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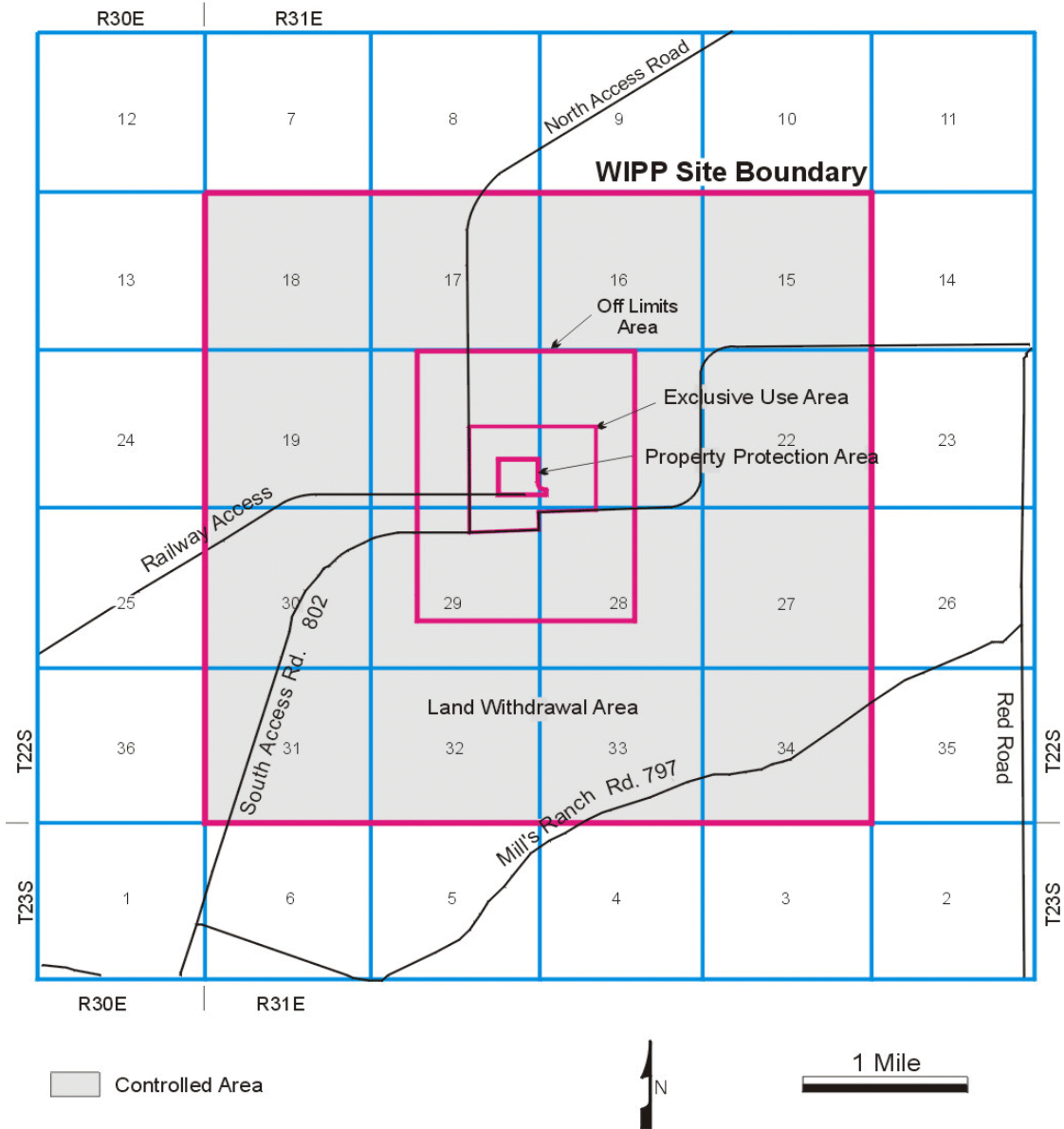
3.0 FACILITY DESCRIPTION

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 *Subparts B and C (EPA 1993)*. The U.S. Department of Energy (DOE) has specified *developed* 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 an engineered barrier 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~~ *excavations, and engineered systems that may be significant to long-term performance of the disposal system. Of these engineered systems, the Environmental Protection Agency (EPA) has determined that only magnesium oxide (MgO) meets the regulatory definition of an "engineered barrier" (63 Federal Register [FR] 27397, May 18, 1998). Detailed information on other aspects, such as general facility operations, waste handling, repository mining, ground control, ventilation, transportation, emergency preparedness, training, and maintenance are covered, as appropriate, in other WIPP documents, such as the WIPP Disposal Phase Supplemental Environmental Impact Statement (SEIS-II) (DOE 1997), Contact-Handled Waste Safety Analysis Report (DOE 2003), and other documents available from the DOE.* ~~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) *(34 acres)* and provides security and protection for all major surface structures; (2) the exclusive use area, which is approximately ~~277 acres~~ (112 hectares) *(277 acres)* 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 km^2 square

1 kilometers) (1,454 acres) posted and managed as off limits by the DOE; and (4) the WIPP land
 2 withdrawal area, the 16-section (41.4-km² square kilometers) (16 mi²) federal land area under
 3 jurisdiction of the DOE and bounded by the WIPP site boundary (see Figure 3-1). The WIPP
 4 land withdrawal area is the controlled area for purposes of demonstrating compliance to 40 CFR
 5 Part 191 *Subparts B and C*. The waste area of the repository lies within the bounds of the off
 6 limits area, and within the WIPP land withdrawal area.



7
 8 **Figure 3-1. WIPP Property Sector Designators**

9 The amount of waste to be received at the WIPP is governed by the *WIPP* Land Withdrawal Act,
 10 *Pub. L. No. 104-201, Stat. 2422 (U.S. Congress 1992)*, which sets the total volume for contact-
 11 handled (CH-) and remote-handled (RH-) transuranic (TRU) waste combined at a maximum of
 12 *175,600 m³* (6.2 million *ft³* cubic feet (175,600 cubic meters). *The* 6.2 million *ft³* cubic feet

1 technically corresponds to 175,564 m^3 cubic meters (see page 4-2) but will be routinely
2 represented in this application with four significant digits. The Land Withdrawal Act restricts
3 RH-TRU waste to a maximum activity of 23 curies per liter and not to exceed a total of 5.1
4 million curies (U.S. Congress 1992) (see Chapter 4 for a description of the waste). There is a
5 volume limit of 0.25 million ft^3 cubic feet for RH-TRU waste (DOE 1980, 1-5 *Agreement for*
6 *Consultation and Cooperation, DOE 1988*). The waste disposal area of the WIPP facility
7 consists of eight panels, each of which contains seven rooms, and the access drifts and crosscuts
8 adjacent to the disposal panels. This latter region has been labeled Panels 9 and 10 for
9 convenience as shown in Figure 3-2. At the end of the operational period, the DOE will begin
10 the process of sealing the shafts, which is a part of final facility closure.

11 *Disposal operations in Panel 1 are complete and an explosion-isolation wall has been*
12 *installed. In a typical configuration, waste will be emplaced in all seven rooms of a panel as*
13 *shown in Figure 3-3 with RH-TRU waste inserted into the walls. Figure 3-4 provides the*
14 *layout of the waste as it is emplaced in Panel 1. This is not the configuration typically*
15 *described for WIPP (Compliance Certification Application [CCA]).*

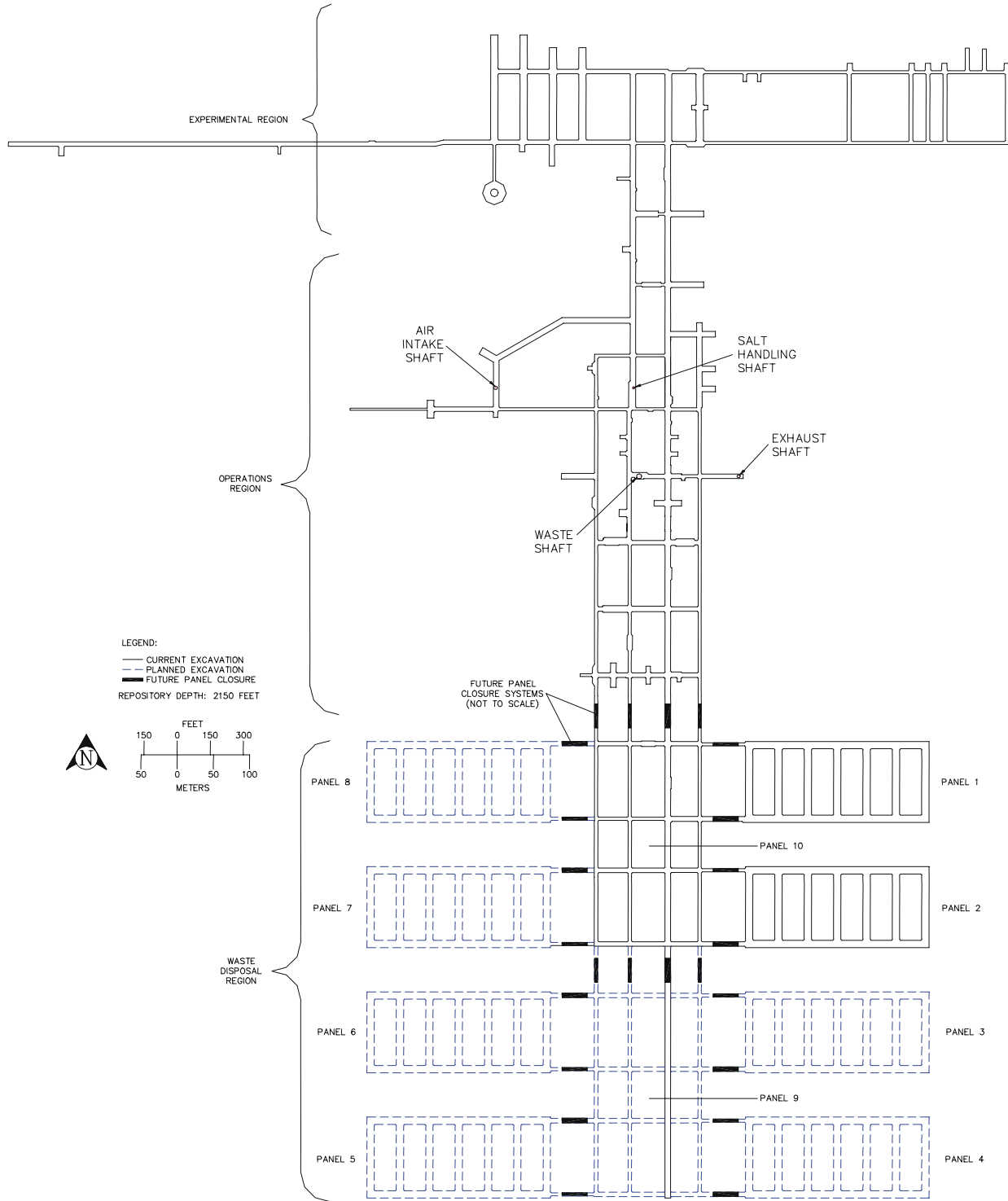
16 *In a submittal dated April 26, 2001 [Docket A-98-49, II-B-3, Item 19], the DOE requested that*
17 *EPA approve a different utilization plan for Panel 1. The flexibility to vary the utilization of*
18 *Panel 1 was important from both a worker safety and operational efficiency perspective. The*
19 *rooms of Panel 1 were over 12 years old at the time of the proposed change. The natural*
20 *processes of room closure had reduced the vertical clearance to the extent that re-mining*
21 *would be necessary to provide sufficient headroom and acceptable floor conditions for waste*
22 *to be emplaced as described in the CCA, i.e., three containers high. Based upon the analyses*
23 *performed by Sandia National Laboratories (SNL), the DOE concluded that this request was*
24 *not a significant departure from the original design and that aspects of the repository system*
25 *important to waste containment would not be affected or changed. The EPA agreed with*
26 *DOE's conclusion in a letter dated August 7, 2001 [Docket A-98-49, II-B-3, Item 19], stating*
27 *"DOE's proposed alternative use of Panel 1 is compliant with terms and conditions of WIPP's*
28 *certification." There is no RH-TRU waste disposed in Panel 1.*

