3.0 FACILITY DESCRIPTION

Chapter 3.0 provides technical information about those engineered systems at the Waste Isolation Pilot Plant (WIPP) disposal system that are important to meeting the disposal standards of Title 40 of the Code of Federal Regulations (CFR) Part 191. The U.S. Department of Energy (DOE) has specified a facility design that facilitates the rapid encapsulation of emplaced waste by creep closure of salt, forming a nearly impermeable barrier around the waste. In addition, the DOE has taken a defense in depth approach in the design of engineered shaft sealing systems to ensure the shafts will not become pathways for radionuclide release. Shaft seals incorporate multiple engineered materials and compacted crushed salt which will effectively reduce the permeability of the shaft-seal system to values near those of unexcavated intact salt. The DOE also employs backfill to chemically condition any brine that may reach the waste in order to reduce radionuclide solubility. Finally, the DOE will close each panel of waste with a panel closure system to provide for operational protection of workers, the public and the environment from emplaced waste. In addition, the panel closure system provides a long-term benefit to the performance of the disposal system. The DOE's choices of engineered barriers complement the natural barriers at the site that were key to site selection. These engineered barriers are incorporated in the conceptual model used for disposal system performance assessment described in Section 6.4.

In this chapter, descriptions are provided for the shafts, the underground waste disposal region and support facilities, and the engineered barriers as these are the only engineered systems germane to long-term performance of the disposal system. Information on other aspects such as general facility operations, waste handling and emplacement process, repository mining, ground control and the use of roof bolts, ventilation, transportation, emergency preparedness, training and maintenance are covered, as appropriate, in other WIPP documents such as the Final Environmental Impact Statement (FEIS) (DOE 1980), Safety Analysis Report (SAR) (DOE 1995), and the hazardous waste facility permit application, and other documents that are available from the DOE.

The facility has been divided into four areas designated for protection of human health and the environment: (1) the property protection area, which is surrounded by a chain-link security fence that encloses approximately 34 acres (13.7 hectares) and provides security and protection for all major surface structures; (2) the exclusive use area, which is approximately 277 acres (112 hectares) restricted exclusively for the use of the DOE, its contractors, and subcontractors in support of the project and posted against trespass and use by the general public; (3) the off limits area, which consists of approximately 1,454 acres (5.9 square kilometers) posted and managed as off limits by the DOE; and (4) the WIPP land withdrawal area, the 16-section (41.4-square-kilometer) federal land area under jurisdiction of the DOE and bounded by the WIPP site boundary (see Figure 3-1). The WIPP land withdrawal area is the controlled area for purposes of demonstrating compliance to 40 CFR Part 191. The waste area of the repository lies within the bounds of the off limits area, and within the WIPP land withdrawal area.

The amount of waste to be received at the WIPP is governed by the Land Withdrawal Act, which sets the total volume for contact-handled (CH-) and remote-handled (RH-) transuranic

(TRU) waste combined at a maximum of 6.2 million cubic feet (175,600 cubic meters). 6.2 million cubic feet technically corresponds to 175,564 cubic meters (see page 4-2) but will be routinely represented in this application with four significant digits. The Land Withdrawal Act restricts RH-TRU waste to a maximum activity of 23 curies per liter and not to exceed a total of 5.1 million curies (U.S. Congress 1992) (see Chapter 4 for a description of the waste). There is a volume limit of 0.25 million cubic feet for RH-TRU waste (DOE 1980, 1 – 5). The waste disposal area of the WIPP facility consists of eight panels, each of which contains seven rooms, and the access drifts and crosscuts adjacent to the disposal panels. This latter region has been labeled Panels 9 and 10 for convenience as shown in Figure 3-2. At the end of the operational period, the DOE will begin the process of sealing the shafts, which is a part of final facility closure.

Table 3-1 delineates pertinent site features of the WIPP facility.

Table 3-1. WIPP Site Features

Facility Name	Waste Isolation Pilot Plant (WIPP)
U.S. Environmental Protection Agency (EPA) Identification Number	NM 4890139088
Location	26 miles east of Carlsbad, New Mexico
Latitude	32°22'11"N
Longitude	103°47'30"W
County	Eddy
Section	15-22 and 27-34
Township	22S
Range	31E
Land Withdrawal Area	16 square miles (41.4 square kilometers)
Property Protection Area	34 acres (13.7 hectares)
Depth to repository horizon	2,150 feet below grade level (655 meters)

3.1 General Facility Design

The DOE has designed the WIPP facility to accomplish four primary goals:

1. to receive, handle, and dispose of TRU waste and TRU-mixed waste (in this document, the term TRU waste is used to describe both TRU and TRU-mixed waste unless otherwise noted);

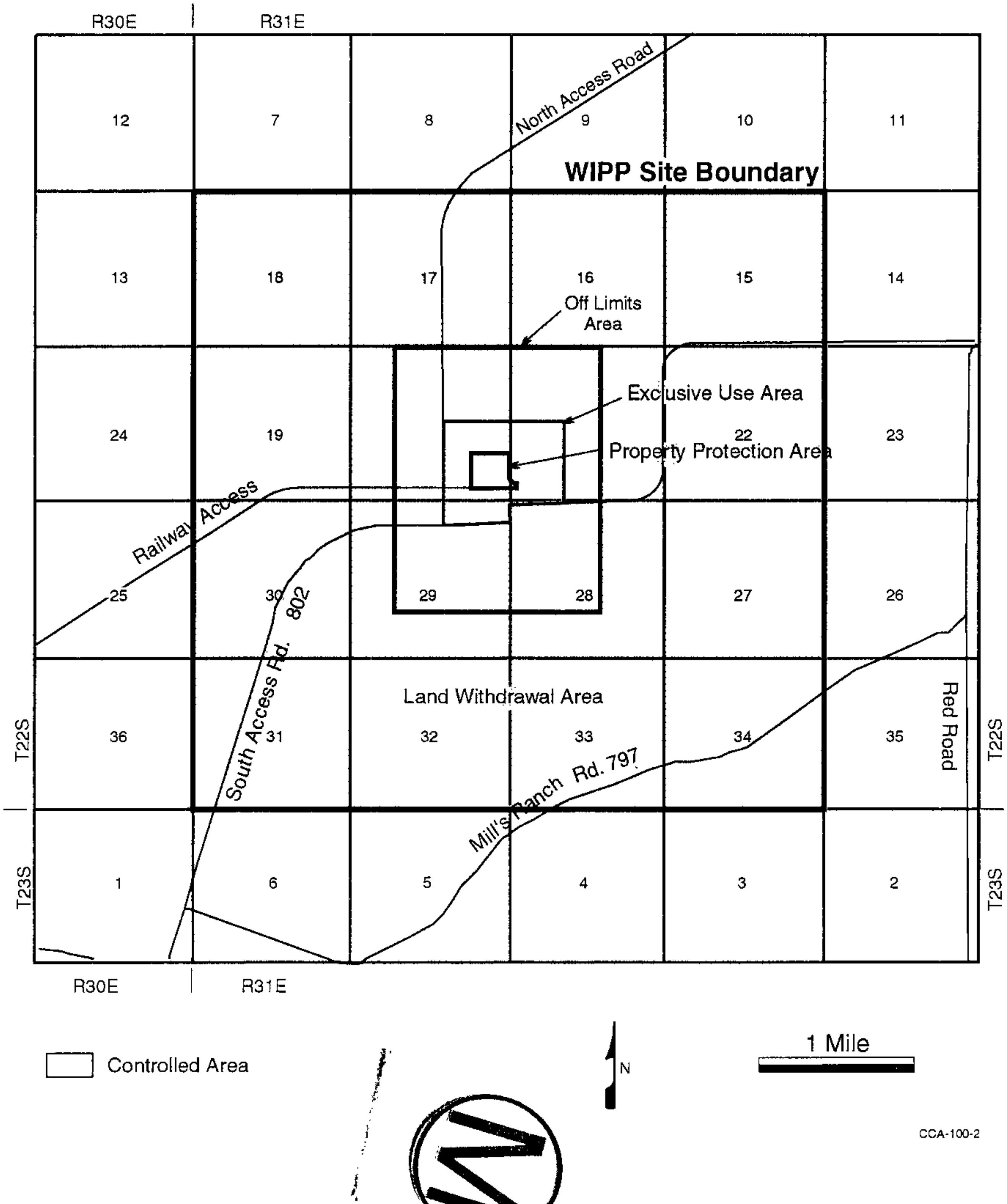

Figure 3-1. WIPP Property Sector Designators

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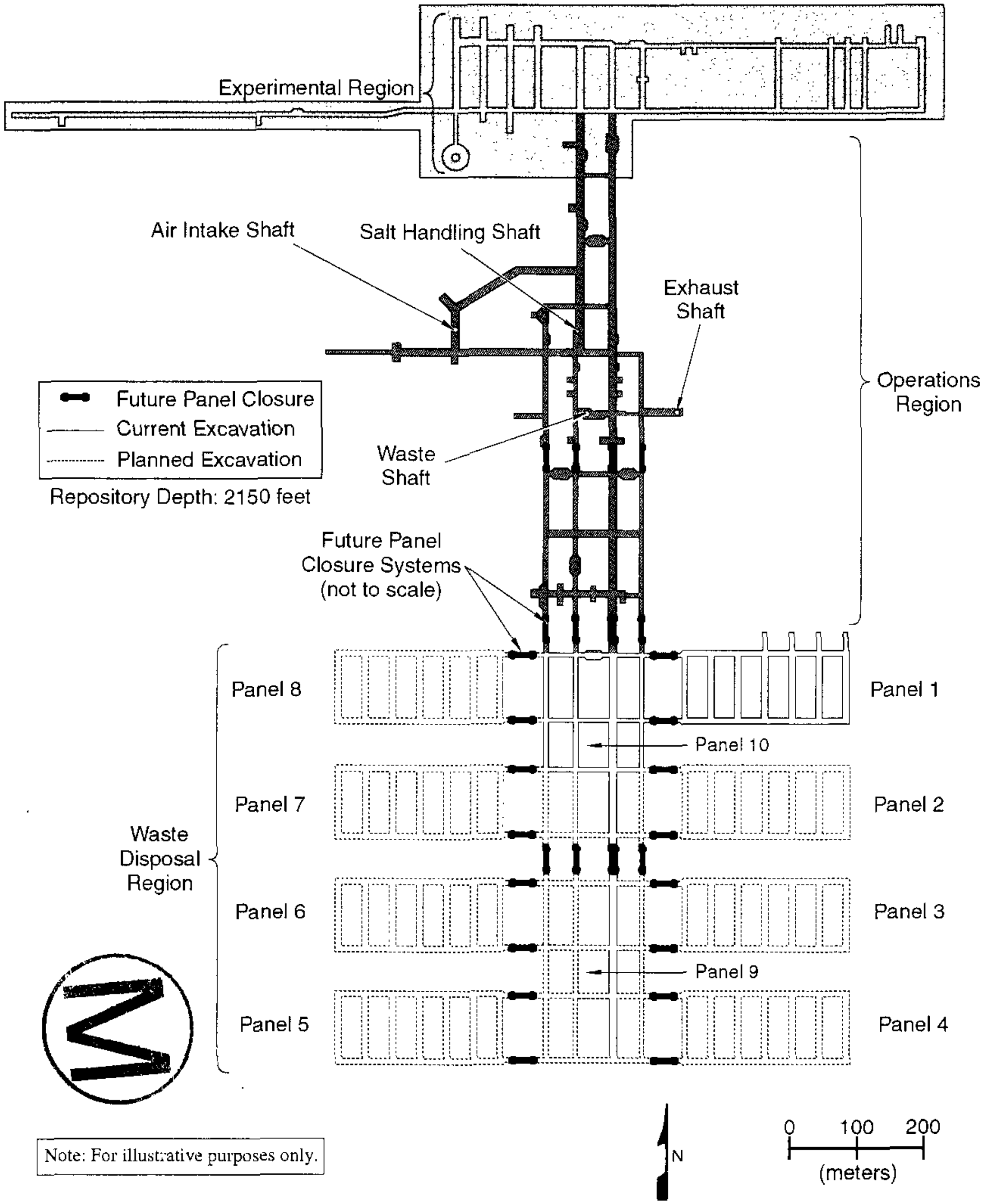

Figure 3-2. Plan View of WIPP Underground Facility and Panel Closure Systems

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2. to protect the health and safety of workers, the public, and the environment;

3. to comply with applicable radiation protection standards; and

4. to comply with other environmental statutes and regulations, and requirements of federal, state, and local agencies (as discussed in Appendix BECR).

