 12 in. (0.3 m), a mean annual runoff of from 0.1 to 0.2 in. (2.5 to 5 millimeters [mm]), and a mean annual pan evaporation of more than 100 in. (2.5 m). Brackish water with total dissolved solids (TDS) concentrations of more than 3,000 parts per million (ppm) is common in the shallow wells near the WIPP site. Surface waters (Section 1.2.2) typically have high TDS concentrations, particularly of chloride, sulfate, sodium, magnesium, and calcium.

At the WIPP site, the DOE obtains hydrologic data from conventional and special-purpose test configurations in multiple surface and underground boreholes. (Figure D6-2 is a map of surface borehole locations.) Geophysical logging of the surface boreholes has provided hydrologic information on the rock strata intercepted. Pressure measurements, fluid samples, and ranges of rock permeability have been obtained for selected formations through the use of standard and modified drill-stem and packer tests. Slug injection or withdrawal and tracer tests have provided additional data to aid in the estimation of transmissivity and storage of several water-bearing units. Also, the hydraulic head of groundwaters within many water-bearing zones in the region has been mapped from measured depths to water and fluid pressure measurements in the surface boreholes.

D6-2a Groundwater Hydrology

Rock units that are important to WIPP hydrology are the Bell Canyon of the Delaware Mountain Group, the Castile, the Salado, the Rustler, the Dewey Lake, and the Santa Rosa (or Dockum Group) (Figures D6-27 and D6-28). Of these rock units, the Castile and the Salado are defined as aquitards (nonwater-transmitting layers of rock that bound an aquifer).

The Bell Canyon is of interest to the DOE because it is the first regionally continuous water-bearing unit beneath the WIPP. The Castile provides a hydrologic barrier underlying the Salado, though it may contain isolated occurrences of pressurized brine.

The Culebra is the first laterally continuous unit located above the WIPP underground facility to display hydraulic conductivity sufficient to warrant concern over lateral contaminant transport. Barring a direct breach to the surface, the Culebra provides the most direct pathway between the WIPP underground and the accessible environment. The hydrology and fluid geochemistry of the Culebra are very complex and, as a result, have received a great deal of study in WIPP site characterization. (See for example LaVenue et al. (1988), Haug et al. (1987), and Siegel et al. (1991) in the Bibliography.)

At the site, the Dewey Lake is 60 ft (18 m) below the surface and about 490 ft (149 m) thick. These units appear to be mostly unsaturated hydrologically in the vicinity of the WIPP shafts and over the waste emplacement panels.

At the WIPP site, the DOE recognizes the Culebra and the Magenta of the Rustler as the most significant water-bearing units. The DOE's sampling and analysis of groundwater has focused on these two rock units, and the hydrologic background presented here is more detailed than for other rock units. The hydrologic properties of the interface between the Rustler and the Salado will also be discussed. Table D6-2 provides an overview of the hydrologic characteristics of the rock units of interest at the WIPP site and the Rustler/Salado contact zone.

D6-2a(1) Hydrology of the Capitan Limestone

The Capitan, cropping out in the southern end of the Guadalupe Mountains, is a massive limestone unit that grades basinward into recemented, partly dolomitized reef breccia and shelfward into bedded carbonates and evaporites. Its hydraulic conductivity ranges from 1 to 25 ft (0.3 to 7.6 m) per day in southern Lea County and is 5 ft (1.5 m) per day east of the Pecos River at Carlsbad. Hiss reported in 1976 average transmissivities around the northern and eastern margins of the Delaware Basin are 10,000 square ft (929 square m) per day in thick sections and 500 square ft (46.5 square m) per day in incised submarine canyons. In the aquifer, water-table conditions are found southwest of the Pecos River at Carlsbad; however, artesian conditions exist to the north and east. A deeply-incised-submarine canyon near the Eddy/Lea County line has been identified. This canyon is filled with sediments of lower permeability than the Capitan and according to Hiss restricts fluid flow. The hydraulic gradient to the southeast of this restriction has been affected by large oil-field withdrawals. The Capitan limestone is recharged by percolation

through the northern shelf aquifers, by flow from underlying basin aquifers to the south and west, and by direct infiltration at its outcrop in the Guadalupe Mountains.

D6-2a(2) Hydrology of the Delaware Mountain Group

Formations of the Delaware Mountain Group underlie the Capitan reef and form the floor of the Delaware Basin evaporite sequence. Three separate formations, each about 1,000 ft (305 m) thick, are assumed to form a single aquifer system, with an average hydraulic conductivity of 0.02 ft (0.065 m) per day and a calculated transmissivity of about 50 square ft (4.6 square m) per day. Figure D6-29 presents a potentiometric map representing a composite surface for the Delaware Mountain Group and the Capitan aquifer. The data were adjusted for saline density and expressed as freshwater equivalents. The brines in the Delaware Mountain Group flow northeasterly under a hydraulic gradient of from 25 to 40 ft per mi (4.7 to 7.6 m per km) and discharge into the Capitan aquifer. Velocities range from 0.2 to 0.3 ft (0.06 to 0.09 m) per year, and groundwater yields from wells in the Delaware Mountain Group are from 0.6 to 1.5 gallons (gal) (2.3 to 5.8 liters [l]) per minute.

D6-2a(3) Hydrology of the Salado and Castile Formations

The Castile and the Salado consist mainly of halite and anhydrite. A considerable amount of information about the hydraulic properties of these rocks has been collected through field and laboratory experiments. Mercer et al. in 1987 compile and summarize this information.

Salado Hydrology

Hydraulic testing in the Salado halite-rich sections provided quantitative estimates of the hydraulic properties controlling brine flow through the Salado. The tests were interpreted by Beauheim et al. in 1991 and 1993 using models based on potentiometric flow. The tests influenced rock as far as 33 ft (10 m) distant from the test zone and were not thought to significantly alter the pretest conditions of the rock. The stratigraphic intervals tested include both pure and impure halite. Because tests close to the repository are within the DZ, it is reasonable to use the results of the tests farthest from the repository as most representative of undisturbed conditions.

Twenty-two hydraulic tests have been performed in impure halite, and two in pure halite. Interpreted permeabilities using a Darcy-flow model range from $1x10^{-22}$ to $4x10^{-17}$ ft^2 ($1x10^{-23}$ to $4x10^{-18}$ m^2) for impure halite intervals. Interpreted formation pore pressures range from 0.3 to 9.7 Megapascal (MPa) for impure halite. Tests in pure halite show no observable response, indicating either extremely low permeability (10^{-22} ft^2 [$<10^{-23}$ m^2]) or no flow whatsoever.

Fourteen hydraulic tests have been performed in anhydrite. Interpreted permeabilities using a Darcy-flow model range from $2x10^{-19}$ to $7x10^{-17}$ ft^2 ($2x10^{-20}$ to $7x10^{-18}$ m^2) for anhydrite intervals. Interpreted formation pore pressures range from atmospheric to 12.5 MPa for anhydrite intervals. Lower values are caused by depressurization near the excavation.

The properties of anhydrite interbeds have also been investigated in the laboratory. Tests were performed on three groups of core samples from Marker Bed 139 as part of the Salado Two-Phase Flow Laboratory Program. The laboratory experiments provided porosity, intrinsic permeability, and capillary pressure data. Preliminary analysis of capillary pressure test results indicate a threshold pressure of less than 1 MPa.

Fluid pressure that are much higher than hydrostatic pressures are a hydrologic characteristic of the Castile and the Salado that the DOE believes plays a potentially important role in the repository behavior. It is difficult to accurately measure natural pressures in these formations, because the boreholes or repository excavations required to access the rocks decrease the stress in the region measured. Stress released instantaneously decreases fluid pressure in the pores of the rock, so measured pressures must be considered as a lower bound of the natural pressures. Stress effects related to test location, and the difficulty of making long-duration tests in lower permeability rocks, results in higher pore pressures being observed to date in anhydrites. The highest observed pore pressure in halite-rich units, near Room Q, is on the order of 9 MPa, whereas the highest pore pressures observed in anhydrite are 12.5 MPa. It is expected that the far-field pore pressures in halite-rich and anhydrite beds in the Salado at the repository level are similar. For comparison, the hydrostatic pressure at the depth of the repository is about 7 megapascals, and the lithostatic pressure calculated from density measurements in ERDA-9 is about 15 mPa.

Fluid pressures in sedimentary basins that are much higher or much lower than hydrostatic are referred to as "abnormal pressures" in the literature of the petroleum industry, where they have received considerable attention. The explanations of how these pressures can be maintained over very long periods of time, perhaps millions of years, generally fall into two categories. The first is based on the concept that the maintenance of abnormal pressures indicates the rock volumes containing the high pressures must be "hydraulically isolated" from normally pressured sediments. The second maintains that all rocks have finite permeability and that abnormal pressures must be viewed as a transient phenomenon. In the absence of a generating method, according to the second category, these pressures would decay away over geologic time even in rocks with extremely low permeability.

It has been demonstrated that the rocks of the Castile and the Salado, except for the pure halites, have a small but finite permeability. The high pressures are almost certainly maintained because of the large compressibility and plastic nature of the halite, and to a lesser extent, the anhydrite. The lithostatic pressure at a particular horizon must be supported by a combination of the stress felt by the rock matrix and the pore fluid. In highly deformable rocks, the portion of the stress that must be borne by the fluid exceeds hydrostatic pressure but cannot exceed lithostatic pressure.

Brine content within the Salado is estimated at 1 to 2 percent by weight, although the thin clay seams have been observed by the Brine Sampling and Evaluation Program (BSEP) reported in 1991 by Deal et al. to contain up to 25 percent brine by weight. This brine may move toward areas of low pressure, such as a borehole or a mined section of the Salado. Ten years of BSEP

data have been collected by the DOE and interpreted by some investigators as showing that clay seams are the most likely source of the Salado brine flowing into the excavations. This mechanism predicts that brine flow ceases after structural creep in the formation ceases.

Observation of the response of pore fluids in the Salado to potential gradients (to walls in the repository, to boreholes without packers, or to packer-sealed boreholes) is complicated by low permeability and low porosity. Flow has been observed to move to walls in the repository, to boreholes without packers, and to packer-sealed boreholes. In certain cases, evidence for flow is no longer observed where it once was; in others, flow has begun where it once was not observed. In many cases, observations and experiments must last for months or years to obtain useful results. In part because of design requirements such as duration (experimental period is short relative to the time required for the geological materials to fully respond), few quantitative data have been obtained for certain lithologic units within the Salado. There is much direct, qualitative experience regarding the behavior of flow crossing the walls of the repository.

D6-2a(3)(a) Castile Formation Hydrology

The hydrology of the Castile differs from that of the Salado in that fracturing in the upper anhydrite has generated regions with much greater permeability than the surrounding intact anhydrite. These regions are located in the area of structural deformation. The higher permeability regions of the Castile contain brine at pressures greater than hydrostatic and have been referred to as "brine reservoirs." The fluid pressure measured in the WIPP-12 borehole (12.7 MPa) is greater than the nominal hydrostatic pressure for a column of equivalent brine at that depth (11.1 MPa). Therefore, under open-hole conditions, brine could flow upward through an intrusion borehole.

Hydraulic tests performed in the ERDA-6 and WIPP-12 boreholes suggest that the highly permeable portions of the Castile are limited in extent. The vast majority of brine is thought to be stored in low-permeability microfractures; about 5 percent of the overall brine volume is stored in large open fractures. The volumes of the ERDA-6 and WIPP-12 brine reservoirs were estimated by Popielak et al. in 1983 to be 3.5×10^6 ft^3 (100,000 m^3) and 9.5×10^6 ft^3 (270,000 m^3), respectively.

Results from several geochemical studies provide information about the origin of brine in the Castile. Popielak et al. (1983) concluded that the ratios of major and minor element concentrations in the brines indicate that these fluids originated from ancient seawater and that there is no evidence for fluid contribution from present meteoric waters. The gas and brine chemistries of Castile waters from the ERDA-6 and WIPP-12 reservoirs are distinctly different from each other and from local groundwaters. The brines are saturated, or nearly so, with respect to halite and, consequently, have little or no halite dissolution potential.

D6-2a(4) Hydrology of the Rustler-Salado Contact Zone

In the vicinity of the Nash Draw, the contact between the Rustler and the Salado is an unstructured residuum of gypsum, clay, and sandstone created by the dissolution of halite. The residuum is absent under the WIPP site. It is clear that dissolution in the Nash Draw occurred after deposition of the Rustler.

Brine in the Rustler/Salado contact residuum, immediately above the top of the salt in the vicinity of the Nash Draw, was first described by Robinson and Lang in 1938 and referred to as the "brine aquifer." They suggested that the structural conditions that caused the development of the Nash Draw might control the occurrence of the brine; thus, the brine aquifer boundary may coincide with the topographic surface expression of the Nash Draw. The studies of Robinson and Lang (1938) show the brine to be concentrated along a strip from 2 to 8 mi (3.3 to 13 km) wide and about 26 mi (43 km) long. Data from the test holes Robinson and Lang (1938) drilled indicate that the residuum (containing the brine) ranges in thickness from 10 to 60 ft (3 to 18 m) and averages about 24 ft (7 m). In 1954, hydraulic properties were determined by Hale et al. primarily for the area between Malaga Bend on the Pecos River and the Laguna Grande de la Sal. They calculated a value of transmissivity of 8,000 square ft per day ($8.6x10^{-3}$ square m per second [sec]) and estimated the potentiometric gradient to be 1.4 ft per mile (0.27 m per km). In this area, the "Rustler/Salado residuum" apparently is part of a continuous hydrologic system as evidenced by the coincident fluctuation of water levels in the test holes (as far away as the Laguna Grande de la Sal) with pumping rates in irrigation wells along the Pecos River.

In the northern one-half of the Nash Draw, the approximate outline of the brine aquifer (Rustler/ Salado contact residuum) as described by Robinson and Lang in 1938 has been supported by drilling associated with the WIPP hydrogeologic studies. These studies also indicate that the main differences in areal extent occur along the eastern side where the boundary is very irregular and, in places (test holes P-14 and H-07), extends farther east than previously indicated by Robinson and Lang (1938).

Other differences from the earlier studies include the variability in thickness of residuum present in test holes WIPP-25 through WIPP-29. These holes indicate thicknesses ranging from 11 ft (3.3 m) in WIPP-25 to 108 ft (33 m) in WIPP-29 in the Nash Draw, compared to 8 ft (2.4 m) in test hole P-14 east of the Nash Draw. The specific geohydrologic mechanism that has caused dissolution to be greater in one area than in another is not apparent, although a general increase in chloride concentration in water from the north to the south may indicate the effects of movement down the natural hydraulic gradient in the Nash Draw.

The average hydraulic gradient within the residuum in the Nash Draw is about 10 ft per mi (1.9 m per km); in contrast, at the WIPP site the average gradient is 39 ft per mi (7.4 m per km). This difference reflects the changes in transmissivity, which are as much as five orders of magnitude greater in the Nash Draw. The transmissivity determined from aquifer tests in test holes completed in the Rustler/Salado contact residuum of the Nash Draw ranges from $2x10^{-4}$ square ft per day ($2.1x10^{-10}$ square m per sec) at WIPP-27 to 8 square ft per day ($8.6x10^{-6}$ square m per sec) at WIPP-29. This is in contrast to the WIPP site proper, where transmissivities range from

$3x10^{-5}$ square ft per day ($3.2x10^{-11}$ square m per sec) at test holes P-18 and H-05c to $5x10^{-2}$ square ft per day ($5.4x10^{-8}$ square m per sec) at test hole P-14. Locations and estimated hydraulic heads of these wells are illustrated in Figure D6-30.

Hale et al. in 1954 believed the Rustler/Salado contact residuum discharges to the alluvium near Malaga Bend on the Pecos River. Because the confining beds in this area probably are fractured due to dissolution and collapse of the evaporites, the brine (under artesian head) moves up through these fractures into the overlying alluvium and then discharges into the Pecos River.

Evidence for very slow groundwater movement is found in the water quality, especially in the magnesium concentrations. Large magnesium concentrations appear to be indicative of an environment in which groundwater flow is extremely slow and there has been extensive interaction between the water and its host rock. Large concentrations of magnesium, ranging from 21,000 ppm (21,000 milligrams [mg]/L) in water from test hole H-06 to 82,000 ppm (82,000 mg/L) in water from test hole H-05, were present in most of the test wells in the eastern part of the WIPP site. Aquifer tests at these test holes were characterized by very low transmissivities. To the west, approaching the more developed part of the flow system of the Rustler/Salado contact residuum in Nash Draw, the magnesium concentrations decreased by one to two orders of magnitude. Magnesium concentrations of 1,200 ppm (1,200 mg/L) in water from test hole P-14 and 350 ppm (350 mg/L) in water from test hole P-15 may indicate the eastern boundary of the more developed Rustler/Salado flow system. Magnesium concentrations are as small as 430 ppm (430 mg/L) in water from test hole H-08; other values range from 910 ppm (910 mg/L) in water from test hole H-07 to 3,200 ppm (3,200 mg/L) in water from test hole WIPP-25.

According to Mercer (1983), water in the Rustler/Salado contact residuum contains the largest concentrations of dissolved solids in the WIPP area, ranging from 79,800 ppm (79,800 mg/L) in test hole H-07 to 480,000 ppm (480,000 mg/L) in test hole H-01. These waters are classified as brines. The dissolved mineral constituents in the brine largely consist of sulfates and chlorides of calcium, magnesium, sodium, and potassium; the major constituents are sodium and chloride. Concentrations of the other major ions vary according to the spatial location of the sample and probably are directly related to the interaction of the brine and the host rocks and reflect residence time within the rocks. Residence time of the brine depends upon the transmissivity of the rock. For example, the presence of large concentrations of potassium and magnesium in water is correlated with minimal permeability and a relatively undeveloped flow system.

D6-2a(5) Hydrology of the Rustler Formation

The Rustler is of particular importance for the WIPP because it contains the most transmissive units above the repository. The Rustler is divided into four formally named members and an unnamed lower member. These five units are, in ascending order, the unnamed lower member (the oldest), the Culebra, the Tamarisk, the Magenta, and the Forty-niner member (the youngest).

D6-2a(5)(a) The Unnamed Lower Member of the Rustler Formation

The basal interval of the unnamed lower member is composed of siltstone, mudstone, and claystone and can be considered the water-producing zones of the lowermost Rustler. Transmissivities of 2.7×10^{-4} ft^2 per day (2.9×10^{-10} m^2 per sec) and 2.2×10^{-4} ft^2 per day (2.4×10^{-10} m^2 per sec) were calculated by Beauheim (1987, p. 50) from tests at well H-16 that included this interval. These transmissivity values correspond to hydraulic conductivities of 4.2×10^{-6} ft per day (1.5×10^{-11} m per sec) and 3.4×10^{-6} ft per day (1.2×10^{-11} m per sec). Hydraulic conductivity in the lower portion of the unnamed lower member is believed by the DOE to increase to the west in and near the Nash Draw, where dissolution in the underlying Rustler/Salado contact zone has caused subsidence and fracturing of the sandstone and siltstone.

The remainder of the unnamed lower member contains mudstones, anhydrite, and variable amounts of halite. The hydraulic conductivity of these lithologies is extremely low: tests of mudstones and claystones in the Waste Shaft gave hydraulic conductivity values ranging from 2×10^{-9} ft per day (6×10^{-15} m per sec) to 3×10^{-8} ft per day (1×10^{-13} m per sec) according to Saulnier and Avis (1988, p. 6-11).

D6-2a(5)(b) The Culebra Member of the Rustler Formation

The Culebra is modeled in the PA as the most likely pathway for the release of radionuclides to the accessible environment because of its relatively high transmissivity near the WIPP site, and hydrologic research activity has concentrated on the unit for over a decade.

According to Mercer (1983), the transmissivity of the Culebra varies over six orders of magnitude from east to west in the vicinity of the WIPP (Figure D6-31). It ranges from 1×10^{-3} ft^2 per day (1×10^{-9} m^2 per sec) at well P-18 east of the WIPP site to 1×10^{3} ft^2 per day (1×10^{-3} m^2 per sec) at well H-7 in the Nash Draw (see Figure D6-2 for the locations of these wells).

Measured matrix porosities of the Culebra range from 0.03 to 0.30. Fracture porosity values have not been measured directly, but interpreted values from tracer tests at the H-3, H-6, and H-11 hydropads range from 5×10^{-4} to 3×10^{-3}. Data are insufficient to map the spatial variability of the porosity.

Variations in transmissivity in the Culebra are believed by many experts to be controlled by the relative abundance of open fractures rather than by primary (i.e., depositional) features of the unit. Lateral variations in depositional environments were small within the mapped region, and primary features of the Culebra show little map-scale spatial variability according to Holt and Powers (1988). Direct measurements of the density of open fractures are not available from core samples because of incomplete recovery and fracturing during drilling, but comparisons with the relatively unfractured exposures in the WIPP shafts suggest that the density of open fractures in the Culebra decreases to the east. Qualitative correlations have been noted between transmissivity and several geologic features possibly related to open-fracture density, including

(1) the distribution of overburden above the Culebra, (2) the distribution of halite in other members of the Rustler, (3) the dissolution of halite in the upper portion of the Salado, and (4) the distribution of gypsum fillings in fractures in the Culebra.

The distribution of groundwater hydrogeochemical facies is not consistent with the southward flow direction calculated by LaVenue et al. in 1990 from potentiometric data, if one assumes that the ionic strength of a groundwater increases along a flow path. One possible model for the relationship between the facies distribution and the flow paths has been proposed by Chapman in 1986 and 1988, who coupled an extensive compilation of stable and radiogenic isotope ratios of Rustler groundwaters with isotopic data from regional groundwaters and surficial waters. Chapman cited evidence for short times of Culebra groundwaters and postulated that recharge from the surface could account for the less concentrated groundwaters south of the WIPP site. That explanation, however, is not supported by interpretations of isotopic and solute data presented by Lambert, Siegel, and others.

Specifically, radiogenic isotopic signatures suggest that the age of the groundwater in the Culebra is on the order of tens of thousands of years (see for example Lambert 1987; Lambert and Carter 1987; Lambert and Harvey 1987 in the bibliography). A conceptual model was put forth by Siegel et al. in 1991 who contend that there has been a change in the location and amount of recharge since the last glacial maximum and that the present distribution of solutes and isotopes in the Culebra is a relict of a flow regime of a wetter climate. The current distribution of hydrogeochemical facies, therefore, represents a rock-water system that is still slowly reaching a new chemical and physical equilibrium. However, a conceptual or calculational model of how paleoflow could have been toward the east has not been presented.

Currently the issue of the relationship between water chemistry and groundwater flow in the Culebra remains unresolved. It is possible that lack of resolution reflects the way the problem has been posed and the relatively simple conceptual models that have been used to represent the hydrology of the system. Previous discussions, for example, have focused on flow directions but not flow rates. Computer models of flow in the Culebra suggest that flow rates are orders of magnitude slower in the region of the sodium chloride facies than in the region of the calcium sulfate facies. It is possible that the geochemical signature of flow from the sodium chloride facies to the calcium sulfate facies is not observed because only minute amounts of water flow along this path. In addition, some of the previous studies have not considered, or have not ruled out, transport of solutes from units above and below the Culebra. For example, the region of the sodium chloride facies correlates well with the extent of halite in strata above and below the Culebra. The possibility that the Sodium Chloride (NaCl) facies results from vertical advective or diffusive transport into a region of extremely slow flow in the Culebra has not been investigated. Preliminary results of calculations using the groundwater basin approach suggest that addressing these issues as a three-dimensional transport system will facilitate resolution.

D6-2a(5)(c) The Tamarisk Member of the Rustler Formation

Attempts were made in two wells, H-14 and H-16, to test a 7.9-ft (2.4-m) sequence of the Tamarisk that consists of claystone, mudstone, and siltstone overlain and underlain by anhydrite. Permeability was too low to measure in either well within the time allowed for testing; consequently, Beauheim in 1987b estimated the transmissivity of the claystone sequence to be one or more orders of magnitude less than that of the tested interval in the unnamed lower member. Transmissivity in the Tamarisk was estimated to be less than approximately 2.5×10^{-5} ft^2 per day (2.7×10^{-11} m^2 per sec), corresponding to a hydraulic conductivity of less than approximately 1.3×10^{-6} m^2 per day (1.4×10^{-12} m per sec).

D6-2a(5)(d) The Magenta Member of the Rustler Formation

The Magenta of the Rustler is a fine-grained dolomite that ranges in thickness from 13 to 26 ft (4 to 8 m) and is about 19 ft (6 m) thick at the WIPP. The Magenta is saturated except near outcrops along the Nash Draw, and hydraulic data are available from 15 wells. According to Mercer (1983), transmissivity ranges over five orders of magnitude from 1×10^{-3} to 4×10^{2} ft^2 per day (1×10^{-9} to 4×10^{-4} m^2 per sec).

The hydraulic transmissivities of the Magenta, based on sparse data, show a decrease in conductivity from west to east, with slight indentations of the contours north and south of the WIPP that correspond to the topographic expression of the Nash Draw. In most locations, the hydraulic conductivity of the Magenta is 1 to 2 orders of magnitude less than that of the Culebra.

No porosity measurements have been made on the Magenta. Beauheim (1987, pp. 111, 115) assumed a porosity representative of dolomite of 0.20 for the interpretations of well tests. The hydrologic gradient across the site varies from 16 to 20 ft per mi (3 to 4 mper km) on the eastern side, steepening to about 32 ft per mi (6 m per km) along the western side near the Nash Draw (Figure D6-32).

D6-2a(5)(e) The Forty-niner Member of the Rustler Formation

The uppermost member of the Rustler, the Forty-niner is about 66 ft (20 m) thick throughout the WIPP area and consists of low-permeability anhydrite and siltstone. Tests by Beauheim (1987) in H-14 and H-16 yielded transmissivities of about 3×10^{-2} to 7×10^{-2} ft^2 per day (3×10^{-8} to 8×10^{-8} m^2 per sec) and 5×10^{-3} to 6×10^{-3} ft^2 per day (5×10^{-9} to 6×10^{-9} m^2 per sec), respectively.

D6-2a(6) Hydrology of the Supra-Rustler Rocks (the Dewey Lake and the Santa Rosa)

The supra-Rustler rocks, consisting of (in ascending order) the Dewey Lake and the Santa Rosa, are comprised of a confining siltstone bed, water-bearing sandstone, and a confining mudstone bed (respectively). The Dewey Lake may retard downward percolation of surface waters, while the Santa Rosa provides water for irrigation and livestock.

D6-2a(6)(a) The Dewey Lake

Hydrologic properties of the Dewey Lake are characterized based on only a few measurements compared to the more extensive data set available for members of the Rustler. As a result, the spatial distribution of saturated conditions is not well known. The average hydraulic conductivity of the Dewey Lake, assuming saturation, is estimated to be $3x10^{-3}$ ft per day (10^{-8} mper sec), corresponding to the hydraulic conductivity of fine-grained sandstone and siltstone. Hydraulic properties are somewhat variable, as relatively high water production from a fractured zone (as observed during a downhole video survey) within the WIPP site boundary was recently observed at Water Quality Sampling Program (WQSP)-6A. However, in the vicinity of the WIPP shafts, the Dewey Lake is not saturated, has not produced water, and does not appear to contain open fractures. Several wells operated by the J.C. Mills Ranch south of the WIPP produce sufficient quantities of water from the Dewey Lake to supply livestock.

D6-2a(6)(b) The Santa Rosa Formation

The Santa Rosa is about 140 to 300 ft (43 to 91 m) thick and is present over the eastern half of the WIPP site. It dips gently westward, except in local areas of collapse, and crops out northeast of the Nash Draw. As a water-bearing unit, the Santa Rosa near the WIPP site has a saturated thickness of only from 1 to 2 ft (0.3 to 0.61 m) and occurs in lenses that are very limited in extent. It has a porosity of about 13 percent and a specific capacity of 0.14 to 0.20 gal. per minute per ft (0.029–0.041 L per sec per m) of drawdown. Lows in the potentiometric surface near the Eddy/ Lea County line and the San Simon Swale suggest discharge from the Santa Rosa into underlying rocks, possibly through collapse zones, and a possibility of a groundwater divide (at a surface ridge) between the site and San Simon Swale. In general, groundwater flows south and is of better quality than that found in the Rustler.

It is not known at this time what quantities of water, if any, discharge from the Santa Rosa to the shallow aquifers along the Pecos River. The groundwater gradient in adjacent Texas along the Pecos River is influenced by a large-scale withdrawal of groundwater, resulting in a net loss of groundwater storage. The declines in water levels in Texas have created sizable cones of depression along the river and gradients toward the river. The Santa Rosa aquifer in southwest Texas adjacent to the New Mexico border is not downgradient from the WIPP site. Several reasons for believing that Santa Rosa waters at the WIPP site flow into the Pecos River rather than to the south into Texas are the configuration of the potentiometric head map, the influence of extensive pumping, and a topographic groundwater divide east of the WIPP site. Groundwaters pumped from the Santa Rosa and alluvium deposits are used extensively for irrigation and livestock.

D6-2a(7) Groundwater Elevation Measurements in 1991

Groundwater levels have been measured monthly in some units in the vicinity of the WIPP site for several years. These levels can be used to determine the longer term trends in water-level

changes, either natural or in response to human activities in the region. The groundwater-level data indicate that there is a gradual trend of rising water-level elevations within the Culebra in recent years. Of the surveillance locations, 39 of the 46 showed some increase in water-level elevations within the Culebra during the past few years. Two anomalous occurrences were noted in the data for 1991. The first was a net loss of 8.64 ft (2.62 m) of groundwater-level elevation at the Cabin Baby (CB)-1 well site from January through December 1991, and the second was a gain of 24.77 ft (7.51 m) of groundwater-level elevation at well P-18 (Figure D6-2). The two wells are located within 5 mi (8.3 km) of each other. The suspected cause of the loss of water-level elevation at CB is the failure of a bridge plug located between the Culebra and the portion of the hole open to the Salado and the Castile. The anomalous water-level elevation increase at P-18 is gradually decreasing from year to year. In 1988, the water level in well P-18 increased approximately 45 ft (14 m), whereas the increase was approximately 33 and 25 ft (10 and 7.6 m), respectively, in 1990 and 1991. The smaller increase from year to year indicates that P-18 is trending toward an equilibrium state; however, the magnitude of elevation gains indicates that years may pass before equilibrium is achieved.

Freshwater head distribution in the Culebra indicates that the generalized directional flow of groundwater is north to south. However, caution should be used when making assumptions based on groundwater-level data alone. Recent studies in the Culebra have shown that fluid density variations in the Culebra can affect flow direction. One should also be aware that the fractured media of the Culebra, coupled with variable fluid densities, can cause localized flow patterns to have little or no relationship to general flow patterns.

Measurements at 11 surveillance locations in the Magenta also indicated an upward trend in water-level elevations. No anomalous losses or gains were noted within the Magenta. Seven of eleven Magenta surveillance locations show a gain in the elevation of groundwater levels from January to December 1991. Four wells showed lower groundwater-level elevations in December than in January 1991. All of the four surveillance locations that indicated a loss of head elevation from January to December were wells that are pumped routinely as part of the WQSP. These locations are H-03b1, H-04c, H-05c, and H-06c. Recovery from these pumping events may have influenced the water-level data collected at these locations.

When groundwater elevations taken in 1991 are compared to potentiometric elevation maps produced by Mercer (1983), groundwater elevations appear to be below 1983 levels. The 1983 study was performed prior to the onset of the large-scale hydrologic activities that took place in the vicinity of the WIPP site to support site characterization and other hydrologically oriented activities during the mid to late 1980s. Since the end of the 1980s, only modest amounts of groundwater have been removed from these formations. The possibility exists that the increasing groundwater elevations observed in 1991 and subsequent years represent a natural trend for the recovery of the formations to groundwater elevations near those of the 1983 potentiometric elevations.

D6-2b Surface-Water Hydrology

The WIPP site is in the Pecos River basin, which contains about 50 percent of the drainage area of the Rio Grande Water Resources Region. The Pecos River headwaters are west of Las Vegas, New Mexico, and the river flows to the south through eastern New Mexico and western Texas to the Rio Grande. The Pecos River has an overall length of about 500 mi (805 km), a maximum basin width of about 130 mi (209 km), and a total drainage area of about 44,535 mi^2 (115,301 km^2) (about 20,500 mi^2 [53,075 mi^2] contained within the basin have no external surface drainage and their surface waters do not contribute to Pecos River flows). Figure D6-33 shows the Pecos River drainage area.

The Pecos River is generally perennial, except in the reach below Anton Chico and between Fort Sumner and Roswell, where the low flows percolate into the stream bed. The main stem of the Pecos River and its major tributaries have low flows, and the streams are frequently dry. About 75 percent of the total annual precipitation and 60 percent of the annual flow result from intense local thunderstorms between April and September. The principal tributaries of the Pecos River in New Mexico, in downstream order, are the Gallinas River, Salt Creek, the Rio Hondo, the Rio Felix, the Eagle Creek, the Rio Peñasco, the Black River, and the Delaware River.

There are no perennial streams at the WIPP site. At its nearest point, the Pecos River is about 12 mi (19 km) southwest of the WIPP site boundary. The drainage area of the Pecos River at this location is 19,000 mi^2 (47,500 km^2). A few small creeks and draws are the only westward-flowing tributaries of the Pecos River within 20 mi (32 km) north or south of the site. A low-flow investigation has been initiated by the USGS within the Hill Tank Draw drainage area, the most prominent drainage feature near the WIPP site. The drainage area is about 4 mi^2 (10 km^2) with an average channel slope of 1 to 100, and drainage westward into the Nash Draw. Two years of observations showed only four flow events. The USGS estimates that the flow rate for these events was under 2 cubic ft (ft^3) per sec (0.057 cubic meters [m^3] per sec). The Black River (drainage area: 400 mi^2 [1,035 km^2]) joins the Pecos from the west about 16 mi (25 km) southwest of the site. The Delaware River (drainage area: 700 mi^2 [1,812 km^2] and a number of small creeks and draws also join the Pecos River along this reach. The flow in the Pecos River below Fort Sumner is regulated by storage in Sumner Lake, Brantley Reservoir, Lake Avalon, and several other smaller irrigation dams.

Four major reservoirs are located in the Pecos River basin: Sumner Lake, Brantley Reservoir, Lake Avalon, and Red Bluff Reservoir, the last located just over the border in Texas (Figure D6-33). The storage capacities of these reservoirs and other Pecos River reservoirs adjacent to the Pecos River basin are shown in Table D6-3.

With regards to surface drainage onto and off of the WIPP site, there are no major lakes or ponds within 10 mi (16 km) of the center of the site. The Laguna Gatuña, Laguna Tonto, Laguna Plata, and Laguna Toston are playas more than 10 mi (16 km) north of the site and are at elevations of 3,450 ft (1050 m) or higher. Thus, surface runoff from the site (elevation 3,310 ft [1010 m] above sea level) would not flow toward any of them. To the north, west and northwest, Red Lake,

Lindsey Lake, the Laguna Grande de la Sal, and a few unnamed stock tanks are more than 10 mi (16 km) from the site, at elevations of from 3,000 to 3,300 ft (914 to 1,006 m).

The mean annual precipitation in the region is about 12 in. (0.3 m), and the mean annual runoff is 0.1 to 0.2 in. (2.5 to 5 mm). The maximum recorded 24-hour precipitation at Carlsbad was 5.12 in. (130 mm) in August 1916. The predicted maximum 6-hour, 100-year precipitation event for the site is 3.6 in. (91 mm) and is most likely to occur during the summer.

The maximum recorded flood on the Pecos River occurred near the town of Malaga, New Mexico, on August 23, 1966, with a discharge of 120,000 ft^3 (3,396 m^3) per sec and a stage elevation of about 2,938 ft (895 m) above mean sea level. The minimum surface elevation of the WIPP site is over 500 ft (152 m) above the river bed and over 400 ft (122 m) above the elevation of this maximum historical flood elevation (DOE, 1980, §7.4.1).

More than 90 percent of the mean annual precipitation at the site is lost by evapotranspiration. On a mean monthly basis, evapotranspiration at the site greatly exceeds the available rainfall; however, intense local thunderstorms may produce runoff and percolation.

Water quality in the Pecos River basin is affected by mineral pollution from natural sources and from irrigation return flows. At Santa Rosa, New Mexico, the average suspended-sediment discharge of the river is about 1,650 tons (1,819 metric tons [1,000 kg]) per day. Large amounts of chlorides from Salt Creek and Bitter Creek enter the river near Roswell. River inflow in the Hagerman area contributes increased amounts of calcium, magnesium, and sulfate; and waters entering the river near Lake Arthur are high in chloride. Below Brantley Reservoir, springs flowing into the river are usually submerged and difficult to sample; springs that could be sampled had TDS concentrations of from 3,350 to 4,000 ppm (3,350 to 4,000 mg/L). Concentrated brine entering at Malaga Bend adds an estimated 70 tons per day of chloride to the Pecos River.

D6-2c Groundwater Discharge and Recharge

The only documented points of naturally occurring groundwater discharge in the vicinity of the WIPP are the saline lakes in the Nash Draw and the Pecos River, primarily near Malaga Bend. Although this is local flow associated with the Nash Draw and unrelated to groundwater flow at the WIPP site, it is presented here for completeness. Discharge into one of the lakes from Surprise Spring (see Figure D6-1) was measured by Hunter in 1985 at a rate of less than 0.35 ft^3 (0.01 m^3) per sec in 1942. Hunter also estimated total groundwater discharge into the lakes is 24 ft^3 (0.67 m^3) per sec. According to Mercer (1983) discharge from the spring comes from fractured and more transmissive portions of the Tamarisk of the Rustler, and the lakes are hydraulically isolated from the Culebra and lower units.

Groundwater discharge into the Pecos River is greater than discharge into the saline lakes. Groundwater discharge into the Pecos River between Avalon Dam north of Carlsbad and a point south of Malaga Bend was no more than approximately 32.5 ft^3 (0.92 m^3) per sec . Most of this

gain in stream flow occurs near Malaga Bend (see Figure D6-1) and is the result of groundwater discharge from the residuum at the Rustler/Salado contact zone.

The only documented point of groundwater recharge is also near Malaga Bend, where an almost immediate water-level rise has been reported by Hale et al. in 1954 in a Rustler-Salado well following a heavy rainstorm. This location is hydraulically downgradient from the repository, and recharge here has little relevance to flow near the WIPP. Examination of the potentiometric surface map for the Rustler/Salado contact zone indicates that some inflow may occur north of the WIPP, where freshwater equivalent heads are highest. Additional inflow to the contact zone may occur as leakage from overlying units, particularly where the units are close to the surface and under water-table conditions.

No direct evidence exists for the location of either recharge to or discharge from the Culebra. The freshwater-head surface map (Figure D6-34) implies inflow from the north and outflow to the south. Recharge from the surface probably occurs 9 to 19 mi (15 to 30 km) northwest of the WIPP in and north of Clayton Basin where the Rustler crops out. An undetermined amount of inflow may also occur as leakage from overlying units throughout the region.

The freshwater-head contour map (Figure D6-34) indicates that flow in the Culebra is toward the south. Some of this southerly flow may enter the Rustler/Salado contact zone under water table conditions near Malaga Bend and may ultimately discharge into the Pecos River. Additional flow may discharge directly into the Pecos River or into alluvium in the Balmorhea/Loving Trough to the south.

Recharge to the Magenta may also occur north of the WIPP in Bear Grass Draw and Clayton Basin. The potentiometric surface map indicates that discharge is toward the west in the vicinity of the WIPP, probably into the Tamarisk and the Culebra near the Nash Draw. Some discharge from the Magenta may ultimately reach the saline lakes in the Nash Draw. According to Brinster in 1991, additional discharge probably reaches the Pecos River at Malaga Bend or the alluvium in the Balmorhea/Loving Trough.

Isotopic data from groundwater samples suggest that groundwater travel time from the surface to the Dewey Lake and the Rustler is long and rates of flow are extremely slow. Based on observations by Lambert and Harvey reported in 1987, low tritium levels in all WIPP-area samples indicate minimal contributions from the atmosphere since 1950. Lambert in 1987 indicated four modeled radiocarbon ages from the Rustler and the Dewey Lake groundwater are between 12,000 and 16,000 years. The uranium isotope activity ratios observed require a conservative minimum residence time in the Culebra of several thousands of years and more probably reflect minimum ages of from 10,000 to 30,000 years.

Potentiometric data from four wells support the conclusion that little infiltration from the surface reaches the transmissive units of the Rustler. Hydraulic head data are available for a claystone in the Forty-niner from wells DOE-2, H-3, H-4, H-5, and H-6. Beauheim, in 1987, compared these

heads to heads in the surrounding Magenta wells and showed that flow between the units at all four wells may be upward. This observation offers no insight into the possibility of infiltration reaching the Forty-niner, but it rules out the possibility of infiltration reaching the Magenta or any deeper units at these locations.

D6-2d Water Quality

This section presents a discussion of the quality of groundwater and surface water in the WIPP area.

D6-2d(1) Groundwater Quality

Based on the major solute compositions described by Siegel et al. in 1991, four hydrochemical facies are delineated for the Culebra.

Zone A. Sodium-chloride brine (approximately 3.0 molar) with magnesium/calcium (Mg/Ca) mole ratios between 1.2 and 2.0. Zone A water is found in the eastern third of the WIPP site. The zone is roughly coincident with the region of low transmissivity described by LaVenue et al. in 1988. On the western side of the zone, halite in the Rustler has been found only in the unnamed lower member. In the eastern portion of the zone, halite has been observed throughout the Rustler.

Zone B. A dilute calcium-sulfate-rich water (ionic strength <0.1 molar) occurs in the southern part of the site. The Mg/Ca mole ratios are uniformly low (0.0 to 0.5). This zone is coincident with a high-transmissivity region, and halite is not found in the Rustler in this zone.

Zone C. Waters of variable composition with low to moderate ionic strength (0.3 to 1.6 molar) occur in the western part of the WIPP site and along the eastern side of the Nash Draw. Mg/Ca mole ratios range from 0.5 to 1.2. This zone is coincident with a region of variable transmissivity. In the eastern part of this zone, halite is present in the lower member of the Rustler. Halite is not observed in the formation on the western side of the zone. The most sodium-chloride-rich water is found in the eastern edge of the zone, close to core locations where halite is observed in the Tamarisk.

Zone D. A fourth zone can be defined based on inferred contamination related to potash-refining operations in the area. Waters from these wells have anomalously high solute concentrations (3 to 6 molar) and potassium/sodium (K/Na) weight ratios (0.22) compared to waters from other zones (K/Na = 0.01-0.09). In the extreme southwestern part of this zone, the composition of the Culebra well water has changed over the course of a seven-year monitoring period. The Mg/Ca mole ratio at WIPP-29 is anomalously high, ranging from 10 to 30 during the monitoring period.

This zonation is consistent with that described by Ramey in 1985, who defined three zones. The fourth zone (D) was added by Siegel et al. in 1991 to account for the local potash contamination.

Together, the variations in solutes and the distribution of halite in the Rustler exhibit a mutual interdependence. Concentrations of solutes are lowest where Rustler halite is less abundant, consistent with the hypothesis that solutes in Rustler groundwaters are derived locally by dissolution of minerals (e.g., halite, gypsum, and dolomite) in adjacent strata.

The TDS in the Magenta groundwater ranges in concentration from 5,460 to 270,000 mg/L. This water is considered saline to briny. The transmissivity in areas of lower TDS concentrations is very low, thus greatly decreasing its usability, and the Magenta is not considered as a water supply. In general, the chemistry of Magenta water is variable. Groundwater types range from a predominantly sodium-chloride type to a calcium-magnesium-sodium-sulfate-type chemistry. The water chemistry may indicate a general overall increase in TDS concentrations to the south and southwest, away from the WIPP site, and a potential change to a predominantly sodium-chloride water in that area.

In the WIPP area, the water quality of the Magenta is better than that of the Culebra. However, water from the Magenta is not used anywhere in the vicinity of the WIPP.

D6-2d(2) Surface-Water Quality

The Pecos River is the nearest permanent water source to the WIPP site. Natural brine springs, representing outfalls of the brine aquifers in the Rustler, feed the Pecos River at Malaga Bend, 12 mi (19 km) southwest of the site. This natural saline inflow adds approximately 70 tons of chloride per day to the Pecos River. Return flow from irrigated areas above Malaga Bend further contributes to the salinity. The concentrations of potassium, mercury, nickel, silver, selenium, zinc, lead, manganese, cadmium, and barium also show significant elevations at Malaga Bend but tend to decrease downstream. The metals presumably are rapidly adsorbed onto the river sediments. Natural levels of certain heavy metals in the Pecos River below Malaga Bend exceed the water quality standards of the World Health Organization, the U.S. Environmental Protection Agency, and the State of New Mexico. For example, the water quality standards specify a maximum level for lead is 50 parts per billion (ppb); however, levels of up to 400 ppb have been measured.

As it flows into Texas south of Carlsbad, the Pecos River is a major source of dissolved salt in the west Texas portion of the Rio Grande Basin. Natural discharge of highly saline groundwater into the Pecos River in New Mexico keeps TDS levels in the water in and above the Red Bluff Reservoir very high. The TDS levels in this interval exceed 7,500 mg/L 50 percent of the time and, during low flows, can exceed 15,000 mg/L . Additional inflow from saline water-bearing aquifers below the Red Bluff Reservoir, irrigation return flows, and runoff from oil fields continues to degrade water quality between the reservoir and northern Pecos County in Texas. Annual discharge-weighted average TDS concentrations exceed 15,000 mg/L . Water use is varied in the southwest Texas portion of the Pecos River drainage basin. For the most part, water use is restricted to irrigation, mineral production and refining, and livestock watering. In many instances,

surface-water supplies are supplemented by groundwaters that are being depleted and are increasing in salinity.

D6-3 Resources

The topic of resources is used to broadly define both economic (mineral and nonmineral) and cultural resources associated with the WIPP site. These resources are important since they (1) provide evidence of past uses of the area and (2) indicate potential future use of the area with the possibility that such use could lead to disruption of the closed repository. Because of the depth of the disposal horizon, it is believed that only the mineral resources are of significance in predicting the long-term performance of the disposal system. However, the nonmineral and cultural resources are presented for completeness.

This section refers to the significance of specific natural resources that lie beneath the WIPP site. Resources are minerals or hydrocarbons that are potentially of economic value. Reserves are the portion of resources that are economic at today's market prices and with existing technology.

For hydrocarbons, proven reserves can be expected to be recovered from new wells on undrilled acreage or from existing wells where a relatively major expenditure is required to establish production. Probable reserves refer to reserves of hydrocarbons suspected of existing in certain locations based on favorable engineering and/or geologic data. Possible reserves are based on conditions where limited engineering and/or geologic data support recoverable potential.

Mineral resource discussions are focused principally on hydrocarbons and potassium salts, both of which have long histories of development in the region and both of which could be disruptive to the disposal system. The information regarding the mineral resources concentrates on the following factors:

- Number, location, depth, and present state of development including penetrations through the disposal horizon
- Type of resource
- Accessibility, quality, and demand
- Mineral ownership in the area.

In addition to extractable resources, this section includes cultural and economic resources. These are focused on a description of past and present land uses unrelated to the development of minerals. The archaeological record supports the observation that changes on land use are principally associated with climate and the availability of forage for wild and domestic animals. In no case does it appear that past or present land use has had an impact on the subsurface beyond the development of shallow groundwater wells for watering livestock.

D6-3a Extractable Resources

The geologic studies of the WIPP site have included the investigation of potential natural resources to evaluate the impact of denying access to these resources and other consequences of their occurrence. This study was completed in support of the *Final Environmental Impact Statement* (FEIS) (DOE, 1980) to ensure knowledge of natural resources once the impacts of their denial was included in the decision-making process for the WIPP. Of the natural resources expected to occur beneath the site, five are of practical concern: first, the two potassium salts sylvite and langbeinite, which occur in strata above the repository salt horizon, and second, the three hydrocarbons crude oil, natural gas, and distillate liquids associated with natural gas, which occur in strata below the repository horizon. Other mineral resources beneath the site are caliche, salt, gypsum, and lithium; enormous deposits of these minerals near the site and elsewhere in the country are more than adequate (and more economically attractive) to meet future requirements for these materials. In 1995 the NMBMMR performed a reevaluation of the mineral resources at and within 1 mi (1.6 km) around the WIPP site.

D6-3a(1) Potash Resources at the WIPP Site

Throughout the Carlsbad Potash District, commercial quantities of potassium salts are restricted to the middle portion, locally called the McNutt Potash Member of the Salado. A total of 11 horizons, or orebeds, have been recognized in the McNutt Potash Member. Horizon Number 1 is at the base, and Number 11 is at the top. The 11th ore zone is not mined.

The USGS uses three established standard grades—low, lease, and high—to quantify the potash resources at the site. The USGS assumes that the "lease" and "high" grades comprise reserves because some lease-grade ore is mined in the Carlsbad Potash District. Most of the potash that is mined, however, is better typified by the high grade. Even the high-grade resources may not be reserves, however, if their properties make processing uneconomic.

The 1995 study contains a comprehensive summary of all previous evaluations.

Griswold (in NMBMMR, 1995, Chapter VII) used 40 existing boreholes drilled on and around the WIPP site to perform a reevaluation of potash resources. Holes were drilled using brine so that the dissolution of potassium salts was inhibited. The results of the chemical analyses of the ore-bearing intervals were adjusted to calculate the percentage equivalent as individual natural mineral species. Only the K_2O (potassium oxide) percentages as either sylvite or langbeinite were used to compute ore reserves. The conclusion reached by Griswold is that only the 4th and 10th ore zones contain economic potash reserves. The quantities are summarized in Table D6-4.

D6-3a(2) Hydrocarbon Resources at the WIPP Site

In 1974 the NMBMMR conducted a hydrocarbon resource study in southeastern New Mexico under contract to ORNL. The study included an area of 1,512 mi^2 (3,914 km^2). At the time of that

study, the proposed repository site was about 5 mi (8 km) northeast of the current site. The NMBMMR evaluation included a more detailed study of a four-township area centered on the old site; the present site is in the southwest quadrant of that area. The NMBMMR hydrocarbon resources study is presented in more detail in the FEIS (DOE, 1980, §9.2.3.5). The reader is referred to the FEIS or the original study (Foster, 1974) for additional information.

The resource evaluation was based both on the known reserves of crude oil and natural gas in the region and on the probability of discovering new reservoirs in areas where past unsuccessful drilling was either too widely spread or too shallow to have allowed discovery. All potentially productive zones were considered in the evaluation; therefore, the findings may be used for determining the total hydrocarbon resources at the site. A fundamental assumption in this study was that the WIPP area has the same potential for containing hydrocarbons as the much larger region in which the study was conducted and for which exploration data are available. Whether such resources actually exist can be satisfactorily established only by drilling at spacings close enough to give a high probability of discovery. A 1995 mineral resource reevaluation by the NMBMMR contains a comprehensive summary of this and other previous evaluations.

Broadhead et al. (NMBMMR, 1995, Chapter XI) provided a reassessment of hydrocarbon resources within the WIPP site boundary and within the first mile adjacent to the boundary. Calculations were made for resources that are extensions of known, currently productive oil and gas resources that are thought to extend beneath the study area with reasonable certainty (called probable resources in the report). Qualitative estimates are also made concerning the likelihood that oil and gas may be present in undiscovered pools and fields in the area (referred to as possible resources). Possible resources were not quantified in the study. The results of the study are shown in Tables D6-5 and D6-6.

D6-3b Cultural and Economic Resources

D6-3b(1) Demographics

The WIPP facility is located 26 mi (42 km) east of Carlsbad in Eddy County in southeastern New Mexico and includes an area of 10,240 acres (ac) (4,143 hectares [ha]). The facility is located in a sparsely populated area with fewer than 30 permanent residents living within a 10-mi (16-km) radius of the facility. The area surrounding the facility is used primarily for grazing, potash mining, and hydrocarbon production. No resource development that would affect WIPP facility operations or the long-term integrity of the facility is allowed within the 10,240 ac (4,143 ha) that have been set aside for the WIPP Project.

The community nearest to the WIPP site is the town of Loving, New Mexico, 18 mi (29 km) west-southwest of the site center. The population of Loving decreased from 1,355 in 1980 to 1,243 in 1990. The nearest population center is the city of Carlsbad, New Mexico, 26 mi (42 km) west of the site. The population of Carlsbad has decreased from 25,496 in 1980 to 24,896 in 1990. Hobbs, New Mexico, 36 mi (58 km) to the east of the site had a 1980 population of 29,153 and

a 1990 population of 29,115. Eunice, New Mexico, 40 mi (64 km) east of the site, had a 1980 population of 2,970 and a 1990 population of 2,731. Jal, New Mexico, 45 mi (72 km) southeast of the site, had a population of 2,575 in 1980 and of 2,153 in 1990.

The WIPP site is located in Eddy County near the border to Lea County, New Mexico. The Eddy County population increased from 47,855 in 1980 to 48,605 in 1990. The Lea County population decreased from 55,993 in 1980 to 55,765 in 1990.

D6-3b(2) Land Use

At present, land within 10 mi (16 km) of the site is used for potash mining operations, active oil and gas wells, and grazing. This pattern is expected to change little in the future.

The WIPP Land Withdrawal Act of 1992 (LWA) provided for the transfer of the WIPP site lands from the Department of the Interior to the DOE and effectively withdraws the lands, subject to existing rights, from entry, sale, or disposition; appropriation under mining laws; and operation of the mineral and geothermal leasing laws. The LWA directed the Secretary of Energy to produce a management plan to provide for grazing, hunting and trapping, wildlife habitat, mining, and the disposal of salt tailings.

There are no producing hydrocarbon wells within the volumetric boundary defined by the land withdrawal (T22S, R31E, S15-22, 27-34). One active well, referred to as James Ranch 13, was drilled in 1982 to tap gas resources beneath Section 31. This well was initiated in Section 6, outside the WIPP site boundary. The well enters Section 31 below a depth of 6,000 ft (1.82 km) beneath ground level.