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

30 **3.1 General Facility Design**

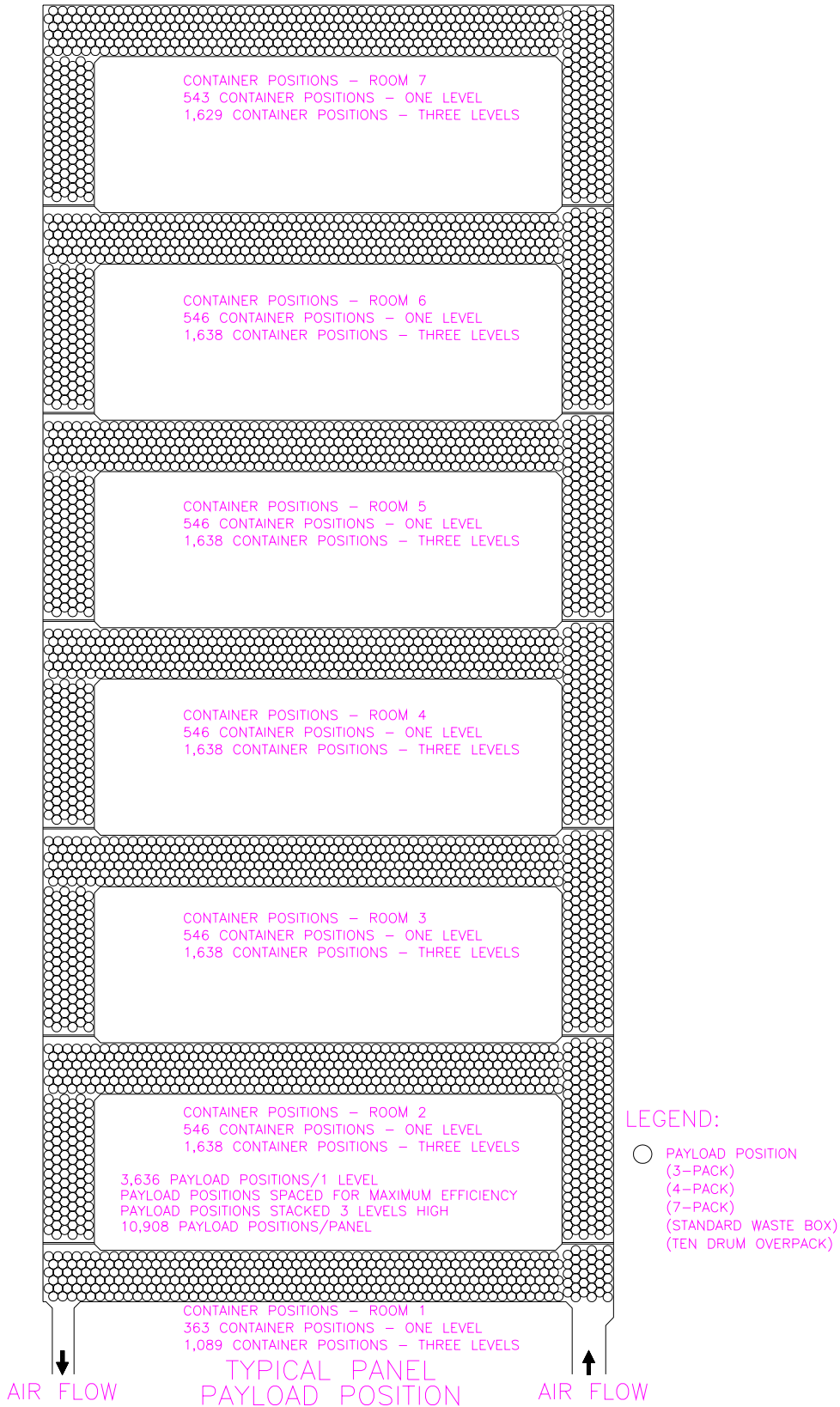
31 The DOE has designed the WIPP facility to accomplish four primary goals:

- 32 1. to receive, handle, and dispose of TRU waste and TRU-mixed waste (in this document,
33 the term TRU waste is used to describe both TRU and TRU-mixed waste unless
34 otherwise noted);
- 35 2. to protect the health and safety of workers, the public, and the environment;
- 36 3. to comply with applicable radiation protection standards; and



1

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



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Figure 3-3. Typical Panel Waste Emplacement

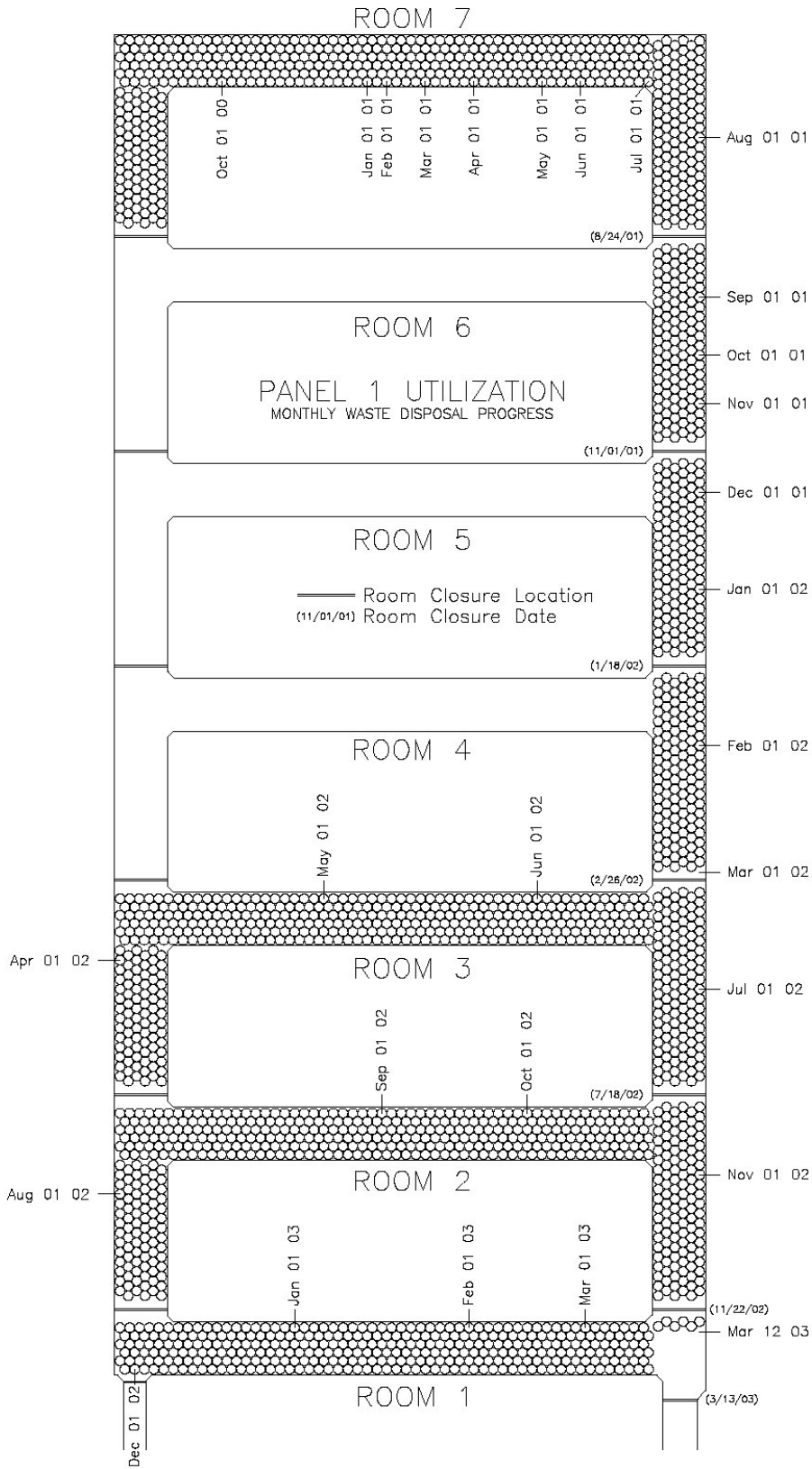


Figure 3-4. Panel 1 Waste Emplacement

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Table 3-1. WIPP Site Features

Facility Name	Waste Isolation Pilot Plant (WIPP)
U.S. Environmental Protection Agency (EPA) Identification Number	NM 4890139088
Location	41.84 km (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	41.4 km² (16 mi²) square miles (41.4 square kilometers)
Property Protection Area	13.7 hectares (34 acres) (13.7 hectares)
Depth to repository horizon	655 meters (2,150 feet) below grade level (655 meters)

2 4. to comply with other environmental statutes and regulations, and requirements of federal,
3 state, and local agencies (as discussed in *the WIPP Biennial Environmental Compliance*
4 *Reports (DOE 2002, et seq.* ~~Appendix BECR).~~

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

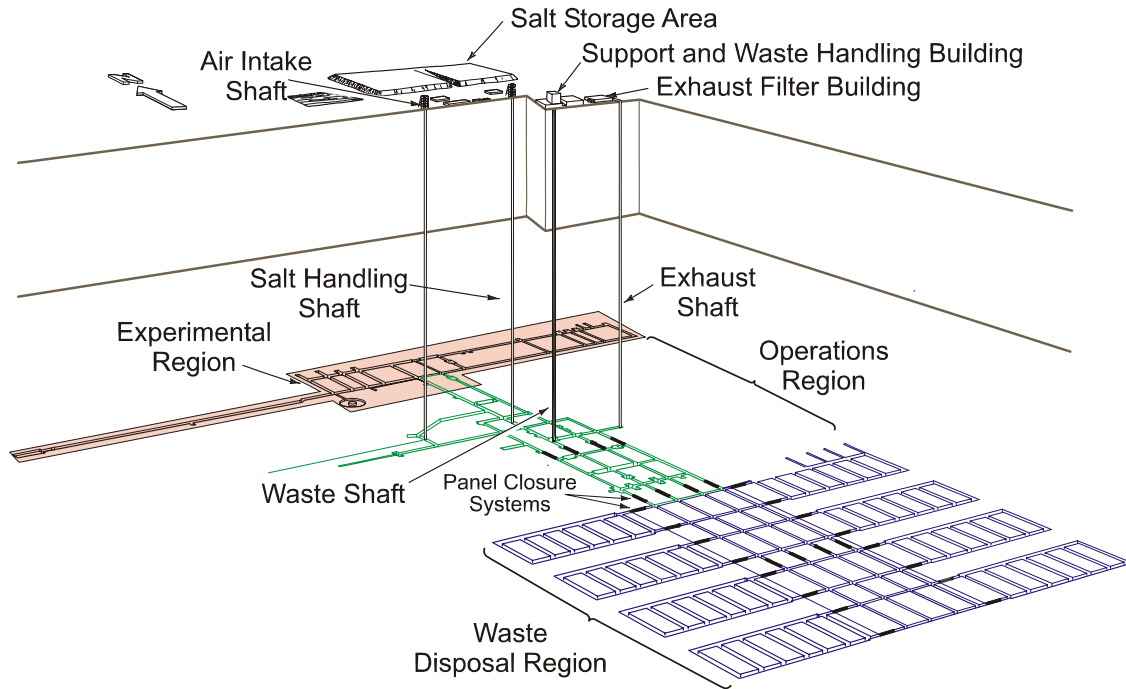
- 11 • waste disposal area,
- 12 • shaft pillar area, and
- 13 • associated support facilities.

14 Figure 3-35 provides a spatial view of the WIPP facility.

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

21 **3.1.1 DOE Facility Acquisition Process**

22 Federal facility acquisition policies were applied to the design and construction of the WIPP
23 facility. WIPP structures are designed to meet *the Carlsbad Field Office (CBFO) Functions,*



Note: For illustrative purposes only.
Not to scale.

CCA-087-2

1
2 **Figure 3-33-5. Spatial View of the WIPP Facility**

3 ***Responsibilities, and Authorities Manual (DOE/WIPP 98-2287, 2001), 10 CFR Part 830,***
 4 ***Subpart B (design qualifications), and the Quality Assurance Program Document (QAPD)***
 5 ***(DOE 1996) for general issues of quality*** DOE design and QA requirements as documented in
 6 ***the Final Safety Analysis Report (DOE 1990b). Appropriate*** structures, systems and
 7 components are designed to meet the requirements applicable to Design Class II structures,
 8 systems, and components for nonreactor nuclear facilities. The design class designations are
 9 categorized in accordance with their importance relative to health and safety of the public and
 10 on-site personnel during plant operations.

11 **3.1.2 Configuration Control**

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

1 ~~QA~~**Quality assurance** requirements applicable to *the* WIPP facility design and configuration
2 control activities are founded on the basic and supplemental requirements of the American
3 Society of Mechanical Engineers' QA program requirements for nuclear facilities (American
4 Society of Mechanical Engineers' NQA-1 1989). As discussed in Section 5.2, the DOE now
5 implements these requirements through the ~~CAO's QAPD~~**CBFO's QAPD**, which is provided in
6 Appendix QAPD. Design QA elements include (1) documentation, review, and approval of
7 design inputs; (2) control of design analyses, design verification, and design changes; and (3)
8 institution of design interface controls and records management practices. These and other
9 applicable configuration management QA requirements are discussed in Section 5.4-~~6~~**3.3**.

