Table of Contents

List of Figures

List of Tables

This page intentionally left blank

7.0 ASSURANCE REQUIREMENTS

In the Preamble to Title 40 of the Code of Federal Regulations (CFR) Part 191 (EPA 1985) (50 FR 30879), the U.S. Environmental Protection Agency (EPA) points out that:

> There are too many uncertainties in projecting the behavior of natural and engineered components for many thousands of years—and too many opportunities for mistakes or poor judgments in such calculations—for the numerical requirements on overall system performance in Subpart B to be the sole basis to determine the acceptability of disposal systems for these very hazardous wastes.

In view of this, the EPA developed assurance requirements (40 CFR § 191.14) to ensure that implementing agencies act cautiously and take steps to reduce the impacts of these uncertainties. According to the EPA, these assurance requirements are considered an essential complement to the containment requirements, which, when implemented, should ensure that the level of protection desired by the EPA is achieved. Contained in 40 CFR § 191.14 are these six separate assurance requirements:

- active institutional controls,
- monitoring,
- passive institutional controls,
- use of different types of barriers,
- resource disincentives, and
- waste removal.

Figure 7-1 provides a timeline illustrating the implementation of these assurance requirements. Waste removal is not included in Figure 7-1 because it is not a planned activity. Waste removal is discussed in CCA Appendix WRAC. See Table 1-7 for a list of appendices that provide additional information supporting this chapter.

The provisions of 40 CFR 194 (EPA 1996a) contain detailed criteria that the U.S. Department of Energy (DOE) is to use in implementing the assurance requirements contained in 40 CFR 191. The following sections detail the DOE's compliance with the assurance requirements of 40 CFR 191 and the associated certification criteria in 40 CFR 194. In addition to addressing the six assurance requirements stated above, the DOE used some conservative assumptions in the performance assessment that provide additional assurance. Use of conservative assumptions is discussed in Section 6.5.4.

7.1 Active Institutional Controls

Active institutional controls and passive institutional controls satisfy two roles:

(1) they meet assurance requirements per 40 CFR 191 and 194, and

(2) they contribute to performance assessment per 40 CFR 194.

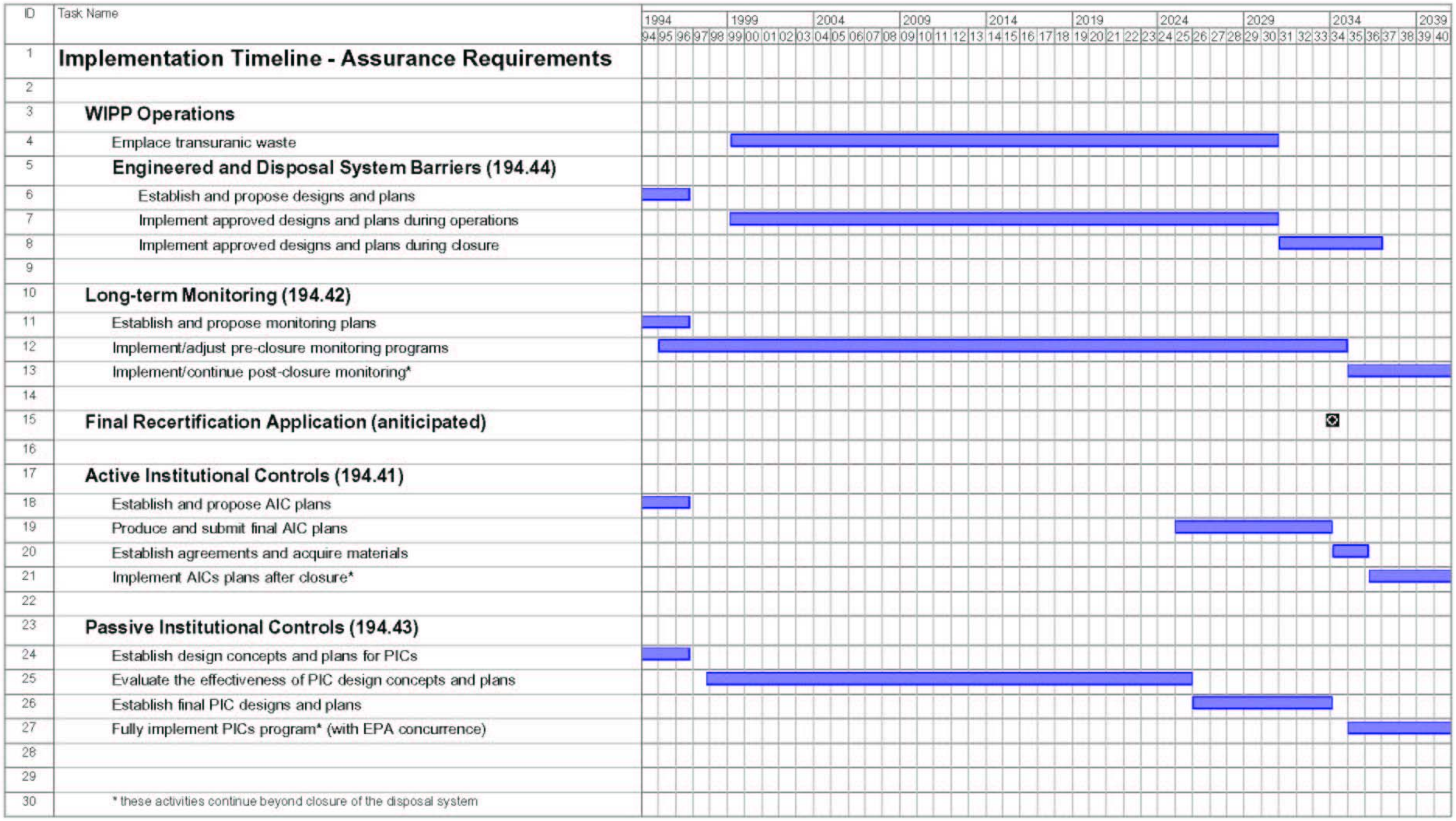


Figure 7-1. Implementation Timeline – Assurance Requirements

Once the facility at the Waste Isolation Pilot Plant (WIPP) is decommissioned and decontaminated (D&D), positive actions (active institutional controls) will be taken to ensure site access control. Active institutional controls begin after final facility closure. The EPA has specified that no more than 100 years of active institutional controls can be assumed in predictions of long-term performance. The DOE interprets this requirement to mean that control programs should be implemented as long as such controls are useful and practical, but credit for active institutional controls cannot be considered in the performance assessment beyond 100 years from the final closure of the repository. Therefore, performance assessment does not consider credit for active institutional controls beyond 100 years.

The EPA defines active institutional controls as "(1) controlling access to a disposal site by any means other than passive institutional controls, (2) performing maintenance operations or remedial actions at the site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance" (40 CFR § 191.12). Active institutional controls to be used by the DOE include facility guarding, evaluation of land use in the area, postoperational monitoring, land reclamation, and maintenance of fences and buildings. In addition, active institutional controls are integrated with the D&D activities described in CCA Appendix D&D. That appendix remains unchanged and, therefore, is not included in this recertification application.

During the rulemaking process for the original WIPP certification, the DOE developed and provided the following to the EPA:

(1) detailed information regarding the schedule for implementing the active institutional controls,

(2) DOE's approach to maintaining and replacing active institutional controls, and

(3) minimum standards that will be applied during construction and maintenance of the active institutional controls.

This information was provided to the EPA via letter dated February 7, 1997 (Docket A-93-02, Item II-I-07, Enclosure 1c).

The DOE also provided sample inspection checklists for site surveillance and maintenance and a discussion of training requirements that will be applied to site patrol personnel. The DOE conducted a "capabilities survey" of regional security firms and concluded that the surveillance requirements for the WIPP site were within the scope of current local capabilities. The EPA contacted the Eddy County Sheriff's Office and confirmed that, while the Sheriff's Office may be able to patrol the site after closure, the services of a private firm would have to be contracted for routine patrols. On the basis of the documentation provided by the DOE, the EPA found the active institutional controls plans to be adequate and that the implementation may be effective for 100 years after disposal (63 FR 27395; see also CARD 41 located in EPA Docket A-93-02, Item V-B-2).

7.1.1 Requirements for Active Institutional Controls

In prescribing active institutional controls, the EPA has specified that "active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal" (40 CFR § 191.14[a]). The EPA addresses the effectiveness of these controls and the length of the time for which such controls should be considered effective for the performance assessment.

Section 194.41(a) specifies that "any compliance application shall include detailed descriptions of proposed active institutional controls, the controls' location, and the period of time the controls are proposed to remain active." Section 194.41(a) also states that any assumptions pertaining to the effectiveness of active controls in preventing inadvertent human intrusion should be supported by such descriptions. This section provides support for the assumptions pertaining to the active institutional controls program for the WIPP facility. Prior to decommissioning of the facility and full implementation of the active controls program, the DOE will reevaluate the proposed active controls program and make any changes necessary as indicated by experience and evaluation of data. The design of the DOE's active controls program is described in CCA Appendix AIC.

