Mr. Frank Marcinowski
U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
401 M. Street S.W.
Washington, D.C. 20460

Dear Mr. Marcinowski:

The purpose of this correspondence is to provide advance notice to the Environmental Protection Agency that the Department of Energy (DOE) proposes to allow the installation of the OMNISita astrophysics experiment in the core storage alcove of the Waste Isolation Pilot Plant (WIPP) underground. Our acceptance of this project is based on a comprehensive assessment of potential environmental, industrial hygiene, safety and operational impacts developed during WIPP's routine project review and approval process. A description of these assessments is provided as an enclosure to this correspondence.

The OMNISita project is being advanced by a collaboration of scientists, led by Dr. Richard Boyd of Ohio State University and Dr. David Cline of the University of California at Los Angeles. The purpose of the OMNISita Project is to develop a prototype neutrino detector that will test proof of concept principles and measure background cosmic radiation levels within the WIPP underground. The results and experience gained from this project will be used to design future neutrino detection experiments, including OMNIS (the Observatory for Multi-flavor neutrinos from Supernovae), a similar detector system currently being proposed to the National Science Foundation. Details of the experiment design, installation, and the associated health and safety concerns associated with the OMNISita experiment are provided in the attached Project Description.

The DOE has determined that the WIPP facilities and infrastructure can provide support for this project without interfering with the primary mission of the WIPP, which is to safely manage and dispose of transuranic wastes. The enclosed information is intended to provide the EPA with a comprehensive understanding of both the project and the scope of DOE's review. The enclosed analyses also support the DOE conclusion that this project will not affect the certified baseline or the performance of the disposal system.
Mr. Frank Marcinowski

April 26, 2001

In summary, the project will have no effect on the long-term performance of the disposal system since the experiment: is not a part of the disposal circuit; will be placed in an existing alcove; utilizes materials with no known potential for salt interactions; and, will be completely removed from the underground prior to disposal facility closure.

Based on this assessment, the DOE plans to allow the installation of equipment for the OMNISita project to begin in May 2001. If you have any questions, please contact Mr. Harold Johnson at (505) 234-7349.

Sincerely,

[Signature]

Dr. Inés R. Triay
Manager

Enclosure

cc: w/ enclosure
D. Huizenga, EM-20
M. Kruger, EPA-ORIA
C. Byrum, EPA-ORIA
N. Stone, EPA-Region 6
P. Magiore, NMED
S. Zappe, NMED
M. Silva, EEG

cc: w/o enclosures
H. Johnson, CBFO
B. Lilly, CBFO
R. Nelson, CBFO
J. Lee, WTS
M. Turnbough, Consultant
Project Description
For
OMNISita Experiment
OMNISita Project Description

Contents:
1. Introduction
2. Location
3. Configuration of OMNISita
4. Equipment
5. Hazards
6. Training
7. Applicable Procedures/Required Reading
8. Specific Goals for OMNISita
9. Construction: Requirements
10. Completion and Removal

Appendices:
I. Diagrams of OMNISita
II. Job Hazard Analysis
III. MSDS sheets
IV. Industrial Hygiene Exposure Monitoring Plan
V. Annual Ground Control Operating Plan
VI. Unresolved Safety Question (USQ) Safety Evaluation Worksheet
1. Introduction

The purpose of the OMNISita Project is to develop a prototype neutrino detector that will test proof of concept principles and measure background cosmic radiation levels within the WIPP underground. The results and experience gained from this project will be used to design future neutrino detection experiments, including OMNIS (the Observatory for Multi-flavor neutrinos from Supernovae), a similar detector system currently being proposed to the National Science Foundation. An assessment of the environmental, safety and health aspects of the OMNISita project has been completed and details of the experiment design, installation, potential chemical hazards, and the health and safety concerns associated with the experiment are included in this document.

2. Location

This project will be located in the WIPP underground in the W170 drift at approximately S400 in the Core Storage Alcove (CSA). Figure 1 shows the location of the OMNISita experiment in the underground.

Figure 1 Schematic drawing showing location of OMNISita experiment
An area located in the rear of the CSA about 50 feet by 24 feet will be enclosed within a chain link fence to support the experiment. A floor plan of the area is shown in Figure 1a.

Proposed layout for the CSA

![Proposed Layout](image)

Approximately 18,000 actual cubic feet of airflow per minute is supplied to the CSA from the S90 drift through an auxiliary ventilation duct and fan. Once air is circulated through the alcove it discharges into the W170 drift, inter-mixes with exhaust air from the active mining area, and flows directly to the exhaust shaft without passing through any additional work areas. It is important to note that this is a separate air ventilation circuit from the ventilation circuits that service the waste handling and disposal areas of the mine. Should an “event” occur in the CSA, there would be no impact on the ventilation in the waste handling areas of the repository.

Another important consideration for the design of the OMNISita project is the potential for salt creep in the experimental area. Based on historical geotechnical studies, salt creep will have minimal impact on the OMNISita project due to the 3-4-year duration of the experiment. Roof bolts have been installed in the experimental area and daily inspection by underground personnel will ensure that potential ground control issues are identified and mitigated immediately.
3. Configuration of the OMNISita Project

The OMNISita project will be constructed upon a horizontal and flat floor area in the CSA. Support for the detector array and associated shielding will consist of two connected sections of 1/2” thick steel plate. The entire detector array will be constructed within a secondary containment structure to provide sufficient containment for the entire volume of scintillation fluids. The steel drums used to transport the scintillator fluid will also be stored within secondary containment. The synthetic liner will be inspected routinely to ensure its integrity. In the event that the liner is breached, appropriate repairs will be made or the liner will be replaced.

Shielding for the detectors will be provided by a self-supporting lead structure, approximately 20 feet long, 6 feet wide and 3 feet high. The lead shielding surrounding the scintillation tanks will be constructed by stacking courses of lead bricks. The lead bricks will be stacked upon each other in an overlapping manner to ensure a stable configuration. One-quarter inch thick steel plates will be used to support the top most layers of lead and the upper layer of acrylic tanks. The structure, initially totaling about 50 tons, will be built as shown in Figure 2 and the detailed schematics provided in Appendix I. At a later date, more lead bricks may be added to increase the depth of shielding around the scintillation tanks.

The neutron detectors will consist of twelve acrylic tanks filled with mineral oil scintillation solutions. Material Safety Data Sheets (MSDS) for the scintillation solutions and other materials used in this experiment are provided in Appendix III. The outside dimensions of each of these tanks are 177.2 inches long, 5.12 inches wide and 10.25 inches high. Attached to each end of each tank will be two standard 5 inch diameter photomultiplier tubes (PMT), which are in turn connected to a high voltage supply (<2000V) and a PC+CAMAC oriented electronic read out. The PMTs are housed in mu-metal magnetic shields, with outer dimensions (additional in length to the tubes, when assembled) of 11 inches long, 5.095 inches wide and 10.155 inches high. The acrylic tanks themselves are completely enclosed within a copper or aluminum sheet providing a light tight environment for the mineral oil.

Additional tests are planned using an existing steel tube detector design currently in use at Ohio State University. This tube is 118 inches long and 6 inches in diameter, and has curved ultra-reflective aluminum sheeting on the inside surface. Borosilicate glass ends are attached with Teflon O-rings gaskets. The purpose of these tests is to compare the performance of the acrylic tube design to the performance of the steel and aluminum tube design, in a low background environment.

Mineral oil scintillator fluid (BC-517p) will be used in the OMNISita detector array. This scintillator fluid will allow OMINSita personnel to study issues such as background and signal height. At least one detector tube will be filled with gadolinium-loaded scintillator fluid (BC-525b). Tests with the gadolinium solution will evaluate the neutron detection abilities of this solution and provide a test of this liquid’s light output and degradation over time. Copies of the MSDSs for the two scintillator fluids are provided in Appendix III.

The computers and electronic equipment associated with the project will be housed inside a connex to provide a relatively dust free environment and protect them from exposure to the salty
The connex is approximately 8 feet wide by 20 feet long by 8 feet high. Ventilation air has been ducted into the experimental area from the air-intake near the Q-room to maintain air quality in the experimental area.

Fig. 2. Semi transparent schematic drawing of the proposed OMNISita detector. For clarity, several features are not shown: the copper- or aluminum-foil light tight wrapping, the mu-metal magnetic shields, and the secondary containment features. The Connex housing electronics and office space is shown on the right, see Figure 1 and Appendix I for further details.
4. Equipment

Power

The expected power needs for OMNISita are as follows:

- 1 - 20 amp / 240 volt circuit for air conditioning for connex enclosure.
- 1 - 20 amp / 120 volt circuit for lights.
- 1 - 20 amp / 120 volt circuit for electronics.
- 1 - 20 amp / 120 volt circuit for computers/printers/networking.
- 1 - 20 amp / 120 volt circuit for remaining misc, including scopes, radio, etc.

Inventory

At this time, our best estimate of the entire inventory of components that will be required for OMNISita is as follows:

- 240" length x 100" wide x ½" depth steel floor plate (in two sections, connected as shown in Figure 7 of Appendix I)
- 233½” length x 32” wide x ¼” depth steel plate (in fourteen sections, each weighing 36kg, with holes for rope-straps to facilitate carrying by two people) to support top layer of lead
- 233½” length x 32” wide x ¼” depth steel plate (in fourteen sections, each weighing 36kg, with holes for rope-straps to facilitate carrying by two people) to support top layer of acrylic tanks.
- 515 sq. ft (X-5) 30 mil. Synthetic liner
- 1.5’ diameter HDPE Pipe
- Lead: initially 50 T, in the form of 2” x 4” x 8” bricks (each about 26lb)
- 12 - acrylic tubes. Dimensions: 177.2” length, 5.12” wide and 10.25”
- 1 - steel tube with ultra-reflective aluminum interior. Dimensions 3m long x 6” diameter.
- 9 - 55 gallon tight head steel drums
- 55 gallons gadolinium loaded liquid scintillator (BC-525b) for one acrylic tank
- 440 gallons mineral oil liquid scintillator (BC-517p) for 11 acrylic tanks (may replace with gadolinium loaded scintillator fluid BC-525b).
- 30 gallons gadolinium loaded liquid scintillator (BC-525b) for steel tube detector.
- 6 - Plastic scintillators detectors, dimensions 3’x 6”x2”
- Heavy-duty plastic sheeting for wrapping of lead bricks on pallets. Approx 400 sq. m. (4300 sq. ft) required.
- Heavy-duty plastic sheeting for dust enclosing wrapping of lead in place in OMNISita. Approx 40 sq. m (430 sq. ft.) required.
- Acrylic cement. Not more that 0.5 liters. Only for minor, incidental use – we do not expect to undertake any significant acrylic tank construction underground.
- 53 - 5” diameter PMT (48 plus 5 spares)
- 14 - 2” diameter PMT (12 plus spares)
- 1 litre silicone optical couplant gel (Bicron Corp. product BC-630, MSDS attached)
- 53 - 5” PMT bases (48 + spares)
- 14 - 2” PMT bases (12 + spares)
- Connex for housing of data acquisition and data analysis workstation. Dimensions 8' x 8' x 20'
- 50 each -3000V high voltage supplies, or several multiple power supplies
- 16 each +2000V high voltage supplies, or several multiple power supplies
- CAMAC Crate. DSP Technology Inc. Optima 860 or equivalent
- 8 x 8-channel ADC
- 53 - NIM fast amplifiers (48 + spares)
- 53 - NIM spectroscopy amplifiers (48 + spares)
- 15 - NIM quad-CFD modules
- 30 - NIM TAC modules (24 + spares)
- 400 m of high voltage SHV cables (non-pvc based)
- 400 m of BNC (non-pvc based)
- 100 m of lemo cable (non-pvc based)
- 100 lemo-to-BNC connectors
- 25 - NIM bins
- 10 - 6' high Racks
- Power cords, extension cords, etc. as required (NOTE: Extension cords will be GFCI. Extension cords will not be used for permanent use.)
- Oil-free pump - for pumping liquid scintillator
- 14 - near-UV LEDs
- 2 wooden crates for 6 acrylic tanks each. Approx dimensions: 180” length x 26 5/8” high x 23 1/2” wide (to return to surface after contents removed)
- 1 PC operating Windows 98 or equivalent. With monitor, mouse, keyboard, printer
- Table, chair, bookcase
- 2 - Uninterruptible Power Supplies, power rating: 5kW (approx)
- Cathode Ray Oscilloscope
- Digital multi-meter
- Disposable low lint paper wipes
- Ethanol for cleaning experimental surfaces – total volume not more than 1 litre in the underground at any time.
- Standard Toolbox
- Duct tape.
- Tyvek overalls
- Nitrile gloves
- Tape measure
- Filing cabinet for storage of paper copies of all MSDS sheets, electronic module manuals, etc.
- 200’ of Nylon rope (for support plate straps and other incidental use).

**Major Equipment Items**

The team will require access to these items, but they will be used at the convenience of WIPP Mine Operations

- Forklifts (5 Ton) - required on surface and below ground
- Large trailer for office space (above ground)
5. Hazards

Lead (in the form of 2" X 4" X 8" bricks)

Prior to transportation of the lead bricks to the WIPP, they will be lightly washed to remove salt deposits, carbonate, and oxide layers on the surfaces, and will be placed onto wooden pallets in quantities of approximately 55 bricks per pallet. Any wastes generated by these processes will be characterized and managed in accordance with all applicable state and federal regulations. Before entering the WIPP, each pallet will be covered with a plastic wrap to contain any lead dust that might be generated during installation in the WIPP underground. Upon arrival in the WIPP experimental area the dust covers will be removed, and the lead bricks HEPA vacuumed to remove lead dust. Personnel wearing Nitrile coated work gloves, Tyvek overalls, and steel-toed boots or metal shoe covers for protection against dropping will then install the bricks in the experiment. The initial area and personnel monitoring for airborne lead concentrations will be conducted in accordance with the attached sampling plan (Appendix IV) to establish the administrative controls necessary to control respirable exposure to the lead. The OMNIS structure will be completely enclosed with heavy-duty plastic sheeting.

One of the objectives of the OMNISita project is to experiment with various test and shielding configurations. During these configuration changes the lead bricks and the steel plates will carefully be removed and the structure vacuumed to remove any dust deposits.

A WIPP approved job hazard analysis has been completed to identify the proposed lead monitoring, ergonomic evaluation, proper lifting techniques, PPE and mechanical aids that will be used. All lead contaminated personal protective equipment and other wastes such as plastic tarps and pallets will be characterized and managed in accordance with state and federal regulations and WIPP site generated waste procedures.

Liquid Scintillation Fluid

The use of a combustible liquid scintillator in the proximity of the high voltages associated with the PMTs is addressed in the OMNISita Job Hazard Analysis. If a spill were to occur, the incident will be evaluated and managed in accordance with the WIPP Hazardous Material Spill and Release Response procedure WP02 ER-4902, and be managed in accordance with the WIPP Spill Response and Reporting Procedure, WP02-EC.3506.

The acrylic scintillation tanks provide the primary containment of scintillation solutions. A secondary containment structure will be provided to minimize the potential for any releases to the environment. The floor of the experimental alcove area where the OMNISita project will be conducted will be lined with approximately 515 square feet of 30 mil, thick X-5 synthetic liner to provide secondary containment. The secondary containment structure will hold approximately 1500 gallons, about double the volume required to contain all liquids utilized during the project. The storage and transfer of all scintillation fluids into tanks will occur within the containment structure.
During filling of the detectors, a common electrical ground for the pump, the piping through which the liquid is poured, and the acrylic tanks into which the liquid is being delivered, will be maintained at all times to eliminate the possibility of developing static charge. Grounding cables will be attached at points near to the location of flow. No smoking signs will be posted, and smoking will not be allowed within 25 feet of the experimental area. Class A,B,C fire extinguishers will be located at the location where filling is to occur. The fire extinguishers will be located in the alcove throughout the duration of the experiment and a documented inspection program will be completed in accordance with NFPA requirements. WIPP will include these extinguishers in the annual fire extinguisher inspection program for the underground.

6. Training

All experimental personnel will receive the required WIPP training to support their activities and abide by all applicable WIPP Operating procedures.

General:

- Complete General Employee Training 200B (16 hour self paced course)
- Complete Hazardous Environment Training (8 hour course)
- Complete SAF-501 Inexperienced Underground Miner (40 hour course)
- Review all applicable MSDSs (Appendix III) prior to use.

Field Functions:

- SAF-641 Fall Prevention (1 hour course on use of ladders and/or scaffolding)
- RIG-001 Incidental Rigger (16 hour course on safe operation of lift systems and loads)
- Electric Cart Operations (1 hour course on operation of an electric golf cart)
- ELC-103 Electrical Safety (4 hour course on installation/operation of electrical equipment)
- CPR for access around or near electrical circuits.
- HWW-101 Hazardous Waste Worker (24 hour course required for project lead or selected SAA custodian)
- SAR 101 Hazardous Materials Area Representative
7. Applicable Procedures/Required Reading (other procedures may apply)

- 30 CFR 56/57/58  Federal Metal and Nonmetallic Mine Safety and Health Regulations
- NFPA 122  Standard for Fire Prevention and Control in Underground Metal and Nonmetal Mines
- WP 04-AD3011  Equipment Tagout/Lockout
- WP 09-CN3021  Component Indices
- WP 10-WC3208  Work Change Notice
- WP 12 IS.01  Industrial Safety Program
- WP 12-IH.02  Industrial Hygiene Program
- WP 12-FP.01  Fire Protection Program
- WP 14-TR.01  WIPP Training Program
- WP 15-PS.2  Technical Procedure Writer's Guide
- WP 12-ER4902  Hazardous Material Spill and Release Response
- WP 02-RC.01  Hazardous and Universal Waste Management
- WP 02-RC3108  Request for Disposal
- WP 02-EC.04  Management of Hazardous Materials
- WP 02-EC.3506  Environmental Incident Reporting

8. OMNISita Project Specific Goals

Tests of the Event Detection and Event-Type Discrimination Strategies

Many of the individual experiments performed during the OMNISita Project will directly address detector efficiency issues, in order to identify the best and most efficient strategy for the detection of neutrons. Parameters such as lead wall thickness, neutron energy, PMT gain, and electronics settings will be investigated. Members of the Ohio State University experimental team have already investigated parameters, such as lead wall thickness, which lend themselves to computer simulation (Zach et al. 2001), so as to formulate an optimum design configuration. The OMNISita studies will allow the experimental team to improve on these efforts and to judge the accuracy of the computer simulations themselves. Any time that the OMNISita detector is reconfigured, the appropriate industrial hygiene and safety procedures and controls will be utilized. Wastes generated during the reconfiguration of the OMNISita detector will be characterized and disposed of in accordance with applicable regulations and WIPP procedures.

Scintillator Fluid Performance

The computer based Monte Carlo simulations include the best data available regarding the signal strength that will be obtained from the neutrons and gamma rays detected in OMNISita. However, the combinations of these acrylic tanks and the liquid scintillators to be used (both the Los Alamos...
BC-517p mineral oil, and the BC-525b gadolinium loaded liquid) have not been used together. It is therefore necessary to perform actual measurements using both scintillation solutions.

**Electronics Development and Prototyping**

A major cost associated with neutrino detection experiments is the electronics and associated data acquisition equipment. One of the objectives for OMNISita will be to evaluate equipment and experiment configurations for performance and cost effectiveness. Initially, the OMNISita experiment will use standard CAMAC data acquisition, and standard NIM-type electronics modules. This equipment configuration will change over the course of the experiment as development and prototype testing of dedicated electronics and data acquisition equipment progresses.

**Background Radiation Sensitivity**

It is critical to determine if super nova neutrinos can be detected over the backgrounds anticipated. Thus, detailed computer based Monte-Carlo simulations (Zach *et al.* 2001) have been performed to predict the sensitivity of neutron detection under the expected background radiation levels of WIPP and expected levels of radioactive impurities in the iron and lead. These simulations suggest that an acceptable signal-to-noise ratio using a fairly simple event detection and identification strategy can be achieved. However, experimental tests of the actual backgrounds, and rejection of background-initiated events, are vital to plans for similar experiments in the future. In addition, the tests will be used to evaluate the accuracy of the Monte Carlo code, which in turn will impact its use in determining the optimum configuration for future detector projects.

**Cosmic Ray Sensitivity**

One of the objectives of future neutrino detection experiments will be to extract events caused by high-energy cosmic rays from the events originating from gamma ray and neutron emission within the salt walls and the components of the experiment itself. A major part of this capability will be achieved through use of plastic scintillator detectors placed above the lead and steel components of these experiments. To test and explore this concept, project personnel will place several plastic scintillator detectors on the top most layer of lead shielding. Additional testing may include running the OMNISita experiment in time coincidence with cosmic ray detectors, again with plastic scintillators on the surface of the detectors. This test would not be expected to occur within the first 18 months of the OMNISita project.

**WIPP Environment: Air Quality, Radio Frequency, and Vibration**

Other potential problem that the team will study is how the WIPP environment could impact the equipment used to perform the experiment. These potential impacts include the effects of underground air quality, radio frequencies, electromagnetic interference, and vibrations generated by movement of heavy equipment. While no serious effects are anticipated, mu-metal shields will be placed around the PMTs to help reduce any electromagnetic effects.
9. Construction Requirements

Initial construction of the OMNISita Project is expected to take 6-8 weeks. Construction activities and the movement of experimental materials will be coordinated with the Westinghouse TRU Solutions, CH Waste Operations and Mine Operations Departments to ensure that equipment and personnel are available to complete or support required tasks. In many instances materials will be moved during the back shifts to avoid potential conflicts with TRU waste operations. The WIPP Technical Support Engineer will schedule all activities on the Plan Of The Day Schedule. Use of the WIPP hoisting system and Mining Operations personnel for experiment equipment and component hoisting and transport to the CSA will be coordinated around WIPPs primary mission activities.