10 **3.1.3 Surface Structures**

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

- 18 • hoist houses,
- 19 • support building,
- 20 • guard and security building,
- 21 • office trailers,
- 22 • exhaust filter building,
- 23 • warehouse and shops,
- 24 • water pump house,
- 25 • training building,
- 26 • engineering building,
- 27 • **materials, tools, and electronics and tool crib** ~~core storage~~ building,
- 28 • safety and emergency services building.

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

1 The WIPP facility does not lie within a 100-year floodplain. There are no major surface-water
2 bodies within ~~five miles~~ (~~8~~ **eight km (five mi)** kilometers) of the site, and the nearest river, the
3 Pecos River, is approximately ~~12 miles~~ (~~19 km (12 mi)~~ kilometers) away. The general ground
4 elevation in the vicinity of the surface facilities (approximately ~~3,400 feet~~ [~~1,036 m~~ **3,400**
5 **ft**meters] above mean sea level) is about ~~500 feet~~ (~~152 m (500 ft)~~ meters) above the riverbed and
6 ~~400 feet~~ (~~122 m (400 ft)~~ meters) above the 100-year floodplain. (**Chapter 2.0 provides more**
7 **information on surface hydrology and climate.**) Protection from flooding or ponding caused by
8 ~~probable maximum precipitation (PMP)~~ events is provided by the diversion of water away from
9 the WIPP facility by a system of peripheral interceptor diversions. Additionally, grade
10 elevations of roads and surface facilities are designed so that storm water will not collect on the
11 site under the most severe conditions.

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

15 The mean annual precipitation in the region is about ~~12 inches~~ (~~30 cm (12 in.)~~ centimeters), and
16 the mean annual runoff is ~~0.1 to 0.2 inch~~ (~~0.25 to 0.50 cm (0.1 to 0.2 in.)~~ centimeters). The
17 maximum recorded 24-hour precipitation at Carlsbad was ~~5.12 inches~~ (~~13 cm (5.12~~
18 **in.** centimeters) in August 1916. The ~~six~~-hour, 100-year precipitation event for the site is ~~3.6~~
19 **inches** (~~9.1 cm (3.6 in.)~~ centimeters) and is most likely to occur during the summer. The
20 maximum daily snowfall at Carlsbad was ~~10 inches~~ (~~76 cm (10 in.)~~ centimeters) in December
21 1923.

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

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

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

39 Two separate water-seal rings are incorporated in each key. Performance of the seals is
40 monitored by inspection of the bottom of the key for seepage. If groundwater is detected

1 flowing past the upper ring, this condition ~~is~~ *can be* corrected by injecting chemical sealants or
 2 ~~ement~~ *ementitious* grouts to stop the leakage.

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

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

17 **3.2 Repository Configuration**

18 A preliminary design of the WIPP repository was presented in the ~~FEIS~~ *Final EIS* (DOE 1980).
 19 Validation efforts for the WIPP repository preliminary design began in 1981 with the Site and
 20 Preliminary Design Validation (SPDV) program. The SPDV program was implemented to
 21 further characterize and validate the WIPP site geology and to provide preliminary validation of
 22 the underground excavation. The SPDV program involved the excavation of four full-sized
 23 disposal rooms, excavated ~~13 feet~~ *(4 m (13 ft meters))* high, ~~33 feet~~ *(10 m (33 ft meters))* wide, and
 24 ~~300 feet~~ *(91 m (300 ft meters))* long, and separated by ~~100-foot~~ *(31-m (100-ft meter))*-wide pillars.
 25 Data obtained from geologic field activities and geomechanical instrumentation were analyzed to
 26 determine the suitability of the design criteria and design bases and to provide confirmation of
 27 the underground opening reference design. Analyses of these preliminary designs performed by
 28 the WIPP architect and engineer ~~are included~~ *can be found* in *CCA* Appendix DVR. These
 29 analyses considered expected creep closure rates in determining disposal room sizes.
 30 Information in *CCA* Appendix DVR (Section DVR.6.4.2) meets the criterion specified in 40
 31 CFR § 194.14(b)(2). Figures 12-21 and 12-22 ~~in~~ *of* the Final Design Validation Report in *CCA*
 32 Appendix DVR show the creep closure histories used for designing the disposal rooms. The
 33 specified size was selected to ensure no CH-TRU containers would breach due to creep closure
 34 while a panel is being filled with waste. A nominal five-year life is used for operational
 35 purposes for mining, emplacement, and closure with no risk of CH-TRU waste containers
 36 breaching. Remote-handled containers will not breach in this time period due to the canister wall
 37 thickness and the ~~2 to 4 inch~~ *(5.08 to 10.16 cm (2 to 4 in. centimeter))* creep tolerance in each
 38 RH-TRU emplacement hole.

39 The WIPP underground facilities are located on the repository horizon ~~2,150 feet~~ *(655 m (2,150*
 40 *ft meters))* beneath the surface (see Figure 3-2). In Chapter 2.0, Figure 2-~~8~~ *12* shows a
 41 stratigraphic column which displays the repository and its position relative to mean sea level.
 42 These facilities include the waste disposal region, the operations region, an experimental region,

1 and associated support facilities. The underground support facilities service and maintain
2 underground equipment for mining and disposal operations, monitor for radioactive
3 contamination, and allow limited decontamination of personnel and equipment.

4 Waste panels consist of seven rooms. Each room ~~will have~~*has* nominal dimensions of ~~300 feet~~
5 ~~(91 m (300 ft-meters))~~ long, ~~33 feet (10.1 m (33 ft-meters))~~ wide, and ~~13 feet (4.0 m (13 ft-meters))~~
6 high. Pillars between rooms are ~~400 feet (30 m (100 ft-meters))~~ thick. Eight waste panels will be
7 separated from each other and the main entries by nominally ~~200 feet (61-m (200-ft-meters))~~
8 pillars. In addition to the eight panels, the main north-south and east-west access drifts in the
9 waste regions are available for waste disposal. These have been designated Panels 9 and 10 for
10 permitting and modeling purposes (see Figure 3-2). Section 6.4.2.1 describes the treatment of all
11 waste panels in BRAGFLO. Additional information can also be found in Appendix *PA*,
12 *Attachment MASS.5*. Rockbolts, or related types of ground support, are used as necessary to
13 maintain safe underground personnel access. In the panels, this will typically consist of localized
14 bolting when needed. All panels will be closed using the panel closure system described in
15 Section 3.3.23.

16 The underground is connected to the surface by four vertical shafts: the waste shaft, the salt
17 handling shaft, the exhaust shaft, and the AIS. The waste shaft, salt handling shaft, and the air
18 intake shaft have permanently installed hoists capable of moving personnel, equipment, and
19 materials between the surface and the repository. All shafts will eventually be sealed using the
20 seal design described in Section 3.3.42. A summary of information describing existing WIPP
21 shafts is given in ~~Table 4-2 of Appendix SEAL~~ *Appendix BARRIERS, Section BARRIERS-3.0*.

22 Mining of the shafts and underground passages within the repository gives rise to a disturbed
23 rock zone (DRZ) that is important to repository performance. The DRZ forms as a consequence
24 of unloading the rock in the vicinity of the excavation. Increased permeability is created by
25 microfractures along grain boundaries and by bed separation along lateral seams. The DRZ
26 development begins immediately after excavation and continues as salt creeps into the opening.
27 The DRZ surrounding the shafts is symmetrical and has been characterized and incorporated into
28 the shaft seal design as discussed in Appendix ~~SEAL~~ *BARRIERS*. As shaft seal elements resist
29 inward creep, the stress state becomes compressive and gives rise to fracture healing, and a
30 return of the disturbed salt to its original extremely low permeability. The lateral DRZ along
31 passages in the underground includes fracture in nonhalitic rock, such as anhydrite, and bed
32 separation on clay seams. These zones will not naturally heal in a manner similar to healing of
33 halite. ~~Panel closure systems discussed in Section 3.3.2 will prevent further development of the~~
34 ~~DRZ in panel entries, thereby restricting flow from the panels to that existing in the DRZ at the~~
35 ~~time of panel closure construction.~~ *Rigid components of the panel closure system will prevent*
36 *further development of the DRZ.*

37 *In a letter dated June 26, 2000 [Docket A-98-49, II-A-3, Item 24, Attachment 1], the CBFO*
38 *submitted a planned change to raise the repository horizon in Panels 3, 4, 5, 6, and 9 by*
39 *approximately 2 m (6.6 ft) so that the back (roof) is at Clay Seam G. Positioning the back at*
40 *Clay Seam G results in a more stable back configuration and improves repository ground*
41 *conditions. Raising the horizon also reduces the rate of roof-beam deformation and slows the*
42 *development of fractures, thus reducing risks during mining and waste handling in the*
43 *underground repository. This change also results in less maintenance being required to*

1 *assure acceptable ground conditions. In a letter dated August 11, 2000 [Docket A-98-49, II-A-*
2 *3, Item 24], the EPA agreed "... that (this change) will enhance operational safety without*
3 *significantly affecting the long-term performance of the facility." (Chapter 6.0 provides more*
4 *detail related to Clay Seam G.)*

5 **3.3 Engineered Disposal-System Barriers**

6 In addition to the natural barriers provided by the geology and hydrology of the disposal system,
7 the DOE's design of the WIPP includes engineered barriers to significantly delay the migration
8 of radionuclides to the accessible environment. These engineered barriers are integral parts of
9 the disposal system as modeled in Section 6.4 and are included in the demonstration of
10 compliance to the containment standards in Section 6.5. Because the WIPP uses the concept of
11 multiple barriers, that is, both natural and engineered barriers, the requirements in 40 CFR
12 § 191.14(d) are met. *Disposal system barriers are used in the DOE's design of the WIPP to*
13 *isolate waste and delay the migration of radionuclides to the accessible environment.*
14 *Disposal-system barriers include the geology and hydrology of the disposal system or natural*
15 *barriers, engineered systems, and an engineered barrier designed to meet the regulatory*
16 *requirements of 40 CFR § 194.14(d).* In addition, the incorporation of *disposal-system barriers*
17 *(both engineered and natural barriers)* satisfies the criterion stated in 40 CFR § 194.44(a).

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

20 *In the CCA, the DOE proposed four elements* ~~The DOE has elected to incorporate four types of~~
21 ~~engineered barriers in the design of the disposal system~~ *as engineered barriers:*

- 22 (1) shaft seals,
- 23 (2) panel closures,
- 24 (3) *MgO* ~~backfill~~ around the waste, and
- 25 (4) borehole plugs.

26 *In its certification decision, the EPA concluded that only MgO meets the regulatory definition*
27 *of an engineered barrier. The certification decision includes the following regarding*
28 *engineered barriers (63 FR 27397, May 18, 1998):*

29 *The EPA finds that DOE complies with Sec. 194.44. The EPA found that DOE conducted the*
30 *requisite analysis of engineered barriers and selected an engineered barrier designed to prevent*
31 *or substantially delay the movement of water or radionuclides toward the accessible*
32 *environment. The DOE provided sufficient documentation to show that MgO can effectively*
33 *reduce actinide solubility in the disposal system. The DOE proposed to emplace a large amount*
34 *of MgO around waste drums in order to provide an additional factor of safety and thus account*
35 *for uncertainties in the geochemical conditions that would affect CO₂ generation and MgO*
36 *reactions.*

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

1 *Although shaft seals, panel closures, and borehole plugs are not defined by EPA as*
2 *engineered barriers, these features may affect disposal system performance and thus are*
3 *included in the performance assessment (PA) (Appendix PA, Section PA-4.2).* Shaft seals and
4 borehole plugs will limit migration of liquid and gases in the WIPP shafts and boreholes. Panel
5 closures will limit the communication of brine and gases among waste disposal panels. Designs
6 of shaft seals, borehole plugs, and panel closures use common engineering materials that possess
7 low permeability, appropriate mechanical properties, and durability.