For the purposes of this application, the DOE will begin the active controls period within sixty days of completion of final facility closure.

7.1.2 Objectives for Active Institutional Controls

The primary goal of DOE's active institutional controls program is to prevent unauthorized use of the WIPP site. Because of the massive body of rock that separates the waste from the accessible environment, there are not many activities that pose a threat to the WIPP disposal system. The threats that are severe enough or likely enough to consider are addressed in Appendix PA, Attachment SCR and in the conceptual models description located in Section 6.4. The DOE has identified four objectives for the design of the active controls program: (1) eliminating those site features that would cause future populations to develop the WIPP site (see Section 7.1.3.1), (2) identifying allowed and disallowed activities, (3) identifying and minimizing the impacts of the intentional user, and (4) controlling allowed activities and preventing unallowed activities. In addition, the DOE will install and protect monitoring equipment and any test facilities established for evaluating the long-term marker system.

In order to design an active controls program around these four objectives, the DOE has assumed the following:

- site restoration will be to as near the original condition as practicable,
- future authorized site uses will not be significantly different than they are now, as described in CCA Appendix LMP, and
- a threat of future unauthorized use exists.

The WIPP Land Management Plan (LMP) (DOE/WIPP 93-004) provides guidance for managing the land withdrawn for the WIPP through project decommissioning. Active institutional controls are implemented after decommissioning and, by definition, the LMP is not part of the WIPP active institutional controls program. A planned change pursuant to 40 CFR § 194.4(b)(3) was submitted to the EPA in January 2002 requesting removal of CCA Appendix LMP from the Compliance Baseline. In a letter sent to the DOE dated March 15, 2002 (Marcinowski to Triay; EPA Docket A-98-49, II-B-3, Item 24), the EPA approved the planned change allowing CCA Appendix LMP to be eliminated from future recertification applications.

Restoration of the WIPP site includes any activities associated with demobilization following D&D. In addition, as part of the active institutional controls program, the DOE will implement monitoring systems suitable for assessing disposal system performance. The objectives of the active institutional controls program, the monitoring program, and the decommissioning plan overlap; therefore, the DOE believes it is both prudent and within the EPA’s intent to conduct these programs simultaneously. This provides for a more comprehensive understanding of the multitude of activities that will be taking place during the active controls period.

7.1.3 Implementation of the Active Institutional Controls Program

The first step in the process of implementing the active institutional controls program was to identify measures needed to satisfy the active institutional controls requirements. Certain characteristics of active institutional controls measures have been identified, such as minimizing features that would attract future development of the site, warning of potential hazards through signage, implementing the measures for at least 100 years, addressing the standards, and preventing development. These characteristics were used to develop conceptual designs for active institutional controls.

Some active institutional controls were obvious at the outset, including site access control, site remedial actions, site maintenance, and site monitoring. Information and specifications useful in implementing these and possibly other controls have been gathered. A detailed explanation of the resulting active institutional controls is provided in CCA Appendix AIC (Section 2). The plan will be reviewed periodically and updated as appropriate during WIPP’s operations phase. Ongoing review and evaluation will ensure that the active institutional controls implemented are appropriate for the conditions that may exist at that time. The DOE will review the design prior to implementation, and should it be determined the design should be modified, the changes shall be reported per the change requirements at 40 CFR § 194.4.

The final operational activity at the repository will be closing the waste disposal area and sealing the shafts. All surface structures, except for the concrete hot cell structure (CCA Appendix AIC), and a sufficient quantity of salt tailings to support construction of the permanent marker berm (CCA Appendix PIC) will be removed and the site regraded and revegetated to as near its original condition as practicable.

In order to determine the active controls that would be beneficial, the DOE analyzed the types of land uses anticipated and, based on that analysis, developed a design plan for active institutional controls. The following two sections summarize the analysis and the design plan.

7.1.3.1 Analysis of Activities

The purpose of the analysis of activities is to determine the types of disturbances that may be associated with each activity, the depth of such disturbances, and the need for any mitigation of these activities. These activities are supported with screening decisions in Appendix PA, Attachment SCR. This section addresses the following activities:

- ranching,
- farming,
- hunting,
- scientific activities,
- utilities and transportation,
- groundwater pumping,
- surface excavation,
- potash exploration,
- hydrocarbon exploration,
- construction, and
- hostile and illegal activities.

Table 7-1 indicates the active institutional controls that will be applied to prevent unauthorized activities.

7.1.3.1.1 Ranching

Description of the Activity: Ranching involves the management of herds of cattle on the public lands surrounding and including the WIPP. These activities are regulated on federal lands such as the WIPP under a permitting process administered by the Bureau of Land Management (BLM). There is little surface-disturbing activity associated with ranching except for the construction of fences, the construction and operation of watering facilities, and the occasional drilling of groundwater wells. Currently, only the 277 acres within the Exclusive Use Area are not used for ranching. In the future, barbed wire enclosures will be constructed to provide security for monitoring facilities, test areas, and construction areas. Eventually, the entire surface is expected to be released for ranching activities. Only those activities associated with groundwater use could have any impact on the disposal system. These are discussed in Section 7.1.3.1.6. Figure 7-2 depicts the current grazing allotments on the WIPP site.

Goal of Active Controls: Active controls will ensure that grazing leases are administered consistently and in compliance with applicable regulations. Fencing will be needed to protect government property. In addition, areas will be fenced as needed to prevent cattle from disturbing reclaimed areas until vegetation has been reestablished.

7.1.3.1.2 Farming

Description of the Activity: Farming includes soil preparation, planting, irrigation, and harvesting. Significant quantities of water are needed to support crops in the Delaware Basin.

Table 7-1. Effectiveness of Active Controls Activities

Active Institutional Controls	*Activities*										
	Ranching	*Farming*	*Hunting*	*Scientific Activities*	*Utilities and Transpor-tation*	*Ground-water Pumping*	*Excavation*	*Potash Explora-tion*	*Hydrocarbon Exploration*	*Con-struction*	*Hostile and Illegal Activities*
Fence	●[1]	●	●				●			●	
Roadway				●	●	●					
Signs		●	●		●		●	●	●	●	●
Contract for Inspection and Maintenance	●	●	●	●	●	●	●	●	●	●	●
Security Surveillance	●	●	●	●	●	●	●	●	●	●	●
Testing				●	●						
Disposal System Monitoring				●		●					
Permanent Marker System Installation				●							
Response	●	●	●	●	●	●	●	●	●	●	●
Reporting	●	●	●	●	●	●	●	●	●	●	●

[1] "●" Indicates component addressed by active institutional controls

Crops grown in the farming area nearest to the WIPP include cotton, alfalfa, peppers, and pecans. Small quantities of other crops are also grown. Farming using irrigation would require access to large amounts of fresh water, either through the diversion of surface water or the construction of groundwater wells. There is currently no known farming near the WIPP because of the lack of good quality water and the poor soil composition. Farming, therefore, is screened out of the performance assessment on the basis that any impacts are of low consequence to the disposal system (see Appendix PA, Attachment SCR, Arable Farming FEP H53).

Goal of Active Controls: While farming is unlikely, the fence, signs, and other measures will prevent farming activities from disturbing test areas or affecting monitoring locations.

7.1.3.1.3 Hunting

Description of the Activity: Currently, hunting occurs outside the WIPP Off Limits Area. The prohibition from hunting is mandated by DOE policy. Unless the restrictions are lifted, hunting will continue to be prohibited in this 1,454-acre (590-hectare) area. The restriction has been placed to provide protection for facilities and personnel working at the WIPP. Game animals in the vicinity include deer, small mammals, and birds. There are no hunting activities that are anticipated to impact the disposal system. Figure 7-3 depicts the area within the WIPP site boundary where hunting is allowed.

Goal of Active Controls: Protection of facilities and personnel engaged in monitoring, reclamation, and testing activities will be needed throughout the active controls period. Local and state hunting laws and restrictions will apply.