WTS Environmental, Safety and Health Department will provide support for industrial safety and hygiene and waste management services to ensure compliance with the applicable state and federal statutes and regulations. WTS Emergency Management Section will provide response in the unlikely event of a spill or release of hazardous materials or substances.

All chemicals and materials to be used in the OMNISita project will be reviewed and approved by the WTS Environment Safety and Health Department, and will be managed in accordance with the Industrial Hygiene Program (WP 12-IH.02) and Management of Hazardous Materials Plan (WP 02-EC.04).

All materials received by the WIPP warehouse shall be opened and inspected to the shipping/packing list included with the shipment. All experimenters are responsible to notify the WIPP Technical Support Engineer and the WIPP warehouse of any expected shipments.

10. Completion and Removal

Once the OMNISita experiments have been completed, the project will be decommissioned. Some or all of the equipment may be retained in place to be used as a high sensitivity/low background counting facility to screen materials for acceptable natural radiation levels prior to their use in future experiments. All equipment, materials, and wastes will be removed from the site prior to decommissioning of the WIPP as defined in Attachment I of the Closure Plan, WIPP Hazardous Waste Facility Permit.
Appendix I

OMNISita Diagrams:
Figures 3 through 7
OMNISita design: Plan view of base

240" length, ¾" thick steel floor plate (in two parts)

4.5m (171.6") acrylic liquid scintillator tank

5.12" width acrylic tanks

Not Shown: Top lead layer and ¾" steel support sheets

Alex Murphy. April 16 2001

Scale 1:33.3
Fig 4: OMNISita viewed from the side.

OMNISita design: Side view of OMNISita

Not Shown: Front side lead layer

Alex Murphy. Mar 27 2001

Scale 1:33.3
Figure 5: OMNISita viewed from one end

OMNISita design: End view of OMNISita

Features of this design:

- Dimensions of Acrylic vessels: 177.16" x 10.25" x 5.12"
- Number of acrylic vessels: 12
- Total number of lead bricks: 4448
- Total mass of lead bricks required: 58.2 T
- Extra space on floor plate: ~24" x 240"

Not shown: Front end layer of lead

Alex Murphy, Mar 27 2001

Scale 1:33.3
OMNISita steel base plate

Required: Two \( \frac{3}{4}'' \) thick x 100" x 120" plates. We need to be able to attach these together using two smaller plates. These are to be 4.5" x 16½" and have holes for sixteen \( \frac{3}{4}'' \) steel bolts. The large base plates need to have threaded holes for these connecting plates to screw into. Bolts should not overly extend out of holes.

240" length, \( \frac{3}{4}'' \) thick steel floor plate (in two parts)

16½" x 4.5" x \( \frac{3}{4}'' \) steel strip with sixteen \( \frac{3}{4}'' \) diameter holes (not threaded) for bolts

Two 120" x 100" x \( \frac{1}{4}'' \) base plates, with holes (threaded) for \( \frac{3}{4}'' \) bolts

Bottom surface needs to be flush, so \( \frac{3}{4}'' \) diameter bolts must be only 1" long.

Alex Murphy, Ohio State University. Mar 27 2001
614-292-4775

Scale 1:33.3

Scale 1:5
**Figure 7: Design of the steel support plates.**

**OMNISita steel support plates**

Required: Plates ¼" thick to provide support over an area of 64" x 232" for upper layer of acrylic tanks, and for uppermost layers of lead. We need to be able to manually move these plates (relatively frequent access to PMTs is likely to be required, and getting lifting machinery in each time would be a pain!)

We therefore propose subdividing each of these plates into 14 pieces, each with holes drilled and ropes attached to allow lifting by two or more people). Each plate would then weigh 36kg.

Alex Murphy. Ohio State University. Mar 27 2001
614-292-4775

Scale approx 1:33.3
Appendix II

Job Hazard Analysis
OMNISita Job Hazard Analysis

Contents:
1. Introduction
2. Location
3. Configuration
4. Hazards
5. Planned Response to an Occurrence
6. Charts of Formal Analysis for Work Performed at WIPP

1. Introduction

The OMNISita project involves the use of several potentially hazardous materials, as well as several potentially hazardous activities associated with its construction and operation. This document is aimed at identifying those areas that require extra attention, and providing a detailed plan of the measures that will be used to minimize the hazards involved. Furthermore, countermeasures will be described that will be used in the unlikely event of an accident or spill of a potentially hazardous material. This document should be read in conjunction with the OMNISita Project Description. This JHA also describes the specific ground control inspections required of the experimental team during normal operations of the OMNISita experiment.

2. Location

This project will be located in the WIPP underground in the W170 drift at approximately S400 in the Core Storage Alcove (CSA). An area located in the rear of the alcove about 50 feet by 24 feet has been enclosed within a chain link fence to support the experiment. A proposed floor plan of the area is shown below:
3. Configuration of OMNISita

OMNISita will consist of twelve acrylic tanks filled with a mineral oil liquid scintillator enclosed within a lead brick structure, as shown in the accompanying diagrams. Attached to each end of each tank will be two standard 5” diameter photomultiplier tubes (PMT), which are in turn connected to a high voltage supply (<2000V) and a PC+CAMAC oriented electronic readout. The PMTs are housed in mu-metal magnetic shields. The acrylic tanks themselves will be completely enclosed within a copper or aluminum sheet providing a light tight environment for the mineral oil. The lead will initially total about 30 tons, and will be built as shown in Figure 2, forming a self-supporting, stable structure of approximate dimension of 20’ long, 6’ wide and 3’ high. We are hoping to obtain more lead so as to increase the surrounding depth. OMNISita will be built on a steel plate as shown.
4. Hazards

(a) Lead Bricks and Lead Particulate

The lead to be used as shielding comes in the form of brick that are 2" X 4" X 8" in size and weight 26lb each. The lead bricks have several hazards associated with them.

i) Their intrinsic weight means that during the construction of OMNISita several precautions must be followed.

a. Steel toe capped shoes will be worn at all times.

b. NIOSH lifting procedures will be followed. This means that appropriate lifting techniques will be used at all times. The Occupational Health and Safety department at Ohio State University will train the designated Safety Officer, Dr
Alex Murphy, in the correct lifting techniques, such that he will be able to train any others involved in the construction phase. The revised NIOSH lifting equation (DHHS, NIOSH Publication 94-110 1994) applied to the OMNISita situation results in a lifting index of about 1.1, which while indicating no major worries, does recommend that only physically fit people should be involved. Mechanical aids will be made use of wherever possible; specifically, a cart will be used to carry the bricks over any significant distances, such as from where a forklift deposits the bricks to where they are needed.

c. Prior to transportation, the lead bricks will be placed onto wooden pallets in quantities of approximately 55 bricks per pallet. A plywood sheet will be placed over the top of the bricks, and that banded to the pallet. Additionally, shrink-wrap material will secure the bricks to the pallet. This is expected to provide ample protection against bricks falling off unexpectedly.

ii) Lead dust is recognized as a toxic metal with a federal 8-hour human exposure limit of 50µg/m³, and a WIPP action level of 30 µg/m³. The white deposits that have been observed on the bricks are likely to be lead carbonate and there is a reasonable expectation that this could become airborne. Therefore several measures will be taken to ensure that no undue exposure is created.

a. Before entering the WIPP, each brick will be surface washed with an alcohol-dampened cloth to remove surface carbonate and oxide layers. The used cloths will be regarded as hazardous waste and disposed of appropriately.

b. Each pallet will be covered with a plastic wrap to contain any lead dust that might be generated during transportation into the WIPP underground.

c. Upon arrival in the core storage alcove, the pallets will only be placed on surfaces which protect the salt floor from becoming contaminated with dust, usually by there being a layer of heavy duty plastic beneath. The dust covers and bands will then be removed. Care must be taken and leather and nitrile gloves and safety glasses must be worn when removing the bands to protect against potential cutting and falling hazards.

The first time bricks are un-stacked from their storage in the Core Storage Alcove, a test of the possible airborne dust will be made. This will involve the Carlsbad Environmental Monitoring and Research Center (CEMRC) and Westinghouse groups as described in Appendix III Industrial Hygiene Exposure Monitoring Plan. Subsequent bricks will then be installed in the experiment using administrative controls established by the exposure sampling. Personnel will wear leather and nitrile work gloves, and disposable Tyvec coveralls, and approved respirators if exposure sampling indicates they are necessary. Whenever bricks are moved they will be lifted, not dragged. A dust cover will be installed consisting of heavy-duty plastic sheeting. No eating drinking or smoking will be allowed. After leaving the area simple practices of good hygiene will be required, such as prompt changing and cleaning of clothes and washing of hands. Upon any changes to the lead structure (as anticipated, as tests of various configurations is one of the objectives of the OMNISita project) the plastic will carefully be removed and the structure vacuumed to remove any dust deposits. If
the lead dust measurements indicated that there is a potential for exposure, administrative controls will be introduced to ensure that nobody could be exposed to a lead dust level above the WIPP action level.

(b) Scintillation Fluids
The use of combustible liquid scintillator, in the proximity of the high voltages associated with the PMTs, requires several safety protocols to be adhered to.

(i) During filling of the detectors, the flow of the liquid could feasibly result in a build up of static electricity. To eliminate the possibility of this leading to a spark, additional common electrical grounding of the pump, the piping through which the liquid is poured, and the acrylic tanks into which the liquid is being delivered, will be maintained at all times. Since many of these parts are insulators, the grounding cables will be attached at points near to the location of flow. Class A,B,C fire extinguishers will be located at the location where filling is to occur. The flash point of the BC517p liquid scintillator is approximately 240 degrees F, and that of the BC525b is ~ 124 degrees F, so these are classified as combustibles and do not represent a serious safety hazard.

(ii) However, it still must be ascertained that the scintillator tanks do not leak, and that no spillage of the liquid scintillator can occur. Double containment will be provided to prevent spillage of the liquid scintillation fluid in the unlikely even of a spill or equipment leak. This will consist of approximately 515 square feet of 30 mil, thick X-5 synthetic liner covering the area around the scintillation tanks and drum storage area in the Core Storage Alcove behind the chain link.

(iii) In the event of a spill or leak, the liquid would be controlled with spill materials within the secondary containment and as possible, be pumped back into the 55-gallon drums. The remaining solutions will be collected on absorbent pads. Any liquid that does spill will be assumed to be contaminated and will be managed in accordance with applicable WIPP waste disposal procedures.

The mineral oil liquid scintillator (BC-517p from the LSND veto detector, (MSDS provided in Appendix III) is not the scintillator solution that the experimental team proposes to use in the later OMNIS array. However, this scintillator is currently available and will allow us to study issues such as background and signal height during the OMNISita tests. At least one tube, and probably more as time and funds permit, will be the gadolinium loaded BC-525b solution, and will be used to provide tests of the neutron detection abilities, and to provide a test of the liquids degradation with time. (MSDS provided in Appendix III).

(e) Wooden Pallets
The wooden pallets clearly add to the overall level of combustibles in the WIPP underground, and so should be minimized.
(i) Pallets will be taken to the core storage library via forklift, and placed in the core storage alcove on tarp to avoid possible contamination of the underlying salt with lead dust.

(ii) Once placed, a minimum number of pallets will be stored in the underground (available in case the lead needs to be moved). The remaining pallets will be removed from the underground for storage at the surface (at BEC Rentals and sales). The expected number of pallets in the underground is expected to be around 10.

(iii) It would be preferable for HDPE or steel pallets to be used. Wooden pallets will be replaced as finances allow.

(d) Electrical

(i) **110 V supply.** The OMNISita project will involve the use of many electronic modules and photomultiplier tubes, all of which are powered through 110V lines hooked up to Power Substation 4. Ground fault circuit breakers will be used. Extension cords will not be used except as a temporary measure.

(ii) **High Voltage.** The PMTs operate at a voltage around 2000V. Fusing and ground fault protection will be used.

(iii) **Static discharge.** See the hazards listed under Liquid Scintillator.

(e) Steel Plates

The steel plates are heavy and require the use of steel-toed boots, appropriate lifting techniques, and use of mechanical lifting devices wherever mechanical lifting devices are available. There are not expected to be a significant tripping hazard generated by the steel plates, however, tripping hazard tape will be applied to the edge of the steel plate to identify potential hazards.

(f) Acrylic

There are no direct expected hazards associated with the acrylic tanks; however, their impact has been assessed as it relates to response to a potential fire.

(g) Plastic Sheeting (tarp and shrink-wrap)

There are no expected hazards associated with this. MSDS provided in Appendix III.

(h) Secondary Spill Containment Liner

There are no expected hazards associated with the liner material. This material is typically used in Hazardous Waste Disposal Facilities for containment.
(i) **Ground Control**

Trained personnel anticipate no expected ground control problems due to the installation of routine ground control devices and the daily inspection of work areas. 30 CFR 57 requires that persons experienced in examining and testing for loose ground shall be designated by the mine operator. Personnel at WIPP are designated for this task after completing a 40-hour miner-training course. Each person is required to examine, and as applicable test ground conditions in areas where work is to be performed, prior to work commencing. Requirements for ground control are provided in the Annual Ground Control Operating Plan (Appendix V).

5. Plans for response to an accident or an occurrence.

(a) **Response to a leak of the liquid scintillator or Ethanol used to clean equipment**

i) **Minor leak, e.g. a small leak in the plumbing, fittings or tanks.**

All connections will be inspected prior to use and replaced if any leaking is observed. If a spill occurs during the fluid transfer process, work will be stopped, the CMR shall be notified, and the fluid will be contained, absorbed, and managed in accordance with approved spill response and reporting procedures. Waste products will be characterized and properly managed and disposed of using approved WIPP site generated waste management procedures.

ii) **Failure of an acrylic vessel.**

The experiment shall be stopped, the CMR shall be notified, and the fluid shall be cleaned up using approved spill response and reporting procedures. Waste products will characterized and properly disposed in accordance with approved WIPP waste management procedures.

(b) **Response in the event of an underground fire**

Response to fire in the underground will be in accordance with approved WIPP procedures. Personnel discovering a fire should notify CMRO (8111) or use the Mine Pager phone. Personnel should attempt to extinguish the fire using a portable fire extinguisher only if they feel capable and safe in doing so. If unable to extinguish the fire, evacuate to an egress hoist station. Personnel in the smoke should don their self-rescuer immediately. **NOTE:** Self-rescuer’s are for emergency egress only and ARE NOT to be used for fire fighting purposes.
(c) **Response to lead dust exposure**

Assessment of the exposure of the individual, and measures for future work (such as reduced lead handling time or additional PPE) will be made in accordance with the Industrial Hygiene Exposure Monitoring Plan (Appendix IV).

(d) **Response to an injury (e.g. from dropping a brick)**

Have a first aid kit in the OMNISita Conex for immediate action; notify the CMR on the mine pager phone. Request assistance from trained WIPP medical personnel.

(e) **Emergency evacuation routes**

**Primary route:**
Exit the core storage alcove to the left. Proceed north along W170. Turn right at S90. Turn left at W30. Assemble/exit at Salt Handling Shaft.

**Secondary route**
Exit the core storage alcove to the right. Proceed along W170. Turn left at S700 through man-door. Turn left at W30 and proceed to the Assembly area/exit at the Salt Handling Shaft.
## Movement of Bricks to Underground and on to The Core Storage Library

**Type of Work Performed:**

<table>
<thead>
<tr>
<th>STEP</th>
<th>HAZARD</th>
<th>MITIGATING ACTIONS</th>
</tr>
</thead>
</table>
| 1) Truck deliver to staging area | a) Shifting of load, bricks fall, damage equipment, injure personnel  
  b) Failure of pallet, bricks fall, damage equipment, injure personnel  
  c) Airborne lead dust inhalation | a) Load secured  
  b) Pallets inspected prior to being received at site. Defective pallets replaced  
  c) Bricks cleaned and wrapped in plastic prior to receipt. Air monitoring for lead. |
| 2) Forklift stages bricks on surface | a) Pallet failure, bricks fall, damage equipment, injure personnel  
  b) Misaligned forks, bricks fall, damage equipment, injure personnel  
  c) Misaligned forks, plastic rips, airborne lead dust inhalation  
  d) Plastic comes loose, lead dust inhalation | a) Qualified forklift operator. Pallets inspected. Faulty pallets replaced.  
  b) Qualified forklift operator and spotter, bricks secured with plastic and straps.  
  c) Qualified forklift operator and spotter.  
  d) Plastic secured on site. Inspect before handling. Repair with duct tape if necessary. Air monitoring for lead. |
| 3) Forklift load bricks on cage | a) Pallet failure, bricks fall, damage equipment, injure personnel  
  b) Misaligned forks, bricks fall, damage equipment, injure personnel  
  c) Misaligned forks, plastic rips, airborne lead dust inhalation  
  d) Plastic comes loose, lead dust inhalation | a) Qualified forklift operator. Pallets inspected. Faulty pallets replaced.  
  b) Qualified forklift operator and spotter, bricks secured with plastic and straps.  
  c) Qualified forklift operator and spotter.  
  d) Inspect. Repair with duct tape if necessary. Air monitoring for lead. |
| 4) Forklift remove bricks from cage | a) Pallet failure, bricks fall, damage equipment, injure personnel  
  b) Misaligned forks, bricks fall, damage equipment, injure personnel  
  c) Misaligned forks, plastic rips, airborne lead dust inhalation  
  d) Plastic comes loose, lead dust inhalation | a) Qualified forklift operator. Pallets inspected. Faulty pallets replaced.  
  b) Qualified forklift operator and spotter, bricks secured with plastic and straps.  
  c) Qualified forklift operator and spotter.  
  d) Inspect. Repair with duct tape if necessary. Air monitoring for lead. |
| 5) Forklift unload bricks at Core Storage | a) Pallet failure, bricks fall, damage equipment, injure personnel  
  b) Misaligned forks, bricks fall, damage equipment, injure personnel  
  c) Misaligned forks, plastic rips, airborne lead dust inhalation  
  d) Plastic comes loose, lead dust inhalation  
  b) Qualified forklift operator and spotter, bricks secured with plastic and straps.  
  c) Qualified forklift operator and spotter.  
  d) Inspect. Repair with duct tape if necessary. Air monitoring for lead.  
  e) Qualified operators. |

- **Equipment:** (list any tools that may represent a hazard and all chemicals)
- **PPE:** (list all PPE required)
- **Can pushing, pulling, lifting, bending or twisting cause strain?**
• Is there a danger of striking against, being struck by, or otherwise making a harmful contact with an object?
• Is fall protection equipment required?
• Have MSDS been reviewed for chemicals used?
• Are there any environmental issues: heat, cold, lighting?

• Comments:
OMNISita
JOB HAZARD ASSESSMENT WORKSHEET

Assembly of Detector
(Type of Work Performed)

Author: __________ Date: ____ WIPP Safety Engineer Concurrence _______ Date:

<table>
<thead>
<tr>
<th>STEP</th>
<th>HAZARD</th>
<th>MITIGATING ACTIONS</th>
</tr>
</thead>
</table>
| 1) Placement of Steel Plates onto conveyor belt material that is placed on top of the liner to prevent liner damage | a) Lifting  
b) Drop or pinch point  
c) Sharp edges | a) Training in proper lifting. Using mechanic means where possible. Apply NIOSH lifting equation.  
b) Steel toed shoes required. Use mechanical lifting where possible.  
c) Examine sheet before manual lifting. Remove sharp edges with grinder. Use leather gloves to move. |
| 2) Placement of Lead Bricks | a) Lifting  
b) Lead dust - inhalation  
c) Lead dust - ingestion  
d) Tripping on liner  
b) DO NOT SLIDE BRICKS. Bricks will be cleaned before arrival at site. Remove plastic cover slowly. Perform initial air monitoring under limited lifting scenario. HEPA vacuum loose dust. Establish administrative controls based on monitoring results.  
c) Use impervious gloves and coveralls while moving brick. Remove PPE using contamination methods. Wash hands immediately after removing PPE.  
d) Training. Use caution bi-folds.  
e) Steel toed shoes required. |
| 3) Assembly of tubes | a) Lifting | a) Training in proper lifting. |
| 4) Filling of tubes | a) Skin contact with fluid  
b) Ingestion of fluid  
c) Eye contact with fluid  
d) Fire hazard | a) Use of impervious gloves. Tubes will be inspected prior to use.  
b) Hands and body parts will be washed upon contact with fluid and at the end of the job.  
c) Chemical goggles or a face shield will be used during transfer of the liquid.  
d) Containers will be grounded during liquid transfer. No smoking signs will be posted at experimental area. |
| 5) Assembling detector | a) Electrical | a) Only qualified electricians will perform work following site procedures. GFCIs are required. Extension cords may not be used on a permanent basis. |

- Equipment: (list any tools that may represent a hazard and all chemicals)
- PPE: (list all PPE required)
- Can pushing, pulling, lifting, bending or twisting cause strain?
- is there a danger of striking against, being struck by, or otherwise making a harmful contact with an object?
• Is fall protection equipment required?
• Have MSDS been reviewed for chemicals used?
• Are there any environmental issues: heat, cold, lighting?
• Comments:
Appendix III

Material Safety Data Sheets for Components in OMNISita
MSDS PRODUCT: BC-400 Organic Plastic Scintillator