The surface facilities at the WIPP accommodate the personnel, equipment, and support services required for the safe receipt and transfer of TRU waste from the surface to the underground. The surface structures are located within a perimeter security fence. This area is the property protection area on Figure 3-1. Access is controlled by security officers 24 hours a day. Four vertical shafts connect the surface facilities to the underground. The underground facilities include the

- waste disposal area,

- shaft pillar area, and

- associated support facilities.

Figure 3-3 provides a spatial view of the WIPP facility.

The DOE acquisition process that was used for the design and construction of the WIPP determined the steps and processes taken to assure that the WIPP was constructed consistent with applicable codes and standards. This process defined key activities and milestones that were applicable and specified such project management activities as initial and final design, independent review, acceptance testing, start-up, and quality assurance (QA). Additional detail is provided in the following sections.

3.1.1 DOE Facility Acquisition Process

Federal facility acquisition policies were applied to the design and construction of the WIPP facility. WIPP structures are designed to meet DOE design and QA requirements as documented in the Final Safety Analysis Report (DOE 1990b). Structures, systems and components are designed to meet the requirements applicable to Design Class II structures, systems, and components for nonreactor nuclear facilities. The design class designations are categorized in accordance with their importance relative to health and safety of the public and on-site personnel during plant operations.

3.1.2 Configuration Control

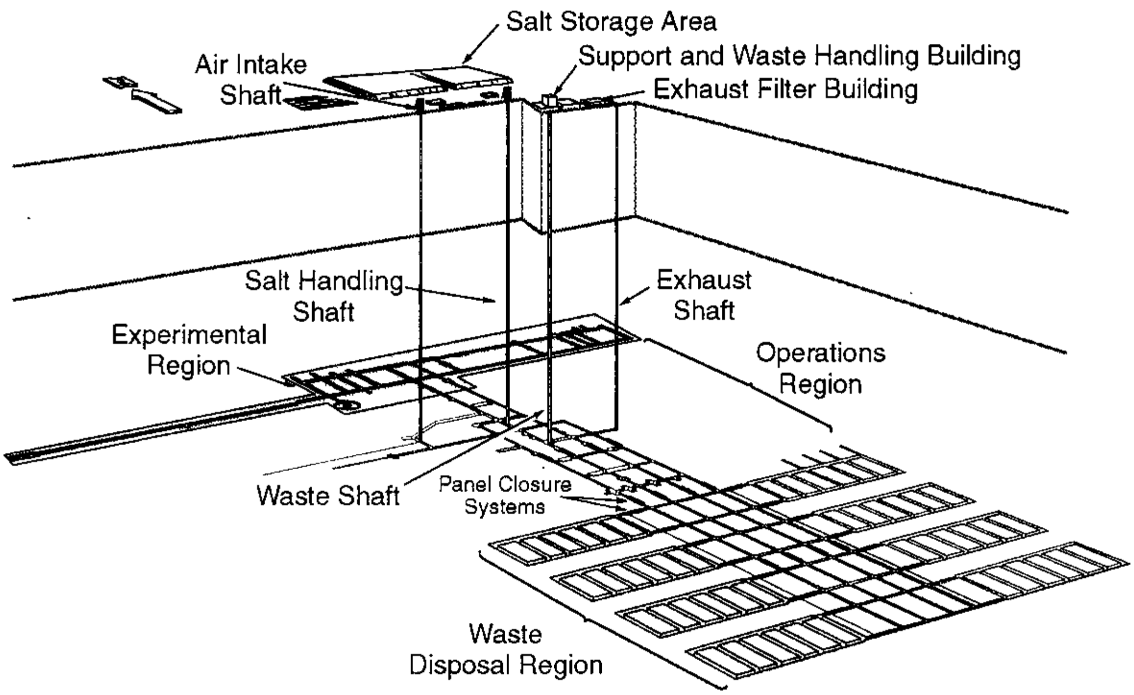
The DOE mandates that the configuration control of the WIPP facility be accomplished through written procedures and policies as set forth in DOE Orders and regulations. For example, the WIPP System Design Descriptions provide a framework for the configuration control. Any changes to the facility, and subsequently configuration documentation (design descriptions, as-built drawings, specifications, etc.), must be reviewed and approved by cognizant personnel. These documented reviews determine if the change will affect the ability of the facility to comply with applicable environmental, safety, and health requirements. The DOE must approve proposed changes that could affect the Safety Analysis Report and may elect to conduct an independent review of analyses supporting the change.

QA requirements applicable to WIPP facility design and configuration control activities are founded on the basic and supplemental requirements of the American Society of Mechanical Engineers' QA program requirements for nuclear facilities (American Society of Mechanical Engineers' NQA-1 1989). As discussed in Section 5.2, the DOE now implements these requirements through the CAO's QAPD, which is provided in Appendix QAPD. Design QA elements include (1) documentation, review, and approval of design inputs; (2) control of design analyses, design verification, and design changes; and (3) institution of design interface controls and records management practices. These and other applicable configuration management QA requirements are discussed in Section 5.1.6.

3.1.3 Surface Structures

WIPP surface structures accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of waste from the surface to the underground areas. These surface structures serve the operational functions of the WIPP and are not intended to serve long-term performance functions. The surface facilities are located in the Property Protection Area of approximately 34 acres (13.7 hectares) within the perimeter fence. The principal surface structure is the Waste Handling Building; other surface structures include the following:

- hoist houses,
- support building,
- guard and security building,
- office trailers,
- exhaust filter building,
- warehouse and shops,



Note: For illustrative purposes only.
Not to scale.

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Figure 3-3. Spatial View of the WIPP Facility

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- water pump house,
- training building,
- engineering building,
- core storage building,
- safety and emergency services building.

In addition to these structures, the DOE has employed a system of berms and ditches to divert storm-water runoff away from the surface facilities. The WIPP facility drainage system is designed so that storm runoff caused by the probable maximum precipitation event will not flood the WIPP facility (DOE 1995).

The WIPP facility does not lie within a 100-year floodplain. There are no major surface-water bodies within five miles (8 kilometers) of the site, and the nearest river, the Pecos River, is approximately 12 miles (19 kilometers) away. The general ground elevation in the vicinity of the surface facilities (approximately 3,400 feet [1,036 meters] above mean sea level) is about 500 feet (152 meters) above the riverbed and 400 feet (122 meters) above the 100-year floodplain. Protection from flooding or ponding caused by probable maximum precipitation (PMP) events is provided by the diversion of water away from the WIPP facility by a system of peripheral interceptor diversions. Additionally, grade elevations of roads and surface facilities are designed so that storm water will not collect on the site under the most severe conditions.

Repository shafts are elevated at least 6 inches (15.2 centimeters) to prevent surface water from entering the shafts. The floor levels of all surface facilities are above the levels calculated for local flooding due to PMP events.

The mean annual precipitation in the region is about 12 inches (30 centimeters), and the mean annual runoff is 0.1 to 0.2 inch (0.25 to 0.50 centimeters). The maximum recorded 24-hour precipitation at Carlsbad was 5.12 inches (13 centimeters) in August 1916. The 6-hour, 100-year precipitation event for the site is 3.6 inches (9.1 centimeters) and is most likely to occur during the summer. The maximum daily snowfall at Carlsbad was 10 inches (76 centimeters) in December 1923.

The WIPP facility design includes four shafts: the waste shaft, the salt handling shaft, the exhaust shaft, and the air intake shaft (AIS). Each shaft includes a shaft collar, a shaft lining, and a shaft key section. The shaft and shaft liner design information is discussed in detail in the Site Characterization and Validations studies from 1983 to 1987. The shaft design features have not changed.

The reinforced concrete shaft collars extend from the surface to the top of the underlying consolidated sediments. Each collar serves both to retain adjacent unconsolidated sands and soils and to prevent surface runoff from entering the shaft. The shaft linings extend from the base of the collar to the top of the salt beds approximately 850 feet (259.1 meters) below the surface. The shaft lining serves to inhibit water seepage into the shafts from water-bearing formations, such as the Magenta and Culebra members of the Rustler. The liners are also designed to retain loose rock. The shaft liners are concrete except in the salt handling shaft, in which a steel shaft liner has been grouted in place.

The shaft key is a circular reinforced concrete section emplaced in each shaft below the liner in the base of the Rustler and extending about 100 feet (30.5 meters) below and into the Salado. The shaft key functions to resist lateral pressures and to contain the water seals.

Two separate water-seal rings are incorporated in each key. Performance of the seals is monitored by inspection of the bottom of the key for seepage. If groundwater is detected flowing past the upper ring, this condition is corrected by injecting chemical sealants or cement grouts to stop the leakage.

On the inside surface of each shaft, excluding the salt handling shaft, there are three water collection rings. The first is located just below the Magenta interval, the second just below the Culebra interval, and the last at the lowermost part of the key section. These collection rings function to collect any groundwater that may seep into the shaft through the liner. Therefore, flooding of the WIPP repository as a result of PMP events is not a credible event because of the site-runoff design.

Flood-control structures are inspected as part of a general facility inspection at least annually. During this inspection, the structures are checked to assure that there has been no wind or rain erosion or animal-caused damage that would cause the structures to fail. Further, the areas around the structures are inspected to ensure they are free of vegetation, debris, or other items that would impede the diversion of water. Experience with these structures has shown that annual structural inspection are adequate for the climate and soil conditions at the WIPP facility; however, inspections are also conducted after severe natural events, such as severe storms or earthquakes.