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

17 **3.3.31 *Backfill MgO Engineered Barrier***

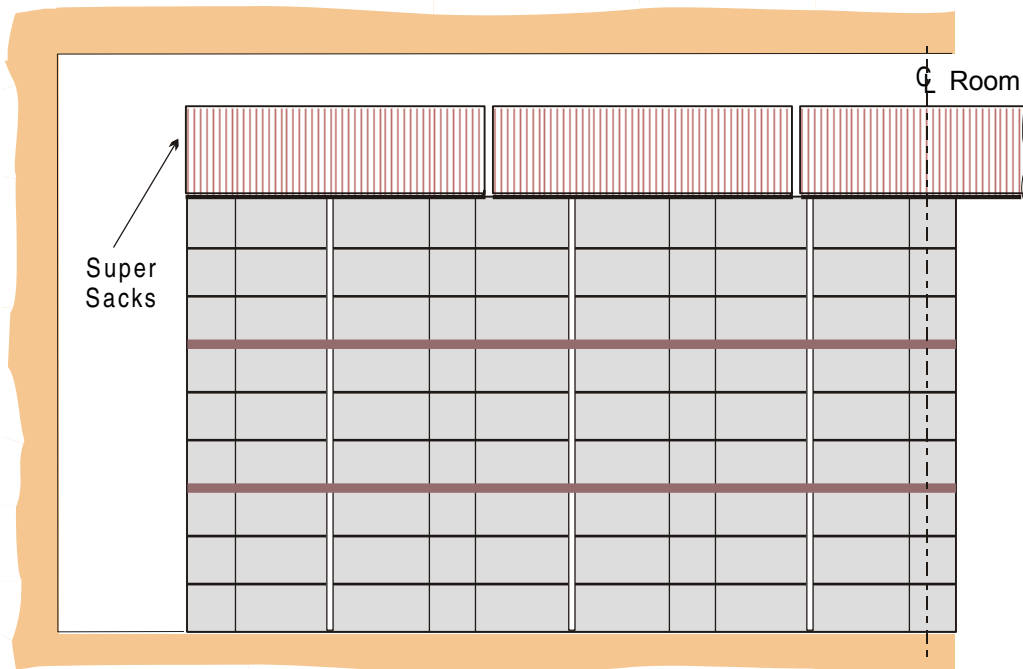
18 The DOE has concluded that it is desirable to add MgO to the repository to improve *the*
19 performance of the disposal system (see Appendix ~~BACK~~*BARRIERS*). This additive ~~will be~~ *is*
20 *being* protected in *supersacks* until the *supersacks* are broken during creep closure of the room.
21 The MgO backfill ~~will be~~ *is being* purchased ~~prepackaged in the proper containers~~ *polypropylene*
22 *supersacks* for emplacement in the underground. *Emplacement in supersacks (1) facilitates*
23 *handling and emplacement of MgO; (2) minimizes potential worker exposure to dust; and (3)*
24 *minimizes the exposure of periclase, the main, reactive constituent of MgO, to atmospheric*
25 *carbon dioxide (CO₂) and water prior to rupturing of the supersacks.* ~~Purchasing prepackaged~~
26 ~~backfill eliminates handling and placement problems associated with bulk materials, such as dust~~
27 ~~creation. In addition, prepackaged materials will be easier to emplace, thus reducing potential~~
28 ~~worker exposure to radiation.~~

29 The MgO backfill will be purchased and received in two different containers: (1) ~~a supersack~~
30 ~~holding several thousand pounds, and (2) a mini sack holding 25 pounds (11.3 kilograms).~~
31 Quality assurance requirements, such as material quality, will be addressed through the
32 procurement quality requirements in Section 2.3 of the Westinghouse Waste Isolation Division
33 (WID) Quality Assurance Program Description (see Appendix QAPD). MgO is available from
34 several suppliers in a range of grain sizes and purities. Typical purities range from 93 percent
35 MgO for baked dolomite to 98 percent for MgO extracted from brines. Chemical grade product
36 (100 percent MgO) is also available. MgO is available in a variety of milled and screened grain
37 sizes ranging from a powder (minus 325 mesh) to granular (0.5 inch by 6 mesh). The filled
38 containers will be shipped by road or rail and will be delivered underground using current shaft
39 and material handling procedures and processes.

40 The mini sack will be 34 inches (86.4 centimeters) long, 6 inches (15 centimeters) in diameter
41 and will be fabricated of a single layer of polyethylene or other suitable material. It will have an
42 integral handle and hook attached into the sack closure. Six sacks will be manually placed in the

1 external voids of each seven-pack unit just before the seven-pack is positioned on the waste
 2 stack. The mini sack will be lifted up behind the shrink wrap around the top of the seven-pack,
 3 slid into place, and held there by the 4-inch (10-centimeter) hole in the lower slip sheet (see
 4 Figure 3-7). Once the sacks are in place, the seven-pack will be positioned on the waste stack in
 5 the normal manner. A similar process will be used for standard waste boxes (SWB) except that
 6 the sacks will be hung from the lift clips on these units as shown in Figure 3-7.

7 Supersacks, which may be up to 4,000 pounds (1,814 kilograms) *contain 1900 ± 23 kg (4200 ±*
 8 *50 lbs), are* will be handled and placed using normal waste-handling techniques. Once each row
 9 of waste units is in place, a layer of super-sack *supersacks* will be placed on top of them as
 10 shown in Figure 3-86. The super-sack *supersacks are constructed of woven polypropylene,*
 11 *which serves as a barrier to CO₂ and moisture* will be of multiwall construction with a vapor
 12 and moisture barrier. The super-sack *supersacks are placed on support sheets* have an integral
 13 slip sheet or base attachment so that *they* can be handled and placed in a manner that is
 14 identical to how waste units are emplaced. Typically, the space above a stack of containers will
 15 be 36 to 48 inches (90 to 122 *cm (36 to 48 in.* centimeters), of which about 18 inches (45 *cm*
 16 *(18 in.* centimeters) will contain *MgO* the backfill material.



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Figure 3-6. Room Cross-Section Showing the Position of Supersacks

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

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

3 ~~There are about 3,700 linear feet (1,128 linear meters) of waste stack in a panel. The stated~~
4 ~~configuration provides about 4,000 pounds per linear foot (5,952 kilograms per linear meter) of~~
5 ~~waste stack or about 7,400 short tons (6,712 metric tons) per panel. About 10,836 waste disposal~~
6 ~~units (that is, seven packs of drums and SWBs) will be placed in a panel and at six 25-pound~~
7 ~~(11.3 kilogram) mini sacks per unit, this will provide about 800 short tons (726 metric tons) per~~
8 ~~panel. Finally, material stacked along the ribside at 100 pounds per linear foot (148.8 kilograms~~
9 ~~per linear meter) of rib will provide about 360 short tons (327 metric tons) per panel. This gives~~
10 ~~a total of about 8,560 short tons (7,764 metric tons) per panel or approximately 85,600 short tons~~
11 ~~(77,640 metric tons) for the repository.~~

12 ~~Backfill placed in this manner is protected until exposed when sacks are broken during creep~~
13 ~~closure of the room and compaction of the backfill and waste. Backfill in sacks use existing~~
14 ~~techniques and equipment and eliminates operational problems such as dust creation and~~
15 ~~introducing additional equipment and operations into waste handling areas. There are no mine~~
16 ~~operational considerations (for example, ventilation flow and control) when backfill is placed in~~
17 ~~this manner. Backfill performance and disposal system impacts are discussed in more detail in~~
18 ~~Section 6.4.3. Appendix BACK provides the rationale for the use of MgO as a backfill.~~
19 ~~Appendix SOTERM (Section SOTERM.2.2) contains information regarding the chemical effects~~
20 ~~of MgO in the disposal room. The commercially available code EQ3/EQ6 was used in the~~
21 ~~determination of chemical effects.~~
22 *The performance of MgO and its impacts on the disposal*
23 *system are discussed in more detail in Section 6.4.3.4. Appendix BARRIERS provides the*
24 *rationale for the use of MgO as an engineered barrier and contains information regarding its*
25 *effects on chemical conditions in the repository. Laboratory experiments and thermodynamic*
26 *modeling were used to predict the long-term effects of MgO on chemical conditions. Appendix*
27 *PA, Attachment SOTERM describes how these conditions were used to calculate actinide*
solubilities.

28 *Initially, MgO was emplaced in both minisacks and supersacks. Minisacks, which contained*
29 *11 kg (25 lbs.) of MgO, were placed among the waste containers and on the floor between the*
30 *waste containers and the ribs. Supersacks, which contain 1900 ± 23 kg (4200 ± 50 lb) of*
31 *MgO, are handled and emplaced using normal waste-handling techniques. Once each stack*
32 *of waste containers is emplaced, a layer of supersacks is emplaced on top of them. Two*
33 *changes related to MgO have occurred since the submittal of the CCA. These changes and*
34 *their effects are described below.*

35 3.3.1.1 Change of MgO Supplier

36 *After the original supplier stopped producing MgO in 2000, another supplier was selected.*
37 *The new MgO is slightly less dense than the previous product. To compensate for this, the*
38 *volume of MgO emplaced in the repository was increased by approximately two percent to*
39 *ensure the emplacement of the same mass of MgO proposed in the CCA. The product*
40 *provided by the new supplier meets all of the technical specifications for MgO. The DOE*
41 *evaluated the properties of the new MgO and concluded that the change has no impact on its*
42 *expected performance as the engineered barrier (see Appendix BARRIERS).*

1 3.3.1.2 Elimination of MgO Minisacks

2 *In order to enhance worker safety and operational efficiency, DOE requested EPA approval of*
 3 *the elimination of the MgO minisacks. Elimination of the minisacks resulted in a 15 percent*
 4 *reduction in the total mass of MgO to be emplaced in the WIPP. An impact assessment*
 5 *carried out to support the DOE modification request demonstrated that the elimination of*
 6 *minisacks and the associated 15 percent reduction of MgO would not affect its performance as*
 7 *the engineered barrier (consumption of CO₂ from possible microbial activity and concomitant*
 8 *reduction of actinide solubilities). The assessment also demonstrated that the reduction of*
 9 *MgO would not reduce the additional benefits of brine consumption and constant chemical*
 10 *conditions.*

11 *In a letter from the EPA dated January 11, 2001 [Docket A-98-49, II-B-3, Item 15], the EPA*
 12 *approved the elimination of the MgO minisacks. Appendix BARRIERS provides additional*
 13 *information on MgO.*

14 ~~3.3.2~~ Shaft Seals

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

23 Material specifications and construction techniques for the shaft seal system are given in
 24 Appendix *Barriers; and in CCA Appendix SEAL in SEAL 5.0 and 6.0.* Chapter 5 (Materials
 25 Specification) and Chapter 6 (Construction Techniques). Chapter 5 of Appendix SEAL *Section*
 26 *SEAL 5.0* also provides the rationale and quantification methods used to develop parameter
 27 distribution functions. Appendix SEAL also has ~~Appendices A and B, which are materials~~
 28 ~~specification and construction techniques, respectively.~~ *Appendix PA, Section PA-4.2.6*
 29 *summarizes the representation of the shafts in PA; Appendix PA, Attachment PAR, Table*
 30 *PAR-17 provides parameter values in the modeling.* ~~provides a complete summary of~~
 31 ~~parameters used as inputs to the performance assessment codes.~~ The presently envisaged shaft
 32 seal system is described in this section *at a summary level with detail provided in Appendix*
 33 *BARRIERS,* including the configuration of material, seal material specifications, construction
 34 ~~methods, rock mechanics analyses, and fluid flow evaluations.~~

35 The shaft seal design package in Appendix SEAL thoroughly explores function and performance
 36 of the WIPP shaft seal system and provides well-documented assurance that such a shaft seal
 37 system can be constructed using available materials and methods. Sections of CCA Appendix
 38 SEAL provide hydrologic and structural calculations, material specifications and properties,
 39 construction methods, and engineering drawings. Documentation of material properties and their
 40 satisfactory application in the site-specific environment for regulatory time periods aid in
 41 assuring that the WIPP shaft seal system will meet performance expectations. Documentation of

1 the analyses conducted and the results can be referenced in **CCA** Appendix SEAL (Chapter 2.4
2 of Appendix A, and ~~in Appendix SEAL, Chapter 3.1.2 of Appendix D).~~