Grazing leases have been issued for all land sections immediately surrounding the WIPP facility. Grazing within the WIPP site lands operates within the authorization of the Taylor Grazing Act of 1934, the Federal Land Policy and Management Act, the Public Rangelands Improvement Act of 1978, and the Bankhead-Jones Farm Tenant Act of 1973. The responsibilities of the DOE include supervision of ancillary activities associated with grazing (e.g., wildlife access to livestock water development); tracking of water developments inside WIPP lands to ensure that they are configured according to the regulatory requirements; and ongoing coordination with respective allottees. Administration of grazing rights is in cooperation with the Bureau of Land Management (BLM) according to the Memorandum of Understanding and the coinciding Statement of Work through guidance established in the East Roswell Grazing Environmental Impact Statement. The WIPP site is composed of two grazing allotments administered by the BLM: the Livingston Ridge (No. 77027) and the Antelope Ridge (No. 77032).

D6-3b(3) History and Archaeology

The WIPP site boundary consists of a 10,240-ac (16-m^2) area located in southeastern New Mexico. From about 10,000 B.C. to the late 1800s, this region was inhabited by nomadic

aboriginal hunters and gatherers who subsisted on various wild plants and animals. From about A.D. 600 onward, as trade networks were established with Puebloan peoples to the west, domesticated plant foods and materials were acquired in exchange for dried meat, hides, and other products from the Pecos Valley and Plains. In the mid-1500s, the Spanish Conquistadors encountered Jumano and Apachean peoples in the region practicing hunting and gathering and engaging in trade with Puebloans. After the Jumanos abandoned the southern Plains region, the Comanches became the major population of the area. Neighboring populations, with whom the Comanches maintained relationships ranging from mutual trade to open warfare, included the Lipan, or Southern Plains Apache; several Puebloan groups; Spaniards; and the Mescalero Apaches.

The best documented indigenous culture in the WIPP region is that of the Mescalaro Apaches, who lived west of the Pecos. The lifestyle of the Mescalaro Apaches represents a transition between the full sedentism of the Pueblos and the nomadic hunting and gathering of the Jumanos and the Sumas. In 1763 the San Saba expedition encountered and camped with a group of Mescaleros in Los Medaños. Expedition records indicate the presence of both Lipan and Mescalero Apaches in the region.

A peace accord reached between the Comanches and the Spaniards in 1768 resulted in two historically important economic developments: (1) organized buffalo hunting by Hispanic and Puebloan "ciboleros" and (2) renewal and expansion of the earlier extensive trade networks by Comancheros. These events placed eastern New Mexico in a position to receive a wide array of both physical and ideological input from the Plains culture area to the east and north and from Spanish-dominated regions to the west and south. Comanchero trade began to mesh with the Southwest American trade influence in the early nineteenth century. However, by the late 1860s the importance of Comanchero trade was cut short by Texan influence.

The first cattle trail in the area was established along the Pecos River in 1866 by Charles Goodnight and Oliver Loving. By 1868, Texan John Chisolm dominated much of the area by controlling key springs along the river. Overgrazing, drought, and dropping beef prices led to the demise of open range cattle ranching by the late 1880s.

Following the demise of open-range livestock production, ranching developed using fenced grazing areas and production of hay crops for winter use. Herd-grazing patterns were influenced by the availability of water supplies as well as by the storage of summer grasses as hay for winter use.

The town now called Carlsbad was founded as "Eddy" in 1889 as a health spa. In addition to ranching, the twentieth century brought the development of the potash, oil, and gas industries that have increased the population eightfold in the last 50 years.

Although technological change has altered some of the aspects, ranching remains an important economic activity in the WIPP region. This relationship between people and the land is still an

important issue in the area. Ranch-related sites that date to the 1940s and 1950s are common in parts of the WIPP area. These will be considered historical properties within the next several years and thus will be treated as such under current law.

The National Historic Preservation Act (NHPA) (16 USC 470 et seq.) was enacted to protect the nation's cultural resources in conjunction with the states, local governments, Indian tribes, and private organizations and individuals. The policy of the federal government includes (1) providing leadership in preserving the prehistoric and historic resources of the nation; (2) administering federally owned, administered, or controlled prehistoric resources for the benefit of present and future generations; (3) contributing to the preservation of nonfederally owned prehistoric and historic resources; and (4) assisting state and local governments and the national trust for historic preservation in expanding and accelerating their historic preservation programs and activities. The act also established the National Register of Historic Places ("National Register"). At the state level, the State Historic Preservation Officer (SHPO) coordinates the state's participation in implementing the NHPA. The NHPA has been amended by two acts: the Archaeological and Historic Preservation Act (16 USC 469 et seq.), and the Archaeological Resource Protection Act (16 USC 470aa et seq.).

In order to protect and preserve cultural resources found within the WIPP site boundary, the WIPP submitted a mitigation plan to the New Mexico SHPO describing the steps to be taken to either avoid or excavate archaeological sites. A "site" was defined as a place used and occupied by prehistoric people. In May 1980, the SHPO made a determination of "no adverse effect from WIPP facility activities" on cultural resources. The National Advisory Council on Historic Preservation concurred that the WIPP Mitigation Plan is appropriate to protect cultural resources.

Known historical sites (more than 50 years old) in southeastern New Mexico consist primarily of early twentieth century homesteads that failed or isolated features from late nineteenth century and early twentieth century cattle or sheep ranching and military activities. To date, no Spanish or Mexican conquest or settlement sites have been identified. Historic components are rare but are occasionally noted in the WIPP area. These include features and debris related to ranching.

Since 1976, cultural resource investigations have recorded 98 archaeological sites and numerous isolated artifacts within the 16-mi^2 (41.5-km^2) area enclosed by the WIPP site boundary. In the central 4-mi^2 (10.4-km^2) area, 33 sites were determined to be eligible for inclusion on the National Register as an archaeological district. Investigations since 1980 have recorded an additional 14 individual sites outside the central 4-mi^2 (10.4-km^2) area that are considered eligible for inclusion on the National Register. The major cultural resource investigations to date are broken out in the following. Additional information can be found in the bibliography.

1977 The first survey of the area was conducted in 1977 by Nielson of the Agency for Conservation Archaeology (ACA) for SNL. This survey resulted in the location of 33 sites and 64 isolated artifacts.

1979 MacLennan and Schermer of ACA performed the next survey in 1979. It was conducted for access roads and a railroad right-of-way for Bechtel, Inc. The survey encountered 2 sites and 12 isolated artifacts.

1980 Schermer performed another survey in 1980 to relocate the sites originally recorded by Nielson. This survey redescribed 28 of the original 33 sites.

1981 Hicks directed the excavation of nine sites in the WIPP core-area in 1981.

1982 Bradley in 1985 recorded one site and four isolated artifacts in an archaeological survey for a proposed water pipeline.

1985 Lord and Reynolds examined three sites in 1985 within the WIPP core area. These sites consisted of two plant-collecting and processing sites and one base camp used between 1000 B.C. and A.D.1400. The artifacts recovered from the excavations have been placed in the Laboratory of Anthropology at the Museum of New Mexico in Santa Fe.

1987 Mariah Associates, Inc., identified 40 sites and 75 isolates in 1987 in an inventory of 2,460 ac in 15 quarter-section units surrounding the WIPP site. In this investigation, 19 of the sites were located within the WIPP site's boundary. Sites encountered in this investigation tended to lack evident or intact features. Of the 40 new sites defined, 14 were considered eligible for inclusion in the National Register, 24 were identified as having insufficient data to determine eligibility, and 2 were determined to be ineligible for inclusion. The eligible and potentially eligible sites have been mapped and are being avoided by the DOE in its current activities at the WIPP site. Figure D6-35 maps out the 40 archaeological sites identified by the Mariah study.

1988–1992 Several archaeological clearance reports have been prepared for seismic testing lines on public lands in Eddy County, New Mexico, during this period.

The Delaware Basin has been used in the past for an isolated nuclear test. This test, Project Gnome, took place in 1961 at a location approximately 8 mi (13 km) southwest of the WIPP. The primary objective of Project Gnome was to study the effects of an underground nuclear explosion in salt. The Gnome experiment involved the detonation of a 3.1-kiloton nuclear device at a depth of 1,200 ft (361 m) in the bedded salt of the Salado. The explosion created a cavity of approximately 1,000,000 ft^3 (27,000 m^3), and caused surface displacements over an area of about a 1,200-ft (360-m) radius. Fracturing and faulting caused measurable changes in rock permeability and porosity at distances up to approximately 330 ft (100 m) from the cavity. No earth tremors were reported at distances over 25 mi (40 km) from the explosion. Project Gnome was decommissioned in 1979.

D6-4 Seismicity

Seismic data are presented in two time frames, before and after the time when seismographic data for the region became available. The earthquake record in southern New Mexico dates back only to 1923, and seismic instruments have been in place in the state since 1961. Various records have been examined to determine the seismic history of the area within 180 mi (288 km) of the site. With the exception of a weak shock in 1926 at Hope, New Mexico, and shocks in 1936 and 1949 felt at Carlsbad, all known shocks before 1961 occurred to the west and southwest of the site more than 100 mi (160 km) away.

The strongest earthquake on record within 180 mi (288 km) of the site was the Valentine, Texas, earthquake of August 16, 1931. It has been estimated to have been of magnitude 6.4 on the Richter scale (Modified Mercalli Intensity of VIII). The Valentine earthquake was 130 mi (208 km) south-southwest of the site. Its Modified Mercalli Intensity at the site is estimated to have been V; this is believed to be the highest intensity felt at the site in this century.

In 1887, a major earthquake occurred in northeast Sonora, Mexico. Although about 335 mi (536 km) west-southwest of the site, it is indicative of the size of earthquakes possible in the eastern portion of the Basin and Range Province, west of the province containing the site. Its magnitude was estimated to have been 7.8 (VIII to IX in Modified Mercalli Intensity). It was felt over an area of 0.5 million mi^2 (1.3 million km^2) (as far as Santa Fe to the north and Mexico City to the south); fault displacements near the epicenter were as large as 26 ft (18 m).

Since 1961, instrumental coverage has become comprehensive enough to locate most of the moderately strong earthquakes (local magnitude >3.5) in the region. Instrumentally determined shocks that occurred within 180 mi (288 km) of the site between 1961 and 1979 are shown in Figure D6-36. The distribution of these earthquakes may be biased by the fact that seismic stations were more numerous and were in operation for longer periods north and west of the site.

Except for the activity southeast of the site, the distribution of epicenters since 1961 differs little from that of shocks before that time. There are two clusters, one associated with the Rio Grande Rift on the Texas-Chihuahua border and another associated with the Central Basin Platform in Texas near the southeastern corner of New Mexico. The latter activity was not reported before 1964. It is not clear from the record whether earthquakes were occurring in the Central Basin Platform before 1964, although local historical societies and newspapers tend to confirm their absence before that time.

A station operating for 10 months at Fort Stockton, Texas, indicated many small shocks from the Central Basin Platform. Activity was observed at the time the station opened on June 21, 1964. This activity may be related to the injection of water underground for oil recovery. In the Ward-Estes North oilfield, operated by the Gulf Oil Corporation, the cumulative total of water injected up to 1970 was over 1 billion barrels. Accounting for 42 percent of the water injected in Ward and Winkler counties, Texas, the quantity is three times the total injected in all the oil fields of

southeastern New Mexico during the same period. Water injection has not been used in the region of the WIPP site to stimulate gas production. The nearest oil fields in the Delaware Basin, where secondary recovery might be attempted, are adjacent to the WIPP site boundary in the Delaware Formations.

A recent earthquake felt at the WIPP site occurred in January 1992 and is referred to as the Rattlesnake Canyon Earthquake.[1] It occurred 60 mi (100 km) east-southeast of the WIPP site. The earthquake was assigned a magnitude of 5.0. This event had no effect on any of the structures at the WIPP as documented by post-event inspections by the WIPP staff and the New Mexico Environment Department. This event was within the parameters used to develop the seismic risk assessment of the WIPP facility for the purposes of construction and operation.

The Rattlesnake Canyon event likely was tectonic in origin based on a 7±1 mi (12± 2 km) depth. This suggests some uncertainty regarding the origin of earthquakes associated with the Central Basin Platform.

D6-5 Rock Geochemistry

An understanding of the mineralogy/geochemistry of the host repository rock is considered critical to predicting the long-term waste isolation capability of the repository. Chemical composition of the different minerals and any impurities are important to understand and predict waste-rock compatibility of the Salado. This section emphasizes the following topics:

- Mineral content and composition
- Fluid inclusions
- Fracture fillings.

The Salado is dominated by various evaporite salts; the dominant mineral is halite (NaCl) of varying purity and accessory minerals. The major accessory minerals are anhydrite ($CaSO_4$), clays, polyhalite ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$), and gypsum ($CaSO_4 \cdot 2H_2O$). In the vicinity of the repository, authigenic quartz (SiO_2) and magnesite ($MgCO_3$) are also present as accessory minerals. The marker beds in the salt are described as anhydrite with seams of clay. The clays within the Salado are enriched in magnesium and depleted in aluminum. The magnesium enrichment probably reflects the intimate contact of the clays with brines derived from evaporating sea water, which are relatively high in magnesium.

A partial list of minerals found in the Delaware Basin evaporites, together with their chemical formulas, is given in Table D6-7. The table also indicates the relative abundances of the minerals in the evaporite rocks of the Castile, the Salado, and the Rustler. Minerals found either only at

[1]An earthquake occurred on April 13, 1995, near the town of Alpine, Texas. This earthquake has been assigned a local magnitude of M = 5.5. Details of the earthquake have not yet been published. The Alpine earthquake was felt at the WIPP site; however, no damage to WIPP facilities occurred as the result of this earthquake.

depth, removed from influence of weathering, or only near the surface, as weathering products, are also identified. Although the most common Delaware Basin evaporite mineral is halite, the presence of less soluble interbeds (dominantly anhydrite, polyhalite, and claystone) and more soluble admixtures (e.g., sylvite, glauberite, and kainite) has resulted in chemical and physical properties significantly different from those of pure NaCl. In particular, the McNutt Potash Member, between Marker Beds 116 and Marker Bed 126, is locally explored and mined for K-bearing minerals of economic interest. Under differential stress, brittle interbeds (anhydrite, polyhalite, magnesite, and dolomite) may fracture while, under the same stress regime, pure NaCl would undergo plastic deformation. Fracturing of brittle interbeds, for example, has locally enhanced the permeability, allowing otherwise nonporous rock to carry groundwater (e.g., fractured dolomite beds in the Rustler). Some soluble minerals incorporated in the rock salt (e.g., polyhalite, sylvite, leonite, and langbeinite) can be radiometrically date, their longevity marking the time of most recent water-incursion into the evaporite section. The survival of such minerals is significant, in that such dating is impossible in pure NaCl or calcium sulfate.

Liquids were collected from fluid inclusions and from seeps and boreholes within the WIPP drifts. Analysis of these samples indicated that there is compositional variability of the fluids showing the effects of various phase transformations on brine composition. The fluid inclusions belong to a different chemical population than do the fluids emanating from the walls. It was concluded that much of the brine is completely immobilized within the salt and that the free liquid emanating from the walls is present as a fluid film along intergranular boundaries mainly in clays and in fractures in anhydrites.

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TABLES

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TABLE D6-1
CULEBRA THICKNESS DATA SETS

Source	Data Set Location								
	T22S, R31E			T21-23S, R30-32E			Entire Set		
	n	ave	std dev	n	ave	std dev	n	ave	std dev
Richey (1989)	7	7.5 m	1.04 m	115	7.9 m	1.45 m	633	7.7 m	1.65 m
Holt and Powers (1988)	35	6.4 m	0.59 m	122	7.0 m	1.26 m	508	6.5 m	1.89 m
LaVenue et al. (1988)							78	7.7 m	
WIPP Potash Drillholes									
Jones (1978)				21	7.5 m	0.70 m			
Holt and Powers (1988)				21	6.3 m	0.50 m			

Key:
n = Number of boreholes or data points
ave = Average or mean
std dev = Standard deviation

TABLE D6-2
HYDROLOGIC CHARACTERISTICS OF ROCK UNITS AT THE WIPP SITE

Member Name	Thickness (m)		Hydraulic Conductivity (m/s)		Porosity	
	max	min	max	min	max	min
Forty-niner	20	–	5.0×10^{-9}	5.0×10^{-10}	–	–
Magenta	8	4	5.0×10^{-5}	5.0×10^{-10}	–	–
Tamarisk	84	8	–	–	–	–
Culebra	11.6	4	1×10^{-4}	2×10^{-10}	0.30	0.03
Unnamed	36	–	1×10^{-11}	6×10^{-15}	–	–
Rustler/ Salado Contact Zone	33	2.4	1×10^{-6}	1×10^{-12}	0.33	0.15

m = meters
m/s = meters per second
max = maximum
min = minimum

TABLE D6-3
CAPACITIES OF RESERVOIRS IN THE PECOS RIVER DRAINAGE

Reservoir	River	Total Storage Capacity[a] (acre-feet)	Use[b]
Los Esteros	Pecos	282,000	FC
Sumner	Pecos	122,100	IR, R
Brantley	Pecos	42,000	IR, R, FC
Avalon	Pecos	5,000	IR
Red Bluff	Pecos	310,000	IR
Two Rivers	Rio Hondo	167,900	FC

[a]Capacity below the lowest uncontrolled outlet or spillway.
[b]Key:
FC = Flood control
IR = Irrigation
R = Recreation

TABLE D6-4
CURRENT ESTIMATES OF POTASH RESOURCES AT THE WIPP SITE

Mining Unit	Product	Recoverable Ore (10^6 tons)	
		Within the WIPP site	Outside the WIPP site
4th Ore Zone	Langbeinite	40.5 @ 6.99%	126.0 @ 7.30%
10th Ore Zone	Sylvite	52.3 @ 13.99%	105.0 @ 14.96%

Source: NMBMMR, 1995, Chapter VII

TABLE D6-5
IN-PLACE OIL WITHIN STUDY AREA

Formation	Within WIPP site (10^6 bbl)	Outside WIPP site (10^6bbl)	Total (10^6 bbl)
Delaware	10.33	20.8	31.13
Bone Spring	0.44	0.8	1.25
Strawn	0.4	0.4	0.8
Atoka	1.1	0.1	0.2
Total	12.3	22.9	35.3

Source: NMBMMR 1995, Chapter XI.

TABLE D6-6
IN-PLACE GAS WITHIN STUDY AREA

Formation	Gas Reserves	
	Within WIPP Site Boundary (mcf)	Adjacent to WIPP Site Boundary (mcf)
Delaware	18,176	32,873
Bone Springs	956	1,749
Strawn	9,600	9,875
Atoka	123,336	94,410
Morrow	32,000	28,780

Source: NMBMMR, 1995, Chapter XI

TABLE D6-7
CHEMICAL FORMULAS, DISTRIBUTIONS, AND RELATIVE ABUNDANCES OF MINERALS IN DELAWARE BASIN EVAPORITES

Mineral	Formula	Occurrence/Abundance
Amesite	$(Mg_4Al_2)(Si_2Al_2)O_{10}(OH)_8$	S,R
Anhydrite	$CaSO_4$	CCC,SSS,RRR; rarely near surface
Calcite	$CaCO_3$	S,RR
Carnallite	$KMgCl_3 \cdot 6H_2O$	SS**
Chlorite	$(Mg,Al,Fe)_{12}(Si,Al)_8O_{20}(OH)_{16}$	S*,R*
Corrensite	mixed-layer chlorite/smectite	S*,R*
Dolomite	$CaMg(CO_3)_2$	RR
Feldspar	$(K,Na,Ca)(Si,Al)_4O_8$	C*,S*,R*
Glauberite	$Na_2Ca(SO_4)_2$	C,S (never near surface)
Gypsum	$CaSO_4 \cdot 2H_2O$	CCC (only near surface),S,RRR
Halite	NaCl	CCC,SSS,RRR; rarely near surface)
Illite	$K_{1-1.5}Al_4[Si_{7-6.5}Al_{1-1.5}O_{20}](OH)_4$	S*,R*
Kainite	$KMgClSO_4 \cdot 3H_2O$	SS**
Kieserite	$MgSO_4\ H_2O$	SS**
Langbeinite	$K_2Mg_2(SO_4)_3$	S***
Magnesite	$MgCO_3$	C,S,R
Polyhalite	$K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$	SS,R (never near surface)
Pyrite	FeS_2	C,S,R
Quartz	SiO_2	C*,S*,R*
Serpentine	$Mg_3Si_2O_5(OH)_4$	S*,R*
Smectite	$(Ca_{1/2},Na)_{0.7}(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH)_4\ nH_2O$	S*,R*
Sylvite	KCl	SS***

Key to Occurrence/Abundance notations:
C = Castile Formation; S = Salado Formation; R = Rustler Formation
3 letters = abundant; 2 letters = common; 1 letter = rare or accessory
*** Potash-ore mineral (never near surface)
** Potash-zone non-ore mineral (never near surface)
* In claystone interbeds

FIGURES

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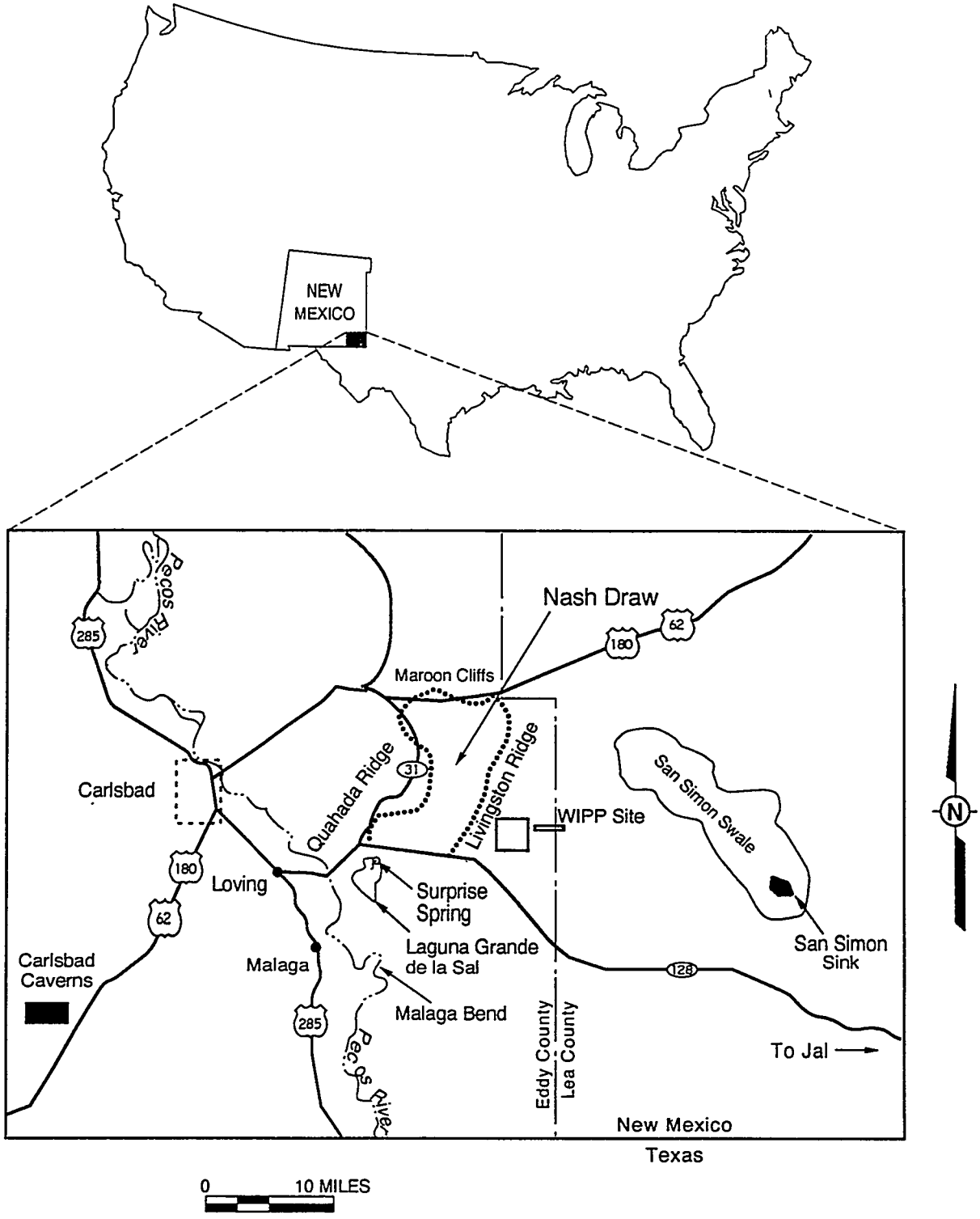


Figure D6-1
WIPP Site Location in Southeastern New Mexico

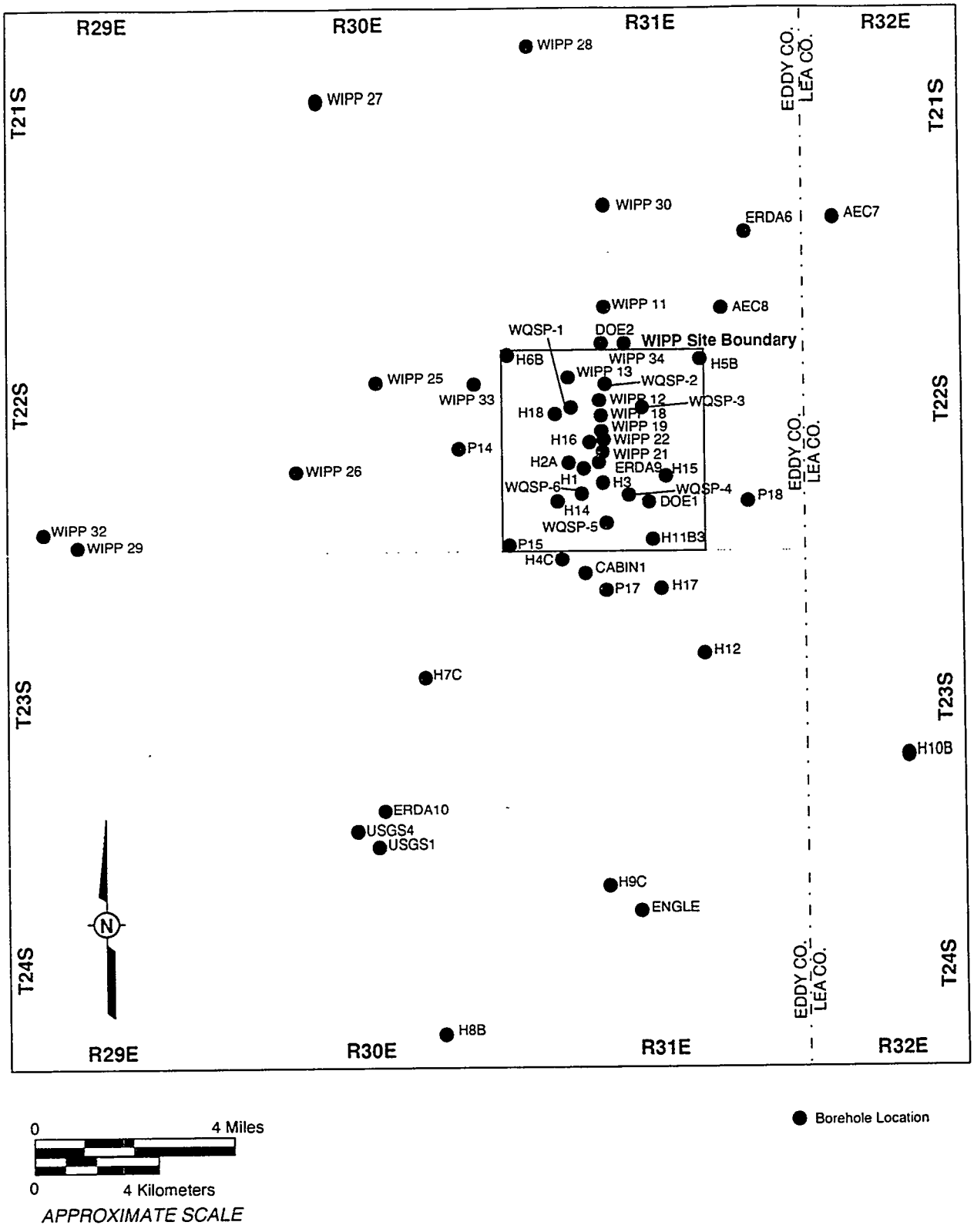


Figure D6-2
Borehole Location Map

ERA	PERIOD	EPOCH	YEARS DURATION	YEARS BEFORE PRESENT	MAJOR GEOLOGIC EVENTS SOUTHEAST NEW MEXICO REGION
CENOZOIC	Quaternary	Holocene	10,000		Eolian and erosion/solution activity. Development of present landscape.
		Pleistocene	1,590,000	1,600,000	
	Tertiary	Pliocene	3,700,000		Deposition of Gatuña fan sediments. Formation of caliche caprock. Regional uplift and east-southeastward tilting; Basin-Range uplift of Sacramento and Guadalupe-Delaware Mountains.
		Miocene	18,400,000		
		Oligocene	12,900,000		Erosion dominant. No Early to Mid-Tertiary rocks present.
		Eocene	21,200,000		
		Paleocene	8,600,000	66,400,000	Laramide "revolution" Uplift of Rocky Mountains. Mid tectonism and igneous activity to west and north.
MESOZOIC	Cretaceous		77,600,00	144,000,000	Submergence. Intermittent shallow seas. Thin limestone and clastics deposited.
	Jurassic		64,000,000	208,000,000	Emergent conditions. Erosion, formation of rolling terrain. Deposition of fluvial clastics.
	Triassic		37,000,000	245,000,000	Erosion. Broad flood plain develops.
PALEOZOIC	Permian		41,000,000	286,000,000	Deposition of evaporite sequence followed by continental redbeds. Sedimentation continuous in Delaware, Midland, Val Verde basins and shelf areas.
	Pennsylvanian		34,000,000	320,000,000	Massive deposition of clastics. Shelf, margin, basin pattern of deposition develops.
	Mississippian		40,000,000	360,000,000	Regional tectonic activity accelerates, folding up Central Basin platform. Matador arch, ancestral Rockies. Regional erosion. Deep, broad basins to east and west of platform develop.
	Devonian		48,000,000	408,000,000	Renewed submergence. Shallow sea retreats from New Mexico; erosion. Mild epeirogenic movements. Tobosa basin subsiding. Pedernal landmass and Texas Peninsula emergent until Middle Mississippian.
	Silurian		30,000,000	438,000,000	
	Ordovician		67,000,000	505,000,000	Marathon-Quachita geosyncline, to south, begins subsiding. Deepening of Tobosa basin area; shelf deposition of clastics, derived partly from ancestral Central Basin platform and carbonates.
	Cambrian		65,000,000	570,000,000	Clastic sedimentation – Bliss sandstone.
	PRECAMBRIAN				Erosion to a nearly level plain. Mountain building, igneous activity, metamorphism, erosional cycles.

Figure D6-3

Major Geologic Events - Southeast New Mexico Region

System	Series	Group	Formation	Member
Recent	Recent		Surficial Deposits	
Quaternary	Pliestocene		Mescalero Caliche	
			Gatuña	
Tertiary	Mid-Pliocene		Ogallala	
Triassic		Dockum	Santa Rosa	
Permian	Ochoan		Dewey Lake	
			Rustler	Forty-Niner
				Magenta Dolomite
				Tamarisk
				Culebra Dolomite
				Unnamed
			Salado	Upper
				McNutt Potash
				Lower
			Castile	
	Guadalupian	Delaware Mountain	Bell Canyon	
			Cherry Canyon	
			Brushy Canyon	

Figure D6-4
Site Geologic Column

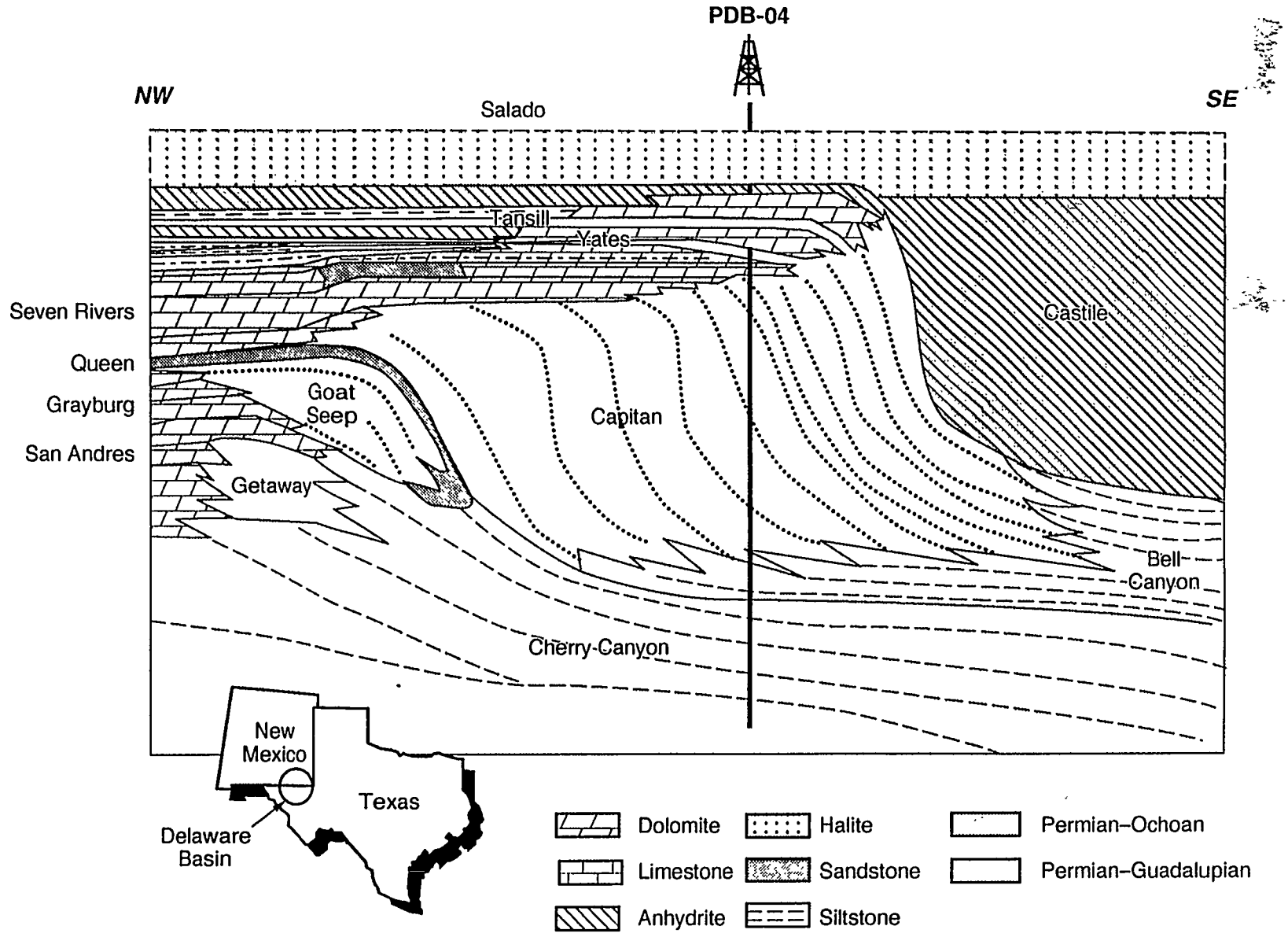


Figure D6-5
Cross Section from Delaware Basin (Southeast)
Through Marginal Reef Rocks to Back-Reef Facies

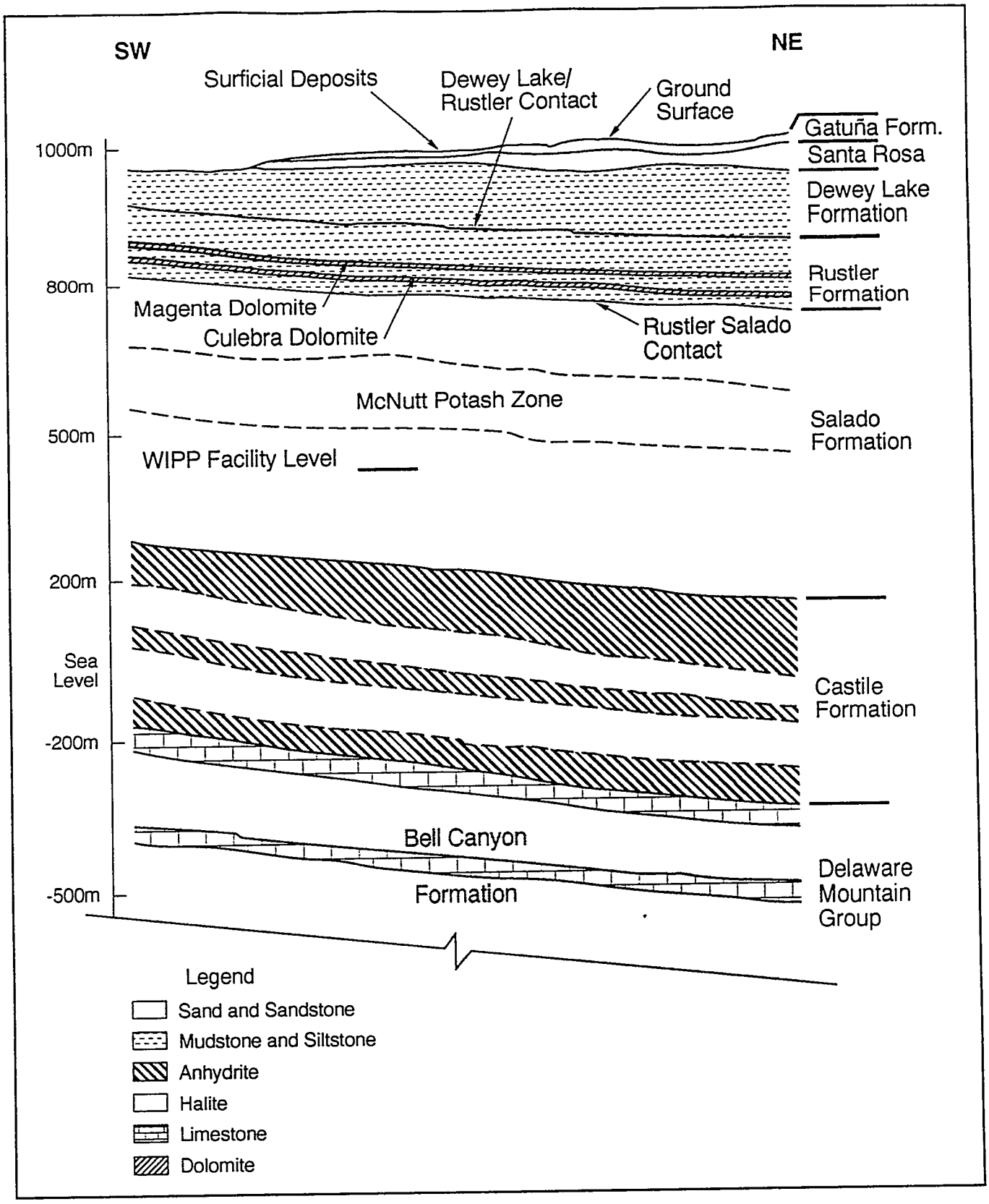


Figure D6-6
Generalized Stratigraphic Cross Section above Bell Canyon Formation at WIPP Site