3.2 Repository Configuration

A preliminary design of the WIPP repository was presented in the FEIS (DOE 1980). Validation efforts for the WIPP repository preliminary design began in 1981 with the Site and Preliminary Design Validation (SPDV) program. The SPDV program was implemented to further characterize and validate the WIPP site geology and to provide preliminary validation of the underground excavation. The SPDV program involved the excavation of four full-sized disposal rooms, excavated 13 feet (4 meters) high, 33 feet (10 meters) wide, and 300 feet (91 meters) long, and separated by 100-foot (31-meter)-wide pillars. Data obtained from geologic field activities and geomechanical instrumentation were analyzed to determine the suitability of the design criteria and design bases and to provide confirmation of the underground opening reference design. Analyses of these preliminary designs performed by the WIPP architect and engineer are included in Appendix DVR. These analyses considered expected creep closure rates in determining disposal room sizes. Information in Appendix DVR (Section DVR.6.4.2) meets the criterion specified in 40 CFR § 194.14(b)(2). Figures 12-21 and 12-22 in the Final Design Validation Report in Appendix DVR show the creep closure histories used for designing the disposal rooms. The specified size was selected to ensure no CH-TRU containers would breach due to creep closure while a panel is being filled with waste. A nominal five-year life is used for operational purposes for mining, emplacement, and closure with no risk of CH-TRU waste containers breaching. Remote-handled containers will not breach in this time period due to the canister wall thickness and the 2 to 4 inch (5.08 to 10.16 centimeter) creep tolerance in each RH-TRU emplacement hole.

The WIPP underground facilities are located on the repository horizon 2,150 feet (655 meters) beneath the surface (see Figure 3-2). In Chapter 2.0, Figure 2-8 shows a stratigraphic column which displays the repository and its position relative to mean sea level. These facilities include the waste disposal region, the operations region, an experimental region, and associated support facilities. The underground support facilities service and maintain underground equipment for mining and disposal operations, monitor for radioactive contamination, and allow limited decontamination of personnel and equipment.

Waste panels consist of seven rooms. Each room will have nominal dimensions of 300 feet (91 meters) long, 33 feet (10.1 meters) wide, and 13 feet (4.0 meters) high. Pillars between rooms are 100 feet (30 meters) thick. Eight waste panels will be separated from each other and the main entries by nominally 200-foot (61-meter) pillars. In addition to the eight panels, the main north-south and east-west access drifts in the waste regions are available for waste disposal. These have been designated Panels 9 and 10 for permitting and modeling purposes (see Figure 3-2). Section 6.4.2.1 describes the treatment of all waste panels in BRAGFLO. Additional information can also be found in Appendix MASS.5. Rockbolts, or related types of ground support, are used as necessary to maintain safe underground personnel access. In the panels, this will typically consist of localized bolting when needed. All panels will be closed using the panel closure system described in Section 3.3.2.

The underground is connected to the surface by four vertical shafts: the waste shaft, the salt handling shaft, the exhaust shaft, and the AIS. The waste shaft, salt handling shaft, and the air intake shaft have permanently installed hoists capable of moving personnel, equipment, and materials between the surface and the repository. All shafts will eventually be sealed using the seal design described in Section 3.3.1. A summary of information describing existing WIPP shafts is given in Table 4-2 of Appendix SEAL.

Mining of the shafts and underground passages within the repository gives rise to a disturbed rock zone (DRZ) that is important to repository performance. The DRZ forms as a consequence of unloading the rock in the vicinity of the excavation. Increased permeability is created by microfractures along grain boundaries and by bed separation along lateral seems.

The DRZ development begins immediately after excavation and continues as salt creeps into the opening. The DRZ surrounding the shafts is symmetrical and has been characterized and incorporated into the shaft seal design as discussed in Appendix SEAL. As shaft seal elements resist inward creep, the stress state becomes compressive and gives rise to fracture healing, and a return of the disturbed salt to its original extremely low permeability. The lateral DRZ along passages in the underground includes fracture in nonhalitic rock, such as anhydrite, and bed separation on clay seams. These zones will not naturally heal in a manner similar to healing of halite. Panel closure systems discussed in Section 3.3.2 will prevent further development of the DRZ in panel entries, thereby restricting flow from the panels to that existing in the DRZ at the time of panel closure construction.

3.3 Engineered Barriers

In addition to the natural barriers provided by the geology and hydrology of the disposal system, the DOE's design of the WIPP includes engineered barriers to significantly delay the migration of radionuclides to the accessible environment. These engineered barriers are integral parts of the disposal system as modeled in Section 6.4 and are included in the demonstration of compliance to the containment standards in Section 6.5. Because the WIPP uses the concept of multiple barriers, that is, both natural and engineered barriers, the requirements in 40 CFR § 191.14(d) are met. In addition, the incorporation of both engineered and natural barriers satisfies the criterion stated in 40 CFR § 194.44(a).

> Disposal systems shall incorporate engineered barrier(s) designed to prevent or substantially delay the movement of water or radionuclides toward the accessible environment.

The DOE has elected to incorporate four types of engineered barriers in the design of the disposal system:

(1) shaft seals,

(2) panel closures,

(3) backfill around the waste, and

(4) borehole plugs.

These four types of engineered barriers are described in the following sections.

Shaft seals and borehole plugs will limit migration of liquid and gases in the WIPP shafts and boreholes. Panel closures will limit the communication of brine and gases among waste disposal panels. Designs of shaft seals, borehole plugs, and panel closures use common engineering materials that possess low permeability, appropriate mechanical properties, and durability.

The DOE performed an Engineered Alternatives Cost/Benefit Study (see Appendix EBS) to examine the benefits and detriments associated with an array of engineered barrier alternatives. This study, in combination with past sensitivity and other analyses, was used to make a decision about an additional engineered barrier, a chemical backfill that will improve performance of the WIPP. The DOE has chosen an MgO backfill to buffer the chemical composition of brine that may enter the repository over the 10,000-year regulatory period. The principal beneficial performance characteristic resulting from this backfill is a reduction in actinide solubility in brine. Specific performance information on backfill is presented in Section 6.4.3.

3.3.1 Shaft Seals

The purpose of the shaft seal system is to limit fluid flow within four existing shafts after the WIPP is decommissioned. Such a seal system will not be implemented for several decades, but in order to establish performance requirements now that can be achieved at a later date, a shaft seal system has been designed possessing excellent durability, performance, and constructability using existing technology. The design approach is conservative, with redundant functional elements and various common materials. Because this design is not the only possible combination of materials and construction strategies that would adequately limit fluid flow within the shafts, future developments may change the design.

Material specifications and construction techniques for the shaft seal system are given in Appendix SEAL in Chapter 5 (Materials Specification) and Chapter 6 (Construction Techniques). Chapter 5 of Appendix SEAL also provides the rationale and quantification methods used to develop parameter distribution functions. Appendix SEAL also has Appendices A and B, which are materials specification and construction techniques, respectively. Appendix PAR provides a complete summary of parameters used as inputs to the performance assessment codes.

The presently envisaged shaft seal system is described in this section, including the configuration of material, seal material specifications, construction methods, rock mechanics analyses, and fluid flow evaluations.

The shaft seal design package in Appendix SEAL thoroughly explores function and performance of the WIPP shaft seal system and provides well-documented assurance that such a shaft seal system can be constructed using available materials and methods. Sections of Appendix SEAL provide hydrologic and structural calculations, material specifications and properties, construction methods, and engineering drawings. Documentation of material properties and their satisfactory application in the site-specific environment for regulatory time periods aid in assuring that the WIPP shaft seal system will meet performance expectations. Documentation of the analyses conducted and the results can be referenced in Appendix SEAL (Chapter 2.4 of Appendix A, and in Appendix SEAL, Chapter 3.1.2 of Appendix D).

3.3.1.1 Site Setting

The geologic setting and groundwater hydrology in the proximity of the WIPP site are presented in Sections 2.1 and 2.2. These sections describe low brine-flow quantities and low hydrologic gradients, both very positive features with regard to sealing shafts or boreholes. As noted in Section 2.2, one of DOE's site selection criteria was a favorable geologic setting that minimizes fluid flow as a transport mechanism. Although these positive hydrologic attributes are documented, the shaft seal design concentrates on further mitigating fluid transport. For the purposes of the hydrologic sealing evaluation, the lithologies have been divided into the Rustler (and overlying strata) and the Salado. The fluid transport phenomena of seal materials within Salado lithologies are the primary design concerns.

3.3.1.2 Design Objectives

Design objectives for the shaft seal system address the need for the WIPP to comply with system requirements and to follow accepted engineering practices using demonstrated technology. Shaft seal design objectives are summarized as follows:

- limit radionuclides from reaching regulatory boundaries,
- restrict groundwater flow through the sealing system,
- use engineered materials possessing good long-term stability,
- protect against structural failure of system components,
- minimize subsidence and prevent accidental entry, and
- use available construction methods and materials.

Details of the design respond to these qualitative design objectives and present an implementation approach. The shaft seal system design was completed under the QA program described in Chapter 5.0 and includes review by independent, qualified experts. Reviewers examined the complete design including conceptual, mathematical, and numerical models, and computer codes. The design reduces uncertainty associated with any particular element by using multiple sealing system components constructed from different materials. The shaft seal system design review is documented in Appendix SEAL (Chapter 1.4).

3.3.1.3 Design Description

A schematic of the shaft seal system as configured for the AIS is shown in Figure 3-4. Slight differences in seal element geometry occur within the four shafts owing to different shaft diameters or stratigraphic variations.