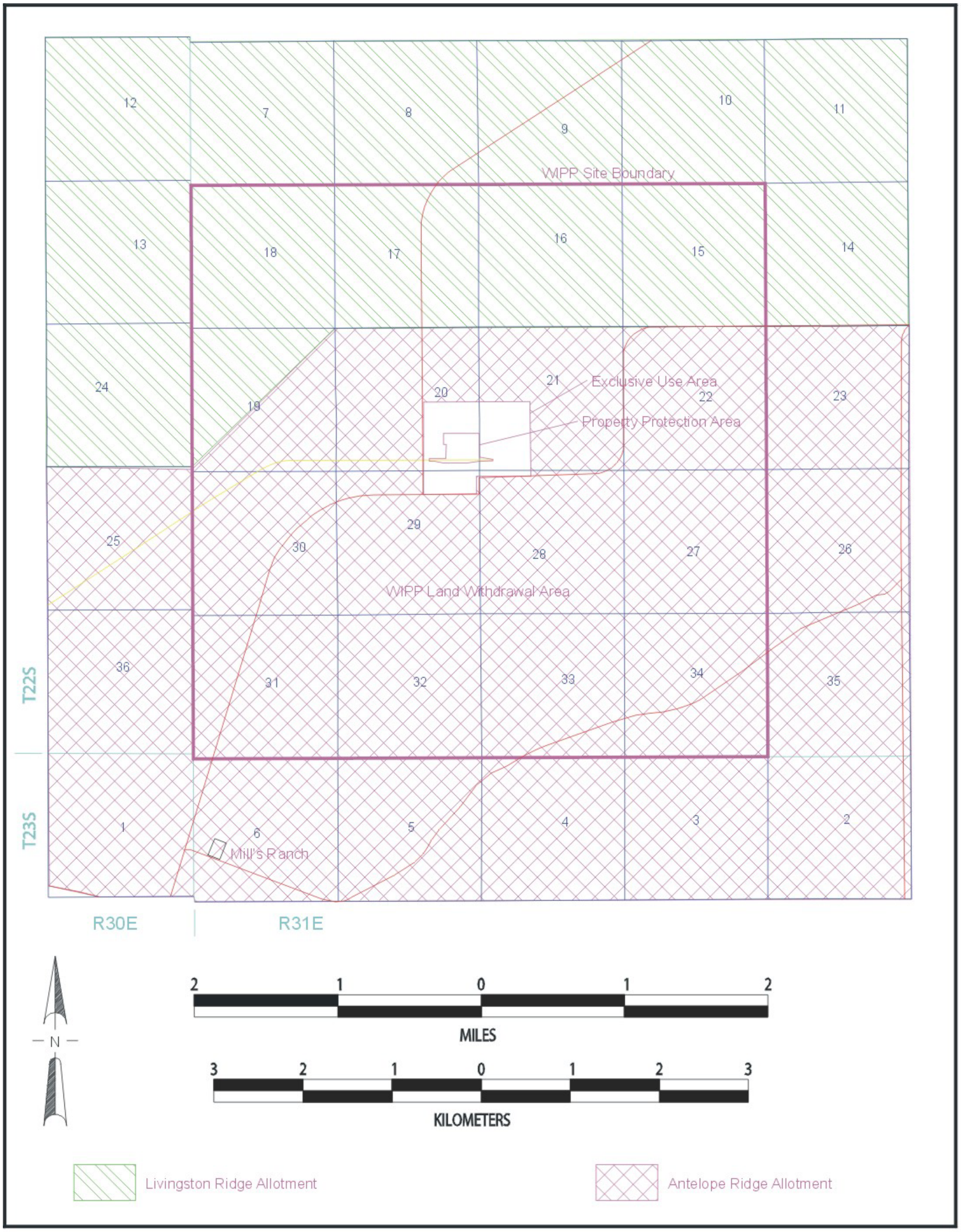
7.1.3.1.4 Scientific Activities

Description of the Activity: Scientific activities can include both those conducted by the DOE for the WIPP and those conducted by outside organizations. Types of activities include archeological investigations, wildlife studies, vegetation studies, grazing studies, geomorphic studies, passive marker testing, passive marker construction, hydrologic studies, disposal system monitoring, and others. Prolonged studies of vegetation, geomorphic features, or grazing impacts may require the construction of fenced enclosures. Some may involve the placement of monitoring or other types of equipment or monuments that need to be protected from vandalism.

Goal of Active Controls: In the case of scientific studies, active controls will ensure that scientific activities can proceed undisturbed without impacting the disposal system. Specific needs for protection may be identified with each study proposed for the area.

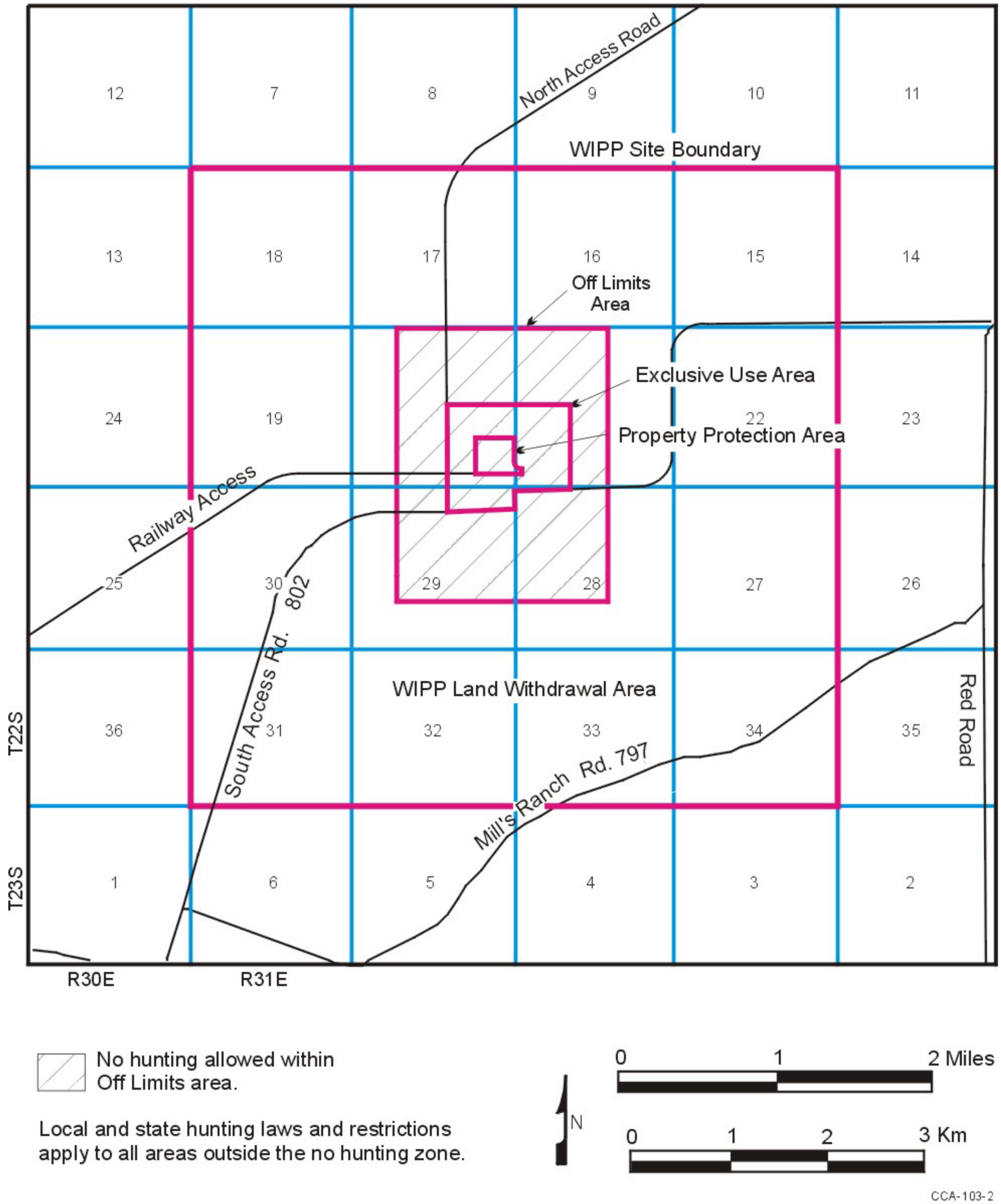
7.1.3.1.5 Utilities and Transportation

Description of the Activity: Currently, the WIPP site boundary is traversed by several pipelines (natural gas), buried telephone lines, power lines, a highway, and a railroad. Future transportation needs are expected to remain the same. Construction and maintenance of utilities

1 

2 **Figure 7-2. Grazing Allotments on the WIPP Site as of September 2002**

1



2

3 **Figure 7-3. Area Where Hunting is Permitted Within the WIPP Site Boundary**

and transportation facilities involve significant surface-disturbing activities. However, they are confined to the upper several meters of soil and will not impact the disposal system. Currently, the construction of utilities and transportation facilities are controlled by a permitting process administered by the DOE for the WIPP and the BLM for other federal lands. The BLM ensures that operators remain within designated rights-of-way and that they comply with applicable environmental protection regulations. Figure 7-4 depicts the current rights-of-way that have been granted for utilities or transportation on the WIPP site.

Goal of Active Controls: Active controls will ensure that utility and transportation activities are conducted in a manner that is consistent with permits and that locations are selected to avoid conflicts with permanent markers. Measures, such as fences, may be needed to provide mutual protection for personnel, livestock, and rights-of-way uses.