Page 1 Date: September 24, 1997

BICRON MATERIAL SAFETY DATA SHEET
PRODUCT: BC-400 EMERGENCY PHONE NO. (440) 564-2251
SECTION I SUPPLIER INFORMATION
COMMON NAME : BC-400
CHEMICAL NAME : POLYVINYL TOLUENE & ORGANIC FLUORS
FORMULA : C10H11
PRODUCT CAS #: 9017-21-4
SUPPLIER : BICRON
ADDRESS : 12345 KINSMAN ROAD
CITY/STATE/ZIP : NEWBURY, OH 44065
PHONE : (440)564-2251
TELEFAX : (440)564-8047
SECTION II HAZARDOUS INGREDIENT INFORMATION
INGREDIENT %WT. PEL-OSHA TLV-ACGIH
POLYVINYL TOLUENE >97.0 N/A
ORGANIC FLUORS <3.0 N/A
INGREDIENT HAZARD STATEMENT
NOTE:
N/A
SECTION III PHYSICAL/ChemICAL CHARACTERISTICS
BOILING POINT : N/A
SPECIFIC GRAVITY (H2O=1) : 1.03
MELTING POINT : N/A
VAPOR PRESSURE (mm Hg) : N/A
VAPOR DENSITY (air=1) : N/A
EVAPORATION RATE (BUTYL ACETATE=1): N/A
% SOLUBILITY/WATER: NIL
APPEARANCE AND ODOR:
Clear Fluorescent solid plastic. No odor
SECTION IV FIRE AND EXPLOSION HAZARD DATA
FLASH POINT: None
AUTO-IGNITION: N/A
LEL: N/A
UEL: N/A
NFPA HAZARD CLASSIFICATION
HEALTH: N/A FLAMMABLE: N/A REACTIVITY: N/A
HMIS HAZARD CLASSIFICATION
HEALTH: N/A FLAMMABLE: N/A REACTIVITY: N/A
EXTINGUISHING MEDIA:
Waterfog, foam, alcohol foam, Co 2 , dry chemical
SPECIAL FIRE FIGHTING PROCEDURES:
Use self-contained breathing apparatus for protection against degradation products
UNUSUAL FIRE AND EXPLOSION HAZARDS:
None
SECTION V REACTIVITY DATA
STABILITY: Stable
AVOID temperatures over 300 o C
INCOMPATIBILITY: N/A
HAZARDOUS DECOMPOSITION OR BY-PRODUCTS: Smoke noxious gases
(carbon monoxide and hydrocarbons)
POLYMERIZATION: Will not occur
AVOID: N/A
SECTION VI HEALTH HAZARD DATA

ROUTES OF ENTRY
EYES: NO SKIN: NO INHALATION: NO INGESTION: NO

EFFECTS OF OVEREXPOSURE
EYE: N/A
SKIN: N/A
INHALATION: N/A
INGESTION: N/A

NOTE:
Considered physiologically inert

CARCINOGENICITY:
NTP: N/A IARC: N/A OSHA: N/A

CHRONIC HEALTH HAZARD:
N/A

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:
N/A

EMERGENCY FIRST AID
EYE AND SKIN CONTACT: N/A
INHALATION: N/A
INGESTION: N/A
SECTION VII PRECAUTIONS FOR SAFE HANDLING AND USE
EPA: WASTE #: N/A
UN #: N/A
DOT CLASSIFICATION: N/A
STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:
N/A
WASTE DISPOSAL METHOD:
Follow local, state, federal regulations
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:
N/A
SECTION VIII CONTROL MEASURES
RESPIRATORY PROTECTION:
When machining or polishing, wear an approved dust respirator.
VENTILATION:
Good, general ventilation
PROTECTIVE EQUIPMENT:
Wear gloves for general hand protection and safety glasses.
WORK/HYGIENE PRACTICES:
N/A
SECTION IX FEDERAL AND STATE REGULATIONS
SARA HAZARD CATEGORIES
IMMEDIATE (ACUTE) HEALTH HAZARD: YES [ ] NO [ X ]
DELAYED (CHRONIC) HEALTH HAZARD: YES [ ] NO [ X ]
FIRE HAZARD: YES [ ] NO [ X ]
REACTIVITY HAZARD: YES [ ] NO [ X ]
SUDDEN RELEASE OF PRESSURE: YES [ ] NO [ X ]
SARA SECTION 313 NOTIFICATION:
CHEMICAL NAME: CAS # %WT.
NOT APPLICABLE
INFORMATION PRESENTED HEREIN HAS BEEN COMPILED FROM SOURCES CONSIDERED TO BE DEPENDABLE, AND IS ACCURATE AND RELIABLE TO THE BEST OF OUR KNOWLEDGE AND BELIEF, BUT IS NOT GUARANTEED TO BE SO. SINCE CONDITIONS OF USE ARE BEYOND OUR CONTROL, WE MAKE NO WARRANTIES, EXPRESSED OR IMPLIED, EXCEPT THOSE THAT MAY BE CONTAINED IN OUR WRITTEN CONTRACT OF SALE OR ACKNOWLEDGMENT.
PRODUCT: BC-525B

SECTION I: SUPPLIER INFORMATION

COMMON NAME: BC-525B
CHEMICAL NAME: Aromatic hydrocarbons
FORMULA: Proprietary
PRODUCT CAS#: 95-63-6, 8042-47-5
SUPPLIER: BICRON CORPORATION
ADDRESS: 12345 KINSMAN ROAD
CITY, STATE, ZIP: NEWBURY, OHIO, 44065
PHONE: (216)248-7400
TELEFAX: (216)564-8047

SECTION II: HAZARDOUS INGREDIENT INFORMATION

<table>
<thead>
<tr>
<th>INGREDIENT</th>
<th>% WT.</th>
<th>PEL-OSHA</th>
<th>TLV-ACGIH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>24-34</td>
<td>Not determined</td>
<td>25 ppm</td>
</tr>
<tr>
<td>Proprietary</td>
<td>&lt;5.0</td>
<td>TWA 200 ppm</td>
<td>TWA 5 ppm (skin)</td>
</tr>
</tbody>
</table>

INGREDIENT HAZARD STATEMENT: N/A

SECTION III: PHYSICAL CHEMICAL PROPERTIES

BOILING POINT: Not Determined
SPECIFIC GRAVITY (H₂O = 1): Not Determined
MELTING POINT: N/A
VAPOR PRESSURE (mm Hg): Not Determined
VAPOR DENSITY (air = 1): Not Determined
MATERIAL SAFETY DATA SHEET
PRODUCT: BC-525B
Page 2
Dates: 6-17-97

EVAPORATION RATE (BUTYL ACETATE = 1): Not Determined
% SOLUBILITY in WATER: Very low
APPEARANCE AND ODOR: Colorless, fluorescent liquid with slight aromatic odor.

SECTION IV: FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 51°C (124°F) METHOD: Closed cup
AUTO-IGNITION: Not determined LEL: N/A UEL: N/A

NFPA HAZARD CLASSIFICATION Not determined
HEALTH: N/A FLAMMABLE: N/A REACTIVITY: N/A

HMIS HAZARD CLASSIFICATION Not determined
HEALTH: N/A FLAMMABLE: N/A REACTIVITY: N/A

EXTINGUISHING MEDIA: Water fog, CO₂, dry chemical or foam.

SPECIAL FIRE FIGHTING PROCEDURES: Water spray recommended to cool fire-exposed surfaces; to help prevent ignition by dispersing vapors; and to protect personnel attempting shut-off. Avoid using direct water stream; it may spread the fire over a larger area. Wear self-contained breathing apparatus when fire-fighting in confined spaces.

UNUSUAL FIRE AND EXPLOSION HAZARDS: CAUTION! COMBUSTIBLE. High heat, sparks, open flame, or strong oxidizers may ignite this material.

SECTION V: REACTIVITY DATA

STABILITY: Stable
AVOID: High heat, sparks, and open flame.

INCOMPATIBILITY: Strong oxidizers such as fluorine, chlorine, nitric and sulfuric acid.

HAZARDOUS DECOMPOSITION OR BY-PRODUCTS: Combustion/burning can form carbon monoxide.

POLYMERIZATION: Will not occur.
AVOID: None
ROUTES OF ENTRY
EYES: Yes SKIN: Yes INHALATION: Yes INGESTION: Yes

EFFECTS OF OVEREXPOSURE
EYES: A possible eye irritant.
SKIN: Not a skin irritant. Prolonged or repeated exposure may cause dermatitis.
INHALATION: High vapor concentration can cause central nervous system depression.
INGESTION: Ingestion may cause gastrointestinal irritation, diarrhea, and nausea.

CARCINOGENICITY  Not listed
NTP: N/A  IARC: N/A  OSHA: N/A

CHRONIC HEALTH HAZARD: Symptoms of nervousness, tension, anxiety, asthmatic bronchitis, hypochromic anemia, and blood clotting disorders.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: In high concentrations, disorders of the skin, eyes, blood, respiratory system, and nervous system may be aggravated.

EMERGENCY FIRST AID
EYE CONTACT: Flush liberally with low pressure water, lifting the lower and upper eyelids occasionally. If irritation persists, get medical attention.
SKIN CONTACT: Remove contaminated clothing. Wash skin with soap and water. Properly decontaminate clothing before wearing again.
INHALATION: Move person to fresh air. If breathing has stopped, immediately start artificial respiration. Get medical attention as soon as possible.

INGESTION: ASPIRATION HAZARD! DO NOT INDUCE VOMITING! Should vomiting occur, material may enter the lungs and result in chemical pneumonia. Immediately obtain the services of a physician.
SECTION VII: PRECAUTIONS FOR SAFE HANDLING AND USE

EPA WASTE #: Not listed
UN#: 1993
DOT CLASSIFICATION: Combustible liquid, N.O.S.

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:
Eliminate all ignition sources. Stop spill at source, dike area of spill to prevent spreading. Pump liquid to holding tank. Remaining liquid may be taken up with floor absorbent, vermiculite, or other absorbent material and shoveled into containers. Save for proper disposal.

WASTE DISPOSAL METHOD: Follow all federal, state and local regulations.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Containers of this material may be hazardous when empty since all emptied containers retain product residues.

SECTION VIII: CONTROL MEASURES

RESPIRATORY PROTECTION: Wear a NIOSH/MSHA approved respirator.

VENTILATION: Provide sufficient mechanical exhaust to maintain exposure below TLV levels.

PROTECTIVE EQUIPMENT: Wear chemical resistant gloves and chemical splash goggles.

WORK/HYGIENE PRACTICES: To prevent repeated or prolonged skin contact, wear impervious clothing and boots.
SECTION IX: FEDERAL AND STATE REGULATIONS

SARA HAZARD CATEGORIES

IMMEDIATE (ACUTE) HEALTH HAZARD: YES _X_ NO

DELAYED (CHRONIC) HEALTH HAZARD: YES _X_ NO

FIRE HAZARD: YES _X_ NO

REACTIVITY DATA: YES __NO__X

SUDDEN RELEASE OF PRESSURE: YES ____NO ____X

SARA SECTION 313 NOTIFICATION

This product may contain a chemical (or chemicals) subject to the reporting requirements of Section 313 Title III of the Superfund Amendments and reauthorization Act of 1986 and 40 CFR part 372.

CHEMICAL NAME: CAS#: %WT.
1,2,4-trimethylbenzene 95-63-6 24-34
Proprietary <5.0

Information presented herein has been compiled from sources considered to be dependable, and is accurate and reliable to the best of our knowledge and belief, but is not guaranteed to be so. Since conditions of use are beyond our control, we make no warranties, expressed or implied, except those that may be contained in our written contract of sale or acknowledgement.
BICRON CORPORATION
MATERIAL SAFETY DATA SHEET

PRODUCT: BC-517P

SECTION I: SUPPLIER INFORMATION

COMMON NAME: BC-517P
CHEMICAL NAME: Aromatic hydrocarbons
FORMULA: Proprietary
PRODUCT CAS#: 95-63-6, 8012-95-1
SUPPLIER: BICRON CORPORATION
ADDRESS: 12345 KINSMAN ROAD
CITY, STATE, ZIP: NEWBURY, OHIO, 44065
PHONE: (216)248-7400
TELEFAX: (216)564-8047

SECTION II: HAZARDOUS INGREDIENT INFORMATION

<table>
<thead>
<tr>
<th>INGREDIENT</th>
<th>% WT.</th>
<th>PEL-OSHA</th>
<th>TLV-ACGIH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>&lt;10.0</td>
<td>not determined</td>
<td>25 ppm</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>&gt;90.0</td>
<td>not determined</td>
<td>not determined</td>
</tr>
<tr>
<td>Aromatic fluors</td>
<td>&lt; 0.2</td>
<td>not determined</td>
<td>not determined</td>
</tr>
</tbody>
</table>

INGREDIENT HAZARD STATEMENT: N/A

SECTION III: PHYSICAL CHEMICAL PROPERTIES

BOILING POINT: > 275°C at 760 mm Hg
SPECIFIC GRAVITY (H$_2$O = 1): 0.86 at 20°C
MELTING POINT: N/A
VAPOR PRESSURE (mm Hg): <1 mm Hg at 20°C
VAPOR DENSITY (air = 1): >1
EVAPORATION RATE (butyl acetate = 1): very slow, > 70
% SOLUBILITY in WATER: nil
APPEARANCE AND ODOR: Clear, blue fluorescent liquid with slight
hydrocarbon odor.

SECTION IV: FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 115°C (240°F) METHOD: Closed cup
AUTO-IGNITION: not determined LEL: N/A UEL: N/A

NFPA HAZARD CLASSIFICATION Not determined
HEALTH: 1 FLAMMABLE: 0 REACTIVITY: 0

HMIS HAZARD CLASSIFICATION
HEALTH: X FLAMMABLE: 0 REACTIVITY: 0

EXTINGUISHING MEDIA: Foam, carbon dioxide or dry chemical.

SPECIAL FIRE FIGHTING PROCEDURES: Wear self-contained breathing
apparatus with a full facepiece operated in pressure-demand or other positive
pressure mode.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Vapors of heated material are
heavier than air and may travel along the ground and be ignited by pilot lights, or
other ignition sources. Never use a welding or cutting torch near or on drum (even
when empty).

SECTION V: REACTIVITY DATA

STABILITY: Stable
AVOID: N/A.

INCOMPATIBILITY: Avoid contact with strong oxidizing agents.

HAZARDOUS DECOMPOSITION OR BY-PRODUCTS: May form toxic
substances such as carbon dioxide, and carbon monoxide.

POLYMERIZATION: Will not occur.
AVOID: N/A
SECTIONS VI: HEALTH HAZARD DATA

ROUTES OF ENTRY
EYES: Yes  SKIN: Yes  INHALATION: Yes  INGESTION: Yes

EFFECT OF OVEREXPOSURE
EYES: Can cause severe irritation, redness, tearing and blurred vision.
SKIN: Prolonged or repeated contact can cause moderate irritation.
INHALATION: Excessive inhalation of vapors can cause nasal and respiratory irritation, dizziness, weakness, fatigue, nausea, headache, possible unconsciousness and even asphyxiation.
INGESTION: Can cause gastrointestinal irritation, nausea, vomiting and diarrhea. Aspiration of material into lungs can cause chemical pneumonitis which can be fatal.

CARCINOGENICITY  Not listed
NTP: N/A  IARC: N/A  OSHA: N/A

CHRONIC HEALTH HAZARD: Not determined.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Not determined.

EMERGENCY FIRST AID
EYE CONTACT: Flush eyes with copious amounts of water for at least 15 minutes. Get medical attention.
SKIN CONTACT: Remove contaminated clothing. Wash skin thoroughly with soap and water.
INHALATION: Remove to fresh air. If breathing has stopped, give artificial respiration. Get medical attention.
INGESTION: DO NOT INDUCE VOMITING! Keep person warm and quiet and get medical attention.
SECTION VII: PRECAUTIONS FOR SAFE HANDLING AND USE

EPA WASTE #: Not listed
UN#: 1993
DOT CLASSIFICATION: Combustible liquid, N.O.S.

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:
Eliminate all ignition sources. Stop spill at source, dike area of spill to prevent spreading. Pump liquid to holding tank. Remaining liquid may be taken up with floor absorbent, vermiculite, or other absorbent material and shoveled into containers. Save for proper disposal.

WASTE DISPOSAL METHOD: Follow all federal, state and local regulations.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:
Containers of this material may be hazardous when empty since all emptied containers retain product residues.

SECTION VIII: CONTROL MEASURES

RESPIRATORY PROTECTION: Wear a NIOSH/MSHA approved respirator.

VENTILATION: Provide sufficient mechanical exhaust to maintain exposure below TLV levels.

PROTECTIVE EQUIPMENT: Wear chemical resistant gloves and chemical splash goggles.

WORK/HYGIENE PRACTICES: To prevent repeated or prolonged skin contact, wear impervious clothing and boots.
SECTION IX: FEDERAL AND STATE REGULATIONS

SARA HAZARD CATEGORIES

IMMEDIATE (ACUTE) HEALTH HAZARD: YES ___ NO ___ X

DELAYED (CHRONIC) HEALTH HAZARD: YES ___ NO ___ X

FIRE HAZARD: YES ___ NO ___ X

REACTIVITY DATA: YES ___ NO ___ X

SUDDEN RELEASE OF PRESSURE: YES ___ NO ___ X

SARA SECTION 313 NOTIFICATION

This product may contain a chemical (or chemicals) subject to the reporting requirements of Section 313 Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR part 372.

CHEMICAL NAME: 1,2,4-trimethylbenzene

<table>
<thead>
<tr>
<th>CAS#</th>
<th>%WT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>95-63-6</td>
<td>&lt;10.0</td>
</tr>
</tbody>
</table>

Information presented herein has been compiled from sources considered to be dependable, and is accurate and reliable to the best of our knowledge and belief, but is not guaranteed to be so. Since conditions of use are beyond our control, we make no warranties, expressed or implied, except those that may be contained in our written contract of sale or acknowledgement.
BICRON
MATERIAL SAFETY DATA SHEET

PRODUCT: BC-630
EMERGENCY PHONE NO.
(216) 248-7400

SECTION I: SUPPLIER INFORMATION

COMMON NAME: BC-630
CHEMICAL NAME: SILICONE GREASE (Methyl Phenyl Polysiloxane)
FORMULA: N/A
PRODUCT CAS#: (See below)
SUPPLIER: BICRON
ADDRESS: 12345 KINSMAN ROAD
CITY, STATE, ZIP: NEWBURY, OH, 44065
PHONE: (216)248-7400
TELEFAX: (216)564-8047

SECTION II: HAZARDOUS INGREDIENT INFORMATION

INGREDIENT
Substituted Polysiloxane
Silica, Amorphous treated

% WT. PEL-OSHA
90-95
4-6

TLV-ACGIH
N/A
N/A

INGREDIENT HAZARD STATEMENT

NOTE:

SECTION III: PHYSICAL CHEMICAL PROPERTIES

BOILING POINT: N/A
SPECIFIC GRAVITY (H₂O = 1): 1.04 at 25°C (77°F)
MELTING POINT: N/A
VAPOR PRESSURE (mm Hg): N/A (VERY LOW)
VAPOR DENSITY (air = 1): N/A
MATERIAL SAFETY DATA SHEET

EVAPORATION RATE (ETHER = 1): N/A
% SOLUBILITY/WATER: Insoluble

APPEARANCE AND ODOR: Translucent, waxy solid, with slight odor.

SECTION IV: FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 148°C (299°F)
AUTO-IGNITION: N/A
LEL: N/A
UEL: N/A
NFPA HAZARD CLASSIFICATION

HEALTH: 1 FLAMMABLE: 0 REACTIVITY: 0

HMIS HAZARD CLASSIFICATION

HEALTH: 1 FLAMMABLE: 1 REACTIVITY: 0

EXTINGUISHING MEDIA: WATER FOG, CO₂, DRY CHEMICAL, FOAM

SPECIAL FIRE FIGHTING PROCEDURES: Wear NIOSH/MSHA approved breathing apparatus

UNUSUAL FIRE AND EXPLOSION HAZARDS: Product will burn under fire conditions.

SECTION V: REACTIVITY DATA

STABILITY: Stable under normal handling and storage conditions.

INCOMPATIBILITY: Strong acids, strong bases, strong oxidizing agents.

HAZARDOUS DECOMPOSITION OR BY-PRODUCTS: Carbon Monoxide, carbon dioxide, silicon dioxide.

POLYMERIZATION: Will not occur.

AVOID: Combustible material, heat, open flame, spark
SECTION VI: HEALTH HAZARD DATA

ROUTES OF ENTRY

EYE: ND  SKIN: ND  INHALATION: ND  INGESTION: ND

EFFECTS OF OVEREXPOSURE: This product does not contain any substances that are considered by OSHA, NTP, IARC or ACGIH to be “probable” or “suspected” human carcinogens. Under certain conditions, this product may generate formaldehyde as a by product of oxidative thermal decomposition. Formaldehyde is listed as a potential human carcinogen.

EYES: May cause redness, irritation.
SKIN: Non-irritating.
INHALATION: Not likely.
INGESTION: Low acute oral toxicity

NOTE:

CARCINOGENICITY:

NTP: No  IARC: No  OSHA: No

CHRONIC HEALTH HAZARD: This product does not contain any substances that are considered by OSHA, NTP, IARC, or ACGIH to be “probable” or “suspected” human carcinogens.

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: See “Affects of Overexposure”

EMERGENCY FIRST AID

EYE AND SKIN CONTACT:

INHALATION: Inhalation not likely.

INGESTION: Low acute oral toxicity.
SECTION VII: PRECAUTIONS FOR SAFE HANDLING AND USE

EPA WASTE #: N/A
UN#: Not regulated
DOT CLASSIFICATION: Not regulated.

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:

Absorb with an inert absorbent. Scrape up and place in appropriate closed container (see storage). Clean up residual material with solvent like paint thinner or mineral spirits, provided that there is good ventilation and no sources of ignition.

WASTE DISPOSAL METHOD:
Car must be exercised regarding the toxicity, flammability and disposal of solvents used for cleanup.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:
Keep container closed and store below 90°F.

SECTION VIII: CONTROL MEASURES

RESPIRATORY PROTECTION: Should not be necessary, for reasonably foreseeable industrial end uses of this material.

VENTILATION: General area dilution/exhaust ventilation.

PROTECTIVE EQUIPMENT: Gloves and safety glasses.