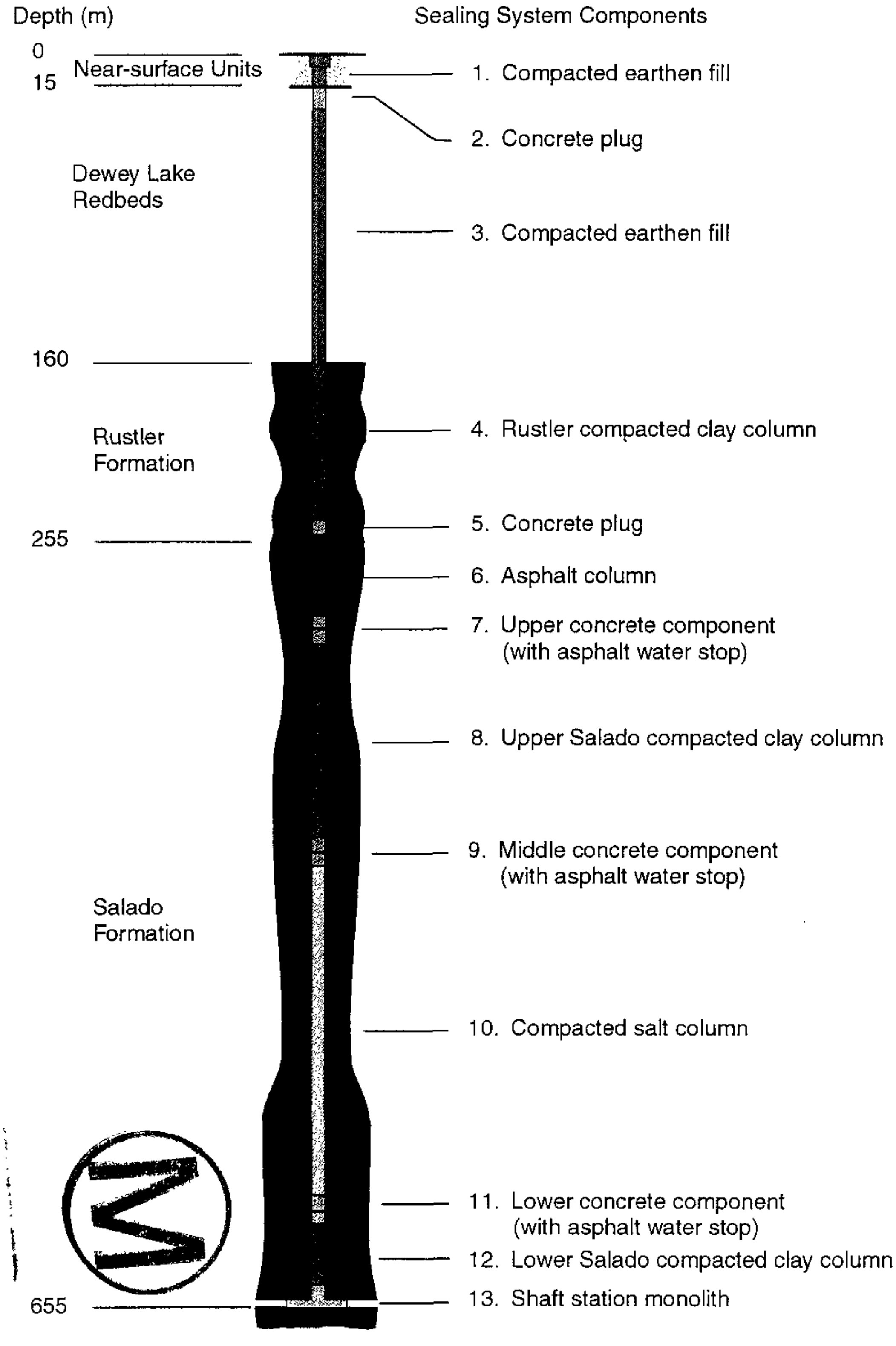

Figure 3-4. Proposed Seal Design for the WIPP AIS

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The shaft seal system has 13 elements that fill the shaft with engineered materials possessing high density and low permeability. Components of the seal system within the Salado provide the primary barrier by limiting fluid transport along the shaft during the 10,000-year regulatory period. Components of the seal system within the Rustler limit commingling of groundwater between water-bearing members. Components of the seal system overlying the Rustler fill the shaft with common materials of high density, consistent with good engineering practices. A brief description of the general shaft seal system is given in this section. The detailed design drawings for each shaft seal system are provided in Appendix SEAL (Appendix E).

3.3.1.3.1 Shaft Station Monolith

At the bottom of each shaft, a salt-saturated concrete monolith (Component #13) is placed to fill the station excavations. All concrete is placed using a slick line from the surface. The salt-saturated concrete is called Salado mass concrete (SMC) because it has been tailored to match site conditions. The salt-handling shaft and the waste-handling shaft have sumps that will also be filled with SMC as part of the monolith. Geometries of the monolith for the four shafts vary slightly because of the differing diameters and station configurations.

3.3.1.3.2 Clay Columns

A commercial well-sealing-grade sodium bentonite clay is used for Components #12 and #8 in the Salado and Component #4 in the Rustler. Construction specifications for these three seal components call for placement of compressed blocks to achieve design requirements. These clay columns effectively limit groundwater movement from the time they are placed and provide an effective barrier to fluid migration throughout the 10,000-year regulatory period. Lengths vary for each shaft based on individual stratigraphy. The lower Salado compacted clay column ranges from 93 to 107 feet (28 to 33 meters) thick, the upper Salado compacted clay column ranges from 335 to 345 feet (102 to 105 meters) thick, and the Rustler compacted clay column ranges from 234 to 235 feet (71 meters) thick in the four shafts. Locations of the Salado compacted clay columns were selected to limit brine migration and the potential for gas migration into the consolidating compacted salt column (Component #10). The lower Salado compacted clay column stiffness is sufficient to promote early healing of fractures in the surrounding rock salt, thus removing the shaft DRZ as a pathway for gases or brines (Appendix SEAL, Section 7.4.3). Handling of the DRZ is addressed in Appendix SEAL (Chapter 5 of Appendix D, Tables D-18 through D-21).

The Rustler groundwater compacted clay column (Component #4) limits groundwater communication between the Magenta and the Culebra. The Culebra accounts for most of the Rustler groundwater movement of significance in the vicinity of the WIPP site. Members above the Magenta (the Forty-niner), between the Magenta and Culebra (the Tamarisk), and below the Culebra (the unnamed lower member) are aquitards in the vicinity of the WIPP shafts. Existing shaft lining is removed from the water-bearing zones for a distance of 10 feet (3 meters) into each of the aquitards to allow the clay to contact the native rock and thus seal the shaft wall interface at these locations.

3.3.1.3.3 Concrete-Asphalt Water Stop Components

The upper (#7), middle (#9), and lower (#11) concrete components in the Salado are composed of three elements: an upper concrete plug, a central asphalt water stop, and a lower concrete plug. Concrete fills irregularities in the shaft wall, while use of the SMC assures good bonding with salt. Salt creep against the rigid concrete components establishes a compressive stress state and promotes early healing of the shaft DRZ surrounding the concrete plugs. Healing of the DRZ is addressed in Appendix SEAL (Chapter 5 of Appendix D, Tables D-18 through D-21). The asphalt water stop intersects the shaft cross section and the shaft DRZ. Like the shaft station monolith, SMC is placed using a slick line while asphalt is placed using a heated slick line.

Concrete Components #7, #9, and #11 have an overall design length of 50 feet (15 meters). The concrete plugs on either side of the asphalt are identical. They fill the shaft cross section and have a design length of 23 feet (7 meters). The plugs are keyed into the surrounding rock. An asphalt water stop is located between concrete plugs. In all cases, a kerf extending one shaft radius beyond the shaft wall is cut into the surrounding salt. The kerf is 1 foot (0.3 meters) thick at its tip, 2 feet (0.6 meters) thick at the shaft wall, and 4 feet (1.2 meters) thick across the shaft. The kerf, which cuts through the existing shaft DRZ, results in the formation of a new DRZ along its perimeter, but at these depths within the Salado, the new DRZ will heal shortly after construction (see Appendix SEAL, Chapter 5 of Appendix D, Tables D-18 through D-21), and thereafter the water stop will provide a low permeability barrier to brine or gas migration (Appendix SEAL, Section 4.3.1).

3.3.1.3.4 Compacted Salt Column

Each shaft seal includes a length of compacted salt (Component #10) that varies from 559 to 563 feet (170 to 172 meters) in the four shafts. Each compacted salt column is constructed of crushed Salado salt with about 1.5-weight-percent water added during construction. Demonstrations have shown that mine-run WIPP salt can be dynamically compacted to a density equivalent to approximately 90 percent of the average density of intact Salado salt. The remaining void space is effectively removed through consolidation caused by creep closure. The location of the compacted salt column near the bottom of the shaft assures the fastest achievable consolidation of the compacted salt column after closure of the repository. Salt creep increases rapidly with depth; therefore, at any given time, creep closure of the shaft is greater with depth. The salt column offers limited resistance to brine migration immediately after placement but becomes less permeable as density increases. Analyses indicate that the salt column becomes an effective long-term barrier in less than 100 years (Appendix SEAL, Section 7.4.2).

3.3.1.3.5 Asphalt Column

An asphalt-aggregate mixture is specified for the asphalt column (Component #6), which bridges the Rustler and Salado contact. Length of the asphalt column ranges from 138 to 143 feet (42 to 44 meters) in the four shafts. The asphalt column is located above the upper concrete and asphalt component (#7) and extends approximately 16 feet (5 meters) above the Rustler and Salado contact. Existing shaft linings and keys are removed from 20 feet (6 meters) above the top of the asphalt column to just below the lowest chemical seal ring. The asphalt column provides an essentially impermeable seal for the shaft cross section and along the shaft wall interface.

3.3.1.3.6 Concrete Plugs

A 20-foot (6-meter)-long concrete plug (Component #5) is located just above the asphalt column. The concrete plug, constructed of SMC, is placed directly on top of the asphalt column and keyed into the surrounding rock. The plug permits work to begin on the overlying clay column before the asphalt has completely cooled and allows the option of constructing the overlying clay column using dynamic compaction, although the present design calls for construction using compressed clay blocks. Another concrete plug (Component #2) is located near the surface extending 40 feet (12 meters) downward from the top of the Dewey Lake. It is placed inside the existing shaft lining; the shaft liner will be removed as necessary.

In all lining removal areas, the shaft is grouted before removal of the shaft lining to assure structural stability of the shaft wall. The grout curtain begins 10 feet (3 meters) above the lining removal areas and extends 10 feet (3 meters) below the lining removal areas. Grouting is used to stabilize the shaft walls and thus provide safer working conditions; it is not considered a flow barrier within the sealing system.

3.3.1.3.7 Earthen Fill

Approximately 500 feet (160 meters) of the upper shaft is filled with compacted earthen fill. These components (#3 and #1) use locally available fill. Component #3 is dynamically compacted (the same method used to construct the salt column) to a density approaching that of the surrounding materials. The length of this column varies from 447 to 486 feet (136 to 148 meters) in the four shafts. The uppermost earthen fill (Component #1) extends from the shaft collar through surface deposits downward to the top of the Dewey Lake. Fill near the surface is compacted with a sheepsfoot roller or vibratory plate compactor. The length of this column varies from 40 to 92 feet (12 to 28 meters) in the four shafts.

3.3.1.4 Materials

The shafts will be filled with dense materials possessing low permeability and/or other desirable attributes. The other desirable attributes include strength, ease of construction, longevity, and cost. These attributes are described in Appendix SEAL (Appendix A). Seal materials include concrete, clay, asphalt, compacted salt, cementitious grout, and earthen fill. Other materials include cementitious grout and earthen fill. Concrete, clay and asphalt are common construction materials, used extensively in hydrologic applications. Concrete is the most common structural material being proposed for the WIPP shaft seal system, and its use and specification have a long history. Clay is often specified as a construction material and bentonitic clay is often specified as a low permeability liner for hazardous waste sites. Asphalt is a widely used paving and waterproofing material used in the mining industry as a seal filler between a concrete liner and the surrounding rock. Compacted and reconsolidated crushed-salt are uniquely applied as seal components. Specifications are provided for all seal materials in Appendix SEAL (Section 5 and Appendix A). Each material is described in the appendix in terms of its

- functions,
- material characteristics,
- construction,
- performance requirements,
- verification methods, and
- references.

Both natural processes and engineered barriers combine to form the shaft seal system. The shaft seal system contains functional redundancy and uses different materials to reduce uncertainty in performance. Materials specifications are used to develop probability distributions and input parameters for performance assessment calculations. Input to performance assessment calculations and treatment of shaft seal elements within performance assessment models are summarized in Section 6.4.4.

3.3.1.5 Structural Analysis

The shaft seal system has been evaluated with regard to structural issues. Mechanical, thermal, physical, and hydrological features of the system are included in a broad suite of structural calculations. Conventional structural mechanics applications normally calculate the loads on system elements and compare the loads to failure criteria. Several such conventional calculations have been performed and show the seal elements to exist in a favorable, compressive stress state, which is low in comparison to the strength of the seal materials. Thermal analyses have been performed to examine the effects of concrete heat of hydration and heat transfer for asphalt elements. Physical coupling between shaft DRZ and fluid flow and between the density and permeability of the consolidating compacted salt column is evaluated within the scope of structural calculations. Creation of a fracture zone around the shaft, its increased transmissivity relative to unfractured rock, and its healing characteristics are analyzed. Similarly, time-dependent density and permeability are calculated for the reconsolidating salt column.

