**Geotechnical Analysis
Report
for
July 1994 - June 1995**

September 1996

Waste Isolation Pilot Plant

MASTER

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FOREWORD AND ACKNOWLEDGMENTS

This report provides an assessment of the geotechnical status of the Waste Isolation Pilot Plant (WIPP). During the construction of the principal underground access and experimental areas, reporting was on a quarterly basis. Since 1987, reports have been published annually because additional excavations are taking place gradually, over extended periods. This report presents and analyzes data collected from July 1, 1994 to June 30, 1995.

The format of the Geotechnical Analysis Report was selected to meet the needs of several audiences. This report focuses on the geotechnical performance of the various underground facilities including the shafts, shaft stations, access drifts, experimental rooms, and waste storage areas. The results of excavation effects, investigations, stratigraphic mapping, and other geologic studies are also included. The report provides an evaluation of the geotechnical aspects of performance in the context of the relevant design criteria and also describes the techniques used to acquire the data and the performance history of the instruments. The depth and breadth of the evaluation for the different underground facilities varies according to the types and quantities of data that are available, and the complexity of the recorded geotechnical responses.

Documentation of data in graph format and instrument history in tabular format can be provided upon request at nominal cost.

The Geotechnical Analysis Report is a multi-author report that was prepared by Westinghouse, Waste Isolation Division for the DOE, Carlsbad Area Office, Carlsbad, New Mexico. Work was supported by the DOE under Contract No. DE-AC04-86AL31950.

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Responsibility for analysis and reporting of the individual chapters is as noted below.

Chapter	Contributors
1.0 Introduction	J.L. Francke
2.0 Geology	L.J. Terrill
3.0 Performance of Shafts and Keys	J.L. Francke
4.0 Performance of Shaft Stations	J.L. Francke and J.D. VandeKraats
5.0 Performance of Access Drifts	R.E. Lewis and J.L. Francke
6.0 Performance of Waste Disposal Area	J.L. Francke, R.E. Lewis, and J.D. VandeKraats
7.0 Numerical Modeling of Underground Excavations	C.T. Francke
8.0 Excavations Effects Program	L.J. Terrill
9.0 Summary	J.L. Francke

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List of Acronyms/Abbreviations

AIS	Air Intake Shaft
C&SH	Construction and Salt Handling
CH	Contact Handled
cm/yr	Centimeters per year
DOE	United States Department of Energy
EEP	Excavation Effects Program
FLAC	Fast Lagrangian Analysis of Continua
GIS	Geomechanical Instrumentation System
in/yr	Inches per year
LTC	Local Termination Cabinets
MB139	Marker Bed 139
SPDV	Site Preliminary Design Validation
TRU	Transuranic
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant

1.0 Introduction

The geotechnical data from the underground excavations at the WIPP are interpreted and presented in this Geotechnical Analysis Report. The data are used to characterize conditions, assess design assumptions, and understand and predict the performance of the underground excavations during operations. The data are obtained as part of a regular monitoring program. They do not include data from tests performed by Sandia National Laboratories, the Scientific Advisor to the project in support of performance assessment studies.

Geotechnical Analysis Reports have been prepared routinely and made available to the public since 1983. During the Site and Preliminary Design Validation Program, the Architect/Engineer for the project produced the reports on a quarterly basis to document the geomechanical performance during and immediately after construction of the underground. Upon completion of the construction phase of the project in 1987, the reports have been prepared annually by the Management and Operating Contractor for the facility. This report describes the performance and conditions of selected areas from July 1, 1994, to June 30, 1995.

1.1 Location and Description

The WIPP is located in southeastern New Mexico, about 30 miles (50 km) east of Carlsbad (Figure 1-1). The surface facilities have been built on the flat to gently rolling hills that are characteristic of the Los Medanos (sand dunes) area. The underground facilities are being excavated approximately 2,150 feet (655 m) beneath the surface, in the Salado Formation. A plan view of the underground facilities at the WIPP site is shown in Figure 1-2.

1.2 Mission

The WIPP was authorized by Congress in 1979 (Public Law 96-164) to provide "...a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." The WIPP is intended to receive, handle, and permanently dispose of transuranic mixed waste. To fulfill this mission, the DOE constructed a full scale facility to demonstrate both technical and operational principles of the permanent storage/disposal of transuranic and transuranic-mixed wastes. Technical aspects are those concerned with the

Figure 1-1
General Location of WIPP Facility

Figure 1-2
Schematic of Underground Facilities

design, construction, and performance of the subsurface structures. Operational aspects refer to the receiving, handling, and emplacement of these transuranic wastes in salt. The facility is also designed for in-situ studies and nonradioactive experiments in salt.

1.3 Development Status

To fulfill its mission, the DOE developed the WIPP in a phased manner. The SPDV phase began in 1980 with the purpose of characterizing the site and obtaining geotechnical data to determine whether site characteristics and design were suitable for a permanent disposal facility. During this phase, the Salt Handling Shaft, a Ventilation Shaft, a drift to the southernmost extent of the proposed waste storage area, a four-room experimental panel, and access drifts were excavated. Surface-based geological and hydrological investigations were also conducted. The data obtained from the SPDV investigations were reported in the Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program (DOE, 1983).

Based on the favorable results of the SPDV investigations, additional activities were initiated. These included construction of surface structures, conversion of the Ventilation Shaft for use as the Waste Shaft, excavation of the Exhaust Shaft, development of additional access drifts to the waste disposal area, and excavation of additional experimental rooms to support research and development activities. Geotechnical data acquired during this phase were used to evaluate the performance of the excavations in the context of established design criteria (DOE, 1984). Results of these evaluations were reported in Geotechnical Field Data Reports (DOE, 1985; DOE, 1986a) and were summarized in the Design Validation Final Report (DOE, 1986b).

The Design Validation Final Report concluded that the facilities including waste disposal areas could be developed and operated to fulfill the long-term mission of the WIPP. However, some modifications to the reference design were proposed in order to meet the requirements for the life of the openings during an initial demonstration phase when retrievability of the waste remained an option. Current modifications are completed in accordance with current design descriptions.

The original design for the waste disposal rooms at the WIPP provided a limited time in which to mine the salt and emplace waste. Each panel, consisting of seven disposal rooms, was scheduled to be mined, filled with waste containers, and backfilled in less than five years before being closed. Field studies, as part of the SPDV Program, showed that unsupported openings of a typical disposal room configuration at the WIPP would remain stable, and that closure from creep would not impact equipment clearances during the five year period following excavation.

The information from these studies provided the validation of the design of openings for the permanent disposal of waste under routine operations.

Panel 1 was developed to receive waste for an operations demonstration and test phase that were scheduled to start in October 1988. This original plan consisted of drums of contact-handled transuranic waste stored in rooms for a period of five years. The waste-filled rooms were to be inaccessible, but the option to re-enter was to be maintained so that the waste could be removed, if required. To assist with the possible re-entry, rockbolts were installed in the rooms in Panel 1 to maintain roof stability.

The operations demonstration was deferred, and the test phase was modified to use contact-handled transuranic waste in bin-scale tests, planned for Room 1, Panel 1. This program was to investigate the repository conditions that would result from the different types of waste to be disposed of underground. The decision to use Room 1, Panel 1 for these bin-scale tests was made in June 1989, when initial waste receipt was anticipated for 1990. For the planned on-site bin-scale tests, an additional seven years of useful life from July 1991 was required for Room 1, Panel 1. These changing requirements led to more stringent criteria for roof stability. In late 1993, the DOE decided to conduct the test phase off site, with a new date for first waste receipt at the WIPP in 1998. Although the test program was moved off site, Panel 1 continues to be maintained and monitored.

1.4 Purpose and Scope of Geomechanical Monitoring Program

The purpose of the geomechanical monitoring program is to provide in-situ data to support:

- early detection of conditions that could compromise operational safety
- evaluation of room closure
- design modifications and remedial actions and,
- interpretation of the in-situ behavior of underground openings, for comparison with established design criteria.

The geomechanical instrumentation system (GIS) used in the WIPP facility provides data which are collected, processed, and stored for analysis. The following discussion briefly describes the major components of the GIS.

1.4.1 Instrumentation

Instruments installed for measuring the geomechanical response of the shafts and other underground openings include convergence points, convergence meters, extensometers, rockbolt load cells, pressure cells, strain gauges, piezometers, and joint meters. A summary of the geomechanical instrumentation specifications is presented in Table 1-1.

1.4.2 Data Acquisition

The individual instruments that comprise the GIS are either read manually, using portable devices, or remotely, by activating polling devices from the surface. Remotely read instruments are connected to one of eleven dataloggers located underground, and readings are collected by referencing the appropriate identifier code. Upon completion of a verification process, as described in WIPP procedures, the data are transferred to a computer database. The manual reading devices are taken to the instrument locations underground, and the instruments are read. The data are recorded on an appropriate data sheet and later entered into database files where they are combined with the remotely acquired readings.

The underground data acquisition system consists of instruments, polling devices, and a communications network. The polling devices are installed in underground local terminal cabinets (LTC) to query each individual instrument. The polling devices are connected by datalink cables and modems to the surface datalogging computer. Each polling device consists of a remote switching station and readout unit that is connected to the instruments throughout the facility. The surface datalogging computer utilizes a datalink cable and modem interface to receive the instrument readings from the polling units.

Whether acquired manually or remotely, geomechanical data are entered into the database files of the GIS data processing system. The processing system consists of programmed routines to enter, reduce, and transfer the instrumentation data to permanent storage files. Using dBase IV[®] software, the datalogging and data processing routines are accessed by a personal computer located on the surface at the WIPP site. Additional routines allows access to these permanent storage files for tabular reporting and graphical plotting.

Table 1-1
Geomechanical Instrumentation System

Instrument Type	Measures	Range	Resolution
Sonic Probe Borehole Extensometer	Cumulative Deformation	0-2 inches	0.001 in.
Convergence Points	Cumulative Deformation	2-50 feet	0.001 in.
Wire Convergence Meters	Cumulative Deformation	0-3 feet	0.001 in.
Sonic Probe Convergence Meters	Cumulative Deformation	0-2.5 feet	0.001 in.
Embedded Strain Gauges	Cumulative Strain	0-3000 $\mu\text{in./in.}$	1 $\mu\text{in./in.}$
Spot-Welded Strain Gauges	Cumulative Strain	0-2500 $\mu\text{in./in.}$	1 $\mu\text{in./in.}$
Rockbolt Load Cells	Load	0-50 tons	40 lb.
Earth Pressure Cells	Pressure	0-1000 psi	1 psi
Piezometers	Fluid Pressure	0-500 psi	0.5 psi
Joint Meters	Cumulative Deformation	0-4 inches	0.001 in.
Vibrating Wire Borehole Extensometer	Cumulative Deformation	0-4 inches	0.001 in.

1.4.3 Data Evaluation

Copies of the instrumentation data base and data plots are available upon request and can also be found in previous geotechnical data reports issued annually since in 1983.

Closure measurements are acquired manually from convergence point anchors and remotely with convergence meters. The plots are presented as ground displacement monitored over time and plotted as either surface displacement or closure versus time.

Extensometers provide relative displacement data acquired from sonic probe and vibrating wire extensometers. The displacement is the measure of movement in the rock strata, intercepted by the extensometer borehole at various depths. The displacement is then compared to a fixed point providing a measured displacement relative to a fixed point.

Extensometers consist of rods that are anchored in a borehole at various depths. The deepest anchor is assumed to be fixed in undisturbed ground and is considered the reference point. Typically, the plots will show greater ground movement near the opening, i.e., the collar of the hole.

Rockbolt load cells are used to determine the bolt loading. Plots consist of load, in pounds, versus time for each instrumented bolt.

Earth pressure cells and strain gauges are used to determine the loads in and around the shaft liners and are depicted in time-based plots. Monitoring of these instruments indicates whether there is any stress buildup in the shaft lining systems.

Piezometers are used to measure the gauge pressure of ground water. They are installed in the shafts at varying elevations to monitor the hydraulic head acting on the shaft liners. Plots from piezometers are presented as pressure versus time.

Joint meters are installed perpendicular to a crack and monitor the separation of the crack over time. Plots are presented as displacement versus time.

1.4.4 Data Errors

As described above, GIS data are processed through a comprehensive database management system. These steps are performed according to approved quality control procedures. Whether acquired manually or remotely, GIS data are processed and permanently stored according to approved procedures. On occasion, when an erroneous reading occurs; there are several possible explanations:

- the measuring device was misread
- the reading was recorded incorrectly or,
- the measuring device was not functioning within specifications.

When an erroneous reading is suspected, an immediate evaluation of the previous readings is performed and a second reading is collected. If the second reading falls in line with the instrument trend, the first reading is discarded and the second reading is entered in the database. If the second reading and subsequent readings remain out of the instrument trend, an assessment of ground conditions in the vicinity of the instrument is performed to determine the reason for the discrepancy. In addition, reading frequency may be increased.

All steps performed to correct erroneous readings are documented and filed for future reference.

2.0 Geology

This section provides a generalized description of the stratigraphy of the region surrounding WIPP with the generalized geology of the region depicted in Figure 2-1. Detailed descriptions of the units can be found in Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico Volume I, (SAND 78-1596).

2.1 Castile Formation

The evaporite Castile Formation was created by the precipitation of sulfates (gypsum, anhydrite), carbonates (calcite) and halite within the confines of the Delaware Basin, a great Permian reef complex. Lithologically, the Castile is the least complex of the evaporite formations, being composed chiefly of anhydrite with a few interbeds of halite and some limestone. The formation is approximately 1250 ft (380 m) thick in the WIPP vicinity.

2.2 Salado Formation

Ultimately the thickness of the Castile Formation created a shallow saline lagoon environment which then progressed through numerous wetting and drying cycles resulting in the deposition of nearly 2000 ft (610 m) of evaporites (primarily halite) of the Salado Formation. The wetting and drying cycles are reflected in cyclic sequences present in the formation.

Each cycle begins with a layer consisting predominantly of claystone. This lowermost zone is followed by a layer of anhydrite, which is in turn followed by a layer of halite. The entire sequence is capped by a bed of argillaceous (clay-rich) halite.

The Salado Formation is subdivided into three informal members, each of which contains similar amounts of halite, anhydrite, and polyhalite, and are differentiated on the basis of other potassium and magnesium-bearing minerals. The WIPP facility disposal and experimental horizons are located within the unnamed lower member, at 2,150 ft (660 m) below the surface.

The excavations lie with a 40 ft (12 m) section which is laterally continuous as described above. Within this section, layers of clay and anhydrite are locally designated as shown in Figure 2-2.

Figure 2-1
Generalized Regional Geology

SCALE IN
INCREMENTS OF
FIVE FEET
(1.5 m)

LEGEND

Halite	Polyhalitic Halite

Anhydrite	Anhydrite Stringers

Argillaceous Halite	Clay Seam

NOTES:

1. Distances are averaged from representative core hole logs and shaft and test room mapping. Actual distances may vary locally from those shown.
2. Descriptions are based on core hole data, shaft mapping, and visual inspection of exposure in underground drifts.
3. Percentages of argillaceous material and polyhalite are based on visual estimates from examination of drill core and exposures in the underground excavations. Sandia National Laboratories measurements of insolubles from selected core were used as a point of reference.

Figure 2-2
Generalized Facility Stratigraphy

Anhydrite "a", underlain by Clay H, is located about 13 ft (4 m) above the disposal horizon roof of the excavations. Anhydrite "b", underlain by Clay G, is located about 6.5 ft (2 m) above the roof and a diffuse layer, Clay F, is found in the ribs about 2 ft (0.6 m) below the roof.

A 20 to 32 in (50 to 80 cm) thick, bed of anhydrite, identified as Marker Bed 139 (MB139), typically lies about 5 ft (1.5 m) below the floor throughout the storage horizon. Lateral variability in thickness, up to 6 in (15 cm), and in composition exist within MB139 at both repository and regional scale. The top of MB139 is undulatory while the bottom is subhorizontal and is underlain by Clay E. The layers of clay and anhydrite have a significant impact on the mechanical performance of the excavation. Clay layers provide surfaces along which slip and separation can occur, whereas anhydrite acts as a brittle unit that does not deform plastically.

Excavations in the experimental horizon lie 6 m (18 ft) above the storage horizon. The floor is located at Anhydrite "b" and Anhydrite "a" is visible in the ribs or roof. Clay I typically occurs at 1.3 to 1.5 m (4.5 to 5 ft) above the roof in the access drifts and at the roof in the rooms. As in the storage horizon, the clay layers have a significant impact on the geomechanical deformation of the experimental excavations.