3 3.3.24.1 Site Setting

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

13 3.3.24.2 Design Objectives

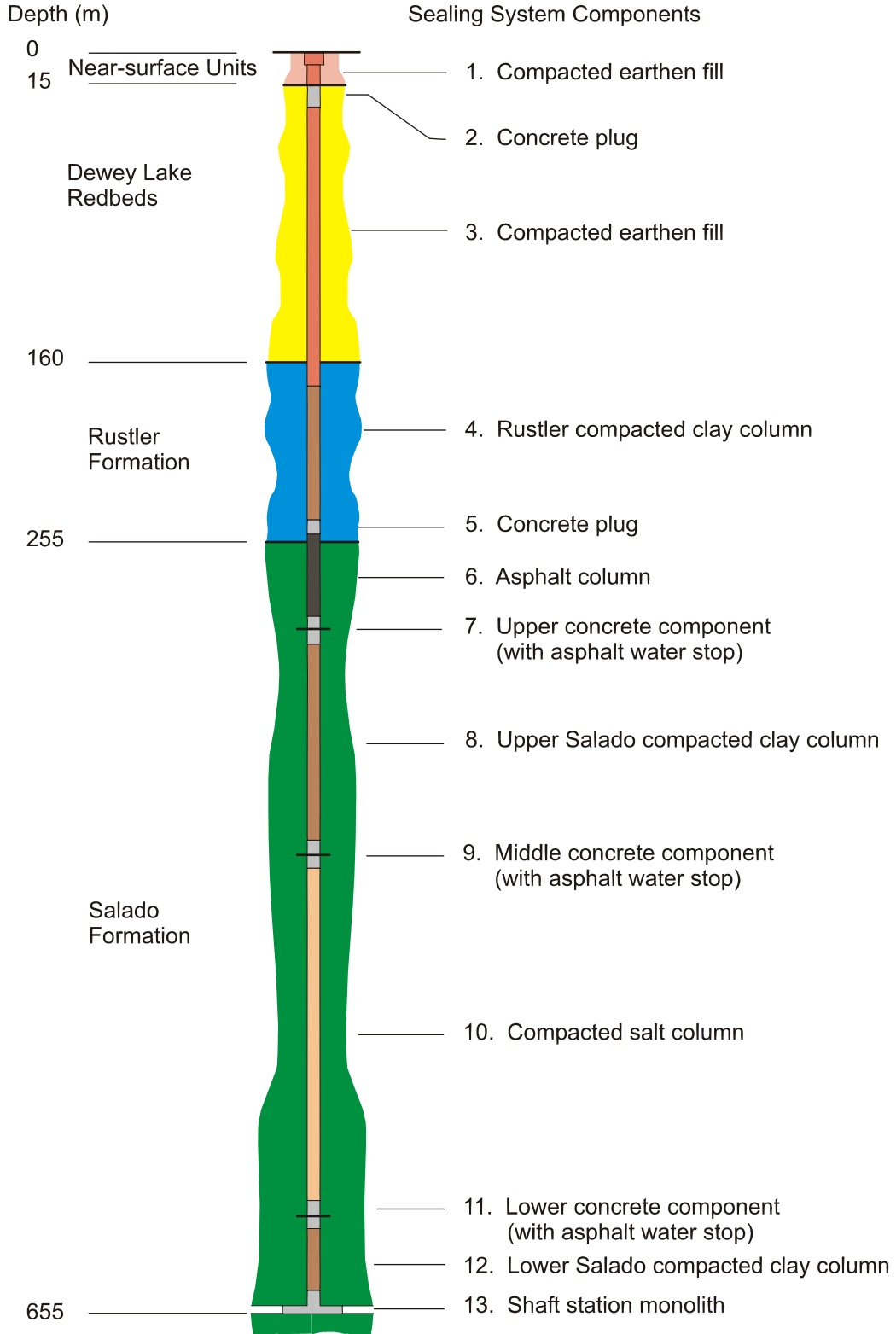
14 Design objectives for the shaft seal system address the need for the WIPP to comply with system
15 requirements and to follow accepted engineering practices using demonstrated technology. Shaft
16 seal design objectives are summarized as follows:

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

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

30 3.3.24.3 Design Description

31 A schematic of the shaft seal system as configured for the AIS is shown in Figure 3-4 ~~3-7~~. Slight
32 differences in seal element geometry occur within the four shafts owing to different shaft
33 diameters or stratigraphic variations. The shaft seal system has 13 elements that fill the shaft
34 with engineered materials possessing high density and low permeability. Components of the seal
35 system within the Salado provide the primary barrier by limiting fluid transport along the shaft



1

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2

Figure 3-43-7. Proposed Seal Design for the WIPP AIS

1 during the 10,000-year regulatory period. Components of the seal system within the Rustler
2 limit commingling of groundwater between water-bearing members. Components of the seal
3 system overlying the Rustler fill the shaft with common materials of high density, consistent
4 with good engineering practices. *Appendix BARRIERS provides a detailed description of the*
5 *shaft seal system and detailed design drawings for each shaft seal.* A brief description of the
6 general shaft seal system is given in this section. The detailed design drawings for each shaft
7 seal system are provided in Appendix SEAL (Appendix E).

8 ~~3.3.1.3.1 Shaft Station Monolith~~

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

15 ~~3.3.1.3.2 Clay Columns~~

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

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

1 ~~3.3.1.3.3 Concrete Asphalt Water Stop Components~~

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

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

21 ~~3.3.1.3.4 Compacted Salt Column~~

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

34 ~~3.3.1.3.5 Asphalt Column~~

35 An asphalt aggregate mixture is specified for the asphalt column (Component #6), which bridges
36 the Rustler and Salado contact. Length of the asphalt column ranges from 138 to 143 feet (42 to
37 44 meters) in the four shafts. The asphalt column is located above the upper concrete and asphalt
38 component (#7) and extends approximately 16 feet (5 meters) above the Rustler and Salado
39 contact. Existing shaft linings and keys are removed from 20 feet (6 meters) above the top of the
40 asphalt column to just below the lowest chemical seal ring. The asphalt column provides an
41 essentially impermeable seal for the shaft cross section and along the shaft wall interface.

1 ~~3.3.1.3.6 Concrete Plugs~~

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

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

15 ~~3.3.1.3.7 Earthen Fill~~

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

24 ~~3.3.1.4 Materials~~

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

- 38 ~~• functions,~~
- 39 ~~• material characteristics,~~

- 1 • ~~construction;~~
- 2 • ~~performance requirements;~~
- 3 • ~~verification methods; and~~
- 4 • ~~references.~~

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

11 3.3.1.5— Structural Analysis

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

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

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

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

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

5 Construction analyses examine

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

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

11 3.3.1.5.1 DRZ Behavior

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

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

33 3.3.1.5.2 Compacted Salt Behavior

34 Creep driven consolidation of the compacted salt column is an important long term
35 consideration of the shaft seal system. This behavior has been examined in detail, with three
36 material models selected to describe the phenomenon (see Appendix SEAL, Appendix D,
37 Chapter 3.1.2). Results of tests on WIPP salt were used to evaluate constitutive models for

1 reconsolidating salt (see Appendix SEAL, Appendix D, Chapter 4.2). Coupled with finite
2 element models for the surrounding geologic setting, the models for reconsolidating salt provide
3 estimates of effective permeability of the salt component of the shaft seal system. As an
4 example, structural calculations determine fractional density of the crushed salt seal as a function
5 of time and depth and use results of laboratory tests to determine permeability. Based on these
6 calculations, a desirable fractional density (hence, permeability) is achieved over a substantial
7 length of the compacted salt seal within several decades of placement.

8 3.3.1.6 Hydrologic Evaluations

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

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

- 20 (1) downward migration of groundwater from the Rustler,
- 21 (2) gas migration and reconsolidation of the compacted salt seal component,
- 22 (3) upward migration of brines from the repository, and
- 23 (4) flow between water bearing zones in the Rustler.

24 3.3.1.6.1 Downward Migration of Rustler Groundwater

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

34 At steady state, the flow rate is most dependent on the permeability of the system. Potential flow
35 paths within the seal system consist of the seal material, an interface with the surrounding rock,
36 and the host rock DRZ. Low permeability is specified of the engineered materials and
37 construction methods ensure a tight interface; thus, the flow path most likely to impact
38 performance is the shaft DRZ. Fluid flow analyses conducted are provided in Appendix SEAL

1 (Appendix C). Rock mechanics calculations predict that the DRZ in the Salado will not be
2 vertically continuous because of intermittent layers of stiff anhydrites (marker beds). Concrete
3 and asphalt water stops are included in the design as a means to mitigate DRZ impacts. Effects
4 of marker beds and asphalt water stops on limitation of downward migration are explicitly
5 simulated through permeability variation of the layers of Salado shaft DRZ. Initial, upper, and
6 lateral boundary conditions of the hydrologic model are consistent with field measurements of
7 the physical system. At the base of the shaft a constant, atmospheric pressure is assumed. The
8 hydrologic model predicts a maximum cumulative flow of less than 353 cubic feet (10 cubic
9 meters) through the sealed shafts during the first 200 years following closure.

10 3.3.1.6.2 Gas and Brine Migration

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

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

28 3.3.1.6.3 Upward Migration of Brine

29 Fluid pressure of the Salado is higher than fluid pressure in the Rustler so that upward migration
30 of brines could occur through an inadequately sealed shaft. Results from modeling (discussed
31 above) demonstrate that the crushed salt seal will reconsolidate to a very low permeability within
32 100 years following repository closure (see Appendix SEAL, Appendix C). Structural results
33 reported in Appendix SEAL (Section 7.4) show that the DRZ surrounding the compacted clay
34 and compacted components will completely heal within the first several decades (see Appendix
35 SEAL, Appendix D, Table D-20). As a result, upward brine flux at the Rustler and Salado
36 contact in the sealed AIS is approximately 35 cubic feet (1 cubic meter) over the 10,000-year
37 regulatory period. This brine originates in the marker beds; no brine from the repository
38 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).

3.3.32 Panel Closure System

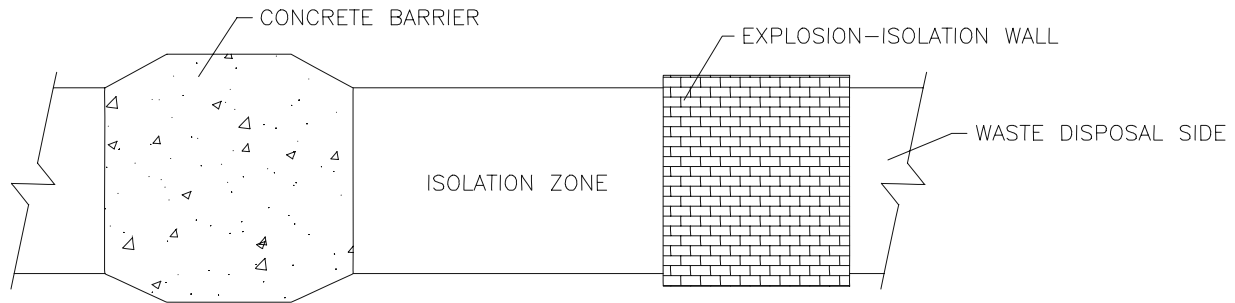
In its final certification decision for WIPP (63 FR 27354), the EPA added a new Appendix A to 40 CFR Part 194. The new appendix specifies four conditions that apply to the certification. Condition 1 pertains to panel closures. It states:

Condition 1: § 194.14(b), Disposal system design, panel closure system. The Department shall implement the panel seal design designated as Option D in Docket A-93-02, Item II-G-1 (October 29, 1996, Compliance Certification Application submitted to the Agency). The Option D design shall be implemented as described in Appendix PCS of Docket A-93-02, Item II-G-1, with the exception that the Department shall use Salado mass concrete (consistent with that proposed for the shaft seal system, and as described in Appendix SEAL of Docket A-93-02, Item II-G-1) instead of fresh water concrete.

Option D involves installation of a concrete block “explosion-isolation wall,” removal of the DRZ along a section of the panel access drifts, and emplacement of a concrete monolith composed of Salado Mass Concrete in that section of each access drift.