Structural calculations conducted as part of the design study generally address one or more of the following concerns: (1) stability of the component, (2) influences of the component on hydrological properties of the seal and surrounding rock, or (3) construction methods. Stability calculations address

- potential for thermal cracking of concrete seals,
- structural stability of seal components under loads resulting from creep of surrounding salt, other seal components through gravity or clay swelling, dynamic compaction, and potential repository-generated gas pressures,
- shaft closure-induced consolidation of compacted salt column, and
- impact of pore pressures on consolidation of compacted salt column.

Structural calculations used to define input conditions to the hydrological calculations include

- spatial extent of the shaft DRZ within the Salado surrounding the shafts as a function of depth, time, and seal material moduli,
- fracturing and shaft DRZ development within Salado interbeds, and
- compacted salt fractional density as a function of depth and time.

Construction analyses examine

- emplacement and structural performance of asphalt water stops and
- potential benefits of backfilling shaft stations.

Details of the structural analyses are provided in Appendix SEAL (Section 7). Calculations pertaining to bulleted items use computational models to demonstrate structural performance of the shaft seal elements.

3.3.1.5.1 DRZ Behavior

The development and subsequent healing of a DRZ in the rock mass surrounding the WIPP shafts are significant concerns in the shaft seal design. It is well known that a DRZ develops in the rock adjacent to the shaft immediately after excavation. After closure of the shaft this fractured zone is initially a major flow path regardless of the material placed within the shaft because the materials selected as seal components possess very low intrinsic permeabilities and the intact Salado halite is essentially impermeable. Additional discussed is provided in Appendix SEAL (Chapter 5 of Appendix D). Knowledge of DRZ behavior allows the design to increase confidence in the overall shaft seal system. For example, low permeability components (termed water stops) are included in the design to intersect the DRZ surrounding the shaft. These water stops are placed to alter the flow direction either inward toward the shaft seal or outward toward intact salt. Structural calculations evaluate performance of the water stops in terms of (1) intersecting the DRZ around the shaft, (2) inducing a new DRZ because of special excavation, and (3) promoting healing of the DRZ.

The DRZ behavior is evaluated for all of the various materials placed in the shaft because DRZ creation and healing depend on the stress state. A DRZ within salt, the major lithology in the Salado, continues to develop creep without a supportive element that would serve as a load-bearing member. Within the formations above the Salado, the DRZ is assumed to be time-invariant because the behavior of the rock masses encountered there is predominantly elastic. The temporal and spatial extent of the DRZ along the entire shaft length is addressed in the shaft seal system. Rigid seal components in the shaft provide a restraint to salt creep closure, thereby inducing healing stress states in the salt.

3.3.1.5.2 Compacted Salt Behavior

Creep-driven consolidation of the compacted salt column is an important long-term consideration of the shaft seal system. This behavior has been examined in detail, with three material models selected to describe the phenomenon (see Appendix SEAL, Appendix D, Chapter 3.1.2). Results of tests on WIPP salt were used to evaluate constitutive models for reconsolidating salt (see Appendix SEAL, Appendix D, Chapter 4.2). Coupled with finite element models for the surrounding geologic setting, the models for reconsolidating salt provide estimates of effective permeability of the salt component of the shaft seal system. As an example, structural calculations determine fractional density of the crushed-salt seal as a function of time and depth and use results of laboratory tests to determine permeability. Based on these calculations, a desirable fractional density (hence, permeability) is achieved over a substantial length of the compacted salt seal within several decades of placement.

3.3.1.6 Hydrologic Evaluations

The ability of the shaft seal system to satisfy design guidance is determined by the performance of the actual seal components within the physical setting in which they are constructed. The guidance used in seal system design is documented in Appendix SEAL (Chapter 3). The important elements of the physical setting are hydraulic gradients of the region, properties of the lithologic units surrounding a given seal component, and potential gas generation within the repository. Hydrologic evaluation focuses on processes that could result in fluid flow through the shaft seal system and the ability of the seal system to limit any such flow. If the carrier fluids are limited, transport of radiological or hazardous constituents will be similarly limited.

The physical processes that could impact seal system performance are presented in detail in Appendix SEAL (Chapter 8). These processes have been incorporated into four models, which are used to evaluate the design. Briefly, these models evaluate

(1) downward migration of groundwater from the Rustler,

(2) gas migration and reconsolidation of the compacted salt seal component,

(3) upward migration of brines from the repository, and

(4) flow between water-bearing zones in the Rustler.

3.3.1.6.1 Downward Migration of Rustler Groundwater

The shaft seal system is designed to limit groundwater flowing into and through the shaft sealing system. The principal source of groundwater to the seal system is the Culebra. The Magenta is a less significant groundwater source. No significant sources of brine or water exist within the Salado; however, brine seepage has been noted at a number of the marker beds and is included in the models. Downward migration of Rustler groundwater is limited to ensure liquid saturation of the Salado salt column does not impact the consolidation process and to limit quantities of brine reaching the repository horizon. Because the limitation of liquid flow into the salt column necessarily limits liquid flow to the repository, the volumetric flux of liquid into and through the salt column was selected as the design performance measure for this model.

At steady-state, the flow rate is most dependent on the permeability of the system. Potential flow paths within the seal system consist of the seal material, an interface with the surrounding rock, and the host rock DRZ. Low permeability is specified of the engineered materials and construction methods ensure a tight interface; thus, the flow path most likely to impact performance is the shaft DRZ. Fluid flow analyses conducted are provided in Appendix SEAL (Appendix C). Rock mechanics calculations predict that the DRZ in the Salado will not be vertically continuous because of intermittent layers of stiff anhydrites (marker beds). Concrete and asphalt water stops are included in the design as a means to mitigate DRZ impacts. Effects of marker beds and asphalt water stops on limitation of downward migration are explicitly simulated through permeability variation of the layers of Salado shaft DRZ. Initial, upper, and lateral boundary conditions of the hydrologic model are consistent with field measurements of the physical system. At the base of the shaft a constant, atmospheric pressure is assumed. The hydrologic model predicts a maximum cumulative flow of less than 353 cubic feet (10 cubic meters) through the sealed shafts during the first 200 years following closure.

3.3.1.6.2 Gas and Brine Migration

A multiphase flow model of the lower seal system evaluates the performance of components extending from the middle asphalt-concrete water stop (located at the top of the salt column) to the repository horizon for 200 years following closure. The 200-year period was selected arbitrarily; however, this ensures that the calculations are continued well beyond the time required for salt component consolidation (see Appendix SEAL, Appendix C). During this time period, the principal fluid sources to the salt column consist of gas (potentially generated by the waste) and lateral brine migration within the Salado. The predicted downward migration of Rustler groundwater (discussed above) is included in this analysis. Performance measures for the model are the volume of gas that migrates through the seal components to the middle asphalt-concrete component and the time-dependent permeability of the crushed-salt component. These performance measures address the need to limit fluid flow upward from the repository and to predict the performance of the salt component.

In the physical setting, pore fluids can create pore pressure and reduce the rate of the compacted salt column reconsolidation. Calculations demonstrate that repository gas pressure will not impact reconsolidation. The fluid flow analyses conducted to support seal system design efforts can be reviewed in Appendix SEAL (Appendix C). As a result, the salt column achieves its long-term effective permeability at 100 years following seal construction.

3.3.1.6.3 Upward Migration of Brine

Fluid pressure of the Salado is higher than fluid pressure in the Rustler so that upward migration of brines could occur through an inadequately sealed shaft. Results from modeling (discussed above) demonstrate that the crushed-salt seal will reconsolidate to a very low permeability within 100 years following repository closure (see Appendix SEAL, Appendix C). Structural results reported in Appendix SEAL (Section 7.4) show that the DRZ surrounding the compacted clay and compacted components will completely heal within the first several decades (see Appendix SEAL, Appendix D, Table D-20). As a result, upward brine flux at the Rustler and Salado contact in the sealed AIS is approximately 35 cubic feet (1 cubic meter) over the 10,000-year regulatory period. This brine originates in the marker beds; no brine from the repository migrates up the shaft.

3.3.1.6.4 Intra-Rustler Flow

Based on estimated undisturbed and measured disturbed head differences between the various members of the Rustler (see Table C-2 of Appendix C of Appendix SEAL), nonhydrostatic conditions exist within the Rustler. Therefore, the potential exists for vertical flow within water-bearing strata within the Rustler. The dolomitic members of the Rustler have the greatest potential to produce significant interflow within the Rustler in response to nonhydrostatic conditions. The relatively low undisturbed permeabilities of the mudstone and anhydrite units separating the Culebra and the Magenta naturally limit crossflow. However, the construction and subsequent closure of the shaft could provide a vertical conduit connecting water-bearing units.

The primary motivation for limiting formation crossflow within the Rustler is to prevent mixing of formation waters within the Rustler. In the vicinity of the shafts, the potential for fluid migration between the two most transmissive units is from the Magenta unit with the lower total dissolved solids to the Culebra unit with the higher dissolved solids. This calculation shows that the potential flow rate between the Culebra and the Magenta is expected to be of such a limited quantity that (1) it will not affect either the hydraulic or chemical regime within the Culebra or the Magenta and (2) it will not be detrimental to the seal system itself. The fluid flow analysis conducted for the purposes of seal system design is included in Appendix SEAL (Appendix C).

3.3.2 Panel Closure System

Panel closures have been included for the purpose of Resource Conservation and Recovery Act (RCRA) disposal unit closure and to prevent potentially unacceptable levels of volatile organic compound release during waste management operations. The panel closure system was not designed or intended to support long-term repository performance. The panel closures do, however, provide a solid within the drifts which prevent the preexisting DRZ from increasing in permeability after closure system installation. The DRZ permeability value and the supporting rationale are provided in Appendix PAR. Additional information is provided in Appendix MASS (MASS Attachment 7-1). A panel closure system will be emplaced in the panel access drifts, in accordance with the design (see Appendix PCS) in the WIPP facility closure plan prepared for the RCRA permit application. The panel closure system has been designed according to a number of operational objectives set out by the DOE, the main elements of which are

1. the panel closure system shall restrict flow from the panels,

2. the panel closure system should perform its intended functions under loads generated by creep closure, and in general under the most severe ground conditions expected in the waste disposal area during the operational phase,

3. the panel closure system should be capable of containing and continuing to perform its intended function under conditions of a postulated methane explosion,

4. the panel closure system should be constructed of materials that are compatible with its emplacement environment and function,

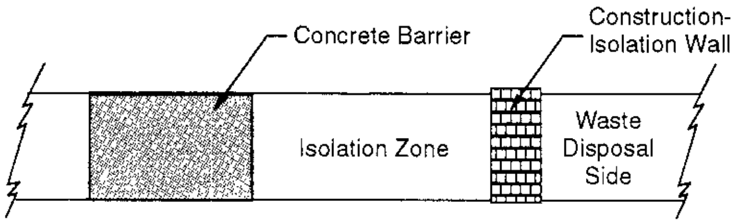
5. engineering design of the panel closure system should include structural analyses using WIPP specific data, and should address such issues as the thermal cracking of concrete, and

6. the panel closure system should be designed and constructed using conventional mining practices, with full consideration of shaft and underground access and services. It should be constructed to generally accepted national design and construction standards, with a QA and quality control program used to verify material properties and construction practices.