WORK/HYGIENE PRACTICES: Wear suitable long sleeve clothing. Wash hands and face before eating, drinking, using tobacco, applying cosmetics, or using the toilet.
SECTION IX: FEDERAL AND STATE REGULATIONS

SARA HAZARD CATEGORIES

IMMEDIATE (ACUTE) HEALTH HAZARD: YES [X]  NO [ ]

DELAYED (CHRONIC) HEALTH HAZARD: YES [ ]  NO [X]

FIRE HAZARD: YES [ ]  NO [X]

REACTIVITY DATA: YES [ ]  NO [X]

SUDDEN RELEASE OF PRESSURE: YES [ ]  NO [X]

SARA SECTION 313 NOTIFICATION


CHEMICAL NAME:  CAS#:  %WT.

INFORMATION PRESENTED HEREIN HAS BEEN COMPiled FROM SOURCES CONSIDERED TO BE DEPENDABLE, AND IS ACCURATE AND RELIABLE TO THE BEST OF OUR KNOWLEDGE AND BELIEF, BUT IS NOT GUARANTEED TO BE SO. SINCE CONDITIONS OF USE ARE BEYOND OUR CONTROL, WE MAKE NO WARRANTIES, EXPRESSED OR IMPLIED, EXCEPT THOSE THAT MAY BE CONTAINED IN OUR WRITTEN CONTRACT OF SALE OR ACKNOWLEDGEMENT.

N/A – Not Available
ND – Not Determined
ACGIH – American Conference of Governmental Industrial Hygienists
OSHA – Occupational Safety and Health Administration
Appendix IV

Industrial Hygiene Exposure Monitoring Plan
APPENDIX V

ANNUAL GROUND CONTROL OPERATING PLAN
FOR THE WASTE ISOLATION PILOT PLANT

Westinghouse
Geotechnical Engineering
# TABLE OF CONTENTS

1.0 INTRODUCTION ..................................................................................................... 1

1.1 Regulatory Compliance .................................................................................... 1
  1.1.1 Resource Conservation and Recovery Act Requirements ..................... 1
  1.1.2 Mine Safety and Health Administration Requirements ..................... 2
  1.1.3 Environmental Protection Agency Requirements ........................... 2

1.2 Scope ................................................................................................................ 2

1.3 Background ....................................................................................................... 2
  1.3.1 Summary of 2000 Ground Control Actions ............................................ 3
  1.3.2 Projected Ground Control Measures for 2001 ...................................... 4

2.0 CURRENT STATUS AND CONDITIONS OF UNDERGROUND OPENINGS ......... 5

2.1 Geology ............................................................................................................ 5

2.2 Opening Dimensions .................................................................................... 14

2.3 Operational Use ............................................................................................ 17

2.4 Excavation Age ............................................................................................ 17

2.5 Projected Life .............................................................................................. 18

2.6 Ground Conditions .......................................................................................... 18
  2.6.1 General Roof Beam Failure Mechanisms and Patterns ....................... 19
  2.6.2 Panel 1 ................................................................................................. 20

2.7 Support System Conditions ............................................................................ 21
  2.7.1 General ................................................................................................ 21
  2.7.2 Panel 1 ................................................................................................. 21

3.0 MONITORING AND EVALUATION ................................................................... 22

3.1 Overall Geotechnical Evaluation Process ...................................................... 23

3.2 Waste Disposal Area Evaluation And Acceptability ....................................... 25

3.3 Surface Observations by Geotechnical Engineering ...................................... 26

3.4 Observation Borehole Data ............................................................................ 27

3.5 Geotechnical Instrumentation Data ............................................................... 27

3.6 Rockbolt Failure Data ..................................................................................... 28

3.7 Ground Support System Monitoring .............................................................. 30
6.0 SUMMARY STATEMENT ................................................................. 47
7.0 REFERENCES .............................................................................. 48
LIST OF TABLES

TABLE

2-1 Underground Assessment Zones — Statistical Information........................................ 7
2-2 Underground Inspection Survey Summary .............................................................. 11
2-3 Panel 1 — Total Vertical and Horizontal Closure ................................................ 20
4-1 Chronology of Panel 1 Ground Support ............................................................... 35

LIST OF FIGURES

FIGURE

2-1 WIPP Underground Assessment Zones ................................................................. 7
2-2 Typical Stratigraphy at the WIPP Facility Horizon ............................................... 16
2-3 Planned Stratigraphic Location of Future Waste Disposal Rooms ..................... 17
3-1 Rockbolt Failures by Type .................................................................................... 30
1.0 INTRODUCTION

This Annual Ground Control Operating Plan (AGCOP) is an internal guidance document for short- and long-term planning for the Westinghouse Underground Operations and Engineering groups. The data collected for the plan and the evaluation of those data are most useful when used or considered immediately after collection. Use of the data becomes more difficult and less certain with time. Because of the dynamic nature of the underground openings and associated geotechnical activities, this plan is updated annually, and each successive document supersedes the previous document. The data, evaluations, and support plans may be updated more frequently. This document is not intended to be used as a final plan for construction. Detailed plans are developed specifically for that purpose. This plan is also a foundation document for development and revision of the more general and broad-based annual Long-Term Ground Control Plan (LTGCP).

1.1 Regulatory Compliance

This plan presents background information and a working guide to assist Underground Operations and Engineering in developing strategies for addressing ground control issues at the Waste Isolation Pilot Plant (WIPP). With the initial receipt of waste in March of 1999, this document provides additional detail to Panel 1 and Panel 2 activities and options.

1.1.1 Resource Conservation and Recovery Act Requirements

Both the AGCOP and the LTGCP serve to ensure that Resource Conservation and Recovery Act (RCRA) permit requirements specific to WIPP site ground control activities are met. The RCRA permit for the WIPP states that “The ground-control program at the WIPP facility will ensure that any room in a Hazardous Waste Disposal Unit (HWDU) in which waste will be placed will be sufficiently supported to assure compliance with the applicable portions of the Land Withdrawal Act (LWA). Which requires a regular review of roof-support plans and practices by the Bureau of Mines and the Mine Safety and Health Administration (MSHA). Support is installed to the requirements of 30 CFR Part 57 Subpart B”. All ground control activities were examined for compliance with RCRA permit requirements and no deficiencies were noted. This report documents that examination and is submitted, when necessary, to support permit compliance. The United States Bureau of Mines no longer exists.
1.1.2 Mine Safety and Health Administration Requirements

Support systems at the WIPP are installed to the requirements of Code of Federal Regulations (CFR) 30 Part 57 Subpart B. Quality assurance/quality control personnel conduct random and as-requested checks as each system is installed. In addition, roof-support plans and practices are regularly reviewed and inspected by the Mine Safety and Health Administration and the New Mexico Bureau of Mine Inspection.

1.1.3 Environmental Protection Agency Requirements

Insofar as ground control activities may influence long-term repository performance and performance assessment calculations, no changes in ground control practices and ground control system behavior and performance were noted.

1.2 Scope

Chapter 2.0 documents the current status of all underground excavations with respect to location, geology, geometry, age, ground support, operational use, projected life, and physical conditions. Chapter 3.0 presents the methods used to evaluate ground conditions, including visual observations of the roof, ribs, and floor; inspection of observation holes; and review of geomechanical instrumentation data. Chapter 4.0 lists several ground-support options and specific applications of each. Chapter 5.0 presents projections and recommendations for ground control actions based on the information in Chapters 2.0 through 4.0 of this plan and on a rating of the critical nature of each specific area. Chapter 6.0 presents a summary statement, and Chapter 7.0 provides references.

1.3 Background

Underground excavation at WIPP began in 1982. Since that time, approximately 8 miles of drifts, rooms, and alcoves have been excavated with several areas now closed to access. The excavations vary in geometry, geology, age, and operational use. These parameters affect the selection of ground control measures, but the ability of the salt to creep or flow with time, and the related fracture process, has the greatest impact on selection of ground control systems. All ground control mechanisms are subjected to the salt-creep forces.

The ground control program at WIPP consists of many aspects, including continuous visual inspections of the underground openings, extensive geomechanical monitoring, numerical modeling, tracking and analysis of rockbolt failures, implementation of
selective ground control procedures, and comprehensive in situ and laboratory testing and evaluation of ground control components and systems.

Plans for areas that involve waste handling/emplacement are based on the most current waste receipt schedules provided by the Department of Energy's Carlsbad Field Office (CBFO). An area designated for near-term waste emplacement is cleared from a ground control standpoint for a specific period of time. The ground control program at WIPP has produced a greater understanding of the failure mechanisms involved in the mine roof and the support systems installed in it. The database of information is a tool that aids the ability to preserve and maintain optimal ground conditions and to predict and/or mitigate hazardous conditions.

1.3.1 Summary of 2000 Ground Control Actions

The receipt of waste initiated additional activities that affected ground control actions in 2000. Mining of Panel 2 and its associated access drifts was completed. To ensure that salt disposal from Panel 2 excavation was not impeded by limitations of the salt handling shaft, reopening of selected areas of the north end of the facility was authorized by the DOE. Panel 1 was also monitored more closely as Panel 2 was mined to evaluate effects of the mining on the existing openings.

This plan addresses ground control issues on a contemporary basis. Major ground control measures implemented in Calendar Year 2000 include the following:

- Areas in the north portion of the facility that had previously been closed were inspected, supported as necessary (rockbolted), and cleared for salt storage to support excavation of Panel 2. One aspect of this process included installation of a row of threaded-bar bolts at each end of the Site and Preliminary Design Validation (SPDV) rooms that remain closed.

- Cable lacing was installed in South-1600 between Rooms 1 and 6 of Panel 1.

- Additional threaded-bar bolts were installed at the south end of Room 1.

- A system consisting of Geobrugg Mesh (a heavy cable mesh) was installed at the ventilation overcast at South-2520 and East-300. The system covers the entire overcast and extends around the brows.

- Limited spot bolting to address isolated drummy areas was performed in newly excavated areas associated with Panel 2.
Existing ground control was maintained as appropriate. Broken bolts in active patterns were replaced. Scaling, adding mesh, and bolting were performed on an as-needed basis in localized areas not actively supported.

Floor milling activities were performed as required.

1.3.2 Projected Ground Control Measures for 2001

Panel 1 conditions are scrutinized carefully to ascertain suitability for waste disposal. All areas of the panel are reinforced with supplemental threaded-bar bolt installations. Current projections call for adding additional ground control only as needed and, preferably, immediately prior to waste emplacement in a specific area. With the waste disposal schedule being a controlling parameter, ground control projections for Panel 1 include:

- Replace broken bolts in most recent generation of support as necessary until near the time each room is required for waste disposal.
- Roof mats will be installed in the rooms selected for waste emplacement and their associated entry drifts as necessary prior to emplacement operations in those areas. The roof mats will be attached with a pattern of threaded-bar and mechanical-anchor rockbolts.
- If required, the floor in areas required for waste emplacement will be milled or mined to achieve operational clearance requirements.
- Room 7 is receiving waste and no additional ground control efforts are anticipated for 2001 with the exception of replacing accessible threaded-bar bolts that fail.

Detailed projections for Panel 1 are discussed in Section 5.2. If the rate of waste receipt is significantly slow, the economics of maintaining all of Panel 1 for waste emplacement may make the use of some areas of the panel less desirable than others.

Tentative projections for routine ground control actions in the remainder of the facility include the addition of mesh and supplemental pattern bolting with threaded-bar bolts, mechanical-anchor bolts, or yielding cable bolts as required. Ground control projections are tentative, based on evaluations of current conditions, and prioritized based on safety. Anticipated ground control actions that will or are scheduled to be performed in the next year include:

- Roof beam removal will be performed in the East-0 Drift from North-150 to North-1400. This activity is currently in progress. Following beam removal, a
pattern of 6-foot-long mechanical-anchor rockbolts and chain-link mesh will be installed.

- Beam removal is also planned for the East-140 Drift from North-250 to North-1400 and the associated cross drifts between East-140 and East-0.
- Additional support may be added in the South-1300 crosscut between West-30 and West-170. This support may include splitting the existing bolt pattern with No. 7 threaded-bar bolts.
- In the West-30 Drift from South-90 to South-400, supplemental support will be installed.
- Supplemental support is planned for both brows at the Air Intake Shaft.
- Supplemental support will be installed on the both brows at the Waste Shaft Station and from the East-140 South-400 intersection to the Waste Shaft Station.

2.0 CURRENT STATUS AND CONDITIONS OF UNDERGROUND OPENINGS

The underground is divided into zones for ground control assessment purposes. The current status of the zones is constantly evaluated and documented. Figure 2-1 presents a layout of the facility with the numeric identification of each zone. Table 2-1 lists statistical information on each zone, such as area description, roof beam dimensions, opening geometry, excavation age, ground support, and operational use. This table also gives the projected life of the zone based on its operational use. Table 2-2 lists the current physical condition assessment of each zone based on field surveys performed in December and January of 2000 and 2001, respectively. The information provided in Table 2-2 is based on qualitative evaluations of roof, rib, and floor fracturing and related degradation of the opening. The data presented in Tables 2-1 and 2-2 are used for making ground control projections. A change in the conditions of an area may necessitate ground control actions not anticipated at this time.

2.1 Geology

The underground facility horizon lies within the Salado Formation. The basic constituents of the formation are near horizontal beds of clear halite (salt), argillaceous (clayey) halite, and polyhalitic halite. A detailed geologic discussion of the Salado Formation can be found in Holt and Powers [1984]. Two mining horizons are located within the facility horizon: (1) the disposal horizon and (2) the experimental horizon.
EXPERIMENTAL HORIZON