7.1.3.1.6 Groundwater Pumping

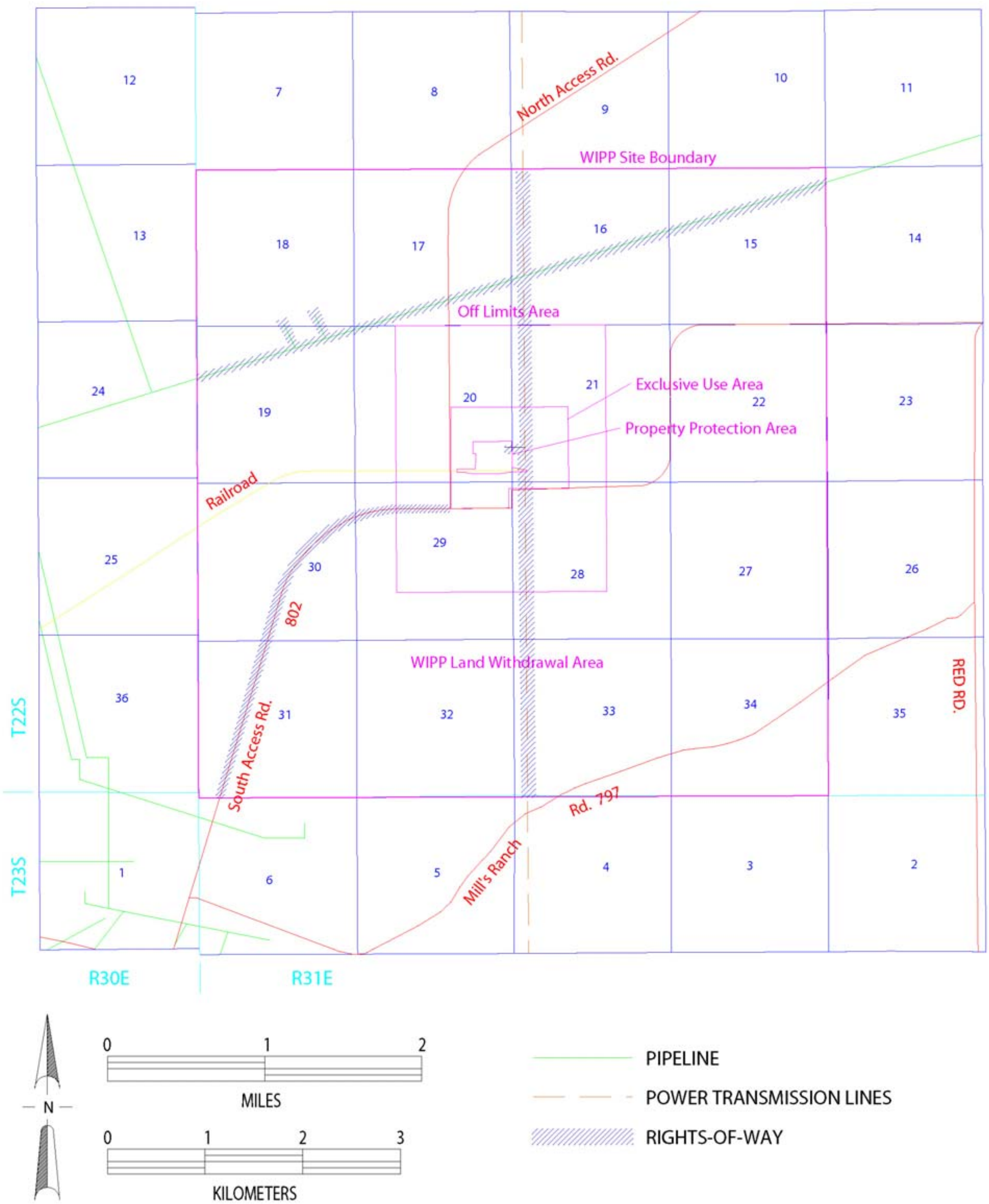
Description of the Activity: Groundwater wells are drilled for several uses near the WIPP. The most common use within the controlled area is in support of the WIPP groundwater monitoring program. These wells generally target water in the Culebra Member of the Rustler Formation. . Before a groundwater well can be drilled, a permit must be obtained and the State Engineer must be notified of the final well configuration and its use. Wells are abandoned in accordance with state regulations that govern the plugging of such wells (see Section 3.3.4). Groundwater well drilling unrelated to the DOE is prohibited by the LWA within the WIPP site boundary. Figure 7-5 shows the location of wells monitored for groundwater composition within the WIPP site boundary.

Goal of Active Controls: The active controls program will ensure that the prohibition on drilling groundwater wells and fluid injection within the WIPP site boundary is enforced and that those wells that currently exist, or that are drilled to support future WIPP activities, are plugged and abandoned in accordance with applicable regulations.

7.1.3.1.7 Surface Excavation

Description of the Activity: Both sand and caliche are mined locally for use in construction. Mining for sand and caliche is always limited to surface quarries. To mine these materials on public lands, a permit must be obtained from the DOE or the BLM. The permit limits the quantity that can be removed and specifies appropriate environmental protections, including reclamation. Sand or caliche removal will have no impact on the disposal system (Appendix PA, Attachment SCR, Other Resources FEP H8).

Many surface quarries within the WIPP site boundary have been remediated, which included recontouring the surface and planting vegetation. Others will be remediated either during the operational phase or as part of postdecommissioning land management. The development of surface quarries unrelated to the DOE is prohibited by the LWA. Figure 7-6 shows the location of surface quarries within the WIPP site boundary.



1

2 **Figure 7-4. Locations of Rights-of-Way Within the WIPP Site Boundary as of September**
3 **2002**