2.3 Rustler Formation

Overlying the Salado Formation is the Rustler Formation. The Rustler is about 300 ft (92 m) thick and contains proportionately the largest amount of clastic material of the three Permian evaporite formations. The Rustler is subdivided into five members of decreasing age as follows: an unnamed lower member, the Culebra Dolomite Member, the Tamarisk Member, the Magenta Dolomite Member and the Forty-niner Member.

At the WIPP facility, the Rustler is lithologically divided. The lower portion contains primarily sandstone with lesser amounts of anhydrite, polyhalite and halite. The anhydritic upper portion contains interbeds of mudstone and dolomite. The Culebra and Magenta Dolomite Members are found within this upper portion and are areally persistent, serving as important marker units. The Culebra is the most transmissive hydrologic unit in the Rustler.

2.4 Dewey Lake (Redbeds) Formation

The Dewey Lake (Redbeds) Formation is the uppermost of the Permian Series in the WIPP vicinity. The Dewey Lake represents a transition from the lower marine-influenced evaporite deposition to fluvial deposition on a broad, low-relief, fluvial plain. The redbeds, about 475 ft

(145 m) thick, consist of interbedded fine sandstone, siltstone, mudstone, and claystone with locally abundant greenish-gray reduction spots and gypsum-filled fractures.

2.5 Dockum Group

The Dockum Group consists of about 25 ft (7.6 m) of fine-grained flood plain sediments and coarse alluvial debris of Triassic age. At the WIPP facility, the Dockum Group occurs as an erosional wedge pinching out near the center of the site. Some authors (eg. Holt and Powers, 1990) use the term Santa Rosa to refer to local rocks of Triassic age.

2.6 Gatuña Formation and Mescalero Caliche

The Gatuña Formation and Mescalero Caliche are of Pleistocene age. The Gatuña, which overlies the Dockum Group in the WIPP vicinity, consists of about 13 ft (4 m) of poorly consolidated sand, gravel, and silty clay which is light red and mottled with dark stains. The unit contains abundant calcium carbonate but is poorly cemented.

The Mescalero Caliche, about 4 ft (1.2 m) thick in the WIPP vicinity, is a hard, resistant soil horizon that lies beneath a cover of wind-blown sand. The horizon is petrocalcic, or very strongly cemented with calcium carbonate. Petrocalcic horizons form slowly beneath a stable landscape at the maximum depth of infiltration of soil moisture. Many of the surface structures at WIPP are founded on top of the Mescalero Caliche.

3.0 Performance of Shafts and Keys

3.1 Salt Handling Shaft

The first construction activity undertaken during the SPDV work was the excavation of the Exploratory Shaft, subsequently designated the Construction and Salt Handling (C&SH) Shaft, and currently designated the Salt Handling Shaft (Figure 1-2). The shaft was drilled from July 4 to October 24, 1981, and geologic mapping was conducted in the spring of 1982 (DOE, 1983). Figure 3-1 presents the generalized stratigraphy at the Salt Handling Shaft.

The Salt Handling Shaft is lined with steel casing and has a 10-foot (3-meter) inside diameter from the ground surface to a depth of 846 feet (258 meters). The 10-foot (3-meter) diameter casing extends through the concrete shaft key to a depth of 880 feet (268 meters). The nominal shaft diameter is 12 feet (4 m) from the key to the bottom of the shaft at 2,298 feet (700 meters) and is unlined. The steel liner thickness increases with depth, starting at 0.62-inch (1.6-centimeter) thick at the top and increasing to 1.5 inches (3.8 centimeters) thick at the key. Cement grout is placed between the liner and rock interface. The shaft key is a 37.5-foot (11.4 meter)-long reinforced-concrete structure at the base of the steel liner.

3.1.1 Shaft Performance

During this reporting period no modifications were made to the Salt Handling Shaft. Shaft inspections were performed on a weekly basis. The shaft is in satisfactory condition.

3.1.2 Instrumentation

Installation of geomechanical instrumentation in the Salt Handling Shaft took place during April and July of 1982. Instrumentation consists of extensometers, piezometers, and radial convergence points at various levels in the shaft as shown in Figure 3-2. In the shaft key, instrumentation includes strain gauges, pressure cells, and piezometers (Figure 3-3).

Seventy-two percent of the instrumentation in the Salt Handling Shaft remain functional. Instruments that are still in operation include one extensometer at level 2057' (627 m), all twelve piezometers, three earth pressure cells, and 31 strain gauges.

SALT HANDLING SHAFT

Figure 3-1
Generalized Salt Handling Shaft Stratigraphy

SALT HANDLING SHAFT

NOTES

1. RC's at each level consist of four points.
2. The term "level" is an approximate depth from the top of the shaft bunion at elevation of 3410.0 feet (1039.4 meters) MSL.
3. Levels are shown in units of feet and meters.
4. Piezometers are oriented at N30°W and S30°E.

LEGEND

- PE Piezometer
- RC Radial Convergence Points (RC's)
- GE Extensometer

GG653

Figure 3-2
Salt Handling Shaft Instrumentation (without Shaft Key)

**Figure 3-3
Salt Handling Shaft Key Instrumentation**

3.2 Waste Shaft

As part of the SPDV program, a six-foot (2-meter) diameter ventilation shaft was excavated from December 1981 through February 1982 in order to allow a two-shaft underground air circulation scheme to function. From October 11, 1983 through June 11, 1984, this shaft was enlarged to 20- to 23-foot (6- to 7- meter) diameter and lined, then renamed the Waste Shaft. Geologic mapping was conducted during shaft enlargement from December 9, 1983 through June 5, 1984 (Holt and Powers, 1984). The generalized stratigraphy of the Waste Shaft is presented in Figure 3-4.

The Waste Shaft is lined with unreinforced concrete and has a 19-foot (6-meter) inside diameter from the ground surface to 837 feet (255 meters). Liner thickness increases with depth from 10 inches (25 cm) at the surface to 20 inches (51 cm) at the key. The Waste Shaft key is 63 feet (19 m) long, 4.25 feet (1.3 m) thick, and constructed of reinforced concrete. The bottom of the key is at 900 feet (274 meter). The section of the shaft below the key is 20 feet (6 m) in diameter and increases to 23 feet (7 m) just above the shaft station. The 23-foot (7-meter) diameter extends to a depth of approximately 2,286 feet (697 meters).

3.2.1 Shaft Performance

Shaft inspections are conducted on a weekly basis by mining operations personnel. The condition of the shaft is satisfactory. During this reporting period no modifications have been made to the Waste Shaft. The cable-support ground control system installed in the east brow of the shaft station was detensioned twice during this reporting period.

3.2.2 Instrumentation

Extensometers, piezometers, earth pressure cells, and radial convergence points were installed in the Waste Shaft from August 27 through September 10, 1984. The instrumentation configuration is presented in Figures 3-5 and 3-6.

Nine multi-position borehole extensometers were installed in arrays at levels 1071' (326 m), 1566' (477 m), and 2059' (628 m) as shown in Figure 3-5. Each array consists of three extensometers. Currently, five extensometers remain functional.

Figure 3-4
Generalized Waste Shaft Stratigraphy

WASTE SHAFT

NOTES

1. RC's at each level consist of four points.
2. The term "level" is an approximate depth from the shaft collar at elevation 3409 ft (1039 m) above MSL.
3. Piezometers are oriented at N30°W and S30°E.

LEGEND

- PE Piezometer
- RC Convergence Points (RC's)
- GE Extensometer

GG654.2

Figure 3-5
Waste Shaft Instrumentation (without Shaft Key)

Figure 3-6
Waste Shaft Key Instrumentation

Twelve piezometers were installed in the lined section of the Waste Shaft on September 7, and 8, 1984 to monitor pressure behind the shaft liner and key section in the shaft. All twelve piezometers remain in operation

Four earth pressure cells were installed in the key section of the Waste Shaft during concrete emplacement from March 23 through April 3, 1984. These instruments measure the normal stress between the concrete key and the Salado Formation as the creep effects load the key structure. All earth pressure cells remain in working condition.

3.3 Exhaust Shaft

The Exhaust Shaft was excavated from September 22, 1983, through November 29, 1984, to establish a dedicated route for exhaust air from the underground facility to the surface. Comprehensive geologic mapping was conducted from July 16, 1984, through January 18, 1985, (DOE, 1986c). The generalized Exhaust Shaft stratigraphy is presented in Figure 3-7.

The Exhaust Shaft is lined with unreinforced concrete from the surface to the top of the shaft key at a depth of 844 feet (257 m). The liner thickness increases from 10 to 16 inches (25 to 41 cm) over that distance. The Exhaust Shaft key is 63 feet (19 m) long and 3.5 feet (1 meter) thick.

The diameter below the shaft key is 15 feet (5 m). There, the shaft is lined with wire mesh anchored by rockbolts. The shaft terminates at the facility horizon, 2150 feet (655 m), since there is no shaft sump.

3.3.1 Shaft Performance

Quarterly video inspections were performed. These inspections indicate that the shaft is in satisfactory condition. During this reporting period, on March 22, 1995, a scheduled video inspection revealed for the first time a thin stream of water spouting from the liner into the shaft, approximately 75 to 80 feet (23 to 24 meters) below the shaft collar. At time of reporting, work was underway to determine the source of the water.

3.3.2 Instrumentation

The Exhaust Shaft was equipped with geomechanical instrumentation in two stages. Earth pressure cells were installed behind the liner key during November 1984, and piezometers and multi-position borehole extensometers were installed during November and December 1985. The instrumentation configuration is presented in Figures 3-8 and 3-9.

EXHAUST SHAFT

EXPLANATION

	Sand and Sandstone
	Mudstone and Siltstone
	Anhydrite

	Halite
	Dolomite
	Concrete

NOTES

1. All rock below the Dockum Group are Permian in age.
2. All levels are measured from the collar at 3409 feet (1039 meters) above MSL.
3. MB=Marker Bed

02550.2

Figure 3-7
Generalized Exhaust Shaft Stratigraphy

EXHAUST SHAFT

NOT TO SCALE

NOTES

1. The term "level" is an approximate depth from the shaft collar at elevation 3409 ft (1039 m) above MSL.
2. Piezometers and extensometers are oriented at N75°E, N45°W and S15°W.

LEGEND

- (PE) Piezometer
 (GE) Extensometer

GG655

Figure 3-8
Exhaust Shaft Instrumentation (without Shaft Key)

**Figure 3-9
Exhaust Shaft Key Instrumentation**

Nine multi-position borehole extensometers were installed in the Exhaust Shaft, and only one, at level 1078' (329 m), remains operational. Of the 21 piezometers installed, 20 remain in working condition.

3.4 Air Intake Shaft

The Air Intake Shaft was excavated from December 4, 1987 through August 31, 1988 to establish a dedicated route for surface air to enter the underground facility. Comprehensive geologic mapping was conducted from September 14, 1988 through November 14, 1989 (DOE, 1990a). The generalized Air Intake Shaft stratigraphy is presented in Figure 3-10.

The Air Intake Shaft was lined with unreinforced concrete from the surface to a depth of 903 feet (275 m), the bottom of the shaft key. The Air Intake Shaft key is 81 feet (25 m) long with an inside diameter of 16 feet (5 m). The diameter below the shaft key is 20 feet (6 m), and the shaft is unlined from 81 feet (25 m) to depth of 2,150 feet (655 m).

3.4.1 Shaft Performance

The Air Intake Shaft is in satisfactory condition. Weekly inspections are performed.

3.4.2 Instrumentation

At the present time, the Air Intake Shaft is monitored by Sandia National Laboratories. Data collected is not included in this report.

AIR INTAKE SHAFT

EXPLANATION

	Sand and Sandstone
	Mudstone and Siltstone
	Anhydrite

	Halite
	Dolomite
	Concrete

NOTES

1. All rock below the Dockum Group are Permian in age.
2. Rustler depths were measured from the subcollar (18.5 ft (6 m) below top of cement). Keyway and brow were measured from the top of cement (Elev. 3409 ft (1039 m) above MSL.)
3. MB=Marker Bed

Figure 3-10
Generalized Air Intake Stratigraphy

4.0 Performance of Shaft Stations

4.1 Salt Handling Shaft Station

The Salt Handling Shaft Station was excavated from May 2 to June 3, 1982 by drilling and blasting. In 1987, the station was trimmed, removing the roof beam up to Anhydrite "b" between S90 and N20 using a mechanical scaler. The station area south of the shaft is 90 feet (27 m) long and 32 to 38 feet (10 to 12 m) wide. The height of the station south of the shaft is 18 feet (5.5 m) for a distance of 54 feet (16.5 m), and 14 feet (4.3 m) for the remaining 36 feet (11 m). The station dimensions north of the shaft are approximately 30 feet (9 m) long, 32 to 35 feet (10 to 11 m) wide and 18 feet (5.5 m) high. The shaft extends approximately 140 feet (43 m) below the facility horizon to accommodate the skip loading equipment and to act as a sump to collect any water, primarily rain water and condensation, that might enter the shaft. A generalized cross section of the station is shown in Figure 4-1.

4.1.1 Modifications to Excavation

Modifications made during this reporting period include local scaling of roof and ribs. In addition, the north brow of the Salt Handling Shaft was removed up to anhydrite "b" for a length of approximately 20 ft (6 meters). Brow removal was completed in May 1995 under Action Request (AR) No. 94-03021.

4.1.2 Instrumentation

Geomechanical instrumentation was installed in the Salt Handling Shaft Station from June 1982 through February 1983, with subsequent reinstallation of extensometers and convergence points as necessary. Figure 4-2 details the instrument locations in the Salt Handling Shaft Station before the roof was removed. Most of the instruments were either removed, or readings were suspended prior to the mining of the roof. Figure 4-3 details the instrument locations after the roof was taken down.

Currently, there are no functioning extensometers in the Salt Handling Shaft Station, however work is in progress to restore the extensometers located in the roof at S30, and S65. These extensometers were installed in September 1988, replacing two extensometers mined out during trimming activities. In addition, five convergence point arrays are monitored at N39, S18, S30, S65, and W12.

By combining data collected before and after roof beam removal, total convergence was calculated. As shown in Figure 4-4, the largest amount of vertical convergence has occurred at E0-S65 with approximately 35 inches (88.9 cm) over a period of 12.34 years followed by E0-S30 with a total convergence of approximately 30 inches (76.2 cm) over a period of 12.44 years.

From Figure 4-4, it is apparent that removal of the roof beam did influence vertical convergence as evident in data collected at arrays located at S65 and along the east and west ribs at S18. The trend in total convergence indicates a decrease after roof beam removal when compared to data collected prior to mining activities.

Currently only one horizontal convergence chord is monitored, it is located at E0-N39. Figure 4-5 shows a total horizontal convergence at N39 to be approximately 17 inches (43.2 cm), 37 percent lower than vertical convergence.

Figure 4-1
Generalized Salt Handling Shaft Station Stratigraphy

Figure 4-2
Salt Handling Shaft Station Instrumentation before Roof Excavation

Figure 4-3
Salt Handling Shaft Station Instrumentation after Roof Excavation

**Figure 4-4
Vertical Closure at Salt Handling Shaft Station**

**Figure 4-5
Horizontal Closure at Salt Handling Shaft**

4.2 Waste Shaft Station

The Waste Shaft Station was initially excavated with a continuous miner as a ventilation connection to a six foot (1.8 m) diameter exhaust shaft in November 1982. In 1984, the shaft station was enlarged to a height of 15 to 19 feet (4.5 to 6 m), and a width of 20 to 30 feet (6 to 9 m); the station is approximately 150 feet (46 m) long. In 1987, the station was trimmed, and concrete was placed on the floor. In February 1991, a portion of the concrete slab was removed. The portion of the concrete slab removed was approximately 53 feet (16 m) long, 23 feet (7 m) wide, and 18 inches (46 cm) thick. A generalized cross section of the station is shown in Figure 4-6.

4.2.1 Modifications to Excavation

During this reporting period approximately 30 ft (9 meters) of the remaining portion of the concrete slab was removed at the Waste Shaft Station. In addition, routine maintenance activities were performed.

4.2.2 Instrumentation

Initial instrumentation was installed between November 12 and December 2, 1982. Figure 4-7 details the instrument locations in the Waste Shaft Station before enlargement of the station, and Figure 4-8 details the locations after enlargement.

Currently there are three functioning extensometers in the Waste Shaft Station, they are located in the roof at W30, E35, and E140. In addition, convergence points are monitored at E90, and E140. The last convergence point monitored at E30 along the south rib was destroyed during removal of concrete slab during this reporting period.