EXHAUST SHAFT

SALT HANDLING SHAFT

WASTE SHAFT

PROPOSED EXCAVATIONS

COMPLETED EXCAVATIONS

COMPLETED CLOSED EXCAVATIONS
<table>
<thead>
<tr>
<th>Zone Number</th>
<th>Area Description</th>
<th>Opening Dimensions (ft.)</th>
<th>Use</th>
<th>Age (yr.)</th>
<th>Est. Bolt Length (ft.)</th>
<th>Bolt Type</th>
<th>Bolt Spacing (ft.)</th>
<th>Bolt Dimensions (in.)</th>
<th>Roof Beam Dimensions (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ROOM 1 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>14</td>
<td>ST</td>
<td>13</td>
<td>1.600</td>
<td>THR8 SPECIAL</td>
<td>7x33</td>
</tr>
<tr>
<td>2</td>
<td>ROOM 2 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>13</td>
<td>ST</td>
<td>99</td>
<td>9.999</td>
<td>VARY VARIOUS</td>
<td>7x33</td>
</tr>
<tr>
<td>3</td>
<td>ROOM 3 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>13</td>
<td>ST</td>
<td>12</td>
<td>0.875</td>
<td>THR8 4.5SQ</td>
<td>7x33</td>
</tr>
<tr>
<td>4</td>
<td>ROOM 4 PANEL 1(N/2)</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>12</td>
<td>ST</td>
<td>12</td>
<td>0.875</td>
<td>THR8 4.5SQ</td>
<td>7x33</td>
</tr>
<tr>
<td>5</td>
<td>ROOM 5 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>12</td>
<td>ST</td>
<td>13</td>
<td>0.875</td>
<td>THR8 4.5SQ</td>
<td>7x33</td>
</tr>
<tr>
<td>6</td>
<td>ROOM 6 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>12</td>
<td>ST</td>
<td>12</td>
<td>0.875</td>
<td>THR8 4.5SQ</td>
<td>7x33</td>
</tr>
<tr>
<td>7</td>
<td>ROOM 7 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>12</td>
<td>ST</td>
<td>12</td>
<td>0.875</td>
<td>THR8 5x3.8TRI</td>
<td>7x33</td>
</tr>
<tr>
<td>8</td>
<td>S1950 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>13</td>
<td>ST</td>
<td>13</td>
<td>0.750</td>
<td>THR8 4.5SQ</td>
<td>7x33</td>
</tr>
<tr>
<td>9</td>
<td>S1600 R4-R7 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>12</td>
<td>ST</td>
<td>13</td>
<td>0.875</td>
<td>THR8 4.5SQ</td>
<td>7x33</td>
</tr>
<tr>
<td>10</td>
<td>S1600 R1-R4 PANEL 1</td>
<td>13x33</td>
<td>WASTE DISP</td>
<td>13</td>
<td>ST</td>
<td>13</td>
<td>0.875</td>
<td>THR8 4.5SQ</td>
<td>7x33</td>
</tr>
<tr>
<td>11</td>
<td>S1950P1 ENT E140-300</td>
<td>13x20</td>
<td>HAULAGE</td>
<td>14</td>
<td>ST</td>
<td>6</td>
<td>0.625</td>
<td>MECH 5x2.5TRI</td>
<td>7x20</td>
</tr>
<tr>
<td>12</td>
<td>S1950P1 ENT E300-520</td>
<td>13x20</td>
<td>HAULAGE</td>
<td>14</td>
<td>ST</td>
<td>6</td>
<td>0.625</td>
<td>MECH 5x2.5TRI</td>
<td>7x20</td>
</tr>
<tr>
<td>13</td>
<td>S1600 PANEL 1 ENTRY</td>
<td>12x14</td>
<td>VENTILATE</td>
<td>14</td>
<td>ST</td>
<td>6</td>
<td>0.625</td>
<td>MECH 5x2.5TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>14</td>
<td>E300 S1950-S2180</td>
<td>12x14</td>
<td>VENTILATE</td>
<td>14</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 4x2TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>15</td>
<td>E300 S1300-S1600</td>
<td>12x14</td>
<td>VENTILATE</td>
<td>14</td>
<td>LT</td>
<td>6</td>
<td>0.625</td>
<td>MECH 5x2.5TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>16</td>
<td>E300 S1600-S1950</td>
<td>12x14</td>
<td>VENTILATE</td>
<td>14</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x2.5TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>17</td>
<td>E300 S400-S1300</td>
<td>12x14</td>
<td>VENTILATE</td>
<td>14</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 6x3TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>18</td>
<td>E300 S90-S400</td>
<td>15x25</td>
<td>SHOP</td>
<td>7</td>
<td>I</td>
<td>12</td>
<td>0.750</td>
<td>THR8 4.5SQ</td>
<td>5x25</td>
</tr>
<tr>
<td>19</td>
<td>EXHST DRIFT E OF 300</td>
<td>12x20</td>
<td>VENTILATE</td>
<td>16</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x2.5TRI</td>
<td>8x20</td>
</tr>
<tr>
<td>20</td>
<td>E140 S OF 2520</td>
<td>8x25</td>
<td>CLOSED</td>
<td>17</td>
<td>CL</td>
<td>0</td>
<td>0.000</td>
<td>MECH UNKNOWN</td>
<td>6x25</td>
</tr>
<tr>
<td>21</td>
<td>E140 S2050-S2180</td>
<td>15x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>8</td>
<td>0.750</td>
<td>MECH 12x3TRI</td>
<td>5x25</td>
</tr>
<tr>
<td>22</td>
<td>E140 S1950-S2050</td>
<td>15x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>4</td>
<td>0.625</td>
<td>MECH 5x3TRI</td>
<td>6x25</td>
</tr>
<tr>
<td>23</td>
<td>E140 S1300-S1600</td>
<td>20x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>5</td>
<td>0.625</td>
<td>MECH 5x3TRI</td>
<td>6x25</td>
</tr>
<tr>
<td>24</td>
<td>E140 S1000-S1300</td>
<td>20x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>5</td>
<td>0.625</td>
<td>MECH 5x3TRI</td>
<td>6x25</td>
</tr>
<tr>
<td>25</td>
<td>E140 S700-S1000</td>
<td>15x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>12</td>
<td>0.875</td>
<td>THR8 4.5SQ</td>
<td>5x25</td>
</tr>
<tr>
<td>26</td>
<td>E140 S400-S700</td>
<td>15x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>8</td>
<td>0.750</td>
<td>MECH 12x3TRI</td>
<td>5x25</td>
</tr>
<tr>
<td>27</td>
<td>E140 S90-S400</td>
<td>15x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x2.5TRI</td>
<td>5x25</td>
</tr>
<tr>
<td>28</td>
<td>E140 N460-N780</td>
<td>15x25</td>
<td>STORAGE</td>
<td>17</td>
<td>LT</td>
<td>99</td>
<td>9.999</td>
<td>VARY VARIOUS</td>
<td>5x25</td>
</tr>
<tr>
<td>29</td>
<td>E140 N780-N1100</td>
<td>15x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>ST</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x2.5TRI</td>
<td>5x30</td>
</tr>
<tr>
<td>30</td>
<td>E140 N1100-N1400</td>
<td>15x30</td>
<td>HAULAGE</td>
<td>17</td>
<td>ST</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x2.5TRI</td>
<td>5x30</td>
</tr>
<tr>
<td>31</td>
<td>W30 S1950-S2180</td>
<td>12x14</td>
<td>ACCESS</td>
<td>12</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 6x3TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>32</td>
<td>W30 S1600-S1950</td>
<td>12x14</td>
<td>ACCESS</td>
<td>14</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x2.5TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>33</td>
<td>W30 S1175-S1300</td>
<td>12x14</td>
<td>ACCESS</td>
<td>15</td>
<td>LT</td>
<td>6</td>
<td>0.625</td>
<td>MECH 5x3TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>34</td>
<td>W30 S1300-S1500</td>
<td>12x14</td>
<td>ACCESS</td>
<td>15</td>
<td>LT</td>
<td>6</td>
<td>0.750</td>
<td>MECH 4x6SQ</td>
<td>6x25</td>
</tr>
<tr>
<td>35</td>
<td>W30 S400-S700</td>
<td>12x20</td>
<td>VENTILATE</td>
<td>15</td>
<td>LT</td>
<td>6</td>
<td>0.750</td>
<td>MECH 5x3TRI</td>
<td>8x20</td>
</tr>
<tr>
<td>36</td>
<td>W30 S700-S1000</td>
<td>12x14</td>
<td>ACCESS</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x3TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>37</td>
<td>W30 S1000-1125</td>
<td>12x14</td>
<td>ACCESS</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x3TRI</td>
<td>8x14</td>
</tr>
<tr>
<td>38</td>
<td>W30 S90-S400</td>
<td>12x20</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH 5x2.5TRI</td>
<td>8x20</td>
</tr>
<tr>
<td>Zone Number</td>
<td>Area Description</td>
<td>Opening Dimensions (ft.)</td>
<td>Use</td>
<td>Age (yr.)</td>
<td>Est. Life</td>
<td>Bolt Length (ft.)</td>
<td>Bolt Diam. (in.)</td>
<td>Bolt Type</td>
<td>Bolt Spacing (ft.)</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
<td>--------------------------</td>
<td>-----</td>
<td>-----------</td>
<td>-----------</td>
<td>------------------</td>
<td>----------------</td>
<td>------------</td>
<td>------------------</td>
</tr>
<tr>
<td>39</td>
<td>E0 N460-N780</td>
<td>12x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>39</td>
<td>E0 N780-N1100</td>
<td>12x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>ST</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>40</td>
<td>E0 N1100-N1400</td>
<td>12x25</td>
<td>HAULAGE</td>
<td>17</td>
<td>ST</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>41</td>
<td>W170 S1950-S2180</td>
<td>12x14</td>
<td>HAULAGE</td>
<td>11</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>42</td>
<td>W170 S1300-S1600</td>
<td>12x14</td>
<td>HAULAGE</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>42</td>
<td>W170 S1600-S1950</td>
<td>12x14</td>
<td>HAULAGE</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>43</td>
<td>W170 S1000-S1300</td>
<td>12x14</td>
<td>HAULAGE</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>44</td>
<td>W170 S700-S1000</td>
<td>12x14</td>
<td>HAULAGE</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>44</td>
<td>W170 S90-S700</td>
<td>12x14</td>
<td>HAULAGE</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>45</td>
<td>W170/N150 S90/E0</td>
<td>12x14</td>
<td>HAULAGE</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>46</td>
<td>S2180 E140-E300</td>
<td>13x20</td>
<td>CROSS</td>
<td>16</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>47</td>
<td>S2180 W30-E140</td>
<td>13x20</td>
<td>CROSS</td>
<td>16</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>48</td>
<td>S1950 W30-E140</td>
<td>12x14</td>
<td>CROSS</td>
<td>14</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>49</td>
<td>S1600 E140-E300</td>
<td>12x20</td>
<td>CROSS</td>
<td>14</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x4TRI</td>
</tr>
<tr>
<td>50</td>
<td>S1600 E140-W30</td>
<td>12x20/27</td>
<td>WASHBAY</td>
<td>16</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x3TRI</td>
</tr>
<tr>
<td>51</td>
<td>S1600 W30-W170</td>
<td>12x20</td>
<td>CROSS</td>
<td>12</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>52</td>
<td>S1300 E140-E300</td>
<td>12x25</td>
<td>VENTILATE</td>
<td>16</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x3TRI</td>
</tr>
<tr>
<td>53</td>
<td>S1300 W30-E140</td>
<td>12x20</td>
<td>OFFICES</td>
<td>15</td>
<td>I</td>
<td>6</td>
<td>0.625</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>54</td>
<td>S1300 W30-W170</td>
<td>14x20</td>
<td>SHOP</td>
<td>15</td>
<td>I</td>
<td>6</td>
<td>9.999</td>
<td>MECH</td>
<td>4x2TRI</td>
</tr>
<tr>
<td>55</td>
<td>S1000 E140-E300</td>
<td>12x20</td>
<td>CROSS</td>
<td>14</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x5TRI</td>
</tr>
<tr>
<td>56</td>
<td>S1000 E140-W30</td>
<td>12x25</td>
<td>CROSS/VEN</td>
<td>16</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x5TRI</td>
</tr>
<tr>
<td>57</td>
<td>S1000 W30-W170</td>
<td>12x33</td>
<td>OFFICES</td>
<td>14</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x5TRI</td>
</tr>
<tr>
<td>58</td>
<td>S700 E140-E300</td>
<td>14x33</td>
<td>SHOP</td>
<td>16</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x5TRI</td>
</tr>
<tr>
<td>59</td>
<td>S700 E140-W30</td>
<td>12x20</td>
<td>HAULAGE</td>
<td>14</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>60</td>
<td>S700 W30-W170</td>
<td>12x32</td>
<td>OFFICES</td>
<td>15</td>
<td>I</td>
<td>6</td>
<td>0.625</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>61</td>
<td>S400 E140-E300</td>
<td>VARES</td>
<td>VENTILATE</td>
<td>16</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x3TRI</td>
</tr>
<tr>
<td>62</td>
<td>WASTE SHAFT STATION</td>
<td>16x22</td>
<td>STATION</td>
<td>17</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x5TRI</td>
</tr>
<tr>
<td>63</td>
<td>S90 E140-E300</td>
<td>12x12</td>
<td>ACCESS</td>
<td>14</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>64</td>
<td>S90 E0-E140</td>
<td>12x25</td>
<td>ELECT SUBS</td>
<td>14</td>
<td>I</td>
<td>0</td>
<td>0.000</td>
<td>NONE</td>
<td>NONE</td>
</tr>
<tr>
<td>65</td>
<td>S90 W30-W170</td>
<td>12x14</td>
<td>ACCESS</td>
<td>15</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>66</td>
<td>S90 W170-AIS</td>
<td>12x14</td>
<td>VENTILATE</td>
<td>12</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>67</td>
<td>S90 AIS-Q</td>
<td>12x20</td>
<td>EXPERIMEN</td>
<td>11</td>
<td>ST</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>68</td>
<td>Q ALCOVE</td>
<td>15x30</td>
<td>EXPERIMEN</td>
<td>11</td>
<td>ST</td>
<td>6</td>
<td>0.625</td>
<td>MECH</td>
<td>6x6TRI</td>
</tr>
<tr>
<td>69</td>
<td>Q ROOM</td>
<td>9.5RND</td>
<td>CLOSED</td>
<td>10</td>
<td>CL</td>
<td>0</td>
<td>0.000</td>
<td>MECH</td>
<td>NONE</td>
</tr>
<tr>
<td>70</td>
<td>AIS STATION @ SHAFT</td>
<td>20x25</td>
<td>STATION</td>
<td>12</td>
<td>LT</td>
<td>12</td>
<td>0.750</td>
<td>MECH</td>
<td>6x6TRI</td>
</tr>
<tr>
<td>70</td>
<td>AIS STATION LOW BRWS</td>
<td>12x25</td>
<td>STATION</td>
<td>12</td>
<td>LT</td>
<td>6</td>
<td>0.750</td>
<td>MECH</td>
<td>6x6TRI</td>
</tr>
<tr>
<td>71</td>
<td>ROOM V</td>
<td>12x25</td>
<td>EXPERIMEN</td>
<td>12</td>
<td>ST</td>
<td>4</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>72</td>
<td>AIS ACCESS N215</td>
<td>13x25</td>
<td>VENTILATE</td>
<td>12</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>73</td>
<td>N300 OE-WEST</td>
<td>13x25</td>
<td>VENTILATE</td>
<td>12</td>
<td>LT</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>74</td>
<td>E140 N460 ALCOVE</td>
<td>13x25</td>
<td>OFFICES</td>
<td>9</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>75</td>
<td>N460 E0-E140</td>
<td>13x25</td>
<td>ACCESS</td>
<td>17</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
</tr>
<tr>
<td>76</td>
<td>E140 N780 ALCOVE</td>
<td>13x25</td>
<td>STORAGE</td>
<td>9</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>77</td>
<td>N780 E0-E140</td>
<td>13x25</td>
<td>SHOP</td>
<td>17</td>
<td>I</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>78</td>
<td>N1100 E0-E140</td>
<td>12x14</td>
<td>CROSS</td>
<td>17</td>
<td>ST</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>4x2TRI</td>
</tr>
<tr>
<td>79</td>
<td>N1100 E140-E300</td>
<td>12x24</td>
<td>CLOSED</td>
<td>16</td>
<td>CL</td>
<td>0</td>
<td>0.000</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>79</td>
<td>N1100 E300-RAMP</td>
<td>9x14</td>
<td>CLOSED</td>
<td>16</td>
<td>CL</td>
<td>0</td>
<td>0.625</td>
<td>MECH</td>
<td>5x5TRI</td>
</tr>
<tr>
<td>80</td>
<td>N1100 RAMP</td>
<td>9x14</td>
<td>CLOSED</td>
<td>16</td>
<td>CL</td>
<td>0</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
</tr>
<tr>
<td>Zone Number</td>
<td>Area Description</td>
<td>Opening Dimensions (ft.)</td>
<td>Use</td>
<td>Age (yr.)</td>
<td>Est. Life</td>
<td>Bolt Length (ft.)</td>
<td>Bolt Diam. (in.)</td>
<td>Bolt Type</td>
<td>Pile Bolt Spacing (ft.)</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------</td>
<td>--------------------------</td>
<td>-----</td>
<td>-----------</td>
<td>-----------</td>
<td>------------------</td>
<td>-----------------</td>
<td>-----------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>81</td>
<td>N1100 RAMP-ROOM B</td>
<td>9'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>6</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>8'x14</td>
</tr>
<tr>
<td>82</td>
<td>N1100 ROOMS A-D</td>
<td>9'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>6</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>8'x14</td>
</tr>
<tr>
<td>83</td>
<td>ROOM D</td>
<td>18'x18</td>
<td>CLOSED</td>
<td>16</td>
<td>10</td>
<td>0.875</td>
<td>THRB</td>
<td>5x5TRI</td>
<td>5'x14</td>
</tr>
<tr>
<td>84</td>
<td>ROOM M</td>
<td>11'x24</td>
<td>CLOSED</td>
<td>16</td>
<td>4</td>
<td>0.625</td>
<td>MECH</td>
<td>5x5SQ</td>
<td>6'x24</td>
</tr>
<tr>
<td>85</td>
<td>N1400 ROOMS A3-D</td>
<td>12'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>6</td>
<td>0.750</td>
<td>MECH</td>
<td>4x3TRI</td>
<td>5'x14</td>
</tr>
<tr>
<td>86</td>
<td>ROOM C-1</td>
<td>18'x18</td>
<td>CLOSED</td>
<td>16</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>5'x14</td>
</tr>
<tr>
<td>87</td>
<td>ROOM C-2</td>
<td>18'x18</td>
<td>CLOSED</td>
<td>16</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x3TRI</td>
<td>5'x14</td>
</tr>
<tr>
<td>88</td>
<td>N1400 ROOMS A1-A3</td>
<td>12'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>6</td>
<td>0.625</td>
<td>MECH</td>
<td>4x3TRI</td>
<td>5'x14</td>
</tr>
<tr>
<td>89</td>
<td>N1400 ROOMS A1-B</td>
<td>12'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>6</td>
<td>0.625</td>
<td>MECH</td>
<td>5x3TRI</td>
<td>5'x14</td>
</tr>
<tr>
<td>90</td>
<td>N1400 RAMP-ROOM B</td>
<td>12'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>4x3TRI</td>
<td>5'x14</td>
</tr>
<tr>
<td>91</td>
<td>N1400 RAMP</td>
<td>12'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>VARES</td>
</tr>
<tr>
<td>92</td>
<td>N1400 E140-RAMP</td>
<td>12'x14</td>
<td>CLOSED</td>
<td>16</td>
<td>10</td>
<td>0.625</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>6'x14</td>
</tr>
<tr>
<td>93</td>
<td>N1100 E0-SPDV RMI</td>
<td>12'x20</td>
<td>HAULAGE</td>
<td>17</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x5TRI</td>
<td>6'x20</td>
</tr>
<tr>
<td>94</td>
<td>N1100 SPDV ROOMS 1-4</td>
<td>12'x20</td>
<td>HAULAGE</td>
<td>17</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x5TRI</td>
<td>6'x20</td>
</tr>
<tr>
<td>95</td>
<td>ROOM G AND G ACCESS</td>
<td>10'x20</td>
<td>SALT STORE</td>
<td>15</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>VARIOUS</td>
<td>10'x20</td>
</tr>
<tr>
<td>96</td>
<td>SPDV ROOM 4</td>
<td>13'x33</td>
<td>HAULAGE</td>
<td>17</td>
<td>10 &amp; 72</td>
<td>0.875</td>
<td>THRG</td>
<td>4x4SQ</td>
<td>7'x33</td>
</tr>
<tr>
<td>97</td>
<td>ROOM L-4</td>
<td>13'x33</td>
<td>SALT STORE</td>
<td>11</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>7'x33</td>
</tr>
<tr>
<td>98</td>
<td>ROOM L-3</td>
<td>13'x33</td>
<td>SALT STORE</td>
<td>11</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>7'x33</td>
</tr>
<tr>
<td>99</td>
<td>ROOM L-2</td>
<td>13'x33</td>
<td>SALT STORE</td>
<td>16</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>4x2TRI</td>
<td>7'x33</td>
</tr>
<tr>
<td>100</td>
<td>ROOM L-1</td>
<td>13'x33</td>
<td>SALT STORE</td>
<td>16</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>7'x33</td>
</tr>
<tr>
<td>101</td>
<td>N1400 E0-E140</td>
<td>12'x20</td>
<td>HAULAGE</td>
<td>17</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>6'x20</td>
</tr>
<tr>
<td>102</td>
<td>N1400 E0-ROOM L1</td>
<td>12'x20</td>
<td>HAULAGE</td>
<td>17</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>8'x20</td>
</tr>
<tr>
<td>103</td>
<td>N1400 ROOMS L1-L4</td>
<td>12'x20</td>
<td>HAULAGE</td>
<td>17</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>4x4TRI</td>
<td>8'x20</td>
</tr>
<tr>
<td>104</td>
<td>E300 N1100-1400 SHOP</td>
<td>13'x33</td>
<td>CLOSED</td>
<td>10</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>7'x33</td>
</tr>
<tr>
<td>105</td>
<td>ROOM J</td>
<td>12'x23</td>
<td>SALT STORE</td>
<td>16</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>4x4TRI</td>
<td>8'x23</td>
</tr>
<tr>
<td>106</td>
<td>ROOM H ACCESS</td>
<td>10'x11</td>
<td>CLOSED</td>
<td>16</td>
<td>99</td>
<td>0.750</td>
<td>MECH</td>
<td>5x3TRI</td>
<td>10'x11</td>
</tr>
<tr>
<td>107</td>
<td>ROOM H</td>
<td>10'x36</td>
<td>CLOSED</td>
<td>15</td>
<td>99</td>
<td>9.999</td>
<td>MECH</td>
<td>5x5TRI</td>
<td>8'x14</td>
</tr>
<tr>
<td>110</td>
<td>NB40 ALOCE 0E</td>
<td>12'x14</td>
<td>STORAGE</td>
<td>11</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>6x3TRI</td>
<td>8'x14</td>
</tr>
<tr>
<td>111</td>
<td>E0 N320 ALOCE</td>
<td>12'x25</td>
<td>STORAGE</td>
<td>11</td>
<td>10</td>
<td>0.625</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>8'x25</td>
</tr>
<tr>
<td>112</td>
<td>W170 S400 ALOCE</td>
<td>13'x25</td>
<td>STORAGE</td>
<td>11</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>5x2.5TRI</td>
<td>7'x25</td>
</tr>
<tr>
<td>113</td>
<td>E0 N150 OVERCAST</td>
<td>20'x15</td>
<td>VENTILATE</td>
<td>13</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>4x4SQ</td>
<td>7'x15</td>
</tr>
<tr>
<td>114</td>
<td>N150 OVERCAST-E140</td>
<td>10'x14</td>
<td>VENTILATE</td>
<td>17</td>
<td>10</td>
<td>0.750</td>
<td>MECH</td>
<td>8x4.5TRI</td>
<td>10'x14</td>
</tr>
<tr>
<td>115</td>
<td>ROOM 1 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>116</td>
<td>ROOM 2 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>117</td>
<td>ROOM 3 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>118</td>
<td>ROOM 4 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>119</td>
<td>ROOM 5 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>120</td>
<td>ROOM 6 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>121</td>
<td>ROOM 7 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>122</td>
<td>S250 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>123</td>
<td>S250 PANEL 2</td>
<td>13'x33</td>
<td>WASTE DISP</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>124</td>
<td>F250 PANEL 2 ENTRY</td>
<td>13'x20</td>
<td>HAULAGE</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>125</td>
<td>S2100 PANEL 2 ENTRY</td>
<td>12'x14</td>
<td>VENTILATE</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>126</td>
<td>E300 S2180-S2520</td>
<td>13'x16</td>
<td>VENTILATE</td>
<td>1</td>
<td>LT</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>127</td>
<td>E140 S2180-S2520</td>
<td>15'x25</td>
<td>HAULAGE</td>
<td>1</td>
<td>LT</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>128</td>
<td>W30 S2180-S2520</td>
<td>13'x16</td>
<td>ACCESS</td>
<td>1</td>
<td>LT</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>129</td>
<td>W170 S2180-S2520</td>
<td>13'x16</td>
<td>HAULAGE</td>
<td>1</td>
<td>LT</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>130</td>
<td>S2520 E140-E300</td>
<td>13'x20</td>
<td>HAULAGE</td>
<td>1</td>
<td>ST</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>131</td>
<td>S2520 W30-E140</td>
<td>13'x20</td>
<td>CROSS</td>
<td>1</td>
<td>I</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### Table 2-1. Underground Assessment Zones — Statistical Information (Page 4 of 4)

<table>
<thead>
<tr>
<th>Zone Number</th>
<th>Area Description</th>
<th>Opening Dimensions (ft.)</th>
<th>Use</th>
<th>Age (yr.)</th>
<th>Est. Life</th>
<th>Bolt Type</th>
<th>Bolt Diam. (in.)</th>
<th>Bolt Length (ft.)</th>
<th>Patt. Bolt Spacing (ft.)</th>
<th>Roof Beam Dimensions (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>S2520 W30-W170</td>
<td>13x20</td>
<td>CROSS</td>
<td>1</td>
<td>I</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>133</td>
<td>S2180 W30-W170</td>
<td>13x20</td>
<td>CROSS</td>
<td>1</td>
<td>I</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

Notes: For evaluation purposes, Zone 96 was combined with Zone 95, and Zone 107 was combined with Zone 94.

Age is calculated using the date of this printing and the date of completion of the first excavation sequence. The date of printing is February 2001. Zones 115 through 133 are less than 1 year old.

Zeros (e.g., 0.000) in a numerical column indicate that no information is available. Nines (e.g., 9.999) in a numerical column indicate multiple types or dimensions.

Key:
- **ST** - Short-term
- **I** - Intermediate
- **LT** - Long-term
- **CL** - Closed
- **THRBP** - Threaded-Bar Bolt
- **MECH** - Mechanical Anchor
- **TRI** - Triangular
- **SQ** - Square