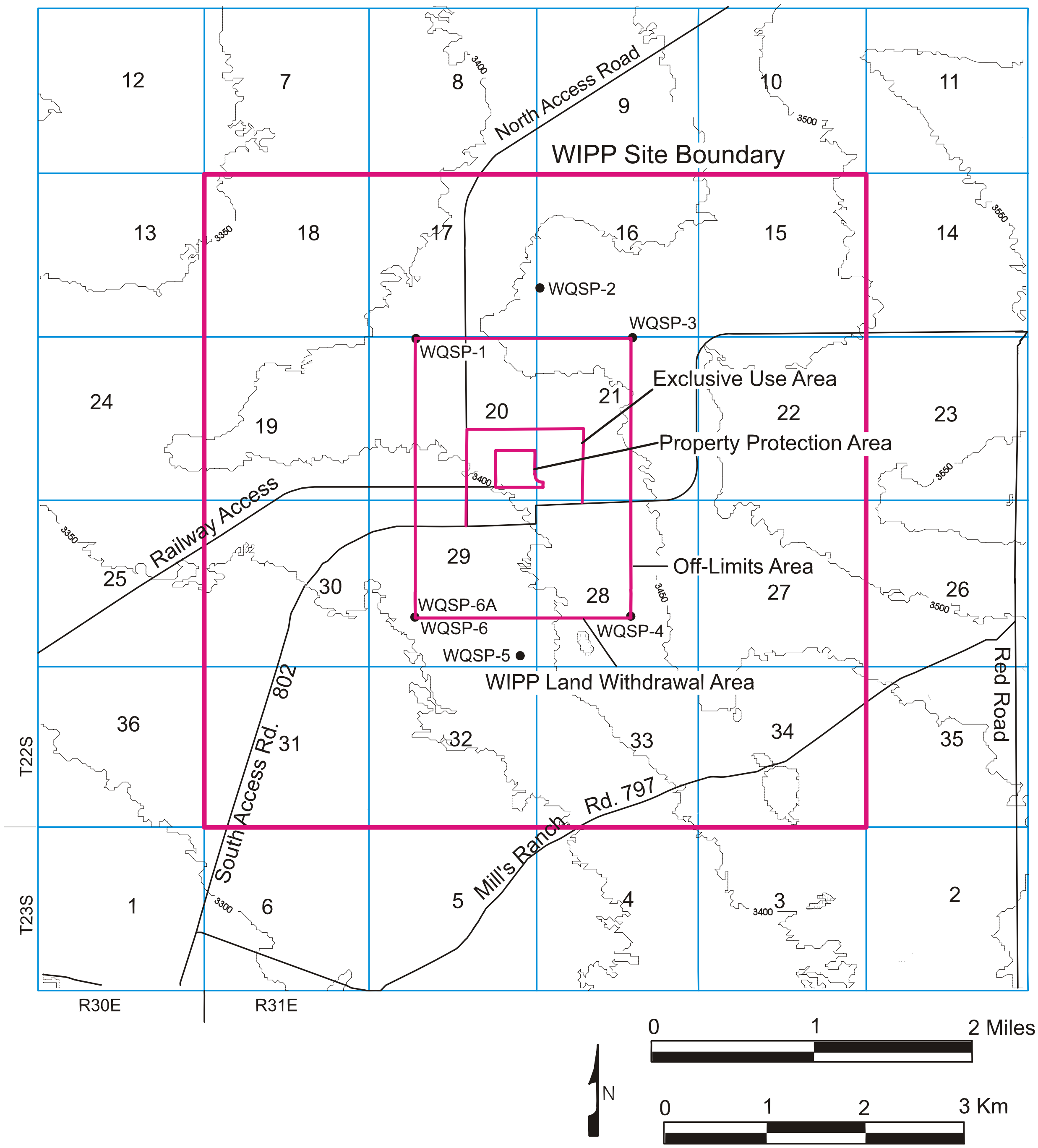


Figure 7-5. Locations of Water Quality Sampling Wells

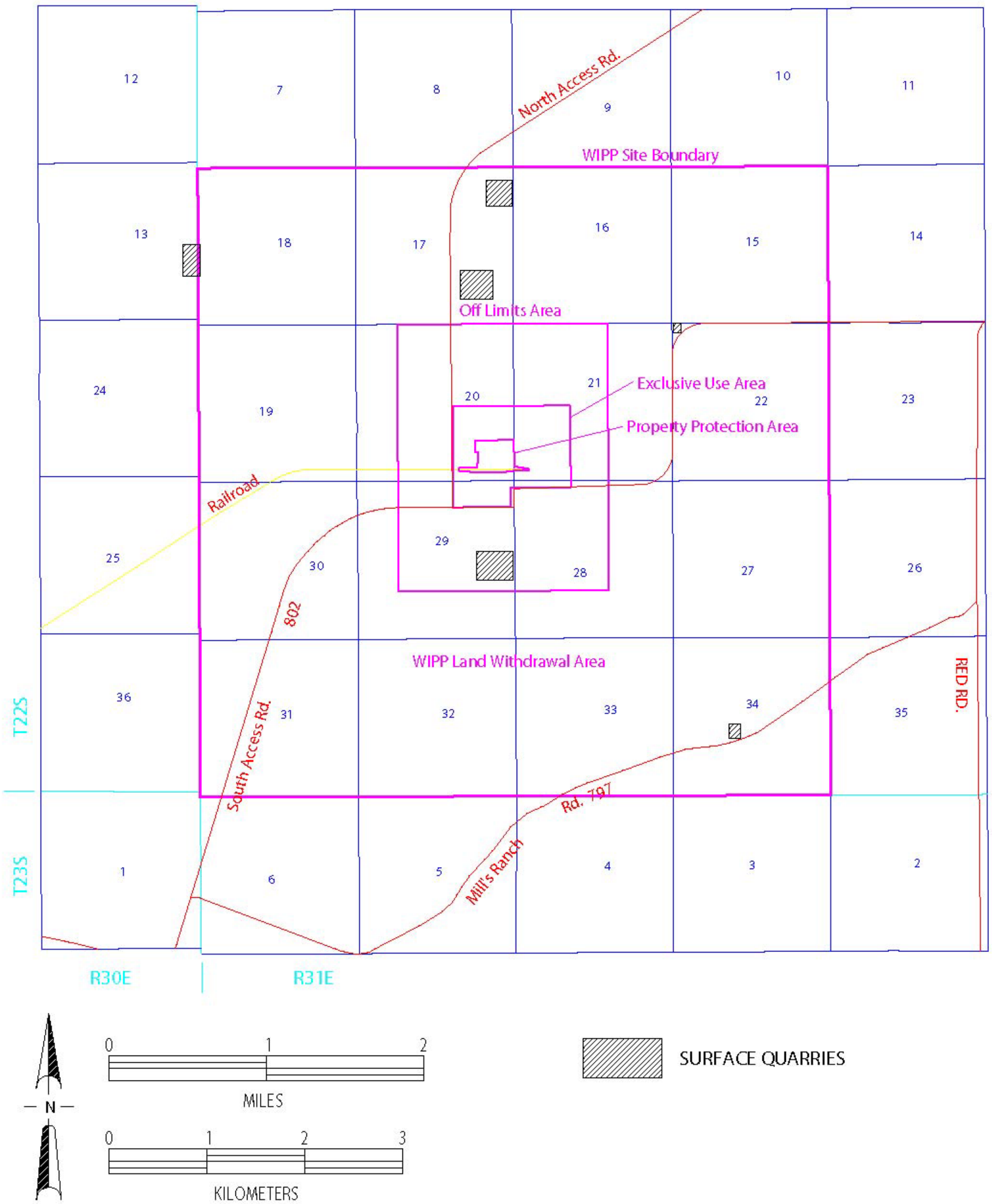


Figure 7-6. Location of Surface Quarries Within the WIPP Site Boundary as of September 2002

Goal of Active Controls: The objective of the DOE with respect to surface excavation is to ensure that the development of mineral leases does not affect the integrity of the disposal system. In accordance with the LWA requirement that no surface or subsurface mining unrelated to the DOE may be conducted within the boundaries of the land withdrawal area, the DOE and the state of New Mexico have entered into a memorandum of understanding (MOU). This MOU dictates that the state will forward any mining and reclamation plans to the DOE for review and comment in determining issuance of such permits within one mile of the withdrawal area boundary. In addition to the commitments in the MOU, the DOE will conduct perimeter surveillance and evaluate potential encroachment of ancillary activities associated with mines.

7.1.3.1.8 Potash Exploration and Extraction

Description of the Activity: Potash mineralization is known to exist beneath the WIPP site (see Section 2.3.1.1). The extent of mineralization is generally determined through the drilling of core holes and the examination and analysis of rock cores. Sufficient core holes have already been drilled within the WIPP site boundary to characterize the resident mineralization. Future drilling, however, is prohibited by the LWA. Holes drilled for the exploration of potash must be closed in accordance with state or federal regulations, depending on the location of the potash lease (see CCA Appendix DEL, Section DEL.5.5). The closure of potash holes within the WIPP site boundary is discussed in Section 3.3.4.

Extraction of potash in the Delaware Basin is accomplished through the use of conventional underground mining technologies. Development of resources within the WIPP site boundary would require that a mine be built in the vicinity or that an existing mine be expanded to include the WIPP. Potash mining is conducted in accordance with the rules and regulations of the BLM on federal lands and the State of New Mexico on state lands. The impacts of mining are evaluated in the performance assessment in accordance with the requirements of 40 CFR § 194.32(b) and are discussed in Section 6.4. Figure 7-7 shows a map of the distribution of potash exploration holes and the extent of currently economically minable reserves.

Goal of Active Controls: The active controls program, especially routine security patrols, will ensure that mineral leasing and development within the WIPP site boundary are prevented and that existing or near future mines do not encroach on the site.

7.1.3.1.9 Hydrocarbon Exploration

Description of the Activity: Hydrocarbon resources are assumed to exist below the WIPP site. The amount of these resources and their locations are projected from information that the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) compiled and interpreted for the DOE in 1995. (See Section 2.3 for a discussion of this report.) Exploration companies use surface-based geophysical techniques to determine likely locations for hydrocarbon accumulations and then investigate the prospect using deep drilling. Both the geophysical and the drilling activities have historically occurred on the WIPP site, but further drilling is prohibited by the LWA. Figure 7-8 shows the location of hydrocarbon wells within the WIPP site boundary.