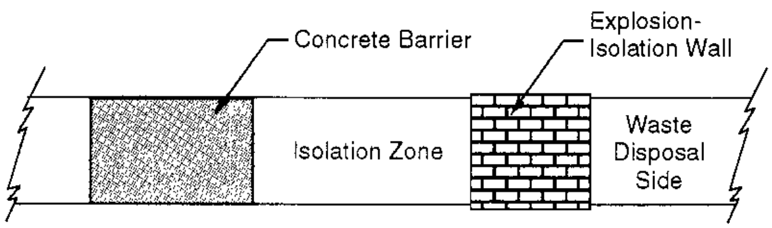
The design of this closure system, as described in Appendix PCS, includes a number of detailed engineering studies that analyze operational requirements and structural and material requirements. As a result of these analyses, a composite panel closure system was designed, consisting of a rigid concrete component, emplaced with or without removal of the DRZ, and either an explosion-isolation wall or a construction-isolation wall. The various options for the closure designs are shown in Figures 3-5. The excavation configurations for these closure designs are shown in Figure 3-6. These designs allow for components to be added or removed, or their shapes to be adjusted. Decisions about the shape of the rigid concrete component will depend on the particular ground conditions at the time of installation and the time when installation occurs relative to final facility closure. The concrete for the component is chosen to be compatible with the environment. Contact grouting around the concrete component is carried out as needed. The material for the isolation walls is concrete construction block.

Figures 3-5 and 3-6 show a diagram of the panel closure design and installation envelopes. Appendix PCS provides the detailed design and the design analysis for the panel closure system. The panel closure design is such that components can be added or removed or their shapes adjusted depending on the particular ground conditions at the time of installation. For example, in Figure 3-5, Option A represents the likely closure of panels less than 20 years old at the time of final facility closure and whose entries are sufficiently intact such that DRZ removal is not needed. These would likely include Panels 6 through 8. Option B represents the preferred option for panels that will be closed for more than 20 years prior to final facility closure and whose entries are reasonably intact at time of closure. These will likely be Panels 2 through 5. Option C may be desirable for panels whose entries require DRZ removal and whose closure precedes final facility closure by less than 20 years. This is the likely configuration of the closure for Panels 9 and 10. Finally, Option D may be appropriate for panels whose entires require significant removal of the DRZ and whose closure will precede final facility closure by more than 20 years. Panel 1 is the most likely candidate for this type of closure.

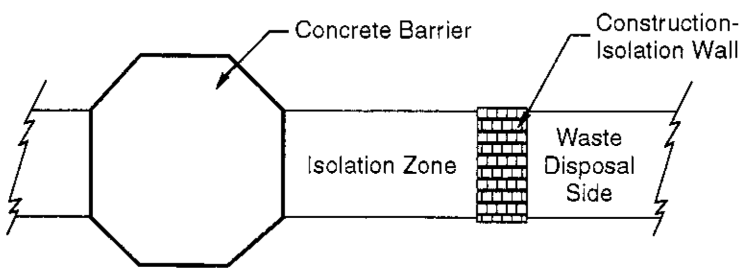
The 20-year limit in the design selection process is based on what the DOE believes to be conservative analytical results that indicate methane, being generated by waste degradation at the rate of 0.1 mole per drum per year, will not reach flammable concentrations for at least 20 years. As part of the decision-making process on design selection, an investigation of the DRZ would precede the selection of the concrete component and the specification of the amount of excavation that is needed. These investigations could be done using geophysical methods (such as ground penetrating radar) or drillholes. Drillholes can be investigated using video cameras or scratchers.



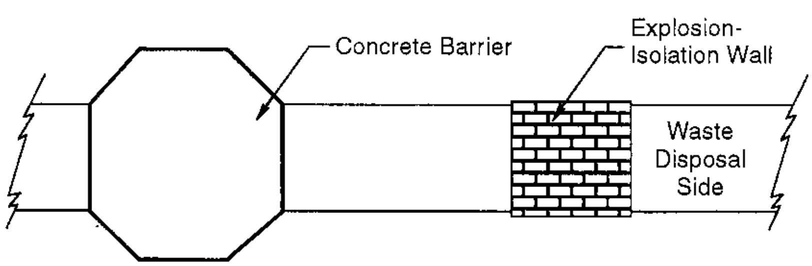
Option A. Construction-Isolation Wall and
Concrete Barrier without the DRZ Removed



Option B. Explosion-Isolation Wall and
Concrete Barrier without the DRZ Removed



Option C. Construction-Isolation Wall and
Concrete Barrier with DRZ Removed



Option D. Explosion-Isolation Wall and
Concrete Barrier with DRZ Removed

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Figure 3-5. Panel Closure Design

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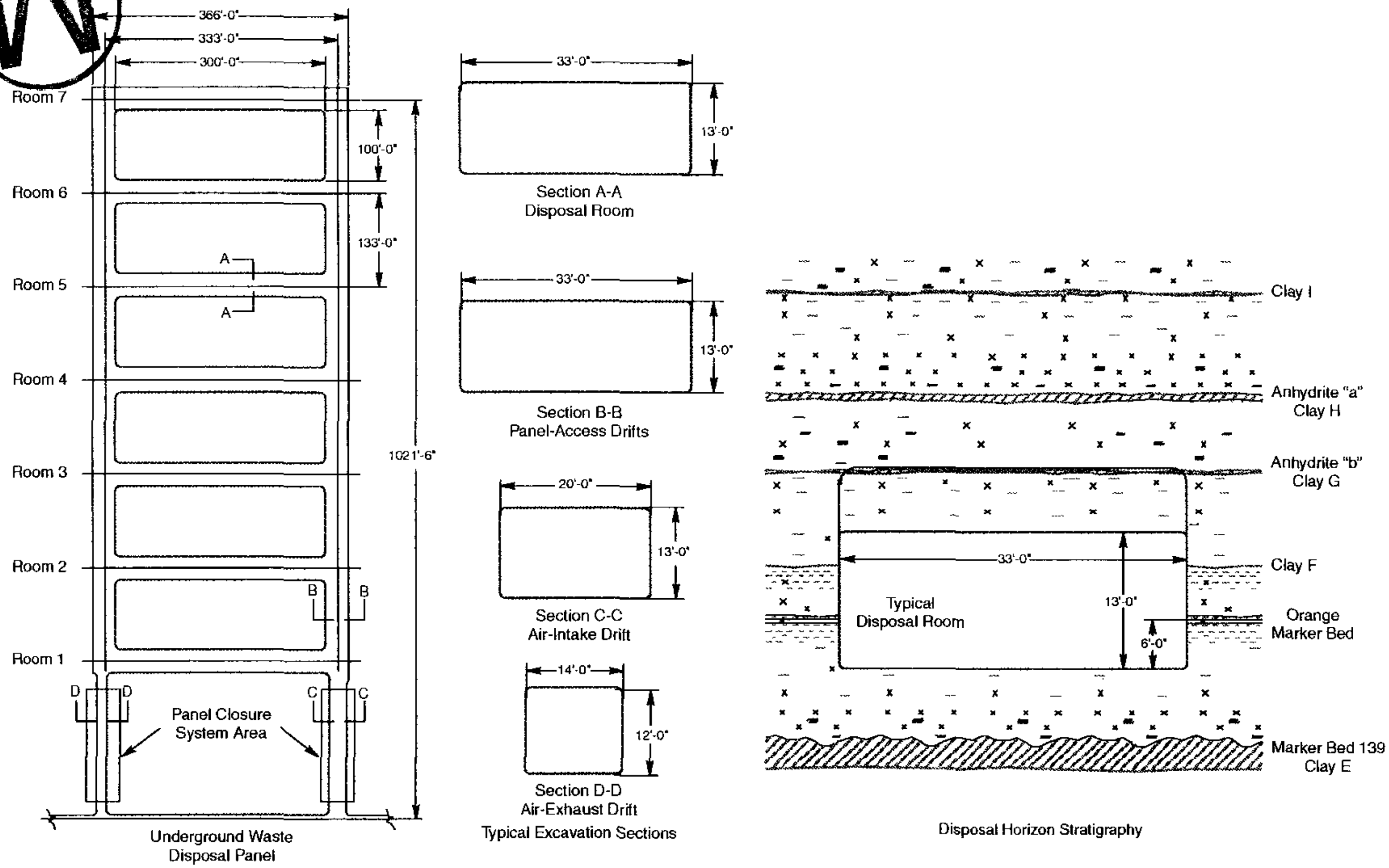

Note: Figure is not to scale. All dimensions shown are nominal.

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Figure 3-6. Location of Panel Closure System

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The DOE will evaluate these criteria at the time a panel closure is needed and will select the proper closure design. If a design different from those listed above is identified, the appropriate permit modification will be sought.

Although the design of this closure system was based on its need to protect public health and the environment during the operations period, the use of these systems coupled with any other material placed in the panel entries will also influence fluid connections between panels during the postclosure phase. Flow of fluids into or out of the panels will be controlled by the permeability of the panel closure and the surrounding DRZ. Consideration of the current panel closure designs indicated that they will maintain their structural integrity for the regulatory period. Concrete degradation may occur by interaction with brine flowing through the plug or with brines flowing along the plug and salt interface or through the DRZ.

Calculations show that insufficient brine transport is available to begin degradation processes (Appendix MASS, MASS Attachment 7-1). The concrete element of the closure system will continue to provide resistance to inward deformation of the surrounding salt and will thereby prohibit growth of the DRZ from its initial state. Therefore, the concrete components are not expected to degrade to a condition that is more permeable than the DRZ in the regulatory period of 10,000 years. Although the panel closures are neither intended nor designed for long-term regulatory compliance, they provide a solid within the drifts that prevents the existing DRZ from increasing in permeability after panel closure. Development of the value for DRZ permeability is given in Appendix PAR. Additional information specific to the DRZ can be reviewed in the following records packages in the Sandia WIPP Central Files: WPOs 32905, 32906, and 32907.

3.3.3 Backfill

The DOE has concluded that it is desirable to add MgO to the repository to improve performance of the disposal system (see Appendix BACK). This additive will be protected in sacks until the sacks are broken during creep closure of the room. The MgO backfill will be purchased prepackaged in the proper containers for emplacement in the underground. Purchasing prepackaged backfill eliminates handling and placement problems associated with bulk materials, such as dust creation. In addition, prepackaged materials will be easier to emplace, thus reducing potential worker exposure to radiation.

The MgO backfill will be purchased and received in two different containers: (1) a supersack holding several thousand pounds, and (2) a mini sack holding 25 pounds (11.3 kilograms). Quality assurance requirements, such as material quality, will be addressed through the procurement quality requirements in Section 2.3 of the Westinghouse Waste Isolation Division (WID) Quality Assurance Program Description (see Appendix QAPD). MgO is available from several suppliers in a range of grain sizes and purities. Typical purities range from 93 percent MgO for baked dolomite to 98 percent for MgO extracted from brines. Chemical grade product (100 percent MgO) is also available. MgO is available in a variety of milled and screened grain sizes ranging from a powder (minus 325 mesh) to granular (0.5 inch by 6 mesh). The filled containers will be shipped by road or rail and will be delivered underground using current shaft and material handling procedures and processes.

The mini sack will be 34 inches (86.4 centimeters) long, 6 inches (15 centimeters) in diameter and will be fabricated of a single layer of polyethylene or other suitable material. It will have an integral handle and hook attached into the sack closure. Six sacks will be manually placed in the external voids of each seven-pack unit just before the seven-pack is positioned on the waste stack. The mini sack will be lifted up behind the shrink wrap around the top of the seven-pack, slid into place, and held there by the 4-inch (10-centimeter) hole in the lower slip sheet (see Figure 3-7). Once the sacks are in place, the seven-pack will be positioned on the waste stack in the normal manner. A similar process will be used for standard waste boxes (SWB) except that the sacks will be hung from the lift clips on these units as shown in Figure 3-7.