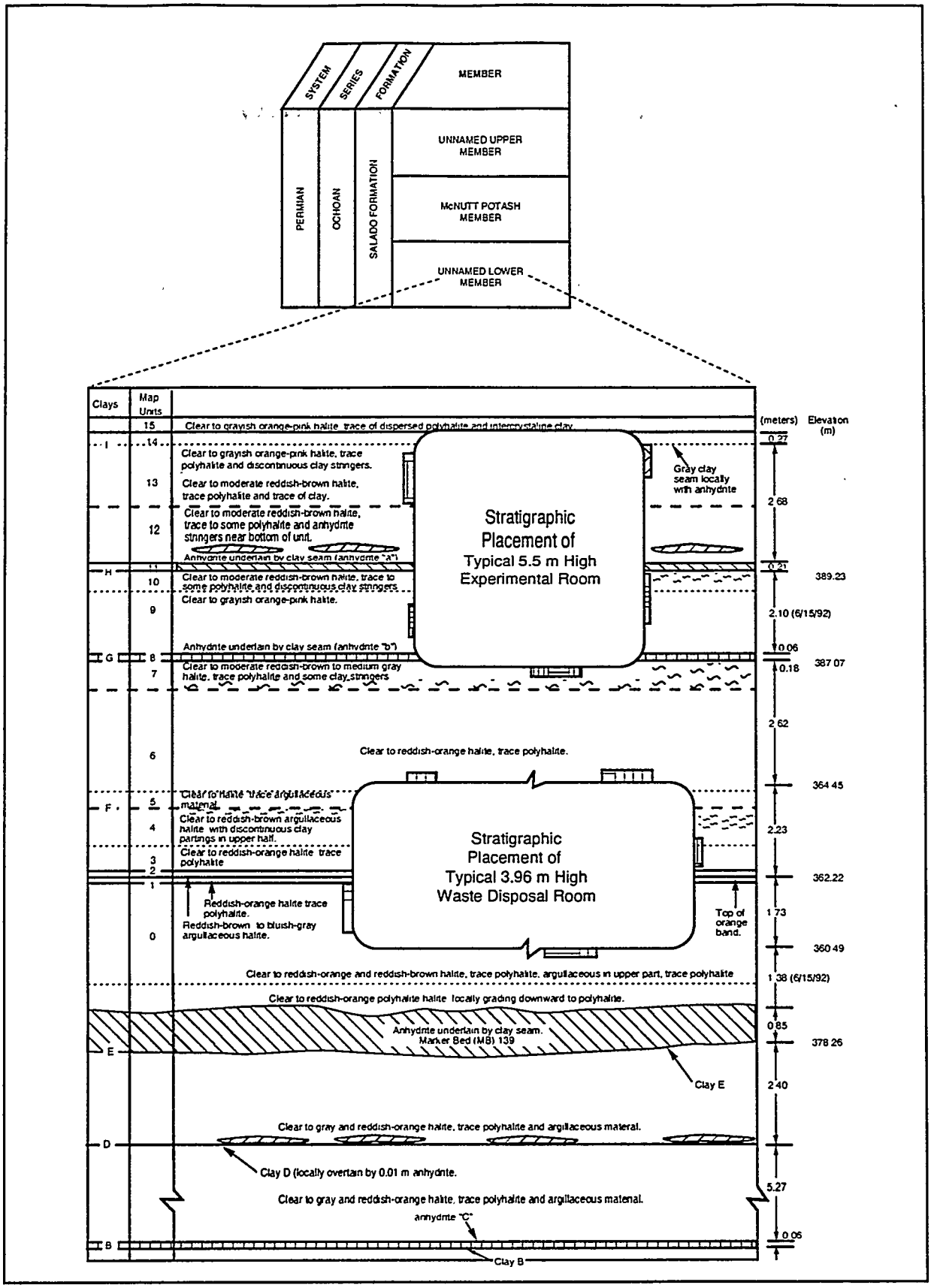


Figure D6-7
Salado Stratigraphy

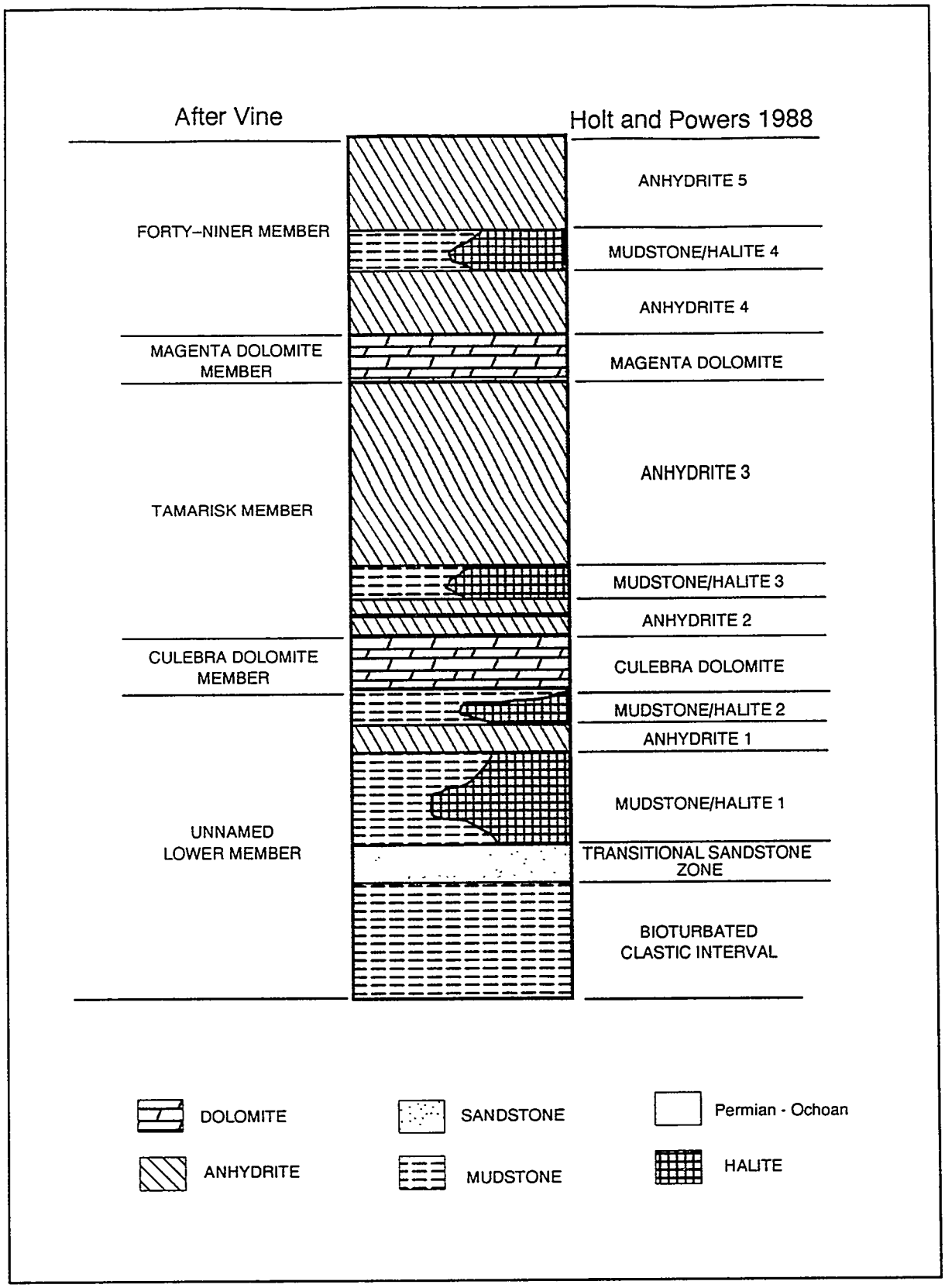


Figure D6-8
Rustler Stratigraphy

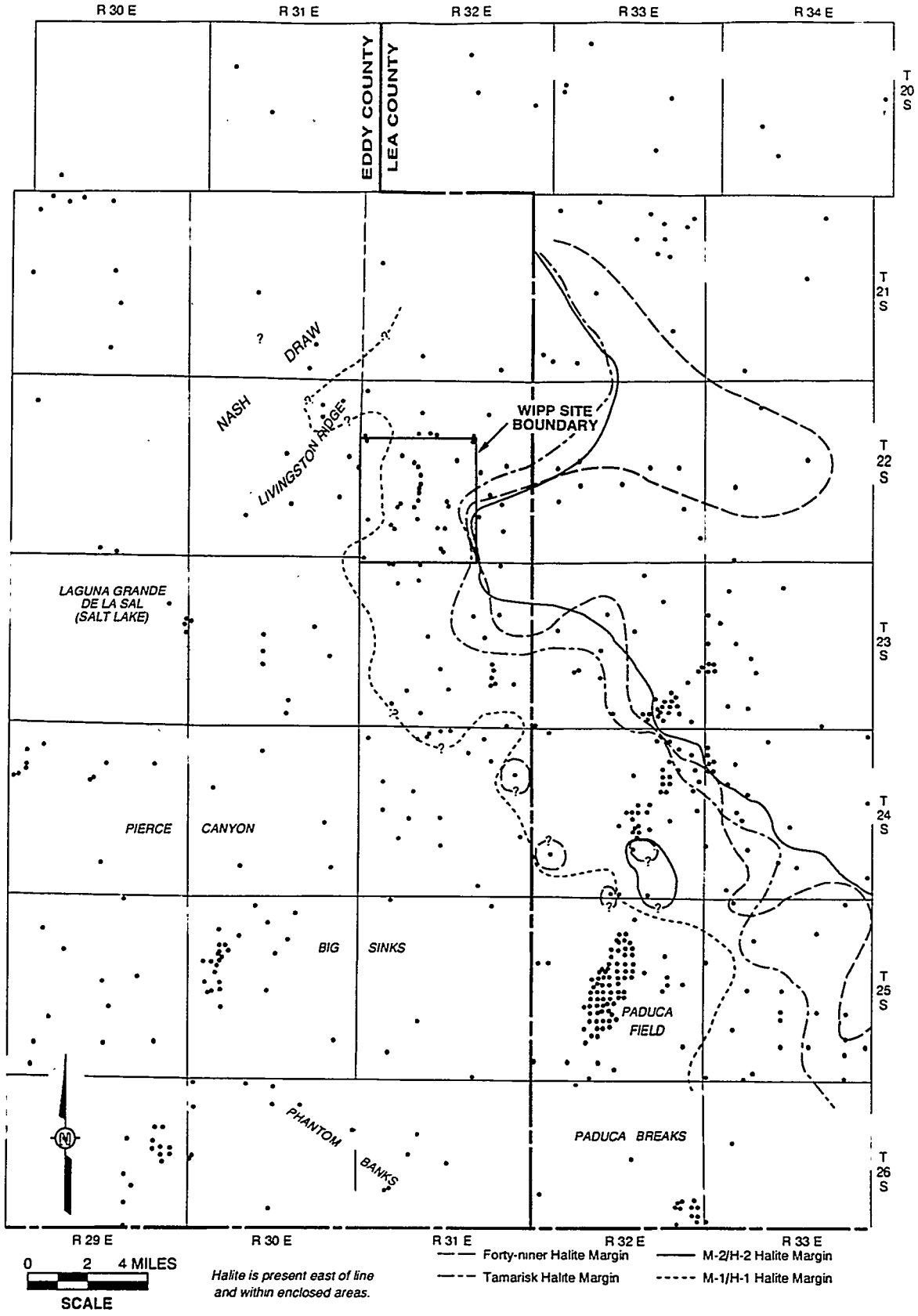


Figure D6-9
Halite Margins in Rustler

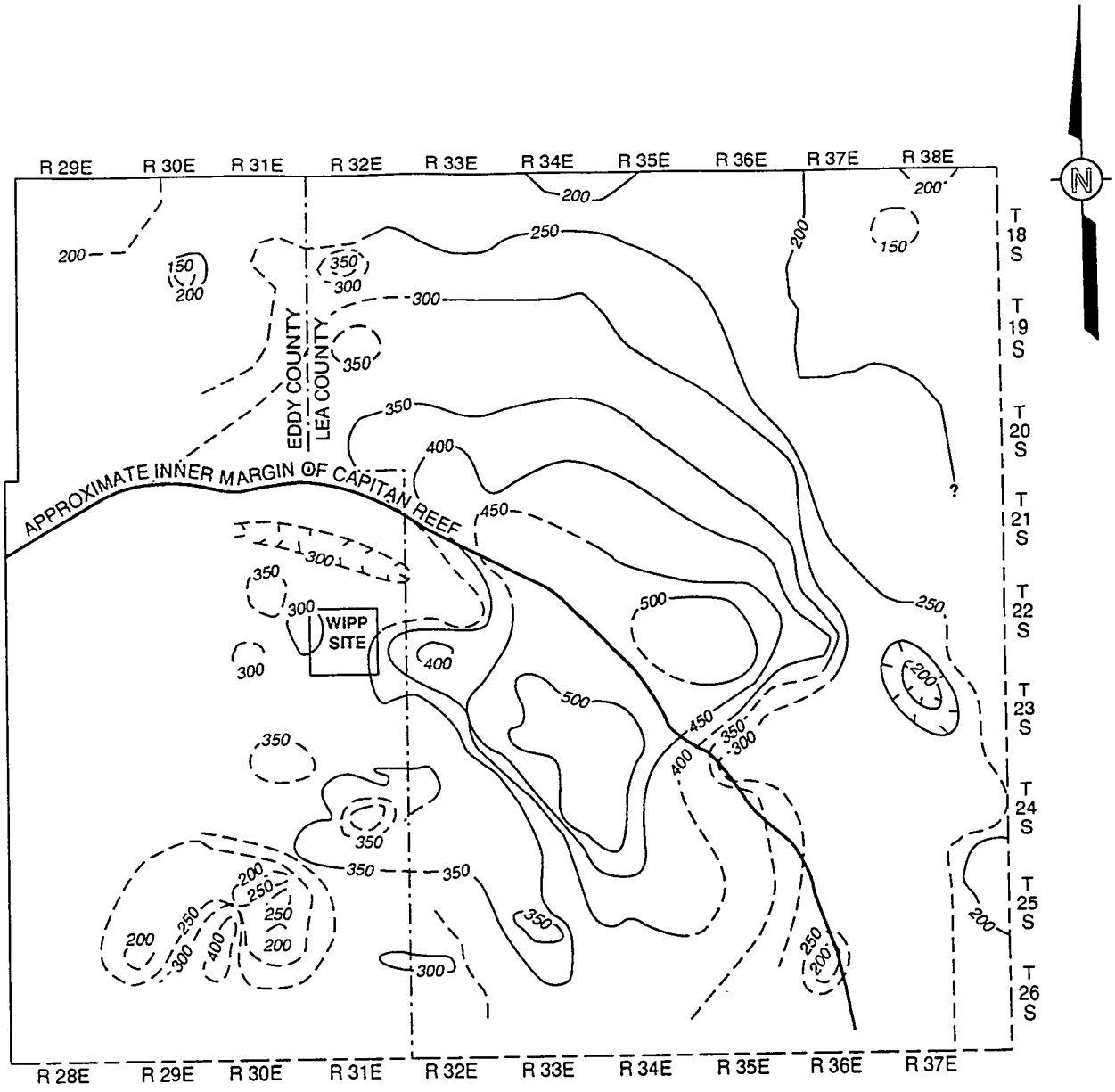


Figure D6-10
Isopach Map of the Entire Rustler

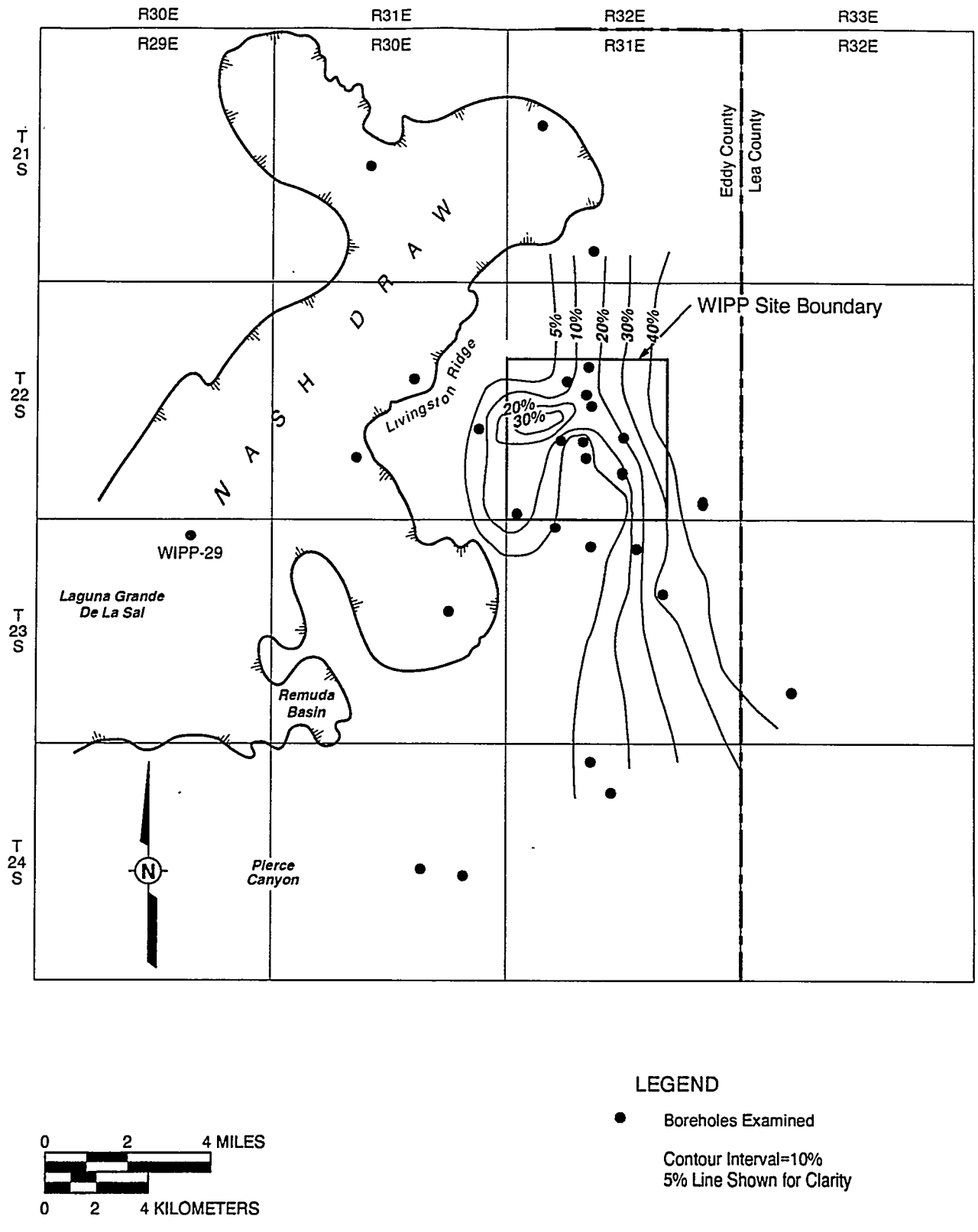


Figure D6-11
Percentage of Natural Fractures in the Culebra Filled with Gypsum

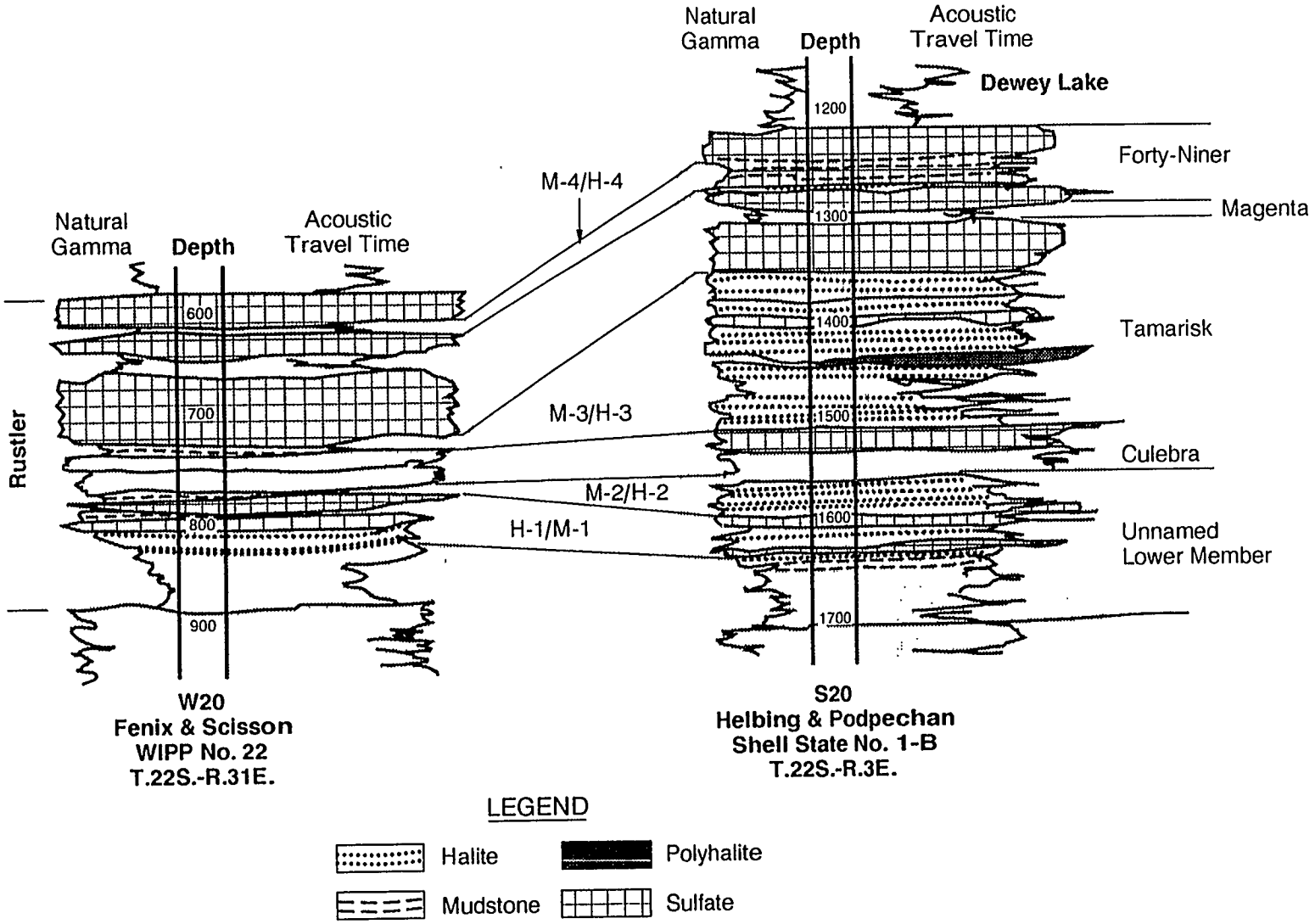


Figure D6-12
Log Character of the Rustler Showing Mudstone-Halite Lateral Relationships

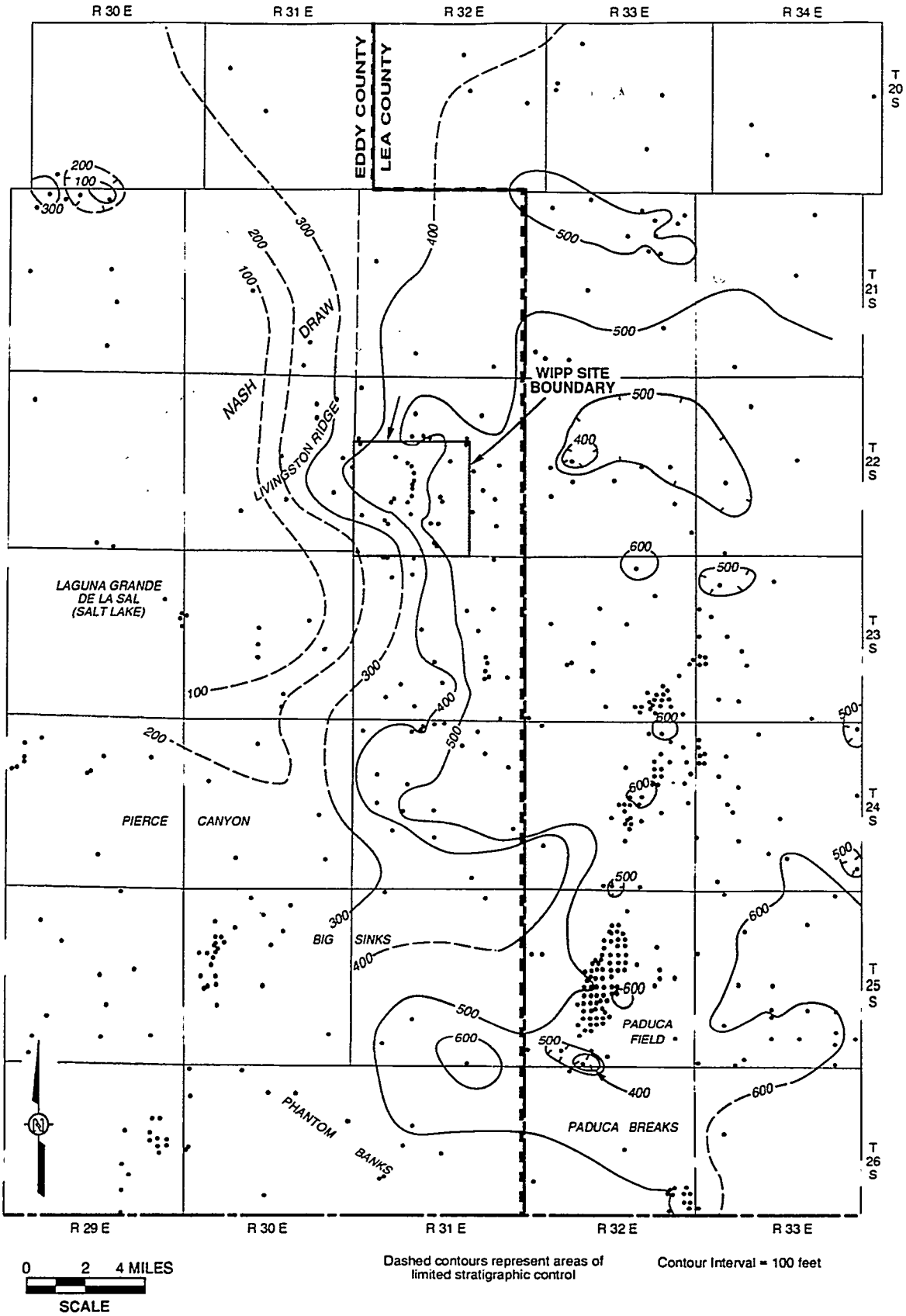


Figure D6-13
Isopach of the Dewey Lake

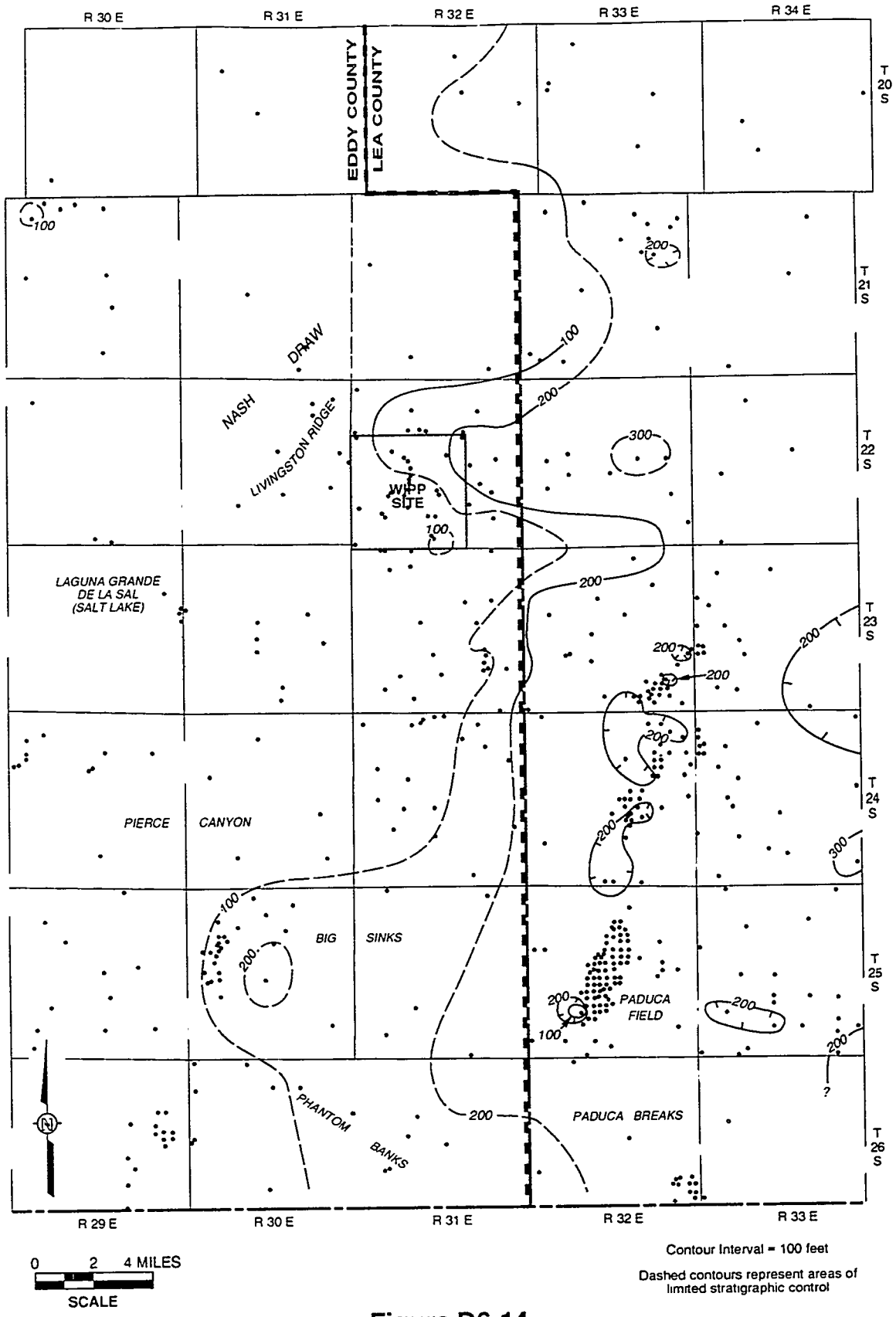


Figure D6-14
Isopach of the Santa Rosa

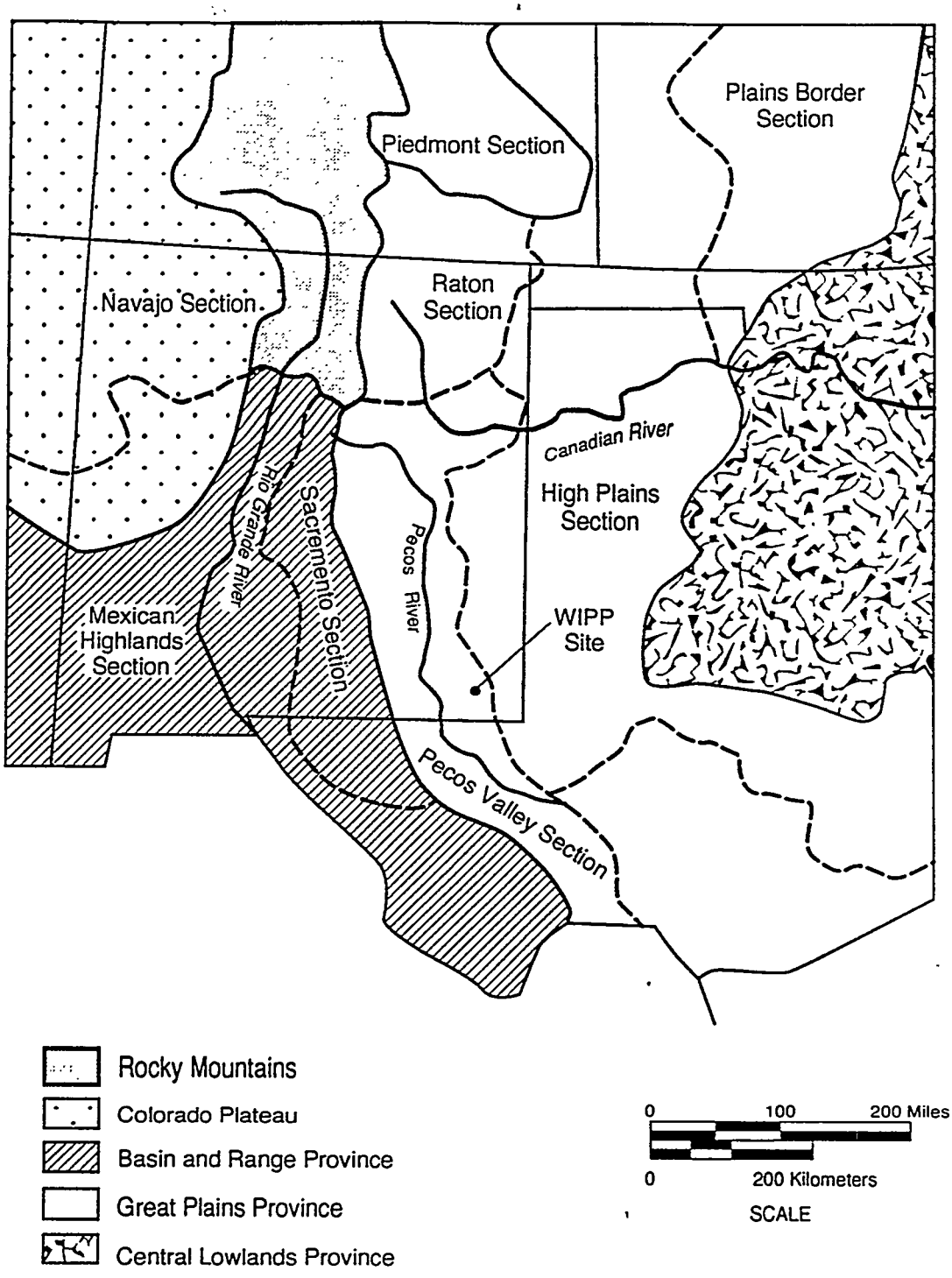


Figure D6-15
Physiographic Provinces and Sections

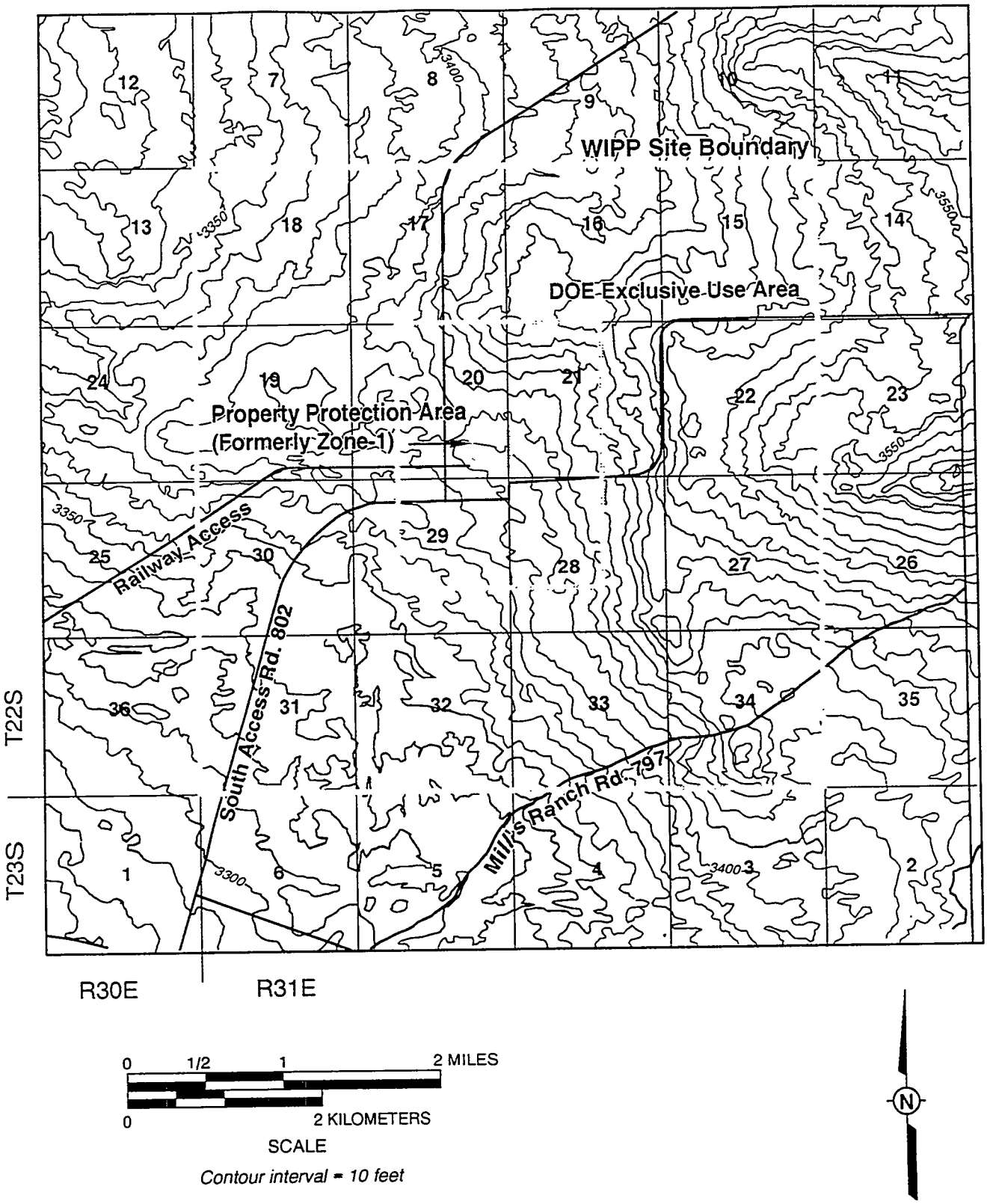


Figure D6-16
Site Topographic Map

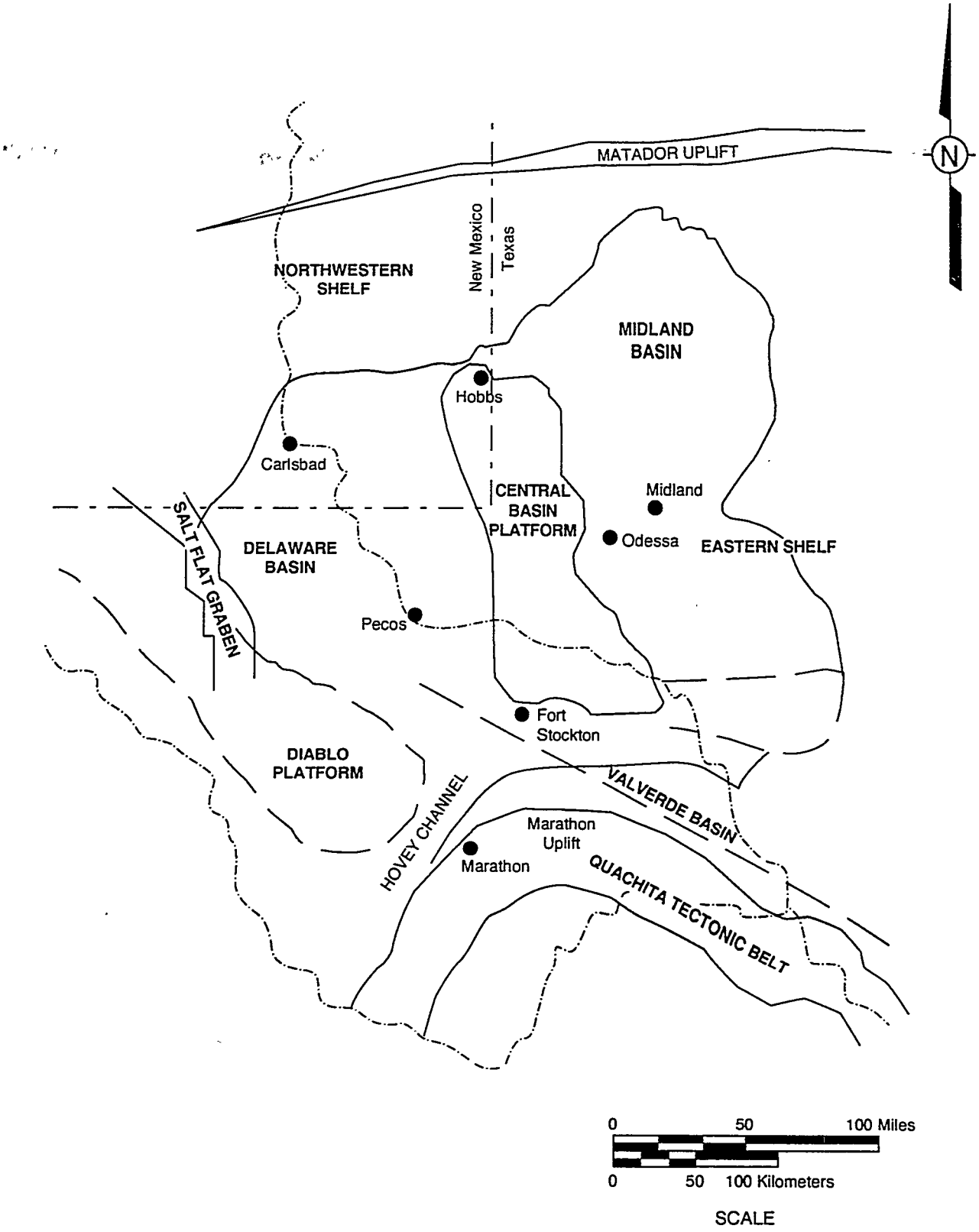
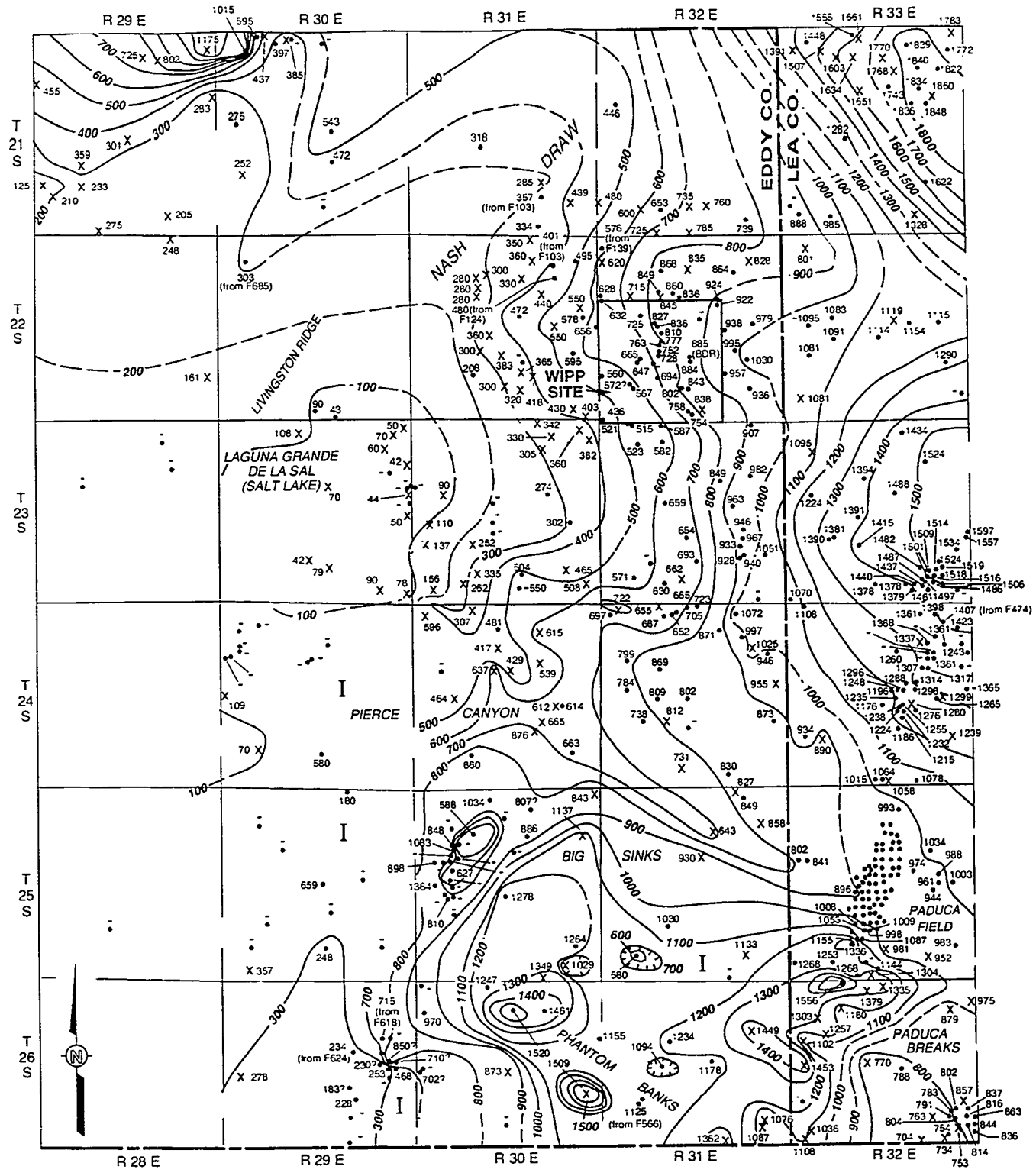


Figure D6-17
Structural Provinces of the Permian Basin Region



0 2 4 MILES

SCALE

I Area of incomplete contouring

• Represents Borehole and Data as Reported in Holt and Powers (1988) or interpreted from additional geophysical log data

x Represents Borehole and Data as Reported in Richey (1989)

Figure D6-18
Depth to Base of Culebra

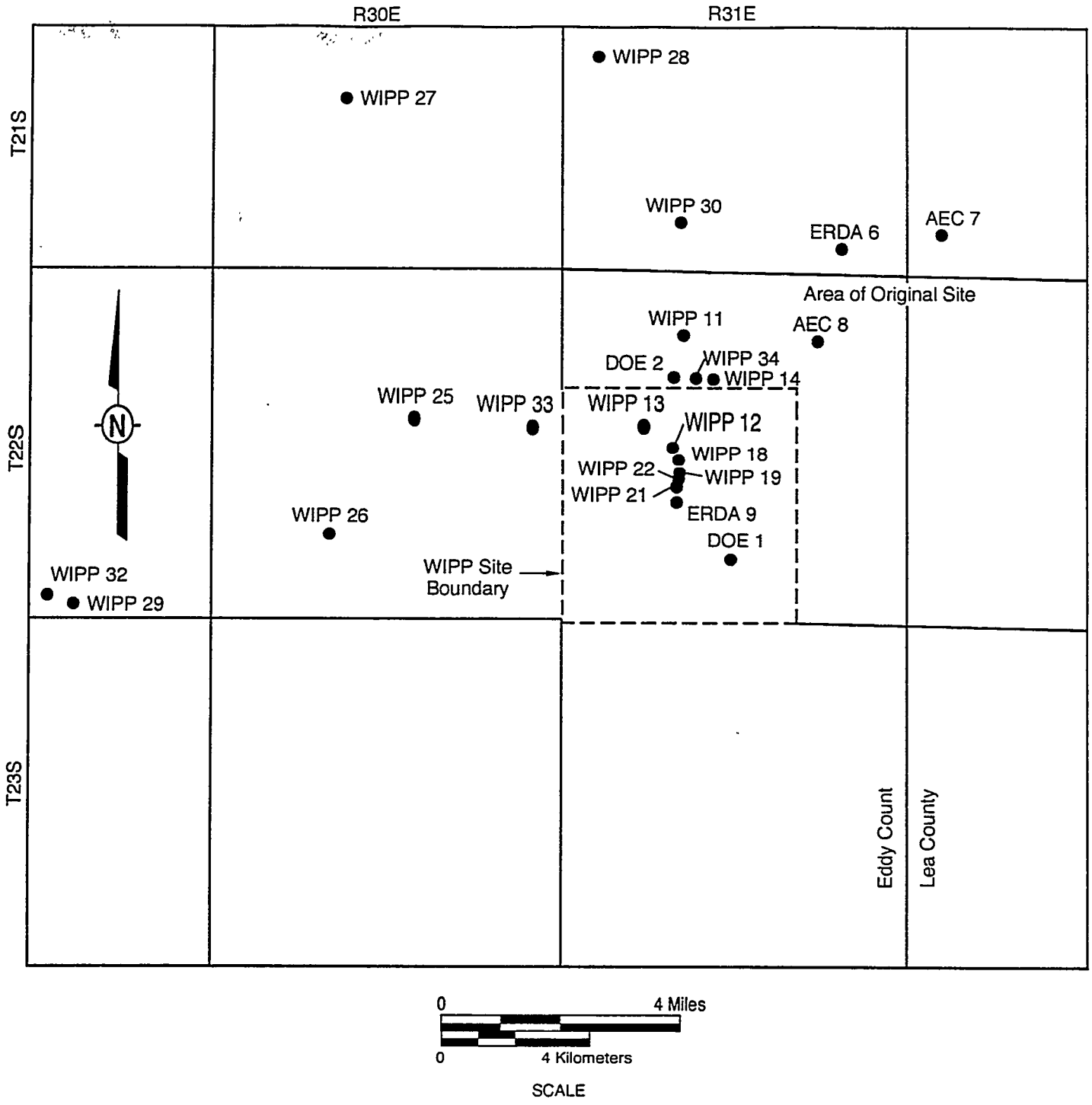
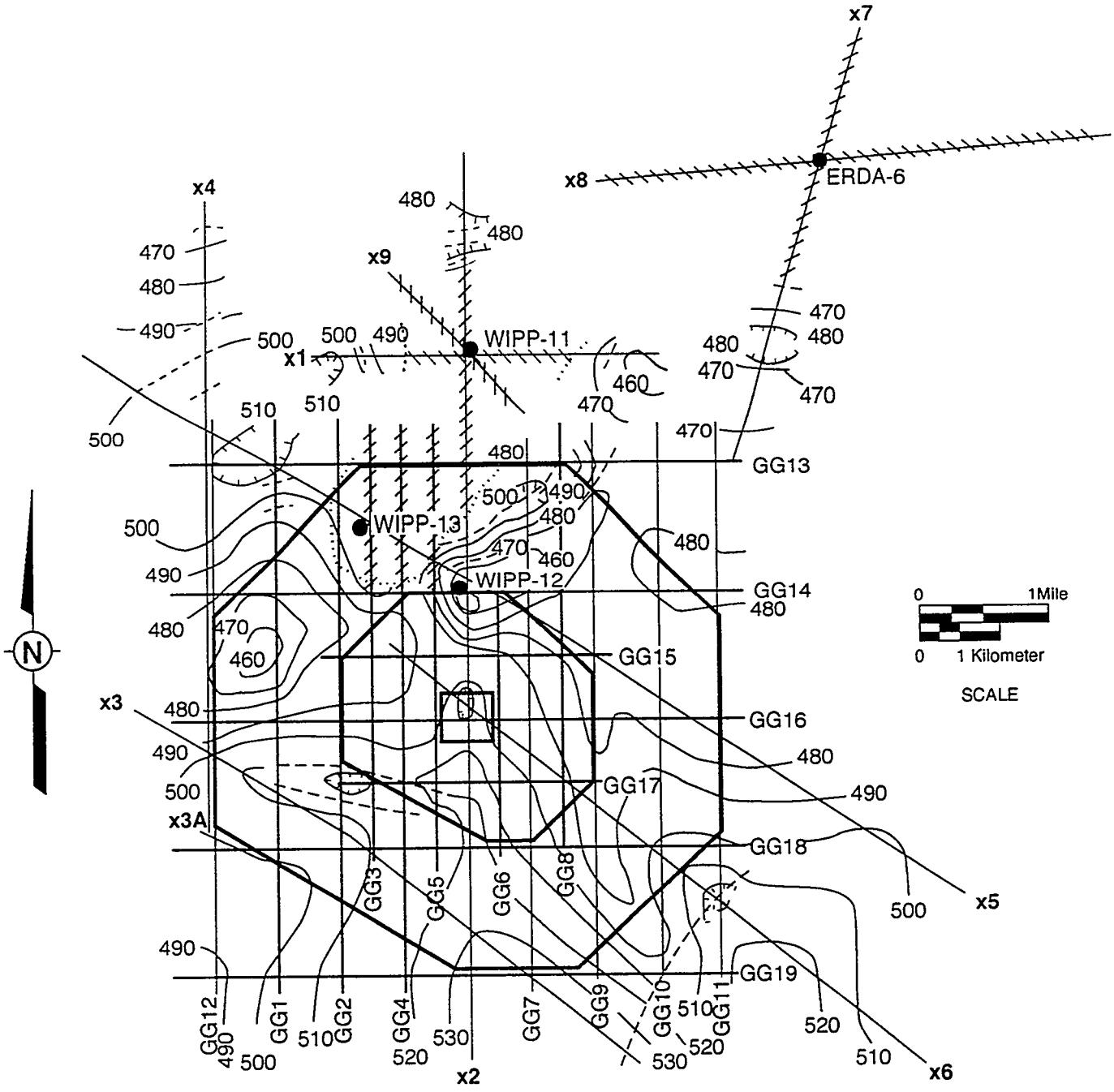


Figure D6-19
Location of Main Stratigraphic Drillholes



NOTES:

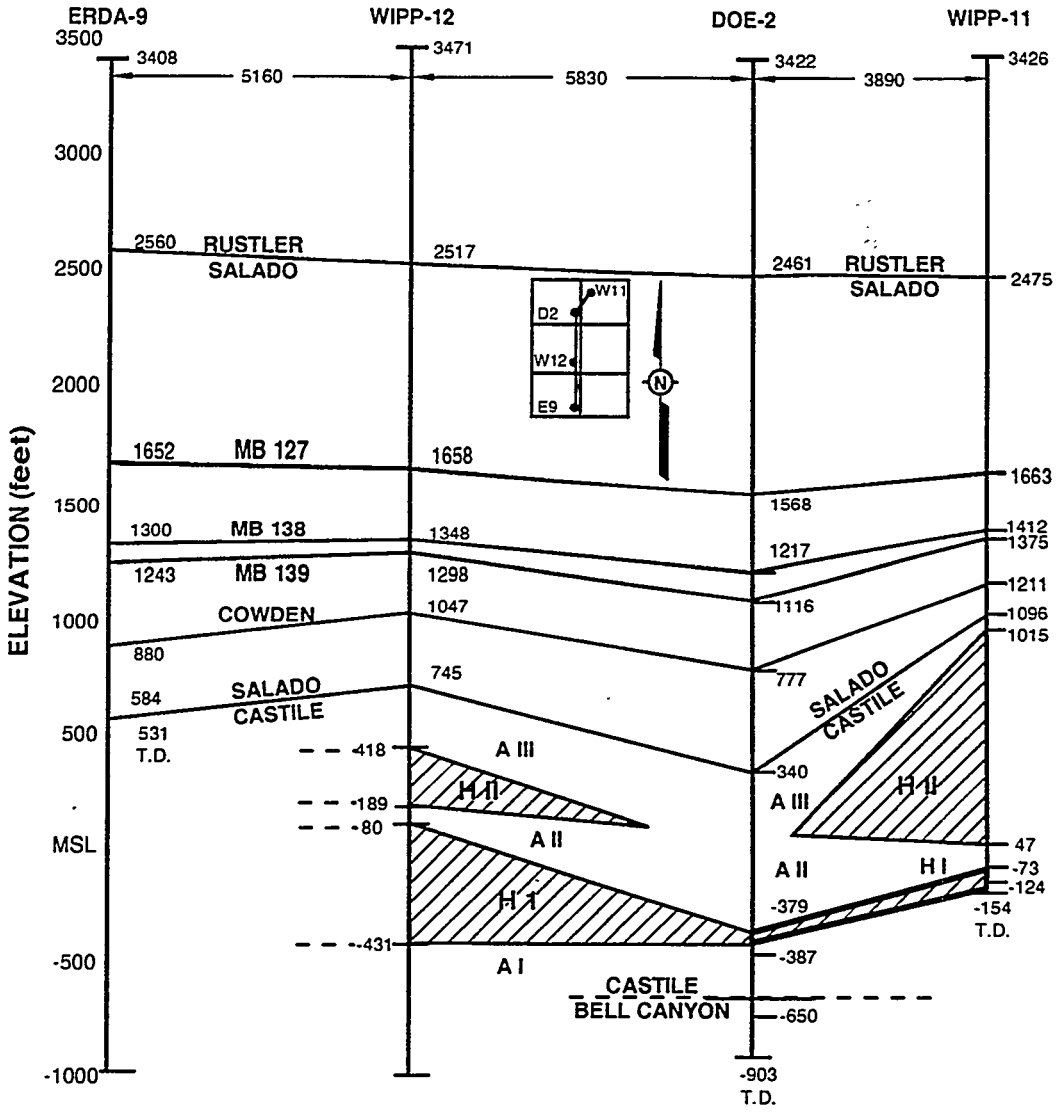
1. Contour Interval 10 Milliseconds; Datum 3350 Feet Above Sea Level.
2. Contour Interval in Feet Would be Approximately 75 Feet Based on an Average Seismic Velocity of 7620 FT./Sec. Averaged Over the Entire Stratigraphic Interval from Ground Surface to the Middle of the Castile Formation.

LEGEND

530	Milliseconds Two-Way Time	·····	Area of Complex Structure
GG17	Seismic Line (Crossed Where Ambiguous)	– – –	Fault
		WIPP-12 ●	Borehole to Horizon

Source: Popielak et at., 1983

Figure D6-20
Seismic Time Structure Middle Castile Formation



(Source: Borns, 1987)