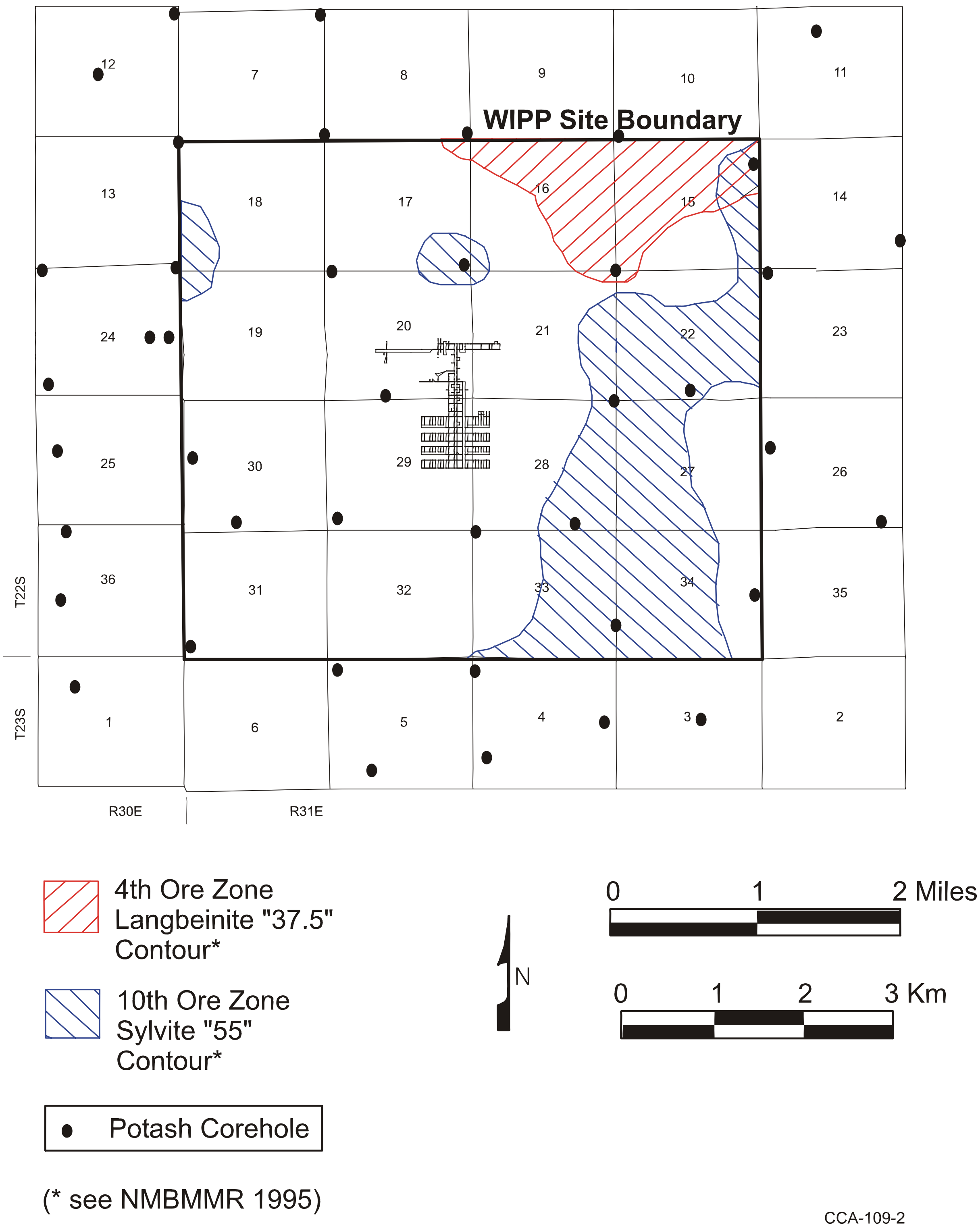


Figure 7-7. Location of Potash Exploration Holes and Economically Minable Potash Within the WIPP Site Boundary as of September 2002

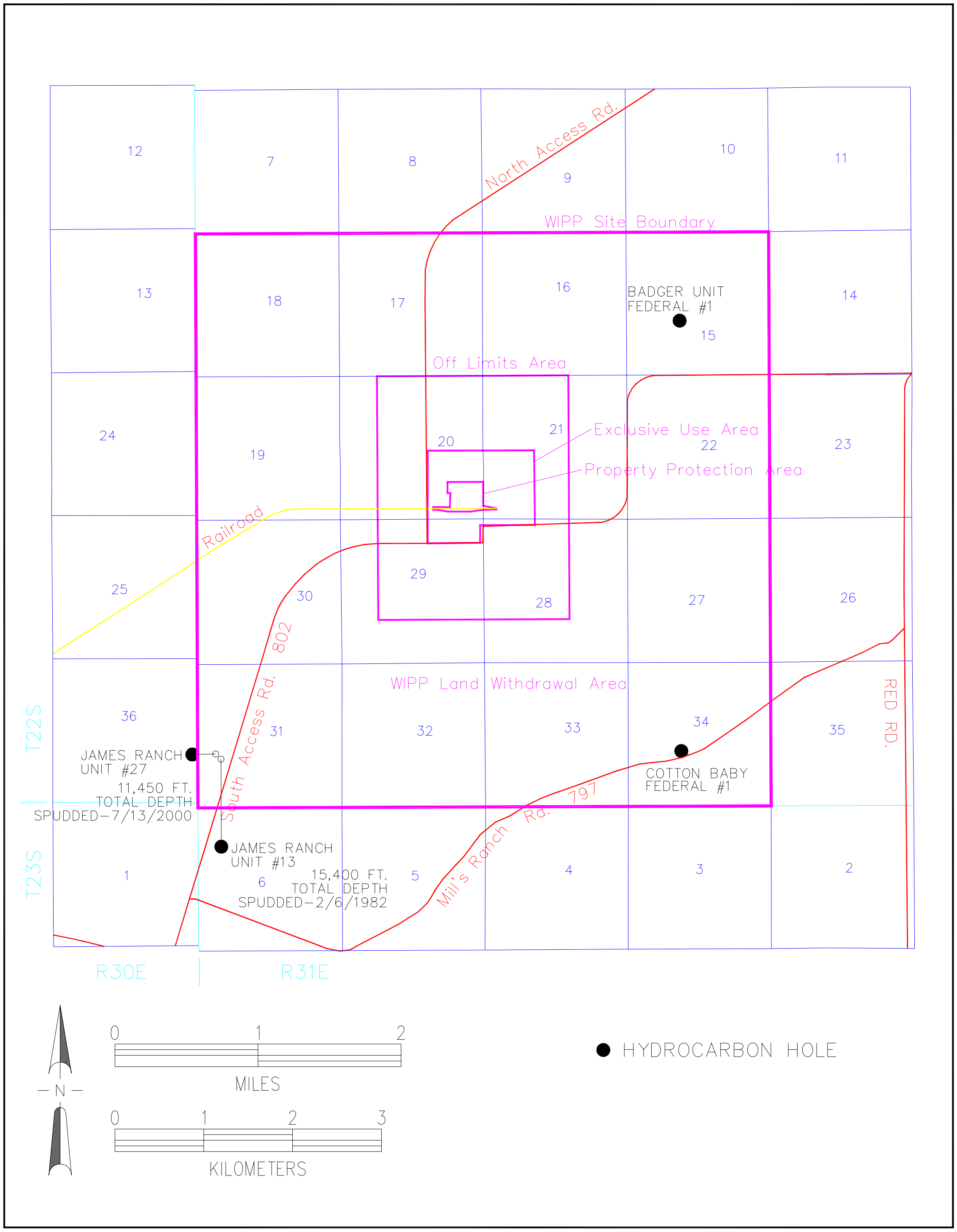


Figure 7-8. Hydrocarbon Holes Located Within the WIPP Site Boundary as of September 2002

Goal of Active Controls: The active controls program will ensure that the prohibition on the drilling of hydrocarbon wells is enforced. In addition, the BLM and the state of New Mexico will administer permits to perform geophysical investigations.

7.1.3.1.10 Construction

Description of Activity: The construction of a permanent building typically involves activities that disturb the surface only to a depth of a few meters, with the exception of the drilling of a groundwater well. Construction is currently prohibited by the DOE for public protection reasons during disposal operations. Because the WIPP site is federally owned, only federal facilities can be built there and any construction will require federal permits. After the conclusion of operations and during the active institutional controls period, construction will not be allowed within the areas reserved for the permanent marker system.

Goal of Active Controls: Controls will ensure that construction does not occur within the WIPP site boundary prior to the end of the active institutional controls period and that no construction will interfere with the goals of the passive controls system.

7.1.3.1.11 Hostile and Illegal Activities

Description of Activity: Activities in this category include vandalism, sabotage, theft, and artifact hunting. All of these activities are prohibited by federal and state law. None is expected to have an impact on the disposal system, although they could impact monitoring efforts, the construction and preservation of permanent markers, the integrity of fences and test areas, and other authorized uses.

Goal of Active Controls: Active controls will prevent the occurrence of hostile and illegal activities to the extent practicable within the WIPP site boundary. Controls may include access control and other security measures.

7.1.3.2 Active Controls Design Features

Based on these possible land uses, the DOE has specified the following design features for the active controls system. Additional detail is presented in CCA Appendix AIC (Section 1).

- Signage will be established to control access to the WIPP site. A fence will be erected along the perimeter of the repository surface footprint. The fence will have gates placed approximately midway along each of the four sides.

- Roadways will be constructed as needed to provide easy visual inspection and ready vehicle access to any point around the fenced perimeter and to facilitate maintenance of the fence line. These roadways will connect to the paved south access road.

- The fence line and the WIPP site perimeter will be posted with signs having as a minimum a legend reading “Danger—Unauthorized Personnel Keep Out” and a warning against entering the area without specific permission of the DOE. Signs prohibiting hunting will also be posted as appropriate. In addition, the DOE will include the area in the local one-call system.

- Upon installation of the permanent marker system, the active institutional controls program will be revised as deemed appropriate.

- Guidelines will be developed for identifying and implementing the appropriate corrective measures to address any abnormal conditions identified during periodic surveillance and inspections.

- Reports of activities associated with the postdisposal active access controls will be prepared in accordance with regulatory requirements for submittal to the appropriate regulatory and legislative authority.

7.1.3.3 Description of Active Institutional Controls Features

Most of the active institutional controls measures, such as long-term site monitoring and site remedial actions, will be implemented simultaneously with facility closure and D&D. It may be possible, however, to implement some measures earlier. For example, salt disposal may begin prior to final facility closure. Reclamation and restoration of unused disturbed surface areas have already begun. Guarding and maintenance activities, which are in place, could evolve into an appropriate type of postclosure activity.