Super sacks, which may be up to 4,000 pounds (1,814 kilograms) will be handled and placed using normal waste handling techniques. Once each row of waste units is in place, a layer of super sacks will be placed on top of them as shown in Figure 3-8. The super sack will be of multiwall construction with a vapor and moisture barrier. The super sack will have an integral slip sheet or base attachment so that it can be handled and placed in a manner that is identical to how waste units are emplaced. Typically, the space above a stack of containers will be 36 to 48 inches (90 to 122 centimeters), of which about 18 inches (45 centimeters) will contain the backfill material.

Finally, mini sacks will be manually stacked on the floor in the space between the waste stack and ribside. These sacks can be placed horizontally or vertically as may be convenient and loading rates up to 100 pounds per linear foot (148.8 kilograms per linear meter) can be achieved simply and quickly.

Quality control will be provided within waste handling operating procedure to record that the correct number of sacks are placed and that the condition of the sacks is acceptable.

There are about 3,700 linear feet (1,128 linear meters) of waste stack in a panel. The stated configuration provides about 4,000 pounds per linear foot (5,952 kilograms per linear meter) of waste stack or about 7,400 short tons (6,712 metric tons) per panel. About 10,836 waste disposal units (that is, seven-packs of drums and SWBs) will be placed in a panel and at six 25-pound (11.3-kilogram) mini sacks per unit, this will provide about 800 short tons (726 metric tons) per panel. Finally, material stacked along the ribside at 100 pounds per linear foot (148.8 kilograms per linear meter) of rib will provide about 360 short tons (327 metric tons) per panel. This gives a total of about 8,560 short tons (7,764 metric tons) per panel or approximately 85,600 short tons (77,640 metric tons) for the repository.

Backfill placed in this manner is protected until exposed when sacks are broken during creep closure of the room and compaction of the backfill and waste. Backfill in sacks use existing

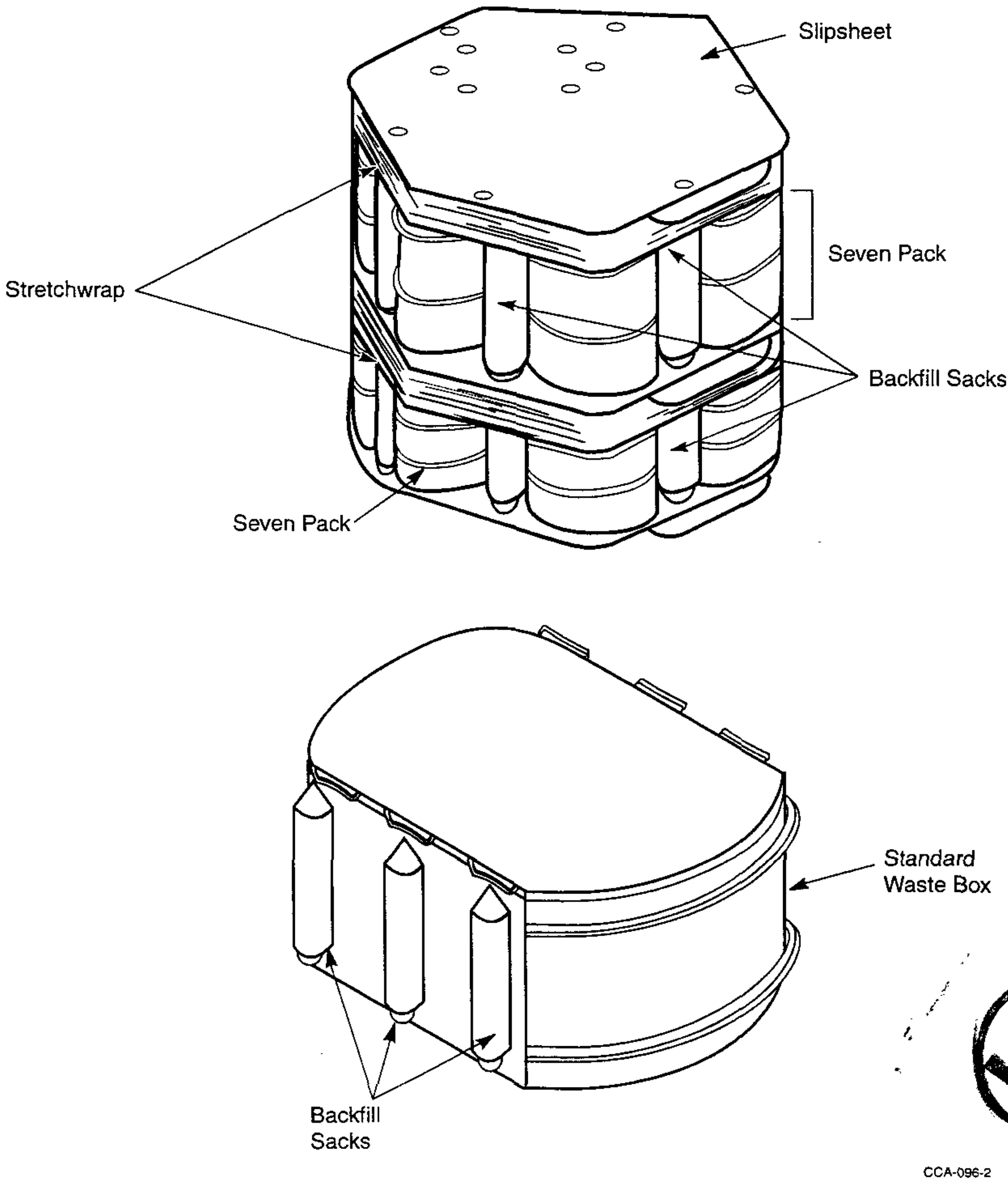

Figure 3-7. Backfill Sacks Used with Seven-Pack and SWB

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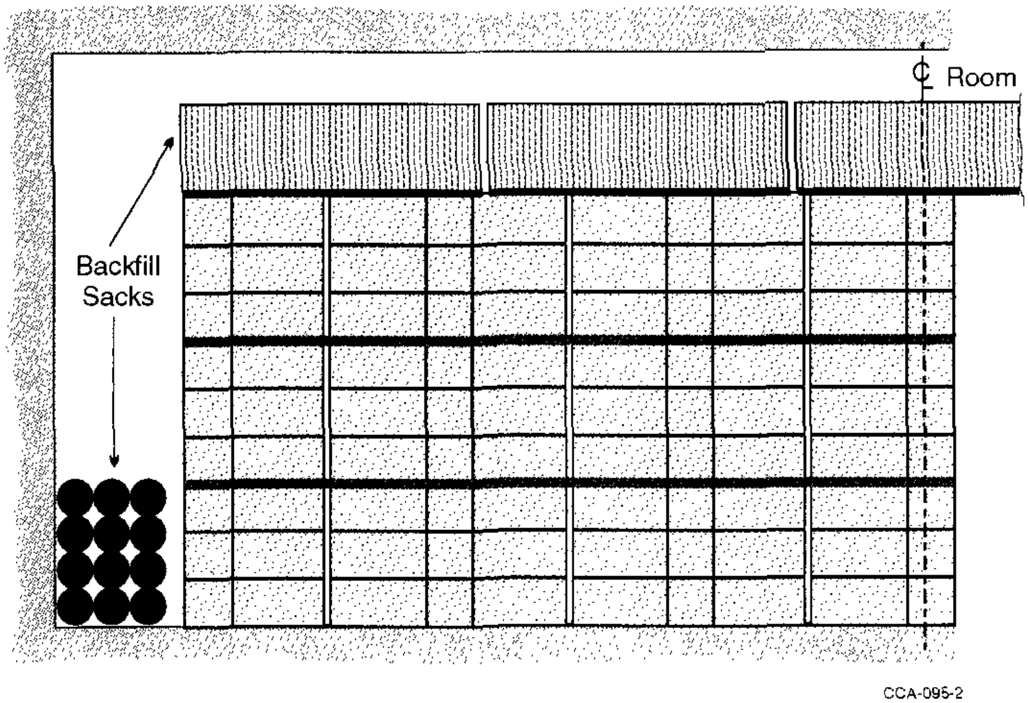

Figure 3-8. Room Cross Section Showing the Position of Backfill Sacks

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techniques and equipment and eliminates operational problems such as dust creation and introducing additional equipment and operations into waste handling areas. There are no mine operational considerations (for example, ventilation flow and control) when backfill is placed in this manner. Backfill performance and disposal system impacts are discussed in more detail in Section 6.4.3. Appendix BACK provides the rationale for the use of MgO as a backfill. Appendix SOTERM (Section SOTERM.2.2) contains information regarding the chemical effects of MgO in the disposal room. The commercially available code EQ3/EQ6 was used in the determination of chemical effects.

3.3.4 Borehole Plugs

Figure 3-9 identifies existing unplugged boreholes that lie within the controlled area. Of these boreholes, four are deep boreholes that exceed the depth of the repository, and the remainder are shallow boreholes that do not reach the repository horizon.

To mitigate the potential for migration of contaminants toward the accessible environment, the DOE has specified that borehole plugs be designed to limit the volume of water that could be introduced to the repository from the overlying water-bearing zones and to limit the volume of contaminated brine released from the repository to the accessible environment.

Grout-plugging procedures are routinely performed in standard oil-field operations; however, quantitative measurements of plug performance are rarely obtained. The Bell Canyon Test reported by Christensen and Peterson (1981, 25) was a field test demonstration of the use of cementitious plugging materials and modification of existing industrial emplacement techniques to suit repository plugging requirements. The test was performed in an 8 inch (20 centimeter) well bore near the top of the Bell Canyon. The test bore intercepted an aquifer at a depth of 4,495 feet (1,370 meters) with a shut in pressure of 1,800 pounds per square inch (12.4 megapascals). A 6 foot (2 meter) grout plug was emplaced above the aquifer and tested by unloading the hole (that is, removing fluids) above the plug to allow the full pressure in the aquifer to bear on the plug. This plug was observed to reduce the flow by five orders of magnitude, to 0.2 gallons per day (0.6 liters per day).

Cement emplacement technology was found to be generally adequate to satisfy repository plugging requirements. Christensen and Peterson (1981) also report

> that grouts can be effective in sealing boreholes, if proper care is exercised in matching physical properties of the local rock with grout mixtures.

A significant amount of research has been completed by the DOE to optimize concrete mixtures for the conditions expected in the Salado. The results of this research have been used to design the shaft sealing system as discussed in Appendix SEAL. (Concrete is discussed in Appendix A of Appendix SEAL, Section A2.1.) Consequently, the DOE has identified materials that will provide suitable plugs for boreholes. In addition, appropriate national standards such as the American Petroleum Institute Specification 10 and American Society for Testing Materials specification Volume 04.02 are available to assure the quality of borehole plugging material and installation. Section 2.1.4 of the CAO QAPD (Appendix QAPD) provides the quality assurance requirements for the control of special processes such as plugging.