Figure D6-21
Fence Diagram Using DOE-2 and Adjacent Holes

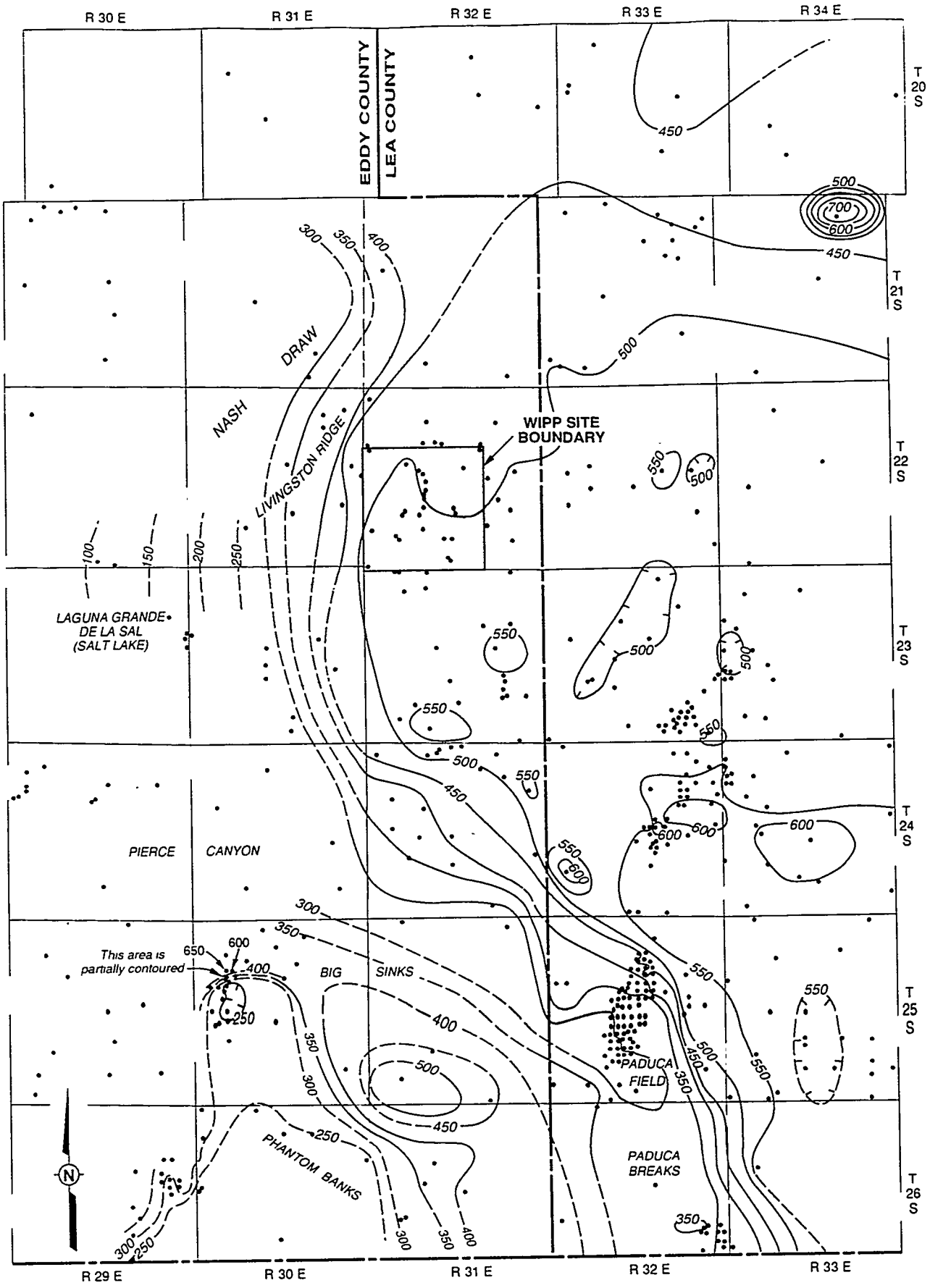


Figure D6-22

Isopach from the Top of the Vaca Triste to the Top of the Salado

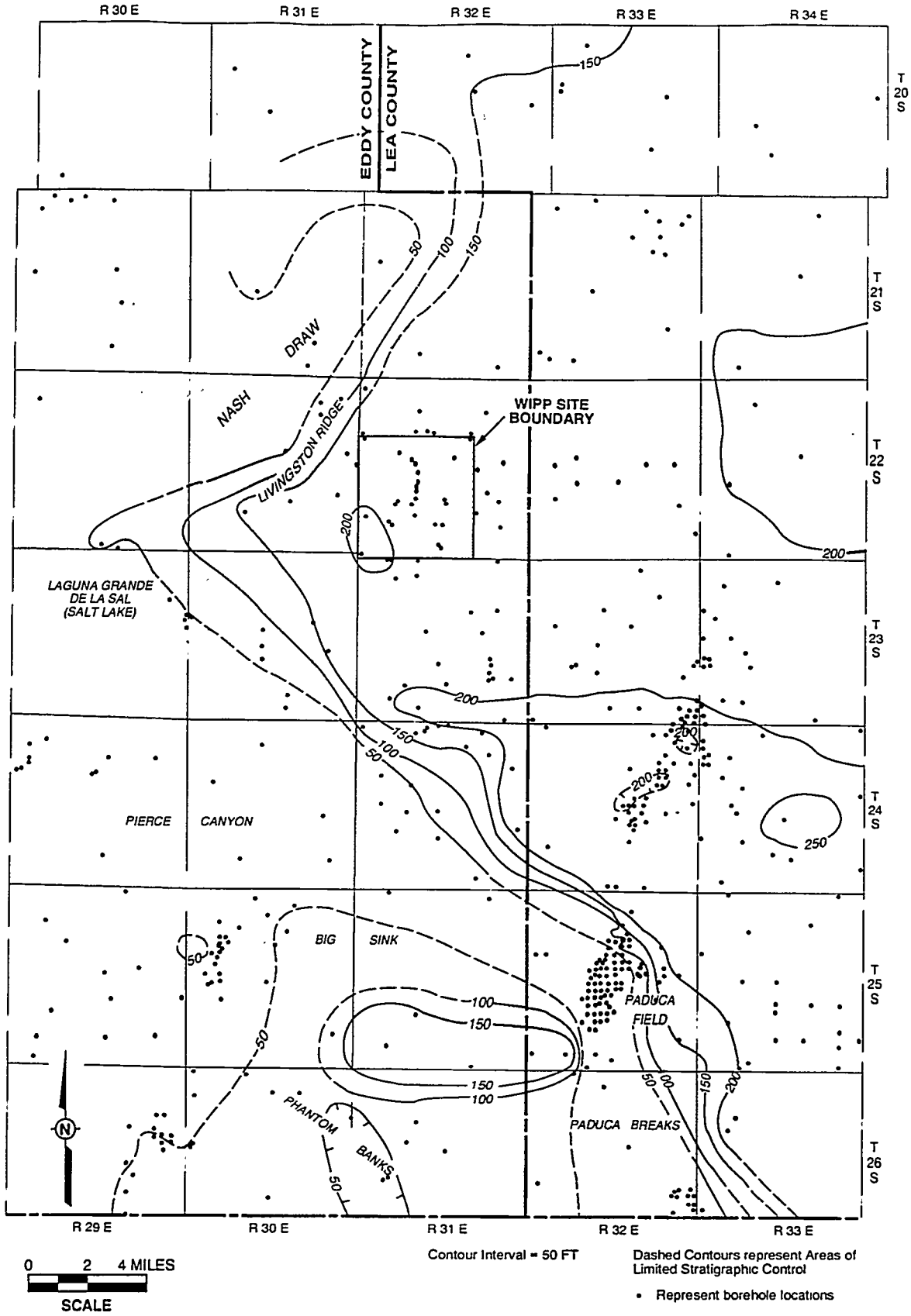


Figure D6-23
Isopach from the Base of MB 103 to the Top of the Salado

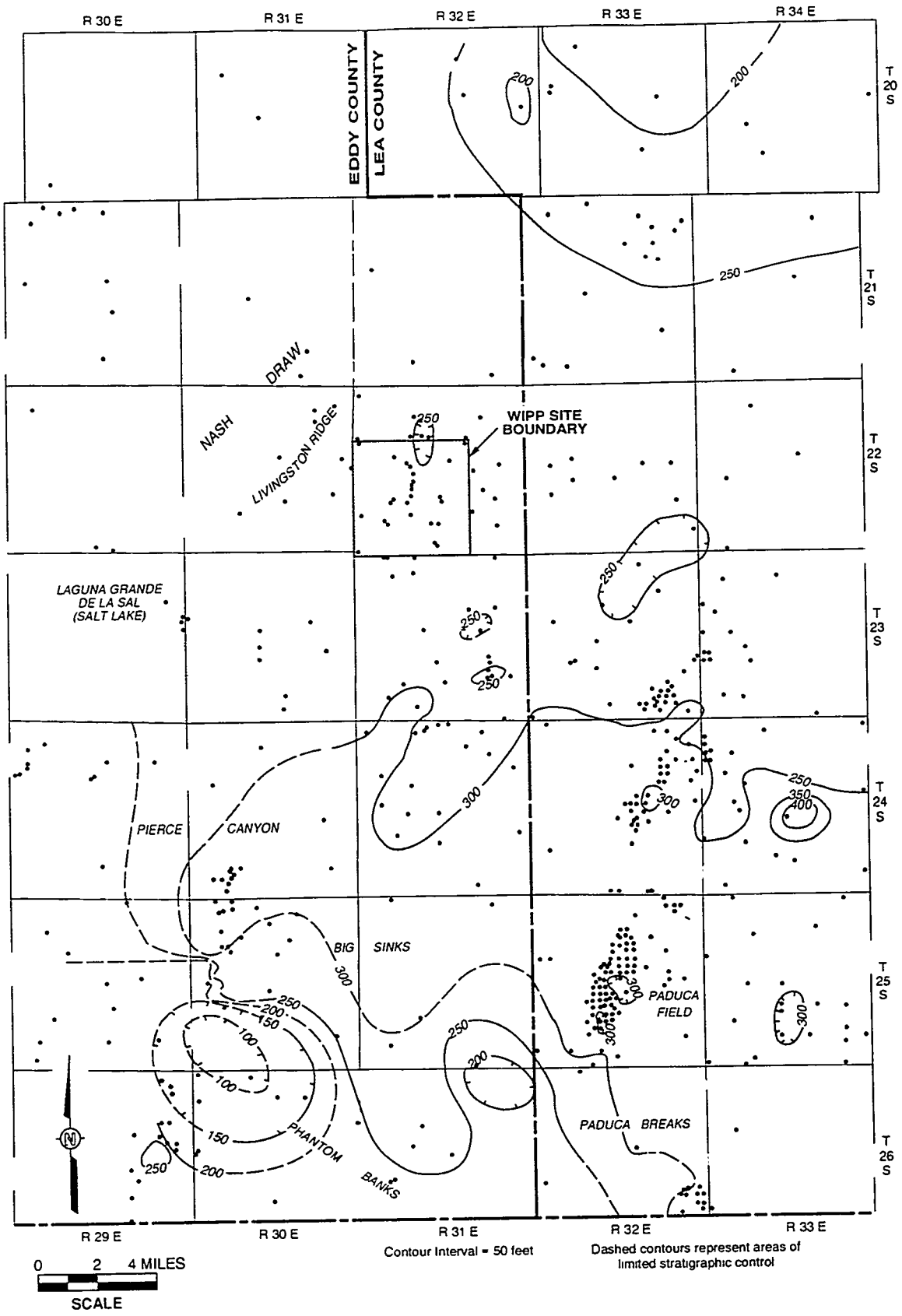


Figure D6-24
Isopach from the Base of MB 123/124 to the Base of the Vaca Triste

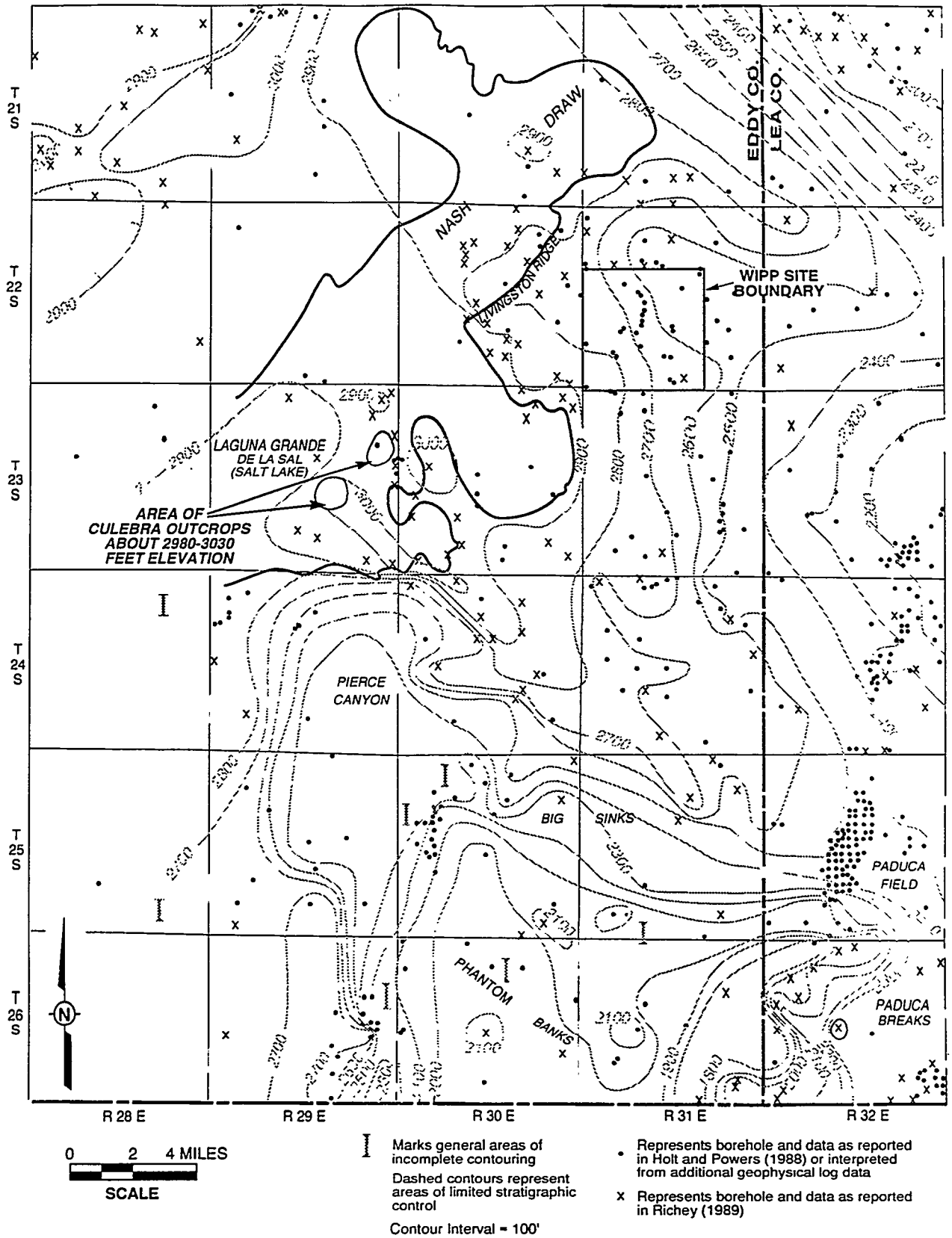


Figure D6-25
Structure Contour Map of Culebra Dolomite Base

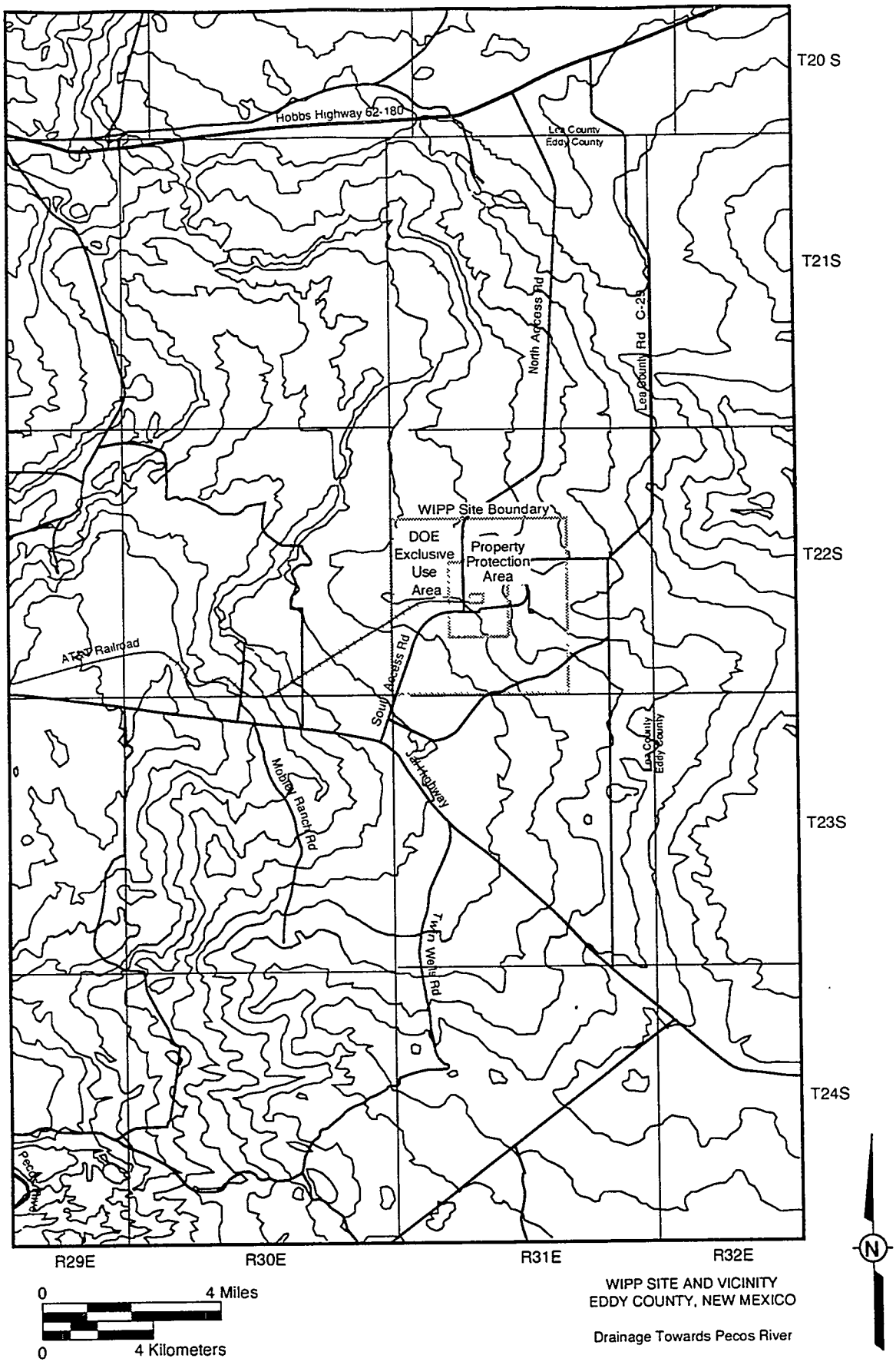


Figure D6-26
Drainage Pattern in the Vicinity of the WIPP Facility

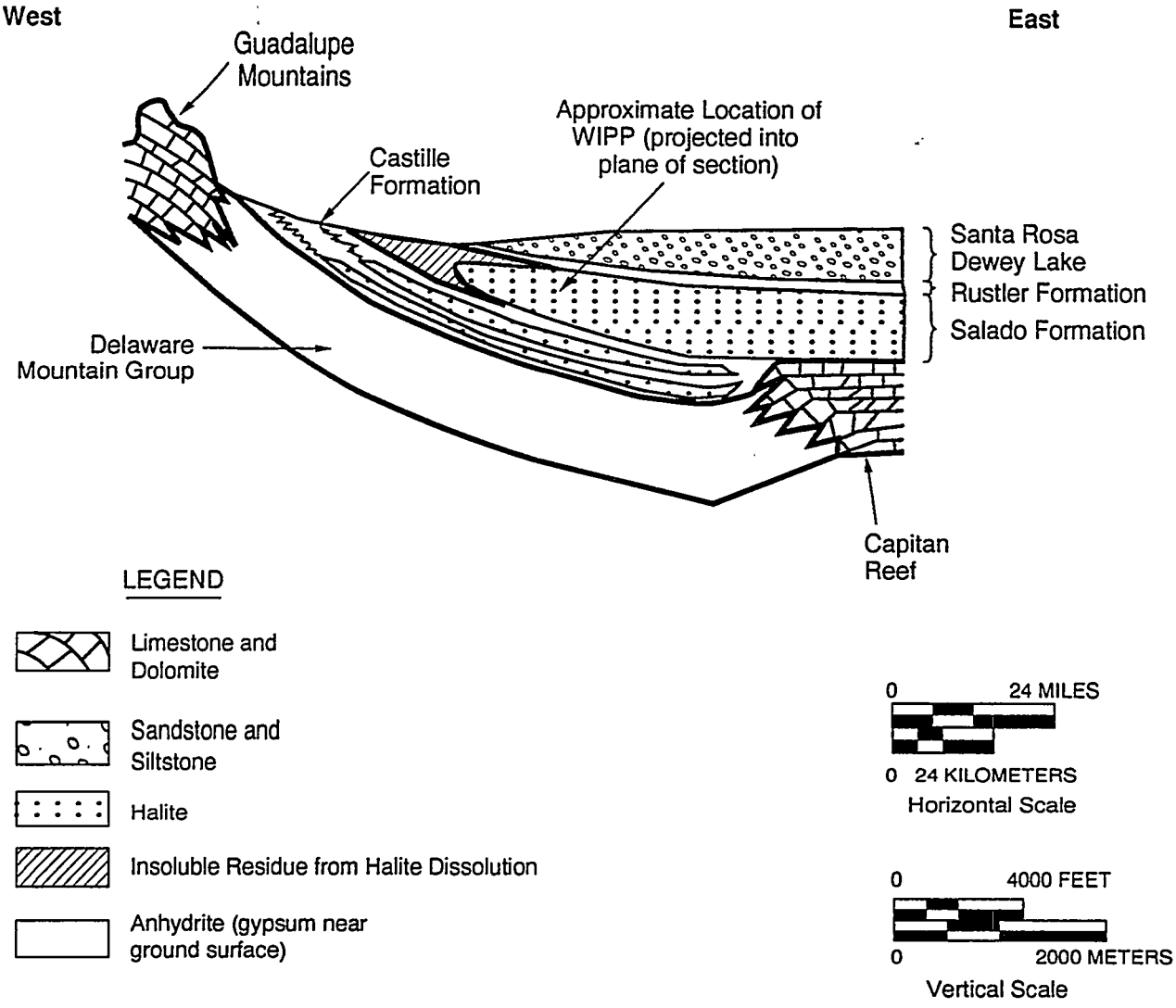


Figure D6-27
Schematic West-East Cross-Section through the North Delaware Basin

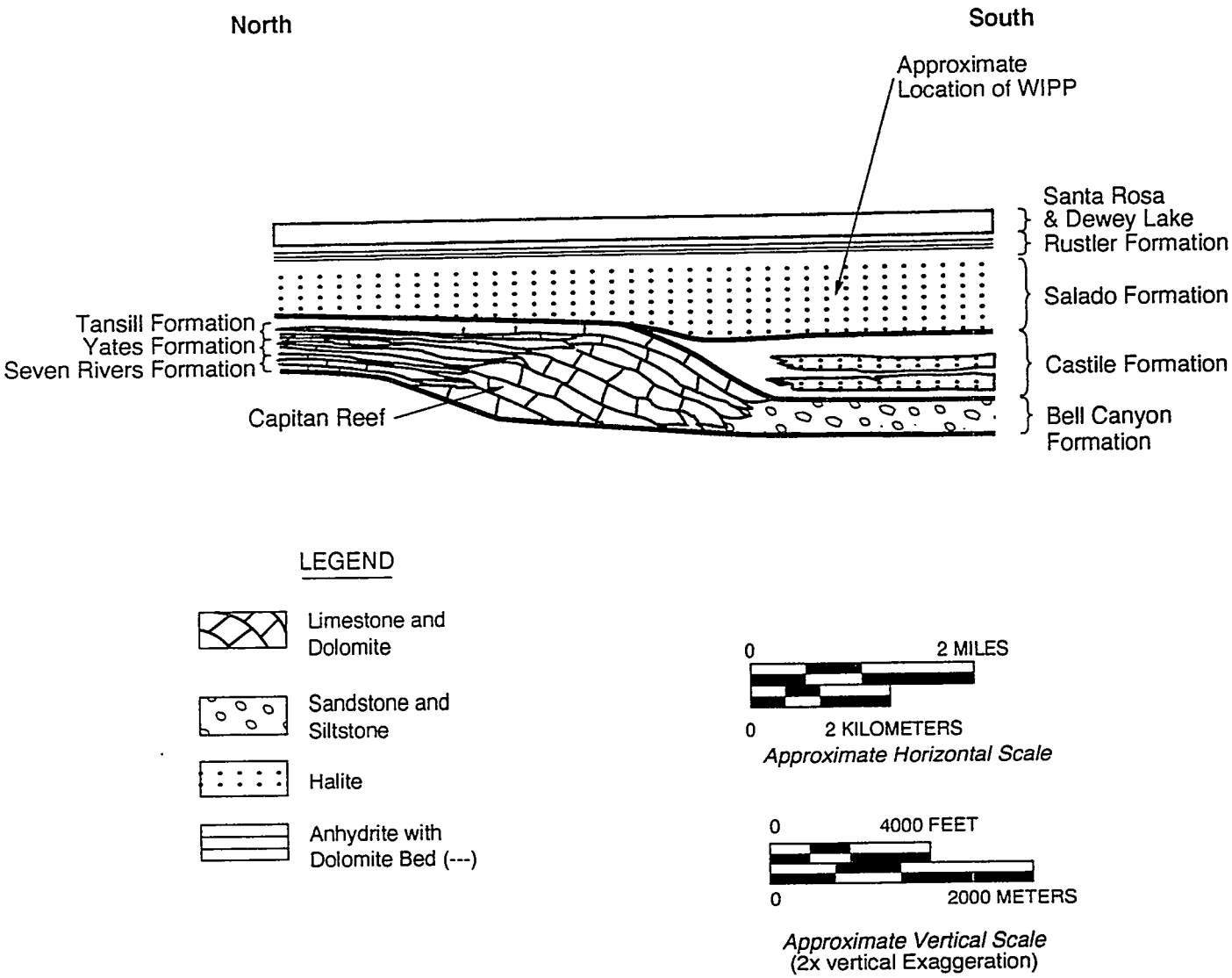


Figure D6-28
Schematic North-South Cross-Section through the North Delaware Basin

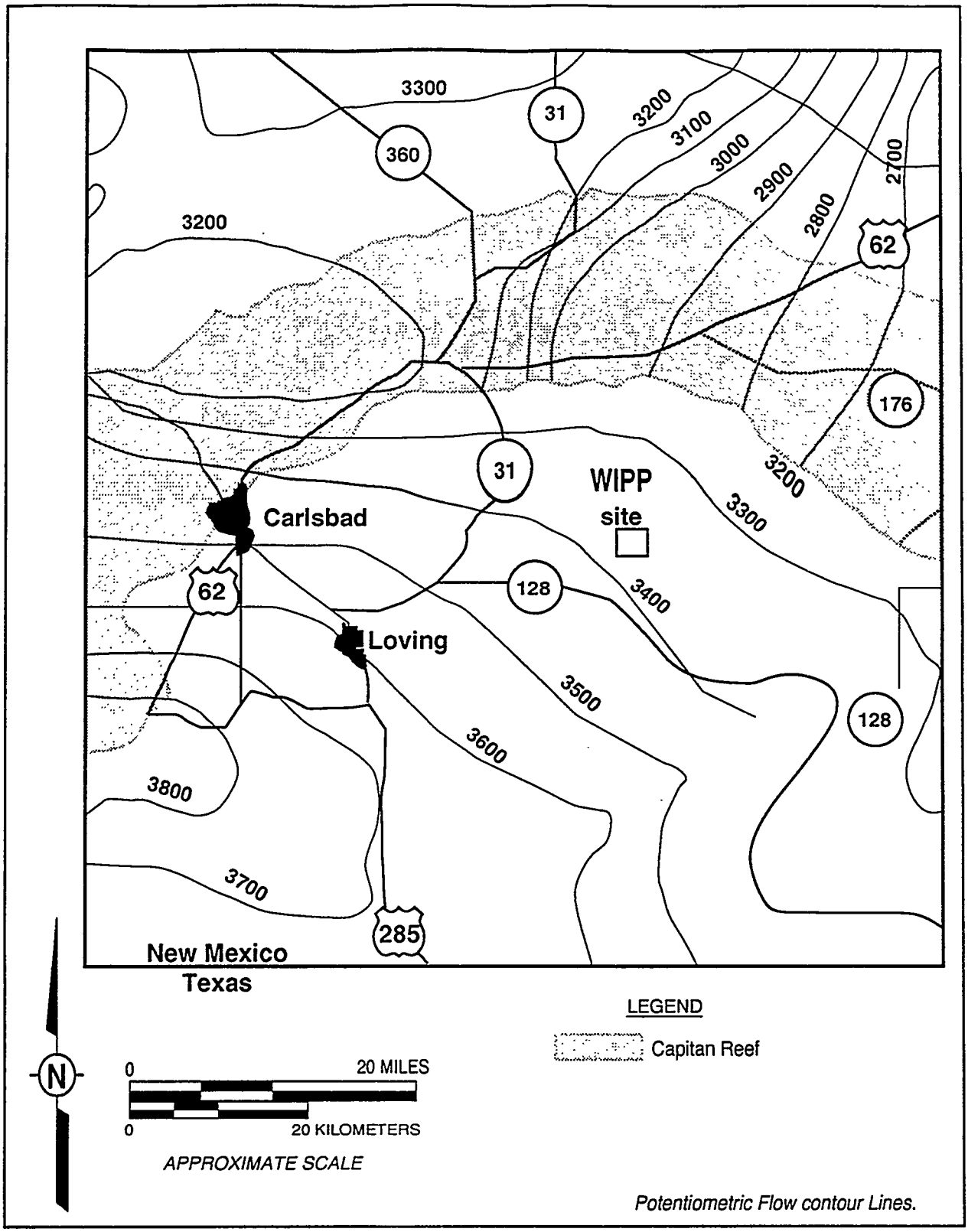


Figure D6-29
Potentiometric Surface Map (composite) of the Delaware Mountain Group and Capitan Aquifer

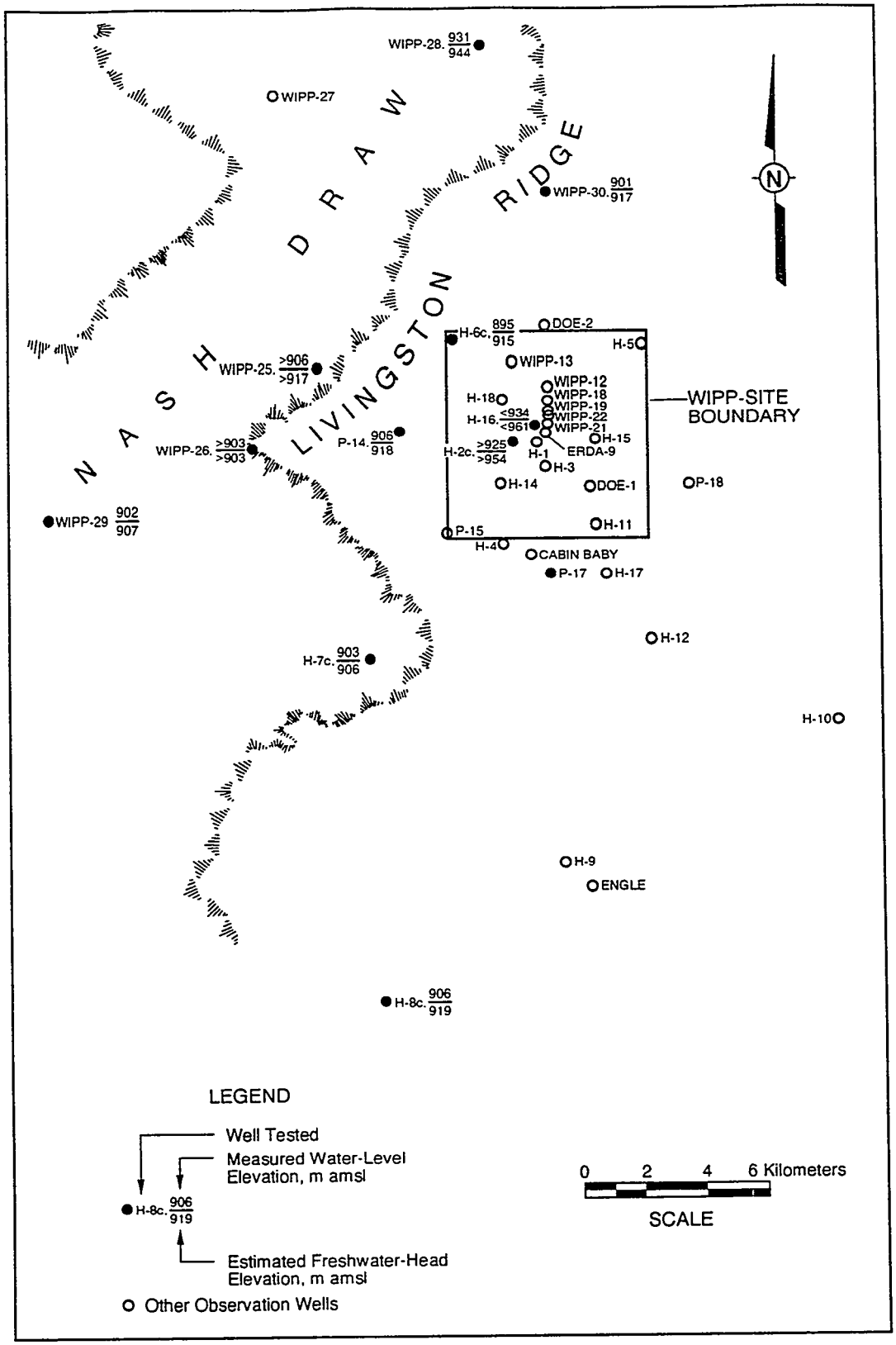


Figure D6-30
Measured Water Levels and Estimated Freshwater Heads of the Unnamed Lower Member and Rustler-Salado Contact Zone.

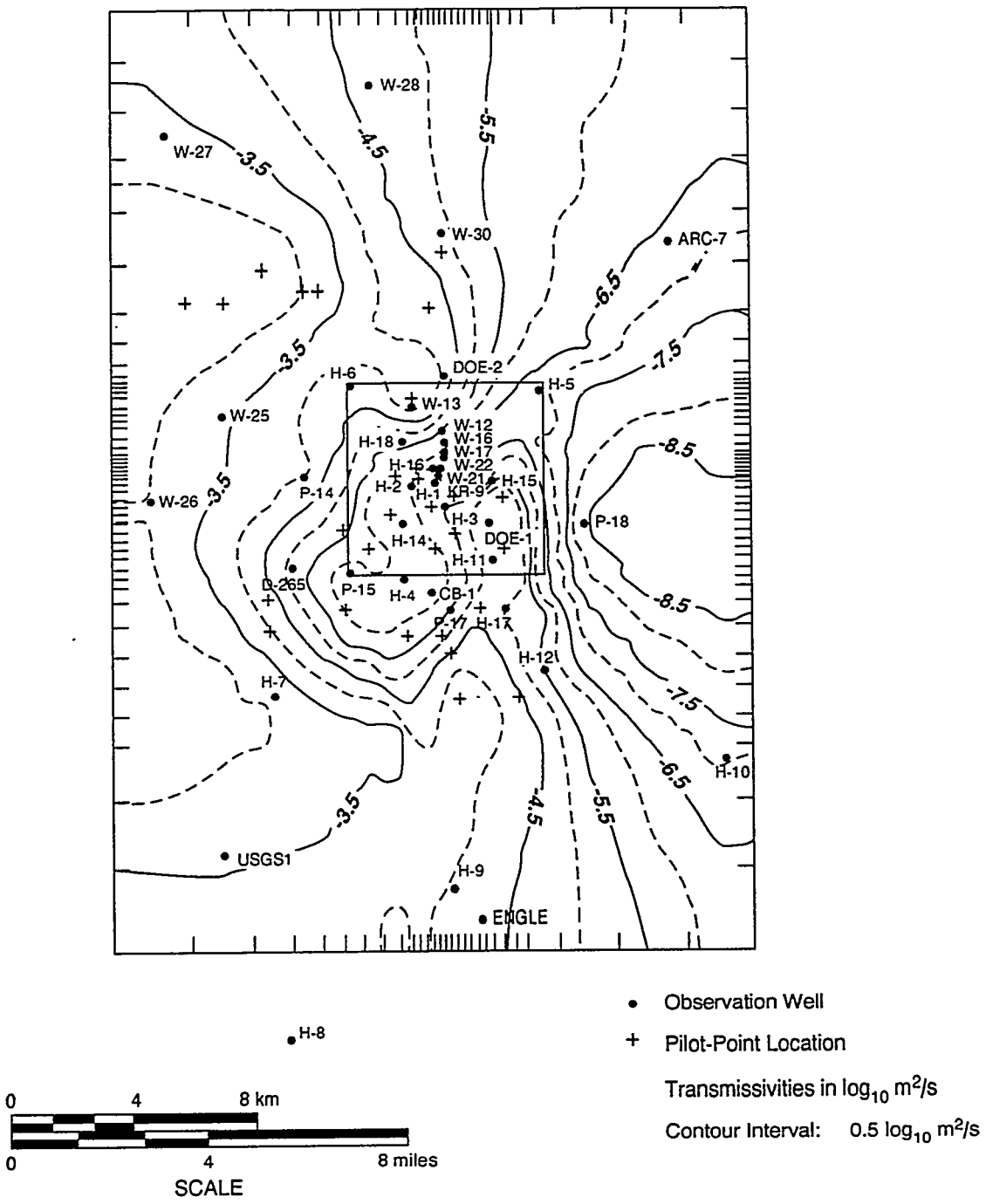


Figure D6-31

The Transient Calibrated Log_{10} Transmissivities

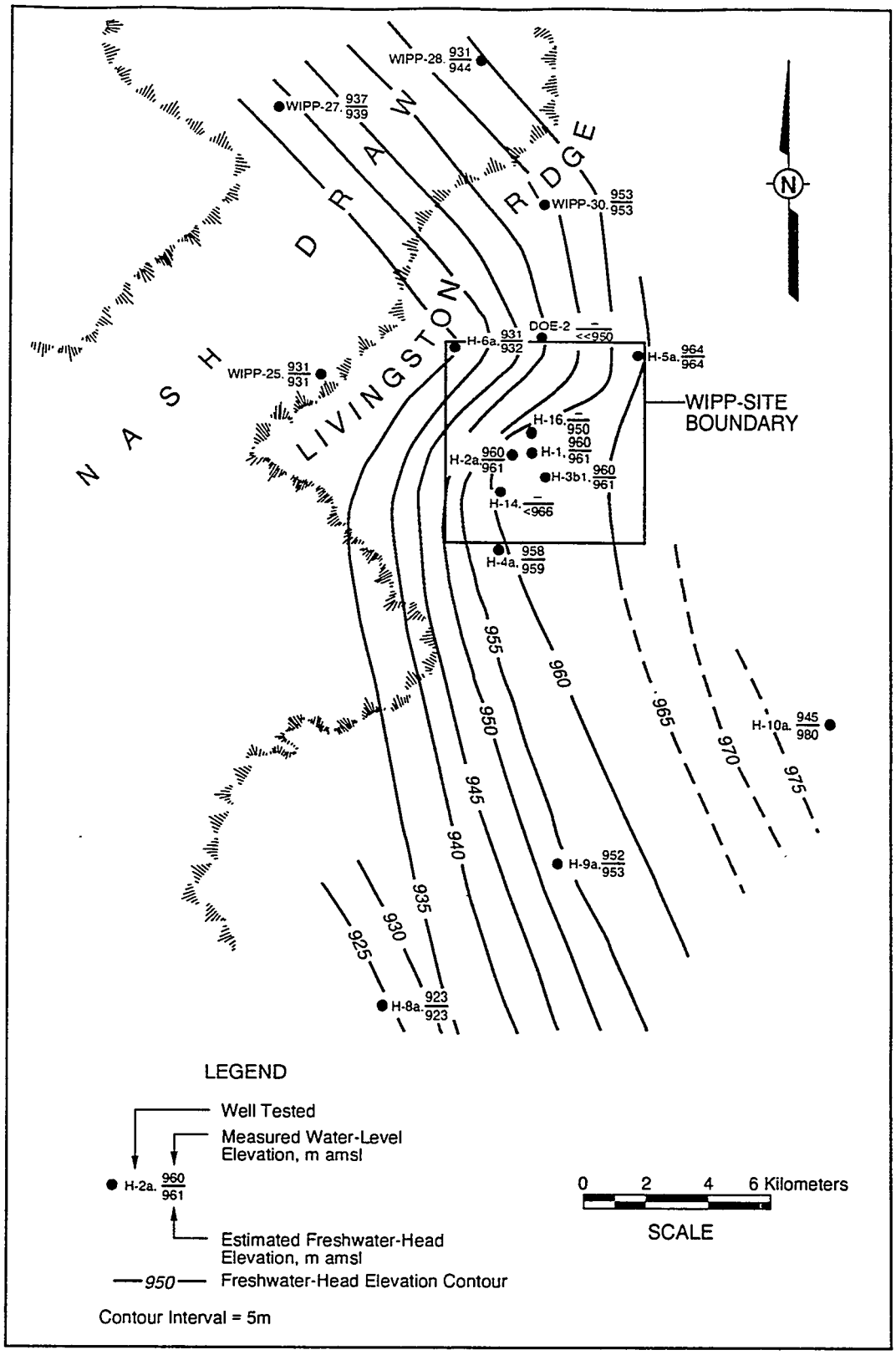


Figure D6-32
Water Levels and Estimated Freshwater Heads in the Magenta (Holt et al. 1989)

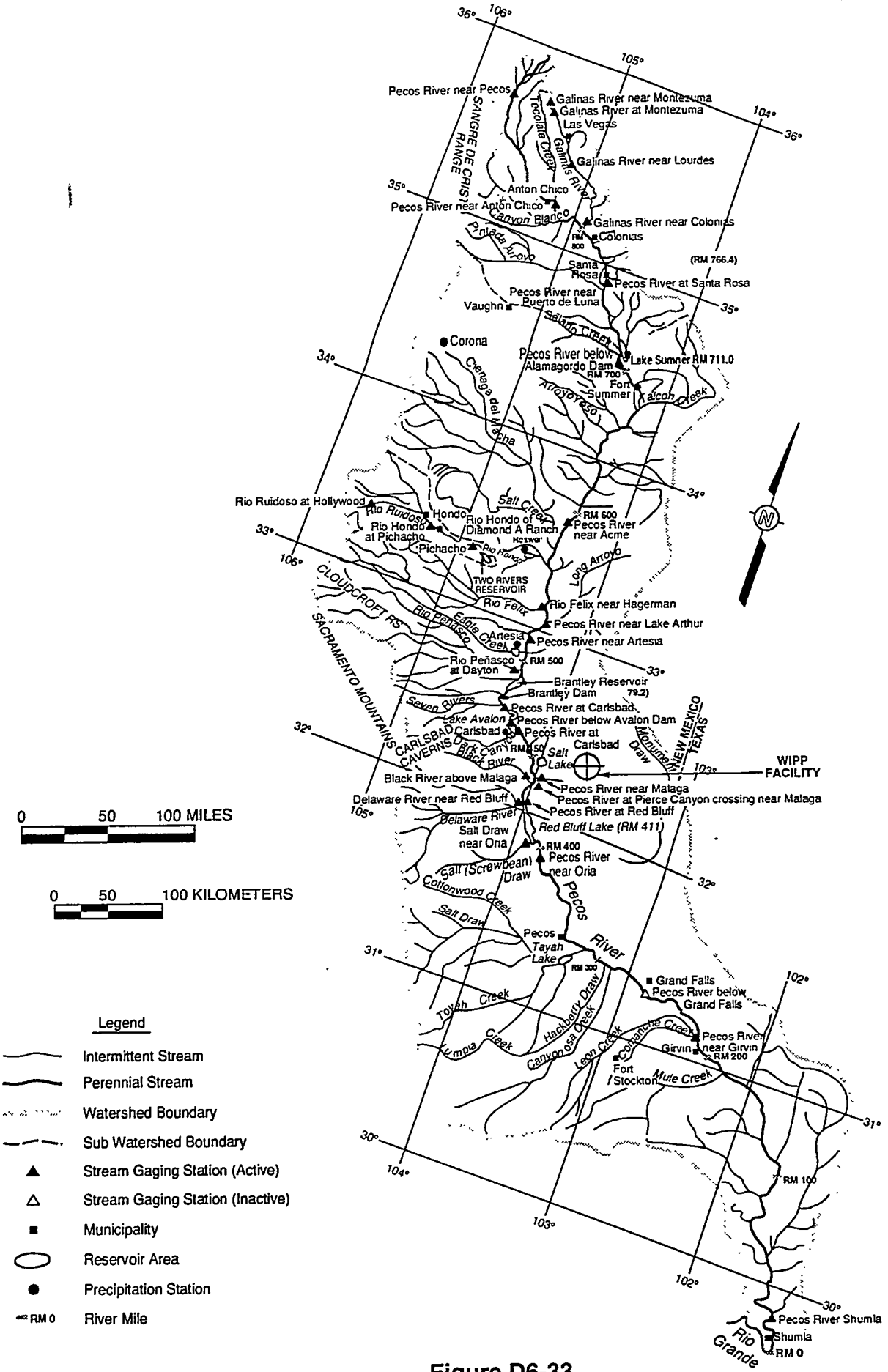


Figure D6-33

Location of Reservoirs and Gauging Stations in the Pecos River Basin

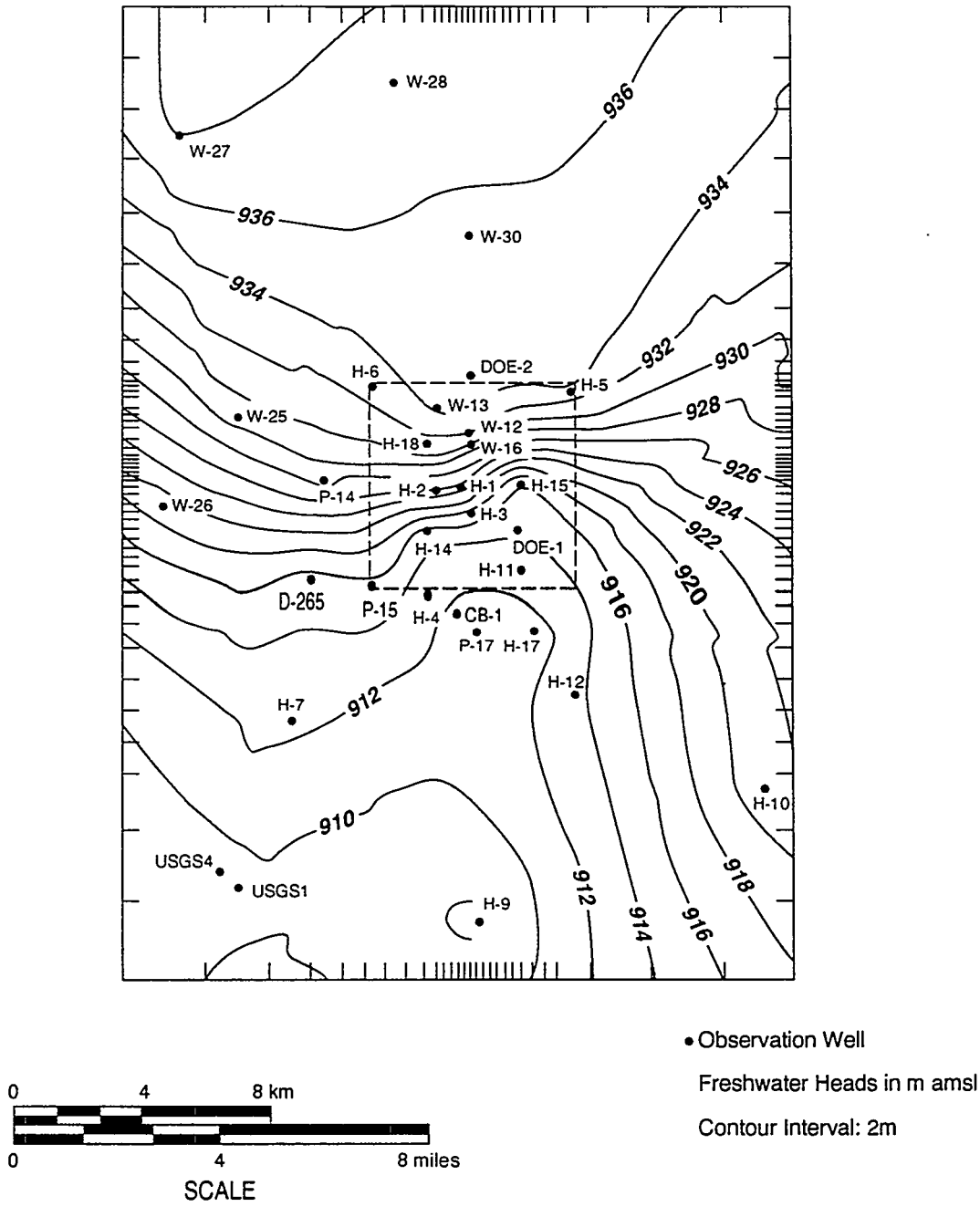


Figure D6-34
Culebra Freshwater-Head Contour Surface

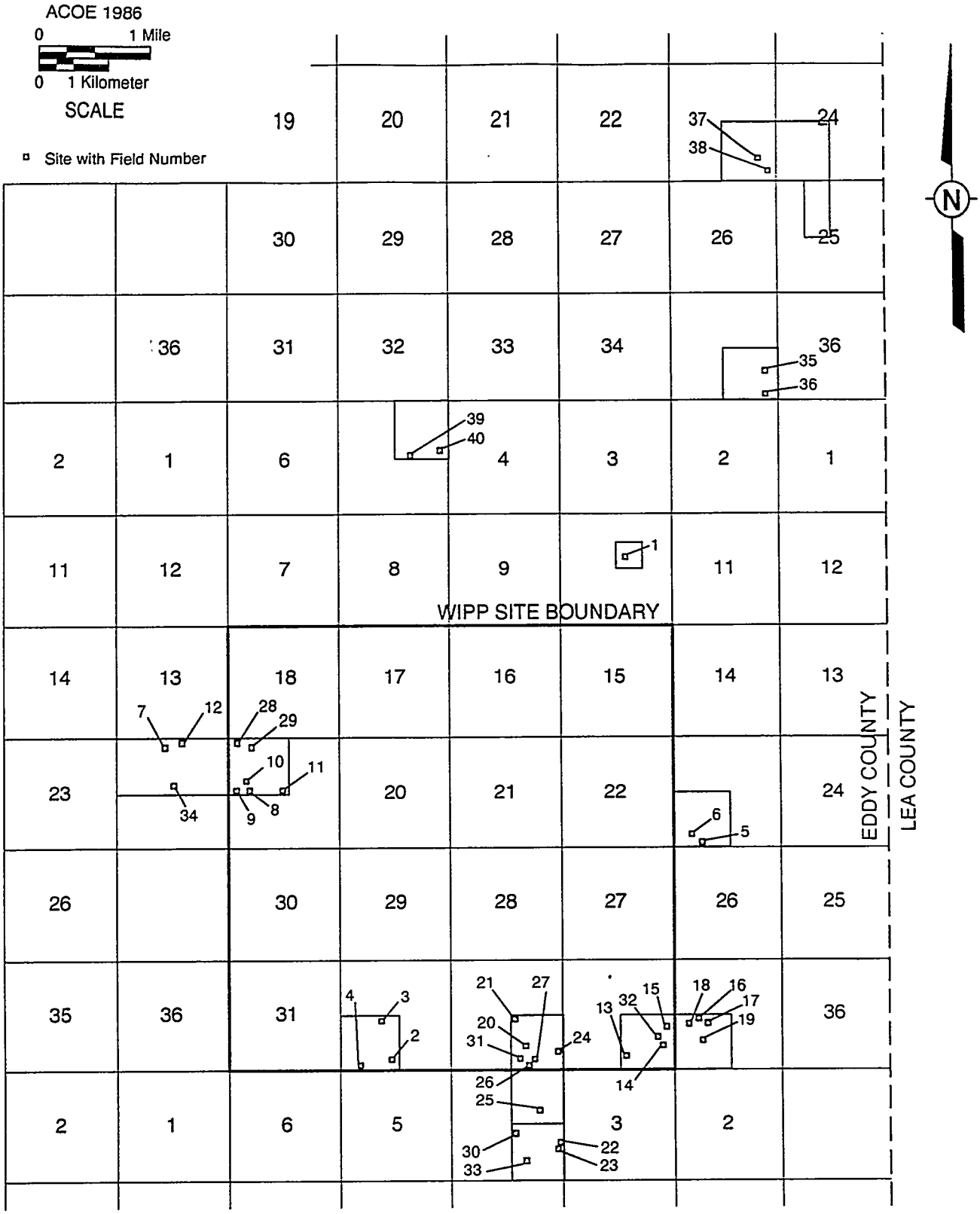
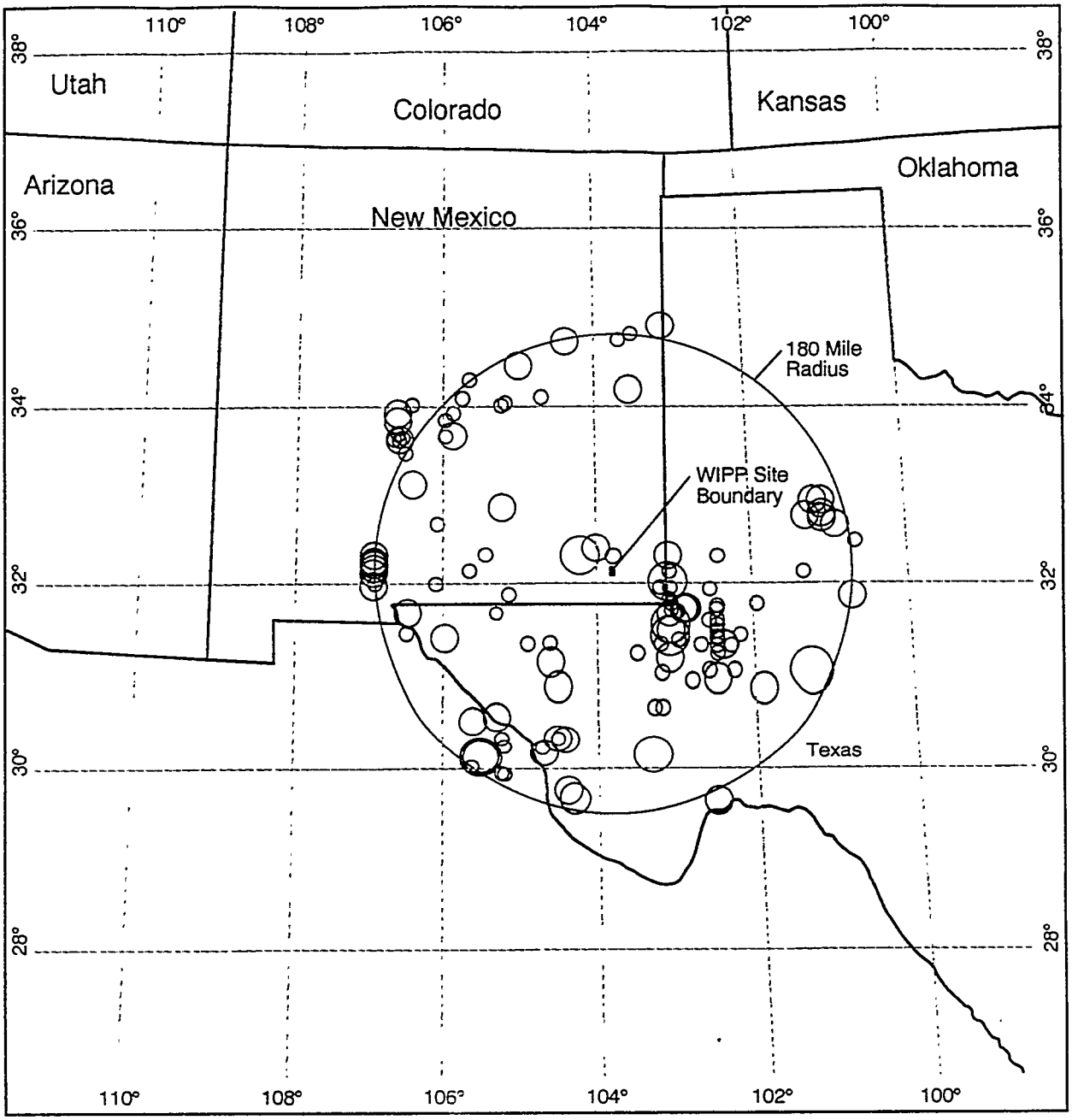
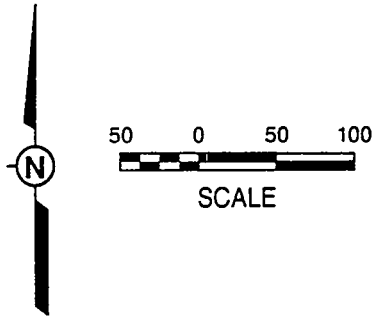


Figure D6-35
Mariah Study Archaeological Sites





Notes:
Locations of earthquakes within 180 miles of the WIPP Site. Epicenters were determined instrumentally and cover the period from 1962 through 1995. For drafting clarity, no earthquake with a magnitude less than 2.0 is shown. In areas where crowding occurs some epicenters are slightly offset for drafting convenience.

Magnitude
>3.5
2.5-3.5
>2.5

Figure D6-36
Regional Earthquake Epicenters Occurring after 1961

APPENDIX D6

WASTE ISOLATION PILOT PLANT
RCRA PART B PERMIT APPLICATION
Subappendix BH

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BOREHOLE DATA

for

SOUTHEASTERN NEW MEXICO

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VALIDATION OF THE BOREHOLE DATA FOR SOUTHEASTERN NEW MEXICO

This data base was prepared by Stoller, Robin Strickland Robin Strickland

This data base was validated by Stoller, Jim Waters Jim Waters

This data base was validated by Merrick, James Ward James Ward

Dated: 02/28/95

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COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-374
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0359163

LOCATION: 424' North 45 degrees West from S1/4
Corner of Section 30, SW1//4 Section 30,
Township 22 South, Range 31 East. NMPM

ELEVATION: 3340'
TOTAL DEPTH: 1538'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 04/15/65 **Date Completed:** 04/27/65
Rotary Drill
6-1/4" Rockbit: 0-714'
3-7/8" Rockbit: 714-1149'
3-7/8" Corebit: 1149-1538'

CASING RECORD: 4" Casing: 0-714'
Recovered: 0-437'

PLUGGING SCHEDULE:
From: 1538'
To: 714'
Int: 824'
Material: Cement

From: 714'
To: 470'
Int: 244'
Material: Cement

From: 470'
To: 20'
Int: 450'
Material: Mud

From: 20'
To: 0'
Int: 20'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 360'
Top of Salt: 690'
Top of USGS 124 Bed: 1399'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	I-375
OPERATOR:	International Minerals & Chemical Corp.
PERMIT NO.:	Potassium Prospecting Permit NM-0359161
LOCATION:	144' South 24 degrees East from Northwest Corner of Section 33, NW1/4 Section 33, Township 22 South, Range 31 East. NMPM
ELEVATION:	3390'
TOTAL DEPTH:	1746'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company
DRILLING RECORD:	**Date Started:** 04/28/65 **Date Completed:** 05/13/65 Rotary Drill 6-1/4" Rockbit: 0-520' 3-7/8" Rockbit: 520-1300' 3-7/8" Corebit: 1300-1746'
CASING RECORD:	4" Casing: 0-817' Recovered: 0-129'
PLUGGING SCHEDULE:	From: 1746' To: 817' Int: 929' Material: Cement From: 817' To: 510' Int: 307' Material: Cement From: 510' To: 20' Int: 490' Material: Mud From: 20' To: 0' Int: 20' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 470' Top of Salt: 790' Top of USGS 124 Bed: 1602'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-376
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384583

LOCATION: 400' South 75 degrees East from Northwest Corner of Section 20, NW1/4 Section 20, Township 22 South, Range 31 East. NMPM

ELEVATION: 3410'
TOTAL DEPTH: 1702'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 06/15/65 **Date Completed:** 06/23/65
Rotary Drill
6-1/4" Rockbit: 0-840'
3-7/8" Rockbit: 840-1328'
3-7/8" Corebit: 1328-1702'

CASING RECORD: 4" Casing: 0-840'
Recovered: 0-840'

PLUGGING SCHEDULE:
From: 1702'
To: 800'
Int: 902'
Material: Cement

From: 800'
To: 720'
Int: 80'
Material: Mud

From: 720'
To: 660'
Int: 60'
Material: Cement

From: 660'
To: 540'
Int: 120'
Material: Mud

From: 540'
To: 480'
Int: 60'
Material: Cement

From: 480'
To: 30'
Int: 450'
Material: Mud

From: 30'
To: 0'
Int: 30'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 500'
Top of Salt: 840'

Top of USGS 124 Bed: 1581'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-377
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 105' South 48 degrees East from Northwest Corner of Section 22, NW1/4 Section 22, Township 22 South, Range 31 East. NMPM

ELEVATION: 3490'
TOTAL DEPTH: 1876'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Co.

DRILLING RECORD: **Date Started:** 06/26/65 **Date Completed:** 07/16/65
Rotary Drill
6-1/4" Rockbit: 0-996'
3-7/8" Rockbit: 996-1530'

CASING RECORD: 4" Casing: 0-996'
Recovered: 0-996'

PLUGGING SCHEDULE:

From: 1876'
To: 996'
Int: 880'
Material: Cement

From: 996'
To: 925'
Int: 71'
Material: Mud

From: 925'
To: 885'
Int: 40'
Material: Cement

From: 885'
To: 730'
Int: 155'
Material: Mud

From: 730'
To: 700'
Int: 30'
Material: Cement

From: 700'
To: 10'
Int: 690'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 700'
Top of Salt: 1014'
Top of USGS 124 Bed: 1770'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	I-383
OPERATOR:	International Minerals & Chemical Corp.
PERMIT NO.:	Potassium Prospecting Permit NM-0359160
LOCATION:	287' South 52 degrees East from W1/4 Corner of Section 1, SW1/4 Section 1, Township 23 South, Range 30 East. NMPM
ELEVATION:	3272'
TOTAL DEPTH:	1307'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company
DRILLING RECORD:	**Date Started:** 07/19/65 **Date Completed:** 08/26/65 Rotary Drill 6-1/4" Rockbit: 0-481' 3-7/8" Rockbit: 481-1000' 3-7/8" Corebit: 1000-1307'
CASING RECORD:	4" Casing: 0-481' Recovered: 0-105'
PLUGGING SCHEDULE:	From: 1307' To: 481' Int: 826' Material: Cement From: 481' To: 320' Int: 161' Material: Cement From: 320' To: 210' Int: 110' Material: Mud From: 210' To: 150' Int: 60' Material: Cement From: 150' To: 15' Int: 135' Material: Mud From: 15' To: 0' Int: 15' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 160' Top of Salt: 475' Top of USGS 124 Bed: 1211'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	I-456
OPERATOR:	International Minerals & Chemical Corp.
PERMIT NO.:	Potassium Prospecting Permit NM-0384584
LOCATION:	300' from South Line and 2650' from East Line of Section 22, SW1/4 Section 22, Township 22 South, Range 31 East. NMPM
ELEVATION:	3520'
TOTAL DEPTH:	1975'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company
DRILLING RECORD:	**Date Started:** 06/22/76 **Date Completed:** 07/07/76 Rotary Drill 6-1/4" Rockbit: 0-940' 3-7/8" Rockbit: 940-1580' 3-7/8" Corebit: 1580-1975'
CASING RECORD:	4" Casing: Unknown Recovered: All
PLUGGING SCHEDULE:	From: 1975' To: 0' Int: 1975' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 790' Top of Salt: 1080' Top of USGS 124 Bed: 1853'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	I-457
OPERATOR:	International Minerals & Chemical Corp.
PERMIT NO.:	Potassium Prospecting Permit NM-0384584
LOCATION:	200' from South Line and 1200' from West Line of Section 27, SW1/4 Section 27 Township 22 South, Range 31 East. NMPM
ELEVATION:	3460'
TOTAL DEPTH:	1885'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company
DRILLING RECORD:	**Date Started:** 07/08/76 **Date Completed:** 07/22/76 Rotary Drill 6-1/4" Rockbit: 0-940' 3-7/8" Rockbit: 940-1480' 3-7/8" Corebit: 1480-1885'
CASING RECORD:	4" Casing: 0-980' Recovered: 0-980'
PLUGGING SCHEDULE:	From: 1885' To: 0' Int: 1885' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 660' Top of Salt: 980' Top of USGS 124 Bed: 1777'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	I-458
OPERATOR:	International Minerals & Chemical Corp.
PERMIT NO.:	Potassium Prospecting Permit NM-0384584
LOCATION:	2500' from North Line and 400' from East Line of Section 4, NE1/4 Section 4, Township 23 South, Range 31 East. NMPM
ELEVATION:	3410'
TOTAL DEPTH:	1750'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company
DRILLING RECORD:	**Date Started:** 07/23/76 **Date Completed:** 08/09/76 Rotary Drill 6-1/4" Rockbit: 0-960' 3-7/8" Rockbit: 960-1385' 3-7/8" Corebit: 1385-1750'
CASING RECORD:	4" Casing: Unknown Recovered: All
PLUGGING SCHEDULE:	From: 1750' To: 0' Int: 1750' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 580' Top of Salt: 970' Top of USGS 124 Bed: 1623'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	**I-459**
OPERATOR:	International Minerals & Chemical Corp.
PERMIT NO.:	Potassium Prospecting Permit NM-0384584
LOCATION:	2500' from North Line and 2000' from East Line of Section 3, NE1/4 Section 3, Township 23 South, Range 31 East. NMPM
ELEVATION:	3385'
TOTAL DEPTH:	1855'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company
DRILLING RECORD:	**Date Started:** 08/11/76 **Date Completed:** 08/24/76 Rotary Drill 6-1/4" Rockbit: 0-900' 3-7/8" Rockbit: 900-1330' 3-7/8" Corebit: 1330-1855'
CASING RECORD:	4" Casing: Unknown Recovered: All
PLUGGING SCHEDULE:	From: 1855' To: 0' Int: 1885' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 580' Top of Salt: 940' Top of USGS 124 Bed: 1739'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: NFU-1
OPERATOR: Farmers Educational and Cooperative Union of America
PERMIT NO.: Potassium Prospecting Permit NM-065503

LOCATION: 100' from North Line and 100' from West
Line of Section 9, NW1/4 Section 9,
Township 22 South, Range 31 East. NMPM

ELEVATION: 3422'
TOTAL DEPTH: 1747'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 12/19/50 **Date Completed:** 01/21/51
Rotary Drill
6-1/4" Rockbit: 0-944'

CASING RECORD: 4" Casing: 940'
Recovered: 675'

PLUGGING SCHEDULE: 4 sacks cement at 1640'
7 sacks cement at 955'
7 sacks cement at 840'
8 sacks cement at 740'

Could not pull 4" casing, but broke circulation around it before pumping in 7 sacks at 955'. Shot casing at 900', 700', and 675'. Recovered 675' of 940'. Filled hole with mud and placed 4" pipe marker.