During the disposal phase, the DOE will manage and store waste in a manner that limits the public's exposure to radiation in accordance with the standards of 40 CFR 191, Subpart A. Subsequent to disposal and after shafts are backfilled and sealed, radioactive releases to the accessible environment, exposures to humans, and concentrations in groundwater cannot exceed the standards of 40 CFR Part 191, Subparts B and C. The periods of active institutional controls and passive institutional controls begin when the disposal phase ends, and according to the EPA, run concurrently for at least 100 years. Also per the EPA, after 100 years, credit for active controls must end, but credit for passive controls may continue for up to 700 years after final facility closure (see Section 7.3.4.2).

The active controls program design described above is implemented through the following components. Additional detail is provided in CCA Appendix AIC (Section 2):

- Signage that indicates the areal extent of the WIPP and a fence that restricts access to the repository footprint, respectively, and includes the area in which the passive markers will be constructed. This area (shown in Figure 7-9) is referred to as the repository footprint and represents the surface projection of all areas underground that contain waste. Note that additional fencing may be needed for remote locations that are used for disposal system monitoring. Such fences will meet the same construction specifications as those for the perimeter footprint.

- A 16-foot (4.9 meter) wide roadway around the perimeter of the WIPP site boundary. Roads to remote sites will also be constructed and maintained as needed.

- Surveillance that includes drive-by patrolling two or three times per week. This frequency will be sufficient to detect and remove the most severe threats to the disposal system, such as drilling.

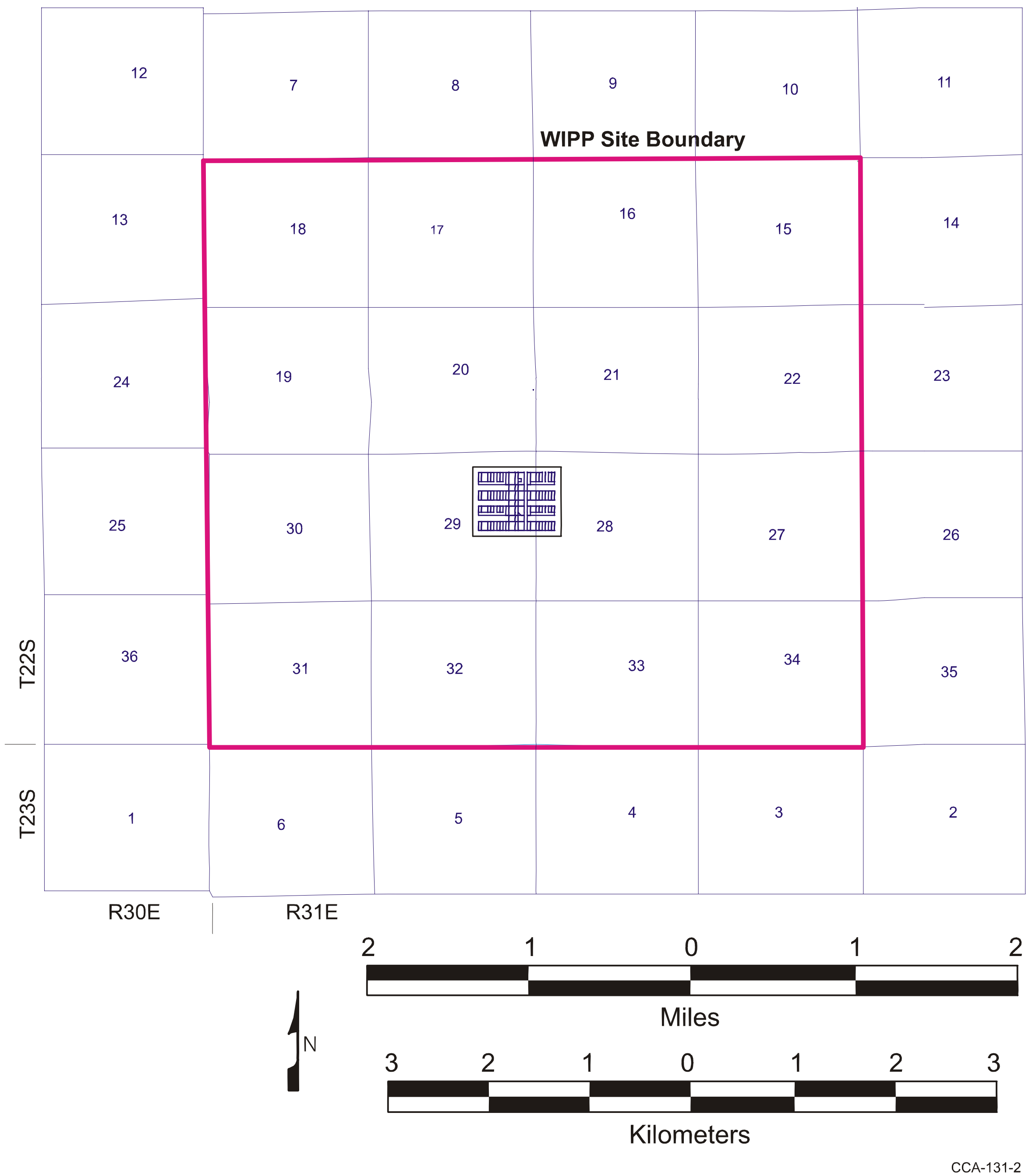


Figure 7-9. Planned Repository Footprint

- Maintenance services for fences, gates, cattle guards, signs, and monitoring equipment.
- Site restoration activities in accordance with the postclosure land management plan.
- Agreements with the BLM to administer grazing and other permitted land uses consistent with the DOE's postclosure land management plan.
- Monitoring of the disposal system.
- Construction of a permanent marker system.

7.1.4 Effectiveness of the Active Institutional Controls Program

Performance assessment for the WIPP assumes that the active institutional controls program will be one hundred percent effective in preventing human intrusion into the repository for the 100 years immediately following disposal. The DOE believes that this assumption is supported by the proposed design features alone (that is, fencing, postings, perimeter inspections, surveillance, and mitigation measures) and the defense-in-depth nature of the features and resulting controls. The DOE believes that taking one hundred percent credit for 100 years of active controls is justified by the repetitive and redundant nature of the active controls that will be implemented at the WIPP site. The DOE is committed to retaining active control over the site for as long as is practicable, but at least for 100 years.

Governments have successfully controlled and protected facilities of national importance for hundreds of years. The U.S. Government has existed and effectively maintained many facilities under its control for over 200 years. The DOE and its predecessor agencies have successfully maintained (preventing intrusion) several major facilities for over 50 years. Therefore, the DOE believes there is a reasonable expectation that active institutional controls will be effective for at least the assumed 100-year institutional control period, and are likely to be effective for substantially longer periods.

In its certification decision (63 FR 27395), EPA ". . . found it reasonable for DOE to assume credit in the PA for 100 years. The EPA found the assumptions regarding longevity and efficacy of the proposed AICs to be acceptable based on the fact that the types of inadvertent intrusion which AICs are designed to obviate are not casual activities, but require extensive resources, lengthy procedures for obtaining legal permission, and substantial time to set up at the site before beginning."

7.2 Monitoring

The requirements for disposal system monitoring are stated in 40 CFR § 191.14(b). In order to certify the DOE's compliance with these requirements, the EPA has established certification criteria that the DOE must satisfy in its application for certification. These criteria are stated in 40 CFR § 194.42. The requirements and the criteria form the basis for the DOE's monitoring program. Appendix MON-2004, Pre-Closure and Post-Closure (Long-Term) Monitoring Plan, describes the details of the DOE's monitoring program.

The criteria provided in 40 CFR § 194.42(a) state

> The Department shall conduct an analysis of the effects of disposal system parameters on the containment of waste in the disposal system and shall include the results of such analysis in any compliance application. The results of the analysis shall be used in developing plans for preclosure and postclosure monitoring required pursuant to paragraphs (c) and (d) of this section. The disposal system parameters analyzed shall include, at a minimum:
>
> (1) Properties of backfilled material, including porosity, permeability, and degree of compaction and reconsolidation;
>
> (2) Stresses and extent of deformation of the surrounding roof, walls, and floor of the waste disposal room;
>
> (3) Initiation or displacement of major brittle deformation features in the roof or surrounding rock;
>
> (4) Ground water flow and other effects of human intrusion in the vicinity of the disposal system;
>
> (5) Brine quantity, flux, composition, and spatial distribution;
>
> (6) Gas quantity and composition; and
>
> (7) Temperature distribution.

Attachment 1 (MONPAR) to CCA Appendix MON is an "Analysis of the Effects of Disposal System Parameters on Waste Containment" that the DOE has used to base decisions regarding disposal system monitoring. 40 CFR § 194.42 dictates the manner in which the stated analysis will be used in deriving the monitoring program, including the specification that the program consider preclosure monitoring as an integral component of meeting the monitoring requirements.

CCA Appendix MON, Attachment 1's (MONPAR's) scope of analyzed parameters exceeds the minimum parameters identified in 40 CFR § 194.42(a). The following is a summary of the results of the analysis with respect to those parameters identified in 40 CFR § 194.42(a).