The EPA Preamble to 40 CFR Part 194 Final Rule Section VIII.A.b stated “if a design different from those listed above is identified, the appropriate permit modification will be sought.” Since the certification of WIPP by the EPA, DOE has reevaluated a number of its engineering and construction aspects, including the panel closure systems. Therefore, DOE submitted a proposed change request to EPA on October 7, 2002 (DOE CBFO letter 2002). The EPA responded to DOE with a letter dated November 15, 2002. In this letter, EPA concluded that the panel closure request requires a modification to the rulemaking and “...will likely take a minimum of 12 months to complete from receipt of “complete” information on the requested changes. ... Since the rulemaking likely would not be completed before we receive the WIPP compliance recertification application, ... we are deferring review

1 *of this proposal until after we have issued our recertification decision.” Consistent with this*
 2 *direction from EPA, the PA calculations assume a panel closure with characteristics*
 3 *consistent with Option D (see Figures 3-8 and 3-9). In the same letter, EPA agreed to a delay*
 4 *in completing the panel closure system.*



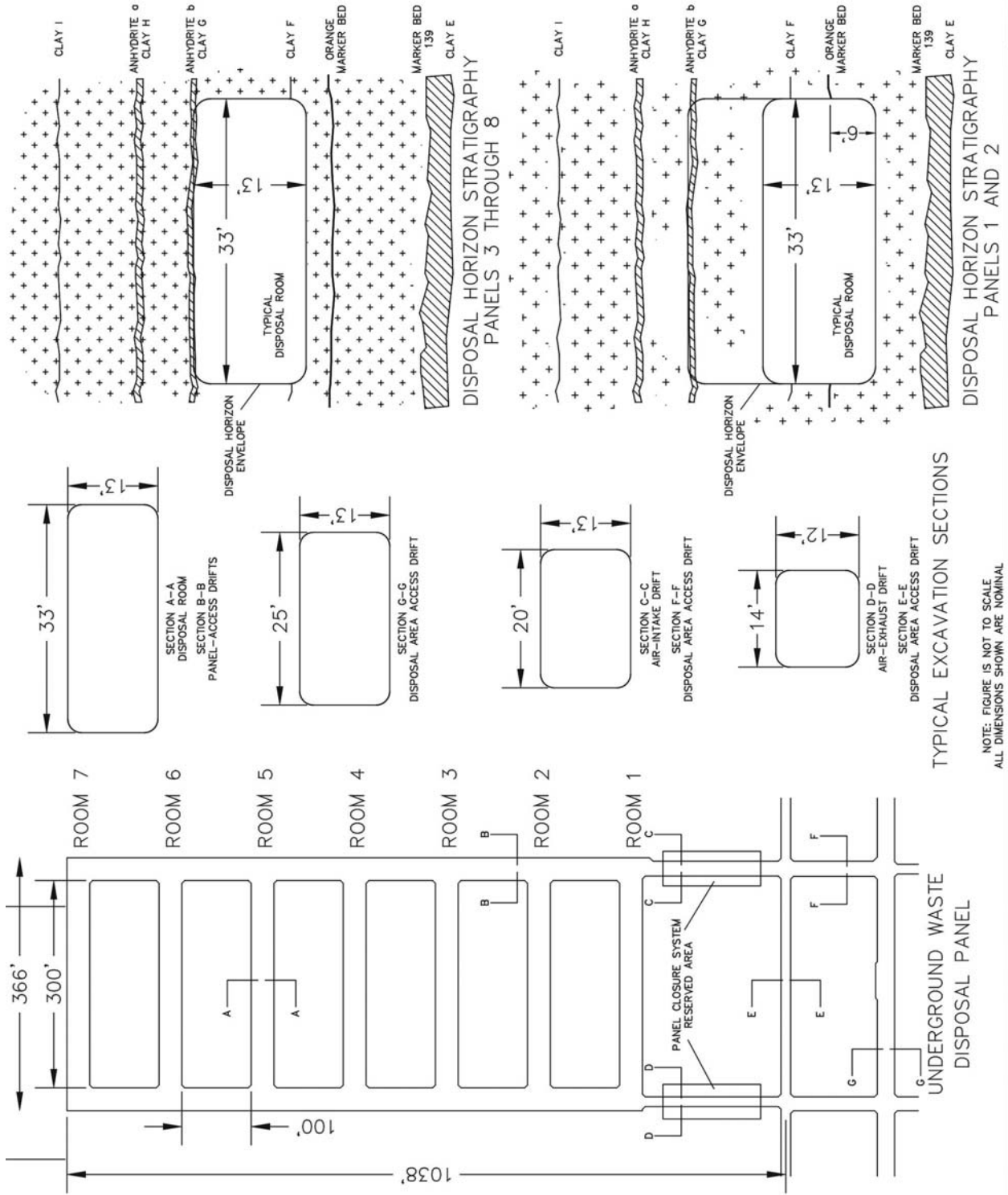
5 OPTION D. EXPLOSION ISOLATION WALL AND
 6 CONCRETE BARRIER WITH DRZ REMOVED

7 **Figure 3-53-8. Panel Closure**

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

- 20 1. the panel closure system shall restrict flow from the panels,
- 21 2. the panel closure system should perform its intended functions under loads generated by
 22 creep closure, and in general under the most severe ground conditions expected in the
 waste disposal area during the operational phase,
- 23 3. the panel closure system should be capable of containing and continuing to perform its
 24 intended function under conditions of a postulated methane explosion,
- 25 4. the panel closure system should be constructed of materials that are compatible with its
 26 emplacement environment and function,
- 27 5. engineering design of the panel closure system should include structural analyses using
 28 WIPP specific data, and should address such issues as the thermal cracking of concrete, and

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NOTE: FIGURE IS NOT TO SCALE
ALL DIMENSIONS SHOWN ARE NOMINAL

Figure 3-63-9. Location of Panel Closure System

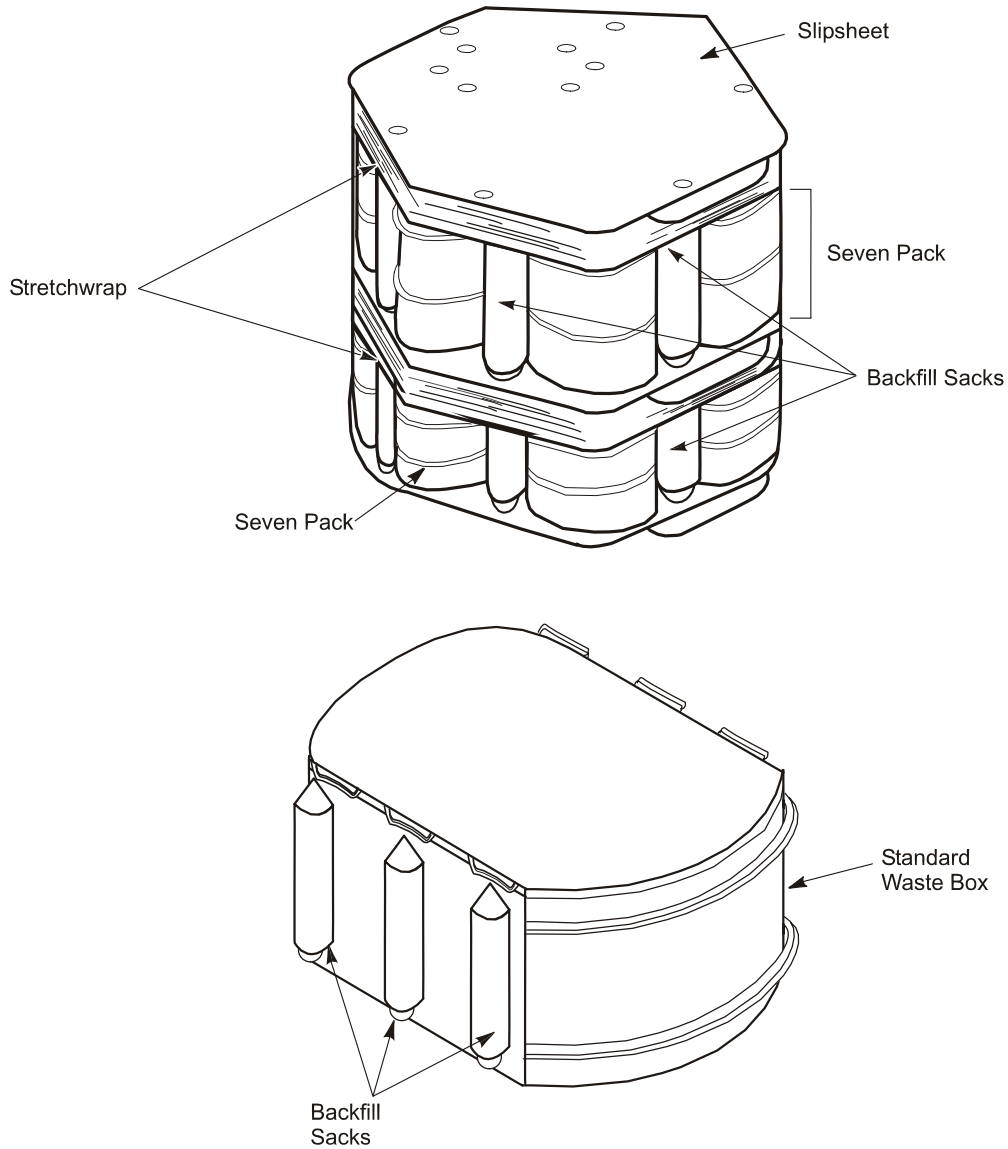
- 1 6. the panel closure system should be designed and constructed using conventional mining
2 practices, with full consideration of shaft and underground access and services. It should
3 be constructed to generally accepted national design and construction standards, with a
4 QA and quality control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

6 *See Appendix BARRIERS for a detailed discussion of panel closure. Representation of the*
7 *panel closures in PA is described in Appendix PA, Section PA-4.2.7; parameters relevant to*
8 *the panel closures are provided in Appendix PA, Attachment PAR, Table PAR-19.*

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

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

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



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Figure 3-7. Backfill Sacks Used with Seven-Pack and Standard Waste Box

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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.

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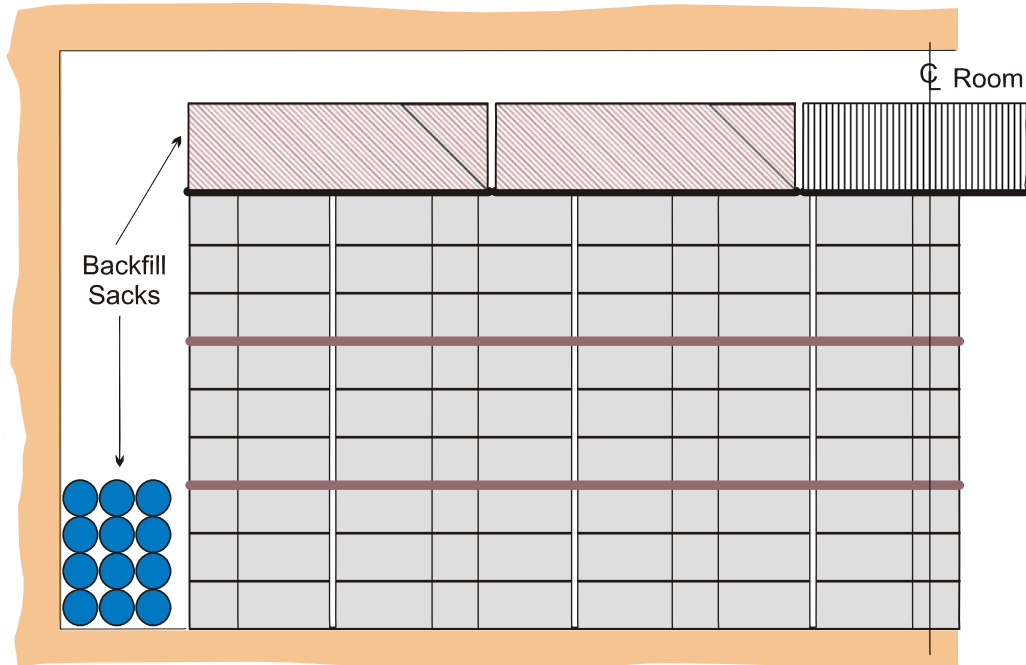
Although the design of this closure system was based on its need to protect public health and the environment during the operations period, the use of these systems coupled with any other material placed in the panel entries will also influence fluid connections between panels during the postclosure 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.

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

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.