STRATIGRAPHIC SUMMARY: Rustler Formation: 635'
Top of Salt: 935'
Base of USGS 124 Bed: 1641'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	FC-70
OPERATOR:	Farm Chemical Resources Development Corporation
PERMIT NO.:	Potassium Prospecting Permit LC-065506
LOCATION:	177' from South Line and 177' from West Line of Section 7, NE1/4 Section 7, Township 22 South, Range 31 East. NMPM
ELEVATION:	3388'
TOTAL DEPTH:	1603'
TYPE OF WELL:	Potash Core Test
DRILLER:	Joy Mfg. Company, Drilling Division
DRILLING RECORD:	**Date Started:** 09/26/56 **Date Completed:** 10/09/56 Rotary Drill 6-1/4" Rockbit: 0-902' Corebit: 902-1603'
CASING RECORD:	4-1/2" Casing: 902' Recovered: 902'
PLUGGING SCHEDULE:	From: 1603' To: 1370' Int: 233' Material: Brine & Salt From: 1370' To: 902' Int: 468' Material: Cement From: 902' To: 10' Int: 892' Material: Mud From: 10' To: 0' Int: 10' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 541' Top of Salt: 898' USGS 124 Bed: 1515'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-82
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-057290

LOCATION: 154' from South Line and 37' from West Line of Section 8, Township 22 South, Range 31 East. NMPM

ELEVATION: 3382'
TOTAL DEPTH: 1684'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/21/61 **Date Completed:** 10/03/61
6-1/4" Rockbit: 0-922'
Corebit: 922-1684'

CASING RECORD: 5-1/2" Casing: 922'
Recovered: 922'

PLUGGING SCHEDULE:

From: 1684'
To: 922'
Int: 762'
Material: Cement

From: 922'
To: 710'
Int: 212'
Material: Brine & Salt

From: 710'
To: 510'
Int: 200'
Material: Cement

From: 510'
To: 10'
Int: 500'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 538'
Top of Salt: 910'
USGS 124 Bed: 1593'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	FC-91
OPERATOR:	Farm Chemical Resources Development Corporation
PERMIT NO.:	Potassium Prospecting Permit NM-075014
LOCATION:	200' from South Line and 200' from West Line of Section 10, SW1/4, Township 22 South, Range 31 East. NMPM
ELEVATION:	3460'
TOTAL DEPTH:	1788'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 04/07/62 **Date Completed:** 04/17/62 Rotary Drill Rockbit: 0-1070' Corebit: 1070-1788'
CASING RECORD:	4-1/4" Casing: 1070' Recovered: 1070'
PLUGGING SCHEDULE:	From: 1788' To: 1060' Int: 728' Material: Cement From: 1060' To: 840' Int: 220' Material: Cuttings & Brine From: 840' To: 800' Int: 40' Material: Cement From: 800' To: 10' Int: 790' Material: Cuttings & Brine From: 10' To: 0' Int: 10' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 630' Top of Salt: 1070' Base of USGS 124 Bed: Unknown

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-92
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-094314

LOCATION: 200' from South Line and 200' from East Line of Section 8, SE1/4, Township 22 South, Range 31 East. NMPM

ELEVATION: 3420'
TOTAL DEPTH: 1818'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/21/62 **Date Completed:** 05/03/62
Rockbit: 0-1058'
Corebit: 1058-1818'

CASING RECORD: 4-1/2" Casing: 1058'
Recovered: 1058'

PLUGGING SCHEDULE:
From: 1818'
To: 945'
Int: 873'
Material: Cement

From: 945'
To: 850'
Int: 95'
Material: Cuttings & Brine

From: 850'
To: 810'
Int: 40'
Material: Cement

From: 810'
To: 10'
Int: 800'
Material: Cuttings & Brine

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: Unknown
Top of Salt: 950'
Base of USGS 124 Bed: Unknown

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	D-104
OPERATOR:	Duval Sulphur & Potash Company
PERMIT NO.:	Potassium Prospecting Permit PPP-058761
LOCATION:	2585' from North Line and 1394' from East Line of Section 24, NE1/4 Section 24, Township 22 South, Range 30 East. NMPM
ELEVATION:	3388'
TOTAL DEPTH:	1597'
TYPE OF WELL:	Potash Core Test
DRILLER:	Weaver Drilling Company
DRILLING RECORD:	**Date Started:** 09/25/52 **Date Completed:** 10/07/52 Rotary Drill 6-1/4" Rockbit: 0-759' Corebit: 759-1597' Lost Circulation: 730-747'
CASING RECORD:	4" Casing: Unknown Recovered: All
PLUGGING SCHEDULE:	All casing was pulled and the following plugs run: 1) 62 sacks mixed with brine and 3% CaCl^2 at bottom of hole. 2) 30 sacks mixed with fresh water bottomed at 660'. The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.
STRATIGRAPHIC SUMMARY:	Rustler Formation: 520' Top of Salt: 759' Top of USGS 124 Bed: 1504'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-120
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit PPP-058761

LOCATION: 1562' South and 1565' East of NW Corner
Section 13, NW1/4 Section 13, Township 22
South, Range 30 East. NMPM

ELEVATION: 3338'
TOTAL DEPTH: 1500'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 02/14/53 **Date Completed:** 02/27/53
Rotary Drill
6-1/4" Rockbit: 0-704'
3-13/16" Corebit: 704-1500'

CASING RECORD: 4" Casing: 704'
Recovered: 704'

PLUGGING SCHEDULE: All casing was pulled and the following plugs run:
1) 62 sacks of cement mixed with brine and 3% CaCl^2 and brine at bottom of hole.
2) 30 sacks of cement mixed with fresh water bottomed at 590'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 330'
Top of Salt: 684'
Top of USGS 124 Bed: 1407'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	D-123
OPERATOR:	Duval Sulphur & Potash Company
PERMIT NO.:	Potassium Prospecting Permit LC-066112
LOCATION:	2614' North and 277' West of Southeast Corner of Section 34, NE1/4 Section 34, Township 22 South, Range 31 East. NMPM
ELEVATION:	3432'
TOTAL DEPTH:	1880'
TYPE OF WELL:	Potash Core Test
DRILLER:	Weaver Drilling Company
DRILLING RECORD:	**Date Started:** 07/19/53 **Date Completed:** 08/07/53 Rotary Drill 6-1/4" Rockbit: 0-934' Corebit: 934-1880'
CASING RECORD:	4" Casing: 934' Recovered: 692'
PLUGGING SCHEDULE:	Shot casing at 910' and 850'. Pulled 692' leaving 242' in hole. The following cement plugs were run: 1) 73 sacks of cement mixed with 3% CaCl^2 and brine at bottom of hole. 2) 45 sacks of cement mixed with fresh water bottomed at 880'. The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.
STRATIGRAPHIC SUMMARY:	Rustler Formation: 670' Top of Salt: 988' Top of USGS 124 Bed: 1779'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	**D-160**
OPERATOR:	Duval Sulphur & Potash Company
PERMIT NO.:	Potassium Prospecting Permit M-2618
LOCATION:	2464' from South Line and 1117' from West Line of Section 36, SW1/4 Section 36, Township 22 South, Range 30 East. NMPM
ELEVATION:	3305'
TOTAL DEPTH:	1354'
TYPE OF WELL:	Potash Core Test
DRILLER:	Weaver Drilling Company
DRILLING RECORD:	**Date Started:** 07/21/54 **Date Completed:** 07/31/54 Rotary Drill 6-1/4" Rockbit: 0-596' Corebit: 596-1354' Encountering an air blow at 860' causing seat to leak.
CASING RECORD:	4" Casing: 596' Recovered: 596'
PLUGGING SCHEDULE:	All casing was pulled and the following plugs run: 1) 58 sacks of cement mixed with brine and 3% CaCl^2 and brine at bottom of hole. 2) 37 sacks of cement mixed with fresh water bottomed at 445'. The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.
STRATIGRAPHIC SUMMARY:	Rustler Formation: 240' Top of Salt: 543' Top of USGS 124 Bed: 1301'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	D-207
OPERATOR:	Duval Sulphur & Potash Company
PERMIT NO.:	Potassium Prospecting Permit NM-08285
LOCATION:	1480' North and 1330' East of Southwest Corner of Section 19, SW1/4 Section 19 Township 22 South, Range 31 East. NMPM
ELEVATION:	3406'
TOTAL DEPTH:	1613'
TYPE OF WELL:	Potash Core Test
DRILLER:	Joy Drilling Company
DRILLING RECORD:	**Date Started:** 06/16/58 **Date Completed:** 07/03/58 Rotary Drill 6-1/4" Rockbit: 0-811' 3-13/16" Corebit: 811-1613'
CASING RECORD:	4" Casing: 811' Recovered: 811'
PLUGGING SCHEDULE:	All casing was pulled and the following cement plugs were run: 1) 66 sacks of cement mixed with 3% CaCl^2 and brine at bottom of hole. 2) 25 sacks of cement mixed with fresh water bottomed at 560'. The remainder of the hole was filled with cuttings and soil, a four-foot marker post set, and the location left in good order.
STRATIGRAPHIC SUMMARY:	Rustler Formation: 330' Top of Salt: 811' Top of USGS 124 Bed: 1519'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-235
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit LC-062188

LOCATION: 2878' from South Line and 789' from West Line of Section 25, NW1/4 Section 25, Township 22 South, Range 30 East. NMPM

ELEVATION: 3336'
TOTAL DEPTH: 1506'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/11/77 **Date Completed:** 11/03/77
Rotary Drill
6-1/4" Rockbit: 0-689'
3-7/8" Corebit: 689-1506'
Encountering an air blow at 860'

CASING RECORD: 4" Casing: 689'
Recovered: 400'

PLUGGING SCHEDULE: 400' of 4" casing was pulled. Pennsylvania Drilling Company then cemented the hole with 110 sacks of neat cement making a continuous plug from T.D. to surface. A four-foot marker post was then set and drill location was left in good order.

STRATIGRAPHIC SUMMARY: Rustler Formation: Unknown
Top of Salt: 670'
Top of USGS 124 Bed: 1390'

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ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: AEC-7
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1323

LOCATION: 2036.97' FNL, 2033.23' FEL
Sec. 31, T 21 S, R 32 E

ELEVATION: 3657.25' (Top of Casing)
TOTAL DEPTH: 4734'
TYPE OF WELL: Geological Exploration
DRILLER: Verna Drilling Company

DRILLING RECORD: **Date Started:** 03/20/74 **Date Completed:** 04/19/80

CASING RECORD:
Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 40
Cement:

Diameter: 8 5/8
Grade: H-40
Wt/Ft: 28
From: 0
To: 1016
Cement:

PLUGGING SCHEDULE:
No plugging data. Testing still in progress.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-7	Quaternary	
	Holocene-Eolian Sand	16.2-20.2
	Mescalero Caliche	20.2-24.2
	Triassic	
	Santa Rosa Sandstone	24.2-133.0
	Permian	
	Dewey Lake Red Beds	133.0-675.0
	Rustler Formation	675.0-1000.6
	Magenta Dolomite Member	733.5-767.0
	Culebra Dolomite Member	872.2-900.5
	Salado Formation	1000.6-3014.7
	Upper Member	1000.6-1505.1
	MB 101	1125.8
	MB 102	1158.5
	MB 103	1171.4-1186.5
	MB 104	1197.0
	MB 105	1211.5
	MB 106	1230.5
	MB 107	1269.0
	MB 108	1278.0
	MB 109	1303.8-1324.5
	MB 111	1378.0
	MB 112	1397.5
	MB 114	1450.5
	MB 116	1498.4
	McNutt Potash Zone	1505.1-1881.0
	Vaca Triste Sandstone	1505.1-1514.1
	MB 117	1578.9
	MB 118	1595.6
	MB 119	1619.8
	MB 121	1661.5
	MB 122	1668.5
	Union Anhydrite	1696.2-1705.0
	MB 123	1774.8-1781.2
	MB 124	1785.5-1795.5
	MB 126	1881.0
	Lower Member	1881.0-3104.7
	MB 128	1918.0
	MB 129	1943.9
	MB 131	2013.5
	MB 132	2039.0
	MB 133	2057.5
	MB 134	2097.0-2109.0
	MB 136	2161.0-2168.0
	MB 139	2267.5
	MB 140	2302.8-2314.2
	MB 141	2364.5
	MB 142	2400.2-2406.5
	MB 143	2453.0-2455.6
	Cowden Anhydrite	2520.0-2539.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-7	Castile Formation	3014.7-4535.3
	Anhydrite III	3014.7-3113.0
	Halite II	3113.0-3310.0
	Anhydrite II	3310.0-3506.9
	Halite II	3506.9-3588.2
	Anhydrite II	3588.2-4055.0
	Halite I	4055.0-4182.3
	Anhydrite I	4182.3-4535.5
	Bell Canyon Formation	4535.5-4731.9 (T.D.)
	Reef Talus	4535.5-4584.7
	Lamar Limestone	4584.7-4633.3
	Ramsey Sandstone	4633.3-4678.5
	Ford Shale	4678.5-4714.9
	Olds Sandstone	4714.9-4731.9

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: AEC-8
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 935' FNL, 1979' FWL
Sec. 11, T 22 S, R 31 E

ELEVATION: 3532' (Top of Casing)
TOTAL DEPTH: 4922'
TYPE OF WELL: Geological Exploration
DRILLER: Sonora Drilling Company

DRILLING RECORD: **Date Started:** 06/28/76 **Date Completed:** 08/05/76

CASING RECORD:
Diameter: 13 3/8
Grade:
Wt/Ft: 54.5
From: 0
To: 42
Cement:

Diameter: 8 5/8
Grade:
Wt/Ft: 28
From: 0
To: 885
Cement: 660 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 4919
Cement: 2481 Cu. Ft.

Note: Completed logging. Ran 7 7/8" bit in the hole and conditioned mud to run casing. Corrected total depth to 4922'. Laid down drill pipe. Ran 123 joints (4933.72') of 5 1/2" O.D., 15.50#, J-55, range 3, ST&C casing in the hole and landed at 4918.77' (4907.22' GL). A Halliburton guide shoe was on bottom with a float shoe at 4859.52' GL. Centralizers were placed at 4905' GL, 4827' GL, 800' GL and 50' GL. 38 joints (1533.25') of casing were sand blasted for better bond from 2374' to 4907' KB.

Completed running casing. Cemented annulus using Halliburton with 1500 sacks (2085 cu ft) of 50-50 Pozmix "C" with 9.7 #/sk of salt and 2% bentonite followed by 300 sacks (396 cu ft) of Class "C" cement. Displaced cement with 117 barrels of water. Casing was reciprocated during displacement. After displacing 90 barrels approximately 2 barrels of cement circulated to the surface, circulation was lost at this point. Bumped plug with 2000 psi and held. Cement in place at 0220 hours. Ran Dresser Atlas temperature log, top of cement at 880'. Ran Sperry-Sun gyroscopic multishot survey in the hole on 25' stations and 100' stations out of the hole.

All depths are measured from Kelly Bushing 11.5' above ground level.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-8	Quaternary: Holocene-Eolian Sand	9.0-29.0
	Mescalero Caliche	29.0-35.0
	Triassic	
	Santa Rosa Sandstone	35.0-177.4
	Permian	
	Dewey Lake Red Beds	177.4-668.0
	Rustler Formation	668.0-990.0
	Magenta Dolomite Mem	727.3-749.5
	Culebra Dolomite Mem	848.3-873.3
	Salado Formation	990.0-2979.6
	Upper Member	990.0-1469.3
	MB 101	1101.0-1116.5
	MB 102	1146.7
	MB 103	1157.7-1173.7
	MB 104	1184.4
	MB 105	1197.6
	MB 106	1215.3
	MB 107	1240.5
	MB 108	1261.3
	MB 109	1286.1-1304.7
	MB 111	1351.9
	MB 112	1370.4
	MB 113	1398.7
	MB 114	1418.2
	MB 115	1451.3
	MB 116	1462.5
	McNutt Potash Zone	1469.3-1826.5
	Vaca Triste Sands	1469.3-1484.1
	MB 117	1535.4
	MB 118	1557.0
	MB 119	1580.5
	MB 120	1603.2
	MB 121	1622.0
	MB 122	1628.6
	Union Anhydrite	1648.0-1657.9
	MB 123	1733.5
	MB 124	1746.8
	MB 126	1826.5
	Lower Member	1826.5-2979.6
	MB 127	1849.5
	MB 128	1861.5
	MB 129	1885.3
	MB 130	1894.7
	MB 131	1959.6
	MB 132	1989.0
	MB 133	2005.5
	MB 134	2047.9-2060.5
	MB 135	2076.0
	MB 136	2114.0-2128.3
	MB 137	2138.5

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-8	MB 138	2187.4
	MB 139	2247.8
	MB 140	2309.1-2316.5
	MB 141	2369.1
	MB 142	2411.8-2419.6
	MB 143	2465.2-2472.7
	MB 144	2498.8-2510.9
	Cowden Anhydrite	2539.5-2561.6
	Castile Formation	2979.6-4315.0
	Anhydrite III	2979.6-3290.0
	Halite II	3290.0-3555.0
	Anhydrite II	3555.0-3695.5
	Halite I	3695.5-4038.0
	Anhydrite I	4038.0-4315.0
	Bell Canyon Formation	4315.0-4918.0 (T.D.)
	Lamar Limestone	4344.5-4374.0
	Ramsey Sand	4374.0-4436.0
	Ford Shale	4436.0-?

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: ERDA-6
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 2152' FSL, 910' FEL
Sec. 35, T 21 S, R 31 E

ELEVATION: 3540.2' (Top of Casing)
TOTAL DEPTH: 2775'
TYPE OF WELL: Geologic Exploration
DRILLER: Boyles Bros. Drilling Company: 06/11/75 to 08/15/75 - Pan AM

DRILLING RECORD: **Date Started:** 06/13/75 **Date Completed:** 09/23/75

CASING RECORD:
Diameter: 13 3/8
Grade:
Wt/Ft: 54.5
From: 0
To: 30
Cement: Ready Mix

Diameter: 8 5/8
Grade: K-55
Wt/Ft: 24
From: 0
To: 880
Cement: 575 SX.

Note: Plugged back 2773' to 2560' with 225 cement. Hole filled with brine.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-6	Quaternary	
	Holocene-Eolian Sand	0-9
	Mescalero Caliche	9-17
	Triassic	
	Santa Rosa Sandstone	17-72
	Permian	
	Dewey Lake Red Beds	72-538
	Rustler Formation	538-811
	Dissolution Residue	570-581
	Magenta Dolomite Member	598-623
	Dissolution Residue	696-707
	Culebra Dolomite Member	713-739
	Dissolution Residue	742-762
	Salado Formation	811-2396.5
	Upper Unit	811-1276.6
	MB 100	NR
	MB 101	923.5-929.9
	MB 102	956.8-958.2
	MB 103	970.3-984.3
	MB 104	992.1-992.4
	MB 105	NR
	MB 106	NR
	MB 107	1060.0-1060.9
	MB 108	1069.1-1069.9
	MB 109	1090.9-1113.5
	MB 110	NP
	MB 111	1161.5-1161.8
	MB 112	1178.9-1180.2
	MB 113	NP
	MB 114	1224.9-1226.9
	MB 115	1256.1-1257.2
	MB 116	1268.7-1271.4
	McNutt Potash Zone	1276.6-1612.9
	Vaca Triste Sandstone	1276.6-1287.3
	11th Ore Zone	1324.7-1329.8
	MB 117	1340.7-1342.7
		1346-1349.0
	MB 118	1359.0-1366.2
	MB 119	1378.4-1379.4
	10th Ore Zone	1386.1-1395.5
	MB 120	1401.0-1402.3
	9th Ore Zone	1403.2-1410.3
	MB 121	1413.3-1415.5
	MB 122	1422.3-1424.3
	8th Ore Zone	1424.9-1437.0
	Union Anhydrite	1444.6-1453.8
	7th Ore Zone	1464.0-1468.5
	6th Ore Zone	1479.7-1482.2
	5th Ore Zone	1487.8-1494.9
	MB 123	1517.7-1524.9

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-6	MB 124	1529.4-1537.5
	4th Ore Zone	1541.9-1549.1
		1549.7-1553.0
	3rd Ore Zone	1555.5-1567.2
	2nd Ore Zone	1571.0-1574.3
	MB 125	NP
	1st Ore Zone	1587.0-1603.3
	MB 126	NP
	Lower Member	1612.9-2396.5
	MB 127	1635.0-1635.7
	MB 128	1647.7-1648.5
	MB 129	1670.0-1671.5
	MB 130	NP
	MB 131	1743.0-1743.7
	MB 132	1770.6-1771.4
	MB 133	1785.6-1789.2
	MB 134	1833.2-1843.4
	MB 135	1860.4-1861.5
	MB 136	1900.5-1910.5
	MB 137	NP
	MB 138	1967.5-1967.7
	MB 139	2019.5-2022.4
	MB 140	2060.4-2075.6
	MB 141	2124.5-2126.6
	MB 142	2163.8-2169.5
	MB 143	2212.7-2215.6
	MB 144	2237.0-2237.7
	Cowden Anhydrite	2269.5-2291.0
	Castile Formation	2400.5-2775.0
	Halite II	2400.5-2555.1
	Anhydrite II	2555.1-2732.5 (Fault or Rupture Zone)
	Halite I	2732.5-2775.0
	Cowden Anhydrite	2540.0-2653.0
	Castile Formation	2836.0-2889.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: ERDA-9
OPERATOR: Sandia National Labs
PERMIT NO.: Unknown

LOCATION: 267.17' FSL, 176.74' FEL
Sec. 20, T 22 S, R 31 E

ELEVATION: 3410.10' (Top of Casing)
TOTAL DEPTH: 2886'
TYPE OF WELL: Geologic Exploration
DRILLER: Sonora Drilling Company

DRILLING RECORD: **Date Started:** 04/28/76 **Date Completed:** 06/26/76

CASING RECORD:
Diameter: 16
Grade:
Wt/Ft:
From: 0
To: 40
Cement: 95 Cu. Ft.

Diameter: 10 3/4
Grade: J-55
Wt/Ft: 40.5
From: 0
To: 1045
Cement: 1159 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 2883
Cement: Mud Pack

Note: Ran Dresser Atlas caliper log. Ran 79 joints (2889.66') of 7" O.D., 23# casing with a Dowell swirl type shoe on bottom and a Dowell orifice fill collar on top of the bottom joint. Set casing at 2882.66' with centralizers at 2868', 2520', and 1030'. Rigged up Dowell and pumped in 140 barrels of Baroid casing pack mud. Cemented annulus with 10 barrels of water, 12 barrels of chemical wash. 12 barrels of oil base slurry ahead of 122 cu. ft. (115 sacks) of Class "H" cement + 3% calcium chloride. Seated plug with 1000 psi, plug holding. Cement in place at 1445 hours.

All depths are measured from Kelly Bushing 11.5' above ground level.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-9	Kelly Bushing (KB) to Land Surface (LS)	0-12.0
	Holocene Deposits	12.0-22.0
	Pleistocene Rocks	
	Mescalero Caliche	22.0-27.0
	Gatuna Formation	27.0-54.0
	Triassic	
	Santa Rosa Sandstone	54.0-63.0
	Permian	
	Dewey Lake Red Beds	63.0-550.0
	Rustler Formation	550.0-860.0
	Dissolution Residue	580.0-592.0
	Magenta Dolomite Member	608.0-632.0
	Dissolution Residue	691.0-710.0
	Culebra Dolomite Member	716.0-739.0
	Dissolution Residue	742.0-748.0
	Salado Formation	860.0-2836.0
	Upper Member	860.0-1362.0
	MB 100	939.0
	MB 101	984.0
	MB 102	1026.0
	MB 103	1040.0-1050.0
	MB 104	1061.0
	MB 105	1075.0
	MB 106	1093.0-1094.0
	MB 107	1132.0
	MB 108	1142.0
	MB 109	1165.0-1188.0
	MB 110	NP
	MB 111	1238.0
	MB 112	1256.0-1258.0
	MB 113	1282.0-1284.0
	MB 114	1306.0
	MB 115	1340.0-1344.0
	MB 116	1354.0-1356.0
	McNutt Potash Zone	1362.0-1742.0
	Vaca Triste Sands	1365.0-1367.0
	11th Ore Zone	1420.0-1422.0
	MB 117	1431.0-1433.0
	MB 118	1455.0-1463.0
	MB 119	1482.0
	10th Ore Zone	1487.0-1493.0
	MB 120	1501.0-1502.0
	9th Ore Zone	1507.0-1512.0
	MB 121	1515.0-1517.0
	MB 122	1524.0
	8th Ore Zone	1531.0-1542.0
	Union Anhydrite	1549.0-1557.0
	7th Ore Zone	1572.0-1576.0
	6th Ore Zone	1590.0-1593.0
	5th Ore Zone	1597.0-1603.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-9	MB 123	1630.0-1637.0
	MB 124	1645.0-1653.0
	4th Ore Zone	1659.0-1669.0
	3rd Ore Zone	1676.0-1688.0
	2nd Ore Zone	1696.0-1698.0
	MB 125	NP
	1st Ore Zone	1712.0-1723.0
	MB 126	1742.0
	Lower Member	1742.0-2836.0
	MB 127	1768.0-1770.0
	MB 128	1778.0-1781.0
	MB 129	1803.0-1805.0
	MB 130	1815.0
	MB 131	1884.0
	MB 132	1914.0-1915.0
	MB 133	1933.0-1935.0
	MB 134	1976.0-1989.0
	MB 135	2006.0
	MB 136	2043.0-2058.0
	MB 137	2075.0
	MB 138	2120.0-2121.0
	MB 139	2177.0-2180.0
	MB 140	2241.0-2251.0
	MB 141	2320.0-2330.0
	MB 142	2377.0-2391.0
	MB 143	2450.0-2456.0
	MB 144	2493.0-2506.0
	Cowden Anhydrite	2540.0-2653.0
	Castile Formation	2836.0-2889.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE:	ERDA-10
OPERATOR:	Sandia National Labs
PERMIT NO.:	Unkown
LOCATION:	200' FNL, 2327' FEL Sec. 34, T 23 S, R 30 E
ELEVATION:	3371.2' (Top of Casing)
TOTAL DEPTH:	4418.5'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Corel Drilling Company
DRILLING RECORD:	Date Started: 08/18/77 Date Completed: 10/14/77

CASING RECORD:
Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 50
Cement: 81 Cu. Ft.

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 805
Cement: 554 Cu. Ft.

Note: Hole plugged to surface.
All depths are measured from Kelly Bushing 13' above ground level.

PLUGGING SCHEDULE:
10/01/77 - Made trip with 7 7/8" bit and conditioned hole. Ran 2 3/8" O.D. tubing in the hole and plugged back hole using Dowell with 10 barrels of water ahead of 48 barrels of mud wash followed by 414 cu. ft. of class "C" cement with 2% calcuim chloride. Displace cement with 12.5 barrels of water. Cement in place at 1300 hours. Pulled tubing and waited on cement.

10/03/77 - Made trip with 7 7/8" bit and tagged cement at 3556', conditioned hole. Made up 7 13/16" core bit and cut core #32 from 3556' to 3595', recovered 10' of cement. Cut core #33 from 3595' to 3623', recovered 20' of cement. Cut core #34 from 3623' to 3630'.

10/04/77 - Completed core #34 from 3630' to 3673', recovered 27' of cement. Ran 2 7/8" O.D. tubing in the hole to 3673'. Cemented plug #2 using Dowell with 10 barrels of water ahead of 84 barrels of mud flush followed by 10 barrels of water ahead of 1040 cu. ft. of 70% class "C" cement and 30% Litepoz. Cement in place at 1140 hours. Pulled tubing to 2300' and curculated hole. Waited on cement. Laid down drill pipe.

10/05/77 - Waited on cement to 0900 hours. Tagged top of plug #2 at 2335' with tubing. Cemented plug #3 with 10 barrels of water, 60 barrels of mud flush and 10 barrels of water, ahead of 1039 cu. ft. of cement slurry. Cement in place at 1420 hours. Pulled tubing to 803' and circulated out mud flush and cement. Waited on cement.

10/06/77 - Tagged top of plug #3 at 827'. Cemented plug #4 to surface with 10 barrels of water, 1000 gallons of mud flush and 10 barrels of water ahead of 417 cu. ft. of cement slurry. Cement in place at 0050 hours. Rigged down government furnished equipment and released rig at 1600 hours.

10/14/77 - Cement had dropped to 11.5' inside the 9 5/8" O.D. casing. Cemented to surface with 6 sacks of cement. Hole plugged

ENERGY DEPARTMENT WELLS DATA BASE

10/14/77.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-10	Quaternary	
	Holocene-Eolian Sand	
	Mescalero Caliche	13.0-17.0
	Triassic	
	Gatuna Formation	17.0-164.0
	Permian	
	Dewey Lake Red Beds	164.0-378.0
	Rustler Formation	378.0-640.0
	Magenta Dolomite Member	378.0-379.0
	Culebra Dolomite Member	489.0-517.0
	Salado Formation	640.0-2350.0
	Upper Member	640.0-1078.0
	MB 101	696.0
	MB 102	743.0
	MB 103	775.0-783.5
	MB 104	794.5
	MB 105	807.0
	MB 106	817.0
	MB 107	829.0
	MB 108	852.5
	MB 109	879.5-904.5
	MB 111	960.0
	MB 112	978.0
	MB 113	1018.0
	MB 114	1035.0
	MB 115	1068.0
	MB 116	1076.0
	McNutt Postash Zone	1087.0-1521.5
	Vaca Triste Sands	1087.0-1092.5
	MB 117	1162.0
	MB 118	1189.0
	MB 119	1225.0
	MB 121	1264.0
	MB 122	1279.5
	Union Anhydrite	1310.0-1330.0
	MB 123	1380.5-1387.0
	MB 124	1399.5-1407.5
	MB 125	1482.5
	MB 126	1521.5
	Lower Member	1521.5-2350.0
	MB 128	1556.0
	MB 129	1590.0
	MB 130	1604.0
	MB 131	1674.5
	MB 132	1704.5
	MB 133	1722.0
	MB 134	1771.5-1781.0
	MB 135	1807.0
	MB 136	1855.0-1864.5
	MB 138	1930.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-10	MB 139	1993.0
	MB 140	2053.0-2062.5
	MB 141	2150.9-2155.4
	MB 142	2220.6-2237.4
	MB 143	2302.6-2313.6
	Castile Formation	2350.0-3842.9
	Anhydrite IV	2350.0-2398.2
	Cowden Anhydrite	2398.2-2424.0
	Anhydrite III	2424.0-3097.2
	Halite II	3097.2-3283.7
	Anhydrite II	3283.7-3377.4
	Halite I	3377.4-3616.4
	Anhydrite I	3616.4-3842.9
	Bell Canyon Formation	3842.9-4430.0 (T.D.)
	Lamar Limestone	3842.9-3870.0
	Ramsey Sandstone	3870.0-3918.0
	Ford Shale	3918.0-3928.0
	Old Sandstone	3928.0-3956.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: BABY-1
OPERATOR: U.S. Department of Energy
PERMIT NO.:

LOCATION: 1989.5' FNL, 2017.1' FEL
Sec 5, T 23 S, R 31 E

ELEVATION: 3328.38' (Top of Casing)
TOTAL DEPTH: 4298.6'
TYPE OF WELL: Oil and Gas Well (Exploratory)
DRILLER: Michel P. Grace - 1974 and Salazar Bros.- 1983

DRILLING RECORD: **Date Started:** 08/12/83 **Date Completed:** 02/08/75

Deepened to 4298.6'
Date Started: 17/18/83
Date Completed: 08/19/83

CASING RECORD:
13 3/8" O.D. casing set in cement to surface 650'
9 7/8" O.D. 650 - 4159'
7 27/32" O.D. 4159 - 4298.6'

PLUGGING SCHEDULE:
Ran 20 joints of 13 3/8 71# casing set at 650'. Cemented with 275 sacks of Trin. Lt. Wt. and 125 sacks Cl. C. and 300# CaCl and 69# celloflake.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
BABY-1	Quaternary	15.5
	Triassic	
	Santa Rosa Sandstone	15.5-142.8
	Permian	
	Dewey Lake Red Beds	142.8-362.9
	Rustler Formation	362.9-653.0
	Magenta Dolomite Member	375.0-414.1
	Culebra Dolomite Member	469.0-487.2
	Salado Formation	653.0-2703.5
	Upper Member	781.3
	MB 101	818.0
	MB 102	845.0-851.0
	MB 103	884.2
	MB 105	922.1
	MB 106	946.8
	MB 107	962.1
	MB 108	977.0-993.9
	MB 109	1036.9
	MB 111	1065.8
	MB 112	1097.0
	MB 113	1117.1
	MB 114	1157.1
	MB 115	1169.8
	MB 116	1182.0-1585.1
	McNutt Potash Zone	1251.0
	MB 117	1277.6
	MB 118	1299.9
	MB 119	1328.9
	MB 120	1346.1
	MB 121	1353.2
	MB 122	1381.8-1395.2
	Union Anhydrite	1454.5-1463.1
	MB 123	1470.0-1481.0
	MB 124	1585.1
	MB 126	1585.1-2703.5
	Lower Member	1610.2
	MB 127	1621.8
	MB 128	1650.1
	MB 129	1663.2
	MB 130	1732.9
	MB 131	1763.7
	MB 132	1784.2
	MB 133	1837.7-1848.9
	MB 134	1871.9
	MB 135	1871.9
	MB 136	1905.2-1912.0
	MB 137	1930.5
	MB 138	1990.4
	MB 139	2040.7
	MB 140	2104.0-2110.6

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
BABY-1	MB 141	2188.8-2196.9
	MB 142	2239.8-2259.0
	MB 143	2314.1-2321.0
	MB 144	2356.0-2370.0
	Cowden Anhydrite	2407.7-2434.7
	Castile Formation	2703.5-4045.0
	Anhydrite III	2703.5-3154.8
	Halite II	3154.8-3373.1
	Anhydrite II	3373.1-3480.0
	Halite I	3480.0-3810.0
	Anhydrite I	3810.0-4045.0
	Bell Canyon Formation	4045.0-T.D.
	Lamar Limestone	4045.0-4086.0
	Ramsey Sandstone	4086.0-4132.0
	Ford Shale	4132.0-4140.0
	Olds Sandstone	4140.0-4171.0
	Hays Sandstone	4171.0-4298.6

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: D-268
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unkown

LOCATION: 720.4 FSL, 762.7 FEL, Sec. 35, T 22 S, R 30 E

ELEVATION: 3280.70 (Top of Casing)
TOTAL DEPTH: 1411'
TYPE OF WELL: Old Potash Drillhole
DRILLER: Pennsylvania Drilling Co.

DRILLING RECORD: **Date Started:** 11/15/89 **Date Completed:**

CASING RECORD:
Diameter: 4 1/2
Grade:
Wt/Ft:
From: 0
To: 528'
Cement: Cement in place

PLUGGING SCHEDULE:
From: 1411'
To: 528'
Int:
Material: Concrete Plug

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
D-268	Quaternary	
	Holocene-Eolian Sand	0-15.0
	Mescalero Caliche	
	Triassic	
	Santa Rosa Sandstone	15.0-30.0
	Permian	
	Dewey Lake Red Beds	30.0-187.0
	Rustler Formation	187.0-494.0
	Megenta Dolomite Member	255.0-275.0
	Culebra Dolomite Member	369.0-392.0
	Salado Formation	469.0
	Upper Member	
	MB 101	
	MB 102	
	MB 103	
	MB 104	
	MB 105	
	MB 106	
	MB 107	
	MB 108	
	MB 109	
	MB 111	
	MB 112	
	MB 114	
	MB 116	
	McNutt Potash Zone	
	Vaca Triste Sandstone	
	MB 117	
	MB 118	
	MB 119	
	MB 121	
	MB 122	
	Union Anhydrite	
	MB 123	
	MB 124	
	MB 126	
	Lower Member	
	MB 128	
	MB 129	
	MB 131	
	MB 132	1411.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: DOE-1
OPERATOR: Westinghouse
PERMIT NO.: Unknown

LOCATION: 182.4' FSL, 607.8' FEL
Sec. 28, T 22 S, R 31 E

ELEVATION: 3465.22' (Top of Casing)
TOTAL DEPTH: 4057.3'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Salazar Bros. Drilling Co.

DRILLING RECORD: **Date Started:** 07/14/82 **Date Completed:** 07/28/82

CASING RECORD:
Diameter: 10 3/4 O.D.
Grade:
Wt/Ft:
From: 0
To: 41
Cement: Set and cemented

Diameter: 10 3/4 O.D.
Grade: J-55
Wt/Ft: 40.5
From: 49
To: 1126.2
Cement:

Diameter: 7 7/8
Grade:
Wt/Ft:
From: 1126.2
To: 4057
Cement: Uncased

PLUGGING SCHEDULE:
No plugging data. Testing still in progress.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-1	Quaternary	
	Eolian Sand	Not Described
	Gatuna Formation	Not Described
	Triassic	
	Santa Rosa Sandstone	46.0-133.0
	Permian	
	Dewey Lake Red Beds	133.0-667.5
	Rustler Formation	667.5-976.5
	Magenta Dolomite Member	722.0-745.0
	Culebra Dolomite Member	828.6-850.5
	Salado Formation	976.5-2936.5
	Upper Member	976.5-1486.0
	MB 101	1102.0
	MB 102	1138.5
	MB 103	1159.0-1169.0
	MB 105	1199.0
	MB 106	1216.0
	MB 107	1254.0
	MB 108	1263.0
	MB 109	1286.0-1309.5
	MB 111	1361.3
	MB 112	1379.8
	MB 113	1406.9
	MB 114	1429.3
	MB 115	1465.8
	MB 116	1477.6
	McNutt Potash Zone	1486.0-1880.3
	Vaca Triste Sandstone	1486.0-1489.8
	MB 117	1557.2
	MB 118	1582.6
	MB 119	1608.0
	MB 120	1632.0
	MB 121	1646.5
	MB 122	1656.0
	Union Anhydrite	1681.4-1694.0
	MB 123	1762.0-1769.9
	MB 124	1773.0-1783.8
	MB 126	1880.3
	Lower Member	1880.3-2936.5
	MB 127	1907.4
	MB 128	1919.7
	MB 129	1944.3
	MB 130	1956.7
	MB 131	2025.8
	MB 132	2056.6
	MB 133	2076.0
	MB 134	2117.0-2130.0
	MB 135	2149.4
	MB 136	2192.1-2197.1
	MB 137	2209.2

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-1	MB 138	2264.0
	MB 139	2323.7
	MB 140	2374.5-2389.0
	MB 141	2457.0
	MB 142	2497.0-2512.0
	MB 143	2563.5-2570.5
	MB 144	2606.0-2621.5
	Cowden Anhydrite	2647.8-2677.0
	Castile Formation	2936.5 (T.D.)
	Anhydrite III	2936.5-3374.8
	Halite II	3374.8-3600.0
	Anhydrite II	3600.0-3708.3
	Halite I	3708.3-4032.3
	Anhydrite I	4032.3-(T.D.)

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: DOE-2
OPERATOR: U.S. Department of Energy
PERMIT NO.: 0.08.1467(State Engineer's Office)

LOCATION: 704.07' FSL, 128.19' FEL
Sec. 8, T 22 S, R 31 E

ELEVATION: 3419.09' (Top of Casing)
TOTAL DEPTH: 4325'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Unkown

DRILLING RECORD: **Date Started:** 09/08/84 **Date Completed:** 09/18/84

CASING RECORD:
Diameter: 9.625
Grade: J-55
Wt/Ft: 36
From: 0
To: 1009
Cement:

Diameter: 13 3/8 O.D.
Grade: H-40
Wt/Ft: 48#
From: 0
To: 39
Cement: Cemented with 81 Cu. Ft.

PLUGGING SCHEDULE:
No plugging data. Testing still in progress.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-2	Quaternary	
	Holocene-Dune Sand	0-8
	Pleistocene-Mescalero Caliche	8-13
	Triassic	
	Santa Rosa Sandstone	13-133.3
	Permian	
	Dewey Lake Red Beds	133.3-639.1
	Rustler Formation	639.1-698.6
	Forty-Niner Member	698.6-722.4
	Magenta Dolomite Member	722.4-823.7
	Tamarisk Member	823.7-846.0
	Culebra Dolomite Member	846.0-960.9
	Unnamed Lower Member	
	Salado Formation	960.9-3082.8
	Upper Member	960.9-1448.7
	MB 101	1080.3-1084.2
	MB 102	1116.6-1117.7
	MB 103	1130.4-1143.5
	MB 104	1154.7-1155.1
	MB 105	1170.8-1171.8
	MB 106	Not Present
	MB 107	1228.0-1228.4
	MB 108	1237.5-1238.1
	MB 109	1260.0-1283.5
	MB 110	Not Present
	MB 111	1330.8-1331.0
	MB 112	1347.0-1349.2
	MB 113	1372.4-1372.9
	MB 114	1394.3-1394.8
	MB 115	1427.7-1430.6
	MB 116	1439.3-1441.4
	McNutt Potash Zone	1448.7-1827.4
	Vaca Triste Sandstone	1448.7-1456.1
	MB 117	1510.0-1511.9
	MB 118	1533.6-1534.7
	MB 119	1556.8-1557.9
	10th Ore Zone	1574.0-1580.0
	MB 120	1581.4-1581.8
	9th Ore Zone	1580-1584(EST.)
	MB 121	1598.5-1599.8
	MB 122	1606.6-1607.5
	8th Ore Zone	1611.1-1619.3
	Union Anhydrite	1630.1-1637.9
	MB 123	1716.5-1721.9
	MB 124	1728.8-1738.4
	4th Ore Zone	1746.0-1748.5
	3rd Ore Zone	1766-1774(EST.)
	2nd Ore Zone	1780-1782.5(EST.)
	MB 125	Not Present
	MB 126	1825.9-1827.4

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-2	Lower Member	1827.4-3082.8
	MB 127	1852.7-1853.8
	MB 128	1864.5-1865.5
	MB 129	1889.9-1891.9
	MB 130	1901.8-1902.0
	MB 131	1971.2-1971.7
	MB 132	1999.7-2001.2
	MB 133	2018.8-2021.7
	MB 134	2069.3-2081.0
	MB 135	2099.8-2100.5
	MB 136	2144.9-2157.3
	MB 137	Not Present
	MB 138	2203.1
	MB 139	2303.3-2306.3
	MB 140	2372.1-2388.0
	MB 141	2450.1-2454.5
	MB 142	2503.6-2517.9
	MB 143	2566.4-2571.6
	MB 144	2603.6-2615.7
	Cowden Anhydrite	2644.5-2669.5
	Castile Formation	3082.8-4071.4
	Anhydrite III	3082.8-3801.1
	Halite II	Not Present
	Anhydrite II	?
	Halite I	3801.1-3809.2
	Anhydrite I	3809.2-4071.4
	Delaware Mountain Group	
	Bell Canyon Formation	4071.4-4325+
	Lamar Limestone Member	4071.4-4103.4
	Ramsey Sand	4103.4-4174.0
	Ford Shale	4174.0-4182.8
	Olds Sand	4182.8-4218.2(?)
	Hays Sand	4218.2(?)-4248+

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GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-11
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.994 (State Engineer's Office)
LOCATION:	711.80' FNL, 294.08' FWL Sec. 9, T 22 S, R 31 E
ELEVATION:	3426.07'
TOTAL DEPTH:	3580'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Verna Drilling Compa
DRILLING RECORD:	**Date Started:** 02/06/78 **Date Completed:** 03/14/78
CASING RECORD:	Diameter: 13 3/8 Grade: H-40 Wt/Ft: 48 From: 0 To: 40 Cement: 81 Cu. Ft. Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 985 Cement: 656 Cu. Ft. Note: Hole loaded with brine based mud, hole temporarily capped pending further testing and/or plugging, all depths are measured from Kelly Bushing 13 ft. above ground level.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-11	MB 136-T	1978.5
	MB 136-B	1978.5-1986.0
	MB 138-T	1986-2025.0
	MB 138-B	2025-2027
	Anhydrite A	Not Encountered
	Anhydrite B	Not Encountered
	MB 139-T	2061.0
	MB 139-B	2061-2064
	MB 140-T	2064-2092
	MB 140-B	2092-2105

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-12**
OPERATOR:	Westinghouse
PERMIT NO.:	Unknown
LOCATION:	149.4' FSL, 80.4' FEL Sec. 17, T 22 S, R 31 E
ELEVATION:	3472.06 (Top of Casing)
TOTAL DEPTH:	3927.5'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 11/17/81 **Date Completed:** 12/07/78
CASING RECORD:	Diameter: 9 5/8 Grade: H-40 Wt/Ft: 32.3 From: 39 To: 1001.8 Cement: 475 Cu. Ft. Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 39 Cement: 475 Cu. Ft. Diameter: 9 5/8 Grade: H-40 Wt/Ft: 32 From: 39 To: 1013 Cement: 475 Cu. Ft. Note: Hole loaded with brine based mud pending further tests. All depths are measured from Kelly Bushing 12.2 ft. above ground level.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-12	Quaternary Deposits	
	Sand (Holocene-eolian)	0-16.2
	Mescalero Caliche	16.2-19.2
	Gatuna Formation	19.2-28.8
	Triassic Rocks	
	Santa Rosa Sandstone	28.8-167.0
	Permian Rocks	
	Dewey Lake Red Beds	167.0-640.0
	Rustler Formation	640.0-966.0
	Magenta Dolomite Member	703.9-727.0
	Culebra Dolomite Member	822.0-846.8
	Salado Formation	966.0-2737.5
	Upper Member	966.0-1444.0
	MB 101	1084.5
	MB 102	1116.0
	MB 103	1130.0-1141.0
	MB 104	1150.0
	MB 105	1167.6
	MB 106	1183.5
	MB 107	1223.5
	MB 108	1232.5
	MB 109	1254.0-1278.0
	MB 111	1324.0
	MB 112	1338.0-1342.0
	MB 113	1367.0
	MB 114	1389.0
	MB 115	1424.5
	MB 116	1436.0
	McNutt Member	1444.0-1798.0
	Vaca Triste Sandstone Member	1444.0-1447.0
	MB 117	1507.5
	MB 118	1531.0
	MB 119	1552.0-1556.5
	MB 120	1575.0
	MB 121	1588.0
	MB 122	1596.0
	Union Anhydrite	1617.0-1625.0
	MB 123	1695.0-1700.8
	MB 124	1708.0-1715.4
	MB 126	1798.0
	Lower Member	1798.0-2737.5
	MB 127	1825.0
	MB 128	1834.0
	MB 129	1856.0
	MB 130	1867.0
	MB 131	1928.0
	MB 132	1957.5
	MB 133	1976.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-12	MB 134	2015.0-2025.0
	MB 135	2040.0
	MB 136	2071.6-2083.1
	MB 138	2135.1
	MB 139	2184.9
	MB 140	2226.1-2238.1
	MB 141	2290.0-2296.0
	MB 142	2332.0-2344.0
	MB 143	2381.5-2387.6
	MB 144	2413.5-2423.9
	Cowden Anhydrite	2445.5-2471.0
	Castile Formation	2337.5-T.D.
	DEEPENED PORTION OF WIPP-12	
	Castile Formation	2776.0-T.D.
	Anhydrite III Member	2776.0-3053.9
	Halite II Member	3053.9-3281.8
	Anhydrite II Member	3281.8-3391.0
	Halite I Member	3391.0-3901.6
	Anhydrite I Member	3901.6-T.D.

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-13
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.09.1182 (State Engineer's Office)
LOCATION:	2565.68' FSL, 1730.59' FWL Sec. 17, T 22 S, R 31 E
ELEVATION:	2565.68' (Top of Casing)
TOTAL DEPTH:	3856'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/26/78 **Date Completed:** 10/05/79 (Recompletion)
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 35.5 Cement: 108 Cu. Ft. Diameter: 9 5/8 Grade: Wt/Ft: 36 From: 0 To: 1023 Cement: 665 Cu. Ft. Note: Hole loaded with brine based mud pending further test and/or plugging. All depths are measured from Kelly Bushing 12.2 ft. above ground except cores between 570 and 878 ft. and Schlumberger logs which were measured from ground level.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-13	Quaternary Deposits	0-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-66
	Permian Rocks	
	Dewey Lake Red Beds	66-517
	Rustler Formation	517-846
	Dissolution Residue	543-550
	Magenta Dolomite Member	565-583
	Dissolution Residue	679-686
	Culebra Dolomite Member	703-726
	Dissolution Residue	730-735
	Top of Highest Salt in Section	745
	Salado Formation	846-1025
	Upper Member	846-1025
	MB 101	967
	MB 102	1003
	MB 103	1018
	DEEPENED PORTION OF WIPP-13 (Distance below K.B.)	
	Permian Rocks	
	Salado Formation	858.0-2971.6
	Upper Member	858.0-1356.7
	MB 103	1030.0-1042.3
	MB 104	1069.8
	MB 105	1091.0
	MB 106	1111.0
	MB 107	1128.0
	MB 108	1136.1
	MB 109	1161.0-1185.0
	MB 111	1232.8
	MB 112	1250.0
	MB 113	1277.9
	MB 114	1300.9
	MB 115	1338.3
	MB 116	1350.0
	McNutt Member	1356.7-1730.4
	Vaca Triste Sandstone Member	1356.7-1359.0
	MB 117	1426.5
	MB 118	1451.5
	MB 119	1478.2
	MB 120	1497.0
	MB 121	1513.8
	MB 122	1522.0
	Union Anhydrite	1542.0-1550.0
	MB 123	1628.0
	MB 124	1644.7
	MB 126	1730.4
	Lower Member	1730.4-2971.6
	MB 127	1757.8

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-13	MB 128	1770.0
	MB 129	1794.0
	MB 130	1804.5
	MB 131	1873.6
	MB 132	1902.0
	MB 133	1924.0
	MB 134	1968.9-1980.6
	MB 135	1996.8
	MB 136	2033.0-2048.0
	MB 137	2063.0
	MB 138	2110.2
	MB 139	2168.3
	MB 140	2221.0-2232.9
	MB 141	2294.6
	MB 142	2341.5-2355.0
	MB 143	2409.0-2417.0
	MB 144	2460.4
	Cowden Anhydrite	2493.9-2521.6
	Castile Formation	2971.6-3861.6+ (T.D.)
	Anhydrite III	2971.6-3518.7
	Halite II	3518.7-3638.0
	Anhydrite II	3638.0-3727.5
	Halite I	3727.5-3821.0
	Anhydrite I	3821.0-3861.6+ (T.D.)