Table 4-1 summarizes the history of the roof extensometers in the Waste Shaft Station. Of the three functioning extensometers, 51X-GE-00277 has had the largest amount of displacement across the deepest rod, at a depth of 50 ft (15.2 m), with a total displacement of 5.801 inches (14.735 cm), followed by 51X-GE-00268 at W30 with a displacement of 5.189 inches (13.180 cm) at a depth of 17 ft (5.2 m), and lastly, 51X-GE-00279 at E140 with a displacement of 4.717 inches (11.981 cm) across the deepest rod with a length of 50 ft (15.2 m). The extensometers remain in good working condition and data collected to date do not indicate an increase in displacement rate occurring in the roof at these locations.

The largest amount of total vertical convergence is at the E90 station, with a total convergence 15.871 inches (40.312 cm) over a period of 7.37 years, followed by E140 intersection. Figure 4-9 depicts vertical convergence for all convergence locations at the Waste Shaft Station. As shown, data does not indicate an increase in convergence rate for this reporting period.

In addition to extensometers and convergence points, monitoring of six rockbolt load cells installed in February 1988 continues.

Figure 4-8
Waste Shaft Station Instrumentation after Trimming

Fieldtag	Date Installed	Last Date Read	Life of Instrument (Days)	Total Displacement of Deepest Rod (inches) (cm)	Location
51X-GE-00231	11/13/82	09/12/83	303	1.263 (3.208)	7 ft (2 m) east of Shaft Centerline
51X-GE-00245	11/18/82	01/14/84	422	1.404 (3.566)	17 ft (5 m) west of Shaft Centerline
51X-GE-00256	09/01/83	11/25/85	816	2.513 (6.383)	E140-S400 Intersection
51X-GE-00257	09/12/83	11/25/85	805	2.587 (6.571)	E140-S400 Intersection
51X-GE-00267	04/09/85	02/04/88	1031	2.126 (5.400)	S400-E55
51X-GE-00268	10/24/84	06/09/95	3880	5.189 (13.180)	S400-W30
51X-GE-00277	11/29/88	06/26/95	2400	5.801 (14.735)	S400-E35
51X-GE-00278	11/29/88	04/28/89	150	0.215 (0.546)	S400-E90
51X-GE-00279	11/29/88	06/29/95	2403	4.717 (11.981)	S400-E140

Table 4-1
Historical Summary of Roof Extensometers in Waste Shaft Station

Figure 4-9
Vertical Convergence at Waste Shaft Station

5.0 Performance of Access Drifts

This section describes the in situ geomechanical performance of the underground access drifts which includes SPDV Room 4 and the northeast section of the mine. Both routine and special studies are conducted and documented to evaluate changes observed during this reporting period. The routine studies include the evaluation of convergence data to confirm that openings continue to behave in accordance with predictions.

5.1 Modifications/Maintenance

No major modifications were performed during this reporting period, however, routine maintenance activities and strategic roof bolting was performed in locations throughout the E140 drift where ground conditions warranted.

5.2 Instrumentation

During this reporting period convergence points data continued to be collected every other month but some locations such the E300 Maintenance Shop (between S90 and N250) and portions of E140 drift are read more frequently.

Monitoring of all underground extensometers continues. Remotely read extensometers are read on a monthly basis and manually read extensometers every other month.

5.3 Excavation Performance

Bimonthly assessments of underground excavations continue to indicate that convergence rates correspond to seasonal variations; convergence rates typically increase during the summer and decrease during winter months. The bimonthly assessments, consist of a comparison of actual convergence rates to a predicted convergence rate. The predicted convergence rate is calculated using a statistical approach based on the age and dimensions of the excavation. Approximately 380 readings are collected from convergence point locations every other month and assessed.

During this reporting period, the area of E140 drift from N300 to N626 along the west rib, consistently had convergence rates above the predicted value. Visual assessment of the area concluded that the high convergence rates were attributed to fracturing within the immediate roof beam. In June 1995, a support system was installed in the area.

Other convergence locations that consistently showed higher than predicted convergence rates include the E300 Experimental Shop between N1100 and N1420, SPDV Test Room 4, and E140 drift from S1375 to S1525. The high convergence rates in these areas have been attributed to fracturing within the immediate roof beam or floor heave, or both. The E300 Experimental Shop between N1100 and N1420, SPDV Room 4 and the rest of the nonradioactive experimental area is scheduled for decommissioning. In addition, plans are in preparation to remove approximately 5 feet (1.5 meters) up to anhydrite "b", of the roof beam in E140 drift from S1300 to S1950.

The roof extensometers have provided added information in assessing areas with high convergence rates such as the E140 drift. High convergence rates in the area between S1375 and S1525 of E140 drift were attributed to fracturing within the immediate roof beam, and confirmed by roof extensometers in the area.

In order to continue future data collection in the proposed closed off-areas, remotely-read instruments such as wire convergence meters and extensometers will be installed as appropriate.

5.4 Analysis of Convergence Data

Room convergence measurements are a primary means of identifying areas where conditions may be deteriorating. Convergence measurements are made throughout the facility, approximately every two months, and are used in conjunction with other observations to assess the geomechanical performance of the excavations.

Convergence is derived by measuring the change in distance between opposing surfaces of the excavations using radial convergence points.

Convergence rates generally indicate how an excavation is performing; rates that decrease or are constant with time generally indicate stable excavations whereas increasing convergence rates, or rates that are higher than anticipated, may indicate potential instability. Previously reported results (DOE, 1990b) indicate that convergence rates generally decline with time and show cyclic variations that can be attributed to seasonal temperature changes.

Convergence rates are plotted against time on a routine basis. Additionally, comparisons are made between consecutive rates of convergence for each convergence location to identify any acceleration that may be occurring. Points that indicate an acceleration are then analyzed to determine the significance of the acceleration. Factors that are considered during the analyses

include the magnitude of the respective convergence rates, percentage increase, convergence history, and any recent excavation in the vicinity.

The locations that exhibited an acceleration in convergence rate over the last two reporting periods are presented in Table 5-1 and Table 5-2. A total of 48 convergence locations had an increase in convergence rate. Thirty-eight of these locations experienced an increase in convergence rate of less than 10%. Three of the highest four increases are from Panel 1, Room 1 and are consistent with the convergence history of that room. The highest increase of 56%, from W170 drift, is relatively insignificant because of the low initial rate of convergence.

Table 5-1
Increases in Vertical Convergence Rates

FIELDTAG	Convergence Rate 1992 (in/yr)	Convergence Rate 1993 (in/yr)	Convergence Rate 1994 (in/yr)	Convergence Rate 1995 (in/yr)	Acceleration in Convergence Rate 1994-95 (% increase)
W170-S850-3			0.36	0.56	56
E520-S1758	2.28	2.20	2.55	3.46	36
E520-S1841	2.10	2.09	2.32	2.84	22
E520-S1717	3.41	3.23	3.53	4.30	22
E140-S1375		2.09	2.26	2.60	15
W170-S700	0.71		0.65	0.74	14
E520-S1802	2.12	2.02	2.16	2.45	13
W170-S1150	0.57		0.45	0.51	13
E520-S1717-4	2.97	2.88	3.03	3.35	11
E520-S1717	2.12	2.04	2.21	2.42	10
E520-S1802	3.38	3.17	3.31	3.61	9
W170-S5	0.62		0.56	0.61	9
W170-S400	0.77		0.70	0.76	9
S90-W100	0.56		0.50	0.54	8
E520-S1802-6		2.79	2.93	3.16	8
TR4-N1110	1.31		1.32	1.42	8
E520-S1758	3.18	2.97	3.18	3.42	8
W170-S1950	0.76		0.68	0.73	7
E300-S2180	0.50		0.41	0.44	7
W170-S1600	0.81		0.74	0.79	7
E920-S1775-5	2.35		2.69	2.87	7
W170-S90	0.71		0.65	0.69	6
E300-S250	0.61	0.68	0.66	0.70	6
W170-S2180	0.82		0.76	0.80	5
W170-S850-4			0.57	0.60	5
E520-S1681	2.63	2.52	2.56	2.68	5
CORE-W73	1.23		1.07	1.12	5
E520-S1841	2.72	2.62	2.76	2.88	4

Table 5-1 continued
Increases in Vertical Convergence Rates

FIELDTAG	Convergence Rate 1992 (in/yr)	Convergence Rate 1990 (in/yr)	Convergence Rate 1994 (in/yr)	Convergence Rate 1995 (in/yr)	Acceleration in Convergence Rate 1994-95 (% increase)
E790-S1775-3	2.42		2.41	2.51	4
W170-S1000	0.80		0.73	0.76	4
TR3-N1110	1.34		1.30	1.35	4
E140-S1450-2	0.87	0.87	0.85	0.88	4
TR4-N1420	2.01	1.91	1.99	2.06	4
W170-S1445	0.71		0.62	0.64	3
S90-W920	1.54		1.26	1.30	3
CORE-W51	1.17		1.03	1.06	3
E520-S1681	2.50	2.38	2.48	2.55	3
N1420-W232-2			2.21	2.27	3
CORE-W133	0.97		0.83	0.85	2
W170-S850-3			0.42	0.43	2
TR2-N1110-2	1.29		1.37	1.40	2
CORE-W30	1.04		0.95	0.97	2
E140-S1375		2.10	2.49	2.54	2
W170-S560-2			0.62	0.63	2
W170-S2060	0.83		0.73	0.74	1
TR1-N1110	1.55		1.62	1.64	1
E520-S1681	1.81	1.69	1.76	1.78	1
CORE-W10	0.99		0.90	0.91	1

Table 5-2
Increases in Horizontal Convergence Rates

FIELDTAG	Convergence Rate 1992 (in/yr)	Convergence Rate 1993 (in/yr)	Convergence Rate 1994 (in/yr)	Convergence Rate 1995 (in/yr)	Acceleration in Convergence Rate 1994-95 (% increase)
W170-S5	0.65		0.65	0.71	9
W170-S850-2	0.81		0.74	0.80	8
E1050-S1775-4			1.50	1.62	8
E1050-S1775-4			1.53	1.65	8
S90-W100	0.55		0.53	0.56	6
W170-S1150	0.79		0.75	0.79	5
W170-S2060	0.83		0.74	0.77	4
E520-S1758	1.44	1.36	1.39	1.44	4
E920-S1775-4	1.99		2.20	2.27	3
E300-S250	0.62	0.68	0.63	0.65	3
E790-S1775-5			1.48	1.52	3
E520-S1717	1.45	1.35	1.41	1.44	2
W170-S1445	0.67		0.59	0.60	2
E660-S1775-5	1.51		1.25	1.27	2
W170-S560	0.74		0.66	0.67	2
S90-W770	1.00		0.73	0.74	1

6.0 Performance of Waste Disposal Area

Excavation of the waste disposal area began in May 1986, with the mining of entries to Panel 1. Initially, the disposal rooms and drifts were developed as pilot drifts that were later excavated to 13 feet (4 m) high, 33 feet (10 m) wide, and 300 feet (91 m) long. Room 1 was excavated to near full dimensions in August 1986, and pilot drifts for disposal rooms 2 and 3 were excavated in January and February of 1987. Rooms 4 through 7 were completed between March and May of 1988.

6.1 Modifications to Excavations

No new excavations were mined in the Waste Disposal Area during the reporting period. However, routine maintenance was performed on ribs, floor, and back. The list below summarizes the installation of support systems in the Waste Disposal Area during this reporting period.

Date	Work Performed
August 1994	North half of Room 4, Panel 1 rebolted with 13 foot (4 meter) threaded bars with slip nuts
October 1994	Room 5, Panel 1 rebolted with 12 foot (3.5 meter) threaded bar
January 1995	South half of Room 4, Panel 1 rebolted with 12 foot (3.5 meter) threaded bar
June 1995	Room 6, Panel 1 was rebolted with 12 foot (3.5 meter) threaded bar.

6.2 Instrumentation

Installation of convergence points immediately followed the completion of each mining pass. Multi-point borehole extensometers were installed after completion of the final room trimming and drilling of the boreholes.

No new extensometers or convergence points were installed during this reporting period. Monitoring continues on all extensometers.

During this reporting period, one wire convergence meter in Room 6 was destroyed as a result of mining activities, currently, monitoring of the three remaining convergence meters continues. The convergence meters were placed at the midpoints of Room 6 to monitor horizontal and vertical convergence of the room.

The 286 rockbolt load cells in the Room 1 yielding roof support system are monitored on a weekly basis and a determination is made as to when the bolts are to be detensioned, based on the indicated load. By detensioning, the loads are maintained between 20,000 lbs and 5,000 lbs.

6.3 Excavation Performance

Convergence points were installed at selected locations immediately following excavation in order to collect early convergence data. Tables 6-1 and 6-2 compare the convergence rate for the Panel 1 rooms and the SPDV rooms. Although the history of the Panel 1 rooms is shorter than that of the SPDV rooms, a similar pattern of convergence is emerging. The vertical convergence rates in Room 1, Panel 1 have shown a slight increase from the last reporting period. Room 1, Panel 1 data will continue to be compared with data from the SPDV rooms in order to determine the effect of rockbolts and the supplemental roof support system on the life of the room. Roof to floor convergence data indicate that the convergence in the waste disposal areas is comparable to that of SPDV rooms 2 and 4 at a similar stage of development.

Convergence rates in the center to northeast portions of Room 1, have been consistently higher than the predicted value during this reporting period. These high convergence rates have been attributed to floor heave and fracturing within the immediate roof, based on analysis of roof extensometer data. Convergence locations that have been consistently higher than the predicted values are the center and east convergence chords at S1717, S1758, and S1802. Table 6-3 summarizes the convergence rates observed for the above mentioned locations.

The fracturing within the immediate roof beam contributes to high convergence rates seen in Room 1. The ground support system in Room 1 is designed specifically to yield in response to deformation, and therefore, has no significant effect on the rate of roof displacement. However, if the roof fracturing increase to the point where a large section of the rock is detached, the yielding support system is designed to support the weight of the roof beam, thus preventing a roof fall. Should conditions in Room 1 change, the ground support system will be upgraded or adjusted as necessary.

Table 6-1
Closure Rates by Time Since Excavation
Vertical Convergence Data (inches/year)

ROOM	DATE OF EXCAVATION AT INSTRUMENT	EXCAVATION COMPLETED TO FINAL DIMENSIONS	YEAR								
			0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
PANEL 1:											
ROOM 1	JUNE 1986	AUGUST 1986	4.13	4.26	4.60	3.24	3.56	3.08	2.76	2.90	3.13
ROOM 2	JANUARY 1987	MARCH 1988	3.02	6.71	3.33	2.91	2.60	2.32	2.32	2.25	
ROOM 3	FEBRUARY 1987	MARCH 1988	1.60	9.85	3.34	2.71	2.46	2.32	2.40	2.56	
ROOM 4	FEBRUARY 1988	MARCH 1988	8.33	3.14	2.56	2.37	2.36	2.54	2.84		
ROOM 5	FEBRUARY 1988	MARCH 1988	9.19	2.76	2.28	2.17	2.10	2.27	2.55		
ROOM 6	FEBRUARY 1988	MAY 1988	8.36	3.41	2.76	2.49	2.44	2.63	2.90		
ROOM 7	MARCH 1988	MARCH 1988	9.26	3.22	2.70	2.51	2.41	2.61	2.61		
SPDV:											
ROOM 1	APRIL 1983	APRIL 1983	6.79	3.75	2.93	2.88	2.85	3.32	4.46	12.40	
ROOM 2	MARCH 1983	MARCH 1983	7.10	3.18	2.39	2.19	2.14	2.33	2.74	2.87	
ROOM 3	MARCH 1983	MARCH 1983	7.89	3.75	2.73						
ROOM 4	APRIL 1983	APRIL 1983	5.40	3.18	2.65	2.33	2.13	2.30	2.45	2.31	2.21

Notes: Year is determined from date of excavation at instrument.