As a result of the Christensen and Peterson (1981) report and subsequent evaluations of plugging materials, the DOE concluded that boreholes within the controlled area, which were previously plugged in accordance with the appropriate state and federal regulations in effect at the time plugging, will mitigate the potential for migration of fluids beyond the repository horizon. Shallow unplugged boreholes within the controlled area will be plugged in accordance with the current state or federal regulations using materials shown to be compatible with the underground environment. Deep unplugged boreholes within the controlled area, shown in Figure 3-9 as WIPP 13, WIPP 12, ERDA 9, and DOE 1, will be plugged according to the state of New Mexico, Oil Conservation Division, Order R-111-P. The governing regulations for plugging and/or abandonment of boreholes are summarized in Table 3-2. These solid cement plugs will go through the salt section and any water-bearing horizon to prevent liquids or gases from entering the hole above or below the salt section. The boreholes not being used for monitoring will be plugged at decommissioning.

Figure 3-10 depicts a typical deep borehole plugged to the requirements of Order R-111-P. This order specifies, among other things, that the cements be mixed with salt-saturated fluids made with salts from the horizon being plugged (see Appendix DEL, Section DEL.6.2.4).

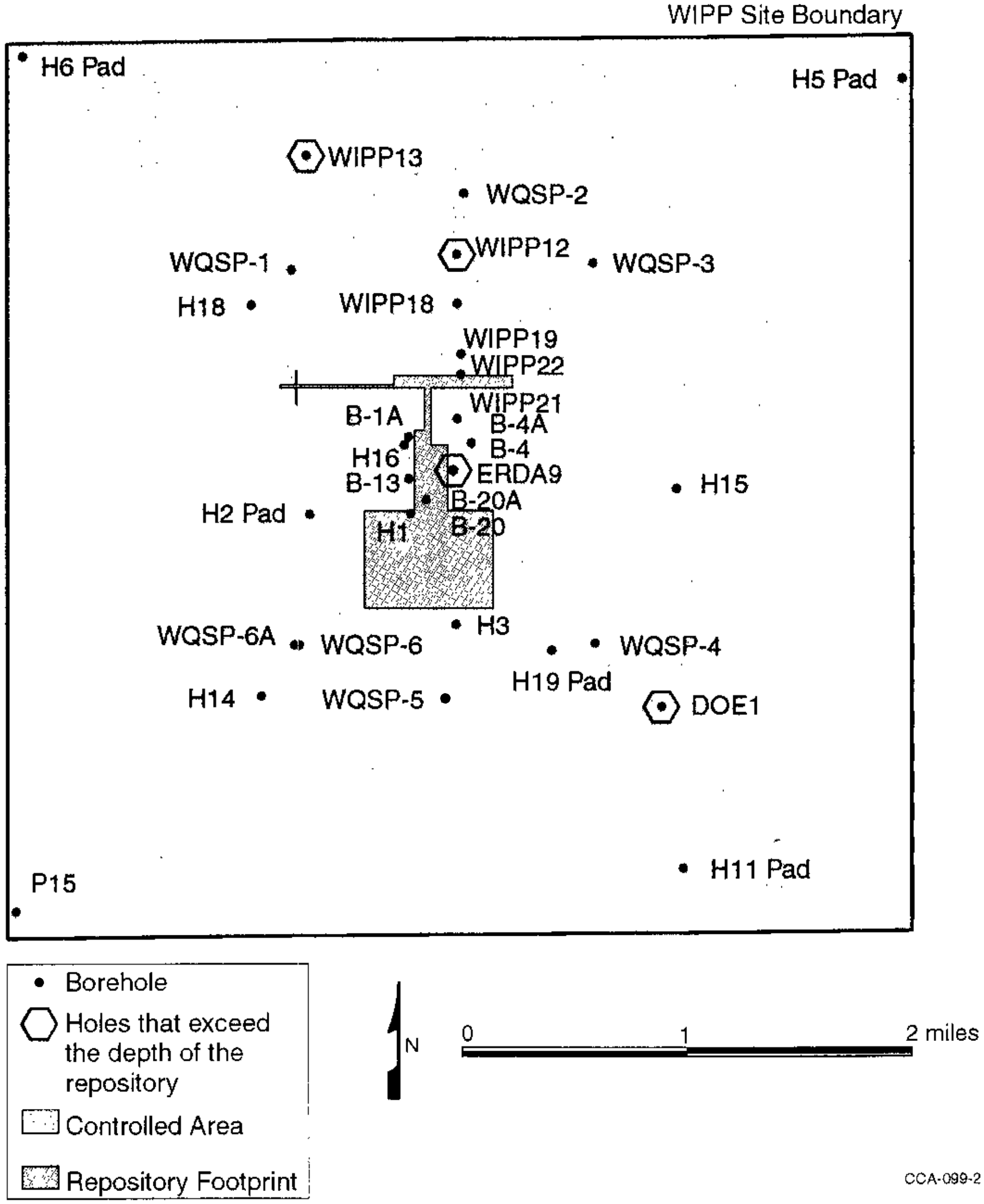

Figure 3-9. Approximate Locations of Unplugged Boreholes

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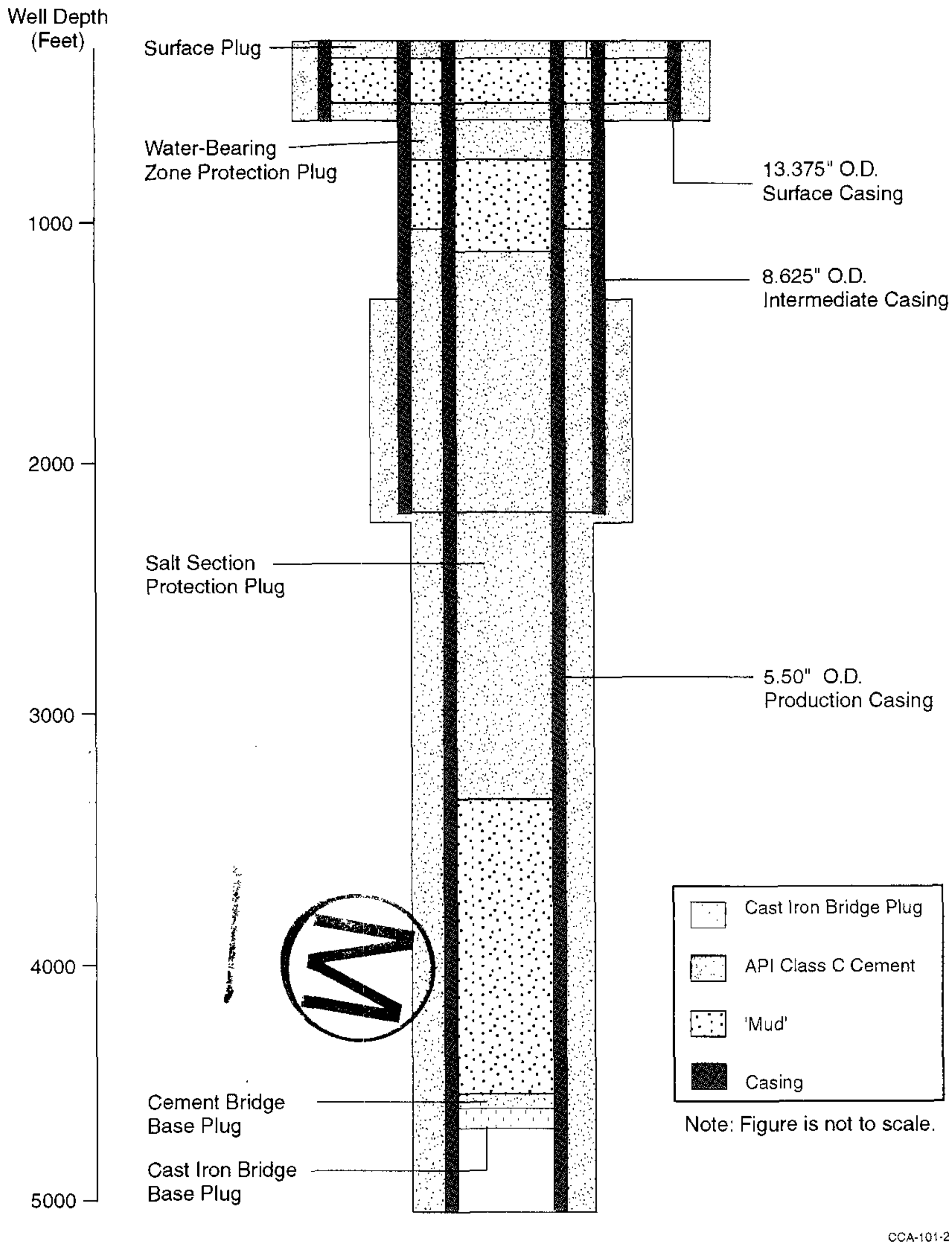

Figure 3-10. Typical Deep Borehole Plugged to Requirements of Order R-111-P

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Table 3-2. Governing Regulations for Borehole Abandonment

Federal or State Land	Type of Well or Borehole	Governing Regulation	Summary of Requirements
Both	Groundwater Wells	State of New Mexico (1995) Rules and Regulations Governing Drilling of Wells and Appropriation and Use of Groundwater in New Mexico, Article 4-14	Any specific plugging requirements and provisions made by the state engineer shall be set forth in the permit.
Federal	Oil and Gas Wells	43 CFR Part 3160, § 3162.3-4 (DOI, 1995a)	The operator shall promptly plug and abandon, in accordance with a plan first approved in writing or prescribed by the authorized officer.
Federal	Potash	43 CFR Part 3590, § 3593.1 (DOI, 1995b)	(b) Surface boreholes for development or holes for prospecting shall be abandoned to the satisfaction of the authorizing officer by cementing and/or casing or by other methods approved in advance by the authorized officer. The holes shall also be abandoned in a manner to protect the surface and not endanger any present or future underground operation, any deposit of oil, gas, or other mineral substances, or any aquifer.
State	Potash	State of New Mexico (1995), Rules and Regulations Governing Drilling of Wells and Appropriation and Use of Groundwater, Article 4-20.2	In the event that the test or exploratory well is to be abandoned, the state engineer shall be notified. Such well shall be plugged in accordance with Article 4-19.1 so that the fluids will be permanently confined to the specific strata in which they were originally encountered.
State	Oil and Gas Well Outside the Oil-Potash Area	State of New Mexico, Oil Conservation Division (1991), Rule 202 (eff. 3-1-91)	B. Plugging (1) Prior to abandonment, the well shall be plugged in a manner to permanently confine all oil, gas, and water in the separate strata where they were originally found. This can be accomplished by using mud-laden fluid, cement, and plugs singly or in combination as approved by the Division on the notice of intention to plug. (2) The exact location of plugged and abandoned wells shall be marked by the operator with a steel marker not less than four inches (4") in diameter, set in cement, and extending at least four feet (4') above mean ground level. The metal of the marker shall be permanently engraved, welded, or stamped with the operator name, lease name, and well number and location, including unit letter, section, township, and range.
State	Oil and Gas Wells Inside the Oil-Potash Area	State of New Mexico, Oil Conservation Division (1988), Order No. R-111-P (eff. 4-21-88)	F. Plugging and Abandonment of Wells (1) All existing and future wells that are drilled within the potash area shall be plugged in accordance with the general rules established by the Division. A solid cement plug shall be provided through the salt section and any water-bearing horizon to prevent liquids or gases from entering the hole above or below the salt selection. It shall have suitable proportions—but no greater than three (3) percent of calcium chloride by weight—of cement considered to be the desired mixture when possible.

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