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-14
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1458 (State Engineer's Office)
LOCATION:	98.57' FSL, 2112.08' FEL Sec. 9, T 22 S, R 31 E
ELEVATION:	3429' (G.L.)
TOTAL DEPTH:	1000'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 05/02/81 **Date Completed:** 06/08/81
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 111 Cement:
	Note: Hole loaded with brine based mud and temporarily abandoned pending further tests and/or plugging.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-14	Quaternary Rocks	
	Sand (Holocene-eolian)	0-15.4
	Triassic Rocks	
	Santa Rosa Sandstone	15.4-141.0
	Permian Rocks	
	Dewey Lake Red Beds	141.0-638.7
	Rustler Formation	638.7-951
	Magenta Dolomite Member	706.5-730.0
	Culebra Dolomite Member	817.2-836.2
	Salado Formation (Upper Member)	951.6

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-15
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.13.00 (State Engineer's Office)
LOCATION:	2426' FNL, 1973' FWL Sec. 18, T 23 S, R 35 E
ELEVATION:	3269.34' (G.L.l)
TOTAL DEPTH:	810'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 03/08/78 **Date Completed:** 04/04/78
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 20 From: 0 To: 13 Cement: Diameter: 6 1/8 Grade: HW Wt/Ft: 11.3 From: 13 To: 592 Cement: Diameter: 4 Grade: Core Wt/Ft: From: 592 To: 810 Cement: Diameter: 4 1/2 Grade: HW Wt/Ft: 11.3 From: 0 To: 555 Cement: Note: Hole loaded with mud and temporarily capped pending further testing and/or plugging. Hole was relinquished to land owner for use as water well to relieve liability for plugging.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-15	Quaternary Deposits	
	Clay	0-34
	Marl	34-99
	Sand	99-153.3
	Clay	153.3-226
	Sand	226-547.2
	Triassic Rocks	
	Chinle	547.2-790.5
	Santa Rosa Sandstone	790.5-812

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-16
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1290 (State Engineer's Office) 0.08.1182 (reentry)
LOCATION:	2356.6' FSL, 138.8' FWL Sec. 5, T 21 S, R 30 E
ELEVATION:	3383.40' (Top of Casing)
TOTAL DEPTH:	1300'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 01/11/80 **Date Completed:** 02/08/80
CASING RECORD:	Diameter: 13 3/8 Grade: H-40 Wt/Ft: 48 From: 0 To: 38 Cement: Diameter: 4 1/2 Grade: J-55 Wt/Ft: 10.5 From: 0 To: 459 Cement: Note: Hole filled with brine based mud and temporarily abandoned.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-16	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	
	Permian Rocks	
	Salado Formation	
	Upper Member	
	MB 103	
	MB 104	
	MB 105	
	MB 106	
	MB 107	
	MB 108	
	MB 109	
	MB 111	
	MB 112	
	MB 113	
	MB 114	
	MB 115	
	MB 116	
	McNutt Member	
	Vaca Triste Sandstone Member	
	MB 117	
	MB 118	
	MB 119	
	MB 120	
	MB 121	
	MB 122	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-18**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1123 (State Engineer's Office)
LOCATION:	983.58' FNL, 11.85' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3458.7' (Top of Casing)
TOTAL DEPTH:	1060'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 03/14/78 **Date Completed:** 04/03/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 16 Cement:
	Note: Hole loaded with mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-18	Quaternary Deposits	
	Holocene Deposits	0-5
	Mescalero Caliche	5-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-138
	Permian Rocks	
	Dewey Lake Red Beds	138-613
	Rustler Formation	613-928
	Dissolution Residue	643-655
	Magenta Dolomite Member	672-696
	Dissolution Residue	757-769
	Culebra Dolomite Member	787-808
	Dissolution Residue	812-822
	Salt-bearing Interval	822-928
	Salado Formation	928-1060
	Upper Member	928-1060
	MB 101	1049
	Maximum Depth Recorded	1060

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-19
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1124 (State Engineer's Office)
LOCATION:	2286.5' FNL, 12.7' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3435.14' (Top of Casing)
TOTAL DEPTH:	1038'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 04/06/78 **Date Completed:** 05/08/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 8 Cement:
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-19	Quaternary Deposits	
	Holocene Deposits	0-7
	Mescalero Caliche	7-14
	Triassic Rocks	
	Santa Rosa Sandstone	14-96
	Permian Rocks	
	Dewey Lake Red Beds	96-590
	Rustler Formation	590-895
	Dissolution Residue	619-629
	Magenta Dolomite Member	647-672
	Dissolution Residue	730-756
	Culebra Dolomite Member	756-779
	Dissolution Residue	781-795
	Salt-bearing Interval	795-895
	Salado Formation	895-1038.2
	Upper Member	895-1038.2
	MB 101	1010-1012
	Maximum Depth Recorded	1034

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-21
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1126 (State Engineer's Office)
LOCATION:	1450.6' FSL, 11.7' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3418.96' (Top of Casing)
TOTAL DEPTH:	1045'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 05/24/78 **Date Completed:** 05/26/78
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 20 Cement:
	Note: Hole loaded with brine mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-21	Quaternary Deposits	
	Holocene Deposits	0-6
	Mescalero Caliche	6-12
	Gatuna Formation	12-39
	Triassic Rocks	
	Santa Rosa Sandstone	39-73
	Permian Rocks	
	Dewey Lake Red Beds	73-560
	Rustler Formation	560-868
	Dissolution Residue	588-601
	Magenta Dolomite Member	618-642
	Dissolution Residue	706-715
	Culebra Dolomite Member	729-753
	Dissolution Residue	755-759
	Salt-bearing Interval	770-868
	Salado Formation	868-1046
	Upper Member	868-1046
	MB 101	986-989
	MB 102	1025-1026
	MB 103	1039
	Maximum Depth Recorded	1046

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-22**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1127 (State Engineer's Office)
LOCATION:	2544.9' FSL, 10.82' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3428.12' (Top of Casing)
TOTAL DEPTH:	1450'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brother Drilling
DRILLING RECORD:	**Date Started:** 05/08/78 **Date Completed:** 05/24/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 20 Cement:
	Note: Hole loaded with mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-22	Quaternary Deposits	
	Holocene Deposits	0-6
	Mescalero Caliche	6-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-81
	Permian	
	Dewey Lake Red Beds	81-574
	Rustler Formation	574-885
	Dissolution Residue	603-614
	Magenta Dolomite Member	630-654
	Dissolution Residue	717-728
	Culebra Dolomite Member	742-764
	Dissolution Residue	767-773
	Salt Interval	777-885
	Salado Formation	885-1450
	Upper Member	883-1363
	MB 101	1000-1003
	MB 102	1036-1037
	MB 103	1049-1063
	MB 104	1071-1072
	MB 105	1086-1087
	MB 106	1102-1103
	MB 107	1142-1143
	MB 108	1150-1151
	MB 109	1172-1196
	MB 111	1242-1243
	MB 112	1259-1261
	MB 113	1285-1286
	MB 114	1307-1308
	MB 115	1342-1344
	MB 116	1353-1355
	McNutt Potash Unit	1363-1450
	Vaca Triste Sandstone Member	1363-1367
	MB 117	1426-1427
	Maximum Depth Recorded	1448

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-25
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1172 (State Engineer's Office)
LOCATION:	1852.77' FSL, 2838.10' FEL Sec. 15, T 22 S, R 30 E
ELEVATION:	3214.39' (Top of Casing)
TOTAL DEPTH:	650'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 08/28/78 **Date Completed:** 09/12/78
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 21 Cement: Diameter: 5 1/2 Grade: K-55 Wt/Ft: 15.5 From: 0 To: 649 Cement: 269 Cu. Ft. Note: 7" casing pulled. Culebra perforated from 445-475 with 120 holes spaced at 4 holes per foot. Magenta perforated from 300-330 with 120 holes spaced at 4 holes per foot. Rustler perforated from 579-608 with 116 holes spaced at 4 holes per foot. Top of Pip Packers set at 572.7 and 365.1.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-25	Pleistocene Deposits	0-17
	Permian Rocks	
	Dewey Lake Red Beds	17-232
	Rustler Formation	232-565
	Dissolution Residue	270-287
	Magenta Dolomite Member	302-328
	Dissolution Residue	415-424
	Culebra Dolomite Member	447-472
	Dissolution Residue	475-512
	Salado Formation	565-655 (T.D.)
	Upper Member	565-600
	Dissolution Residue	565-600
	MB 101	589
	MB 102	599
	Salt Interval	600-655
	MB 103	615
	MB 104	628
	MB 105	640
	Maximum Depth Recorded on Geophysical Logs	651

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-26
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1173 (State Engineer's Office)
LOCATION:	2232.27' FNL, 12.20' FEL Sec. 29, T 22 S, R 30 E
ELEVATION:	3153.20' (Top of Casing)
TOTAL DEPTH:	503'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/28/78 **Date Completed:** 09/11/78
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 268 Cement: Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 502 Cement: 510 Cu. Ft. Note: 7" casing pulled. Culebra perforated from 185-210 with 100 holes spaced at 4 holes per foot. Magenta perforated from 70-100 wih 120 holes spaced at 4 holes per foot, and from 50-70 with 80 holes spaced at 4 holes per foot. Rustler perforated from 288-329 with 164 holes spaced at 4 holes per foot. Top of Pip Packers set at 269 and 139.1.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-26	Holocene Deposits	0-10
	Permian Rocks	
	Rustler Formation	10-309
	Dissolution Residue	34-50
	Magenta Dolomite Member	70-99
	Dissolution Residue	152-174
	Culebra Dolomite Member	186-209
	Dissolution Residue	213-234
	Salado Formation	309-503
	Upper Member	309-503
	Dissolution Residue	309-320
	Salt Interval	320-503
	MB 101	387
	MB 102	423
	MB 103	460
	MB 104	469
	MB 105	481
	MB 106	495
	Maximum Depth Recorded	503

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-27**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1174 (State Engineer's Office)
LOCATION:	89.79' FNL, 1485.03' FWL Sec. 21, T 21 S, R 30 E
ELEVATION:	3178.98' (Top of Casing)
TOTAL DEPTH:	592'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 09/12/78 **Date Completed:** 10/09/78
CASING RECORD:	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 588 Cement: 440 Cu. Ft.
	Note: Culebra perforated from 290-320 with 120 holes spaced at 4 holes per foot. Magenta perforated from 175-195 with 80 holes spaced at 4 holes per foot. Rustler perforated from 425-460 with 135 holes and from 483-513 with 120 holes spaced at 4 holes per foot. Top of Pip Packers set at 399.4 and 267.4.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-27	Quaternary Deposits	
	Holocene Deposits	0-74
	Mescalero Caliche	74-79
	Permian Rocks	
	Dewey Lake Red Beds	79-152
	Rustler Formation	152-421
	Dissolution Residue	152-193
	Magenta Dolomite Member	175-193
	Dissolution Residue	270-281
	Culebra Dolomite Member	292-318
	Dissolution Residue	321-421
	Salado Formation	421-592
	Upper Member	421-592
	Dissolution Residue	421-509
	MB 101	442-447
	MB 102	449-451
	MB 103	456-468
	MB 107-108	481-484
	MB 109	487-494
	Salt Interval	509-592
	MB 113	548-550
	Maximum Depth Recorded	592

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-28
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1175 (State Engineer's Office)
LOCATION:	98.72' FNL, 2400.99' FEL Sec. 18, T 21 S, R 31 E
ELEVATION:	3349.21' (Top of Casing)
TOTAL DEPTH:	801'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/07/78 **Date Completed:** 08/28/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 21 Cement: Ready Mix Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 223 Cement: Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 800 Cement: 314 Cu. Ft. Note: 7" casing pulled. Culebra perforated from 420-446 with 104 holes spaced at 4 holes per foot. Magenta perforated from 285-310 with 100 holes spaced at 4 holes per foot. Rustler perforated from 549-589 with 160 holes spaced at 4 holes per foot. Top of Pip Packers set at 526.7 and 365.1.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-28	Holocene Deposits	0-12
	Permian Rocks	
	Dewey Lake Red Beds	12-215
	Rustler Formation	215-531
	Magenta Dolomite Member	285-310
	Culebra Dolomite Member	420-446
	Salado Formation	531-801 (T.D)
	Upper Member	531-801
	Dissolution Residue	531-589
	MB 101	567
	MB 103	585
	Salt Interval	589-801
	MB 105	598
	MB 106	612
	MB 107	656
	MB 108	664
	MB 109	694
	MB 111	731
	MB 112	743
	MB 113	769
	MB 114	791
	Maximum Depth Recorded	802

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-29**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1176 (State Engineer's Office)
LOCATION:	406.62' FSL, 1827.54' FEL Sec. 34, T 22 S, R 29 E
ELEVATION:	2978.26' (Top of Casing)
TOTAL DEPTH:	377'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 10/03/78 **Date Completed:** 10/10/78
CASING RECORD:	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 376 Cement: 135 Cu. Ft. Note: Top joint of 5.5 casing is 14 lb. Culebra perforated from 10-45 with 140 holes spaced at 4 holes per foot. Rustler perforated from 216-250 with 136 holes spaced at 4 holes per foot. Top of Pip Packers set at 203.7.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-29	Holocene Deposits	0-12
	Permian Rocks	
	Rustler Formation	12-143
	Culebra Dolomite Member	12-42
	Salado Formation	143-377 (T.D.)
	Upper Member	143-248
	Dissolution Residue	143-248
	MB 101	175
	MB 102	181
	MB 103	199
	MB 109	228
	McNutt Potash Zone	248-377 (T.D.)
	Dissolution Residue	248-251
	Vaca Triste Sandstone Member	248-251
	Salt Interval	251-377
	MB 117	319
	MB 118	346
	Maximum Depth Recorded	358

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-30
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1177 (State Engineer's Office)
LOCATION:	667.5' FNL. 177.41' FWL Sec. 33, T 21 S, R 30 E
ELEVATION:	3429.05' (Top of Casing)
TOTAL DEPTH:	913'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/08/78 **Date Completed:** 10/02/78
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 246 Cement: Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 912 Cement: 463 Cu. Ft. Note: 7" casing pulled. Culebra perforated from 631-654 with 92 holes spaced at 4 holes per foot. Magenta perforated from 510-540 with 120 holes spaced at 4 holes per foot. Rustler perforated from 731-753 with 88 holes spaced at 4 holes per foot. Top of Pip Packers set at 701.1 and 585.4.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-30	Permian Rocks	
	Dewey Lake Red Beds	0-449
	Rustler Formation	449-748
	Magenta Dolomite Member	513-537
	Culebra Dolomite Member	631-653
	Salado Formation	748-912 (T.D.)
	Upper Member	748-912
	Salt Interval	748-912
	MB 101	862
	MB 102	894
	MB 103	In Bed at Total Depth
	Maximum Depth Recorded	908

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-31
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	Unknown
LOCATION:	422.54' FSL, 1762.24' FWL Sec. 35, T 20 S, R 30 E
ELEVATION:	3401.43' (Top of Casing)
TOTAL DEPTH:	1981.7'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Chortes Drilling Company
DRILLING RECORD:	**Date Started:** 07/18/80 **Date Completed:** 09/29/80 (Recompletion)
CASING RECORD:	Diameter: Grade: 6' x 6' CEL Wt/Ft: From: 0 To: 5 Cement: Dirt Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 3 To: 37 Cement: 81 Cu. Ft. Diameter: 7 5/8 Grade: J-55 Wt/Ft: 26.4 From: 2.5 To: 808 Cement: 414 Cu. Ft. Note: Hole loaded with brine based mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-31	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-32**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	SEO: 04/25/79; USGS: 10/15/79
LOCATION:	1673.22' FSL, 29.14' FEL Sec. 33, T 22 S, R 29 E
ELEVATION:	3023.26' (Top of Casing)
TOTAL DEPTH:	390'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/07/79 **Date Completed:** 08/23/79
CASING RECORD:	No casing used.
PLUGGING SCHEDULE:	Note: Hole plugged to surface with 500 Cu. Ft. cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-32	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-33
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	SEO: 04/25/79
LOCATION:	1762.48' FSL, 2426.65' FWL Sec. 13, T 22 S, R 30 E
ELEVATION:	3323.23' (Top of Casing)
TOTAL DEPTH:	840'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/13/79 **Date Completed:** 07/26/79
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 192 Cu. Ft. Note: Hole filled with brine based mud. Fluid level at 27 ft.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-33	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	WIPP-34
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	08.08.1291 (State Engineer's Office) 08.08.1195 (reentry)
LOCATION:	201.78' FSL, 1999.73' FWL Sec. 8, T 22 S, R 31 E
ELEVATION:	3433' (Top of Casing)
TOTAL DEPTH:	1820'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/16/79 **Date Completed:** 09/04/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement:
	Note: Hole filled with brine based mud.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-34	Quaternary Deposits	0-11
	Triassic Rocks	
	Santa Rosa Sandstone	11-154
	Permian Rocks	
	Dewey Lake Red Beds	154-657
	Rustler Formation	657-973
	Magenta Dolomite Member	716-741
	Culebra Dolomite Member	834-861
	Salado Formation	973-1820+
	Upper Unit	973-1437
	MB 101	1092
	MB 102	1122
	MB 103	1148
	MB 104	1158
	MB 105	1173
	MB 106	1191
	MB 107	1228
	MB 108	1237
	MB 109	1280
	MB 110	1317
	MB 111	1326
	MB 112	1344
	MB 113	1366
	MB 114	1396
	MB 115	1420
	MB 116	1430
	McNutt Potash Unit	1437-1751
	Vaca Triste Sandstone Member	1437-1442
	MB 117	1498
	MB 118	1520
	MB 119	1540
	MB 120	1560
	MB 121	1573
	MB 122	1580
	Union Anhydrite	1599-1607
	MB 123	1676
	MB 124	1690
	MB 125	---
	MB 126	1751
	Lower Unit	1751-1820+
	MB 127	1768
	MB 128	1775
	MB 129	1785

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-1
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.979 (State Engineer's Office)
LOCATION:	623.2' FNL, 1083.1' FWL Sec. 29, T 22 S, R 31 E
ELEVATION:	3399.53' (Top of Casing)
TOTAL DEPTH:	856'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 05/20/76 **Date Completed:** 06/10/76
CASING RECORD:	Diameter: 10 1/8 Grade: Wt/Ft: 40.5 From: 0 To: 48 Cement: 51 Cu. Ft. Diameter: 7 Grade: K-55 Wt/Ft: 26 From: 0 To: 848 Cement: 192 Cu. Ft. Note: Perforated from 803 to 827 with 72 holes, 703 to 683 with 3 holes per foot, 683 to 675 with 3 holes per foot, 562 to 590 with 3 holes per foot. All depths are measured from Kelly Bushing 8' above ground level except DST's which are measured from ground level.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-1	Holocene	
	Surficial Deposits	0-15
	Pleistocene	
	Gatuna Formation	15-35
	Ochoan	
	Dewey Lake Red Beds	35-502
	Rustler Formation	502-824
	Magenta Dolomite Member	563-589
	Culebra Dolomite Member	676-699
	Top of Salado	824
	Total Depth	856

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-2a
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.990 (State Engineer's Office)
LOCATION:	726.96' FNL, 1697.64', FWL Sec. 29, T 22 S, R 31 E
ELEVATION:	3378.09' (Top of Casing)
TOTAL DEPTH:	672'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 02/14/77 **Date Completed:** 02/21/77
CASING RECORD:	Diameter: 10 3/4 Grade: Wt/Ft: From: 0 To: 33 Cement: 54 Cu. Ft. Diameter: 6 5/8 Grade: J-55 Wt/Ft: 24 From: 0 To: 511 Cement: 260 Cu. Ft.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2a	Holocene	
	Surficial Deposit	0-14
	Pleistocene	
	Gatuna Formation	14-38
	Ochoan	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-672 (T.D.)
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-672 (T.D.)
	Total Depth	672

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-2b1
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.990 (State Engineer's Office)
LOCATION:	695.57' FNL, 1660.57' FWL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3378.46 (Top of Casing)
TOTAL DEPTH:	661'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 02/07/77 **Date Completed:** 02/14/77
CASING RECORD:	Diameter: 10 3/4 Grade: Wt/Ft: From: 0 To: 33 Cement: 54 Cu. Ft. Diameter: 6 5/8 Grade: J-55 Wt/Ft: 24 From: 0 To: 609 Cement: 282 Cu. Ft. Note: Perforated from 510'-538' with 3 holes per foot.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2b1	Holocene	
	Surficial Deposit	0-14
	Pleistocene	
	Gatuna Formation	14-38
	Ochoan	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-661
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-661
	Total Depth	661

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-2b2**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.990 (State Engineer's Office)
LOCATION:	700.6' FNL, 1690.8' FWL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3378.31' (Top of Casing)
TOTAL DEPTH:	660'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/16/83 **Date Completed:** 05/03/84
CASING RECORD:	Diameter: 9.625 O.D. Grade: J-55 Wt/Ft: 36 From: 0 To: 20 Cement: Diameter: 5.5 O.D. Grade: J-55 Wt/Ft: 15.5 From: 0 To: 620 Cement: Note: Open 613-650'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2b2	Holocene	
	Surficial Deposits	0-14
	Quaternary	
	Gatuna Formation	14-38
	Permian	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-660 (T.D.)
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-660 (T.D.)

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-2c
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.990 (State Engineer's Office)
LOCATION:	637.15' FNL, 1708.62' FWL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3378.41' (Top of Casing)
TOTAL DEPTH:	795'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 01/28/77 **Date Completed:** 02/05/77
CASING RECORD:	Diameter: 10 3/4 Grade: Wt/Ft: From: 0 To: 33 Cement: 54 Cu. Ft.
	Diameter: 6 5/8 Grade: J-55 Wt/Ft: 24 From: 0 To: 742 Cement: 339 Cu. Ft.
	Note: Perforated from 618-655 with 3 holes per foot.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2c	Holocene	
	Surficial Deposits	0-34
	Quaternary	
	Gatuna Formation	0-34
	Permian	
	Dewey Lake Red Beds	34-457
	Rustler Formation	
	Magenta Dolomite Member	515-540
	Culebra Dolomite Member	624-642
	Top of Rustler Salt	642
	Salado Formation	764-795 (T.D.)
	Maximum Depth	795

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3b1**
OPERATOR:	Sandia National Lab
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2085.31' FSL, 138.10' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3390.64' (Top of Casing)
TOTAL DEPTH:	902'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/25/76 **Date Completed:** 08/12/76
CASING RECORD:	Diameter: 10 3/4 Grade: Wt/Ft: 40.5 From: 0 To: 38 Cement: 54 Cu. Ft. Diameter: 6 5/8 Grade: J-55 Wt/Ft: 24 From: 0 To: 891 Cement: 625 Sacks Note: Perforated from 813 to 837 with 72 holes, 683 to 703 with 3 holes per ft, 675 to 683 with 3 holes per ft, 562 to 590 with 3 holes per ft.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b1	Holocene	
	Surficial Deposits	0-4
	Quaternary	
	Gatuna Formation	4-22
	Permian	
	Dewey Lake Red Beds	22-502
	Rustler Formation	502-821
	Magenta Dolomite Member	559-584
	Culebra Dolomite Member	672-694
	Top of Rustler Salt	Not Given
	Salado Formation	821- T.D.
	Maximum Depth	902

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3b2**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2122.15' FSL, 231.29' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3390.03' (Top of Casing)
TOTAL DEPTH:	725'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** **Date Completed:**
CASING RECORD:	Diameter: 5 1/2 O.D. Grade: J-55 Wt/Ft: 15.5 From: 0 To: 672.7 Cement:
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b2	Surficial Deposits	0-11
	Gatuna Formation	
	Dockum Group	11-65
	Dewey Lake Red Beds	65-565.7
	Rustler Formation	565.7-788.7
	Magenta Dolomite Member	564-590
	Culebra Dolomite Member	676-700
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	725

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-3b3
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2022.35' FSL, 217.30' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3388.67' (Top of Casing)
TOTAL DEPTH:	730'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** **Date Completed:** 01/30/84
CASING RECORD:	Diameter: 5.5 Grade: J-55 Wt/Ft: 15.5 From: .50 To: 670.5 Cement: Casing cemented in place
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b3	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	
	Rustler Formation	
	Magenta Dolomite Member	563-586
	Culebra Dolomite Member	673-696
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-3d (H-3b4)
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2067.3' FSL, 164.3' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3390.01' (Top of Casing)
TOTAL DEPTH:	554'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** **Date Completed:**
CASING RECORD:	Diameter: 8 5/8 Grade: Wt/Ft: From: 0 To: 39 Cement:
	Note: 7 7/8" uncased borehole 33-559'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3d	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	420
	Rustler Formation	
	Forty-Niner Member	508-537
	Forty-Niner Claystone Member	537-547
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-4a**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1153 (State Engineer's Office)
LOCATION:	545.89' FNL, 720.00' FWL, Sec. 5, T 23 S, R 31 E
ELEVATION:	3333.29' (Top of Casing)
TOTAL DEPTH:	415'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 04/30/78 **Date Completed:** 05/23/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 32 Cement: 63 Cu. Ft. Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 364 Cement: 173 Cu. Ft.
	Note: Hole in standby condition for hydro tracer tests. 4 1/2" inflatable packer set at 485' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder set at 499' in the Culebra Dolomite. The hole is dual completion across the Magenta and Culebra Dolomites.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4a	Holocene	
	Surficial Deposits	0-13
	Pleistocene	
	Gatuna Formation	13-29
	Ochoan	
	Dewey Lake Red Beds	29-315
	Rustler Formation	315
	Magenta Dolomite Member	375-400
	Total Depth	415

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-4b
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1154 (State Engineer's Office)
LOCATION:	498.47' FNL, 632.54' FWL, Sec. 5, T 23 S, R 31 E
ELEVATION:	3333.35 (Top of Casing)
TOTAL DEPTH:	529'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 04/30/78 **Date Completed:** 05/15/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 33 Cement: 63 Cu. Ft. Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 476 Cement: 269 Cu. Ft. Note: Hole is in standby condition for hydro tracer tests.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4b	Surficial Deposits	0-13
	Gatuna Formation	13-29
	Dockum Group	NP
	Dewey Lake Red Beds	29-315
	Rustler Formation	315-T.D.
	Magenta Dolomite Member	377-402
	Culebra Dolomite Member	498-522
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	529

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-4c
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1152 (State Engineer's Office)
LOCATION:	446.36 FNL, 717.89 FWL, Sec. 5, T 23 S, R 31 E
ELEVATION:	3334.04' (Top of Casing)
TOTAL DEPTH:	661'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 04/30/78 **Date Completed:** 05/09/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 33 Cement: 63 Cu. Ft. Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 610 Cement: 270 Cu. Ft. Note: Bridge plug at 530'. Perforated from 494' to 520' with 104 holes spaced at 4 holes per foot. Hole in standby condition for hydro tracer tests.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4c	Surficial Deposits	0-13
	Gatuna Formation	13-29
	Dockum Group	NP
	Dewey Lake Red Beds	29-315
	Rustler Formation	315-626
	Magenta Dolomite Member	377-403
	Culebra Dolomite Member	490-516
	Salado Formation	626-661

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-5a
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1159 (State Engineer's Office)

LOCATION: 1091.98 FNL, 185.03 FEL,
Sec. 15, T 22 S, R 31 E

ELEVATION: 3506.19 (Top of Casing)
TOTAL DEPTH: 824'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/22/78 **Date Completed:** 06/20/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 774
Cement: 192 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests. 4 1/2" inflatable packer set at 895' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder set at 905' in the Culebra Dolomite. The hole is dual-completion across the Magenta and Culebra Dolomites.

PLUGGING SCHEDULE: No plugging data. Testing still in progress.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-5b
OPERATOR:	Sandia National Lab
PERMIT NO.:	0.08.1160 (State Engineer's Office)
LOCATION:	1008.30' FNL, 236.22' FEL, Sec. 15, T 22 S, R 31 E
ELEVATION:	3506.04' (Top of Casing)
TOTAL DEPTH:	925'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 05/22/78 **Date Completed:** 06/13/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 72 Cu. Ft. Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 881 Cement: 336 Cu. Ft. Note: Hole is in standby condition for hydro tracer tests.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-5b	Surficial Deposits	0-8
	Gatuna Formation	NP
	Dockum Group	8-225
	Dewey Lake Red Beds	225-732
	Rustler Formation	732-T.D.
	Magenta Dolomite Member	785-805
	Culebra Dolomite Member	897-920
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-5c**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1161 (State Engineer's Office)
LOCATION:	1005.55 FNL, 134.95 FEL, Sec. 15, T 22 S, R 31 E
ELEVATION:	3506.04' (Top of Casing)
TOTAL DEPTH:	1076'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 05/22/78 **Date Completed:** 06/03/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 72 Cu. Ft.
	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 1024 Cement: 416 Cu. Ft.
	Note: Bridge plug set at 935'. Perforated from 895' to 925' with 120 holes spaced at 4 holes per foot. Hole in standby condition for hydro tracer tests.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-5c	Surficial Deposits	0-8
	Gatuna Formation	NP
	Dockum Group	8-225
	Dewey Lake Red Beds	225-732
	Rustler Formation	732-1041
	Magenta Dolomite Member	788-812
	Culebra Dolomite Member	899-924
	Salado Formation	1041-T.D.
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	1076

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-6a
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1162 (State Engineer's Office)
LOCATION:	283.30' FNL, 274.34' FWL, Sec. 18, T 22 S, R 31 E
ELEVATION:	3347.83' (Top of Casing)
TOTAL DEPTH:	525'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/06/78 **Date Completed:** 07/11/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 72 Cu. Ft.
	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 475 Cement: 155 Cu. Ft.
	Note: Hole in standby condition for hydro tracer tests. 4 1/2" packer set at 594' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder at 608' in the Culebra Dolomite. The hole is dual-completion across the Magenta and Culebra Dolomites.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-6b
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1163 (State Engineer's Office)
LOCATION:	196.34' FNL, 332.96' FWL, Sec 18, T 22 S, R 31 E
ELEVATION:	3348.25' (Top of Casing)
TOTAL DEPTH:	640'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 06/19/78 **Date Completed:** 07/05/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 72 Cu. Ft. Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 590 Cement: 210 Cu. Ft. Note: Hole in standby condition for hydro tracer tests.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-6b	Surficial Deposits	0-12
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-T.D.
	Magenta Dolomite Member	492-511
	Culebra Dolomite Member	604-627
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	640

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-6c**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1164 (State Engineer's Office)
LOCATION:	281.06' FNL, 374.47' FWL, Sec. 18, T 22 S, R 31 E
ELEVATION:	3348.52' (Top of Casing)
TOTAL DEPTH:	741'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 06/19/78 **Date Completed:** 06/26/78
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 72 Cu. Ft. Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: +1.29 To: 699 Cement: 335 Cu. Ft. Note: Bridge plug set at 641'. Perforated from 604' to 631' with 108 holes spaced at 4 holes per foot.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-6c	Surficial Deposits	0-12
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-721
	Magenta Dolomite Member	490-514
	Culebra Dolomite Member	604-627
	Salado Formation	721-T.D.
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	741

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-7a
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08-1271 (State Engineer's Office)
LOCATION:	2495.04' FNL, 2492.35' FWL, Sec. 14, T 23 S, R 30 E
ELEVATION:	3164'
TOTAL DEPTH:	154'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/18/79 **Date Completed:** 10/18/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From:0 To: 38 Cement: 81 Cu. Ft.
	Diameter: 7 Grade: Wt/Ft: 23 From: 0 To: 109 Cement: 265 Cu. Ft.
	Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-7b1
OPERATOR:	Sandia National Lab
PERMIT NO.:	0.08-1272 (State Engineer's Office)
LOCATION:	2565.80' FNL, 2563.45' FWL, Sec. 14, T 23 S, R 30 E
ELEVATION:	3164.17' (Top of Casing)
TOTAL DEPTH:	286'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/13/79 **Date Completed:** 09/18/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 54 Cu. Ft.
	Diameter: 7 Grade: Wt/Ft: 23 From: 0 To: 230 Cement: 270 Cu. Ft.
	Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7b1	Holocene	
	Surficial Deposits	0-5
	Pleistocene	
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-T.D.
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	237-283
	Salado Formation	
	Upper Member	
	Lower Member	
	Castile Formation	
	Total Depth	286

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-7b2
OPERATOR:	Sandia National Labs
PERMIT NO.:	---- (State Engineer's Office)
LOCATION:	2662.16' FNL, 2537.98' FWL, Sec. 14, T 23 S, R 30 E
ELEVATION:	3164.40' (Top of Casing)
TOTAL DEPTH:	295'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/27/83 **Date Completed:** 09/02/83
CASING RECORD:	Diameter: 9 7/8 Grade: Wt/Ft: From: 0 To: 20 Cement: Casing set in cement Diameter: 7 Grade: J-55 Wt/Ft: 20 From: 0 To: 230.19 Cement: Cemented in place
PLUGGING SCHEDULE:	Hole was back filled with peu gravel from 295' to 268' and left open for testing.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7b2	Surficial Deposits	
	Gatuna Formation	57
	Dockum Group	NP
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-T.D.
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	232-280
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	295

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-7c
OPERATOR:	Sandia National Labs
PERMIT NO.:	
LOCATION:	2591.93' FNL, 2467.51' FWL, Sec. 14, T 23 S, R 30 E
ELEVATION:	3164.13 (Top of Casing)
TOTAL DEPTH:	420'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/06/79 **Date Completed:** 11/02/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 68 Cu. Ft.
	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 356 Cement: 706 Cu. Ft.
	Note: Hole in standby condition for testing. Slotted liner installed from 347' to 420'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7c	Holocene	
	Unconsolidated Alluvium and Dune Sand	0-5
	Pleistocene	
	Gatuna Formation	5-57
	Permian	
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-283
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	237-273.5
	Salado Formation	283-420
	Dissolution Residue	283-405
	Top of Salt Interval	405
	Total Depth	420

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-8a
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1274 (State Engineer's Office)
LOCATION:	1962.61' FNL, 1486.59' FEL, Sec. 23, T 24 S, R 30 E
ELEVATION:	3432.99' (Top of Casing)
TOTAL DEPTH:	505'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/07/79 **Date Completed:** 09/18/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 108 Cu. Ft.
	Diameter: 7 Grade: Wt/Ft: 23 From: 0 To: 452 Cement: 393
	Note: Hole in standby condition for testing
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-8b
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1275 (State Engineer's Office)
LOCATION:	1994.76' FNL, 1405.41' FEL, Sec. 23, T 24 S, R 30 E
ELEVATION:	3433.64' (Top of Casing)
TOTAL DEPTH:	624'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/06/79 **Date Completed:** 08/12/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 108 Cu. Ft. Diameter: 7 Grade: Wt/Ft: 20 From: 0 To: 574 Cement: 378 Cu. Ft. Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-8b	Surficial Deposits	0-10
	Gatuna Formation	10-153
	Dockum Group	NP
	Dewey Lake Red Beds	153-399
	Rustler Formation	399-T.D.
	Magenta Dolomite Member	466-490
	Culebra Dolomite Member	586-613
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	624

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-8c
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1276 (State Engineer's Office)
LOCATION:	2059.36' FNL, 1470.14' FEL, Sec. 23, T 24 S, R 30 E
ELEVATION:	3432.90' (Top of Casing)
TOTAL DEPTH:	808'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/27/79 **Date Completed:** 08/06/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 108 Cu. Ft. Diameter: 7 Grade: Wt/Ft: 20 From: 0 To: 734 Cement: 314 Cu. Ft. Note: Hole is standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-8c	Holocene	
	Unconsolidated Alluvium and Eolian Sand	0-4
	Pleistocene Rocks	
	Mescalero Caliche	4-10
	Gatuna Formation	10-153
	Permian	
	Dewey Lake Red Beds	153-399
	Rustler Formation	399-733
	Magenta Dolomite Member	466-488
	Culebra Dolomite Member	588-614
	Salado Formation	733-
	Dissolution Residue	733-774
	MB 103	774-786
	Top of Salt Interval	798
	Total Depth	808

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-9a
OPERATOR:	Sandia National Lab
PERMIT NO.:	0.08.1277 (State Engineer's Office)
LOCATION:	2392.14' FNL, 138.92' FWL, Sec. 4, T 24 S, R 31 E
ELEVATION:	3406.68' (Top of Casing)
TOTAL DEPTH:	692'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/09/79 **Date Completed:** 08/23/83
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 72 Cu. Ft.
	Diameter: 7 Grade: J-55 Wt/Ft: 20 From: 0 To: 570 Cement: 266 Cu. Ft.
	Diameter: 4.5" O.D. Grade: J-55 Wt/Ft: 9.5 From: 0 To: 643 Cement:
	Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-9a	Holocene	
	Surficial Deposits	0-5
	Pleistocene	
	Gatuna Formation	5-25
	Ochoan	
	Dewey Lake Red Beds	25-455
	Rustler Formation	455-T.D.
	Forty-Niner Member	455-523
	Magenta Dolomite Member	523-554
	Tamarisk Member	554-647
	Culebra Dolomite Member	647-677
	Unnamed Part	677-T.D.
	Total Depth	692

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-9b**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1278 (State Engineer's Office)
LOCATION:	2391.04' FNL, 238.63' FWL, Sec. 4, T 24 S, R 31 E
ELEVATION:	3406.86' (Top of Casing)
TOTAL DEPTH:	708'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/14/79 **Date Completed:** 08/28/79
CASING RECORD:	Diameter: 13 3/8 Grade: K-55 Wt/Ft: 48 From: 0 To: 38 Cement: 72 Cu. Ft.
	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 638 Cement: 295 Cu. Ft.
	Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-9b	Surficial Deposits	0-5
	Gatuna Formation	5-25
	Dockum Group	NP
	Dewey Lake Red Beds	24-455
	Rustler Formation	455-T.D.
	Magenta Dolomite Member	523-554
	Culebra Dolomite Member	647-677
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	708

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-9c
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1279 (State Engineer's Office)
LOCATION:	2479.06' FNL, 188.02' FWL, Sec. 4, T 24 S, R 31 E
ELEVATION:	3407.30' (Top of Casing)
TOTAL DEPTH:	816'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/01/79 **Date Completed:** 09/24/79
CASING RECORD:	Diameter: 13 3/8 Grade: K-55 Wt/Ft: 48 From: 0 To: 38 Cement: 72 Cu. Ft.
	Diameter: 7 Grade: J-55 Wt/Ft: 20 From: 0 To: 783 Cement: 320 Cu. Ft.
	Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-10a
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1280 (State Engineer's Office)
LOCATION:	433.0' FSL, 2068.9' FEL, Sec. 20, T 23 S, R 32 E
ELEVATION:	3688.67' (Top of Casing)
TOTAL DEPTH:	1318'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/21/79 **Date Completed:** 08/26/79
CASING RECORD:	Diameter: 13 3/8 Grade: K-55 Wt/Ft: 48 From: 0 To: 38 Cement: 72 Cu. Ft.
	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 1243 Cement: 519 Cu. Ft.
	Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-10b
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1281 (State Engineer's Office)
LOCATION:	484.5' FSL, 1981.8' FEL, Sec. 20, T 23 S, R 32 E
ELEVATION:	3689.47' (Top of Casing)
TOTAL DEPTH:	1398'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 10/07/79 **Date Completed:** 10/13/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 72 Cu. Ft. Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 1346 Cement: 480 Cu. Ft. Note: Hole in standby condition for possible future tests.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-10c
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1282 (State Engineer's Office)
LOCATION:	384.5' FSL, 1981.8 FEL, Sec. 20, T 23 S, R 32 E
ELEVATION:	3687'
TOTAL DEPTH:	1550'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/11/79 **Date Completed:** 08/20/79
CASING RECORD:	Diameter: 13 3/8 Grade: K-55 Wt/Ft: 48 From: 0 To: 38 Cement: 72 Cu. Ft.
	Diameter: 7 Grade: Wt/Ft: 20 From: 0 To: 1483 Cement: 627 Cu. Ft.
	Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-10c	Holocene	
	Unconsolidated Alluvium and Eolian Sand	0-5
	Pleistocene	
	Mescalero Caliche	5-9
	Gatuna Formation	9-90
	Triassic	
	Dockum Group	
	Chinle Formation	90-482
	Santa Rosa Sandstone	482-658
	Permian	
	Dewey Lake Red Beds	658-1204
	Rustler Formation	1204-1501
	Magenta Dolomite Member	1256-1280
	Culebra Dolomite Member	1360-1387
	Salado Formation	1501
	Top of Salt Interval	1501
	Total Depth	1538

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-11b2
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1462 (State Engineer's Office)
LOCATION:	1436.3' FSL, 168.7' FEL, Sec. 33, T 22 S, R 31 E
ELEVATION:	3411.64' (Top of Casing)
TOTAL DEPTH:	776'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 10/83 **Date Completed:** 11/28/83
CASING RECORD:	Diameter: 9 5/8 Grade: H-40 Wt/Ft: 40 From: 0 To: 37 Cement: Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 733.39 Cement: Cemented Note: 4 3/4" open hole from 733.39' to the total depth of 776'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-11b2	Magenta Dolomite Member	618-644
	Culebra Dolomite Member	733-757
	Total Depth	776

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-11b3
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1462 (State Engineer's Office)
LOCATION:	1501.7' FSL, 105.2' FEL, Sec. 33, T 22 S, R 31 E
ELEVATION:	3412.42' (Top of Casing)
TOTAL DEPTH:	788.7' (Below Kelly Bushing)
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 12/01/83 **Date Completed:** 01/84
CASING RECORD:	Diameter: 9 5/8 Grade: H-30 Wt/Ft: 40 From: 0 To: 34 Cement:
	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 55 From: 0 To: 733 Cement:
	Note: 4 3/4" open hole from 733' to the total depth of 788.7'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-11b3	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	
	Rustler Formation	
	Magenta Dolomite Member	616-644
	Culebra Dolomite Member	734-759
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	788.7

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-11b4
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1474 (State Engineer's Office)
LOCATION:	1514.7' FSL, 320.2' FEL, Sec. 33, T 22 S, R 31 E
ELEVATION:	3410.89' (Top of Casing)
TOTAL DEPTH:	765'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 02/23/88 **Date Completed:** 03/17/88
CASING RECORD:	Diameter: 8 5/8 Grade: H-40 Wt/Ft: 28 From: 0 To: 27 Cement: Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 714 Cement: Note: 4 3/4 " open hole from 715' to total depth of 765'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-12**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1463 (State Engineer's Office)
LOCATION:	23.1' FNL, 91.9' FEL, Sec. 15, T 23 S, R 31 E
ELEVATION:	3427.19' (Top of Casing)
TOTAL DEPTH:	1001'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 10/03/83 **Date Completed:** 10/18/83
CASING RECORD:	Diameter: 9 5/8 Grade: H-40 Wt/Ft: 36 From: 0 To: 37 Cement: 63 Cu. Ft. Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: +1.45 To: 820 Cement: Note: 4 3/4 " open hole from 820' to plugged back depth of 890'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-12	Quaternary Deposits	0-10+
	Dockum Group	10+-70
	Dewey Lake Red Beds	70-622
	Rustler Formation	622-976
	Forty-Niner Member	622-678
	Magenta Dolomite Member	678-703
	Tamarisk Member	703-823
	Culebra Dolomite Member	823-850
	Unnamed Lower Member	850-976
	Salado Formation	976-T.D.
	Unnamed Upper Member	976-T.D.
	Total Depth	1001

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-14
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1469 (State Engineer's Office)
LOCATION:	372.2' FSL, 562.4' FWL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3347.11' (Top of Casing)
TOTAL DEPTH:	589'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 10/86 **Date Completed:** 10/86
CASING RECORD:	Diameter: 8.625 Grade: Wt/Ft: 28 From: +1.6 To: 39 Cement:
	Diameter: 5.5 Grade: Wt/Ft: 15.5 From: 0 To: 532 Cement:
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-14	Surficial Deposits	0-13
	Gatuna Formation	13-40
	Dockum Group	NP
	Dewey Lake Red Beds	40-360
	Rustler Formation	360-T.D.
	Magenta Dolomite Member	424-448
	Culebra Dolomite Member	545-572
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	589

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-15
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1470 (State Engineer's Office)
LOCATION:	88.7' FNL, 174.3' FEL, Sec. 28, T 22 S, R 31 E
ELEVATION:	3481.63' (Top of Casing)
TOTAL DEPTH:	900'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 11/86 **Date Completed:** 11/86
CASING RECORD:	Diameter: 8.625 Grade: Wt/Ft: 28 From: 0 To: 39
	Diameter: 5.5 Grade: Wt/Ft: 15.5 From: +1.4 To: 853
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-15	Surficial Deposits	0-8
	Gatuna Formation	4-42
	Dockum Group	42-168
	Dewey Lake Red Beds	168-692
	Rustler Formation	692-T.D.
	Magenta Dolomite Member	748-773
	Culebra Dolomite Member	861-883
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	900

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-16
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1471 (State Engineer's Office)
LOCATION:	1112.6 FSL, 1241.3 FEL, Sec. 20, T 22 S, R 31 E
ELEVATION:	3406.77' (Top of Casing)
TOTAL DEPTH:	850.9'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/13/87 **Date Completed:** 08/18/87
CASING RECORD:	Diameter: 10 3/4 Grade: Wt/Ft: 40.5 From: 0 To: 36.5 Diameter: 7 Grade: Wt/Ft: 23 From: 0 To: 469 Note: 6 1/8" inch open hole from 469' to total depth of 850.9'.
PLUGGING SCHEDULE:	No plugging data. Testing still in progress.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-17
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1477 (State Engineer's Office)
LOCATION:	1465.5' FSL, 994.1' FWL, Sec. 3, T 23 S, R 31 E
ELEVATION:	3385.31' (Top of Casing)
TOTAL DEPTH:	880'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/21/87 **Date Completed:** 11/04/87
CASING RECORD:	Diameter: 10 3/4 Grade: H-40 Wt/Ft: 40.5 From: 0 To: 38 Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 692 Note: 6 1/8" inch open hole from 693' to the plugged back depth of 773'.
PLUGGING SCHEDULE:	The borehole was plugged back with cement grout to a total depth of 773' on 11/06/87.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-17	Quaternary Deposits	
	Holocene	0-15
	Pleistocene	
	Mescalero Caliche	15-21.5
	Upper Triassic	
	Dockum Group	21.5-55
	Upper Permian	
	Dewey Lake Red Beds	55-509
	Rustler Formation	509-855.7
	Forty-Niner Member	509-564
	Magenta Dolomite Member	564-590.8
	Tamarisk Member	590.8-705.8
	Culebra Dolomite Member	705.8-731.4
	Unnamed Lower Member	731.4-855.7
	Salado Formation	855.7-870.3+

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	H-18
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1473 (State Engineer's Office)
LOCATION:	964.8' FNL, 445.6' FWL, Sec. 20, T 22 S, R 31 E
ELEVATION:	3414.21' (Top of Casing)
TOTAL DEPTH:	840'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/29/87 **Date Completed:** 11/16/87
CASING RECORD:	Diameter: 10 3/4 Grade: H-40 Wt/Ft: 40.5 From: 0 To: 39
	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 673
	Note: 6 1/8" inch open hole from 673' to the plugged back depth of 766'.
PLUGGING SCHEDULE:	The borehole was plugged back with cement grout to a total depth of 766' on 11/19/87.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-18	Quaternary Deposits	
	Holocene	
	Drill Pad Material & Unconsolidated Sand	0-5
	Pleistocene	
	Mescalero Caliche	5-8
	Upper Triassic	
	Dockum Group	8-20
	Upper Permian	
	Dewey Lake Red Beds	20-506.1
	Rustler Formation	506.1-820.9
	Forty-Niner Member	506.1-571.2
	Magenta Dolomite	571.2-594.2
	Tamarisk Member	594.2-688.6
	Culebra Dolomite Member	688.6-712.8
	Unnamed Lower Member	712.8-820.9
	Salado Formation	820.9-830.5+

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POTASH BOREHOLE DATA BASE

BOREHOLE:	P-1
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	327' FSL, 551' FWL of Sec. 29, SW 1/4 Sec. 29, T 22 S, R 31 E
ELEVATION:	3345'
TOTAL DEPTH:	1591'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/23/76 **Date Completed:** 09/02/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: 203' of casing left in hole between 591-794' below land surface.
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	358-677'
TOP OF SALADO:	677'
MARKER BED 124:	1477-1486'
PLUGGING SCHEDULE:	From: 1591' To: 0' Int: 1591' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-1	Holocene Deposits	0-10
	Pleistocene Rocks	
	Gatuna Formation	10-40
	Permian Rocks	
	Dewey Lake Red Beds	40-358
	Rustler Formation	358-677
	Magenta Dolomite Member	423-448
	Culebra Dolomite Member	538-565
	Salado Formation	677-1591
	Upper Member	677-1191
	McNutt Potash Zone	1191-1583
	Vaca Triste Sandstone Member	1191-1201
	11th Ore Zone	1246-1250
	MB 117	1259-1262
	MB 118	1282-1285
	MB 119	1307-1309
	10th Ore Zone	1319-1324
	MB 120	1334-1335
	9th Ore Zone	1338-1343
	MB 121	1347-1349
	MB 122	1356-1357
	8th Ore Zone	1361-1370
	Union Anhydrite	1381-1393
	7th Ore Zone	1400-1404
	6th Ore Zone	1414-1416
	5th Ore Zone	1419-1432
	MB 123	1462-1469
	MB 124	1477-1486
	4th Ore Zone	1490-1503
	3d Ore Zone	1511-1526
	2d Ore Zone	1533-1538
	1st Ore Zone	1554-1562
	MB 126	1582-1583
	Lower Member	1583-1587

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-2
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	125' FNL, 172' FEL of Sec. 28, NE1/4 Sec. 28, T 22 S, R 31 E
ELEVATION:	3478'
TOTAL DEPTH:	1895'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/25/76 **Date Completed:** 09/02/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	690-1008'
TOP OF SALADO:	1008'
MARKER BED 124:	1787-1795'
PLUGGING SCHEDULE:	From: 1895' To: 0' Int: 1895' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-2	Holocene Deposits	0-18
	Pleistocene Rocks	
	Gatuna Formation	18-38
	Triassic Rocks	
	Santa Rosa Sandstone	38-164
	Permian Rocks	
	Dewey Lake Red Beds	164-690
	Rustler Formation	690-1008
	Magenta Dolomite Member	748-773
	Culebra Dolomite Member	857-883
	Salado Formation	1008-1895
	Upper Member	1008-1506
	McNutt Potash Zone	1506-1883
	Vaca Triste Sandstone Member	1506-1512
	11th Ore Zone	1562-1565
	MB 117	1574-1576
	MB 118	1599-1601
	MB 119	1622-1626
	10th Ore Zone	1632-1639
	MB 120	1646-1647
	9th Ore Zone	1652-1656
	MB 121	1662-1663
	MB 122	1670-1671
	8th Ore Zone	1678-1687
	Union Anhydrite	1695-1705
	7th Ore Zone	1712-1719
	6th Ore Zone	1731-1733
	5th Ore Zone	1738-1745
	MB 123	1774-1781
	MB 124	1787-1795
	4th Ore Zone	1799-1809
	3d Ore Zone	1818-1832
	2d Ore Zone	1836-1840
	1st Ore Zone	1859-1870
	MB 126	1882-1883
	Lower Member	1883-1894

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-3
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	103' FSL, 3122' FEL of Sec. 20, SW1/4 Sec. 20, T 22 S, R 31 E
ELEVATION:	3382'
TOTAL DEPTH:	1676'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/26/76 **Date Completed:** 09/07/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: 336' of casing left in hole between 490-826' below land surface.
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	468-786'
TOP OF SALADO:	786'
MARKER BED 124:	1571-1579'
PLUGGING SCHEDULE:	From: 1676' To: 0' Int: 1676' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-3	Holocene Deposits	0-10
	Pleistocene rocks	
	Gatuna Formation	10-41
	Permian Rocks	
	Dewey Lake Red Beds	41-468
	Rustler Formation	468-786
	Magenta Dolomite Member	529-553
	Culebra Dolomite Member	642-665
	Salado Formation	786-1668
	Upper Member	786-1287
	McNutt Potash Zone	1287-1668
	Vaca Triste Sandstone Member	1287-1295
	11th Ore Zone	1346-1349
	MB 117	1357-1358
	MB 118	1375-1378
	MB 119	1405-1407
	10th Ore Zone	1415-1420
	MB 120	1428-1429
	9th Ore Zone	1434-1438
	MB 121	1443-1445
	MB 122	1452-1453
	8th Ore Zone	1458-1467
	Union Anhydrite	1473-1481
	7th Ore Zone	1494-1499
	6th Ore Zone	1509-1511
	5th Ore Zone	1515-1525
	MB 123	1555-1563
	MB 124	1571-1579
	4th Ore Zone	1585-1595
	3d Ore Zone	1599-1617
	2d Ore Zone	1623-1627
	1st Ore Zone	1645-1656
	MB 126	1667-1668

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-4
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	146' FSL, 1487' FEL of Sec. 28, SE1/4 Sec. 28, T 22 S, R 31 E
ELEVATION:	3441'
TOTAL DEPTH:	1857'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/28/76 **Date Completed:** 09/04/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water at 850'.
RUSTLER FORMATION:	609-930'
TOP OF SALADO:	930'
MARKER BED 124:	1742-1752'
PLUGGING SCHEDULE:	From: 1857' To: 0' Int: 1857' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-4	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-99
	Permian Rocks	
	Dewey Lake Red Beds	99-609
	Rustler Formation	609-930
	Magenta Dolomite Member	662-686
	Culebra Dolomite Member	775-802
	Salado Formation	930-1857
	Upper Member	930-1446
	McNutt Potash Zone	1446-1853
	Vaca Triste Sandstone Member	1446-1452
	11th Ore Zone	1506-1509
	MB 117	1519-1521
	MB 118	1544-1547
	MB 119	1570-1572
	10th Ore Zone	1581-1589
	MB 120	1596-1597
	9th Ore Zone	1603-1607
	MB 121	1610-1612
	MB 122	1620-1621
	8th Ore Zone	1628-1637
	Union Anhydrite	1646-1659
	7th Ore Zone	1667-1671
	6th Ore Zone	1683-1686
	5th Ore Zone	1690-1700
	MB 123	1728-1735
	MB 124	1742-1752
	4th Ore Zone	1756-1768
	3d Ore Zone	1777-1792
	2d Ore Zone	1798-1803
	1st Ore Zone	1824-1835
	MB 126	1852-1853