(Refer to text for detailed definitions)
<table>
<thead>
<tr>
<th>Zone Number</th>
<th>Area Description</th>
<th>Low-Angle Fracturing</th>
<th>Horizontal Fracturing</th>
<th>Longitudinal Fracturing</th>
<th>Ribs Assessment</th>
<th>Floor Assessment</th>
<th>Increased Closure Rate</th>
<th>Long-Term Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ROOM 1 PANEL 1</td>
<td>E4 W3</td>
<td>2</td>
<td>3</td>
<td>E1 W1</td>
<td>E2 W2</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>ROOM 2 PANEL 1</td>
<td>E2 W3</td>
<td>2</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>ROOM 3 PANEL 1</td>
<td>E3 W2</td>
<td>1</td>
<td>3</td>
<td>E1 W1</td>
<td>E2 W2</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>ROOM 4 PANEL 1(N/2)</td>
<td>E4 W3</td>
<td>2</td>
<td>4</td>
<td>E1 W1</td>
<td>E2 W2</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>ROOM 5 PANEL 1</td>
<td>E4 W2</td>
<td>2</td>
<td>3</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>ROOM 6 PANEL 1</td>
<td>E3 W2</td>
<td>1</td>
<td>3</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>ROOM 7 PANEL 1</td>
<td>E4 W2</td>
<td>1</td>
<td>3</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>S1950 PANEL 1</td>
<td>N3 S1</td>
<td>1</td>
<td>3</td>
<td>N1 S1</td>
<td>N2 S2</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>S1600 R4-R7 PANEL 1</td>
<td>N1 S3</td>
<td>1</td>
<td>2</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>S1600 R1-R4 PANEL 1</td>
<td>N2 S3</td>
<td>1</td>
<td>2</td>
<td>N1 S1</td>
<td>N2 S1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>S1950P1 ENT E140-300</td>
<td>N3 S2</td>
<td>1</td>
<td>2</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>S1600 PANEL 1 ENTRY</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>E300 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>E300 OVERCAST-S1950</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>NA NA</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>E300 S1300-S1600</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>E300 S1600-S1950</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>E300 S400-S1300</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>E300 S90-S400</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>EXHST DRIFT E OF 300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>E140 S2050-S2180</td>
<td>E3 W3</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>E140 S1600-S1950</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>E140 S1950-S2050</td>
<td>E3 W3</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>23</td>
<td>E140 S1300-S1600</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>E140 S1000-S1300</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>E140 S700-S1000</td>
<td>E2 W2</td>
<td>1</td>
<td>1</td>
<td>E2 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>26</td>
<td>E140 S400-S700</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E2 W2</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>E140 S90-S400</td>
<td>E2 W2</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>28</td>
<td>E140 N250-N460</td>
<td>E1 W5</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W2</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>29</td>
<td>E140 S90-N250</td>
<td>E1 W2</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>E140 N460-N780</td>
<td>N/A W5</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>31</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>34</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>35</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>37</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>38</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>39</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td>W30 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>41</td>
<td>W170 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>42</td>
<td>W170 S1950-S2180</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>Zone Number</td>
<td>Area Description</td>
<td>Low-Angle Fracturing</td>
<td>Horizontal Fracturing</td>
<td>Longitudinal Fracturing</td>
<td>Ribs Fracturing Assessment</td>
<td>Floor Fracturing Assessment</td>
<td>Increased Closure Rate</td>
<td>Long-Term Projection</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
<td>----------------------</td>
<td>-----------------------</td>
<td>------------------------</td>
<td>----------------------------</td>
<td>-----------------------------</td>
<td>----------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>43</td>
<td>W170 S1000-S1300</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>43</td>
<td>W170 S700-S1000</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>44</td>
<td>W170 S90-S700</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>45</td>
<td>W170/N150 S90/E0</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>46</td>
<td>S2180 E140-E300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>47</td>
<td>S2180 W30-E140</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>48</td>
<td>S1950 W30-E140</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>48</td>
<td>S1950 W30-W170</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>49</td>
<td>S1600 E140-E300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>S1600 E140-W30</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>51</td>
<td>S1600 W30-W170</td>
<td>N1 S2</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>52</td>
<td>S1300 E140-E300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>53</td>
<td>S1300 E140-W30</td>
<td>N1 S1</td>
<td>2</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>54</td>
<td>S1300 W30-W170</td>
<td>N3 S3</td>
<td>1</td>
<td>3</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>55</td>
<td>S1000 E140-E300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>56</td>
<td>S1000 E140-W30</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>57</td>
<td>S1000 W30-W170</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N2 S2</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>58</td>
<td>S700 E140-E300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>59</td>
<td>S700 E140-W30</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>60</td>
<td>S700 W30-W170</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>61</td>
<td>S400 E140-E300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>62</td>
<td>WASTE SHAFT STATION</td>
<td>N1 S1</td>
<td>2</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>63</td>
<td>S90 E140-E300</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>64</td>
<td>S90 E0-E140</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>65</td>
<td>S90 W30-W170</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>66</td>
<td>S90 W170-AIS</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>67</td>
<td>S90 AIS-Q</td>
<td>N1 S2</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>68</td>
<td>Q ALCOVE</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>70</td>
<td>AIS STATION @ SHAFT</td>
<td>E1 W1</td>
<td>3</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>70</td>
<td>AIS STATION LOW BRWS</td>
<td>E1 W1</td>
<td>3</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>71</td>
<td>ROOM V</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>72</td>
<td>AIS ACCESS N215</td>
<td>N2 S2</td>
<td>2</td>
<td>2</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>73</td>
<td>N300 0E-WEST</td>
<td>N3 S3</td>
<td>1</td>
<td>2</td>
<td>N2 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>74</td>
<td>E140 N460 ALCOVE</td>
<td>N1 S3</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>75</td>
<td>N460 E0-E140</td>
<td>N1 S2</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>76</td>
<td>E140 N780 ALCOVE</td>
<td>N1 S2</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N2 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>77</td>
<td>N780 E0-E140 SHOP</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>111</td>
<td>E0 N620 ALCOVE</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>112</td>
<td>W170 CORE STORAGE</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>113</td>
<td>E0 N150 OVERCAST</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>114</td>
<td>N150 OVERCAST-E140</td>
<td>N1 S1</td>
<td>1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>115</td>
<td>ROOM 1 PANEL 2</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E2 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>116</td>
<td>ROOM 2 PANEL 2</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>117</td>
<td>ROOM 3 PANEL 2</td>
<td>E1 W1</td>
<td>1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table 2-2. Underground inspection Survey Summary (Page 3 of 3)

<table>
<thead>
<tr>
<th>Zone Number</th>
<th>Area Description</th>
<th>Low-Angle Fracturing</th>
<th>Horizontal Fracturing</th>
<th>Longitudinal Fracturing</th>
<th>Ribs Assessment</th>
<th>Floor Assessment</th>
<th>Increased Closure Rate</th>
<th>Long-Term Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>118</td>
<td>ROOM 4 PANEL 2</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>119</td>
<td>ROOM 5 PANEL 2</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>120</td>
<td>ROOM 6 PANEL 2</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>121</td>
<td>ROOM 7 PANEL 2</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E2 W2</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>122</td>
<td>S2520 PANEL 2</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>123</td>
<td>S2180 PANEL 2</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>124</td>
<td>S2520 PANEL 2 ENTRY</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>125</td>
<td>S2180 PANEL 2 ENTRY</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>126</td>
<td>E300 S2180-S2520</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>127</td>
<td>E140 S2180-S2520</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>128</td>
<td>W30 S2180-S2520</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>129</td>
<td>W170 S2180-S2520</td>
<td>E1</td>
<td>W1</td>
<td>1</td>
<td>E1 W1</td>
<td>E1 W1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>130</td>
<td>S2520 E140-E300</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>131</td>
<td>S2520 W30-E140</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>132</td>
<td>S2520 W30-W170</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>133</td>
<td>S2180 W30-W170</td>
<td>N1</td>
<td>S1</td>
<td>1</td>
<td>N1 S1</td>
<td>N1 S1</td>
<td>NA</td>
<td>1</td>
</tr>
</tbody>
</table>

**Notes:** All accessible zones were assessed from December 2000 to January 2001.

Areas north of North-780 were reopened to support salt disposal. These areas were assessed for ground conditions, and scaling and bolting was performed as required.

The roof is assessed on a scale from 1 to 5, "1" being no low-angle fracturing noted, and "5" being low-angle fracturing extending the full length of the zone, with separation or pull away in evidence.

Vertical fracturing (horizontal and longitudinal) is rated from 1 to 5, with "1" being none observed, and "5" being close bolt-to-bolt fracturing.

Ribs are assessed on a scale of 1 to 3, with "1" being good intact ribs, and "3" showing uncontrolled (no mesh or bolts) spalling or sloughing of the surface.

The floor is assessed on a scale of 1 to 3, with "1" being a good intact floor with no fracturing or floor heave present. A "3" represents a badly fractured or heaving floor.

Under the heading "Increased Closure Rate," a "Y" indicates that the measured closure rate at any convergence point within the area has increased more than 5 percent for the annual period ending October 1, 2000, as compared to the annual period ending October 1, 1999.

Long-term projections are rated on a scale of 1 to 3. At a minimum, areas with a rating of "3" are formally reviewed quarterly, those with a "2" are reviewed semiannually, and those rated as "1" are reviewed annually.

**Key:**
- **N** - North half of zone
- **S** - South half of zone
- **E** - East half of zone
- **W** - West half of zone
- **NA** - Not applicable or not available
are seams of anhydrite and clay that have a significant impact on the stability of openings and the selection of ground control systems. All openings in the experimental horizon are closed and no longer accessible; therefore, any reference relative to this horizon is limited to historical perspective. Figure 2-2 shows the typical stratigraphy at the WIPP facility horizon.

It is recognized that localized geologic conditions can have a considerable impact on the stability of an opening. Fracture development at a specific location (e.g., within a roof beam) may be influenced by the clay content or other seemingly minor factors.

The stratigraphic location of the disposal rooms is within the disposal horizon. Over 90 percent of the underground openings are located within this horizon, and all ground control projections presented in this AGCOP are related to this level.

In relationship to Panels 1 and 2 with a 13-foot excavation height, Anhydrite "a" is located approximately 13 feet above the roof and is underlain by clay H, while Anhydrite "b" is located approximately 6.5 feet above the roof and is underlain by clay G. The clay layers provide surfaces along which movement can occur; whereas, the anhydrite layers are stiff units that do not creep. A 30-inch-thick to 32-inch-thick persistent bed of anhydrite, identified as Marker Bed 139 (MB 139), lies about 5 feet below the floor throughout Panels 1 and 2. Lateral variability in composition and thickness exists within this anhydrite bed at both repository and regional scales. MB 139 is underlain by clay E. The undulating top of MB 139 resists shear movement along the interface with the overlying salt [U.S. Department of Energy, 1993].

Current plans call for moving future disposal rooms up approximately 6.5 feet so the roof of a disposal room terminates at clay G. Figure 2-3 shows the new location of future storage rooms with respect to stratigraphy. The slip that occurs along the clay seam will allow the ribs of the excavation to creep inward without creating as much stress in the roof beam. Moving the disposal horizon up will also result in a greater barrier of salt between the floor of the room and MB 139. Panel 3 will be the first panel affected excavated at the new level. Ramping up to the new level beginning in the access drifts is required.

2.2 Opening Dimensions

Most of the underground openings are rectangular in shape. The dimensions or cross-sectional areas of the various drifts, rooms, and alcoves in the underground differ,
primarily, as a function of use. The geometry of an opening, the stratigraphic location of the opening, and the layout and geometry of surrounding excavations each play a role in...

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. There are no currently accessible underground areas at the experimental horizon.
Figure 2-2. Typical Stratigraphy at the WIPP Facility Horizon
Figure 2-3. Planned Stratigraphic Location of Future Waste Disposal Rooms.

the stability of that area. The opening dimensions of each zone are provided in Table 2-1. The dimensions listed are generally “as mined” and will vary slightly because of original mining tolerance; closure from the creep process; and maintenance acts.

2.3

2.4

haulage and ventilation drifts were recently completed and are less than 1 year old. Table 2-1 lists the age of each ground control area. The age of an excavation is important with respect to ground control because of the amount of deformation that has already occurred and the amount that is anticipated to occur during its projected life.

Some underground openings at WIPP (e.g., the main entries) must remain accessible for 50 years or longer. This life expectancy is based on 18 years since excavation and a 35-year operational life after receipt of waste. With this time frame in mind, support
systems must be designed to accommodate creep-related deformation and to support the beam (if it becomes detached). Beam removal is also an option for long-life areas. The age of an excavation at the time a support system is installed and the age of systems in place are factors that are considered when evaluating the long-term effectiveness of those systems.

2.5 Projected Life

Based primarily on its operational use and projections for receipt of waste, an estimated life was assigned to each underground zone. Three categories, short-term, intermediate, and long-term, were established for this purpose. These projections are an additional tool used in the ground control selection process. The criteria for these designations are:

- **Short-Term (ST)** — A projected life of less than 10 years. This designation includes waste disposal rooms.

- **Intermediate (I)** — A projected life of 10 to 15 years. Special use areas such as maintenance shops are included here. Shops will be required for the life of the facility, but because of creep-related closure, it is assumed that they may be relocated periodically.

- **Long-Term (LT)** — A projected life of up to 50 years or the life of the facility. This designation covers all areas critical to the long-term operation of the facility. Shaft stations, main ventilation drifts, and main access and haulage routes fall in this category.

These projections use the excavation date as a start time. If the current use of an area or receipt of waste is delayed significantly, designations for specific zones may be adjusted (e.g., a short-term area may change to an intermediate). Areas closed or accesses are designated as such and have no projected life. The closed areas can and have been reopened. These projections are unofficial and are used solely for the purposes set forth in this plan, primarily ground control planning. Table 2-1 lists the projected life of each zone.

2.6 Ground Conditions

Because salt is a rock that creeps when subjected to load, once an opening is made, a continuous process of deformation and associated fracturing is initiated that is the primary parameter affecting the condition of an excavation. The ground condition in
2.6.1 General Roof Beam Failure Mechanisms and Patterns

Roof beam conditions in general follow a predictable path of deterioration over time with the degree of degradation varying widely throughout the facility. Many areas have remained very stable since their excavation, while low-angle fracturing and bed separation are observed in other areas. The strata interfaces (clay and anhydrite seams) do not provide much, if any, shear resistance, resulting in differential stresses and related strains developing above and below the seams. This differential movement concentrates the stresses in the beam and, with time, produces a stratigraphic offset in boreholes penetrating the seams, including rockbolt holes. Low-angle fractures develop from the ribs upward over the center of the room. They terminate where they reach a discontinuity in the stratigraphy, such as a clay seam. This fracture pattern is common in salt and potash mines and is illustrated in the Long-Term Ground Control Plan [Westinghouse Electric Corporation, 2000] and in the Geotechnical Analysis Report for July 1996 — June 1997 [U.S. Department of Energy, 1998].

Once low-angle fractures on one side of a room are fully developed, movement of the beam may be primarily toward the low-angle fracture because it is the point of least resistance. A cantilever is formed that is wedged downward as it moves horizontally. Installed rockbolts have a tendency to cause a tensile fracture to develop along the thin edge of the wedge. As one end of the cantilever is forced down, tensile fractures may also develop along the top of the beam on the opposite side of the room. Observations made during the beam-removal activities in the East-140 Drift indicate that if separation at clay G occurs, that separation may be located near the upper terminus of the low-angle fracture as opposed to in the center of the drift.

The fracture mechanisms have proven to be consistent in areas experiencing advanced degradation of the roof beam. The monitored roof falls in SPDV Rooms 1 and 2 indicate that a detached section of a roof beam will be somewhat of a wedge shape. Observations of the fracture patterns exposed during the beam-removal process in the East-140 Drift confirm this mode of failure. Knowledge of the type of failure that can be expected in the roof beam aids in the design of ground support systems. For example, support systems designed to support the entire cross-sectional area of the roof beam are considered conservative based on a wedge-type failure. By following the installation procedure of ending the resin column approximately 1 foot above the clay
seam as opposed to flush with the seam, it is anticipated that the bolts will be subjected to a less severe bend as a result of offset.

2.6.2 Panel 1

The ground conditions in Panel 1 follow a pattern similar to that observed in the areas of the East-140 Drift where the roof beam was removed. Low-angle fractures of varying degrees are observed in most areas. The installation of rockbolts has, in many instances, resulted in the thin edge of the wedge associated with a cantilevered beam breaking with an associated vertical fracture that runs roughly parallel to the rib.

Table 2-3 depicts the total vertical and horizontal convergence at room center points for the Panel 1 rooms since their dates of excavation. As is illustrated in the table, total vertical convergence is over 3 feet in all of the panel rooms (over 4 feet in Room 1), and horizontal convergence is near 2 feet in all rooms. Because ground control measures have little or no effect on the creep process, convergence of this type will continue unabated until the openings are completely closed.

As was expected, deformation rates in Panel 1 increased as a result of Panel 2 excavation. The greatest influence from Panel 2 mining has been observed in the southern half of the Panel 1 rooms and in the 1950 drift. Deformation rates in these areas initially increased; however, the rates are currently decreasing and are expected to level off at a rate above the premining rate.
2.7 Support System Conditions

2.7.1 General

The ground support in most of the accessible areas underground consists of a combination of mechanical-anchor and threaded-bar rockbolts anchored above the first clay seam. Other than bolts that have noticeably failed, it is difficult, if not impossible, to tell what condition the remaining bolts are in. However, based on measured deformation and observed offset since their installation date, it can be surmised that a significant number of the mechanical-anchor rockbolts of the original patterns are probably in material yield, are experiencing anchor slippage, or have failed. Bolts are replaced as they fail if determined necessary.

2.7.2 Panel 1

Various support systems have been installed in Panel 1 over a several-year time span. The types of systems and their installation dates are specified in Section 4.1.2 of this report. As in the other areas of the facility, it is difficult, if not impossible, to tell what condition the in-place bolts are in. However, based on measured deformation and observed offset since their installation date, a significant number of the rockbolts in the original patterns installed in Rooms 1 through 6 are probably in material yield, are experiencing anchor slippage, or have failed. Since the mechanical-anchor bolts installed in Room 7, South-1600, and South-1950 do not penetrate the first clay seam, they have not been exposed to the same degree of lateral and axial deformation as the bolts that do penetrate the clay seam.

The entire panel has been rebolted with resin-anchored threaded-bar bolts. The condition of these bolts will vary dependent on their date of installation, location, and method of installation. Excluding the mechanical bolts, the threaded bar installed in Room 1 is the oldest system in place in the panel. The yielding systems in Rooms 1 and 2 are no longer being detensioned and are behaving similar to nonyielding systems in other rooms of the panel. Bolts are being replaced as they fail as deemed necessary.

The bolts recently installed in Room 7 in conjunction with the cable lacing are the second pattern of threaded-bar bolts installed in the room. The rockbolt boreholes were oversized below the clay seam to allow for a larger amount of offset before the bolts are affected by lateral loading. In addition, the latest installations have the resin
column terminated approximately 1 foot above the clay seam to allow for a less severe bend in the bolts once lateral loading begins.

Bolts will fail and require replacement as the panel ages. The rate of failure will increase dependent on the installation dates of the support systems. Based on the latest projected schedule and sequence for waste emplacement in the panel, many of the bolt failures will occur in areas that are filled and closed to access. No bolt replacement will be performed in those areas.

3.0 MONITORING AND EVALUATION

The RCRA permit for the WIPP states that “the geomechanical monitoring program at the WIPP facility is an integral part of the ground-control program. HWDUs, drifts, and geomechanical test rooms will be monitored to provide confirmation of structural integrity. Geomechanical data on the performance of the repository shafts and excavated areas will be collected as part of the geotechnical field-monitoring program. The results of the geotechnical investigations will be reported annually. The report will describe monitoring programs and the geomechanical data collected during the previous year.”

The assessment and evaluation of the condition of WIPP excavations is an interactive, continuing process involving a wide variety of data. These evaluations can be as simple as the required daily visual site checks by personnel working in an area or as complex as the expert review of Room 1, Panel 1 [U.S. Department of Energy, 1991a]. The Geotechnical Engineering group gathers and evaluates data from various sources on a daily and weekly basis. A bimonthly underground geotechnical assessment report is prepared, as is the annual Geotechnical Analysis Report. An in-depth evaluation of all of the accessible underground is performed on an annual basis as part of the preparation of this plan. These evaluations are based on visual observations by Geotechnical Engineering personnel, analyses of instrumentation data, observation borehole data, and rockbolt failure patterns.

Special assessments are performed as needed. For example, assessments are performed to “clear” waste disposal areas for operations prior to emplacement. When this is done, limited areas are examined and evaluated and, if appropriate, approved for emplacement operations to proceed for a specific time period.
Remote monitoring of geotechnical conditions and ground support systems in selected closed locations (e.g., Room D) is also being performed. The monitoring continues to assist in evaluation of systems as they age and trend toward failure. It is intended that data from these zones will provide predictive information on ground falls in areas with installed roof-support systems. To date, there have been no roof falls or accelerations in closure rates in these areas.

3.1 Overall Geotechnical Evaluation Process

The RCRA permit further states that "the stability of an open panel excavation is generally determined by the rock deformation rate. The excavation may be unstable when there is a continuous increase in the deformation rate that cannot be controlled by the installed support system. The permittees will evaluate the performance of the excavation. These evaluations assess the effectiveness of the roof-support system and estimate the stand-up time of the excavation. If an open panel shows the trend is toward adverse (unstable) conditions, the results will be reported to determine if it is necessary to terminate waste disposal activities in the open panel. This report of the trend toward adverse conditions in an open HWDU will also be provided to the Secretary of the New Mexico Environmental Department (NMED) within 5 working days of issuance of the report."

One of the more difficult aspects of ground control is determining and evaluating the criteria that dictate when ground control actions should be initiated. The identification of potential instabilities is essential to maintaining a safe underground environment. Ground control can be expensive and, in some instances, ground control measures can actually have an adverse effect on the in situ conditions (e.g., the breakup of a beam associated with installation of rigid bolts). Therefore, it is prudent to be as rigorous as possible in determining when to initiate ground control actions and what those actions should be. The process followed at WIPP includes evaluation of general categories of information. These categories include:

- Collection and analysis of geomechanical instrumentation data.
- Evaluation of the performance of installed ground support systems.
- Evaluation of physical observations.
- WIPP-specific experience.

Each category is evaluated independently and comparatively to the other categories. With respect to Panel 1 and the waste haulage routes leading to the panel,
emplacement schedules must also be considered for logistic purposes. Criteria for corrective action are continually reevaluated and reassessed based on total performance to date. Actions taken are based on these analyses and planned use of the excavation.

**Collection and Analyses of Geomechanical Instrumentation Data**

Instrumentation data provide quantitative information on rock movement in and around an opening. Convergence and extensometer data are collected on a continuing basis. This information is plotted as displacement versus time and as rate of displacement versus time. These data are analyzed concentrating on trends in rates and changes in patterns as predictors of instability. For example, long-term data may indicate a consistent closure rate in a particular area of approximately 0.5 inch per year. A significant acceleration in this rate may be a warning sign of developing instability.

**Evaluation of the Performance of Installed Ground Support Systems**

Installed support systems are monitored for performance through various means. Visual inspections are performed on a regular, periodic basis. In most cases, one component of a system will show evidence of strain before failures are seen in a system. For example, it is typical to observe dimpling or cracking of bearing plates as support systems age before bolt or component failures. In addition, select support components may have instrumentation installed on them to assist in monitoring system integrity. When bolt or component failures occur, these are closely tracked, and the failed bolt or component is replaced when it is an active part of the installed ground support system in the area.

Bolt or component failures alone do not necessarily indicate an unstable situation. Because of the deformation process associated with creep, it is known that bolts will fail through time. The age of the in-place ground support, as well as the roof beam expansion rates and relative stratigraphic offset rates for the area of interest, must be considered when evaluating system performance. Knowledge of the mechanical properties of support system components and experience with the systems in the WIPP environment allows projection of how the system should perform under specific conditions. When a ground support system is performing in a manner inconsistent with what is expected, attention is increased.

**Evaluation of Physical Observations**

24
Physical observations generally include surface fractures, fractures within boreholes, offset in boreholes, spalling, and any other visually detectable behavior of the ground condition. Similar to the other data, anomalous behavior, such as accelerations in fracture development or increased slabbing, is an indicator of potential instability.

**WIPP-Specific Experience**

With 18 years of site-specific experience at the WIPP facility, many of the ground conditions observed are familiar. When such things as low-angle fracturing are first noticed, the geotechnical team knows what to expect in the future in that area. What ground control systems work well and how ground control affects ground conditions are also lessons learned that aid in the evaluation of current conditions.