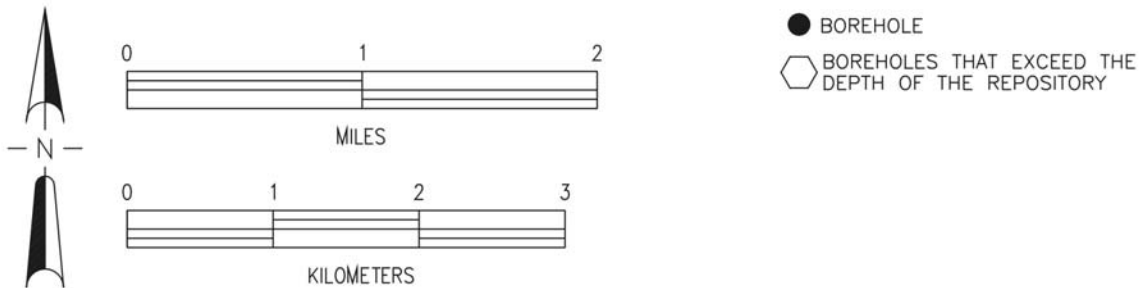
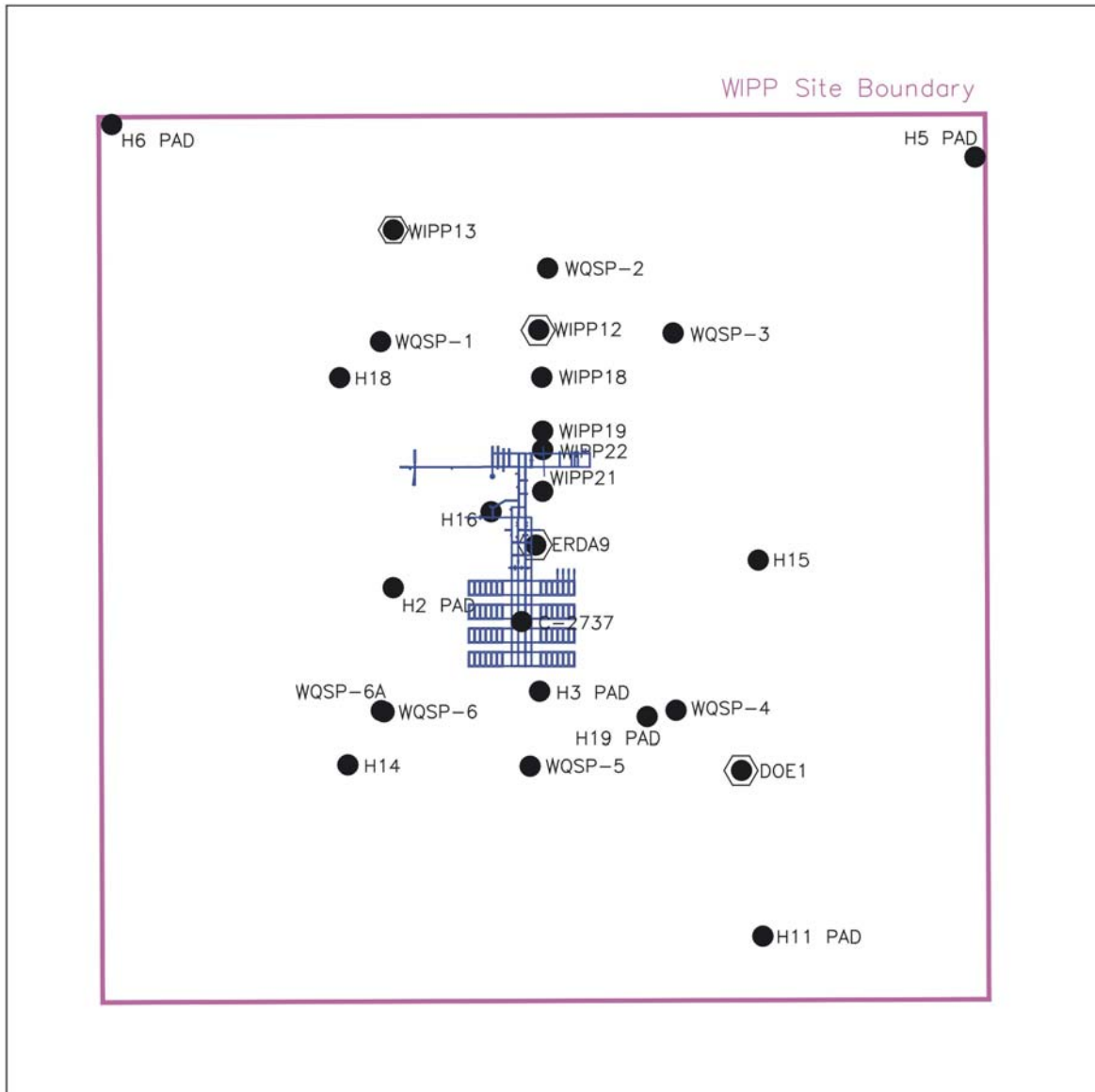
3.3.4 Borehole Plugs

Figure 3-10 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

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Figure 3-93-10. Approximate Locations of Unplugged Boreholes

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1 cementitious plugging materials and modification of existing industrial emplacement techniques
 2 to suit repository plugging requirements. The test was performed in an ~~8-inch (20 cm (8 in.)~~
 3 ~~centimeter)~~ well bore near the top of the Bell Canyon. The test bore intercepted an aquifer at a
 4 depth of ~~4,495 feet (1,370 m (4,495 ft) meters)~~ with a shut in pressure of 1,800 ~~psi~~
 5 ~~pounds per~~
 6 ~~square inch~~ (12.4 megapascals). A ~~6-foot (2-m (6-ft) meter)~~ grout plug was emplaced above the
 7 aquifer and tested by unloading the hole (that is, removing fluids) above the plug to allow the full
 8 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 (0.2 gallons per day))~~.

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

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

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

22 As a result of the Christensen and Peterson (1981) report and subsequent evaluations of plugging
 23 materials, the DOE concluded that boreholes within the controlled area, which were previously
 24 plugged in accordance with the appropriate state and federal regulations in effect at the time
 25 plugging, will mitigate the potential for migration of fluids beyond the repository horizon.
 26 Shallow unplugged boreholes within the controlled area will be plugged in accordance with the
 27 current state or federal regulations using materials shown to be compatible with the underground
 28 environment. Deep unplugged boreholes within the controlled area, ~~shown in Figure 3-9 as~~
 29 ~~WIPP-13, WIPP-12, ERDA-9, and DOE-1,~~ will be plugged according to the state of New
 30 Mexico, Oil Conservation Division (1988), Order R-111-P (*see Appendix BARRIERS*). The
 31 governing regulations for plugging and/or abandonment of boreholes are summarized in
 32 Table 3-2. These solid cement plugs will go through the salt section and any water-bearing
 33 horizon to prevent liquids or gases from entering the hole above or below the salt section. The
 34 boreholes not being used for monitoring will be plugged at decommissioning. *Appendix PA,*
 35 *Section PA-4.2.9 summarizes the representation of the borehole plugs in PA; Appendix PA,*
 36 *Attachment PAR, Tables PAR-14, PAR-15, and PAR-16 provide parameter values used in the*
 37 *modeling.*

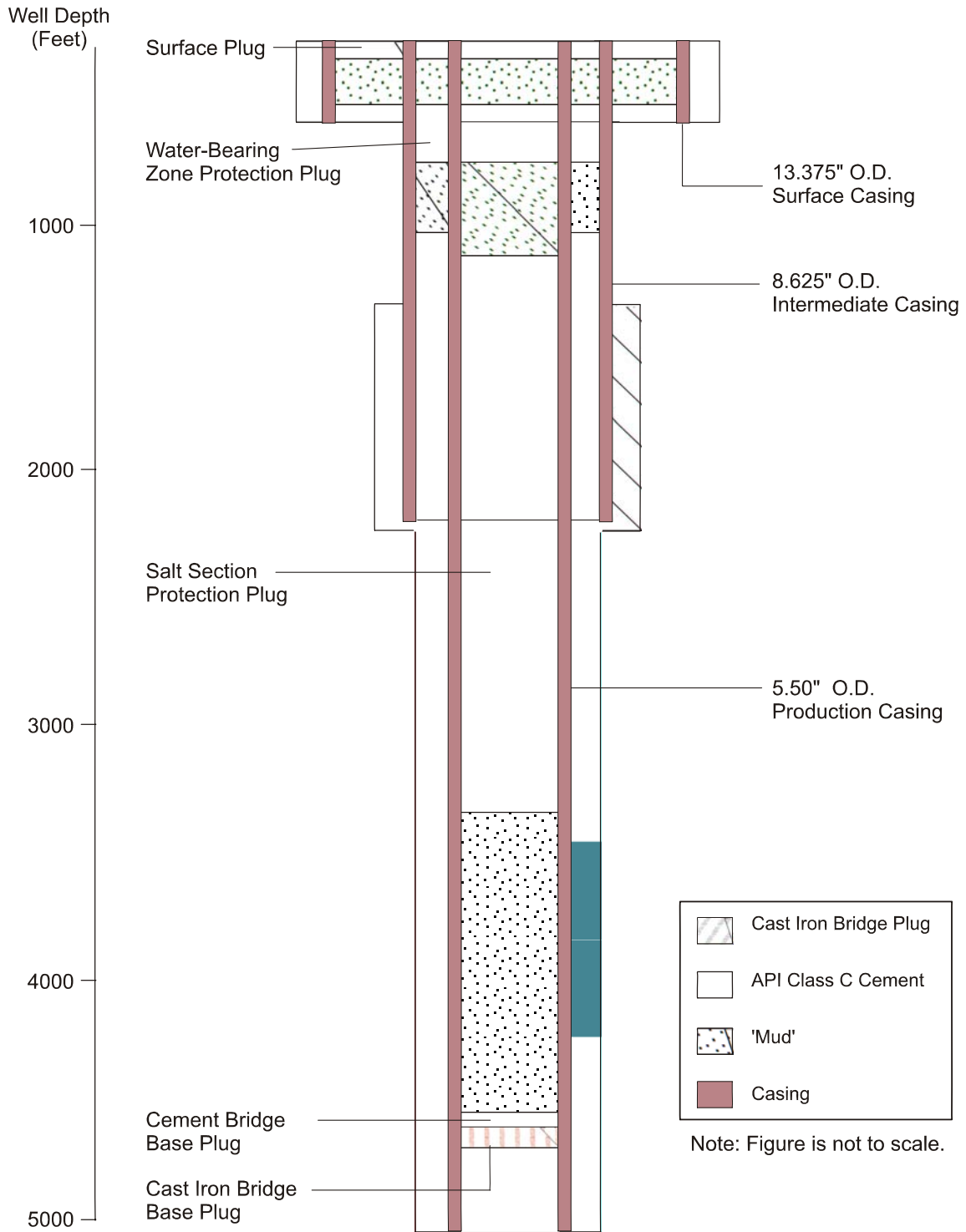
38 ~~Figure 3-10 depicts a typical deep borehole plugged to the requirements of Order R-111-P. This~~
 39 ~~order specifies, among other things, that the cements be mixed with salt-saturated fluids made~~
 40 ~~with salts from the horizon being plugged (see Appendix DEL, Section DEL.6.2.4).~~

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Table 3-12. 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)	<p>B. Plugging</p> <p>(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.</p> <p>(2) The exact location of plugged and abandoned wells shall be marked by the operator with a steel marker not less than 10.16 cm (4 in.) in diameter, set in cement, and extending at least 1.22 m (4 ft) 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.</p>
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)	<p>F. Plugging and Abandonment of Wells</p> <p>(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.</p> <p>It shall have suitable proportions—but no greater than three percent of calcium chloride by weight—of cement considered to be the desired mixture when possible.</p>

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

1 **REFERENCES**

- 2 ASME (American Society of Mechanical Engineers). 1989. *Quality Assurance Program*
3 *Requirements for Nuclear Facilities*. ASME NQA-1-1989, September 15, 1989. The American
4 Society of Mechanical Engineers, New York, NY.
- 5 Christensen, C.L., and Peterson, E.W. 1981. "Field-Test Programs of Borehole Plugs in
6 Southeastern New Mexico." In *The Technology of High-Level Nuclear Waste Disposal*
7 *Advantages in the Science and Engineering of the Management of High-Level Nuclear Wastes*,
8 P.L. Hofman and J.J. Breslin, eds., SAND79-1634C, DOE/TIC-4621, Vol. 1, pp. 354 – 369.
9 Technical Information Center of the U.S. Department of Energy, Oak Ridge, TN.
- 10 State of New Mexico, Oil Conservation Division, Energy, Minerals, and Natural Resources
11 Department. 1988. Order R-111-P, Potash Areas of Eddy and Lea Counties, NM. Case 9316,
12 Revision to Order R-111-P. April 21, 1988. Santa Fe, NM.
- 13 State of New Mexico, Oil Conservation Division, Energy, Minerals, and Natural Resources
14 Department. 1991. Rule 202, Plugging and Permanent Abandonment. March 1, 1991. Santa
15 Fe, NM.
- 16 State of New Mexico, State Engineer's Office. 1995. Article 4, Well Drillers' Licensing-
17 Construction, Repair and Plugging of Wells: Articles 4-14, Shallow Wells Construction Repair
18 Plugging, and 4-20.2, Abandonment-Plugging. Santa Fe, NM.
- 19 U.S. Congress. 1992. *Waste Isolation Pilot Plant Land Withdrawal Act*. Public Law 102-579,
20 October 1992. 102nd Congress, Washington, D.C.
- 21 U.S. Department of Energy (DOE). 1980. *Final Environmental Impact Statement, Waste*
22 *Isolation Pilot Plant*. DOE/EIS-0026, Vol. 1 and 2. U.S. Department of Energy, **Carlsbad, NM**
23 ~~Washington, D.C.~~
- 24 U.S. Department of Energy (DOE). 1986. *Waste Isolation Pilot Plant Design Validation Final*
25 *Report*. DOE/WIPP 86-010. U.S. Department of Energy, Carlsbad, NM.
- 26 U.S. Department of Energy (DOE). 1988. *Agreement for Consultation and Cooperation*
27 *Between the Department of Energy and the State of New Mexico on the Waste Isolation Pilot*
28 *Plant Design Validation Final Report*. April 18, 1988. U.S. Department of Energy, Carlsbad,
29 NM.
- 30 U.S. Department of Energy (DOE). 1990a. *Final Supplement Environmental Impact Statement,*
31 *Waste Isolation Pilot Plant*. DOE/EIS-0026-FS. U.S. Department of Energy, Office of
32 Environmental Restoration and Waste Management, Washington, D.C. Available from NTIS as
33 DE90005774.
- 34 ~~DOE (U.S. Department of Energy)~~ **U.S. Department of Energy (DOE)**. 1990b. *Final Safety*
35 *Analysis Report*. WP 02-9, Rev. 0. May 1990. Westinghouse Electric Corporation, Waste
36 Isolation Division, Carlsbad, NM.