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-5
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	202' FSL, 165' FEL of Sec. 17, SE1/4 Sec. 17, T 22 S, R 31 E
ELEVATION:	3472'
TOTAL DEPTH:	1830'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/10/76 **Date Completed:** 09/21/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: 568' of casing left in hole between 435-1003' below land surface.
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	623-947'
TOP OF SALADO:	947'
MARKER BED 124:	1695-1705'
PLUGGING SCHEDULE:	From: 1830' To: 0' Int: 1830' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-5	Holocene deposits	0-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-146
	Permian Rocks	
	Dewey Lake Red Beds	146-623
	Rustler Formation	623-947
	Magenta Dolomite Member	686-711
	Culebra Dolomite Member	804-827
	Salado Formation	947-1830
	Upper Member	947-1429
	McNutt Potash Zone	1429-1785
	Vaca Triste Sandstone Member	1429-1436
	11th Ore Zone	1482-1486
	MB 117	1492-1494
	MB 118	1514-1517
	MB 119	1541-1543
	10th Ore Zone	1550-1556
	MB 120	1560-1561
	9th Ore Zone	1567-1571
	MB 121	1573-1575
	MB 122	1580-1582
	8th Ore Zone	1589-1595
	Union Anhydrite	1604-1611
	7th Ore Zone	1623-1628
	6th Ore Zone	1635-1638
	5th Ore Zone	1643-1659
	MB 123	1680-1687
	MB 124	1695-1705
	4th Ore Zone	1709-1717
	3d Ore Zone	1725-1737
	1st Ore Zone	1742-1746
	MB 126	1784-1785
	Lower Member	1785-1830
	MB 127	1810-1811
	MB 128	1821-1822

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-6
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	2767' FSL, 199' FWL of Sec. 30, NW1/4 Sec. 30, T 22 S, R 31 E
ELEVATION:	3354'
TOTAL DEPTH:	1573'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/03/76 **Date Completed:** 09/16/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	357-659'
TOP OF SALADO:	659'
MARKER BED 124:	1453-1462'
PLUGGING SCHEDULE:	From: 1573' To: 0' Int: 1573' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-6	Holocene Deposits	0-8
	Pleistocene Rocks	
	Gatuna Formation	8-18
	Permian Rocks	
	Dewey Lake Red Beds	18-357
	Rustler Formation	357-659
	Magenta Dolomite Member	417-443
	Culebra Dolomite Member	537-560
	Salado Formation	659-1573
	Upper Member	659-1162
	McNutt Potash Zone	1162-1560
	Vaca Triste Sandstone Member	1162-1170
	11th Ore Zone	1218-1221
	MB 117	1231-1233
	MB 118	1252-1256
	MB 119	1279-1281
	10th Ore Zone	1291-1296
	MB 120	1307-1308
	9th Ore Zone	1313-1317
	MB 121	1324-1326
	MB 122	1332-1333
	8th Ore Zone	1338-1348
	Union Anhydrite	1357-1365
	7th Ore Zone	1378-1382
	6th Ore Zone	1394-1396
	5th Ore Zone	1400-1410
	MB 123	1436-1443
	MB 124	1453-1462
	4th Ore Zone	1468-1481
	3d Ore Zone	1489-1502
	2d Ore Zone	1509-1513
	1st Ore Zone	1533-1543
	MB 126	1559-1560

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-7
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	513' FNL, 396' FWL of Sec. 5, NW1/4 Sec. 5, T 23 S, R 31 E
ELEVATION:	3332'
TOTAL DEPTH:	1574'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/04/76 **Date Completed:** 09/21/76
	Remarks: Encountered air pocket at 980' below land surface, and lost casing seat. Encountered several air pockets between 980-1264'. Lost mud at 1234'.
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: 210' of casing left in hole between 530-740' below land surface.
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	312-630'
TOP OF SALADO:	630'
MARKER BED 124:	1448-1459'
PLUGGING SCHEDULE:	From: 1830' To: 0' Int: 1830' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-7	Holocene Deposits	0-11
	Pleistocene Rocks	
	Gatuna Formation	11-45
	Permian Rocks	
	Dewey Lake Red Beds	45-312
	Rustler Formation	312-630
	Magenta Dolomite Member	373-398
	Culebra Dolomite Member	496-522
	Salado Formation	630-1574
	Upper Member	630-1155
	McNutt Potash Zone	1155-1566
	Vaca Triste Sandstone Member	1155-1162
	11th Ore Zone	1215-1220
	MB 117	1228-1230
	MB 118	1252-1256
	MB 119	1277-1279
	10th Ore Zone	1291-1296
	MB 120	1307-1308
	9th Ore Zone	1312-1316
	MB 121	1326-1328
	MB 122	1330-1331
	8th Ore Zone	1335-1346
	Union Anhydrite	1358-1372
	7th Ore Zone	1377-1382
	6th Ore Zone	1391-1393
	5th Ore Zone	1398-1407
	MB 123	1433-1441
	MB 124	1448-1459
	4th Ore Zone	1467-1484
	3d Ore Zone	1492-1507
	2d Ore Zone	1513-1518
	1st Ore Zone	1537-1547
	MB 126	1565-1566

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-8
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	642' FNL, 96' FWL of Sec. 4, NW1/4 Sec. 4, T 23 S, R 31 E
ELEVATION:	3336'
TOTAL DEPTH:	1660'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/08/76 **Date Completed:** 09/15/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	No water reported by driller.
RUSTLER FORMATION:	391-715'
TOP OF SALADO:	715'
MARKER BED 124:	1537-1545'
PLUGGING SCHEDULE:	From: 1660' To: 0' Int: 1660' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-8	Holocene Deposits	0-9
	Pleistocene Rocks	
	Gatuna Formation	9-39
	Permian Rocks	
	Dewey Lake Red Beds	39-391
	Rustler Formation	391-715
	Magenta Dolomite Member	450-474
	Culebra Dolomite Member	563-585
	Salado Formation	715-1660
	Upper Member	715-1237
	McNutt Potash Zone	1237-1652
	Vaca Triste Sandstone Member	1237-1245
	11th Ore Zone	1297-1301
	MB 117	1308-1310
	MB 118	1333-1337
	MB 119	1360-1362
	10th Ore Zone	1373-1380
	MB 120	1389-1390
	9th Ore Zone	1395-1399
	MB 121	1405-1407
	MB 122	1413-1414
	8th Ore Zone	1421-1430
	Union Anhydrite	1440-1455
	7th Ore Zone	1461-1465
	6th Ore Zone	1472-1475
	5th Ore Zone	1481-1492
	MB 123	1517-1524
	MB 124	1537-1545
	4th Ore Zone	1554-1567
	3d Ore Zone	1577-1596
	2d Ore Zone	1601-1604
	1st Ore Zone	1624-1633
	MB 126	1661-1662

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-9
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	1493' FSL, 143' FEL of Sec. 33, SE1/4 Sec. 33, T 22 S, R 31 E
ELEVATION:	3409'
TOTAL DEPTH:	1796'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/16/76 **Date Completed:** 09/25/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water at 220' below land surface, making about 25 gpm.
RUSTLER FORMATION:	562-881'
TOP OF SALADO:	881'
MARKER BED 124:	1686-1695'
PLUGGING SCHEDULE:	From: 1796' To: 0' Int: 1796' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-9	Holocene Deposit	0-11
	Triassic Rocks	
	Santa Rosa Sandstone	11-66
	Permian Rocks	
	Dewey Lake Red Beds	66-562
	Rustler Formation	562-881
	Magenta Dolomite Member	617-644
	Culebra Dolomite Member	734-757
	Salado Formation	881-1796
	Upper Member	881-1401
	McNutt Potash Zone	1401-1796
	Vaca Triste Sandstone Member	1401-1410
	11th Ore Zone	1458-1462
	MB 117	1471-1473
	MB 118	1496-1499
	MB 119	1519-1521
	10th Ore Zone	1530-1538
	MB 120	1546-1547
	9th Ore Zone	1552-1555
	MB 121	1561-1563
	MB 122	1569-1570
	8th Ore Zone	1577-1585
	Union Anhydrite	1597-1608
	7th Ore Zone	1613-1618
	6th Ore Zone	1626-1629
	5th Ore Zone	1634-1643
	MB 123	1668-1676
	MB 124	1686-1695
	4th Ore Zone	1699-1714
	3d Ore Zone	1723-1738
	2d Ore Zone	1744-1748
	1st Ore Zone	1769-1778
	MB 126	1795-1796

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-10
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	2315' FNL, 339' FWL of Sec. 26, NW1/4 Sec. 26, T 22 S, R 31 E
ELEVATION:	3508'
TOTAL DEPTH:	2009'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/24/76 **Date Completed:** 10/15/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	686-1086'
TOP OF SALADO:	1086'
MARKER BED 124:	1880-1888'
PLUGGING SCHEDULE:	From: 2009' To: 0' Int: 2009' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-10	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-151
	Permian Rocks	
	Dewey Lake Red Beds	151-686
	Rustler Formation	686-1086
	Magenta Dolomite Member	757-781
	Culebra Dolomite Member	931-957
	Salado Formation	1086-2009
	Upper Member	1086-1594
	McNutt Potash Zone	1594-1983
	Vaca Triste Sandstone Member	1594-1603
	11th Ore Zone	1652-1655
	MB 117	1662-1664
	MB 118	1686-1688
	MB 119	1710-1712
	10th Ore Zone	1717-1725
	MB 120	1733-1734
	9th Ore Zone	1740-1744
	MB 121	1751-1753
	MB 122	1759-1760
	8th Ore Zone	1765-1775
	Union Anhydrite	1784-1798
	7th Ore Zone	1807-1811
	6th Ore Zone	1822-1825
	5th Ore Zone	1831-1841
	MB 123	1868-1875
	MB 124	1880-1888
	4th Ore Zone	1892-1905
	3d Ore Zone	1913-1929
	2d Ore Zone	1934-1938
	1st Ore Zone	1961-1969
	MB 126	1982-1983
	Lower Member	1983-2009
	MB 127	2005-2008

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-11
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	175' FNL and 177' FWL of Sec. 23, NW1/4 Sec. 23, T 22 S, R 31 E
ELEVATION:	3506'
TOTAL DEPTH:	1940'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/24/76 **Date Completed:** 10/16/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	745-1058'
TOP OF SALADO:	1058'
MARKER BED 124:	1824-1833'
PLUGGING SCHEDULE:	From: 1940' To: 0' Int: 1940' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-11	Holocene Deposits	0-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-224
	Permian Rocks	
	Dewey Lake Red Beds	224-745
	Rustler Formation	745-1058
	Magenta Dolomite Member	798-823
	Culebra Dolomite Member	912-938
	Salado Formation	1058-1942
	Upper Member	1058-1550
	McNutt Potash Zone	1550-1917
	Vaca Triste Sandstone Member	1550-1557
	11th Ore Zone	1604-1608
	MB 117	1616-1618
	MB 118	1640-1642
	MB 119	1664-1666
	10th Ore Zone	1674-1682
	MB 120	1687-1688
	9th Ore Zone	1693-1698
	MB 121	1702-1704
	MB 122	1711-1712
	8th Ore Zone	1717-1724
	Union Anhydrite	1735-1740
	7th Ore Zone	1754-1759
	6th Ore Zone	1767-1770
	5th Ore Zone	1775-1785
	MB 123	1811-1818
	MB 124	1824-1833
	4th Ore Zone	1837-1846
	3d Ore Zone	1853-1866
	2d Ore Zone	1871-1874
	1st Ore Zone	1890-1901
	MB 126	1916-1917
	Lower Member	1917-1942
	MB 127	1940-1941

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-12
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	167' FNL, 195' FEL of Sec. 24, NE1/4 Sec. 24, T 22 S, R 30 E
ELEVATION:	3376'
TOTAL DEPTH:	1598'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/17/76 **Date Completed:** 10/20/76
	Remarks: Lost circulation at 742' and 813' below land.
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	461-749'
TOP OF SALADO:	749'
MARKER BED 124:	1494-1509'
PLUGGING SCHEDULE:	From: 1598' To: 0' Int: 1598' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-12	Holocene Deposits	0-8
	Permian Rocks	
	Dewey Lake Red Beds	8-461
	Rustler Formation	461-749
	Magenta Dolomite Member	519-543
	Culebra Dolomite Member	633-656
	Salado Formation	749-1598
	Upper Member	749-1226
	McNutt Potash Zone	1226-1597
	Vaca Triste Sandstone Member	1226-1233
	11th Ore Zone	1280-1284
	MB 117	1290-1292
	MB 118	1314-1317
	MB 119	1338-1340
	10th Ore Zone	1346-1353
	MB 120	1361-1362
	9th Ore Zone	1367-1370
	MB 121	1376-1378
	MB 122	1384-1385
	8th Ore Zone	1390-1398
	Union Anhydrite	1407-1417
	7th Ore Zone	1432-1436
	6th Ore Zone	1442-1445
	5th Ore Zone	1450-1459
	MB 123	1486-1492
	MB 124	1494-1509
	4th Ore Zone	1514-1523
	3d Ore Zone	1533-1546
	2d Ore Zone	1550-1555
	1st Ore Zone	1572-1582
	MB 126	1596-1597

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-13
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	125' FNL, 116' FWL of Sec. 18, NW1/4 Sec. 18, T 22 S, R 31 E
ELEVATION:	3345'
TOTAL DEPTH:	1576'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/17/76 **Date Completed:** 09/23/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Hit water at 630'.
RUSTLER FORMATION:	427-721'
TOP OF SALADO:	721'
MARKER BED 124:	1462-1471'
PLUGGING SCHEDULE:	From: 1576' To: 0' Int: 1576' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-13	Holocene Deposits	0-12
	Pleistocene Rocks	
	Gatuna Formation	12-38
	Permian Rocks	
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-721
	Magenta Dolomite Member	490-514
	Culebra Dolomite Member	604-627
	Salado Formation	721-1573
	Upper Member	721-1201
	McNutt Potash Zone	1201-1547
	Vaca Triste Sandstone Member	1201-1208
	11th Ore Zone	1252-1255
	MB 117	1264-1265
	MB 118	1287-1289
	MB 119	1309-1311
	10th Ore Zone	1317-1323
	MB 120	1330-1331
	9th Ore Zone	1336-1340
	MB 121	1344-1346
	MB 122	1355-1356
	8th Ore Zone	1359-1368
	Union Anhydrite	1377-1382
	7th Ore Zone	1395-1400
	6th Ore Zone	1407-1410
	5th Ore Zone	1413-1423
	MB 123	1447-1453
	MB 124	1462-1471
	4th Ore Zone	1474-1483
	3d Ore Zone	1491-1501
	2d Ore Zone	1506-1510
	1st Ore Zone	1525-1533
	MB 126	1547-1548
	Lower Member	1548-1573
	MB 127	1572-1573

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-14
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	307' FSL, 615.8' FWL of Sec. 24, SW1/4 Sec. 24, T 22 S, R 30 E
ELEVATION:	3358'
TOTAL DEPTH:	1545'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/24/76 **Date Completed:** 10/03/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Hit water at 589'.
RUSTLER FORMATION:	387-687'
TOP OF SALADO:	687'
MARKER BED 124:	1410-1419'
PLUGGING SCHEDULE:	From: 1545' To: 775' Int: 770' Material: Cement From: 775' To: 0' Int: 775' Material: Well Note: Hole plugged from 1545'-775' with cement and converted to hydrologic observation well in Rustler Formation.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-14	Holocene Deposits	0-10
	Pleistocene Rocks	
	Gatuna Formation	10-42
	Permian Rocks	
	Dewey Lake Red Beds	42-387
	Rustler Formation	387-687
	Magenta Dolomite Member	453-475
	Culebra Dolomite Member	573-595
	Salado Formation	687-1540
	Upper Member	687-1133
	McNutt Potash Zone	1133-1510
	Vaca Triste Sandstone Member	1133-1141
	11th Ore Zone	1186-1190
	MB 117	1199-1200
	MB 118	1225-1228
	MB 119	1251-1253
	10th Ore Zone	1257-1263
	MB 120	1273-1274
	9th Ore Zone	1277-1282
	MB 121	1287-1289
	MB 122	1297-1298
	8th Ore Zone	1302-1310
	Union Anhydrite	1319-1328
	7th Ore Zone	1342-1345
	6th Ore Zone	1352-1355
	5th Ore Zone	1361-1370
	MB 123	1394-1400
	MB 124	1410-1419
	4th Ore Zone	1423-1435
	3d Ore Zone	1443-1455
	2d Ore Zone	1461-1465
	1st Ore Zone	1482-1492
	MB 126	1509-1510
	Lower Member	1510-1540
	MB 127	1534-1536

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-15
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	410.8' FSL, 192.32' FWL of Sec. 21, SW1/4 Sec. 31, T 22 S, R 31 E
ELEVATION:	3309.7'
TOTAL DEPTH:	1465'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 10/04/76 **Date Completed:** 10/14/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2": Casing Unknown Recovered: 210' of casing left in hole between 530-740' below land surface.
WATER HORIZONS:	
RUSTLER FORMATION:	
TOP OF SALADO:	
MARKER BED 124:	
PLUGGING SCHEDULE:	From: 1465' To: 620' Int: 845' Material: Cement From: 620' To: 0' Int: 620' Material: Well Note: Hole plugged from 1465'-620' with cement, and converted to hydrologic observation well in Rustler Formation.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-15	Holocene Deposits	0-11
	Pleistocene Rocks	
	Gatuna Formation	11-32
	Permian Rocks	
	Dewey Lake Red Beds	32-231
	Rustler Formation	231-542
	Magenta Dolomite Member	294-321
	Culebra Dolomite Member	413-435
	Salado Formation	542-1465
	Upper Member	542-1057
	McNutt Potash Zone	1057-1453
	Vaca Triste Sandstone Member	1057-1065
	11th Ore Zone	1116-1119
	MB 117	1128-1130
	MB 118	1149-1152
	MB 119	1176-1178
	10th Ore Zone	1187-1195
	MB 120	1203-1204
	9th Ore Zone	1208-1212
	MB 121	1216-1218
	MB 122	1225-1226
	8th Ore Zone	1234-1244
	Union Anhydrite	1251-1263
	7th Ore Zone	1271-1275
	6th Ore Zone	1284-1288
	5th Ore Zone	1292-1301
	MB 123	1326-1333
	MB 124	1343-1353
	4th Ore Zone	1361-1376
	3d Ore Zone	1384-1397
	2d Ore Zone	1404-1408
	1st Ore Zone	1426-1436
	MB 126	1452-1453

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-16
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	951' FSL, 1629' FEL of Sec. 5, SW1/4 Sec. 5, T 23S, R 31E
ELEVATION:	3323'
TOTAL DEPTH:	1585'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/27/76 **Date Completed:** 10/05/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	316-646'
TOP OF SALADO:	646'
MARKER BED 124:	1460-1470"
PLUGGING SCHEDULE:	From: 1585' To: 0' Int: 1585' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-16	Holocene Deposits	0-14
	Pleistocene Rocks	
	Gatuna Formation	14-32
	Permian Rocks	
	Dewey Lake Red Beds	32-316
	Rustler Formation	316-646
	Magenta Dolomite Member	376-401
	Culebra Dolomite Member	500-523
	Salado Formation	646-1587
	Upper Member	646-1174
	McNutt Potash Zone	1174-1585
	Vaca Triste Sandstone Member	1174-1182
	11th Ore Zone	1235-1237
	MB 117	1245-1247
	MB 118	1269-1273
	MB 119	1293-1295
	10th Ore Zone	1307-1313
	MB 120	1323-1324
	9th Ore Zone	1328-1331
	MB 121	1336-1338
	MB 122	1345-1346
	8th Ore Zone	1352-1365
	Union Anhydrite	1373-1390
	7th Ore Zone	1396-1400
	6th Ore Zone	1411-1412
	5th Ore Zone	1417-1425
	MB 123	1450-1456
	MB 124	1460-1470
	4th Ore Zone	1480-1501
	3d Ore Zone	1510-1526
	2d Ore Zone	1533-1536
	1st Ore Zone	1556-1568
	MB 126	1583-1585

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-17
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	1372.2' FSL, 401.9' FWL of Sec. 4, SW1/4 Sec. 4, T 23 S, R 31 E
ELEVATION:	3340'
TOTAL DEPTH:	1660'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 10/18/76 **Date Completed:** 10/26/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: Unknown
WATER HORIZONS:	Hit water at 265' and at 600'.
RUSTLER FORMATION:	382-715'
TOP OF SALADO:	715'
MARKER BED 124:	1527-1535'
PLUGGING SCHEDULE:	From: 1660' To: 731' Int: 929' Material: Cement From: 731' To: 0' Int: 731' Material: Well Note: Hole plugged from 1660'-731 with cement and converted to hydrologic observation well in Rustler Formation.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-17	Holocene Deposits	0-14
	Pleistocene Rocks	
	Gatuna Formation	14-46
	Permian Rocks	
	Dewey Lake Red Beds	46-382
	Rustler Formation	382-715
	Magenta Dolomite Member	438-463
	Culebra Dolomite Member	558-583
	Salado Formation	715-1662
	Upper Member	715-1234
	McNutt Potash Zone	1234-1648
	Vaca Triste Sandstone Member	1234-1242
	11th Ore Zone	1294-1299
	MB 117	1306-1308
	MB 118	1330-1334
	MB 119	1358-1359
	10th Ore Zone	1368-1376
	MB 120	1387-1388
	9th Ore Zone	1391-1396
	MB 121	1402-1404
	MB 122	1410-1411
	8th Ore Zone	1418-1428
	Union Anhydrite	1438-1453
	7th Ore Zone	1456-1461
	6th Ore Zone	1471-1474
	5th Ore Zone	1478-1487
	MB 123	1513-1521
	MB 124	1527-1535
	4th Ore Zone	1544-1563
	3d Ore Zone	1573-1587
	2d Ore Zone	1594-1599
	1st Ore Zone	1619-1630
	MB 126	1647-1648

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-18
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	138.5' FSL, 732.7' FEL of Sec. 26, SE1/4 Sec. 26, T 22 S, R 31 E
ELEVATION:	3479'
TOTAL DEPTH:	1998'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 10/19/76 **Date Completed:** 11/05/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: Unknown
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	626-1088'
TOP OF SALADO:	1088'
MARKER BED 124:	1880-1889'
PLUGGING SCHEDULE:	From: 1998' To: 1125' Int: 873' Material: Cement From: 1125' To: 0' Int: 1125' Material: Well Note: Hole plugged from 1998-1125' with cement, and converted to hydrologic observation well in Rustler Formation.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-18	Holocene Deposits	0-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-87
	Permian Rocks	
	Dewey Lake Red Beds	87-626
	Rustler Formation	626-1088
	Magenta Dolomite Member	704-730
	Culebra Dolomite Member	909-938
	Salado Formation	1088-2000
	Upper Member	1088-1604
	McNutt Potash Zone	1604-1987
	Vaca Triste Sandstone Member	1604-1614
	11th Ore Zone	1658-1662
	MB 117	1670-1672
	MB 118	1692-1694
	MB 119	1716-1718
	10th Ore Zone	1726-1734
	MB 120	1741-1742
	9th Ore Zone	1749-1752
	MB 121	1756-1758
	MB 122	1765-1766
	8th Ore Zone	1772-1783
	Union Anhydrite	1793-1808
	7th Ore Zone	1812-1817
	6th Ore Zone	1828-1830
	5th Ore Zone	1835-1844
	MB 123	1868-1875
	MB 124	1880-1889
	4th Ore Zone	1897-1910
	3d Ore Zone	1919-1933
	2d Ore Zone	1938-1942
	1st Ore Zone	1961-1972
	MB 126	1986-1987

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-19
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	1652' FSL, 2330' FWL of Sec. 23, SW1/4 Sec. 23, T 22 S, R 31 E
ELEVATION:	3546.3'
TOTAL DEPTH:	2000'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 10/19/76 **Date Completed:** 11/04/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	
RUSTLER FORMATION:	
TOP OF SALADO:	
MARKER BED 124:	
PLUGGING SCHEDULE:	From: 2000' To: 0' Int: 2000' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-19	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-232
	Permian Rocks	
	Dewey Lake Red Beds	232-758
	Rustler Formation	758-1117
	Magenta Dolomite Member	814-839
	Culebra Dolomite Member	967-997
	Salado Formation	1117-2002
	Upper Member	1117-1621
	McNutt Potash Zone	1621-2011
	Vaca Triste Sandstone Member	1621-1628
	11th Ore Zone	1677-1681
	MB 117	1688-1690
	MB 118	1711-1713
	MB 119	1735-1737
	10th Ore Zone	1745-1753
	MB 120	1760-1761
	9th Ore Zone	1767-1771
	MB 121	1776-1778
	MB 122	1785-1786
	8th Ore Zone	1792-1801
	Union Anhydrite	1812-1822
	7th Ore Zone	1835-1840
	6th Ore Zone	1850-1854
	5th Ore Zone	1858-1872
	MB 123	1892-1901
	MB 124	1909-1917
	4th Ore Zone	1923-1933
	3d Ore Zone	1944-1955
	2d Ore Zone	1962-1967
	1st Ore Zone	1983-1994

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-20
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	794' FSL, 103' FEL of Sec. 14, SE1/4 Sec. 14, T 22 S, R 31 E
ELEVATION:	3552.9'
TOTAL DEPTH:	1995'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 10/06/76 **Date Completed:** 10/14/76
	Remarks: Very weak air flow noted during logging operation on October 14, 1976. Air pocket escaped detection throughout coring operation. Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	
RUSTLER FORMATION:	
TOP OF SALADO:	
MARKER BED 124:	
PLUGGING SCHEDULE:	From: 1995' To: 0' Int: 1995' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-20	Holocene Deposits	0-6
	Triassic Rocks	
	Santa Rosa Sandstone	6-261
	Permian Rocks	
	Dewey Lake Red Beds	261-780
	Rustler Formation	780-1103
	Magenta Dolomite Member	839-866
	Culebra Dolomite Member	953-979
	Salado Formation	1103-1996
	Upper Member	1103-1604
	McNutt Potash Zone	1604-1977
	Vaca Triste Sandstone Member	1604-1612
	11th Ore Zone	1658-1662
	MB 117	1671-1673
	MB 118	1696-1697
	MB 119	1720-1721
	10th Ore Zone	1728-1735
	MB 120	1742-1743
	9th Ore Zone	1747-1750
	MB 121	1756-1758
	MB 122	1764-1765
	8th Ore Zone	1771-1779
	Union Anhydrite	1789-1795
	7th Ore Zone	1807-1811
	6th Ore Zone	1821-1823
	5th Ore Zone	1828-1839
	MB 123	1866-1873
	MB 124	1880-1891
	4th Ore Zone	1893-1904
	3d Ore Zone	1911-1924
	2d Ore Zone	1928-1932
	1st Ore Zone	1947-1961
	MB 126	1975-1977
	Lower Member	1977-1996

POTASH BOREHOLE DATA BASE

BOREHOLE:	P-21
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	852' FNL, 150' FEL of Sec. 15, NE1/4 Sec. 15, T 22 S, R 31 E
ELEVATION:	3510'
TOTAL DEPTH:	1915'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 10/15/76 **Date Completed:** 10/26/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water between 525-595'.
RUSTLER FORMATION:	734-1043'
TOP OF SALADO:	1043'
MARKER BED 124:	1796-1805'
PLUGGING SCHEDULE:	From: 1915' To: 0' Int: 1915' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-21	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-225
	Permian Rocks	
	Dewey Lake Red Beds	225-734
	Rustler Formation	734-1043
	Magenta Dolomite Member	788-812
	Culebra Dolomite Member	899-924
	Salado Formation	1043-1918
	Upper Member	1043-1526
	McNutt Potash Zone	1526-1887
	Vaca Triste Sandstone Member	1526-1533
	11th Ore Zone	1579-1583
	MB 117	1591-1593
	MB 118	1615-1616
	MB 119	1637-1638
	10th Ore Zone	1647-1653
	MB 120	1659-1660
	9th Ore Zone	1665-1669
	MB 121	1676-1678
	MB 122	1685-1686
	8th Ore Zone	1690-1699
	Union Anhydrite	1707-1714
	7th Ore Zone	1727-1732
	6th Ore Zone	1740-1744
	5th Ore Zone	1748-1757
	MB 123	1781-1789
	MB 124	1796-1805
	4th Ore Zone	1811-1817
	3d Ore Zone	1824-1837
	2d Ore Zone	1841-1845
	1st Ore Zone	1859-1873
	MB 126	1886-1887
	Lower Member	1887-1918
	MB 127	1912-1913

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-1
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499833.57, E666341.70
ELEVATION:	3412.48'
TOTAL DEPTH:	58.2'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/29/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/27/78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-1	Silty Sand, Sand	0-9.5
	Caliche	9.5-14.5
	Gatuna	14.5-38
	(Santa Rosa) Sandstone	38-58.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-1A
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499833.20, E666356.32
ELEVATION:	3412.48'
TOTAL DEPTH:	12.9'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/29/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/29/78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D, 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-1A	Sand	0-11.2
	Caliche	11.2-12.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-2
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499835.35, E666841.60
ELEVATION:	3411.62'
TOTAL DEPTH:	33.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/22/78 **Date Completed:** 11/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D, 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-2	Sand	0-6.5
	Caliche	6.5-15.5
	Gatuna	15.5-23
	Siltstone	23-30.6
	Intercalated Sandstone and Soil	30.6-33.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-3
OPERATOR:	Sergent. Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499837.13, E667341.49
ELEVATION:	3415.33'
TOTAL DEPTH:	29'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/18/78 **Date Completed:** 12/18/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed wtih 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-3	Sand	0-7.8
	Caliche	7.8-14
	Gatuna	14-24.2
	Siltstone	24.2-25
	Sandstone	25-28
	Siltstone	28-29

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-4
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499838.91, E667841.39
ELEVATION:	3417.08'
TOTAL DEPTH:	38.8'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/18/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/17/78 **Date Completed:** 12/18/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and wither air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-4	Silty Sand	0-8.5
	Caliche	8.5-19
	Gatuna	19-37
	Claystone	37-38.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-4A
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499837.97, E667829.91
ELEVATION:	3417.08'
TOTAL DEPTH:	13.6'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/19/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/19/78 **Date Completed:** 12/19/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds of downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-4A	Silty Sand	0-11.5
	Caliche	11.5-13.6

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-5
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499840.69, E668341.29
ELEVATION:	3417.43'
TOTAL DEPTH:	32.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/17/78 **Date Completed:** 12/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-5	Silty Sand	0-8.2
	Caliche	8.2-17
	Gatuna	17-22.4
	Sandsone	22.4-26.9
	Intercalated Siltstone	26.9-32.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-6
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499842.47, E668841.15
ELEVATION:	3422.01'
TOTAL DEPTH:	26.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/17/78 **Date Completed:** 12/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-6	Silty Sand	0-3.5
	Caliche	3.5-10.1
	Gatuna	10.1-26.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-7
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499333.68, E666343.48
ELEVATION:	3404.19'
TOTAL DEPTH:	34.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/21/78 **Date Completed:** 11/21/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-7	Sand	0-5.5
	Caliche	5.5-20
	Gatuna	20-25
	Sandstone	25-27.5
	Santa Rosa	27.5-34.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-8
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.46, E666843.36
ELEVATION:	3408.55'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/03/79 **Date Completed:** 01/03/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-8	Sand	0-7
	Caliche	7-12
	Gatuna	12-35.7
	Santa Rosa	35.7-40
	Dewey Lake	40-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-9
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499337.27, E667343.26
ELEVATION:	3410.47'
TOTAL DEPTH:	38.3
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/19/78 **Date Completed:** 12/19/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test corings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-9	Sand	0-8.1
	Caliche	8.1-18
	Gatuna	18-32.1
	Siltstone	32.1-36
	Sandstone	36-38.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-10**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499339.05, E6678434.11
ELEVATION:	3413'
TOTAL DEPTH:	32'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/19/78 **Date Completed:** 12/19/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-10	Sand	0-10.2
	Caliche	10.2-17
	Gatuna	17-26.5
	Siltstone	26.3-27
	Sandstone	27-32

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-11**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499340.83, E668343.05
ELEVATION:	3414.30'
TOTAL DEPTH:	30'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/15/78 **Date Completed:** 12/15/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-11	Sand	1.2-4.1
	Caliche	4.1-13.5
	Gatuna	13.5-30

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-12**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499342.61, E668842.93
ELEVATION:	3421.77'
TOTAL DEPTH:	41.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/01/78 **Date Completed:** 12/01/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-12	Sand	0-6
	Caliche	6-13
	Gatuna	13-20
	Sandstone	20-26
	Claystone	26-27
	Sandstone	27-31.5
	Claystone	31.5-33.5
	Sandstone	33.5-38.5
	Intercalated Sandstone	38.5-41.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-13
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498833.82, E666345.25
ELEVATION:	3403.91'
TOTAL DEPTH:	28.3'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/12/78 **Date Completed:** 12/16/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-13	Sand	0-7
	Caliche	7-12.5
	Gatuna	12.5-26
	Claystone	26-28.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-14
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498835.60, E666845.14
ELEVATION:	3406.57'
TOTAL DEPTH:	24.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/13/78 **Date Completed:** 12/13/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-14	Sand	0-4.8
	Caliche	4.8-9.9
	Gatuna	9.9-14
	Claystone	14-24.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-15
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498837.40, E667345.06
ELEVATION:	3408.64'
TOTAL DEPTH:	56.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/16/78 **Date Completed:** 11/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-15	Sand	0-9
	Caliche	9-13
	Silty Sand	13-26
	Gatuna	26-51.5
	Santa Rosa	51.5-55
	Shale	54.5-56.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-16
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498839.19, E667844.94
ELEVATION:	3411.21'
TOTAL DEPTH:	31'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/15/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/14/78 **Date Completed:** 12/15/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-16	Sand	0-7
	Caliche	7-15
	Gatuna	15-31

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-17
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498840.97, E668343.86
ELEVATION:	3413.26'
TOTAL DEPTH:	25.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/13/78 **Date Completed:** 12/13/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-17	Silty Sand	0-5.1
	Caliche	5.1-10.5
	Gatuna	10.5-25.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-18
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498842.75, E668844.75
ELEVATION:	3419.32'
TOTAL DEPTH:	33.3'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/15/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/14/78 **Date Completed:** 12/15/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-18	Sand	0-7.1
	Caliche	7.1-15
	Gatuna	15-33.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-19
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498333.94, E666347.03
ELEVATION:	3399.84'
TOTAL DEPTH:	38.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/30/78 **Date Completed:** 11/30/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-19	Sand	0-8.5
	Caliche	8.5-18.5
	Gatuna	18.5-21.1
	Sandstone	21.1-38.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-20
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498335.72, E666846.91
ELEVATION:	3403.53'
TOTAL DEPTH:	14'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/12/78 **Date Completed:** 12/16/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-20	Sand	0-10
	Caliche	10-14

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-20A
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498341.34, E666847.10
ELEVATION:	3403.53'
TOTAL DEPTH:	34.2'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/12/78 **Date Completed:** 12/16/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-20A	Sand	0-13.9
	Caliche	13.9-19
	Gatuna	19-34.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-21**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498337.50, E667346.75
ELEVATION:	3404.55'
TOTAL DEPTH:	40.4'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/17/78 **Date Completed:** 11/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-21	Sand	0-9.5
	Caliche	9.5-20
	Gatuna	20-32.5
	Sandstone	32.5-40.4

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-22
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498339.28, E667846.73
ELEVATION:	3406.85'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/11/78 **Date Completed:** 12/11/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-22	Sand	0-7.5
	Caliche	7.5-13
	Gatuna	13-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-23
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498341.06, E668346.63
ELEVATION:	3412.07'
TOTAL DEPTH:	40.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/06/78 **Date Completed:** 12/06/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-23	Sand	0-6
	Caliche	6-14.3
	Gatuna	14.3-40.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-24**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498342.84, E668846.53
ELEVATION:	3417.87'
TOTAL DEPTH:	29.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/07/78 **Date Completed:** 12/07/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-24	Sand	0-5.5
	Caliche	5.5-12
	Gatuna	12-29.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-25
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499414.91, E666693.11
ELEVATION:	3408.19'
TOTAL DEPTH:	901.8'
TYPE OF WELL:	Deep Exploratory Drilling
DRILLER:	Gil's Drilling Co.
DRILLING RECORD:	**Date Started:** 12/01/78 **Date Completed:** 01/18/79
CASING RECORD:	Drilling Equipment: GD-2000 drill.
PLUGGING SCHEDULE:	From: 909' To: 750.4' Interval: 158.6' Material: Salt Grout From: 750.4' To: 466' Interval: 284.4' Material: Freshwater Grout From: 466' To: 20' Interval: 446' Material: Sand From: 20' To: Surface Interval: 20' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-25	Sand	0-10
	Caliche	10-14
	Gatuna	14-34.7
	Santa Rosa	34.7-44.8
	Dewey Lake	44.8-533
	Rustler Formation	533-842.9
	Magenta Member	592.7-617
	Culebra Member	704.1-728
	Salado Formation	842.9-901.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-26
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499600.58, E666892.43
ELEVATION:	3410.19'
TOTAL DEPTH:	27.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/03/79 **Date Completed:** 01/03/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-26	Sand	0-5
	Caliche	5-11
	Gatuna	11-23
	Siltstone	23-27.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-27
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498982.08, E665854.70
ELEVATION:	3400.20'
TOTAL DEPTH:	25.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/11/79 **Date Completed:** 01/11/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-27	Sand	0-4
	Caliche	4-11
	Gatuna	11-22
	Sandstone	22-22.5
	Claystone	22.5-23
	Sandstone	23-24
	Intercalated Sandstone	24-25.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-28
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499295.02, E666718.53
ELEVATION:	3408.17'
TOTAL DEPTH:	27'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/04/79 **Date Completed:** 01/04/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-28	Sand	0-6
	Caliche	6-12
	Gatuna	12-21
	Sandstone	21-27

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-29
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499397.21, E667253.07
ELEVATION:	3410.87'
TOTAL DEPTH:	28.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/30/78 **Date Completed:** 12/30/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-29	Sand	0-13
	Gatuna	13-28.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-30
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499185.81, E666933.86
ELEVATION:	3408.75'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/28/78 **Date Completed:** 12/28/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-30	Sand	0-7.5
	Caliche	7.5-11.5
	Gatuna	11.5-17.6
	Sandstone	17.6-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-31
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499206.60, E667143.76
ELEVATION:	3410.27
TOTAL DEPTH:	30.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/29//78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-31	Sand	0-7.8
	Caliche	7.8-13.4
	Gatuna	13.4-30.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-32**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499187.96, E667523.76
ELEVATION:	3410.89'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/07/79 **Date Completed:** 01/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-32	Sand	0-12.5
	Caliche	12.5-19.5
	Gatuna	19.5-26.5
	Siltstone & Claystone	26.5-43
	Santa Rosa	43-53
	Dewey Lake	53-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-33**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498874.29, E666470.03
ELEVATION:	3404.05'
TOTAL DEPTH:	30.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/29/78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide curring faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-33	Sand	0-6.7
	Caliche	6.7-15.8
	Gatuna	15.8-19
	Sandstone	19-24
	Intercalated Siltstone & Mudstone	24-29.8
	Sandstone	29.8-30.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-34
OPERATOR:	Sergent, Hauskins. & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498205.49, E666762.36
ELEVATION:	3401.97'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/09/79 **Date Completed:** 01/09/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-34	Sand	0-9.1
	Caliche	9.1-14.8
	Gatuna	14.8-40
	Siltstone & Claystone	40-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-35**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498326.97, E667196.82
ELEVATION:	3402.55'
TOTAL DEPTH:	32'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/05/79 **Date Completed:** 01/05/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-35	Sand	0-7
	Caliche	7-12
	Gatuna	12-23
	Sandstone	23-32

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-36
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499293.25, E669018.07
ELEVATION:	3422.03'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/07/79 **Date Completed:** 01/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-36	Sand	0-5.9
	Caliche	5.9-13.2
	Gatuna	13.2-25
	Siltstone	25-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-37
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499297.91, E670352.77
ELEVATION:	3438.91'
TOTAL DEPTH:	27.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/09/79 **Date Completed:** 01/09/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-37	Sand	0-5.5
	Caliche	5.5-12.5
	Gatuna	12.5-20
	Siltstone	20-20.3
	Sandstone	20.3-27.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-37A
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499260.53, E669370.39
ELEVATION:	3426.68'
TOTAL DEPTH:	22.4'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-37A	Sand	0-5.5
	Caliche	5.5-13.5
	Gatuna	13.5-22.4

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-38
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499155.65, E669683.42
ELEVATION:	3429.88'
TOTAL DEPTH:	50'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 1/23/79
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/11/79 **Date Completed:** 01/23/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-38	Sand	0-5.5
	Caliche	5.5-14
	Gatuna	14-20.5
	Sandstone	20.5-40.2
	Santa Rosa	40.2-43.7
	Dewey Lake	43.7-50

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-39
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499018.31, E669019.04
ELEVATION:	3422.08'
TOTAL DEPTH:	27.6'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/06/79 **Date Completed:** 01/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-39	Sand	0-7
	Caliche	7-13
	Gatuna	13-27.6

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-40
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499023.04, E670353.77
ELEVATION:	3438.48'
TOTAL DEPTH:	27.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/10/79 **Date Completed:** 01/10/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-40	Sand	0-7.6
	Caliche	7.6-13
	Gatuna	13-19
	Sandstone	19-27.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-41
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.51, E666858.36
ELEVATION:	3407.86'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/05/79 **Date Completed:** 01/05/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-41	Sand	0-6
	Caliche	6-15
	Gatuna	15-42
	Santa Rosa	42-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-42
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.57, E666873.35
ELEVATION:	3408.99'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/06/79 **Date Completed:** 01/06/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-42	Sand	0-6
	Caliche	6-14
	Gatuna	14-42
	Santa Rosa	42-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-43
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499202.96, E667523.70
ELEVATION:	3410.75'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/06/79 **Date Completed:** 01/06/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-43	Sand	0-12
	Caliche	12-20
	Gatuna	20-43
	Santa Rosa	43-53
	Dewey Lake	53-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-44
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499172.96, E667523.82
ELEVATION:	3411.48'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-44	Sand	0-16
	Caliche	16-21
	Gatuna	21-38
	Santa Rosa	38-52
	Dewey Lake	52-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-45
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498205.44, E666747.36
ELEVATION:	3401.51'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/10/79 **Date Completed:** 01/17/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-45	Sand	0-7.5
	Caliche	7.5-15.3
	Gatuna	15.3-31.3
	Dewey Lake	31.3-44.2
	Sandstone	44.2-44.7
	Siltstone	44.7-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-46
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498205.54, E666777.36
ELEVATION:	3401.98'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-46	Sand	0-8
	Caliche	8-13
	Gatuna	13-41
	Santa Rosa	41-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-47
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499206.77, E667193.82
ELEVATION:	3409.49'
TOTAL DEPTH:	17.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/25/79 **Date Completed:** 01/25/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-47	Sand	0-8.9
	Caliche	8.9-15
	Gatuna	15-17.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-48
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498839.26, E667854.93
ELEVATION:	3412.12'
TOTAL DEPTH:	15.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/24/79 **Date Completed:** 01/24/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-48	Sand	0-9
	Caliche	9-15.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-49
OPERATOR:	Sergent. Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498937.22, E667294.71
ELEVATION:	3409.07'
TOTAL DEPTH:	19.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/24/79 **Date Completed:** 01/24/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-49	Sand	0-8.5
	Caliche	8.5-10.5
	Silty Sand	10.5-15
	Gatuna	15-19.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-50
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498487.09, E667236.23
ELEVATION:	3405.65'
TOTAL DEPTH:	23.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/26/79 **Date Completed:** 01/26/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-50	Sand	0-9.5
	Caliche	9.5-15
	Gatuna	15-23.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-51
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498337.48, E667341.75
ELEVATION:	3404.74'
TOTAL DEPTH:	15.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/25/79 **Date Completed:** 01/25/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D.. 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-51	Sand	0-7.5
	Caliche	7.5-14.5
	Gatuna	14.5-15.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-52**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N496981.21, E665461.91
ELEVATION:	3385.48'
TOTAL DEPTH:	30.0'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/26/79 **Date Completed:** 01/26/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-52	Sand	0-3.1
	Caliche	3.1-8.5
	Gatuna	8.5-19
	Dewey Lake	19-30

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-53
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N496651.28, E665463.05
ELEVATION:	3386.65'
TOTAL DEPTH:	30.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/30/79 **Date Completed:** 01/30/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-53	Sand	0-8.5
	Caliche	8.5-15.7
	Gatuna	15.7-23.7
	Dewey Lake	23.7-30.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-54
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499386.52, E666651.92
ELEVATION:	3408.60'
TOTAL DEPTH:	210'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 02/14/79
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/13/79 **Date Completed:** 02/14/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-54	Sand	0-6
	Caliche	6-12
	Gatuna	12-25
	Santa Rosa	25-30
	Dewey Lake	30-210

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-301
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/08/79 **Date Completed:** 02/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-301	Sand	0-1
	Caliche	1-24
	Dewey Lake	24-39.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-302
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/07/79 **Date Completed:** 02/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-302	Sand	0-10.4
	Caliche	10.4-23
	Dewey Lake	23-39.0

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-303
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39.1'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/07/79 **Date Completed:** 02/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-303	Sand	0-15.5
	Caliche	15.5-18
	Dewey Lake	18-39.1

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-304
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	41.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/06/79 **Date Completed:** 02/06/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-304	Sand	0-20.6
	Caliche	20.6-33
	Sand	33-41.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-305
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	41'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/06/79 **Date Completed:** 02/06/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-305	Sand	0-14.5
	Caliche	14.5-19.5
	Sand	19.5-25.5
	Caliche	25.5-33
	Sand	33-41

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-306
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	38'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/02/79 **Date Completed:** 02/02/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-306	Sand	0-7.3
	Caliche	7.3-18
	Santa Rosa	18-38

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-307
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	Railroad
ELEVATION:	Not Recorded
TOTAL DEPTH:	40'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/01/79 **Date Completed:** 02/01/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-307	Caliche	0-5.6
	Sand	5.6-11.1
	Gatuna	11.1-17.1
	Dewey Lake	17.1-40

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-308
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	Railroad
ELEVATION:	Not Recorded
TOTAL DEPTH:	39.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/01/79 **Date Completed:** 02/01/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-308	Caliche	0-10.5
	Gatuna	10.5-19.5
	Dewey Lake	19.5-39.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	B-309
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	South Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39.4'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/02/79 **Date Completed:** 02/02/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-309	Sand	0-5.6
	Caliche	5.6-14
	Gatuna	14-19.8
	Santa Rosa	19.8-22
	Dewey Lake	22-39.4

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USGS OFR 81-488, Geologic Data for Borehole ERDA-9, Eddy County, New Mexico

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APPENDIX D7
PROBABLE MAXIMUM PRECIPITATION

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BECHTEL

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

CALC. NO.	0524-C-015
DESIGN CLASS	III-B
SHEET NO.	1 OF 12

BECHTEL JOB 12484
DEPARTMENT OF ENERGY
WASTE ISOLATION PILOT PLANT

CCP-5

STATEMENT OF PROBLEM: PROBABLE MAXIMUM PRECIPITATION (PMP) - UPLAND DESIGN BERMS TO DIVERT PMP RUNOFF AWAY FROM PLANT SITE.

- PERIPHERAL PMP BERMS
- SALT AREA PMP BERM

SAR CHECKED YES SAR CHANGE REQ'D. YES SAR CHANGE REQUEST MADE YES

SOURCE OF DATA:
1. TOPOGRAPHIC MAPS: USGS 15' QUADRANGLE SHEETS
   AERIAL SURVEY, BOHANNAN-HUSTON, 1978
2. HYDROMET. REPORT 51, U.S. NOAA NATIONAL WEATHER SERV., 1978
3.

SOURCE OF FORMULAS & REFERENCES:
1. DESIGN BASIS D-24-C-04 "PLANT SITE STORM DRAINAGE"
2. NATIONAL ENGG. HANDBOOK, SECT. 4, U.S. SOIL CONSERV. SERVICE
3. KING'S HANDBOOK OF HYDRAULICS
4. FLUID MECH. & HYDRAULICS BY R. GILES
5. HYDRAULIC ENGG. CIRCULAR NO. 5 BY FED. HWY ADM.

TITLE OF COMPUTER PROGRAM(S) USED - NONE

COMPUTER PROGRAM(S) VERIFICATION - NONE

TYPE OF CALCULATION: PRELIM. _____ FINAL ✓ SUPERSEDES CALC. NO. _____

SUPERSEDED _____

REFERENCES	P & ID/DWG. NO./REV. NO.	ENTITLED
1.	24-C-053 / Rev. 2	Site Development - Overall Plan
2.	24-C-060 / Rev. 8	Rough Grading - Plan Sh. 1 of 2
3.	24-C-061 / Rev. 8	" " " 2 of 2
4.	24-C-075 / Rev. 2	Rough Grading - Plan & Sect. Sh. 1 of 2
5.	24-C-076 / Rev. 2	" " " " Sh 2 of 2

REV.	DESCRIPTION	BY	DATE	CHK'D	DATE	APPR'D	DATE
△							
△							
△	ISSUED FOR TITLE II	SLN	6/27/82	[illegible]	8/11/82	[illegible]	11/19/82

RECORD OF ISSUES

BECHTEL

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	LS-24-C-015
SHEET NO.	2 OF 112
REV. NO.	0
CHECKED BY	DATE 8/11/82

DESIGN ASSUMPTIONS

RUNOFF $Q_{PMP} = C I_{PMP} A$ RATIONAL METHOD

RUNOFF COEFFICIENT $C = 0.85$ FOR NAT. GROUND & UPLAND

$= 0.90$ FOR CALICHE AREA

RAINFALL INTENSITY I_{PMP} IN./HR

(SEE SH. M10)

DRAINAGE AREA A IN ACRES

TIME OF CONCENTRATION $T_c = \frac{L}{3600\,V}$ IN HRS

LENGTH OF DRAINAGE AREA L IN FT.

VELOCITY V IN FT/SEC

(SEE SH. 9 FOR NEARLY BARE & UNTILLED OVERLAND FLOW

DITCHES

MANNING'S FORMULA $Q = \frac{1.486}{n} A R_h^{2/3} S^{1/2}$

$n = 0.03$ (UNLINED)

R_H HYDRAULIC RADIUS IN FT. $R_H = \frac{A}{P}$

A CROSS-SECTIONAL AREA IN SQ. FT.

P WETTED PERIMETER IN FT.

S SLOPE OF DITCH IN FT/FT.

MAX. ALLOWABLE VELOCITY FOR PMP DITCHES 25 FT/SEC

CULVERTS

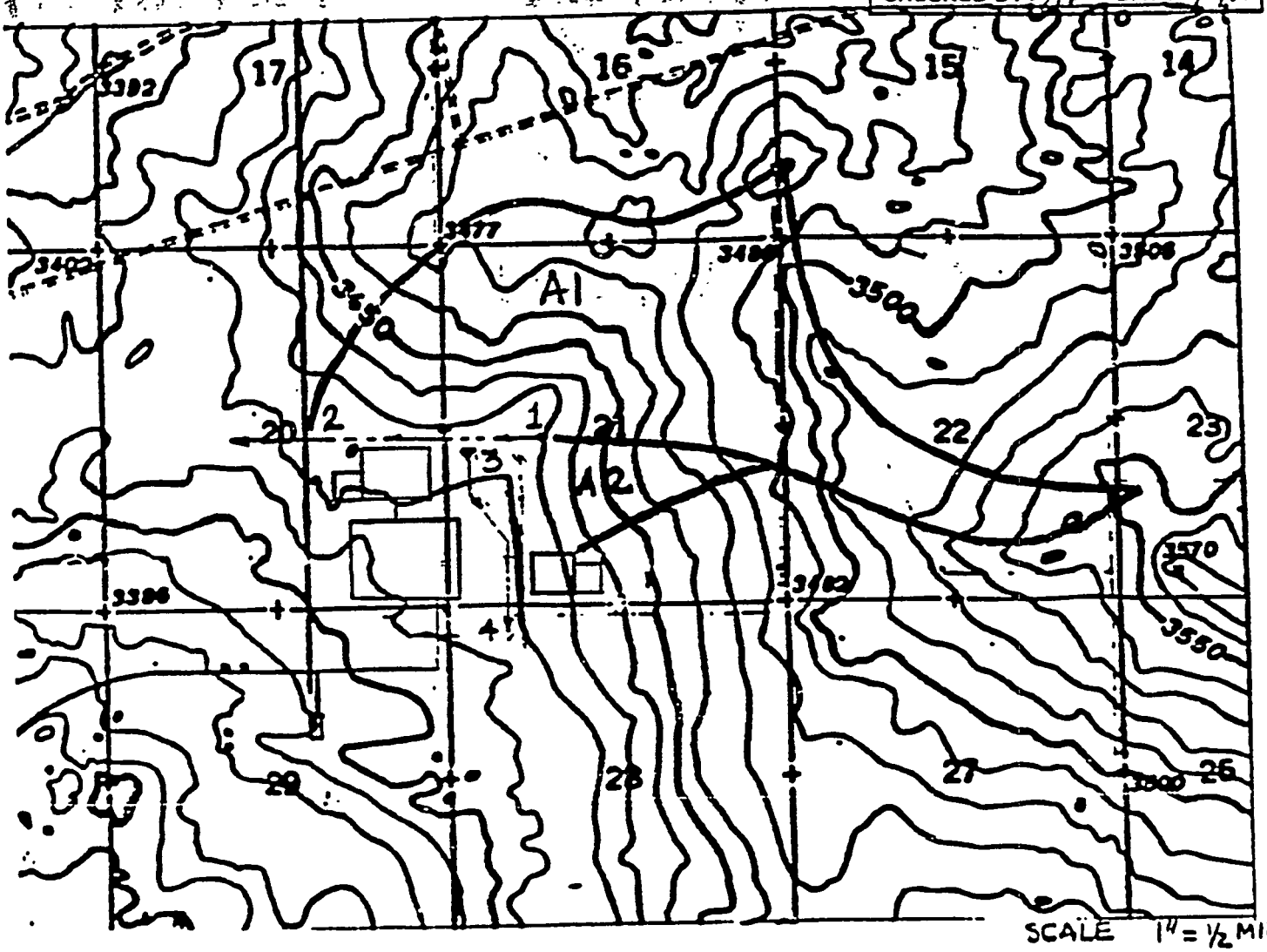
HYDRAULIC ENGG. CIRCULAR NO. 5.