Table 6-2
Closure Rates by Time Since Excavation
Horizontal Convergence Data (inches/year)

ROOM	DATE OF EXCAVATION AT INSTRUMENT	EXCAVATION COMPLETED TO FINAL DIMENSIONS	YEAR								
			0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
PANEL 1:											
ROOM 1	JUNE 1986	AUGUST 1986	4.24	3.00	2.72	1.80	1.78	1.52	1.30	1.32	1.37
ROOM 2	JANUARY 1987	MARCH 1988	1.67	5.29	2.03	1.64	1.43	1.26	1.28	1.26	
ROOM 3	FEBRUARY 1987	MARCH 1988	1.63	8.14	2.26	1.76	1.60	1.41	1.50	1.53	
ROOM 4	FEBRUARY 1988	MARCH 1988	6.53	2.16	1.67	1.55	1.34	1.44	1.48		
ROOM 5	FEBRUARY 1988	MARCH 1988	6.92	2.10	1.66	1.50	1.36	1.48	1.68		
ROOM 6	FEBRUARY 1988	MAY 1988	7.37	2.09	1.64	1.39	1.28	1.31	*	.	
ROOM 7	MARCH 1988	MARCH 1988	6.53	1.93	1.50	1.37	1.16	1.22	1.25		
SPDV:											
ROOM 1	APRIL 1983	APRIL 1983	5.56	2.47	1.95	1.79	1.56	1.89			
ROOM 2	MARCH 1983	MARCH 1983	5.06	2.16	1.63	1.52	1.42	1.55	(1.85)		
ROOM 3	MARCH 1983	MARCH 1983	6.46	2.28	1.75	1.50	2.08	1.77	1.77		
ROOM 4	APRIL 1983	APRIL 1983	4.55	1.79	1.53	1.29	1.17	1.31	1.36	1.28	1.26

Notes: Year is determined from date of excavation at instrument.

() Estimate based on less than one full year of data.

* Not read this reporting period.

Table 6-3
Bimonthly Convergence Rates for Locations S1717, S1758 and S1802
 (Center and East Chords Only)

	S1717 East Qtr. Point	S1717 Drift Centerline	S1758 East Qtr. Point	S1758 Drift Centerline	S1802 East Qtr. Point	1802 Drift Centerline
Convergence Rate inches/year (centimeters/year)						
Jun-94	3.44 (8.74)	2.92 (7.42)	3.28 (8.33)	3.05 (7.75)	3.13 (7.95)	2.76 (7.01)
Aug-94	3.92 (9.96)	3.27 (8.31)	3.58 (9.09)	3.55 (9.02)	3.59 (9.12)	3.13 (7.95)
Oct-94	4.17 (10.59)	3.43 (8.71)	3.70 (9.40)	3.58 (9.09)	3.63 (9.22)	3.19 (8.10)
Dec-94	4.04 (10.26)	3.29 (8.36)	3.58 (9.09)	3.45 (8.76)	3.44 (8.74)	3.04 (7.72)
Feb-95	4.26 (10.82)	3.27 (8.31)	3.29 (8.36)	3.40 (8.64)	3.45 (8.76)	3.02 (7.67)
Apr-95	4.53 (11.51)	3.42 (8.69)	3.19 (8.10)	3.43 (8.71)	3.64 (9.25)	3.18 (8.08)
Jun-95	4.66 (11.84)	3.50 (8.89)	3.34 (8.48)	3.36 (8.53)	3.97 (10.08)	3.41 (8.66)
Predicted Convergence Rate	2.58 (6.55)	2.56 (6.50)	2.61 (6.63)	2.55 (6.48)	2.57 (6.53)	2.57 (6.53)

7.0 Numerical Modeling of Underground Excavations

Rock mechanics numerical models have been used to study rock deformation at the WIPP project since its inception. There are two general purposes for these models: long-term deformation models for assessing regulatory compliance and short-term models for assessing operational safety. This section concentrates on the short-term models primarily developed and analyzed by the Westinghouse Waste Isolation Division (WID) and its subcontractors. Long-term models are generally developed and reported by Sandia National Laboratories.

7.1 Introduction

7.1.1 FLAC

The Fast Lagrangian Analysis of Continua (FLAC) rock mechanics modeling program is a two-dimensional explicit finite difference code which simulates the behavior of structures built in soil, rock, and similar materials (Itasca, 1993). FLAC is capable of modeling groundwater flow, thermal, and dynamic problems in addition to rock deformation. Mechanical constitutive models available in FLAC include isotropic elastic, transversely-isotropic elastic, Mohr-Coulomb plasticity, strain-softening/hardening plasticity, ubiquitous joint, and an experimental double-yield plasticity model. Several creep constitutive models, including the Reference Creep Law, are also available in FLAC. The interface element in FLAC is capable of modeling clay seams that separate and slide.

The main purposes of FLAC models used by WID are:

- prediction of the future performance (stability) of existing excavations
- comparison of excavation design alternatives
- investigation of deformation mechanisms affecting the past performance of existing excavations.

7.1.2 Field Data

The primary source of information on rock deformation is from several thousand individual geomechanical instruments in the underground facility. Many of these instruments have been monitored since excavation began in 1982. Convergence meters and borehole extensometers are the most suitable instruments for comparison of field data to model results. These instruments

cover most of the underground and give reliable data. Rate of convergence is the primary measure of excavation stability used by WID. Convergence rate can be derived for model results. Fracture observations are used to evaluate model accuracy qualitatively. Areas with concentrations of fractures would ideally be manifested in the models by concentrations of shear strain.

7.2 Model Accuracy Requirements

Accuracy can be defined as a measure of how close a measurement is to the true value. This is easily tested for simple cases where there is only one measurement of interest and the true value is known. Testing the accuracy of rock mechanics models is more difficult due to the complexity of the model and the near impossibility of knowing the true values. It is not practical to verify every aspect of a particular model. We must instead select certain parameters of interest and measure the accuracy of the model against them. Further, the model can only be considered accurate for those particular values, over periods of time equal to those for which experience is available. Anything else must be considered an estimate, and the farther into the future, the more doubtful the estimate.

In most cases, WID models are assessed on a comparative basis. One modeled excavation behaves more or less favorably than another excavation. In these cases, the model results are more important comparatively than absolutely. This method of assessment is adequate for comparing excavation alternatives and investigation of deformation mechanisms. However, it is of little use in the prediction of future behavior. In this case, accurate quantitative results are vital. The uses of WID models in excavation design and operational assessment are dictated by the accuracy of WID models. For the most part, it is assumed that the models do not give precise predictions of displacements or strains. WID therefore uses rock mechanics models primarily on a comparative basis, and which is adequate for most requirements. Quantitative accuracy is still important, and improved quantitative accuracy will make model results more useful. It is therefore important to understand how accurate the WID models are and how the accuracy can be assessed.

7.3 Measures of Model Accuracy

The field data that are used to assess the accuracy of WID models will now be examined. The primary use of WID models is excavation stability assessment. Current thinking on WIPP excavation stability proposes several indicators of stability (DOE, 1993a):

- vertical and horizontal convergence rate

- clay seam separation and offset rate
- degree of roof beam fracturing

Excavation convergence and clay seam movements are the main measures of accuracy for the WID models. Comparison of field convergence data to model results will be presented here.

The main difficulty in using field data as measurements of accuracy is the variability in the field data from location to location. Vertical convergence rate measurements taken in apparently near-identical rooms vary widely. For instance, in Panel 1, the average vertical convergence rates at the centers of the seven rooms ranged from 2.1 inches/year (5.33 cm/yr) to 3.6 inches/year (9.14 cm/yr) during the fifth year after excavation of each room (DOE, 1995). For the purposes of a two-dimensional, single-room FLAC model, the seven rooms are identical --- they would all be modeled the same and hence would give the same results. If the FLAC model for a storage room predicted 2.1 inches/year (5.33 cm/yr) for the vertical convergence rate, it would be considered very accurate if compared to the field data from one room, but in error by over 50% if compared to another. This example is for excavations that are in the steady-state creep regime. Rooms with advanced fracturing can have even greater variation in closure rates.

There were order of magnitude differences in the convergence rates of the twelve convergence meters in Site and Preliminary Design Validation (SPDV) Room 2 before the roof fall. The differences in convergence rate among seemingly identical locations is most likely caused either by differences in surrounding excavation geometry (including the excavation sequence) or geological differences. A 2D or 3D model that included multiple rooms might resolve some of these differences. Unfortunately, the effort and time required to develop and run such models is prohibitive in many cases. The effect of local geological differences in a single room or between different rooms may be even more difficult to implement in models, especially if subtle details are found to be important.

Another very important consideration is fracturing. The effect of fracturing on displacements is not directly simulated in the FLAC models. Although fracturing is always present to some degree, the accuracy of the models can be expected to diminish as fracturing around excavations becomes more advanced. A fracture/failure criteria implemented in the models would reduce (or eliminate) this error.

It must be concluded that until the proper geometric (including fracturing) and geologic detail is added to the rock mechanics models, accuracy can only be assessed by comparing model results

to ranges of field data. The model accuracy cannot be better than the range seen in the field data. If the field data show 50% variation, the model cannot predict field conditions better than within 50%.

7.4 Comparisons of Field Data to Model Results

To determine how well the FLAC models correlate to field data for different drift sizes, twenty FLAC models of various drift widths and heights were developed. The models were identical in every case except for the opening and pillar dimensions. The dimensions were chosen to incrementally cover the range of opening widths and heights found in the WIPP underground facility. Opening heights of 9, 11, 13, and 15 feet (2.7, 3.4, 4.0, and 4.6 meters) and widths of 14.5, 20, 25, 28, and 33 feet (4.4, 6.1, 7.6, 8.5, and 10.0 meters) were modeled in every combination. The pillar width was changed from model to model so that the extraction ratio (room width divided by pillar width) in each case was kept constant at 15%. The design basis maximum extraction ratio for areas other than the storage panels is 15%. An additional case (Model REN) was run for a 13 by 33 foot (4 by 10 meter) opening with an extraction ratio of 25%, which is nominal for storage panels. Figure 7-1 shows the stratigraphy used in the FLAC models. Four clay seams (E, G, H, and I) were included. Figure 7-2 shows the mesh for the 9 by 14.5 foot (2.7 by 4.4 meter) opening case. All models used the Reference Creep Law for the creeping materials and the reference material properties from Krieg, 1984, except for polyhalitic halite which is not in Krieg and therefore uses the properties from DOE, 1993b.

The vertical and horizontal convergence rates at different model times were extracted from the results of each case and compared to the field data from all instruments located in drifts with dimensions close to that of the modeled drift. Some combinations of model drift width and height had very little or no field data for comparison. The plots of the model results and field data are shown on Figures 7-3 to 7-23.

The field data in these figures include all manually read convergence points that meet the following criteria:

1. The convergence point must have data covering at least 365 days.
2. The convergence point must be located at the midpoint of the roof or rib cross-section.
3. The convergence point must not be in an intersection.

These criteria resulted in nearly two thousand annual rate values from 441 convergence points. Other than excluding data that did not meet the above criteria, the convergence field data was not

manipulated. The geometric and age information for each convergence point was also determined using a strict, rigorous method. The number of years since excavation used for the field data was the date of the original excavation at the particular location. Drift dimensions were taken from actual measurements if available. Otherwise, nominal drift dimensions were used. In some cases, the strict application of this methodology for determining dimensions and age may have resulted in some data being inappropriately categorized. However, to avoid bias in the information, no adjustments were made. An example of inappropriate categorization would be a case of a vertically-oriented convergence point at a location where there is no horizontal chord. The vertical convergence point would give the height of the drift, but the width would have to be taken from the nominal dimensions. If the walls had been trimmed significantly, the nominal width which was used for the analysis could be significantly less than the actual width. Due to the large number of convergence points used in this analysis and to avoid bias in the data categorization, no attempt was made to correct such cases. No data was adjusted or removed from the database. Visual examination of Figures 7-3 to 7-23 indicate that the vast majority of the data are correctly categorized, which is attested to by the tight grouping of the data points.

The comparison between the FLAC results and the field data shown in Figures 7-3 to 7-23 is quite reasonable. In most cases, the FLAC results are within or very close to the range of field results. There does not appear to be a trend in the degree of similarity between the field data and the model results. The degree of correlation is independent of drift size. A few models had very little or no field data and therefore, a representative range of field results was probably not obtained. Some of these cases, in turn, do not have as good a correlation as the others. The only case that did not have a good correlation and had a large amount of field data for comparison was the horizontal result from the 4 meter high by 10 meter wide, 25% extraction case, REN (Figure 7-23b). In this case, the model predicts a horizontal closure rate about double that seen in the field. The other 4 meter by 10 meter model, RE14 (Figure 7-17), underpredicts vertical convergence rate by about 50%. This is possibly because the field data is mostly from high extraction ratio areas (storage panels and SPDV Rooms) while the model simulates lower extraction (15%).

Insight into a possible cause of the field data variability can be found by comparing the results for the RE14 and REN models (Figures 7-17 and 7-23). The models are identical with the exception of the extraction ratio. Both model a 13 foot (4 meter) high by 33 foot (10 meter) wide room, but the extraction ratio in RE14 is 15% while the ratio in REN is 25%. The difference in results is significant. The 15% extraction ratio model shows steady state vertical convergence rates one half of that in the 25% extraction ratio model (1.3 inches/year (3.3 cm/yr) compared to

2.6 inches/year (6.6 cm/yr)). This is due to the different load in the pillars of the two models and the extreme sensitivity of the Reference Creep Law to stress. These results indicate that the models are sensitive to extraction ratio, which is essentially a boundary condition. However, extraction ratio is somewhat ill-defined. There is no standard for calculating extraction ratio in the field, especially for the relatively irregular excavation layouts at WIPP, and this makes determining the proper boundary conditions in the models somewhat difficult. Depending on the method used, WIPP extraction ratios range from about 5% for isolated drifts to 25% for the storage panels. Comparing the magnitude of the difference in results between the 15% and 25% ratio models to the variation in field data results for similar sized drifts, it can be concluded that variations in extraction ratio are sufficient in magnitude to account for most if not all of the variation in the field data. This has not yet been confirmed analytically. Further analysis of the variability in the field data must be completed to better estimate the accuracy of the models.

Overall, examination of the model results and field data in Figures 7-3 to 7-23 indicates that the FLAC model results are reasonably close to field data. The models are sufficiently accurate for stability analyses. Further improvement in the modeling codes such as fracture generation, and the method with which the codes are applied, such as improved simulation of the extraction ratio, will expand the applicability of the models

Figure 7-1
Stratigraphy Used in FLAC Models

Figure 7-2
 Typical FLAC Excavation Analysis Model Grid

Comparison of Model Results to Field Data
 Model: 9' High, 14.5' Wide Drift (RE0)
 Field Data: 8.1-9.6' High, 13.8-15.6' Wide Drifts

Figure 7-3a
Comparison of Model and Field Vertical Convergence Results: Model RE0

Comparison of Model Results to Field Data
 Model: 9' High, 14.5' Wide Drift (RE0)
 Field Data: 8.2-9.6' High, 13.8-15.6' Wide Drifts

Figure 7-3b
Comparison of Model and Field Horizontal Convergence Results: Model RE0

Comparison of Model Results to Field Data
 Model: 9' High, 20' Wide Drift (RE1)
 Field Data: 8.7-9.2' High, 20.1-20.9' Wide Drifts

Figure 7-4a
Comparison of Model and Field Vertical Convergence Results: Model RE1

Comparison of Model Results to Field Data
 Model: 9' High, 20' Wide Drift (RE1)
 Field Data: 8.7-9.2' High, 20.1-20.9' Wide Drifts

Figure 7-4b
Comparison of Model and Field Horizontal Convergence Results: Model RE1

Comparison of Model Results to Field Data
 Model: 9' High, 25' Wide Drift (RE2)
 Field Data: 8.0-9.7' High, 25.1-26.3' Wide Drifts

Figure 7-5a
Comparison of Model and Field Vertical Convergence Results: Model RE2

Comparison of Model Results to Field Data
 Model: 9' High, 25' Wide Drift (RE2)
 Field Data: 8.0-9.7' High, 25.1-26.3' Wide Drifts

Figure 7-5b
Comparison of Model and Field Horizontal Convergence Results: Model RE2

Comparison of Model Results to Field Data
 Model: 9' High, 28' Wide Drift (RE3)
 Field Data: 8.3' High, 26.7-27.1' Wide Drifts

Figure 7-6a
 Comparison of Model and Field Vertical Convergence Results: Model RE3

Comparison of Model Results to Field Data
 Model: 9' High, 28' Wide Drift (RE3)
 Field Data: 8.3' High, 26.7-27.1' Wide Drifts

Figure 7-6b
 Comparison of Model and Field Horizontal Convergence Results: Model RE3

Comparison of Model Results to Field Data
Model: 9' High, 33' Wide Drift (RE4)
No Field Data

Figure 7-7a
Comparison of Model and Field Vertical Convergence Results: Model RE4

Comparison of Model Results to Field Data
Model: 9' High, 33' Wide Drift (RE4)
No Field Data