### 3.2 Waste Disposal Area Evaluation And Acceptability

The process of determining acceptability of an area for waste emplacement operations and disposal involves an evaluation of projected geotechnical stability for an area for a specific period of time. As in other areas of the facility, roof stability is of primary interest, while rib and floor stability is secondary. Each determination considers performance of the underground excavation, the geomechanical instrument data, performance of any installed ground support, and physical observations. Expected overhead clearance and floor stability are also documented.

Acceptability of an area for waste emplacement is determined upon completion of the evaluation process. If the area is found to be acceptable, a time period is determined during which emplacement operations may proceed before another detailed, specific area acceptability evaluation is required. Present plans assume no more than two areas at a time will be cleared for emplacement and that acceptability periods will not exceed 1 year. Waste receipt rates will affect the size of the areas cleared (i.e., low waste receipt rates will result in smaller areas being cleared as acceptable for emplacement).

Geomechanical monitoring, support system monitoring, and physical observations will continue as long as physically possible during the waste emplacement operation. A reevaluation of an acceptable area will immediately be performed should conditions or data show unexpected behavior of the ground.
This evaluation process is common at the WIPP site. It supports planning and integration of operations processes relating to waste emplacement and room closure. This process is detailed in the document *Operational Guidance For Waste Disposal Area Acceptability And Closure* [Garcia, 1997].

3.3 Surface Observations by Geotechnical Engineering

A two-person team from Geotechnical Engineering performed a visual assessment of the underground facility during December and January of 2000 and 2001, respectively. The conditions of the roof, ribs, and floor were assessed in each ground control zone and were graded on a scale basis. For the purpose of these evaluations, lower numbers represent better conditions (i.e., "1" is better than "2"). The roof was evaluated with respect to low-angle fractures, scaling, and longitudinal or transverse vertical fractures, and then graded on a scale of 1 to 5. The ribs were evaluated on a scale of 1 to 3 based on their general condition, and it was noted if they had been mechanically scaled. The floor was evaluated with respect to heaving and fracturing and graded on a scale of 1 to 3. It was also noted if the floor had been milled. As a general rule, scaling and milling activities remove small amounts of ground and are unlikely to have a significant effect on closure rates and the overall stability of the area.

For evaluation of the ribs, floor, and low-angle fractures in the roof, each zone was divided in half down its length. If an area was north-south running, an assessment of the east side and the west side was performed. An east-west running zone was evaluated on its north and south sides. A summary of these evaluations is given in Table 2-2.

The roof of an area was taken as a whole with regard to longitudinal or vertical fractures. A few vertical fractures may be an indicator of advancing deterioration, but they do not constitute reason for immediate remediation. Areas containing vertical fractures are closely monitored both mechanically and visually. The type and extent of these fractures will affect the ground control system chosen for a given area. An area with only a few longitudinal fractures could probably be supported with a standard bolt system; whereas, an area with extensive, connected fracturing, suggesting a breakup of the beam, might require a more extensive supplemental support system. The ratings of each zone with respect to fracturing are presented in Table 2-2.

Areas receiving higher numbers, based on the visual assessments, warrant closer monitoring. In these cases, the ground conditions are monitored more frequently, and
additional instrumentation is installed when appropriate. At a minimum, areas with a
long-term projection rating of “3” are formally reviewed quarterly, those with a “2” are
reviewed semiannually, and those rated as “1” are reviewed annually. When it is
determined that ground conditions have reached a point where a safety hazard could
develop in the short term, mitigation actions are implemented.

3.4 Observation Borehole Data

The presence of horizontal offsetting (visible in boreholes) confirms lateral movements
in the roof beam. Horizontal offsets occur in association with low-angle fractures and at
clay seams. The greatest rate and magnitude of the observed offsets is near the ribs,
and they generally decrease toward the longitudinal centerline of the room. Initially,
the portion of the borehole from the collar to the offset moves toward the center of the
excavation. It is not unusual for a highly fractured area to exhibit significant asymmetric
lateral movement. For example, if low-angle fracturing on one side of the room extends
to the first clay seam, the entire beam may move toward that side of the room.

A majority of rockbolt failures are related to the lateral movement of the roof beam.
Most of the rockbolts at WPP penetrate the first clay seam above the roof. Analysis of
data from observation holes, offset-load testing of rockbolts, borehole camera
investigations, and recording of failed rockbolts assists in understanding the
relationship of stratigraphic offsetting with rockbolt failure.

3.5 Geotechnical Instrumentation Data

The purpose of the geomechanical monitoring program is to provide in situ data to
support continuing assessments of the behavior of the underground facilities.
Specifically, the program provides:

- Early detection of conditions that could compromise operational safety.
- Evaluation of room closure that could affect operational performance.
- Guidance for design modifications and remedial actions.
- Data for interpreting the actual behavior of underground openings, in comparison
  with established design criteria.
- Data on which to base an accurate assessment of the mechanisms of deformation
  and fracturing that is taking place.
- Compliance requirements as specified in the Regulatory Permit Application.
Geotechnical data collected from each specific ground control zone are evaluated to determine if conditions exist which would warrant closer attention or possibly immediate attention from a ground control standpoint. For the long term, roof expansion rates, along with the expected life of a zone, are important criteria to be considered when selecting ground control measures for that area.

Manual and remote measurements of roof-to-floor and rib-to-rib closure are taken throughout the underground on a routine basis. In addition to closure data, extensometer data are also collected. Extensometer data, combined with information from observation holes, assist in the analyses of separations at clay seams and within salt beams (beam expansion). For the purpose of this document, a comparison of closure rates is performed annually. An increase in the closure rate does not necessarily indicate a problem but draws attention to that area and provides an additional data point for evaluation. A summary of this assessment is presented in Table 2-2; a “Y” (yes) indicates that the measured closure rate at any convergence point within the area has increased more than 5 percent for the annual period ending October 31, 2000, as compared to the annual period ending October 31, 1999.

3.6 Rockbolt Failure Data

Rockbolt failures have occurred throughout the underground facility. Initially, many of the failures were bolt head failures. The majority of current bolt failures are shaft failures associated with lateral movement at clay G in conjunction with tensile loading. In addition, the majority of the bolt failures previous to this year involved mechanical-anchor rockbolts, which were primarily related to their age, quantity, and date of installation with respect to date of excavation. However, systems employing threaded-bar bolts, particularly in Parcel 1, are aging, and failures of these bolt types have increased and were involved in the majority of failures this year.

Observable rockbolt failures are recorded, and a database on failure locations and modes of failure is maintained. Much has already been learned from the analysis of past bolt failures, and as the information base increases, so does understanding of the failure mechanisms involved. Documentation and tracking of these failure patterns assist in short- and long-term ground control planning by highlighting problem areas. This system also provides a means by which to identify trends of bolt failures that may be correlated with installation methods, geometry, mining sequence, and other variables. Figure 3-1 presents a graphical representation of rockbolt failures by type. The overall reduction in bolt failures from 1995 to 1996 represented by the graph is
primarily a function of area closures. The increase in total failures in Calendar Year 2000 is a function of age of installed systems, increased closure rate in Panel 1 as a result of Panel 2 excavation, and failed bolts that were included from newly reopened areas in the north end of the facility.

In addition to tracking the rockbolt failures, a limited rockbolt failure investigation program was implemented. Studies have also been undertaken to address corrosion and loading effects on the premature failure of support system components.

Extensive testing has been performed on the types of rockbolts and rockbolt material used at WIPP [Lucas, 1984; Deoras, 1992; Chua and Lovato, 1994; Stoller Corporation, 1995]. These tests were conducted to determine the failure mechanisms associated with premature bolt failures and conditions that contributed to those failures.

Testing was performed to evaluate the effects of corrosion and its relationship to premature failures. The test results indicated that corrosion did not play a major role in the early failure of bolts (e.g., bolts with a life span of 5 years or less). However, the mechanical-cyclic stress loads the bolts are exposed to while they are under high tensile load (that load sometimes being in excess of the bolts yield limit) result in fatigue failure.
A materials evaluation of the mechanical-anchor-type rockbolts and the threaded-bar rockbolts used at WIPP revealed that there was considerable variation in content; for example, carbon content, from bolt to bolt. The variability in content is within design specifications; however, each bolt may respond differently, to some degree, under similar loading conditions.

3.7 Ground Support System Monitoring

Instrument monitoring of ground support systems is also an integral aspect of the ground control program. Typical ground control instrumentation in use includes load cells, strain gages, and joint meters. Yielding components, such as load indicators, slipnuts, pipe collars, and yielding rockbolts, provide additional monitoring capabilities.

3.7.1 Load Cells

Load cells provide a quantitative measurement of the axial load on individual rockbolts or individual components of a ground support system. Load cells are installed on cable systems used to support brow areas at the Waste Shaft and Air Intake Shaft (AIS) Station areas and the East-0 overcast. Load cells are also installed on rockbolt support systems in other areas of Panel 1, East-140, and in Room D. Load cells included in yielding support systems, such as the yielding cable bolt installations, monitor whether the systems are performing as intended (e.g., yielding at their designed loads).

3.7.2 Strain Gages

Supplemental bolt patterns were installed that incorporated systematic arrays of rockbolts equipped with strain gages. The strain gage data provide a variety of valuable information that includes evaluation of areal effects of creep-related closure loading on the ground control system, the ability to determine when the bolts reach their yield point, and comparison of strain gage data to load cell data.

3.7.3 Yielding Components

Yielding components, such as slipnuts, load indicators, pipe collars, and yielding cable bolts, are incorporated into several of the ground support systems in the facility. The primary purpose of these components is generally to allow for the system to yield with the creep-related deformation of the formation. However, because the components are designed to yield within specific load ranges, they also serve the function of providing...
an indication of the load on the system. These components are visually monitored to
determine the rate and degree of yield on the system.

3.7.4 Joint Meters

The joint meters used at WIPP serve primarily as a geotechnical tool (i.e., to monitor
fracture growth). However, a couple of meters have been incorporated into cable mesh
support systems to monitor strain in the cables.

4.0 GROUND CONTROL OPTIONS

The end objective of each ground control option is to provide safe, geotechnically
stable access for personnel and equipment. The options available to meet this
objective involve providing internal support (e.g., bolts of various kinds), external
support (e.g., cribs), or removing the roof beam. Closure of selected areas is an
administrative choice in lieu of ground control options. Simply stated, these options
are:

- Support the ground
- Remove the ground
- Close the area.

When evaluating these options, the criteria by which each option is judged include: the
degree of safety provided, the support capacity of the system, ease of implementation,
“life expectancy” of both the system and the area in which it is being implemented,
economics, the impact of the chosen method on waste emplacement, and the waste
emplacement schedule. It is important to appreciate the complexity of weighing these
criteria relative to the differing conditions experienced throughout the facility. It is also
important to understand that, although some of the options have no resource
constraints, others may be difficult to implement at given times. (For example, current
beam-removal activities were scheduled to follow excavation of Panel 2.)

The ground control program has produced an extensive database of information on
ground control systems that are related directly to WIPP. Monitoring of installed
supplemental systems continues to provide useful information for ground control
system selection. In addition to in situ testing, laboratory testing is employed, as
required, to evaluate alternative options for ground support.
4.1 Support Systems

With a few exceptions, all of the ground support in currently accessible areas of the underground is provided by internal systems. In general, internal support systems consist of pattern rockbolting. External support systems, such as cribs, have limited application at WIPP because of their operational constraints.

All normally accessible areas of the underground, except the South-90 electrical substation area, are currently rockbolted. Beginning in 1989, the entire facility was pattern bolted with mechanical-anchor rockbolts. Bolts 10 feet in length predominate, although some areas have been bolted with 5-foot, 6-foot, or 8-foot bolts. Within the mechanical rockbolt systems, a 5-foot x 2.5-foot triangular pattern is the most common in the WIPP underground.

More recent support system designs have focused on alternative types of rockbolts, primarily resin-anchored, threaded bar. Resin-anchored, threaded-bar bolts provide superior load-bearing capacity and ductility than the previously discussed mechanically anchored bolts. The threaded bars are anchored above the first clay seam to provide direct support of the roof beam and are commonly used in conjunction with mesh to contain smaller pieces of rock that may detach from the roof. The threaded-bar bolts may also be incorporated into a supplemental system of cable lacing or roof mats.

The primary purpose of pattern bolting is to support the roof beam or, more accurately, a portion of the roof beam, should it become detached as a result of fracturing. A variety of rockbolt patterns exists throughout the underground at WIPP. The design of the patterns is based on the width of the opening and the thickness of the roof beam. The effect of rock creep-related deformation on rockbolts creates a problem that is not common to standard ground support design practice.

Normally, a rockbolt pattern is designed so that the dead weight of the rock, with a factor of safety included, does not exceed the yield limit of the bolts. In rock such as halite, the mechanism of creep-related closure may put the bolts into yield as soon as 1 year after installation, regardless of the number of bolts installed. This may happen sooner if bolts are installed immediately after excavation, as the highest strain rates around a new opening are recorded immediately after the opening is excavated. These rates taper off to near steady state after approximately 1 year.
Creep also produces an offset of the strata at the first clay seam above the roof. The clay seam, with no inherent tensile strength, facilitates a separation between the roof beam and the strata above it. Different stress conditions above and below the seam produce differential strain rates, which result in an offset at the stratigraphic boundary. This offset eventually places a nonaxial load on the bolts that reduce their axial load capacity. The creep-related parameter in support system design complicates the selection process. In addition to the dead weight of the material to be supported, roof expansion rates, installation time with respect to excavation date, offset, and bolt load/elongation properties must be considered in any support design.

Several types and combinations of specialized support systems are incorporated at specific locations within the underground. Some systems are monitored and provide performance information and some systems are designed for specific ground control applications. A variety of yielding systems are in place in the underground as small-scale and full-scale test emplacements. Cribs have been used to a limited extent in areas currently closed to access. Cribs have been placed at the perimeter of closed zones to limit the extent of a roof fall that may occur in areas where continued ground control activities are no longer being performed.

4.1.1 Brows

Brows throughout the facility are provided with supplemental support when there is visual evidence of separation. Wooden cribbing has been used in areas where access was not a problem. Roof mats and wire-rope cable systems are installed on some brows at shaft stations and overcasts to provide additional support. Closure stations are installed on several brows to detect any acceleration in movement that may indicate a need for additional support.

4.1.2 Control of Broken Bolts

In high-use areas and areas where bolt breaking is being observed, Underground Operations provides a secondary attachment of the rockbolts to the roof. A lanyard (safety wire, cable, or chain) is installed on the rockbolt to prevent it from falling to the floor should it fail. Geotechnical Engineering is assisting Underground Operations in evaluating different techniques to secure broken bolts.

The failure of rockbolts in the underground is a common experience, averaging two to three a day. Because of the safety factor calculated into the ground support design, a substantial number of bolts would have to fail before the integrity of the system would
come into question. Therefore, the failure of a rockbolt does not pose a hazard from a ground control standpoint. However, there is a potential hazard associated with personnel or equipment being struck by a falling bolt. Over the years, several different methods of controlling the falling bolts have been employed, with varying degrees of success. Methods used have included expanded metal wire mesh to hold the bolt in place and various lanyards made of wire, chain, or steel cable to catch a broken bolt. The wire mesh method made it difficult or impossible to identify when a bolt had failed. In most cases, the lanyards appear to work well and make identification and removal of a broken bolt relatively easy. A test matrix was developed to evaluate and document the performance characteristics of various lanyard systems. This test matrix included:

- Classification of installed lanyard systems according to physical characteristics (e.g., cable length and diameter).
- Classification of installed lanyard systems according to method of attachment (e.g., nailed to roof or attached to wire mesh).
- Performance tracking of in-place systems.

As a result of the field testing process, a lanyard system has been identified that produces excellent results for the control of broken bolts. The system consists of stainless steel wire rope, 7 x 19 strand core, 1/8 inch in diameter. The wire rope is configured to a length of approximately 18 inches with loops at each end that will snugly fit on a bolt head. The wire rope is passed through a cable thimble in the existing wire mesh and both loops are attached to the head of the bolt.

4.1.3 Panel 1

Rockbolt support was installed in Panel 1 in 1988 using a design based on the requirements for the demonstration program then prescribed. The original plan consisted of the storage of drums of contact-handled transuranic (CH TRU) waste in rooms for a period of 5 years. During this time and immediately following, the rooms were to be inaccessible, but the option to reenter was to be maintained so that the waste could be removed, if required. To assist with the possible reentry and to enhance stability, mechanically anchored rockbolts were installed. Ten-foot-long rockbolts were installed in Rooms 1 through 6, and 6-foot rockbolts were installed in Room 7, South-1600, and South-1950.

In 1991, a supplementary roof-support system was designed and installed in Room 1 to facilitate a planned bin-scale test program. A detailed description of the supplementary
system is presented in the Waste Isolation Pilot Plant Supplementary Roof Support System Underground Storage Area Room 1, Panel 1 [U.S. Department of Energy, 1991b]. Subsequently, additional ground support was installed in all of the Panel 1 rooms and drifts. Primary ground control activities in Panel 1 in the past year has been replacement of failed rockbolts. The roof-support history of Panel 1 is important because information on the age of the openings and when ground support was installed is vital to making predictions about future ground support requirements. A chronology of additional support systems and year of installation in Panel 1 is presented in Table 4-1.

Floor preparation is a planned activity in support of waste emplacement. Floors will be trimmed to provide a flat smooth working surface and to reestablish the appropriate working clearances. As an example, in the case of Room 7, more than 2 feet of floor was removed using the continuous miner. Removing this amount of material required a transition ramp down into the room.

4.2 Removal of the Roof Beam

The removal of the roof beam is not a support system but a mining alternative to ground support. The removal of the beam up to the next competent layer is considered when adequate support cannot be provided in a cost-effective manner or if removal of the beam will result in a safer working environment. In existing drifts with anticipated long lives, creep closure may ultimately require additional excavation to maintain operational clearance. Field results of the beam removal in the East-140 Drift proved this to be a viable alternative in areas of advanced beam deterioration. Observations, in the form of displacement measurements and fracture mapping, support the concept of removing the roof beam to enhance stability.

Table 4-1. Chronology of Panel 1 Ground Support

<table>
<thead>
<tr>
<th>Year of System Installation</th>
<th>System Description</th>
<th>Area of Installation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>Ten-foot-long mechanical-anchor rockbolts</td>
<td>Rooms 1, 2, 3, 4, 5, and 6</td>
</tr>
<tr>
<td>1988</td>
<td>Six-foot-long mechanical-anchor rockbolts</td>
<td>Room 7, South-1600, and South-1950</td>
</tr>
<tr>
<td>1991</td>
<td>A layered support structure of welded wire mesh, expanded metal, channel steel, and threaded-bar bolts</td>
<td>All of Room 1</td>
</tr>
<tr>
<td>1992</td>
<td>Variation of Room 1 system</td>
<td>Parts of Room 2</td>
</tr>
<tr>
<td>Year</td>
<td>Description</td>
<td>Location</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>1994</td>
<td>Supplemental system of 13-foot-long No. 7 threaded bar with full-load nuts</td>
<td>All of Room 7 and the South-1600 Drift</td>
</tr>
<tr>
<td>1994</td>
<td>Supplemental system of 13-foot-long No. 7 threaded bar with slip nuts</td>
<td>North half of Room 4</td>
</tr>
<tr>
<td>1994</td>
<td>Supplemental System of 12-foot-long No. 7 threaded bar with full-load nuts</td>
<td>All of Room 5</td>
</tr>
<tr>
<td>1995</td>
<td>Supplemental System of 12-foot-long No. 7 threaded bar with full-load nuts</td>
<td>South half of Room 4 and all of Room 6</td>
</tr>
<tr>
<td>1996</td>
<td>Supplemental system of 13-foot-long No. 7 threaded bar with full-load nuts</td>
<td>All of Room 3</td>
</tr>
<tr>
<td>1997</td>
<td>Cable slings (wire rope cables run from rib to rib)</td>
<td>Room 6 and Room 7</td>
</tr>
<tr>
<td>1997</td>
<td>Supplemental system of 13-foot-long No. 7 threaded bar with full-load nuts</td>
<td>South 1950 (except between Room 6 and 7)</td>
</tr>
<tr>
<td>1998</td>
<td>Wire rope lacing in conjunction with 13-foot-long No. 7 threaded bar with full-load nuts</td>
<td>Room 7 and South 1600 and 1950 between Rooms 6 and 7</td>
</tr>
<tr>
<td>1998</td>
<td>Cable slings</td>
<td>Center half of Room 5</td>
</tr>
<tr>
<td>1998</td>
<td>Cable slings</td>
<td>Center half of Room 4</td>
</tr>
<tr>
<td>1999</td>
<td>Cable slings</td>
<td>South 1600 Between Rooms 3 and 4</td>
</tr>
<tr>
<td>2000</td>
<td>Supplemental system of 12-foot-long No. 7 threaded bar with full-load nuts</td>
<td>South entry to Room 1</td>
</tr>
<tr>
<td>2000</td>
<td>Cable slings</td>
<td>Remaining areas of South 1600 between Rooms 1 and 6</td>
</tr>
</tbody>
</table>

Beam-removal actions at WIPP have been very successful in accomplishing their prime objective of removing highly fractured ground resulting in a competent roof requiring significantly less ground control maintenance activities. Monitoring results during beam removal in the East-140 Drift indicate that the newly created roof was geotechnically stable and essentially fracture free. In addition, the beam-removal actions provided for operations and geotechnical opportunities that included the following:

- Documentation of removal techniques that prove that the roadheader can mine through threaded bars, bolts, and cable bolts without major difficulty.
- Mapping of roof-beam fracture patterns that confirmed failure modes and mechanisms.
- Observation and evaluation of in-place round support as it was exposed, showing the reaction of various components to beam expansion and stratigraphic offset.
• Evaluation of the inherent stability of the fractured beam after support systems were removed, indicated by the fact no that roof falls were encountered during mining activity.
• Creation of a competent roof verified by extensometer data and physical observations.

Beam-removal operations are currently in progress in the East-0 Drift north of the salt-handling shaft.