- 1 ~~U.S. Department of Energy (DOE). 1995a. *Conceptual Design for Operational Phase Panel*~~
2 ~~*Closure Systems*. DOE WIPP 95 2057. U.S. Department of Energy, Carlsbad Area Office,~~
3 ~~Carlsbad, NM.~~
- 4 ~~DOE (U.S. Department of Energy)~~ ***U.S. Department of Energy (DOE)***. 1995. *Safety and*
5 *Analysis Report*. DOE/WIPP-95-2065, Rev. 0, November 30, 1995. Carlsbad Area Office,
6 Carlsbad, NM.
- 7 ~~U.S. Department of Energy (DOE). 1995e. *Waste Isolation Pilot Plant Seal System Design*~~
8 ~~*Report*. DOE/WIPP 95 3117. U.S. Department of Energy, Carlsbad, NM.~~
- 9 U.S. Department of Energy (DOE). 1996. *U.S. Department of Energy Carlsbad Area Office*
10 *Quality Assurance Program Description*. CAO-94-1012, Rev. 1, April 1996. U.S. Department
11 of Energy, Carlsbad, NM. (This document is included as **Appendix** QAPD.)
- 12 ***U.S. Department of Energy (DOE). 1997. U.S. Department of Energy Carlsbad Area Office***
13 ***Final Supplemental Environmental Impact Statement. DOE/EIS-0026-S-2, September 1997.***
14 ***U.S. Department of Energy, Carlsbad, NM.***
- 15 ***U.S. Department of Energy (DOE). 2001. U.S. Department of Energy Carlsbad Area Office***
16 ***Functions, Responsibilities, and Authorities Manual. DOE/WIPP 98-2287, Rev. 4, August***
17 ***2001. U.S. Department of Energy, Carlsbad, NM.***
- 18 ***U.S. Department of Energy (DOE). 2002. Waste Isolation Pilot Plant Biennial***
19 ***Environmental Compliance Reports. DOE/WIPP-02-2171, 2002. Carlsbad Area Office,***
20 ***Carlsbad, NM.***
- 21 ***U.S. Department of Energy (DOE). 2003. Safety and Analysis Report. DOE/WIPP-95-2065,***
22 ***Rev. 7, June, 2003. Carlsbad Area Office, Carlsbad, NM.***
- 23 ~~U.S. Department of Energy Carlsbad Field Office (CBFO). February 10, 2000. Docket A-98-~~
24 ~~49, II-B-3, Item 17, Enclosure 1~~
- 25 ***U.S. Department of Energy Carlsbad Field Office (CBFO). June, 26, 2000. Docket A-98-49,***
26 ***II-A-3, Item 24.***
- 27 ***U.S. Department of Energy Carlsbad Field Office (CBFO). November 30, 2000. Docket A-98-***
28 ***49, II-B-2, Item 8.***
- 29 ***U.S. Department of Energy Carlsbad Field Office (CBFO). April 26, 2001. Docket A-98-49,***
30 ***II-B-3, Item 19.***
- 31 ***U.S. Department of Energy Carlsbad Field Office (CBFO). October 7, 2002. Letter from DOE***
32 ***to EPA submitting proposed change request related to Panel Closure, Option D.***
- 33 ~~DOI (Department of the Interior)~~ ***U.S. Department of the Interior (DOI)***. 1995a. 43 CFR Part
34 3160, Onshore Oil and Gas Operations, Federal and Indian Oil and Gas Leases Drilling
35 Operations. Subpart 3162, Requirements for Operating Rights, Owners and Operators. Subpart

- 1 3162.3-4, Well Abandonment. 43 CFR Chapter 2. October 9, 1995. 53 *Federal Register* 22
2 847, June 17, 1988. Bureau of Land Management, Washington, D.C.
- 3 ~~DOI (Department of the Interior)~~ ***U.S. Department of the Interior (DOI)***. 1995b. 43 CFR Part
4 3593, Boreholes and Samples. Subpart 3593.1, Core and Testhole Cores, Samples, Cuttings. 43
5 CFR Chapter 2. October 9, 1995. 53 *Federal Register* 22 847, June 17, 1988. Bureau of Land
6 Management, Washington, D.C.
- 7 ~~EPA (U.S. Environmental Protection Agency)~~ ***U.S. Environmental Protection Agency (EPA)***.
8 1993. 40 CFR Part 191 Environmental Standards for the Management and Disposal of Spent
9 Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule. *Federal Register*,
10 Vol. 58, No. 242, pp. 66398 – 66416, December 20, 1993. Office of Radiation and Indoor Air,
11 Washington, D.C.
- 12 ~~EPA (U.S. Environmental Protection Agency)~~ ***U.S. Environmental Protection Agency (EPA)***.
13 1996. 40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste
14 Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule.
15 *Federal Register*, Vol. 61, No. 28, pp. 5224 – 5245, February 9, 1996. Office of Air and
16 Radiation, Washington, D.C. In NWM Library as KF70.A35.C751 1996 (Reference).
- 17 ***U.S. Environmental Protection Agency (EPA). 1997. Docket A-93-01, Item II-B-03, Item 15.***
- 18 ***U.S. Environmental Protection Agency (EPA). 1998. 40 CFR Part 194: Criteria for the***
19 ***Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the***
20 ***40 CFR Part 191 Disposal Regulations: Certification Decision: Final Rule. Federal Register,***
21 ***Vol. 63, 27354-27406. Office of Air and Radiation, Washington, D.C.***
- 22 ***U.S. Environmental Protection Agency (EPA). August 11, 2000. Docket A-98-49, II-A-3,***
23 ***Item 24.***
- 24 ***U.S. Environmental Protection Agency (EPA). January 11, 2001. A-98-49, II-B-3, Item 15.***
- 25 ***U.S. Environmental Protection Agency (EPA). July 2, 2001. Docket A-98-49, II-B-3, Item 26.***
- 26 ***U.S. Environmental Protection Agency (EPA). August 7, 2001. Docket A-98-49, II-B-3, Item***
27 ***19.***
- 28 ***U.S. Environmental Protection Agency (EPA). November 15, 2002. Letter from EPA to DOE***
29 ***regarding Proposed Change Request, Panel Closure Option D.***

30

BIBLIOGRAPHY

1

2 Beauheim, R.L., Saulnier, Jr., G.J., and Avis, J.D. 1991. *Interpretation of Brine Permeability*
 3 *Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report.*
 4 SAND90-0083. Sandia National Laboratories, Albuquerque, NM.

5 Bechtel National. 1986. *Quarterly Geotechnical Field Data Report.* DOE/WIPP-221. U.S.
 6 Department of Energy, Carlsbad, NM.

7 Borns, D.J. 1985. *Marker Bed 139: A Study of Drillcore from a Systematic Array.*
 8 SAND85-0023. Sandia National Laboratories, Albuquerque, NM.

9 Borns, D.J., and Stormont, J.C. 1988. *An Interim Report on Excavation Effect Studies at the*
 10 *Waste Isolation Pilot Plant: The Delineation of the Disturbed Rock Zone.* SAND87-1375.
 11 Sandia National Laboratories, Albuquerque, NM.

12 Borns, D.J., and Stormont J.C. 1989. The Delineation of the Disturbed Rock Zone Surrounding
 13 Excavations in Salt. *Rock Mechanics as a Guide for Efficient Utilization of Natural Resources,*
 14 *Proceedings of the 30th U.S. Symposium on Rock Mechanics, June 19—22, 1989, A.W. Khair,*
 15 *ed., SAND88-2230c, pp. 353—360. A.A. Balkema, Brookfield, VT.*

16 Chan, K.S., Bodner, S.R., Fossum, A.F., and Munson, D.E. 1992. A Constitutive Model for
 17 Inelastic Flow and Damage Evolution in Solids Under Triaxial Compression. *Mechanics of*
 18 *Materials, SAND92-0546J, Vol.14, No.1, pp.1—14.*

19 COE (U.S. Army Corps of Engineers). 1985. *Federal Engineering Operating Procedures for*
 20 *Construction of the Waste Isolation Pilot Plant.*

21 DOE (U.S. Department of Energy). 1986. *Waste Isolation Pilot Plant Design Validation Final*
 22 *Report.* DOE/WIPP 86-010. U.S. Department of Energy, Carlsbad, NM.

23 DOE (U.S. Department of Energy). 1988. *Geotechnical Field Data Report and Analysis Report.*
 24 DOE/WIPP 87-017. U.S. Department of Energy, Carlsbad, NM.

25 DOE (U.S. Department of Energy). 1995. “Waste Isolation Pilot Plant Seal System Design
 26 Report,” DOE/WIPP-95-3117. Carlsbad, NM.

27 DOE (U.S. Department of Energy). 1995. *Conceptual Design for Operational Phase Panel*
 28 *Closure Systems.* DOE WIPP-95-2057, U.S. Department of Energy, Carlsbad Area Office,
 29 Carlsbad, NM.

30 DOE (U.S. Department of Energy). 1996. *U.S. Department of Energy Carlsbad Area Office*
 31 *Quality Assurance Program Description.* CAO-94-1012, Rev. 1, April 1996. U.S. Department
 32 of Energy, Carlsbad, NM. (This document is included as Appendix QAPD.)

33 ERDA (Energy Research and Development Administration). 1976. *Management Guideline and*
 34 *Project Executive Assistance, Construction Management Plan.*

- 1 ~~Fernandez, J. A., Hinkebein, T.E., and Case, J.B. 1989. *Selected Analyses to Evaluate the Effect*~~
2 ~~*of the Exploratory Shafts on Repository Performance at Yucca Mountain.* SAND85-0598,~~
3 ~~Sandia National Laboratories, Albuquerque, NM.~~
- 4 ~~Griswold, G.B. 1977. *Site Selection and Evaluation Studies of the Waste Isolation Pilot Plant*~~
5 ~~*(WIPP), Los Medanos, Eddy County, New Mexico.* SAND77-0946. Sandia National~~
6 ~~Laboratories, Albuquerque, NM.~~
- 7 ~~Nowak, E.J., and McTigue, D.F. 1987. *Interim Results of Brine Transport Studies in the Waste*~~
8 ~~*Isolation Pilot Plant.* SAND87-0880. Sandia National Laboratories, Albuquerque, NM.~~
- 9 ~~ORNL (Oak Ridge National Laboratory). 1973. *Site Selection Factors for the Embedded Salt*~~
10 ~~*Pilot Plant.* ORNL-TM-4219. Oak Ridge National Laboratory, Oak Ridge, TN.~~
- 11 ~~Pfeifle, T.W., and Brodsky, N.S. 1991. *Swelling Pressure Water Uptake and Permeability of*~~
12 ~~*70/30 Crushed Salt Bentonite.* SAND91-7070. Sandia National Laboratories, Albuquerque,~~
13 ~~NM.~~
- 14 ~~Sandia National Laboratories. 1992. *Preliminary Performance Assessment for the Waste*~~
15 ~~*Isolation Pilot Plant, December 1992, Volume 3: Model Parameters.* SAND92-0700/3. Sandia~~
16 ~~National Laboratories, WIPP Performance Assessment Division, Albuquerque, NM.~~
- 17 ~~Stormont, J.C., Howard, C.L., and Daemen, J.J.K. 1991. *In Situ Measurements of Rock Salt*~~
18 ~~*Permeability Changes Due to a Nearby Excavation.* SAND90-3134. Sandia National~~
19 ~~Laboratories, Albuquerque, NM.~~
- 20 ~~Stormont, J.C., Peterson, E.W., and Langus, P.L. 1987. *Summary and Observations about*~~
21 ~~*WIPP Facility Horizon Flow Measurements through 1986.* SAND87-0176. Sandia National~~
22 ~~Laboratories, Albuquerque, NM.~~
- 23 ~~Stormont, J. C. 1991. "Gas Flow Measurements as Index Tests for the Disturbed Rock Zone,"~~
24 ~~Memorandum to Distribution, Sandia National Laboratories, Albuquerque, NM.~~
- 25 ~~Stormont, J. C. 1988. *Preliminary Seal Design Evaluation for the Waste Isolation Pilot Plant.*~~
26 ~~SAND87-3083, Sandia National Laboratories, Albuquerque, NM.~~
- 27 ~~Westinghouse Electric Corporation. 1995. *Conceptual Design for Operational Phase Panel*~~
28 ~~*Closure System.* DOE/WIPP-Draft-2057. *Closure and Post Closure Plans.* Westinghouse~~
29 ~~Electric Corporation, Waste Isolation Division, Carlsbad, NM.~~
30

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