Figure 7-7b
Comparison of Model and Field Horizontal Convergence Results: Model RE4

Comparison of Model Results to Field Data
 Model: 11' High, 14.5' Wide Drift (RE5)
 Field Data: 11.6-12.0' High, 13.4-15.0' Wide Drifts

Figure 7-8a
Comparison of Model and Field Vertical Convergence Results: Model RE5

Comparison of Model Results to Field Data
 Model: 11' High, 14.5' Wide Drift (RE5)
 Field Data: 11.7-12.0' High, 13.5-15.0' Wide Drifts

Figure 7-8b
Comparison of Model and Field Horizontal Convergence Results: Model RE5

Comparison of Model Results to Field Data
 Model: 11' High, 20' Wide Drift (RE6)
 Field Data: 11.2-11.9' High, 19.9-20.3' Wide Drifts

Figure 7-9a
 Comparison of Model and Field Vertical Convergence Results: Model RE6

Comparison of Model Results to Field Data
 Model: 11' High, 20' Wide Drift (RE6)
 Field Data: 11.6-11.9' High, 19.9-21.0' Wide Drifts

Figure 7-9b
 Comparison of Model and Field Horizontal Convergence Results: Model RE6

Comparison of Model Results to Field Data
 Model: 11' High, 25' Wide Drift (RE7)
 Field Data: 10.8-11.8' High, 24.0-25.9' Wide Drifts

Figure 7-10a
Comparison of Model and Field Vertical Convergence Results: Model RE7

Comparison of Model Results to Field Data
 Model: 11' High, 25' Wide Drift (RE7)
 Field Data: 10.8-11.8' High, 24.0-25.9' Wide Drifts

Figure 7-10b
Comparison of Model and Field Horizontal Convergence Results: Model RE7

Comparison of Model Results to Field Data
Model: 11' High, 28' Wide Drift (RE8)
No Field Data

Figure 7-11a
Comparison of Model and Field Vertical Convergence Results: Model RE8

Comparison of Model Results to Field Data
Model: 11' High, 28' Wide Drift (RE8)
No Field Data

Figure 7-11b
Comparison of Model and Field Horizontal Convergence Results: Model RE8

Comparison of Model Results to Field Data
 Model: 11' High, 33' Wide Drift (RE9)
 Field Data: 11.5-11.9' High, 32.8-33.0' Wide Drifts

Figure 7-12a
Comparison of Model and Field Vertical Convergence Results: Model RE9

Comparison of Model Results to Field Data
 Model: 11' High, 33' Wide Drift (RE9)
 Field Data: 11.5-11.7' High, 32.8-33.5' Wide Drifts

Figure 7-12b
Comparison of Model and Field Horizontal Convergence Results: Model RE9

Comparison of Model Results to Field Data
 Model: 13' High, 14.5' Wide Drift (RE10)
 Field Data: 12-13.7' High, 13.3-15.8' Wide Drifts

Figure 7-13a
 Comparison of Model and Field Vertical Convergence Results: Model RE10

Comparison of Model Results to Field Data
 Model: 13' High, 14.5' Wide Drift (RE10)
 Field Data: 12-13.4' High, 13.2-15.8' Wide Drifts

Figure 7-13b
 Comparison of Model and Field Horizontal Convergence Results: Model RE10

Comparison of Model Results to Field Data
 Model: 13' High, 20' Wide Drift (RE11)
 Field Data: 12.1-13.9' High, 20-21.4' Wide Drifts

Figure 7-14a
 Comparison of Model and Field Vertical Convergence Results: Model RE11

Comparison of Model Results to Field Data
 Model: 13' High, 20' Wide Drift (RE11)
 Field Data: 12.1-14' High, 20.1-21.4' Wide Drifts

Figure 7-14b
 Comparison of Model and Field Horizontal Convergence Results: Model RE11

Comparison of Model Results to Field Data
 Model: 13' High, 25' Wide Drift (RE12)
 Field Data: 12.1-14.0' High, 23.8-26.5' Wide Drifts

Figure 7-15a
 Comparison of Model and Field Vertical Convergence Results: Model RE12

Comparison of Model Results to Field Data
 Model: 13' High, 25' Wide Drift (RE12)
 Field Data: 12.1-14.0' High, 23.8-26.5' Wide Drifts

Figure 7-15b
 Comparison of Model and Field Horizontal Convergence Results: Model RE12

Comparison of Model Results to Field Data
 Model: 13' High, 28' Wide Drift (RE13)
 Field Data: 13-13.9' High, 26.8-29.1' Wide Drifts

Figure 7-16a
Comparison of Model and Field Vertical Convergence Results: Model RE13

Comparison of Model Results to Field Data
 Model: 13' High, 28' Wide Drift (RE13)
 Field Data: 13-14' High, 26.8-29.5' Wide Drifts

Figure 7-16b
Comparison of Model and Field Horizontal Convergence Results: Model RE13

Comparison of Model Results to Field Data
 Model: 13' High, 33' Wide Drift (RE14)
 Field Data: 12.1-13.8' High, 32.3-33.7' Wide Drifts

Figure 7-17a
 Comparison of Model and Field Vertical Convergence Results: Model RE14

Comparison of Model Results to Field Data
 Model: 13' High, 33' Wide Drift (RE14)
 Field Data: 12.1-13.9' High, 31.6-33.7' Wide Drifts

Figure 7-17b
 Comparison of Model and Field Horizontal Convergence Results: Model RE14

Comparison of Model Results to Field Data
 Model: 15' High, 14.5' Wide Drift (RE15)
 No Field Data

Figure 7-18a
 Comparison of Model and Field Vertical Convergence Results: Model RE15

Comparison of Model Results to Field Data
 Model: 15' High, 14.5' Wide Drift (RE15)
 No Field Data

Figure 7-18b
 Comparison of Model and Field Horizontal Convergence Results: Model RE15

Comparison of Model Results to Field Data
 Model: 15' High, 20' Wide Drift (RE16)
 Field Data: 14.3-15.0' High, 20.7-21.2' Wide Drifts

Figure 7-19a
Comparison of Model and Field Vertical Convergence Results: Model RE16

Comparison of Model Results to Field Data
 Model: 15' High, 20' Wide Drift (RE16)
 Field Data: 14-15' High, 20.7-21.2' Wide Drifts

Figure 7-19b
Comparison of Model and Field Horizontal Convergence Results: Model RE16

Comparison of Model Results to Field Data
 Model: 15' High, 25' Wide Drift (RE17)
 Field Data: 14-16' High, 25.0-26.5' Wide Drifts

Figure 7-20a
 Comparison of Model and Field Vertical Convergence Results: Model RE17

Comparison of Model Results to Field Data
 Model: 15' High, 25' Wide Drift (RE17)
 Field Data: 14-16' High, 23.9-26.5' Wide Drifts

Figure 7-20b
 Comparison of Model and Field Horizontal Convergence Results: Model RE17

Comparison of Model Results to Field Data
 Model: 15' High, 28' Wide Drift (RE18)
 Field Data: 14.3-14.8' High, 26.7-29.1' Wide Drifts

Figure 7-21a
 Comparison of Model and Field Vertical Convergence Results: Model RE18

Comparison of Model Results to Field Data
 Model: 15' High, 28' Wide Drift (RE18)
 Field Data: 14-16' High, 26.7-29.1' Wide Drifts

Figure 7-21b
 Comparison of Model and Field Horizontal Convergence Results: Model RE18

Comparison of Model Results to Field Data
 Model: 15' High, 33' Wide Drift (RE19)
 Field Data: 14.1-15.7' High, 32.3-33.0' Wide Drifts

Figure 7-22a
 Comparison of Model and Field Vertical Convergence Results: Model RE19

Comparison of Model Results to Field Data
 Model: 15' High, 33' Wide Drift (RE19)
 Field Data: 14.1-14.2' High, 32.3-32.7' Wide Drifts

Figure 7-22b
 Comparison of Model and Field Horizontal Convergence Results: Model RE19

8.0 Excavation Effects

Rock mass structural responses to mining, termed excavation effects, have been observed and monitored since excavation of the WIPP underground facility began. During this reporting period, observations of excavation effects have included:

- Inspections of subsurface fractures and strata displacements in boreholes
- Mapping of fractures on excavation surfaces
- Observations and inspections of rockbolt failures.

These observations detect, quantify, and assist in the interpretation of fractures and bedding plane separations that result from the underground excavations. Borehole inspections provide information on the size and orientation of fracture apertures, or of bedding plane separations within the rock surrounding the excavations. Fracture mapping provides information on the length and orientation of fractures on excavation surfaces. Fracture apertures are recorded as the value at the excavation surface. When possible, estimates are made of the distance that a fracture or separation extends into the rock. Observations of failed rockbolts provide information on the activity and depth of strata displacement.

8.1 Borehole Inspections

The Excavation Effects Program (EEP) of systematic borehole observations was started in mid-1986 to study fractures and separations in the roof and the floor of the repository. Due to restricted access into many of the initial program boreholes, the EEP has been discontinued. Subsurface feature monitoring will continue through inspections of the remaining EEP boreholes, as well as in numerous other observation boreholes.

8.1.1 Excavation Effects Program

The EEP consisted of annual inspections of boreholes arranged in arrays located throughout the underground as shown in Figure 8-1. During the previous reporting period, fracturing had occurred in 89 percent of all EEP roof boreholes. Offsetting had occurred in 90 percent of roof holes and, in recent years, many holes had closed off completely. Of EEP floor holes, 78 percent contained fractures. Offsetting was recorded in 57 percent of the holes, although this number is likely higher as most of the floor holes had become filled with muck in recent years which precluded recent inspection.

Figure 8-1
Locations of Excavation Effects Program Borehole Arrays

The EEP revealed that offsetting in the roof usually occurs at clay seams or within the first few inches of roof at shallow spalls. Lateral offsets in the floor were generally associated with fractures defining large, shallow, dish-shaped slabs. Direction of offset, observed as the movement of the side of the offset nearest the observer relative to the far side, is typically toward excavation centerline at clay seams and toward the ribs at shallow fractures.

The results of the EEP annual inspections revealed that the number and magnitude of offset was greater in boreholes located near ribs as shown in Figure 8-1 ("E", "C", "D" and "F" holes) than in those located along excavation centerlines ("A" and "B" holes). Table 8-1 provides a summary of displacement activity observed at Clays G and E (first clay seams) in EEP boreholes since 1986.

8.1.2 Other Observation Boreholes

Geotechnical observation boreholes are drilled in various locations throughout the underground facility. Roof holes intersecting Clay G comprise the vast majority of these boreholes and are usually drilled in arrays of three across drift width. Inspections of these holes provide data on fractures, separations, and lateral offsets, as well as the behavior of the rock at various clay seams. Table 8-2 provides a summary of displacement activity observed at Clay G during this reporting period.

TABLE 8-1
Excavation Effects Program Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (Inches)	CLAY	DATE OF OFFSET AT CLAY	DEPTH TO OFFSET (feet)	OFFSET (inches)	OFFSET RATE* (in/yr)	LAST INSPECTED
Roof Boreholes:									
1A EEP	N1176 W630	5/15/86	5.0	G	5/19/93	8.00	1.75	0.25	5/26/94
1C EEP	N1175 W618	5/15/86	1.9	G	7/20/89	7.90	1.88	0.59	5/26/94
1E EEP	N1175 W643	5/15/86	1.9	G	3/4/91	8.00	1.50	0.31	5/26/94
2A EEP	N1264 W630	5/16/86	3.0	G	5/27/94	7.50	0.75	0.09	5/27/94
2C EEP	N1264 W618	5/16/86	1.9	G	4/6/88	7.50	0.75	0.40	5/27/94
2E EEP	N1264 W643	5/16/86	1.9	G	3/26/92	7.50	1.88	0.32	5/27/94
3A EEP	N1360 W627	5/16/86	5.0	G	5/19/93	7.60	2.50	0.36	5/27/94
3C EEP	N1360 W618	5/16/86	3.0	G	3/4/91	8.00	2.00	0.42	5/19/93
3E EEP	N1360 W643	5/16/86	3.0	G	3/26/92	6.90	2.00	0.34	5/27/94
4A EEP	N1198 SPDV3	5/15/86	1.9	G	3/31/88	7.40	0.50	0.27	6/22/90
4C EEP	N1198 SPDV3	5/15/86	1.9		N				6/22/90
4E EEP	N1198 SPDV3	5/15/86	1.9		N				6/22/90
5A EEP	N1243 SPDV3	5/15/86	3.0		N				5/15/86
5C EEP	N1243 SPDV3	5/15/86	1.9		N				5/15/86
5E EEP	N1243 SPDV3	5/15/86	1.9		N				5/15/86
6A EEP	N1312 SPDV3	5/15/86	3.0	G	4/7/88	7.00	0.50	0.26	6/15/90
6C EEP	N1312 SPDV3	5/15/86	1.9	G	4/7/88	7.00	1.25	0.66	6/15/90
6E EEP	N1312 SPDV3	5/15/86	1.9	G	4/7/88	7.00	1.25	0.66	6/15/90

TABLE 8-1 (continued)
Excavation Effects Program Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (inches)	CLAY	DATE OF OFFSET AT CLAY	DEPTH TO OFFSET (feet)	OFFSET (inches)	OFFSET RATE* (in/yr)	LAST INSPECTED
7A EEP	N1147 SPDV2	5/21/86	3.0	G	4/5/88	7.00	0.13	0.07	7/21/89
7C EEP	N1147 SPDV2	5/21/86	1.9	G	3/31/88	7.80	0.63	0.34	7/21/89
7E EEP	N1147 SPDV2	5/21/86	1.9	G	4/5/88	7.80	1.00	0.53	7/21/89
8A EEP	N1231 SPDV2	5/21/86	3.0	G	4/6/88	7.20	0.50	0.27	7/21/89
8C EEP	N1231 SPDV2	5/21/86	1.9	G	4/6/88	7.40	1.13	0.60	7/21/89
8E EEP	N1231 SPDV2	5/21/86	1.9	G	4/6/88	7.00	1.00	0.53	7/21/89
9A EEP	N1159 SPDV1	5/21/86	3.0		N				7/21/89
9C EEP	N1159 SPDV1	5/21/86	1.9	G	4/7/88	8.00	1.00	0.53	7/21/89
9E EEP	N1159 SPDV1	5/21/86	1.9	G	4/7/88	7.70	1.00	0.53	7/21/89
10A EEP	N1275 SPDV1	5/21/86	3.0	G	4/6/88	7.10	0.75	0.40	7/21/89
10C EEP	N1275 SPDV1	5/21/86	1.9	G	5/25/87	7.20	0.63	0.62	7/21/89
10E EEP	N1275 SPDV1	5/21/86	1.9	G	4/6/88	7.20	1.88	1.00	7/21/89
11A EEP	N1110 W2	5/30/86	3.0	G	5/31/94	7.40	1.50	0.19	5/31/94
11C EEP	N1110 E5	5/30/86	1.9	G	3/5/91	7.80	1.88	0.39	5/31/94
11E EEP	N1110 W10	5/30/86	1.9	G	5/20/93	8.50	1.50	0.22	5/31/94
12A EEP	N1429 E146	6/5/86	3.0	G	5/26/87	7.10	0.25	0.26	5/31/94
12C EEP	N1429 E151	6/5/86	1.9	G	4/8/88	7.30	0.38	0.21	5/31/94
12E EEP	N1429 E142	6/5/86	1.9	G	4/8/88	6.80	0.50	0.27	5/31/94
13A EEP	N1106 E439	6/20/86	1.9		N				6/6/94
13C EEP	N1102 E439	6/20/86	1.9		N				6/6/94
13E EEP	N1111 E439	6/20/86	3.0	G	5/19/87	7.30	0.75	0.82	6/27/90
14A EEP	N1420 E875	6/5/86	3.0		N				5/19/93
14C EEP	N1420 E875	6/5/86	1.9		N				5/19/93
14E EEP	N1420 E875	6/5/86	1.9	G	4/12/88	4.80	0.50	0.27	5/19/93
15A EEP	N626 W2	6/20/86	3.0	G	5/20/93	8.60	0.63	0.09	5/31/94
15C EEP	N626 W5	6/20/86	1.9	G	4/8/88	8.20	1.00	0.56	5/31/94
15E EEP	N626 W10	6/20/86	1.9	G	3/5/91	8.60	1.88	0.40	3/25/92
17A EEP	N21 W5	5/30/86	3.0		N				6/9/94
17C EEP	N21 W5	5/30/86	3.0		N				6/9/94
17E EEP	N24 W13	5/30/86	3.0		N				6/9/94
18A EEP	S24 W8	6/4/86	3.0		N				6/8/94
18C EEP	S25 E3	6/4/86	3.0		N				6/8/94
18E EEP	S23 W17	6/4/86	3.0		N				6/8/94
19A EEP	S57 W8	6/3/86	1.9		N				6/8/94
19C EEP	S53 E2	6/3/86	3.0		N				7/27/89
19E EEP	S56 W18	6/3/86	1.9		N				6/8/94
20A EEP	S592 E140	7/10/86	3.0	G	5/21/93	6.00	0.38	0.06	6/6/94
20C EEP	S592 E140	7/10/86	1.9	G	6/2/87	7.10	0.19	0.21	6/6/94
20E EEP	S592 E140	7/10/86	1.9		N				6/6/94
21A EEP	S700 E66	7/8/86	3.0		N				6/7/94
21C EEP	S706 E66	7/8/86	1.9		N				6/7/94
21E EEP	S694 E66	7/8/86	1.9	G	4/12/88	8.50	0.38	0.22	6/7/94
22A EEP	S699 E299	7/8/86	3.0	G	5/21/93	8.50	1.00	0.15	6/1/94
22C EEP	S699 E303	7/8/86	1.9	G	6/1/94	8.50	1.00	0.13	6/1/94
22E EEP	S699 E293	7/8/86	1.9	G	5/21/93	8.50	0.38	0.06	6/1/94
23A EEP	S1190 E299	7/9/86	3.0		N				6/1/94
23C EEP	S1190 E303	7/9/86	1.9	G	5/21/93	8.30	0.25	0.04	6/1/94
23E EEP	S1190 E295	7/9/86	1.9	G	6/1/94	8.50	1.00	0.13	6/1/94