4.3 Area Closure

Exercising the option to close an area instead of providing ground support involves administrative decisions as opposed to engineering solutions and, therefore, involves minimal labor and material costs relating to ground control. This option generally applies to areas that have reached the end of their useful life, or that, from an economical and/or safety standpoint, it is more prudent to close than to maintain. Closure of areas of the facility has been exercised in the past (e.g., all areas north of North-780). The option to close select areas of Panel 1 if safety becomes a concern was first formally noted in the 1994 Panel 1 Utilization Plan [Westinghouse Electric Corporation, 1994] and remains viable.

Consideration must also be given to the logistics of reopening an area if reopening is anticipated. For example, areas north of North-780 were reopened to facilitate salt disposal during mining of Panel 2.

5.0 SUPPORT PROJECTIONS

Based on the opening assessments and projections made in Chapter 2.0, areas of concern are identified. They include areas that are operationally critical or exhibiting advanced deterioration as compared to other areas. Panel 1 is given special attention in these projections because of its unique requirements with respect to waste emplacement and the waste emplacement schedule. Table 2-2 lists time projections for support requirements. (A "3" indicates that work is projected to be necessary within 1 year; a "2" indicates that work may be necessary within 5 years; and a "1" indicates that no work beyond normal maintenance is anticipated in the foreseeable future – within 5 years.)
In general terms, where reinforcing of existing support is required, a point-anchored, threaded-bar bolt pattern with full-load anchor nuts will be used to supplement the existing pattern. However, cable bolts may be used where the headroom or clearance in a drift is reduced to the point where bending or coupling of threaded bars would be required for installation. In critical areas where cantilevering or fracturing of the beam is observed, a roof mat system may be used, generally in conjunction with the roof-bolt system. If an opening is projected to be closed to access within a short time, mechanical bolts may be used to reinforce the existing support. New excavations will probably be pattern bolted after the initial high creep response has passed (usually 1 to 3 years after excavation, depending on the opening geometry and nearby excavation). Specific plans and layouts will be prepared and will be based on a detailed evaluation of each area.

5.1 **Area Projections (Excluding Panel 1)**

Following are tentative support projections for specific locations in the underground. These projections are intended to provide planning guidelines for future work. Detailed designs will be prepared as necessary for construction. These support recommendations are based on a continued need to access these areas (i.e., unused rooms will not be abandoned or backfilled).

5.1.1 **East-0 and East-140 — North-150 to North-1400**

This area was excavated over 15 years ago and has deteriorated to the point where it became necessary to install supplementary support, remove the highly fractured roof beam, or close portions of the area. From a technical standpoint, each option was acceptable to provide long-term safety. Removal of the roof beam in these areas has been approved and is in progress.

The beam is being removed up to and including Anhydrite “b” using a continuous mining machine. Based on current plans, the crosscuts at North-460, North-620, North-780, North-1100, and North-1400 will also have the beam removed.

5.1.2 **Air Intake Shaft Station**

The inspection of this area indicates that the upper brow appears to be stable at this time. The lower brow is developing separation fractures. Because the rockbolts in place are only 6 feet in length and do not penetrate the first clay seam, it may be necessary to provide additional support in the station area in the form of a
supplemental bolt pattern that does penetrate the clay seam. This will probably be necessary within the next 1 to 3 years. Details include:

Bolts: Yielding cable bolts rated to yield at 45,000 pounds, 14 feet in length, in 1 3/8-inch x 14-foot holes.

Pattern: Split existing pattern

5.1.3 Air Intake North Access (North-300 and North-215)

Because of the development of low-angle fracturing in these drifts, it is projected that it may be necessary to rebolt the area within 5 years. Projected details for the rebolting project follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch x 14-foot borehole.

Pattern: Split existing pattern

5.1.4 East-140 — North (North From the Waste Shaft Station)

South-90 to South-400

Increased fracturing in this area may require some supplemental support in the next 1 to 3 years. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch x 14-foot borehole.

Pattern: 5-foot x 5-foot nominal square pattern

Mesh: Chain link

South-90 to North-150
Increased fracturing in this area may require some supplemental support in the next 3 to 5 years. Projected details follow:

**Bolts:** No. 7 threaded bar with full-load nuts, 13 feet long, in 1 3/8-inch x 12.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch x 14-foot borehole.

**Pattern:** 5-foot x 5-foot nominal square pattern

**Mesh:** Chain link

### 5.1.5 East-140 — South (Access to Disposal Panels)

Roof beam removal was completed from South-1000 to South-1950 and the new roof remains in excellent condition.

#### South-400 to South-700

Increased fracturing in this area may require installation of supplemental support in the next 3 to 5 years. Projected details follow:

**Bolts:** No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch x 14-foot borehole.

**Pattern:** 5-foot x 5-foot nominal square pattern

**Mesh:** Chain link

#### South-1950 to South-2050

This area was rebolted in 1998 using threaded bars concentrated in the drift center. However, fracturing in the area coupled with the load transfer resulting from mining in Panel 2 and its entries may require some added supplemental support in the next 1 to 3 years. Projected details follow:

**Bolts:** No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond
the first clay seam (installed in 1998 and to be maintained as primary support).

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch x 14-foot borehole.

Supplemental support as follows:

Mesh: Chain link

Strapping: Roof mats or cable slings on 5-foot to 6-foot intervals running from rib to rib

South-2050 to South-2180

This area may require some supplemental support in the next 1 to 3 years based on conditions and history in the adjacent areas as well as the potential for load transfer from the mining activities in Panel 2 and its entries. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch x 14-foot borehole.

Pattern: 5-foot x 5-foot nominal pattern concentrated along the drift center

South-2180 to South-2520

This area may require some supplemental support in the next 1 to 3 years based on conditions and history in the adjacent areas as well as the potential for load transfer from the mining activities in Panel 2 and its entries. Projected details follow:

Bolts: Mechanical-anchor rockbolts, 10 feet long.

Pattern: 5-foot x 5-foot nominal square pattern

Mesh: Chain link

A similar system of mechanical-anchor rockbolts may be used in the areas of East-300, West-30, and West-170 between South-2180 and South-2520.
5.1.6 Waste Shaft Station (East-140 to Waste Shaft)

Because of salt creep and loss of pattern bolts in this area, it is anticipated that the support system in place will need to be augmented within 1 to 3 years. A supplemental system consisting of pattern bolting with threaded-bar bolts may be employed. Details follow:

- **Bolts:** No. 7 threaded bar with full-load nuts, 12 feet long, in 1-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.
- **Pattern:** Split existing pattern
- **Mesh:** None beyond the chain link already in place

5.1.7 Salt Shaft Station

The Salt Shaft Station had the roof beam removed approximately 12 years ago. The geotechnical monitoring in this area indicates that the roof has remained stable since that time. However, small vertical fractures have been observed and the current in-place rockbolts do not penetrate the existing roof beam. Because this is a high-use area, it may be prudent to install some additional bolts as a preventative maintenance measure within 3 to 5 years. The most likely supplemental support alternative would be to install No. 7 threaded-bar bolts through the existing chain link mesh.

5.1.8 West-30, South-1300 to South-1600

Because the pattern bolts in this area do not penetrate the beam, rebolting of this area may be, but is not anticipated to be, necessary within 5 years. Support, if required, will be provided by splitting the existing pattern with threaded-bar bolts or yielding cable bolts. At the present time, continued observation is recommended.

5.1.9 West-30, South-90 to South-400

It is anticipated that some supplementary support will be necessary in this drift within a couple of years because of fracturing observed in the area. Projected details follow:

- **Bolts:** No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

42
Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

5.1.10 West-30, South-1150 Booster Fan Area

Removal of the booster fans is planned for this area. The angled rows created during the installation of the fans are not typical of most brows at WIPP. It is planned that the brows will be reshaped with a mechanical scaler as necessary to form a more stable configuration. Rockbolts will be installed in the new brow and roof as required following removal of the booster fans.

5.1.11 South-1000 Crosscut Between West-30 and West-170

This is a high-use area and may require some supplemental support within 5 years. Projected details follow:

Bolts: No. 7 threaded bar, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

5.1.12 South-1300 Crosscut Between West-30 and West-170

This area was rebolted with threaded-bar bolts approximately 1 year ago. However, this area is used as a mechanical shop and creep closure is limiting hoisting capabilities and overhead clearance. Beam removal for this area is being considered to eliminate these problems. The schedule for beam removal in this area is dependent on the schedule of ongoing beam removal operations.

5.1.13 South-1600 Crosscut Between West-30 and West-170

This area may require some supplemental support within the next 5 years. Projected details follow:
Bolts: No. 7 threaded bar, 12 feet long, in 1 3/8-inch x 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch x 14-foot borehole.

Pattern: 5-foot x 5-foot nominal square pattern

Mesh: Chain link

5.2 Panel 1 Support Options and Plans

The schedule for the sustained rate of receipt, is a crucial parameter in making ground control decisions relative to Panel 1. Because of the age of the panel and the continuing deformation taking place, the timing of waste emplacement will affect the support requirements relative to each room. Ground control plans remain flexible with a long-term, conservative focus. The plans presented in this document are based on the most recent schedule and budget assumptions provided by the Department of Energy Carlsbad Field Office. Significant deviations in the anticipated schedule for receipt of waste can affect ground control preparation and other predisposal activities in two basic ways: (1) if the waste receipt schedule is accelerated, there may not be adequate time to install ground support systems as planned and (2) if the schedule is delayed, the ground control methods planned may not be adequate to sustain the ground without additional measures relative to the new time frame.

From a purely technical standpoint, the ability exists to maintain Panel 1 for waste emplacement for an indefinite period of time. However, the economics and potential operational impacts of this scenario may make it less desirable over time.

5.2.1 Panel 1 Support Options

With receipt of waste, ground control activities are integrally related to waste receipt schedules and related operational considerations. This section provides options for panel usage and the ground control alternatives required to implement those options. Evaluation of specific areas and recommendations for remedial ground control procedures must be made in a time frame that allows for implementation of those procedures prior to waste emplacement. Under all options, general maintenance activities, such as scaling down small pieces of rock and replacing identified broken bolts, would continue in all accessible areas. The identified options are:

- Use all of Panel 1.
- Use as much of the Panel 1 as possible.
- Move to Panel 2 as soon as possible.

In the case of several of the options and alternatives, significant overlap exists. For example, the current plan, consistent with the 1994 Panel 1 Utilization Plan [Westinghouse Electric Corporation, 1994] and the subsequent 1996 update of that plan [Garcia, 1996] is to receive waste in Panel 1 and use as much of the area as possible. Portions of the panel may not be used or substantial efforts may be necessary to maintain the required ground control. A detailed description of options and alternatives can be found in the Long-Term Ground Control Plan for the Waste Isolation Pilot Plant [Westinghouse Electric Corporation, 1998].

5.2.2 Panel 1 Support Plans

Supplementary support is installed in most locations of Panel 1. (The now closed test alcoves and the entries to the panel are excluded.) The active support system in Room 7, including those portions of South-1600 and South-1950 east of Room 6, is a pattern of threaded bars installed through wire ropes laced together and covering a welded wire mesh grid. Similarly Rooms 3 through 6 and the South-1600 and South-1950 Drifts have patterns of threaded bars installed through welded wire mesh panels. Wire rope slings are installed in parts of Rooms 4 through 6. Most areas in Rooms 1 and 2 are bolted with threaded bars through steel channels with cable and mesh.

Numerous scenarios relating to ground response and waste receipt and emplacement rates have been considered to allow better planning and response to conditions that may be encountered. With some flexibility, it is believed that any developing instability or ground control problem can be addressed and safe operations maintained. Detailed plans address expected ground response, emplacement rates that allow filling of the panel by May 2002, as well as the possibility of schedule delays. By necessity these plans are specific, but remain flexible to better accommodate response to changing ground conditions, time constraints, resource availability, economics, and ground support technology improvements.

**Room 7 Detailed Plans:** This area is prepared to and is receiving waste. The floor was milled and the active support system was installed to provide maximum life with minimal maintenance during the waste disposal sequence. Given the current waste disposal schedule, no further support is planned for this area. The existing system should
provide safe and adequate support for several years. However, if waste receipt is delayed or emplacement rate is slow, the existing system may be maintained by replacing broken bolts and adjusting the lacing. There are no plans to replace this system with another system. If delays are long or the waste emplacement rate slow, the system may be further augmented by installing additional bolts through the cable lacing (e.g., cable bolts anchored above anhydrite “a”). If maintenance must be performed after waste is present, radiological safety will be a prime consideration in the operation.

Rooms 3 through 6 Detailed Plans: The existing systems will be maintained by replacing broken pattern bolts as necessary until near the time that a room is needed for waste disposal. In the months immediately prior to waste disposal in each room, the floor will be milled or mined to meet operational height requirements and a new bolt and roof mat support system will be constructed. The new system will incorporate existing components already in place (i.e., mesh and wire ropes) and new bolts. The roof mats will be run perpendicular to the rooms longitudinal axis. It is planned that the roof mats will be supported with five threaded-bar bolts in the center and one mechanical-anchor bolt on each end. Timing of the construction is a function of waste receipt date and emplacement rates. If disposal rates proceed as expected, no further construction or maintenance should be necessary. If first receipt of waste is delayed substantially or if waste emplacement rates are retarded, it may be necessary to install some additional support prior to preparation for disposal or to consider mining the roof beam or closure of the room.

Rooms 1 and 2 Detailed Plans: The existing systems will be maintained by replacing broken bolts as necessary. This will continue until the room is needed for disposal. In the months preceding commencement of disposal operations in the room, the floor will be milled or mined; areas where a supplementary support system has not yet been installed will have a system similar to that described for Rooms 3 through 6, and excessively long bolt tails will be trimmed. A supplemental system may be installed to ensure stability with minimal maintenance during emplacement operations. As with other rooms, if first receipt of waste is delayed substantially or if waste emplacement rates are retarded, it may be necessary to install some additional support prior to preparation for disposal or to consider mining the roof beam or closure of the room.
5.3 **Panel 2 Plans**

At normal operating (waste throughput) rates, rock bolting in Panel 2 may only be required locally. Spot bolting using shorter mechanically anchored bolts will be used as necessary if spalls or loose ground are encountered during and after the mining process. Mesh may be used in conjunction with these bolts to secure any loose ground encountered during normal inspection processes. These bolts will not penetrate through to the next clay/anhydrite interface and will be anchored within the beam formed by the mine roof and the clay/anhydrite interface above. This is the primary or initial support that will be used in Panels 2 through 8.

As deteriorating ground conditions require, pattern bolting may commence at any time after excavation. However, based on experience with the SPDV rooms and the rooms in Panel 1, pattern bolting is not expected to be required until 2 to 5 years after excavation. Disposal rooms may be pattern bolted prior to waste emplacement. Pattern bolting will be designed using the best support technology available at the time. This may include the use of yielding systems or other systems not currently available.

Supplemental support systems are not expected to be necessary in Panel 2. However, should a supplemental system be required, it is anticipated that its design may be similar to those installed and planned for Panel 1.

5.4 **Long-Term, Low-Maintenance Areas**

In general, the remaining areas of the underground facility are in good condition, and it is anticipated that only routine maintenance, which includes scaling and spot bolting, will be necessary to maintain them over the next 5 years.

6.0 **SUMMARY STATEMENT**

This document is used for planning purposes only. Ground conditions at WIPP are dynamic and, as such, projections for ground control actions as presented in this plan may change. The schedule for receipt of waste also affects the projections as presented. Significant delays in the receipt schedule would most likely result in significant changes to current ground control plans. Geotechnical Engineering evaluates a wide variety of current and historical geomechanical and observational data to formulate these projections.
7.0 REFERENCES


Appendix VI

Unresolved Safety Question (USQ)
Safety Evaluation Worksheet
Attachment 4 - USQ Safety Evaluation Worksheet

1. IDENTIFICATION

USQ Evaluation Log Number: 00-052

Proposed Activity Number and Title (e.g., procedure number/title, ECP number/title, etc.):

OMNISita, a small Neutrino detection experiment at the WIPP in Carlsbad, New Mexico.

Proposed Activity or Issue Description:

See Attachment

Entry Condition: (Mark one condition, at most than one may be checked)

- Facility Hardware Modification
- Procedure Change
- New Operation (Test or Experiment)
- Potential Inadequate Safety Analyses (Discovery)
- As-found Discrepancy Between Physical Configuration and TSRs (Discovery)

2. REFERENCE INFORMATION

(Provide detailed answers to the following and attach to this completed worksheet.)

A. Identify Systems, Structures, and Components (SSC) involved.

B. Where is the process or SSC described in the SAR?

C. Reference location of other information used for the USQ Determination (Drawing, ECOs, TSR references, procedures, etc.)

3. IMPACT ON THE ACCIDENTS EVALUATED IN THE SAFETY ANALYSIS REPORT

(Provide detailed answers to the following and attach to this completed worksheet.)

A. Identify the applicable SAR accidents reviewed for potential impact by the change. (SAR Chapter 5 accidents)

B. Identify the applicable SAR event trees in Appendix D, "Determination of Frequency for Selected Accidents" corresponding to the identified accidents.

C. Discuss the impact of the change on the probability of occurrence of these accidents. (Change to basic event logic, initiating event logic, fault tree probability, life cycle estimates, etc.)

D. Identify the applicable SAR tables in Appendix E, "Source Term/Dose Calculations," corresponding to the identified accidents.

E. Discuss how the parameters and SSC affected by the change impact the consequences of these accidents (change the waste volume, magnitude of accident, material at risk, damage ratio, different release point, etc.).
4. POTENTIAL FOR CREATION OF A NEW TYPE OF UNANALYZED ACCIDENT

(Provide detailed answers to the following and attach to this completed worksheet.)

A. Identify potential initiating events resulting from the change which could result in the release of radioactive material. (Will the change or activity be in the proximity of the waste container? Does it affect the waste handling process? Consider changes which may indirectly affect the waste (e.g., placing compressed gas cylinders in waste handling areas which could become missiles).

B. Determine if the impact of this change could result in a new type of initiating event not previously identified (review the "hazard analyses", SAR Chapter 5, SAR Appendix C, and PHA).

C. Determine whether the hazards resulting from the impact of the change could be considered a new type of accident. (What would the hazard rank of the event be? Could the new event be bound by the existing accidents? What is the probability of the event occurrence?)

SUMMARY QUESTIONS
(Circle yes or no for each)

| YES | NO |
|-----------------------------------|
| Based on 3C above, does the change increase the probability of a SAR accident? | |
| Based on 3E above, does the change increase the consequences of a SAR accident? | |
| Based on 4C above, does the change create the possibility for a new type of accident not previously evaluated in the SAR? | |
| Does the change require a TSR Change? | |

EVALUATION RESULTS

| YES | NO |
|-----------------------------------|
| Does the proposed activity/issue result in a USQ or TSR change? (If the answer to any of the above summary questions is "yes," the change requires DOE approval) | |

COMPLETION

Evaluator: Dennis Hofer

Safety Analysis Independent Review: Concurrence Yes ☑ No ☐

Justification:

Safety Analysis Manager: Approval ☑ Disapproval ☐

Page 2 of 3
Attachment 4 - USQ Safety Evaluation Worksheet

<table>
<thead>
<tr>
<th>NRB:</th>
<th>Concur □</th>
<th>Nonconcur □</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe Action Required:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Printed Name</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
</table>
1. Proposed Activity or Issue Description:

The OMNIS (Observatory for Multiflavor Neutrinos from Supernovae) Collaboration proposes to assemble a small Neutrino detection experiment at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico called OMNISita. Such measurement will provide important input for our understanding of WIPP's suitability as the site for future supernovae detection experiments. See attached Project Description.

2. Reference Information:

1. The SSCs involved are the underground drifts in the West 170 and South 400 area of the Underground and the old Underground Core Storage Alcove area.
2. This is a new experiment not related to the Waste Handling process and is therefore not described in the SAR.
3. SAR Chapter 5 and Appendix C Hazop Session Summary.

3. Impact on the Accidents Evaluated in the Safety Analysis Report:

A. Reviewed Chapter 5 and Appendix C Hazop Session Summary. Chapter 5 accidents in the SAR (reviewed section 5.2.3) relate to the waste handling process and this experiment is not related to this process and has no potential impact to SAR Chapter 5 accidents.
B. SAR Appendix D Because this experiment is not related to the CH waste processes it has no potential impact on SAR Chapter 5 accidents.
C. This experiment will be performed in one location, in the Underground Core Storage Alcove at S400/W170 which is about 3000 feet from the waste. Additionally, the experiment will be located in the return Mine Operations ventilation split which is separated from the waste ventilation. Therefore, the proposed activity will not increase the probability of occurrence of SAR Chapter 5 accidents.
D. This experiment will not alter any source term or dose calculations as it is not related to waste handling and does not have any radioactive components other than small (1 inch) encapsulated calibration sources.
E. This experiment can not impact the consequences of these accidents (change the waste volume, magnitude of accident, material at risk, damage ratio, different release point, etc.) Because it is not related to or located near the waste handling process.

4. Potential for Creation of a New Type of Unanalyzed Accident

A. There are no potential initiating events resulting from this experiment which could result in the release of radioactive material. This is because the experiment has no radioactive material involved. This experiment will be performed in one location, in the Underground Core Storage Alcove at S400/W170 which is about 3000 feet from the waste and will not be in the proximity of any waste container. It does not affect the waste handling process. Nothing about this experiment may indirectly affect the waste (e.g., placing compressed gas cylinders in waste handling areas which could become missiles).
B. This experiment can not result in a new type of initiating event not previously identified because it is unrelated to the waste handling process and contains no radioactive material other than small (1 inch) encapsulated calibration sources.
C. There are no hazards resulting from the impact of the change which could be considered a new type of accident. The standard industrial hazards associated with handling of lead bricks and liquid scintillation fluid are discussed and mitigated in section five of the attached project description.