BERMS PMP RUNOFF FROM UPLAND & SALT STORAGE SHALL BE DIVERTED BY INTERCEPT BERMS. NO PMP DITCH REQUIRED TO ACCUMULATED SANDS WHICH ARE BLOWN BY WIND. BERMS SHALL BE STABILIZED WITH 6" OF CALICHE COVER

BECHTEL
NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.. 12484	
CALC. NO. 24 - C - 015	
SHEET NO. 3	OF 12.
REV. NO. 0	
CHECKED BY	DATE 8/11/87



SCALE 1" = ½ MILE

AREAS	BERMS	SH. NO.
A1 = 600 AC.	1-2	4
A2 = 80 AC.	3-4	5

BECHTEL NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	CS 24-CL-015
SHEET NO.	4 OF 12
REV. NO.	0
CHECKED BY	DATE 8/11/82

UPLAND NORTH OF PLANT SITE

BERM 1-2 ℄ BERM N 10,920

FLOW $Q = CIA$

$A = A_1 = 600$ ac.

$L = 14,300$ FT

$\Delta H = 3555 - 3430 = 125$ FT.

$S = 125/14,300 = 0.87\%$

$V = 0.96$ FPS

$T_c = 14300/3600 \times .96 = 4.14$ HRS

$I_{PMP} = 4.8$ IN/HR

$Q_{PMP} = 0.85 \times 4.8 \times 600 = 2448$ CFS ∴

START BERM @ E 9080 EL 3432.00

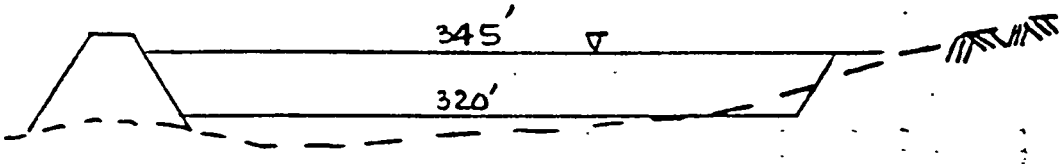
SLOPE OF BERM 0.00067

BERM @ E 6000 EL 3429.94. THEN DAYLIGHT

AVERAGE CROSS-SECTION AREA : $A = 1000$ FT^2

AVERAGE CHANNEL SLOPE $S = 0.00067$

ALLOW 1' FREEBOARD



AVERAGE DEPTH : 3'

HYDRAULIC RADIUS $R_H = \frac{A}{P} = \frac{1000}{320 + 2\sqrt{9^2 + 3^2}} = 2.95'$

$$Q = \frac{1.486}{0.03}(2.95)^{2/3}\ 1000\ (.00067)^{2/3}$$

$Q = 2637$ CFS $>$ $Q_{PMP} = 2448$ CFS OK

BECHTEL NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	1524-C-015
SHEET NO.	5 OF 12
REV. NO.	0
CHECKED BY	[illegible] DATE 2/11/82

UPLAND EAST OF PLANT SITE

BERM 3-4

FLOW $Q = CIA$

$A = A_2 = 80$ AC.

$L = 5600$ FT

$\Delta H = 3476 - 3410 = 66'$

$S = 1.17\%$

$V = 1.05$ FPS

$T_c = 5600 / 3600 \times 1.05 = 1.48$ HRS

$I_{PMP} = 8.4$ IN/HR

$Q_{PMP} = 0.85 \times 8.4 \times 80 = 572$ CFS ∴

START BERM @ EL. 3424.55.

SLOPE OF BERM 0.001 APPROX. DISTANCE 550'

@ 1ST BEND EL. 3424.00

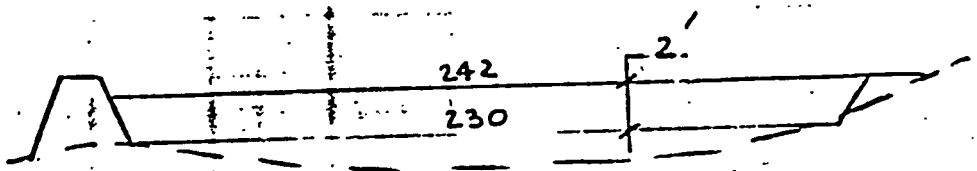
SLOPE 0.001 APPROX. DISTANCE 1000'

@ 2ND BEND EL. 3423.00

GB . SLOPE 0.0057 APPROX DISTANCE 700'

@ SALT HAUL RD EL. 3419.00

TYPICAL CROSS SECTION : 1' FREEBOARD



$X = A = 472$ SF

$R_h = 1.95$ $S_{avg.} = 0.0015$

$Q = \frac{1.486}{0.03} (1.95)^{2/3} (472) (.0015)^{1/2} = 1410$ CFS > 572 CFS

BECHTEL NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO. 12484
CALC. NO. CS24-C-015
SHEET NO. 6 OF 12
REV. NO. 1 0
CHECKED BY [illegible] DATE 8/11/82

SALT STORAGE AREA PMP — BERM 5-6 SEE SH. 12

$Q = CIA$

$A = 1.4$ ac. (Nat. Gr.) $+ 9.65$ ac. (Salt pile)

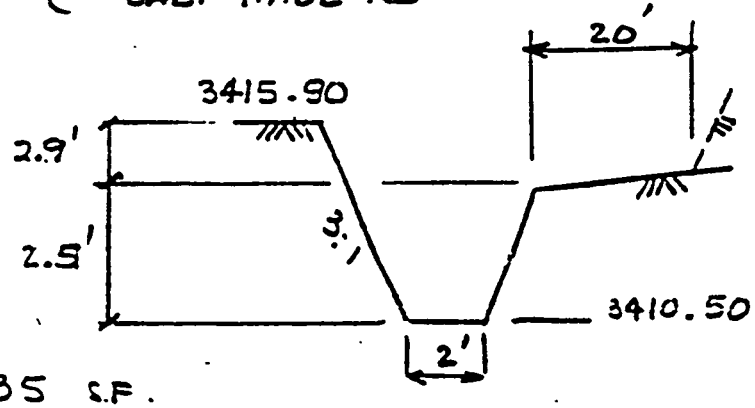
$S = 1\%$, $V = 1$ fps

$L = 640$

$t_c = \frac{640}{60 \times 1} = 10.7$ min. $\quad I_{PMP} = 22.7$ in/hr

$Q = (.85 \times 1.4 + .90 \times 9.65)\, 22.7 = 224$ CFS

BERM 5-6 @ SALT HAUL RD



$A = 135$ S.F.

$P = 17.4 + 2' + 7.9 + 20 + 3 = 50.3'$

$R_h = 2.7'$

$Q_{CAP} = \frac{1.486}{0.03} (2.7)^{2/3}\, 135 \times (.004)^{1/2} = 817$ CFS

CONSIDER 1' FREEBOARD

$A = 80$ SF

$P = 14.2 + 2 + 7.9 + 20 + 2 = 46$

$R_h = 1.73$

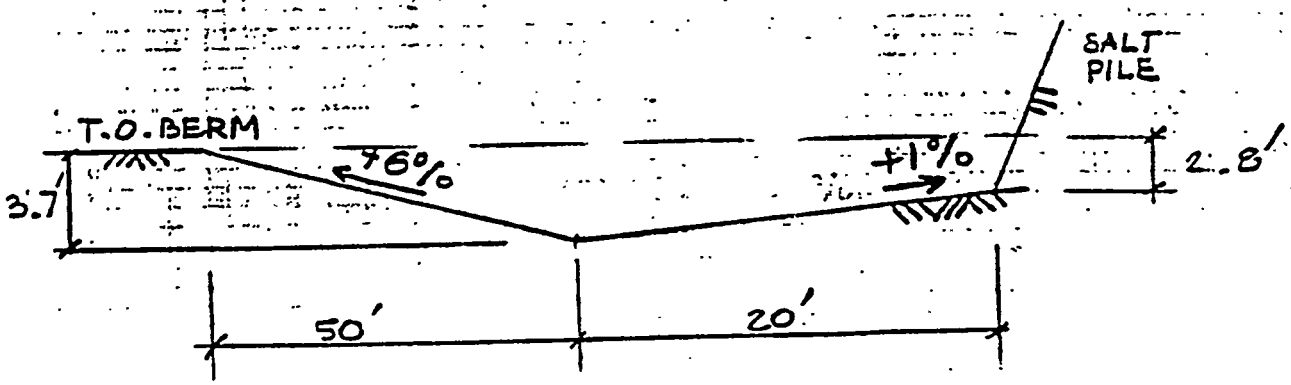
$Q_{CAP} = 361$ CFS OK

BECHTEL
NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	CS24-C-015
SHEET NO.	7 OF 12
REV. NO.	0
CHECKED BY	DATE 2/11/82

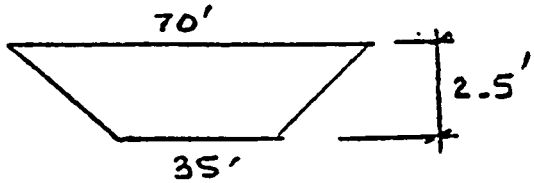
@ SALT HAUL RD, CHECK CAPACITY FOR PMP OVERFLOW



$$A = \frac{2.8+3}{2} \times 20 + \frac{3 \times 50}{2} = 133 \text{ S.F.}$$

$$Q_{WEIR} = 3.367\, b\, H^{3/2} \quad \text{FOR TRAPEZOIDAL WEIR}$$

EQUIVALENT TRAPEZOIDAL AREA



$b = 35$

$H = 2.5'$

$Q_{WEIR\ CAPAC.} = 3.367\,(35)\,(2.5)^{3/2}$

$= 466 \text{ CFS} > 224 \text{ CFS}$ OK

FOR ENTIRE SALT STORAGE PMP BERM 6-7 SEE SH. 12

$Q = CIA$

$A = 1.4 \text{ ac (nat. gr)} + 19.3 \text{ ac (graded area)}$

$S = 1\%$

$$t_c = \frac{720}{60 \times 1} + \frac{1000}{60 \times 0.7} = 35.8 \text{ min}$$

$I_{PMP} = 12.4 \text{ in/hr}$

$Q = (0.85 \times 1.4 + 0.9 \times 19.3)\,12.4 = 230 \text{ CFS}$

SAME DESIGN AS BERM 5-6 , NO FREEBOARD REQ'D.

BECHTEL
NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	US2A-C-015
SHEET NO.	8 OF 12
REV. NO.	0
CHECKED BY	DATE 8/11/82

EAST OF PLANT SITE ; PMP BERM 8-9 SEE SH. 12.

- THERE ARE MINIMUM RUNOFF IN THIS AREA. A 2.5' HIGH BERM IS SUFFICIENT TO BLOCK ANY RUNOFF FROM EAST SIDE OF GRADING AREA.
- TOP OF SPOIL BANK SHALL BE SLOPED DOWN EASTWARD TO DIVERT RUNOFF ON THIS AREA
- LEAVE 10' STRIP BETWEEN EAST TOE OF 8-9 BERM AND TOE OF SPOIL BANK
- SOUTH PORTION OF BERM 8-9 TO BE REWORKED BY CCP-20, RAILROAD, AS FOLLOWS:

a) SOUTH PORTION OF BERM 8-9 TO BE REMOVED TO MAKE WAY FOR THE R/R LINE WHICH RUNS INTO WASTE BLDG.

b) PMP RUNOFF IN THIS AREA SHALL BE DIVERTED TO THE EAST END OF THE R/R TRACK

JOB NO.	12484
CALC. NO.	CS 24-C-015
SHEET NO.	9 OF 12
REV. NO.	0
CHECKED BY	DATE 8/11/82

NUCLEAR FUEL OPERATIONS
15-8

CALCULATION SHEET

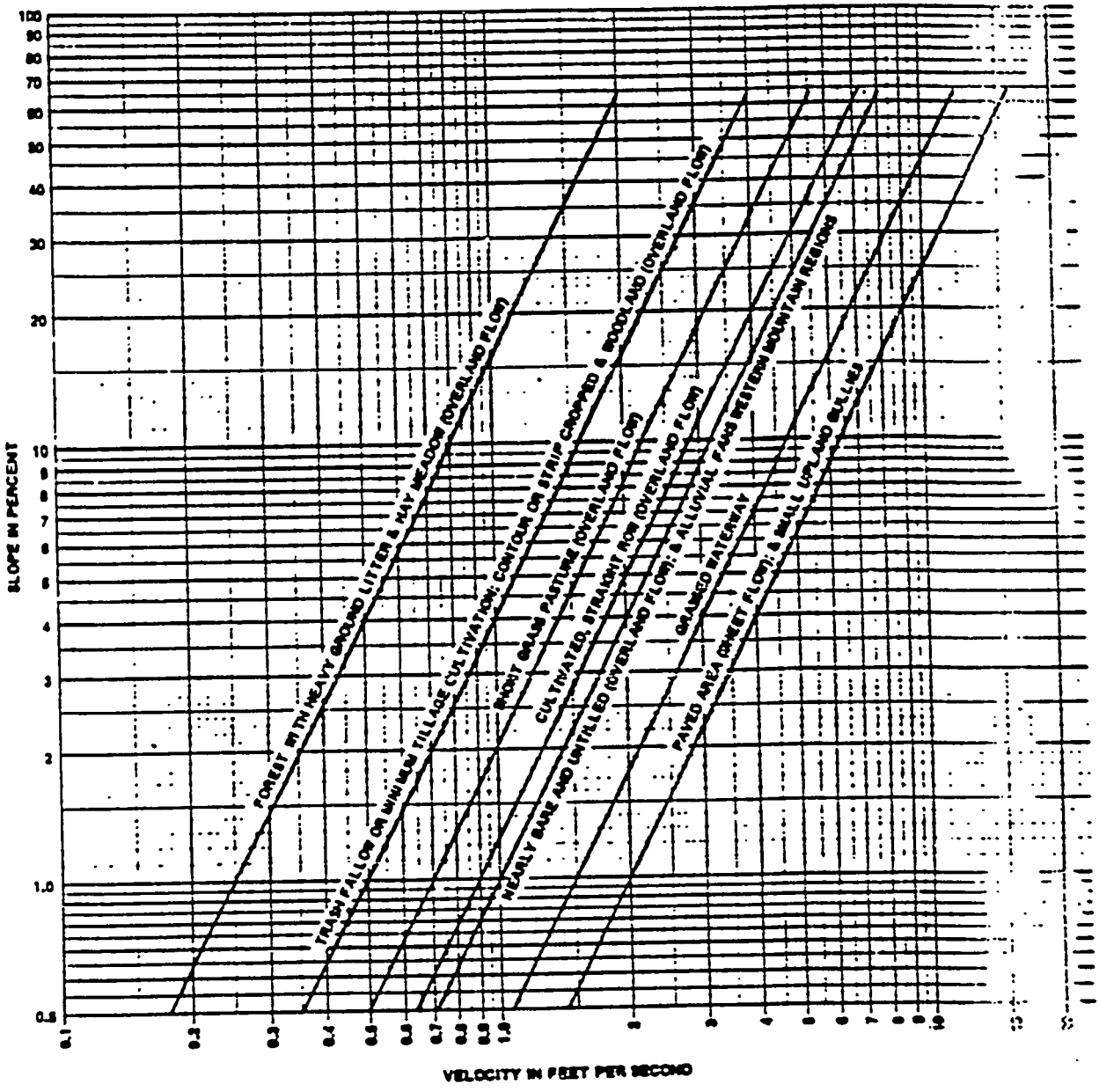


Figure 15.2.—Velocities for upland method of estimating T_c

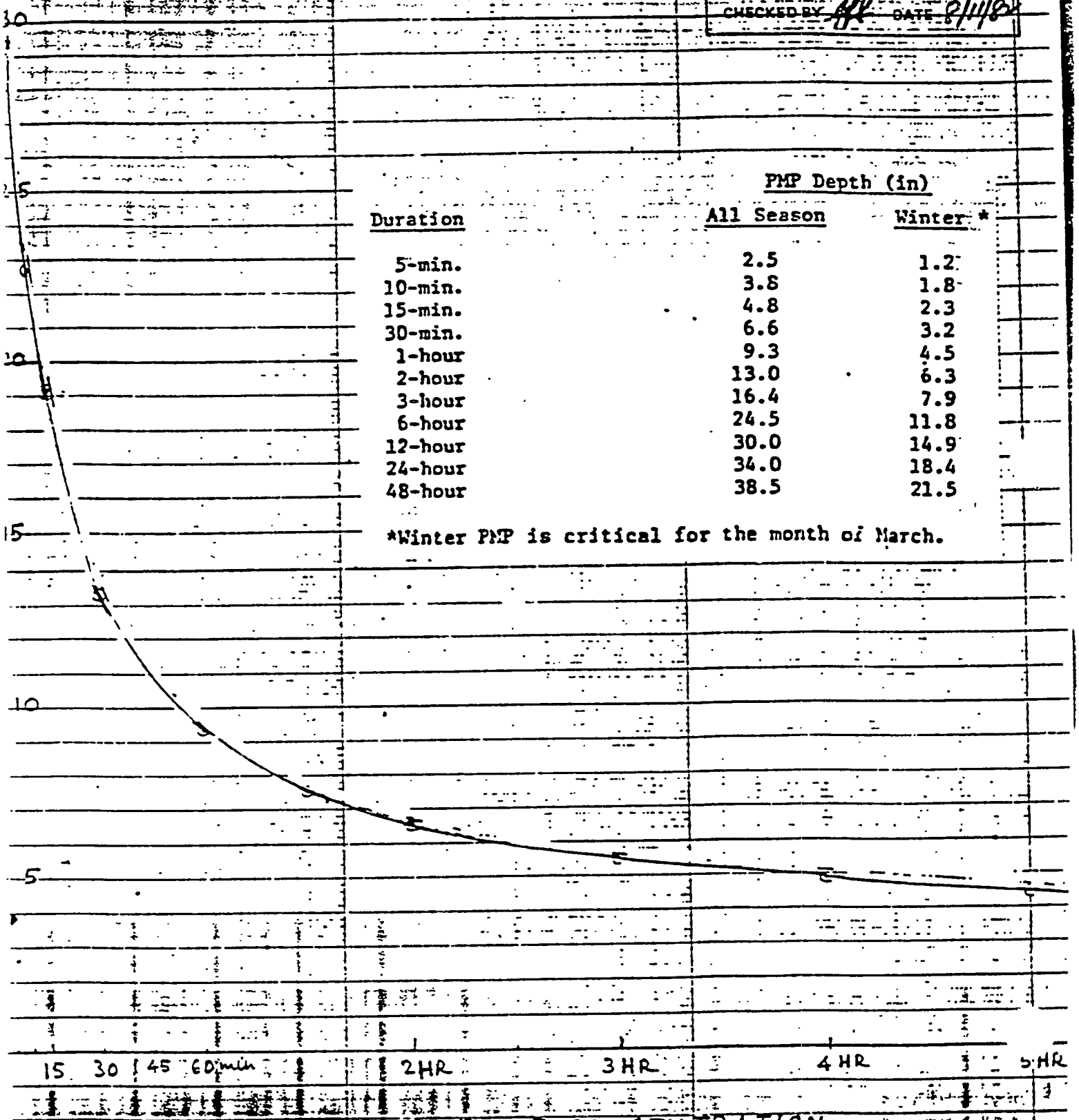
JOB NO. 12484
CALC. NO. S24-C-015
SHEET NO. 10 OF 12
REV. NO. 0
CHECKED BY [illegible] DATE 8/11/80

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

Duration	PMP Depth (in) All Season	PMP Depth (in) Winter *
5-min.	2.5	1.2
10-min.	3.8	1.8
15-min.	4.8	2.3
30-min.	6.6	3.2
1-hour	9.3	4.5
2-hour	13.0	6.3
3-hour	16.4	7.9
6-hour	24.5	11.8
12-hour	30.0	14.9
24-hour	34.0	18.4
48-hour	38.5	21.5

*Winter PMP is critical for the month of March.



BECHTEL

NUCLEAR FUEL
OPERATIONS

CALCULATION SHEET

CALC. NO.	CS24-C-015
SHEET NO.	11 OF 12
REV. NO.	0
CHECKED BY	DATE 8/11/82

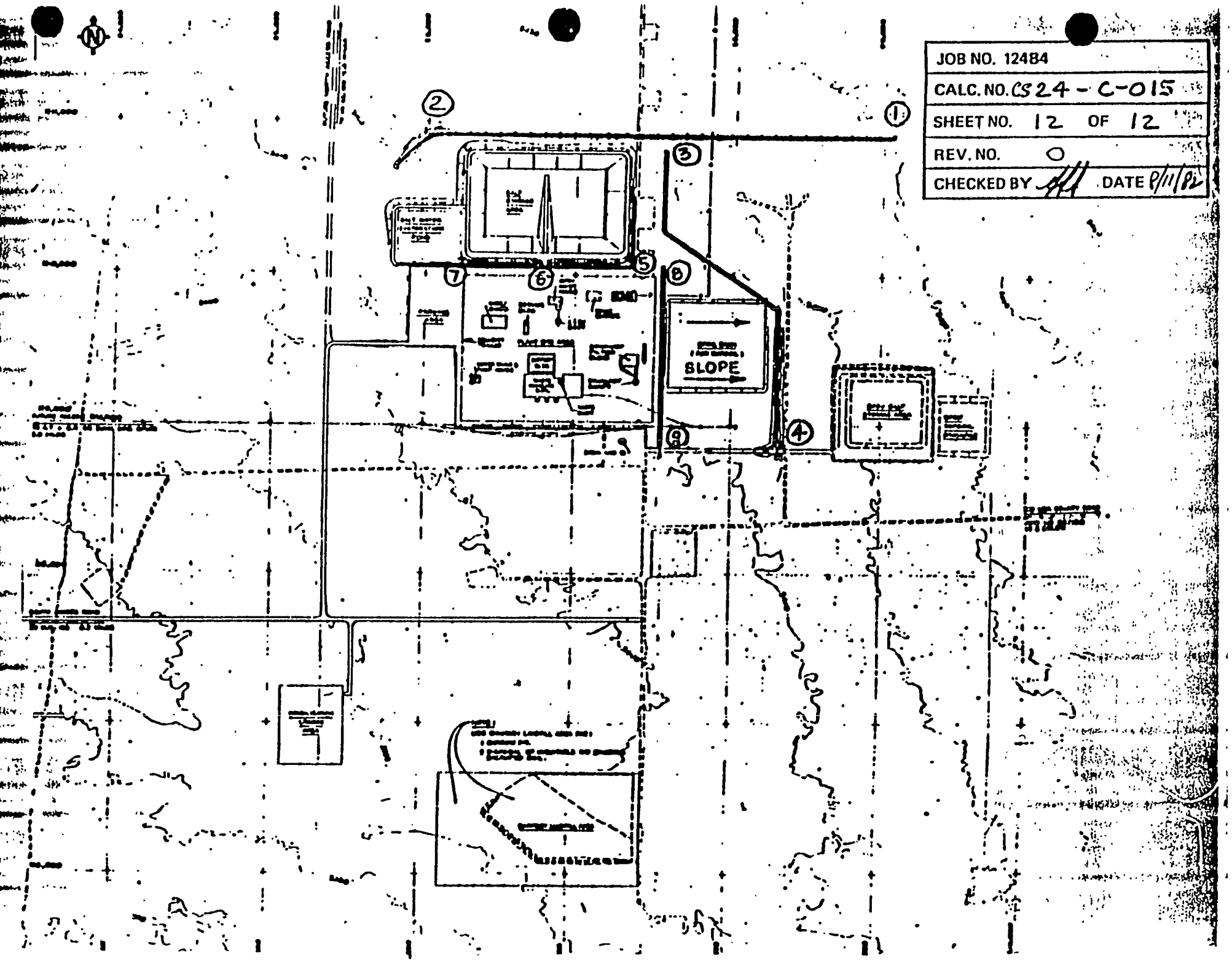
VALUES of DISCHARGE FACTOR K' in $Q = (K'/n)b^{8/3}S^{1/2}$ for TRAPEZOIDAL CHANNELS

(y = depth of flow, b = bottom width of channel)

Side Slopes of Channel Section (horizontal to vertical)

y/b	Vertical	¼:1	½:1	¾:1	1:1	1½:1	2:1	2½:1	3:1	4:1
.01	.00068	.00068	.00069	.00069	.00069	.00069	.00069	.00069	.00070	.00070
.02	.00213	.00215	.00216	.00217	.00218	.00220	.00221	.00222	.00223	.00225
.03	.00414	.00419	.00423	.00426	.00428	.00433	.00436	.00439	.00443	.00449
.04	.00660	.00670	.00679	.00685	.00691	.00700	.00706	.00716	.00723	.00736
.05	.00946	.00964	.00979	.00991	.01002	.01019	.01033	.01047	.01060	.01086
.06	.0127	.0130	.0132	.0134	.0136	.0138	.0141	.0143	.0145	.0150
.07	.0162	.0166	.0170	.0173	.0175	.0180	.0183	.0187	.0190	.0197
.08	.0200	.0206	.0211	.0215	.0219	.0225	.0231	.0236	.0240	.0250
.09	.0241	.0249	.0256	.0262	.0267	.0275	.0282	.0289	.0296	.0310
.10	.0284	.0294	.0304	.0311	.0318	.0329	.0339	.0348	.0358	.0376
.11	.0329	.0343	.0354	.0364	.0373	.0387	.0400	.0413	.0424	.0448
.12	.0376	.0393	.0408	.0420	.0431	.0450	.0466	.0482	.0497	.0527
.13	.0425	.0446	.0464	.0480	.0493	.0516	.0537	.0556	.0575	.0613
.14	.0476	.0502	.0524	.0542	.0559	.0587	.0612	.0636	.0659	.0706
.15	.0528	.0559	.0585	.0608	.0627	.0662	.0692	.0721	.0749	.0805
.16	.0582	.0619	.0650	.0676	.0700	.0740	.0777	.0811	.0845	.0912
.17	.0638	.0680	.0716	.0748	.0775	.0823	.0866	.0907	.0947	.1026
.18	.0695	.0744	.0786	.0822	.0854	.0910	.0960	.1008	.1055	.1148
.19	.0753	.0809	.0857	.0899	.0936	.1001	.1059	.1115	.1169	.1277
.20	.0812	.0876	.0931	.0979	.1021	.1096	.1163	.1227	.1290	.1414
.22	.0934	.1015	.109	.115	.120	.130	.139	.147	.155	.171
.24	.1061	.1161	.125	.133	.140	.152	.163	.173	.184	.204
.26	.119	.131	.142	.152	.160	.175	.189	.202	.215	.241
.28	.132	.147	.160	.172	.182	.201	.217	.234	.249	.281
.30	.146	.163	.179	.193	.205	.228	.248	.267	.287	.324
.32	.160	.180	.199	.215	.230	.256	.281	.304	.327	.371
.34	.174	.198	.219	.238	.256	.287	.316	.343	.270	.423
.36	.189	.216	.241	.263	.283	.319	.353	.385	.416	.478
.38	.203	.234	.263	.288	.312	.353	.392	.429	.465	.537
.40	.218	.253	.286	.315	.341	.389	.434	.476	.518	.600
.42	.233	.273	.309	.342	.373	.427	.478	.526	.574	.668
.44	.248	.293	.334	.371	.405	.467	.525	.580	.633	.740
.46	.264	.313	.359	.401	.439	.509	.574	.636	.696	.816
.48	.279	.334	.385	.432	.474	.553	.625	.695	.763	.897
.50	.295	.355	.412	.463	.511	.598	.679	.757	.833	.983
.55	.335	.410	.482	.548	.609	.722	.826	.926	1.025	1.22
.60	.375	.468	.557	.640	.717	.858	.990	1.117	1.24	1.49
.70	.457	.592	.722	.844	.959	1.17	1.37	1.56	1.75	2.12
.80	.542	.725	.906	1.078	1.24	1.54	1.83	2.10	2.37	2.90
.90	.628	.869	1.11	1.34	1.56	1.98	2.36	2.74	3.11	3.83
1.00	.714	1.022	1.33	1.64	1.93	2.47	2.99	3.48	3.97	4.93
1.20	.891	1.36	1.85	2.33	2.79	3.67	4.51	5.32	6.11	7.67
1.40	1.07	1.74	2.45	3.16	3.85	5.17	6.42	7.64	8.84	11.2
1.60	1.25	2.16	3.14	4.14	5.12	6.99	8.78	10.52	12.2	15.6
1.80	1.43	2.62	3.93	5.28	6.60	9.15	11.6	14.0	16.3	20.9
2.00	1.61	3.12	4.82	6.58	8.32	11.7	14.9	18.1	21.2	27.3
2.25	1.84	3.81	6.09	8.46	10.8	15.4	19.8	24.1	28.4	36.7

*Values from King's "Handbook of Hydraulics", 4th edition, McGraw-Hill Co.



JOB NO.	12484
CALC. NO.	CS24-C-015
SHEET NO.	12 OF 12
REV. NO.	0
CHECKED BY	DATE 8/11/92

APPENDIX D8
PHENOLINE® 305 FINISH PRODUCT DATA SHEET

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PHENOLINE® 305 FINISH

SELECTION DATA

GENERIC TYPE: Modified phenolic. Part A and Part B mixed prior to application.

GENERAL PROPERTIES: A heavy-duty topcoat, PHENOLINE 305 Finish sets to a hard, tough, smooth finish having very good abrasion resistance. The surface is glossy and easily cleaned. Has excellent resistance to a wide range of solvents, caustics, cleaning solutions and acid entrained vapors of high concentration. PHENOLINE 305 Finish has outstanding chemical, physical and application properties. PHENOLINE 305 Finish is easily repaired, has excellent resistance to hydraulic fluids and meets the applicable performance criteria of the American National Standards Institute ANSI N101.2-1972 and ANSI N5.12-1974. It has performed satisfactorily in radiation resistance and decontamination testing at Oak Ridge National Laboratory.

RECOMMENDED USES: PHENOLINE 305 Finish is an excellent coating for the protection of steel and concrete surfaces in nuclear power plants. Because of its glossy appearance and excellent physical properties, PHENOLINE 305 Finish is an excellent topcoat for use by manufacturers of industrial equipment and components. Also used in chemical processing plants, pulp and paper mills for the protection of structural steel and concrete against severe splash, spillage and fume conditions. The addition of 50 mesh silica provides a non-skid surface, making an excellent floor coating.

NOT RECOMMENDED FOR: Immersion service or continuous spillage of hot or concentrated acids.

CHEMICAL RESISTANCE GUIDE:

Exposure	Splash and Spillage	Fumes
Acids	Very Good	Excellent
Alkalies	Excellent	Excellent
Solvents	Excellent	Excellent
Salt	Excellent	Excellent
Water	Excellent	Excellent

TEMPERATURE RESISTANCE: (non-immersion)
Continuous: 200°F (93°C)
Non-continuous 250°F (121°C)

FLEXIBILITY: Fair **WEATHERING:** Very Good

ABRASION RESISTANCE: Very good

SUBSTRATES: Apply over suitably primed metal or cementitious surfaces. Surfacer may be required for concrete surfaces, depending on roughness and texture.

TOPCOAT REQUIRED: Normally none

COMPATIBILITY WITH OTHER COATINGS: May be applied over inorganic zincs, catalyzed epoxies, modified phenolics or others as recommended. Acceptable primers are CARBO ZINC® 11, CARBO ZINC 12, CARBOLINE® 195 Surfacer, CARBOLINE 295WB Surfacer, PHENOLINE 305 Primer, PHENOLINE 305 Concrete Primer, PHENOLINE 307 or others as recommended. A mist coat may be required when applied over inorganic zinc.

SPECIFICATION DATA

THEORETICAL SOLIDS CONTENT OF MIXED MATERIAL:

	By Volume
PHENOLINE 305 Finish	64% ± 2%

RECOMMENDED DRY FILM THICKNESS PER COAT:
4-6 mils (100-150 microns)

THEORETICAL COVERAGE PER MIXED KIT*:

1 gal. kit (yields 1.25 gal.)
1283 mil sq. ft. (25.6 m/l at 25 microns)
320 sq. ft. at 4 mils (6.4 sq. m/l at 100 microns)

5 gal. kit (yields 6.25 gal.)
6416 mil sq. ft. (25.6 sq. m/l at 25 microns)
1603 sq. ft. at 4 mils (6.4 sq. m/l at 100 microns)

*NOTE: Material losses during mixing and application will vary and must be taken into consideration when estimating job requirements.

SHELF LIFE: 24 months minimum

COLORS: Available in a variety of colors. Consult your local Carboline representative or Carboline Customer Service for availability.

GLOSS: Glossy

ORDERING INFORMATION

Prices may be obtained from Carboline sales representative or main office.

APPROXIMATE SHIPPING WEIGHT:

	1 Gal. Kit (1.25 gal.)	5 Gal. Kit (6.25 gal.)
PHENOLINE 305 Finish	17 lbs. (7.7 kg)	80 lbs. (36.3 kg)
PHENOLINE Thinner	9 lbs. (4.1 kg)	45 lbs. (20.5 kg)
CARBOLINE Thinner #2	9 lbs. (4.1 kg)	45 lbs. (20.5 kg)

FLASH POINT: (Pensky-Martens Closed Cup)

PHENOLINE 305 Finish Part A	68°F (20°C)
PHENOLINE 305 Finish Part B	60°F (16°C)
PHENOLINE Thinner	77°F (25°C)
CARBOLINE Thinner #2	30°F (-1°C)

March 84 Replaces May 83

To the best of our knowledge the technical data contained herein are true and accurate at the date of issuance and are subject to change without prior notice. User must contact Carboline to verify correctness before specifying or ordering. No guarantee of accuracy is given or implied. We guarantee our products to conform to Carboline quality control. We assume no responsibility for coverage, performance or injuries resulting from use. Liability, if any, is limited to replacement of products. Prices and cost data if shown, are subject to change without prior notice. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY THE SELLER, EXPRESS OR IMPLIED, STATUTORY, BY OPERATION OR LAW, OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

APPLICATION INSTRUCTIONS

These instructions are not intended to show product recommendations for specific service. They are issued as an aid in determining correct surface preparation, mixing instructions, and application procedure. It is assumed that the proper product recommendations have been made. These instructions should be followed closely to obtain the maximum service from the materials.

607

SURFACE PREPARATION: Remove any oil or grease from surface to be coated with clean rags soaked in CARBOLINE Thinner #2 or toluol in accordance with SSPC-SP1-82.

Steel/Concrete: Apply over clean, dry, recommended primer or surfacer. Application over inorganic zincs may require a mist coat.

MIXING: Mix separately, then combine and mix thoroughly in the following proportions:

	1 Gal. Kit	5 Gal. Kit
PHENOLINE 305 Finish Part A	1 Gal.	5 Gal.
PHENOLINE 305 Finish Part B	1 Qt.	1.25 Gal.
	1.25 gal.	6.25 gal.

Thin up to 25% by volume with PHENOLINE Thinner.

NOTE: Use of thinners other than those supplied or approved by Carboline may adversely affect product performance and void product warranty, whether express or implied.

POT LIFE: One and one half hours at 75°F (24°C) and less at higher temperatures. Pot life ends when coating loses body and begins to sag.

APPLICATION TEMPERATURES:

	Material	Surfaces
Normal	65-85°F (18-29°C)	65-85°F (18-29°C)
Minimum	55°F (13°C)	50°F (10°C)
Maximum	90°F (32°C)	120°F (49°C)
	Ambient	**Humidity**
Normal	65-85°F (18-29°C)	30-60%
Minimum	50°F (10°C)	0%
Maximum	110°F (43°C)	90%

Do not apply when the surface temperature is less than 5°F (2°C) above the dew point.

Special thinning and application techniques may be required above or below normal conditions and when applying over inorganic zinc primers.

SPRAY: Use sufficient air volume for correct operation of equipment.

Use a 50% overlap with each pass of the gun. On irregular surfaces, coat the edges first, making an extra pass later.

NOTE: The following equipment has been found suitable; however, equivalent equipment may be substituted.

Conventional: Use a 3/8" minimum I.D. material hose. Hold gun approximately 12-14 inches from the surface and at a right angle to the surface.

Mfr. & Gun	Fluid Tip	Air Cap
Binks #18 or #62	66	63PB
DeVilbiss P-MBC or JGA	E	704
	approx. .070" I.D.	

Airless: Use a 3/8" minimum I.D. material hose. Hold gun approximately 18-20 inches from the surface and at a right angle to the surface.

Mfr. & Gun	Pump*
DeVilbiss JGB-507	QFA-519
Graco 205-591	President 30:1 or Bulldog 30:1
Binks Model 700	88-36 37:1

*Teflon packings are recommended and are available from pump manufacturer.

Use a .015-.017" tip with 2200 psi.

BRUSH OR ROLLER: For touch-up only. Use natural bristle brush applying with full coat. Avoid rebrushing. Use lambswool roller with phenolic core. Avoid rerolling. Two coats may be required for proper hiding and film build.

APPLICATION FOR NON-SKID SURFACES:
For non-skid surfaces, mix Part A and Part B as usual and add, under agitation, 2½ pints (approximately 4.33 lbs.) of 50 mesh Ottawa Silica for each one-gallon kit of PHENOLINE 305 Finish. Thin up to 25% by volume with PHENOLINE Thinner. Keep material under mild agitation during application.

Conventional: Use a ½" minimum I.D. material hose and an agitated bottom outlet pot with ½" minimum I.D. outlet equipped with dual regulators. Hold gun approximately 12-14 inches from the surface and at a right angle to the surface.

Mfr. & Gun	Fluid Tip	Air Cap
Binks Model 18 or 62	68	68 PB
DeVilbiss P-MBC or JGA	AC	62
	approx. . 110" I.D.	

Airless: Not recommended (abrades tip).

DRYING TIMES:

Temperature	Between Coats	Final Cure
50°F (10°C)	72 hrs.	12 days
60°F (16°C)	36 hrs.	8 days
75°F (24°C)	18 hrs.	4 days
90°F (32°C)	12 hrs.	2 days

CLEAN UP: Use CARBOLINE Thinner #2 or xylol.

STORAGE CONDITIONS:
Temperature: 45-110°F (7-43°C) Humidity: 0-100%

For specific recommendations, consult Carboline Technical Service.

CAUTION: CONTAINS FLAMMABLE SOLVENTS. KEEP AWAY FROM SPARKS AND OPEN FLAMES. IN CONFINED AREAS WORKMEN MUST WEAR FRESH AIRLINE RESPIRATORS HYPERSENSITIVE PERSONS SHOULD WEAR GLOVES OR USE PROTECTIVE CREAM. ALL ELECTRIC EQUIPMENT AND INSTALLATIONS SHOULD BE MADE AND GROUNDED IN ACCORDANCE WITH THE NATIONAL ELECTRICAL CODE. IN AREAS WHERE EXPLOSION HAZARDS EXIST, WORKMEN SHOULD BE REQUIRED TO USE NONFERROUS TOOLS AND TO WEAR CONDUCTIVE AND NONSPARKING SHOES

carboline

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NUCLEAR COATING SYSTEM

SYSTEM	PRODUCT	GENERIC TYPE	DRY FILM THICKNESS	VOLUME SOLIDS	COVERAGE
SURFACER	CARBOLINE 195	EPOXY	20 MILS	97%	78 ft²
TOPCOAT	PHENOLINE 305	PHENOLIC EPOXY	5 MILS	64%	257 ft²*

DESCRIPTION: A two or three coat epoxy surfacer system for floors or where excellent chemical resistance is required. Two coats of 195 Surfacer may be required depending on porosity of concrete. Exhibits excellent gloss and abrasion resistance. A proven system in nuclear plants for more than 16 years.

FEATURES

- High solids, low solvent content
- Excellent abrasion and chemical resistance
- Excellent gloss

BENEFITS

- Fewer fumes than conventional coatings, less effect on personnel and charcoal filters.
- Long wear life, resists chemical attack.
- Easily decontaminated, aesthetics.

*1.25 Gal. Kit

TEST DATA

TEST	METHOD	CONDITIONS	RESULTS
DESIGN BASIS ACCIDENT (DBA)	ANSI N101.2 - 1972 ASTM D3911-80	340°F/70 PSIG (ORNL)	ACCEPTABLE
RADIATION TOLERANCE	ANSI N5.12 - 1974 ASTM D4082-83	1 x 10⁹ RADS	ACCEPTABLE
DECONTAMINATION	ANSI N5.12 - 1974 ASTM D4256-83	PER TEST METHOD AND ORNL PROCEDURES (305)	99.1%
CHEMICAL RESISTANCE	ANSI N5.12 - 1974 ASTM D3912-80	5 DAY IMMERSION (305)	ACCEPTABLE EXCEPT FOR POTASSIUM PERMANGANATE
TABER ABRASION	ANSI N5.12 - 1974 FED STD 141 METHOD 6192	1000 CYCLES 1000g WEIGHT CS-17 WHEEL (305)	69.3 mg LOST

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APPENDIX D9

CALCULATION BRIEFS FOR ENVIRONMENTAL PERFORMANCE ANALYSIS

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TABLE D9-1
MAXIMUM OCCUPATIONAL EXPOSURE FROM UNDERGROUND WASTE EMISSIONS

Compound	Molecular Weight (g/g mole)	Carbon Composite Filter Diffusion (mole/s/molfrac)	Weighted Average Drum Headspace Concentration (ppmv)	Mole Fraction (molfrac)	Average Drum Emission Rate (mole/s/drum)	Open Panel Exhaust Concentrations from Waste Emissions ($\mu g/m^3$)	Open Panel Exhaust Concentrations from Waste Emissions (ppmv)	29 CFR 1910.1000 OSHA 8-hour Permissible Exposure Limit (ppmv)
Carbon Disulfide	76.14	1.57e-06	0.13	1.30e-07	2.04e-13	5.67e-02	1.80e-05	20
Carbon Tetrachloride	153.84	1.21e-06	408.00	4.08e-04	4.94e-10	2.77e+02	4.34e-02	10
Chlorobenzene	112.56	1.16e-06	7.88	7.88e-06	9.14e-12	3.76e+00	8.04e-04	75
Chloroform	119.39	1.34e-06	25.21	2.52e-05	3.38e-11	1.47e+01	2.97e-03	50[1]
1,1-Dichloroethene	96.95	1.40e-06	7.54	7.54e-06	1.06e-11	3.74e+00	9.29e-04	1[2]
Methyl Ethyl Ketone	72.1	1.30e-06	42.42	4.24e-05	5.51e-11	1.45e+01	4.85e-03	200
Methylene Chloride	84.94	1.48e-06	497.93	4.98e-04	7.37e-10	2.29e+02	6.49e-02	500
1,1,2,2-Tetrachloroethane	167.86	1.21e-06	5.73	5.73e-06	6.93e-12	4.25e+00	6.10e-04	5
Toluene	92.13	1.20e-06	18.89	1.89e-05	2.27e-11	7.63e+00	1.99e-03	200

[1]Ceiling value, a 15-minute time weighted average; no 8-hour value specified.
[2]No value listed; assumed to be 1.

Maximum panel exhaust concentration from waste emissions = $$\frac{(X) \times (ADE) \times (MW) \times (10^6\ \mu g/g)}{(V) \times (0.0283\ m^3/ft^3) \times (min / 60\ s)}$$

where
- X = number of drums in the panel = 81,000 drums
- ADE = average drum emission rate (mole/s) = (DF) x (MF)
  - DF= NFT-013 diffusion rate, mole/s/mole fraction
  - MF= mole fraction = (HC) x (molfrac/10^6 ppmv)
  - HC= weighted average drum headspace concentration
- MW = molecular weight by compound (g/mole)
- V = panel ventilation rate, 47,000 ft^3/min (2,000 each of 6 filled rooms + 35,000 working room)

Conversion for $\mu g/m^3$ to ppmv:

$$ppmv = \frac{(\mu g/m^3) \times (0.024)}{(MW)}$$

TABLE D9-2
MAXIMUM OCCUPATIONAL EXPOSURE FROM WASTE HANDLING BUILDING WASTE EMISSIONS

Compound	Molecular Weight (g/g mole)	INEL NFT-013 Diffusion (mole/s/molfrac)	Weighted Average Drum Headspace Concentration (ppmv)	Mole Fraction (molfrac)	Average Drum Emission Rate (mole/s/drum)	Maximum CH Area Concentrations from Waste Emissions ($\mu g/m^3$)	Maximum CH Area Concentrations from Waste Emissions (ppmv)	29 CFR 1910.1000 OSHA 8-hour TWA Concentrations (ppmv)
Carbon Disulfide	76.14	1.57e-06	0.13	1.30e-07	2.04e-13	6.60e-05	2.90e-08	20
Carbon Tetrachloride	153.84	1.21e-06	408.00	4.08e-04	4.94e-10	3.22e-01	5.05e-05	10
Chlorobenzene	112.56	1.16e-06	7.88	7.88e-06	9.14e-12	4.37e-03	9.35e-07	75
Chloroform	119.39	1.34e-06	25.21	2.52e-05	3.38e-11	1.71e-02	3.46e-06	50[1]
1,1-Dichloroethene	96.95	1.40e-06	7.54	7.54e-06	1.06e-11	4.35e-03	1.08e-06	1[2]
Methyl Ethyl Ketone	72.1	1.30e-06	42.42	4.24e-05	5.51e-11	1.69e-02	5.64e-06	200
Methylene Chloride	84.94	1.48e-06	497.93	4.98e-04	7.37e-10	2.66e-01	7.54e-05	500
1,1,2,2-Tetrachloroethane	167.86	1.21e-06	5.73	5.73e-06	6.93e-12	4.94e-03	7.09e-07	5
Toluene	92.13	1.20e-06	18.89	1.89e-05	2.27e-11	8.87e-03	2.32e-06	200

[1] Ceiling value, a 15-minute time weighted average; no 8-hour value specified.
[2] No value listed; assumed to be 1.

Maximum CH panel exhaust concentration from waste emissions = $$\frac{(X) \times (ADE) \times (MW) \times (10^6\ \mu g/g)}{(V) \times (0.0283\ m^3/ft^3) \times (min / 60\ s)}$$

where
- X = number of drums in the WHB at one time = 42 drums
- ADE = average drum emission rate (mole/s) = (DF) x (MF)
  - DF = NFT-013 diffusion rate, mole/s/mole fraction
  - MF = mole fraction = (HC) x (molfrac/10^6 ppmv)
  - HC = weighted average drum headspace concentration of a compound
- MW = molecular weight by compound (g/mole)
- V = CH area ventilation rate = 20,960 ft^3/min

Conversion for $\mu g/m^3$ to ppmv:

$$ppmv = \frac{(\mu g/m^3) \times (0.024)}{(MW)}$$

TABLE D9-3
MAXIMUM PUBLIC EXPOSURE CONCENTRATION AT THE LWB FROM UNDERGROUND WASTE EMISSIONS

Compound	Molecular Weight (g/g mole)	Carbon Composite Filter Diffusion (mole/s/ molfrac)	Weighted Average Drum Headspace Concentration (ppmv)	Drum Headspace Mole Fraction (molfrac)	Average Drum Emission Rate (mole/s/drum)	Land Withdrawal Boundary Concentrations From:				35-year Health-based Limit ($\mu g/m^3$)	Excess Public Risk Level Probability
						Single Open-Panel Emissions ($\mu g/m^3$)	Single Closed-Panel Emissions ($\mu g/m^3$)	All Closed-Panel Emissions ($\mu g/m^3$)	Open- and Closed- Panel Emissions ($\mu g/m^3$)		
Carbon Disulfide	76.14	1.57e-06	0.13	1.30e-07	2.04e-13	6.71e-07	6.78e09	6.78e-08	1.40e-06	10.000	NA
Carbon Tetrachloride	153.84	1.21e-06	408.00	4.08e-04	4.94e-10	3.28e-03	4.30e-05	4.30e-04	6.91e-03	0.133	1.40e-12
Chlorobenzene	112.56	1.16e-06	7.88	7.88e-06	9.14e-12	4.45e-05	6.08e-07	6.08e-06	9.38e-05	20.000	NA
Chloroform	119.39	1.34e-06	25.21	2.52e-05	3.38e-11	1.74e-04	2.06e-06	2.06e-05	3.65e-04	0.087	1.13e-13
1,1-Dichloroethene	96.95	1.40e-06	7.54	7.54e-06	1.06e-11	4.42e-05	5.01e-07	5.01e-06	9.24e-05	0.400	6.25e-13
Methyl Ethyl Ketone	72.1	1.30e-06	42.42	4.24e-05	5.51e-11	1.72e-04	2.10e-06	2.10e-05	3.60e-04	1000.000	NA
Methylene Chloride	84.94	1.48e-06	497.93	4.98e-04	7.37e-10	2.70e-03	2.90e-05	2.90e-04	5.64e-03	4.255	3.58e-14
1,1,2,2-Tetrachloroethane	167.86	1.21e-06	5.73	5.73e-06	6.93e-12	5.03e-05	6.59e-07	6.59e-06	1.06e-04	0.345	8.30e-13
Toluene	92.13	1.20e-06	18.89	1.89e-05	2.27e-11	9.02e-05	1.19e-06	1.19e-05	1.90e-04	400.000	NA

TABLE D9-3 (CONTINUED)
MAXIMUM PUBLIC EXPOSURE CONCENTRATION AT THE LWB FROM WHB CONCENTRATIONS

OPE = single open panel emissions = $\frac{(X) \times (ADF) \times (ADE) \times (MW) \times (10^6\ \mu g/g)}{(V) \times (0.0283\ m^3/ft^3) \times (min/60\ s)}$

where
- X = number of drums per panel = 81,000 drums/panel
- ADF = air dispersion factor = 0.000107
- ADE = average drum emission rate (mole/s) = (DF) x (MF)
  - DF= NFT-013 diffusion rate (mole/s/mole fraction)
  - MF= mole fraction = (HC) x (molfrac/10^6 ppmv)
  - HC= weighted average drum headspace concentration of a compound
- MW = molecular weight by compound (g/mole)
- V = mine ventilation rate (425,000 ft^3/min)

CPE = single closed panel emissions = $\frac{(ADF) \times (MF) \times [(GR) + (VGR)] \times (X) \times (MW) \times (10^6\ \mu g/g)}{(525{,}960\ min/yr \times (V) \times (0.0283\ m^3/ft^3)}$

where
- GR = average gas generation rate (mole/drum/yr) = 0.1 mole/drum/yr
- VGR = equivalent gas generation rate due to panel volumetric reduction (creep) = 0.4 mole/drum/yr

isposal at closure = (SCPE) x (10)
isposal at waste emplacement = (SOPE x 2) + (SCPE x 8)
losed Panel Emissions = (SCPE) x (10)
pen and Closed Panel Emissions = (SCPE x 2) x (SCPE x 8)

xcess Public Risk Level = $\frac{(RL) \times (OCE) \times (PDF)}{(HBL)}$

where
- RL = Risk Level (1e-06 or 1e-05)
- OCE = Open and Closed Panel Emissions
- HBL = 35-Year Health-Based Level
- PDF = Population Density Factor (1/3,700 or 1/37,000)

PDF = (PD) x (RL)

where
- PD = Population Density within a 10 mile (16.1 kilometer) radius = 27

IA = Not Applicable

TABLE D9-4
MAXIMUM PUBLIC EXPOSURE CONCENTRATION AT THE LWB FROM WHB CONCENTRATIONS

Compound	Molecular Weight (g/g mole)	Carbon Compsite Filter Diffusion (mole/s/molfrac)	Weighted Average Drum Headspace Concentration (ppmv)	Mole Fraction (molfrac)	Average Drum Emission Rate (mole/s/drum)	LWB Concentration from Waste Handling Building Emissions ($\mu g/m^3$)	35-Year Health-Based Level ($\mu g/m^3$)	Excess Public Risk Level (Probability)
Carbon Disulfide	76.14	1.57e-06	0.13	1.30e-07	2.04e-13	3.21e-10	1.00e+01	N/A
Carbon Tetrachloride	153.84	1.21e-06	408.00	4.08e-04	4.94e-10	1.57e-06	1.33e-01	3.18e-16
Chlorobenzene	112.56	1.16e-06	7.88	7.88e-06	9.14e-12	2.12e-08	2.00e+01	N/A
Chloroform	119.39	1.34e-06	25.21	2.52e-05	3.38e-11	8.32e-08	8.70e-02	2.59e-17
1,1-Dichloroethene	96.95	1.40e-06	7.54	7.54e-06	1.06e-11	2.11e-08	4.00e-01	1.43e-16
Methyl Ethyl Ketone	72.1	1.30e-06	42.42	4.24e-05	5.51e-11	8.20e-08	1.00e+03	N/A
Methylene Chloride	84.94	1.48e-06	497.93	4.98e-04	7.37e-10	1.29e-06	4.26e+00	8.20e-18
1,1,2,2-Tetrachloroethane	167.86	1.21e-06	5.73	5.73e-06	6.93e-12	2.40e-08	3.45e-01	1.88e-16
Toluene	92.13	1.20e-06	18.89	1.89e-05	2.27e-11	4.31e-08	4.00e+02	N/A

LWB Concentration from WHB emissions = $\frac{(X) \times (ADF) \times (ADE) \times (MW) \times (10^6\ \mu g/g)}{(V) \times (0.0283\ m^3/ft^3) \times (min / 60\ s)}$

where
- X = number of drums in the WHB at one time, 42 drums
- ADF = air dispersion factor = 0.000011
- ADE = average drum emission rate (mole/s) = (DF) x (MF)

  where
  - DF = NFT-013 diffusion rate, mole/s/mole fraction
  - MF = mole fraction = (HC) x (molfrac/10^6 ppmv)
  - HC = weighted average drum headspace concentration of a compound
- MW = molecular weight by compound (g/mole)
- V = WHB exhaust ventilation rate 47,450 ft^3/min

Excess Public Risk Level = $\frac{(RL) \times (LWBC) \times (PDF)}{(HBL)}$

where
- RL = Risk Level (1e-06 or 1e-05)
- LWBC = LWB Concentration
- HBL = 35-Year Health-Based Level
- PDF = Population Density Factor (1/3,700 or 1/37,000)
  PDF = (PD) x (RL)

  where
  - PD = Population Density within a 10-mile radius = 27

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