TABLE 8-1 (continued)
Excavation Effects Program Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (Inches)	CLAY	DATE OF OFFSET AT CLAY	DEPTH TO OFFSET (feet)	OFFSET (Inches)	OFFSET RATE* (in/yr)	LAST INSPECTED
24A EEP	S1300 E156	7/9/86	3.0	G	6/6/94	6.20	0.50	0.06	6/6/94
24C EEP	S1310 E155	7/9/86	1.9	G	6/6/94	5.50	0.88	0.11	6/6/94
24E EEP	S1290 E155	7/9/86	1.9	G	6/6/94	5.90	0.88	0.11	6/6/94
25A EEP	S1129 E155	7/9/86	3.0	G	5/20/93	5.00	1.00	0.15	6/6/94
25C EEP	S1129 E148	7/9/86	1.9	G	5/20/93	4.50	1.88	0.27	6/6/94
25E EEP	S1129 E140	7/9/86	1.9	G	4/10/92	4.50	1.88	0.33	6/6/94
28C EEP	N1106 W418	7/16/86	1.9	G	3/26/92	7.90	1.50	0.26	5/26/94
28E EEP	N1115 W418	7/16/86	3.0	G	5/20/93	7.90	1.75	0.26	5/26/94
29A EEP	S1700 E140	7/10/86	3.0	G	6/6/94	5.80	1.00	0.13	6/6/94
29C EEP	S1700 E140	7/10/86	1.9	G	6/4/87	8.60	0.33	0.37	6/6/94
29E EEP	S1700 E140	7/10/86	1.9	G	6/4/87	8.40	0.25	0.28	7/24/89
30C EEP	N1103 E1297	7/11/86	1.9		N				6/6/94
30E EEP	N1109 E1296	7/11/86	1.9		N				6/6/94
31A EEP	N1426 E1375	3/8/91	3.0		N				5/18/93
31C EEP	N1422 E1375	3/8/91	3.0	I	5/18/93	4.10	0.63	0.29	5/18/93
31E EEP	N1430 E1375	3/8/91	3.0	I	5/18/93	4.60	0.50	0.23	5/18/93
32A EEP	N1426 E1488	3/7/91	3.0		N				5/26/94
32C EEP	N1422 E1488	3/7/91	3.0	I	5/26/94	5.10	0.75	0.23	5/26/94
32E EEP	N1430 E1488	3/7/91	3.0	I	5/26/94	4.80	0.63	0.20	5/26/94
33A EEP	N1420 E1110	3/6/91	3.0	I	1/12/93	4.40	0.25	0.13	5/18/93
33C EEP	N1420 E1110	3/7/91	3.0	I	1/12/93	5.30	0.50	0.27	5/18/93
33E EEP	N1420 E1110	3/6/91	3.0	I	5/18/93	5.10	0.38	0.17	5/18/93
34A EEP	S1859 E789	4/25/91	3.0		N				6/7/94
34C EEP	S1859 E801	4/23/91	3.0	G	6/7/94	7.20	1.00	0.32	6/7/94
34E EEP	S1859 E773	4/23/91	3.0	G	5/20/93	7.10	0.88	0.42	6/7/94
35A EEP	S1785 E789	4/24/91	3.0	G	5/20/93	6.50	0.25	0.12	6/7/94
35C EEP	S1784 E801	4/24/91	3.0	G	6/7/94	6.40	1.25	0.40	6/7/94
35E EEP	S1784 E776	4/25/91	3.0	G	6/7/94	6.40	1.25	0.40	6/7/94
36A EEP	S1710 E789	4/25/91	3.0		N				6/6/94
36C EEP	S1710 E801	4/25/91	3.0	G	6/6/94	7.50	1.13	0.36	6/6/94
36E EEP	S1709 E776	4/26/91	3.0	G	6/6/94	7.40	1.13	0.36	6/6/94
37A EEP	N51 E305	4/1/93	3.0		N				3/7/95
37C EEP	N51 E312	4/2/93	3.0	G	12/21/94	6.80	1.00	0.58	12/21/94
37E EEP	N51 E298	3/3/93	3.0	G	3/7/95	6.50	1.38	0.69	3/7/95
Floor Boreholes:									
1B EEP	N1175 W631	5/15/86	3.0	E	4/5/88	5.90	0.63	0.33	3/4/91
1D EEP	N1175 W618	5/15/86	1.9		N				3/4/91
1F EEP	N1175 W643	5/15/86	5.0		N				5/26/94
2B EEP	N1263 W630	5/16/86	3.0		N				5/27/94
2D EEP	N1264 W618	5/16/86	1.9		N				3/4/91
2F EEP	N1264 W643	5/16/86	1.9		N				5/27/94
3B EEP	N1360 W627	5/16/86	5.0		N				5/27/94
3D EEP	N1360 W618	5/16/86	1.9		N				3/26/92
3F EEP	N1360 W643	5/16/86	1.9	E	4/6/88	7.10	0.75	0.40	5/27/94
4B EEP	N1198 SPDV3	5/15/86	1.9		N				6/22/90
4D EEP	N1198 SPDV3	5/15/86	1.9		N				6/22/90
4F EEP	N1198 SPDV3	5/15/86	1.9	E	3/31/88	6.80	1.00	0.53	6/22/90

TABLE 8-1 (continued)
Excavation Effects Program Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (inches)	CLAY	DATE OF OFFSET AT CLAY	DEPTH TO OFFSET (feet)	OFFSET (inches)	OFFSET RATE* (in/yr)	LAST INSPECTED
5X EEP	N1243 SPDV3	5/15/86	1.9		N				5/15/86
5Y EEP	N1243 SPDV3	5/15/86	3.0		N				5/15/86
6B EEP	N1312 SPDV3	5/15/86	4.0		N				5/21/87
6D EEP	N1312 SPDV3	5/15/86	4.0		N				5/21/87
6F EEP	N1312 SPDV3	5/15/86	4.0		N				5/21/87
7B EEP	N1147 SPDV2	5/21/86	3.0		N				7/21/89
7D EEP	N1147 SPDV2	5/21/86	1.9		N				3/31/88
7F EEP	N1147 SPDV2	5/21/86	1.9	E	4/5/88	6.40	0.13	0.07	7/21/89
8B EEP	N1231 SPDV2	5/21/86	3.0		N				7/21/89
8D EEP	N1231 SPDV2	5/21/86	7.9		N				7/21/89
8F EEP	N1231 SPDV2	5/21/86	1.9		N				7/21/89
9B EEP	N1159 SPDV1	5/21/86	3.0		N				7/21/89
9D EEP	N1159 SPDV1	5/21/86	1.9		N				7/21/89
9F EEP	N1159 SPDV1	5/21/86	1.9		N				7/21/89
10B EEP	N1275 SPDV1	5/21/86	3.0		N				7/21/89
10D EEP	N1275 SPDV1	5/21/86	1.9		N				7/21/89
10F EEP	N1275 SPDV1	5/21/86	1.9		N				7/21/89
11B EEP	N1110 W2	5/30/86	3.0		N				3/5/91
11D EEP	N1110 E5	5/30/86	1.9	E	5/26/87	8.30	0.13	0.13	6/21/90
11F EEP	N1109 W10	5/30/86	1.9		N				3/5/91
12B EEP	N1429 E146	6/5/86	3.0		N				7/21/89
12D EEP	N1429 E151	6/5/86	1.9		N				5/31/94
12F EEP	N1429 E142	6/5/86	1.9	E	4/8/88	7.80	0.13	0.07	6/21/90
13B EEP	N1106 E439	6/20/86	1.9		N				6/27/90
13D EEP	N1102 E439	6/20/86	1.9		N				3/5/91
13F EEP	N1111 E439	6/20/86	1.9		N				3/5/91
14B EEP	N1420 E875	6/5/86	3.0		N				5/19/93
14D EEP	N1420 E875	6/5/86	1.9		N				5/19/93
14F EEP	N1420 E875	6/5/86	1.9		N				5/19/93
15B EEP	N626 W2	6/20/86	4.0		N				5/31/94
15D EEP	N626 W5	6/20/86	1.9	E	4/8/88	7.70	0.13	0.07	5/31/94
15F EEP	N626 W10	6/20/86	1.9	E	4/8/88	7.90	0.13	0.07	4/8/88
16B EEP	N305 E140	6/20/86	1.9		N				7/24/89
16D EEP	N305 E140	7/15/86	1.9		N				7/24/89
16F EEP	N305 E140	7/15/86	1.9		N				7/24/89
17B EEP	N21 W5	5/30/86	3.0	E	4/12/88	7.20	0.50	0.27	6/9/94
17D EEP	N21 W5	5/30/86	1.9		N				6/4/86
17F EEP	N24 W13	5/30/86	1.9		N				6/28/90
18B EEP	S24 W8	6/4/86	3.0		N				6/28/90
18D EEP	S25 E3	6/4/86	1.9		N				6/28/90
18F EEP	S23 W17	6/4/86	1.9		N				6/8/94
19B EEP	S57 W8	6/3/86	3.0		N				6/8/94
19D EEP	S53 E2	6/3/86	1.9		N				4/14/88
19F EEP	S56 W18	6/3/86	1.9		N				4/14/88
19AX EEP	E0 ELECTRIC	6/5/86	1.9		N				6/1/87
19AY EEP	E0 ELECTRIC	6/5/86	1.9		N				4/8/88
20B EEP	S592 E140	7/10/86	3.0		N				6/13/90
20D EEP	S592 E140	7/10/86	1.9		N				5/21/93
20F EEP	S592 E140	7/10/86	1.9		N				6/6/94

TABLE 8-1 (continued)
Excavation Effects Program Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (Inches)	CLAY	DATE OF OFFSET AT CLAY	DEPTH TO OFFSET (feet)	OFFSET (Inches)	OFFSET RATE* (in/yr)	LAST INSPECTED
21B EEP	S700 E66	7/8/86	1.9		N				6/7/94
21D EEP	S706 E66	7/8/86	1.9		N				6/15/90
21F EEP	S694 E66	7/8/86	3.0		N				7/9/86
22B EEP	S699 E299	7/8/86	3.0		N				7/24/89
22D EEP	S699 E303	7/8/86	1.9		N				6/1/94
22F EEP	S699 E293	7/8/86	1.9		N				7/9/86
23B EEP	S1190 E299	7/9/86	3.0		N				7/24/89
23D EEP	S1190 E303	7/9/86	1.9		N				6/1/94
23F EEP	S1190 E295	7/9/86	1.9		N				7/24/89
24B EEP	S1300 E156	7/9/86	3.0	E	3/7/91	7.70	0.13	0.03	4/10/92
24D EEP	S1310 E155	7/9/86	1.9		N				5/21/93
24F EEP	S1290 E155	7/9/86	1.9		N				5/21/93
25B EEP	S1130 E155	7/9/86	3.0		N				6/12/90
25D EEP	S1129 E140	7/9/86	1.9		N				6/4/87
25F EEP	S1129 E140	7/9/86	1.9		N				6/4/87
26B EEP	S2205 E140	7/16/86	1.9		N				4/13/88
26D EEP	S2205 E140	7/16/86	1.9		N				4/13/88
26F EEP	S2205 E140	7/16/86	1.9		N				4/13/88
27B EEP	N1420 W432	7/11/86	3.0		N				5/26/94
27F EEP	N1420 W432	7/11/86	3.0		N				7/24/89
28D EEP	N1106 W418	7/16/86	1.9		N				6/21/90
28F EEP	N1116 W418	7/16/86	3.0		N				5/26/94
30D EEP	N1103 E1298	7/11/86	1.9		N				5/19/87
30F EEP	N1110 E1296	7/11/86	1.9		N				6/5/87
37B EEP	N51 E305	3/10/93	3.0		N				3/7/95
37D EEP	N51 E312	4/5/93	3.0		N				3/7/95
37F EEP	N51 E298	3/4/93	3.0	E	7/28/94	10.00	0.13	0.09	3/7/95

Notes:

1. Rate is calculated for period from date of drilling to date offset was recorded.
2. N=no offset
3. Variation in the field data resulting from interpretation by individual inspectors must be taken into consideration when evaluating the results presented here. Graphical representation of the arrays is available upon request.

TABLE 8-2
Observation Borehole Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (inches)	DATE OF OFFSET AT CLAY G	DEPTH TO OFFSET (feet)	OFFSET (inches)	OFFSET RATE (in/vr)	LAST INSPECTED
E0:								
OH185	N1258 E5	9/28/94	3.0	N				10/17/94
OH186	N1258 W2	9/27/94	3.0	N				10/17/94
OH187	N1258 W8	9/27/94	3.0	N				10/17/94
OH188	N945 E5	8/22/94	3.0	N				9/28/94
OH189	N945 W3	7/8/94	3.0	N				9/28/94
OH190	N945 W8	6/10/94	3.0	N				9/28/94
N780:								
OH191	N781 E82	8/25/94	3.0	N				9/28/94
OH192	N785 E84	8/23/94	3.0	N				9/28/94
OH193	N793 E85	8/26/94	3.0	N				9/28/94
N460:								
OH194	N459 E82	6/9/94	3.0	10/6/94	6.05	0.13	0.40	10/6/94
OH195	N466 E82	6/7/94	3.0	N				10/6/94
OH196	N472 E82	5/31/94	3.0	10/6/94	6.70	0.13	0.37	10/6/94
E140 (North):								
OH182	N965 E164	5/23/94	3.0	9/27/94	8.40	0.13	0.37	9/27/94
OH183	N964 E156	5/20/94	3.0	9/27/94	7.90	0.13	0.37	9/27/94
OH184	N964 E149	5/19/94	3.0	N				9/27/94
OH179	N626 E160	5/31/94	3.0	N				9/27/94
OH180	N626 E154	5/27/94	3.0	N				9/27/94
OH181	N626 E147	5/26/94	3.0	9/27/94	6.80	0.25	0.74	9/27/94
OH176	N314 E161	5/24/94	3.0	N				9/27/94
OH177	N315 E154	5/25/94	3.0	N				9/27/94
OH178	N314 E146	5/25/94	3.0	N				9/27/94
OH173	N90 E161	10/7/94	3.0	N				10/14/94
OH174	N72 E154	10/6/94	3.0	N				10/26/94
OH175	N73 E146	10/5/94	3.0	N				10/26/94
OH170	S249 E160	9/23/94	3.0	N				10/17/94
OH171	S250 E154	10/4/94	3.0	N				10/18/94
OH172	S249 E141	10/3/94	3.0	N				10/17/94
AIS Access:								
OH197	N310 W175	9/21/94	3.0	N				10/18/94
OH198	N303 W175	9/22/94	3.0	N				10/19/94
OH199	N297 W175	9/23/94	3.0	N				10/18/94
OH200	N212 W466	9/16/94	3.0	N				10/18/94
OH201	N218 W469	9/19/94	3.0	N				10/18/94
OH202	N224 W472	9/20/94	3.0	N				10/19/94
E300 Shop:								
OH167	N246 E311	4/8/93	3.0	3/7/95	8.80	0.50	0.26	3/7/95
OH168	N245 E229	4/15/93	3.0	12/21/94	8.00	0.13	0.08	3/7/95
OH169	N246 E158	4/26/93	3.0	N				3/7/95
OH205	N174 E311	12/20/94	3.0	N				12/29/94
OH166	N162 E305	4/6/93	3.0	N				3/7/95
OH206	N174 E298	12/21/94	3.0	N				3/7/95
OH207	N54 E299	1/3/95	3.0	3/7/95	6.50	0.13	0.75	3/7/95
BLDS1	N51 E299	12/30/94	3.0	N				1/5/95
OH208	S41 E311	12/29/94	3.0	N				3/7/95
OH165	S49 E306	4/30/93	3.0	12/21/94	3.90	0.25	0.15	3/7/95
OH209	S41 E299	12/28/94	3.0	3/7/95	5.95	0.13	0.69	3/7/95

TABLE 8-2 (continued)
Observation Borehole Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (Inches)	DATE OF OFFSET AT CLAY G	DEPTH TO OFFSET (feet)	OFFSET (inches)	OFFSET RATE (in/yr)	LAST INSPECTED
E140 (South):								
OH103	S500 E149	5/8/92	3.0	7/12/94	5.30	0.63	0.29	11/4/94
OH104	S498 E155	5/8/92	3.0	N				11/4/94
OH105	S500 E161	5/8/92	3.0	7/12/94	5.20	0.50	0.23	11/4/94
OH106	S549 E148	5/8/92	3.0	7/12/94	6.05	1.00	0.46	11/4/94
OH107	S550 E156	5/8/92	3.0	N				11/4/94
OH108	S550 E161	5/8/92	3.0	7/12/94	6.00	0.75	0.34	11/4/94
OH109	S600 E147	5/8/92	3.0	11/11/94	5.70	1.00	0.40	11/11/94
OH110	S599 E154	5/8/92	3.0	N				11/11/94
OH111	S599 E160	5/8/92	3.0	11/11/94	6.00	1.00	0.40	11/11/94
OH112	S801 E148	5/8/92	3.0	7/12/94	6.10	0.75	0.34	11/3/94
OH113	S800 E154	5/8/92	3.0	11/3/94	5.90	0.63	0.25	11/3/94
OH114	S801 E161	5/8/92	3.0	7/12/94	5.95	0.63	0.29	11/3/94
OH115	S851 E149	5/8/92	3.0	11/3/94	6.10	0.75	0.30	11/3/94
OH116	S851 E155	5/8/92	3.0	N				11/3/94
OH117	S851 E161	5/8/92	3.0	11/3/94	6.00	0.75	0.30	11/3/94
OH118	S900 E149	5/8/92	3.0	11/3/94	6.30	1.00	0.40	11/3/94
OH119	S900 E155	5/8/92	3.0	11/3/94	6.30	0.13	0.05	11/3/94
OH120	S900 E161	5/8/92	3.0	11/3/94	6.00	1.00	0.40	11/3/94
OH121	S900 E148	5/8/92	3.0	11/3/94	5.60	1.50	0.60	11/3/94
OH122	S1101 E154	5/8/92	3.0	N				11/3/94
OH123	S1100 E161	5/8/92	3.0	7/14/94	5.60	1.25	0.57	11/3/94
OH124	S1151 E149	5/8/92	3.0	N				11/3/94
OH125	S1150 E155	5/8/92	3.0	N				11/3/94
OH126	S1150 E161	5/8/92	3.0	N				11/3/94
OH127	S1200 E148	5/8/92	3.0	11/2/94	5.30	1.50	0.60	11/2/94
OH128	S1200 E154	5/8/92	3.0	N				11/2/94
OH129	S1200 E160	5/8/92	3.0	N				11/2/94
OH130	S1345 E146	5/8/92	3.0	11/2/94	5.50	1.25	0.50	11/2/94
OH131	S1345 E153	5/8/92	3.0	N				11/2/94
OH132	S1345 E161	5/8/92	3.0	11/2/94	5.40	1.63	0.66	11/2/94
OH133	S1455 E148	5/8/92	3.0	11/2/94	4.00	1.75	0.70	11/2/94
OH134	S1455 E154	5/8/92	3.0	N				11/2/94
OH135	S1455 E160	5/8/92	3.0	N				11/2/94
OH136	S1505 E148	5/8/92	3.0	11/2/94	5.70	1.63	0.66	11/2/94
OH137	S1505 E154	5/8/92	3.0	N				11/2/94
OH138	S1505 E160	5/8/92	3.0	N				11/2/94
OH139	S1731 E147	5/8/92	3.0	10/31/94	6.00	1.50	0.60	10/31/94
OH140	S1731 E153	5/8/92	3.0	N				10/31/94
OH141	S1731 E159	5/8/92	3.0	N				10/31/94
OH142	S1781 E147	5/8/92	3.0	N				10/31/94
OH143	S1781 E153	5/8/92	3.0	N				10/31/94
OH144	S1780 E160	5/8/92	3.0	N				10/31/94
OH145	S1831 E146	5/8/92	3.0	N				10/31/94
OH146	S1830 E152	5/8/92	3.0	N				10/31/94
OH147	S1830 E160	5/8/92	3.0	N				10/31/94
OH305A	S2010 E155	9/1/93	3.0	N				10/31/94
OH306A	S2091 E153	8/31/93	3.0	N				10/31/94
OH306C	S2091 E159	8/31/93	3.0	10/31/94	5.60	0.25	0.21	10/31/94
OH306E	S2092 E147	8/31/93	3.0	10/31/94	5.80	0.25	0.21	10/31/94
OH307A	S2164 E151	8/31/93	3.0	N				10/31/94
OH307C	S2164 E158	8/31/93	3.0	10/31/94	6.00	0.13	0.11	10/31/94
OH307E	S2163 E146	8/31/93	3.0	10/31/94	6.10	0.13	0.11	10/31/94

TABLE 8-2 (continued)
Observation Borehole Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (Inches)	DATE OF OFFSET AT CLAY G	DEPTH TO OFFSET (feet)	OFFSET (Inches)	OFFSET RATE (In/yr)	LAST INSPECTED
S1600:								
OH102	S1614 E658	11/20/91	3.0	11/11/94	7.50	1.00	0.34	11/11/94
OH101	S1616 E855	11/20/91	3.0	N				11/11/94
OH032	S1615 E1053	6/2/92	3.0	11/11/94	7.00	1.75	0.72	11/11/94
OH100	S1617 E1190	11/20/91	3.0	N				11/11/94
OH099	S1616 E1322	11/21/91	3.0	N				8/8/94
S1950:								
OH095	S1950 E654	11/21/91	3.0	11/11/94	6.50	0.13	0.04	11/11/94
OH096	S1949 E853	11/21/91	3.0	11/11/94	6.90	0.38	0.13	11/11/94
OH097	S1950 E1056	11/21/91	3.0	11/11/94	6.05	0.75	0.25	11/11/94
DHP401	S1949 E1324	12/8/86	4.0	N				8/8/94
Panel 1, Room 1:								
OH094	S1709 E512	2/13/92	3.0	N				12/8/94
OH093	S1709 E516	2/13/92	3.0	N				12/8/94
OH082	S1710 E523	5/1/91	3.0	N				12/8/94
OH092	S1710 E533	2/13/92	3.0	N				12/8/94
OH091	S1711 E536	2/13/92	3.0	12/8/94	6.80	1.38	0.49	12/8/94
OH090	S1784 E511	2/13/92	3.0	12/8/94	7.40	1.25	0.44	12/8/94
OH089	S1783 E515	2/13/92	3.0	12/8/94	7.40	1.50	0.53	12/8/94
OH081	S1784 E523	4/19/91	3.0	N				12/8/94
OH088	S1784 E532	2/13/92	3.0	N				12/8/94
OH087	S1783 E536	2/13/92	3.0	12/8/94	7.10	1.25	0.44	12/8/94
OH086	S1854 E511	2/13/92	3.0	12/8/94	6.80	1.00	0.35	12/8/94
OH085	S1854 E516	2/13/92	3.0	12/8/94	6.90	1.38	0.49	12/8/94
OH080	S1859 E522	5/1/91	3.0	N				12/8/94
OH084	S1855 E530	2/13/92	3.0	12/8/94	6.85	1.38	0.49	12/8/94
OH083	S1855 E534	2/13/92	3.0	12/8/94	6.80	1.50	0.53	12/8/94
Panel 1, Room 2:								
OH347	S1724 E669	9/28/93	3.0	8/9/94	7.70	0.25	0.29	8/9/94
OH348	S1723 E656	9/27/93	3.0	N				8/9/94
OH349	S1723 E642	9/28/93	3.0	8/9/94	7.00	0.38	0.44	8/9/94
OH350	S1794 E669	9/29/93	3.0	N				8/9/94
OH351	S1795 E657	9/30/93	3.0	N				8/9/94
OH352	S1794 E643	9/30/93	3.0	8/9/94	7.30	0.50	0.58	8/9/94
OH353	S1861 E670	10/6/93	3.0	8/9/94	7.50	0.13	0.15	8/9/94
OH354	S1863 E655	10/6/93	3.0	N				8/9/94
OH355	S1863 E643	10/5/93	3.0	8/9/94	8.00	0.38	0.45	8/9/94
Panel 1, Room 3:								
34A EEP	S1859 E789	4/25/91	3.0	1/1/80	0.00	0.00	0.00	6/7/94
34C EEP	S1859 E801	4/23/91	3.0	6/7/94	7.20	1.00	0.32	6/7/94
34E EEP	S1859 E773	4/23/91	3.0	5/20/93	7.10	0.88	0.42	6/7/94
35A EEP	S1785 E789	4/24/91	3.0	5/20/93	6.50	0.25	0.12	6/7/94
35C EEP	S1784 E801	4/24/91	3.0	6/7/94	6.40	1.25	0.40	6/7/94
35E EEP	S1784 E776	4/25/91	3.0	6/7/94	6.40	1.25	0.40	6/7/94
36A EEP	S1710 E789	4/25/91	3.0	1/1/80	0.00	0.00	0.00	6/6/94
36C EEP	S1710 E801	4/25/91	3.0	6/6/94	7.50	1.13	0.36	6/6/94
36E EEP	S1709 E776	4/26/91	3.0	6/6/94	7.40	1.13	0.36	6/6/94

TABLE 8-2 (continued)
Observation Borehole Clay Seam Displacements

BOREHOLE ID	LOCATION	DRILL DATE	DIAMETER (inches)	DATE OF OFFSET AT CLAY G	DEPTH TO OFFSET (feet)	OFFSET (inches)	OFFSET RATE (in/vr)	LAST INSPECTED
Panel 1, Room 4:								
OH338	S1722 E935	10/8/93	3.0	8/11/94	5.10	0.63	0.75	8/11/94
OH339	S1723 E922	10/7/93	3.0	N				8/11/94
OH340	S1723 E908	10/7/93	3.0	8/11/94	6.30	0.38	0.45	8/11/94
OH341	S1797 E934	10/11/93	3.0	8/11/94	6.70	0.50	0.60	8/11/94
OH342	S1820 E921	10/8/93	3.0	N				8/11/94
OH343	S1796 E908	10/8/93	3.0	8/11/94	6.90	0.25	0.30	8/11/94
OH344	S1862 E936	10/12/93	3.0	8/11/94	6.80	0.38	0.46	8/11/94
OH345	S1861 E921	10/13/93	3.0	N				8/11/94
OH346	S1861 E909	10/13/93	3.0	8/11/94	6.70	0.50	0.60	8/11/94
Panel 1, Room 5:								
OH329	S1727 E1068	9/20/93	3.0	8/3/94	6.40	0.38	0.44	8/3/94
OH330	S1727 E1054	9/16/93	3.0	N				8/3/94
OH331	S1727 E1041	9/17/93	3.0	8/3/94	6.20	1.00	1.14	8/3/94
OH332	S1793 E1068	9/21/93	3.0	N				8/3/94
OH333	S1791 E1055	9/22/93	3.0	N				8/3/94
OH334	S1792 E1041	9/22/93	3.0	8/3/94	6.10	0.63	0.73	8/3/94
OH335	S1862 E1068	9/23/93	3.0	8/3/94	6.60	0.38	0.44	8/3/94
OH336	S1861 E1054	9/24/93	3.0	N				8/3/94
OH337	S1859 E1041	9/24/93	3.0	N				8/3/94
Panel 1, Room 6:								
OH320	S1720 E1201	10/15/93	3.0	8/3/94	6.10	0.38	0.48	8/3/94
OH321	S1723 E1187	10/15/93	3.0	N				8/3/94
OH322	S1722 E1174	10/18/93	3.0	8/3/94	6.70	0.50	0.63	8/3/94
OH323	S1793 E1202	10/18/93	3.0	8/3/94	6.60	0.50	0.63	8/3/94
OH324	S1793 E1187	10/18/93	3.0	N				8/3/94
OH325	S1791 E1174	10/20/93	3.0	8/8/94	6.60	0.63	0.79	8/8/94
OH326	S1879 E1202	10/20/93	3.0	8/8/94	6.50	0.38	0.48	8/8/94
OH327	S1880 E1188	10/21/93	3.0	N				8/8/94
OH328	S1879 E1175	10/21/93	3.0	8/8/94	6.70	0.13	0.16	8/8/94
Panel 1, Room 7:								
OH312	S1686 E1332	9/13/93	3.0	8/8/94	5.50	0.75	0.83	8/8/94
OH313	S1687 E1321	9/3/93	3.0	N				8/8/94
OH315	S1783 E1335	9/8/93	3.0	8/8/94	6.90	0.75	0.82	8/8/94
OH098	S1783 E1321	11/21/91	3.0	N				8/8/94
OH316	S1783 E1307	9/8/93	3.0	N				8/8/94
OH317	S1859 E1334	9/10/93	3.0	8/8/94	6.00	0.63	0.69	8/8/94
OH318	S1862 E1321	9/10/93	3.0	N				8/8/94
OH319	S1863 E1308	9/9/93	3.0	8/8/94	6.80	0.50	0.55	8/8/94
W30:								
OH308A	S1458 W17	7/19/93	3.0	N				10/18/94
OH308B	S1460 W24	7/16/93	3.0	N				10/18/94
OH308D	S1459 W10	7/16/93	3.0	N				10/18/94
OH309A	S1771 W17	7/20/93	3.0	N				10/18/94
W170:								
OH310A	S1769 W170	7/19/93	3.0	N				10/18/94
OH311A	S1463 W171	7/19/93	3.0	N				10/18/94
S90:								
OH204	S98 W393	10/10/94	3.0	N				10/19/94

Notes:

1. Rate is calculated for period from date of drilling to date offset was recorded.
2. N=no offset
3. Variation in the field data resulting from interpretation by individual inspectors must be taken into consideration when evaluating the results presented here. Graphical representation of the arrays is available upon request.

8.2 Geologic and Fracture Mapping of Excavation Surfaces

Geologic mapping of WIPP excavations is performed in areas of new mining to provide continuing confirmation of facility horizon geology by:

1. confirming the lateral continuity of facility strata;
2. confirm the absence of disqualifying fractures and faults;
3. confirm the suitability of the facility horizon stratigraphy, lithology, and structure;
4. evaluate interbeds which could have possible unacceptable influence on excavation stability, or containment capability of the rock; and
5. establish a baseline record of the geologic conditions.

Fracture mapping of excavation surfaces are created as required, typically to assist in ground stability assessments. This year, geologic mapping was performed in the E300 maintenance shop, between S90 and N250, and fractures were mapped in the Air Intake Shaft station.

8.2.1 E300 Maintenance Shop - Geology

Geologic rib mapping was performed in the E300 maintenance shop in July. The areas of coverage include the south rib of the N250 drift and the west rib of the E300 drift. At a minimum, map unit 1 was continuously mapped along each rib with the map showing full rib coverage. Survey control of the mapping was established by Geotechnical Engineering using a level and tape. The mapping was accomplished by directly examining and recording lithology, stratigraphy, and structure of the rock (Figures 8-2 and 8-3).

The geologic drift mapping program has demonstrated no major discontinuities in the stratigraphy of the facility horizon. Seven units have been identified and are exposed in most of the drifts. The units are continuous throughout the workings except for minor breaks in map units 1 and 2 caused by syndepositional dissolution and reprecipitation of halite (Powers and Hassinger, 1985).

8.2.2 Air Intake Shaft Station - Roof Fractures

Mapping of surface fractures in the Air Intake Shaft station area was first performed in October 1992. In the station, fractures were mapped in the roof, and in the north and south brows. In the

Figure 8-2
Geologic Rib Map N250, E140 to E300

Figure 8-3
Geologic Rib Map E300, West Rib

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shaft, fractures were mapped from the station roof to Clay I, which lies about 20 ft (6.1 m) above the roof. These areas were remapped in July, 1994.

The station roof is at the base of the halite unit lying immediately above Anhydrite "b", which is visible in the ribs and at the tops of the north and south brows. The ribs were offset into the station along the roof with estimated displacements of up to 1-1/2 inches (3.8 cm). The brow faces extend over a horizontal distance of approximately 13 ft (5 m) and dip approximately forty-five degrees down and away from the shaft. Fractures propagate perpendicularly to the faces with apertures up to 1-1/4 inches (3.2 cm). Separation of the brows at the roof was less than 3/4 inch (1.9 cm). Figure 8-4 depicts the typical separation and fracture propagation characteristics for the brows and Table 8-3 and 8-4 summarizes the description of each fracture set.

The south brow begins approximately 24 ft (7.3 m) from the shaft (Figure 8-5). The roof between the shaft and the brow contained several vertical fractures with apertures up to 1/4 inch (6 mm). In the face, several new fractures occurred primarily near the top and near the ribs. The base (underside) of the brow contained no new vertical fractures; existing fractures had maximum apertures of 3/8 inch (1 cm).

The north brow begins approximately 16 ft (5 m) from the shaft (Figure 8-6). Fractures in the face contained apertures up to 1/2 inch (1.3 cm). The base (underside) of the brow contained vertical fractures, including several new fractures, within 13 ft (4 m) of the face. Maximum apertures were 1/2 inch (1.3 cm).

Fractures within the shaft (Figure 8-7) occurred below Anhydrite "a", with the exception of one fracture on the west side of the shaft, which was located approximately one foot above the anhydrite. Several existing fractures had lengthened, often intersecting with others, and new fractures occurred primarily on the north and east sides of the shaft. Fracture apertures were visually estimated at up to 1-1/4 inches (3.2 cm). Increases in aperture up to 3/4 inch (1.9 cm) were noted, with 1/4 inch (6 mm) being typical.

Figure 8-4
Schematic of AIS Station Brow Fractures

Figure 8-5
AIS Station - South

Figure 8-6
AIS Station - North

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Figure 8-7
AIS Shaft

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Table 8-3
AIS Station Back Fractures

Fracture Set No.	No. of Fractures	DIP	STRIKE	Type (T/D)	Aperture Width (in)	Length (ft)	Depth (ft)	Remarks
1	1	V	E	T	$\frac{1}{4}$	~12	-	-
2	1	V	S	T	$\frac{1}{16}$	~10	-	-
2a	3	V	S	T	$\frac{1}{16}$	~6	-	-
3	1	V	S	T	$<\frac{1}{4}$	~18	-	-
3a	1	V	S	T	$\frac{1}{16}$	~11	-	-
4	1	V	S	T	$\frac{1}{16}$	~11	-	-
4a	1	V	S	T	$\frac{1}{16}$	~8.5	-	-
5	1	H	E	T	$\frac{1}{8}$	~21	-	-
5a	1	V	S-E	T	$\frac{1}{16}$	~4	-	-
5b	1	V	S	T	$\frac{1}{16}$	~2	-	-
6	1	H	E	S	$<\frac{3}{4}$	~21.5	-	-
6a	4	~45N	E	T	$\frac{1}{4}$	~11	-	-
6b	1	-	S	T	$\frac{1}{4}$	~0.5	-	-
6c	1	-	S	T	$<\frac{1}{2}$	~0.7	-	-
7	5	~45N	E	T	$\frac{3}{16}$	~6.7	-	-
7a	4	~45N	E	T	$\frac{1}{2}$	~4	-	-
8	11	~45N	E	T	$\frac{3}{8}$	~9	-	-
9	4	~45N	E	T	$\frac{3}{4}$	~9.5	-	-
10	6	~45N	E	T	$\frac{3}{8}$	~6	-	-
11	1	V	E	T	$\frac{3}{16}$	~6.3	-	-
12	4	V	E	T	$\frac{3}{8}$	~7	-	-
14	2	~45N	E	T	$\frac{1}{4}$	~3	-	-
15	3	~45N	E	T	$\frac{3}{16}$	~7	-	-
16	2	~45N	E	T	$1\frac{1}{4}$	~5	0.55	Fractures reduce to $\frac{1}{16}$ " within ~6.5" of excavation.
17	-	-	-	-	-	-	-	Not inspected.
18	1	H	E	S	-	~25	-	Not inspected closely.
18a	4	~45S	E	T	$<\frac{1}{8}$	~1.5	-	-
18b	1	~45S	E	T	$\frac{3}{4}$	~2.5	-	-
18c	1	~45S	E	T	$\frac{1}{8}$	~2	-	-
19	6	~45S	E	T	$\frac{1}{2}$	~3.5	-	-
20	1	~45S	E	T	$<\frac{1}{2}$	~10	-	-
21	1	~45S	E	T	$<\frac{1}{2}$	~8.5	-	-
22	2	~45S	E	T	$<\frac{1}{4}$	~4.5	-	-
23	2	~45S	E	T	$<\frac{3}{8}$	~14.7	-	-
24	3	~45S	E	T	$<\frac{1}{2}$	~4	-	-
24a	3	~45S	E	T	$<\frac{1}{4}$	~6	-	-
25	3	V	E	T	$\frac{1}{2}$	~10	-	-
26	1	V	E	T	$\frac{3}{16}$	~11	-	-
26a	1	V	E	T	$\frac{3}{8}$	~4	-	-
27	1	V	E	T	$\leq\frac{1}{16}$	~2	-	-
27a	1	V	E	T	$\leq\frac{1}{16}$	~1.5	-	-
27b	1	V	E	T	$\leq\frac{1}{16}$	~2.5	-	-
28	1	V	E	T	$\leq\frac{1}{16}$	~5.5	-	-
29	1	~20SW	SE	T	$\leq\frac{1}{16}$	~1.5	-	-

Table 8-4
AIS Station Brow Fractures

Fracture Set No.	No. of Fractures	DIP	STRIKE	Type (T/S)	Aperture Width (in)	Length (ft)	Depth (ft)	Remarks
1	4	H	-	T	<1	~7.5	-	The largest fracture dips ~W45.
2	1	~45W	-	T	$\frac{1}{2}$	~7	-	-
3	2	H	-	T	$\leq \frac{1}{16}$	~12.5	-	-
4	1	H	-	T	$1\frac{1}{4}$	~20.5	-	-
4a	2	H	-	T	$\frac{3}{16}$	~4.7	-	-
5	4	H	-	T	$\frac{3}{8}$	~10	-	-
5a	7	H	-	T	$\frac{3}{16}$	~1	-	-
6	5	H	-	T	$\frac{3}{8}$	~9.5	-	-
7	1	45S	-	T	$\frac{1}{16}$	~2	-	-
7a	2	H	-	T	$\frac{1}{16}$	~1.5	-	-
8	3	H	-	T	$<\frac{1}{2}$	~8	-	-
9	1	H	-	T	$\leq \frac{1}{16}$	~7.3	-	-

8.3 Observations of Rockbolt Failures

Rockbolt failures are documented as close to the time of failure as possible and recorded in a database. Each failure record includes, when possible, the type of failure, location, bolt length and diameter, plate type, and any unusual condition associated with the installation. Figure 8-8 depicts the numbers of failure types that occurred each month of the reporting period.

8.3.1 Failure Mechanisms

Bolt head failure occurs when the head of the bolt separates from the bolt shaft. Head failures probably can be attributed to conditions causing the bearing plate to be placed at an angle not perpendicular to the bolt axis, which results in the bolt head becoming unevenly loaded as the salt deforms (Figure 8-9). The induced bending moment causes the bolt head to break off as the bolt takes load. Over-torquing may impart high and uneven initial bolt loads, exacerbating other conditions which might lead to failure.

Shaft failure occurs when the bolt breaks along the shaft. Bolts that fail in this manner typically exhibit some degree of bending near the broken ends indicating that lateral forces were exerted on the bolts, and are termed offset shaft failures (Figure 8-10). The lengths of recovered offset failures indicate the depth of the lateral offset. Inspections of observation boreholes located near many of these failures often reveal slip-planes (usually clay layers) lying at approximately the same depth. Rockbolt failures held in place by wire mesh or not otherwise retrievable are usually termed suspected shaft failures.

A relatively small number of bolts experience failure of the anchor or plate. Anchor failures occur when the anchor assemblies fail or slip out of the bolt hole. Plate failures typically exhibit cracking or tearing of the plate around the bolt hole.

8.3.2 Failure Locations

Rockbolt failures occurred at various underground locations with several specific areas containing the majority of the failures. These areas are shown in Table 8-5, which provides the numbers of each failure type that occurred within each selected location. In addition, the average recovered length of shaft failures is given.

Figure 8-8
Bolt Failures by Type and Month

Table 8-5
Rockbolt Failures by Location and Type for Period July 1994 through June 1995

Location		Drift width:	Recovered Shaft Failures				Suspected Shaft Failures	Head Failures	Other Failures	Total for Location
			Percent due to offset:	Average recovered length (feet):	Average distance from nearest rib (feet):					
E300 Shop	33'	7	86	6.4	3.2	102	3	1	113	
Panel 1 Rooms		5	80	6.3	9.3	3	6	1	18	
		(Rooms 1-6)								
		3	67	5.6	9.3					
		(Room 7)								
L-Rooms		43	98	4.1	4.2	6	0	1	50	
E140 North	25'	187	99	6.6	6.2	5	1	9	202	
E140 South		27	93	5.1	4.0	0	11	3	41	
E0		56	98	8.4	5.2	5	3	0	64	
Waste Shaft Station	varies	17	94	6.5	4.0	1	0	0	18	
Other	varies	59	75	varies	varies	5	31	1	96	
Total all locations:		404	94	-	-	127	55	16	602

Figure 8-9
Head Failure

Figure 8-10
Offset. Shaft Failure

Bolt failures in the E300 Experimental Operations Shop between N1100 and N1420, accounted for nineteen percent of the total bolt failures in the underground this period. Shaft failures usually occurred about three feet from the ribs. A wire mesh was installed on the roof to prevent bolts from falling. Bolts that could not be recovered through the mesh are termed suspected shaft failures and accounted for 95 percent of the total suspected shaft failures. Because these bolts were installed almost immediately after excavation, they were probably affected by the early high deformation of the rock immediately after excavation, whereas most pattern bolts in other areas of the facility were installed some years after excavation.

The pattern bolts in Panel 1, Rooms 1 through 6, are ten-feet long and penetrate Clay G, which lies at an average of 6.7 feet (2 meters) above the back. The initial pattern bolts in Room 7, which are only six feet (1.8 m) long, experienced a few offset shaft failures, suggesting that Clay G lies somewhat lower than 6 feet (1.8 m) in areas of the room.

The database of rockbolt failures is updated as bolts fail. Investigations into the causes and impacts of rockbolt failures in the underground are made as additional data are collected.

9.0 *Summary*

At the start of the project, criteria were developed which address the requirements for the design of the WIPP. These criteria (DOE, 1984) cover all aspects of the facility and its operation as a pilot plant for the demonstration of technical and operational methods for permanent isolation of contact- and remote-handled transuranic waste. These criteria are compared with conditions actually observed in the underground from July 1994 to June 1995 (Table 9-1).

Fracture development in the roof is primarily caused by the concentration of compressive stresses in the roof beam and is influenced by the size and shape of the excavation and the stratigraphy in the immediate vicinity of the opening. Pillar deformations induce lateral compressive stresses into the immediate roof and floor. The buildup of stress, with time, causes differential movement along stratigraphic boundaries. This differential movement is identified as offsets in observation boreholes and which is indicated by bending deformations in failed rockbolts. Large strains, associated with lateral movements in the roof, can induce fracturing in the roof which is frequently seen near the ribs. This scenario of roof deterioration, combining a buildup of compressive stresses over time, horizontal offsetting, and large strains associated with lateral movements, is substantiated by the shape and size of roof falls in SPDV Room 1 and SPDV Room 2.

The in situ performance of the excavations generally continues to satisfy the appropriate design criteria, although specific areas are being identified where deterioration due to aging must be addressed through routine maintenance and implementation of engineered systems. This deterioration has been identified through the analysis of data acquired from geomechanical instrumentation and the Excavation Effects Program. The expected life of some of the openings may need to be extended, which may require redesigning the access drifts or additional ground control effort.

In addition to underground instrumentation, qualitative assessments of fracture development are documented through mapping of the underground repository and inspections of the excavation effects boreholes and other observation boreholes. The information acquired from these programs provides early detection of ground deterioration and contributes to the design of effective ground control and support systems.

The use of a two-dimensional finite difference code has provided a means of simulating the behavior of underground openings. By modeling these openings the WID is able to:

- predict the future performance of existing excavations,
- compare excavation design alternatives and,
- investigate deformation mechanisms affecting the past performance of existing excavations.

During this reporting period, FLAC was used to model convergence of underground openings of various dimensions and correlated to actual field data. The correlation proved to be resonable, thereby indicating that the models are sufficiently accurate for future stablility analyses.

Table 9-1
Comparison of Excavation Performance to Design Criteria

Criterion (DOE, 1984)	Description	Comments
Chapter 5: Design Criteria, Underground Item 2: Ground Control a: Shaft Design	"Shafts shall be designed to be structurally stable throughout the operating life of the underground facility and for the period of time thereafter required for decommissioning of the facility."	Water pressure observed on piezometers located behind the shaft keys remains below design levels. Geomechanical data indicate that the shafts are structurally stable.
	"The time dependent closure of shafts due to salt creep shall be considered in the design of shafts. Shafts shall be dimensioned so that the minimum dimensions required for shaft functions are maintained for the entire design life."	Closure of the shafts remains within design requirements.
	"Groundwater inflow to the shaft shall be controlled so that no uncontrolled groundwater reaches the storage horizon via the shafts."	The small amount of groundwater inflow into the shafts have been controlled through grouting.
c. Mine Design	"...deformation of excavations and pillars shall remain within the limits required for structural function, ventilation, and safety."	Pillars remain stable. Deformation of excavations remains within the required limits. A roof fall occurred in SPDV Room 2 in June 1994. SPDV Rooms 1, 2, and 3 remain barricaded.

Table 9-1 (continued)
Comparison of Excavation Performance to Design Criteria

c. Mine Design cont'd.	"Rock bolts shall be used where necessary to provide positive support of roofs and walls."	<p>Rock bolts have been installed throughout the underground to aid in roof and wall support.</p> <p>Failures have been documented and will be studied further as additional data become available.</p>
d. Emplacement Criteria	"The underground storage rooms and access drifts shall be compatible with the waste transport vehicles and with the waste container sizes, shapes, weights, stacking configurations, and the handling and backfilling equipment requirements... The storage rooms shall be sized for efficient handling and stacking of the CH waste containers."	<p>Access Drifts Geomechanical instrument data and visual observations indicate that the current design is compatible with emplacement criteria. Closure rates indicate that access drifts will require periodic trimming in order to provide clearances for equipment. The disposal rooms and access drifts have been sized to permit transportation and disposal of the CH TRU waste.</p> <p>Disposal Rooms Geomechanical instrument data and visual observations indicate that the current design is compatible with emplacement criteria.</p>
e. Retrievability	"All wastes placed into the WIPP are retrievable, with retrievability to be demonstrated, until such time as the pilot plant is converted to an operational repository for permanent disposal of wastes. The storage room shall allow for salt creep and shall be sized to minimize breaching of the CH waste containers for a period of ten years."	<p>Although retrievability is no longer necessary, the capability to retrieve is maintained as described in the System Design Description for Sytem AU00. This capability is maintained by trimming of the floors, backfilling of the floor fractures, and the installation of supplementary roof support in some areas.</p>
f. Instrumentation	"Underground instrumentation is required to measure phenomena important to the performance of the facility or which cannot be otherwise quantified. Instruments shall be provided to measure such phenomena as rock behavior, gases, seismic activity, and groundwater pressures in order to confirm or revise design assumptions."	<p>Geotechnical instrumentation is operated and maintained to meet the requirements of this criteria.</p> <p>Geotechnical experts agree that the monitoring program at the WIPP has been proven adequate, specifically with regard to the instrumentation in Room 1, Panel 1.</p>

10.0 References

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