(1) *Properties of backfilled material, including porosity, permeability, and degree of compaction and reconsolidation;*

Backfill Material Properties. The mechanical and hydrologic properties of the backfill are not significant to the performance assessment. Therefore, they will not be monitored during the preclosure or postclosure periods. See CCA Appendix MON (Attachment 1, MONPAR, Section MONPAR.3.5) for additional detail regarding DOE's analysis of backfill.

(2) *Stresses and extent of deformation of the surrounding roof, walls, and floor of the waste disposal system;*

(3) *Initiation or displacement of major brittle deformation features in the roof or surrounding rock;*

Stress and Extent of Deformation. Creep closure of the repository will occur, and is included within compliance assessment and performance assessment models as a control on waste consolidation and other time-dependent disposal room conditions. The individual creep closure parameters are not significant to performance assessment. Sufficient data have been collected for the purposes of verifying the underlying rock mechanics models. The numerical models of the repository used in performance assessment are based upon assumptions about long-term behavior that are not applicable to behavior during the operational period. Further monitoring of creep closure and stress would not provide information that is useful for calculating disposal system performance, nor would it lead to additional confidence in the performance assessment models.

The initiation or displacement of major brittle deformation features in the roof or surrounding rock, beyond that already accounted for in performance assessment calculations is not significant to the containment of waste. The individual parameters that are used in modeling the mechanical behavior of brittle anhydrite interbeds are not significant to performance assessment. Monitoring mechanical behavior of the interbeds would not provide information that is useful for calculating system performance, nor would it lead to additional confidence in the performance assessment models.

Monitoring of creep closure and mechanical behavior is being conducted during preclosure monitoring to provide information that is relevant to repository operations.

See CCA Appendix MON (Attachment 1, MONPAR, Sections MONPAR.3.1 and MONPAR.3.2) for additional detail regarding DOE’s analysis of creep closure and deformation features.

(4) *Ground water flow and other effects of human intrusion in the vicinity of the disposal system;*

Drilling Intrusions. Intrusion into the repository through drilling may occur during the regulatory time period. In accordance with regulatory requirements, such intrusions are modeled to occur randomly in time and space. Drilling leads to direct releases during the drilling itself and possible long-term releases due to effects on fluid flow in the disposal system. The drilling rate (boreholes per square kilometer per 10,000 years) is significant to repository performance. The DOE uses a drilling rate in performance assessment that is based on historical rates in the Delaware Basin.

The DOE will monitor the drilling activity in the Delaware Basin during the preclosure and postclosure periods and will use the results in performance calculations performed in support of recertification.

Borehole Properties. The properties of a borehole change over time, and are incorporated into performance assessment. The properties are established to be “consistent with practices in the Delaware Basin at the time a compliance application is prepared” (40 CFR § 194.33[c][1]). These parameters are significant to compliance. The current practices will be monitored and changes will be incorporated into the performance assessment models of borehole properties in future calculations in support of recertification.

Groundwater Flow. Historical, current, and near-future human activities in the vicinity of the repository could affect groundwater flow in the Culebra prior to closure of the repository, as well as subsequent to repository closure. The significance of these human activities depends on the extent and magnitude of the induced hydrological, geochemical, and mechanical disturbance. Changes in groundwater in the Culebra are moderately significant to performance. Such changes are incorporated into performance assessment as described in CCA Appendix MON (Attachment 1, MONPAR, Sections MONPAR.4.4 and MONPAR.4.5). Changes to brine flow in the Salado as a result of any current or near future human activities in the vicinity of the repository are not anticipated, and therefore are not significant to performance assessment.

The DOE will monitor water levels and groundwater flow direction in the Culebra during the operational period. Monitoring of groundwater flow conditions in the Salado could create additional pathways for radionuclide transport, and would potentially jeopardize long-term performance of the disposal system; thus the DOE will not perform such monitoring.

See CCA Appendix MON (Attachment 1, MONPAR, Sections MONPAR.4.1, MONPAR.4.3, and MONPAR.4.4) for additional detail regarding DOE's analysis of drilling intrusions, borehole properties, and groundwater flow in the vicinity of the repository.

(5) Brine quantity, flux, composition, and spatial distribution;

Salado Hydrology. Hydrologic properties (quantity, flux, and spatial distribution) of the intact Salado Formation are incorporated into performance assessment through parameters that are consistent with extensive experimental observations. Variations in these parameters have a moderate effect on system performance assessment. There is no indication that properties of the intact (far-field) Salado will change during the regulatory period; thus, they will not be monitored during the operational period nor during the postclosure period. Composition of Salado brines has been well established through investigations. Brine composition is significant and is incorporated into performance assessment calculations. Based on the extensive experimental evidence collected, there is no indication that Salado brine composition will change over the regulatory period; thus it will not be routinely monitored during the operational period nor during the postclosure period.

The presence of a disturbed rock zone (DRZ) surrounding the repository has also been incorporated into performance assessment calculations. The properties of the DRZ have been well characterized; they include altered hydrologic properties that are expected to allow enhanced near-field flow both to and from the repository. The initial conditions and enhanced fluid flow are moderately significant to disposal system performance. In an effort to simplify the calculations, the effects are maximized by the conceptual model and altered properties of the DRZ. This treatment is believed to be a conservative choice with respect to the ultimate impact on predicted release.

Mechanical and hydrologic properties of the disposal room are incorporated into performance assessment as they affect gas generation and fluid flow into and out of the repository. These properties and parameters are moderately significant to disposal system performance. Additional properties are significant in the event of intrusion into the repository; these are discussed in CCA Appendix MON (Attachment 1, MONPAR, Section MONPAR.4.2.). The conceptual model of disposal room behavior is based on extensive experimental data that support a number of assumptions about long-term behavior that will not be applicable during the preclosure period. The closed disposal room will not achieve the expected long-term properties predicted in performance assessment during the operational or active control periods. Therefore, monitoring the mechanical and hydrologic properties would not provide relevant information or verify assumptions used in performance assessment. Thus the disposal room properties will not be monitored during the operational period nor during the postclosure period.

See CCA Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.1, MONPAR.2.2, MONPAR.3.3, and MONPAR.3.4) for additional detail regarding DOE's analysis of these parameters.

Culebra Hydrology. Hydrologic properties (quantity, flux, and spatial distribution) of the undisturbed Culebra Member of the Rustler Formation exhibit spatial variability and are incorporated into performance assessment through both fixed values and parametric ranges that are consistent with experimental observations to date. Variations in some of the parameters are significant to overall disposal system performance. Culebra groundwater is less saline than Salado and Castile brines. The Culebra groundwater is spatially variable, and its composition has been well established through investigations. Groundwater composition is incorporated into performance assessment calculations; however, it is not significant to performance. Based on extensive experimental evidence, there is no indication that Culebra groundwater composition will change over the regulatory period; however, monitoring will provide information that is relevant to a comprehensive environmental monitoring program.

See CCA Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.3 and MONPAR.2.4) for additional details regarding DOE's analysis of these parameters.

Castile Hydrology. The Castile Formation underlying the WIPP may contain reservoirs of pressurized brine. This is incorporated into performance assessment through use of input parameters that address hydrologic properties and the probability that a reservoir will be encountered during an intrusion event. The hydrologic properties are significant to disposal system performance in such an intrusion event. The Castile is not significant to system performance except for the brine reservoirs. There is no indication that the properties of the undisturbed reservoirs will change over the regulatory period. It is not possible to completely define the location and extent of brine reservoirs without jeopardizing the integrity of the disposal system. Composition of brines from two Castile brine reservoirs is moderately significant and is incorporated into performance assessment calculations. There is no evidence to suggest that the brine composition will change over the regulatory period. It is not possible to further investigate composition of any brine that may be present below the repository without jeopardizing the integrity of the disposal system. Therefore, no further investigations or monitoring will be performed neither during the preclosure period nor during the postclosure period. However, monitoring of drilling activity in the Delaware Basin for instances of encountering pressurized brine reservoirs in the Castile will be a part of the preclosure and postclosure monitoring programs.

See CCA Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.5 and MONPAR.2.6) for additional details regarding DOE's analysis of the Castile hydrology parameters.

(6) *Gas quantity and composition;*

Gas Quantity and Composition. Gas generated in the repository may retard creep closure, may fracture the anhydrite interbeds in the DRZ (enhancing fluid flow), and may enhance direct releases (CCA Appendix MON, Attachment 1, MONPAR, Section MONPAR.4.2). These effects are moderately significant and are accounted for in performance assessment. Gas composition (carbon dioxide concentration) and the corrosion rate of metals are controlled chemically by the backfill and are not significant. Gas generation is moderately significant to system performance. The conceptual model of gas generation processes is based on experimental data and incorporates a number of assumptions about long-term behavior that will not be applicable during the operational period (such as anoxic conditions). Monitoring the quantity and composition of gas generated in the closed panels would not provide information that is useful for calculating system performance, nor would it lead to additional confidence in the performance assessment models.

See CCA Appendix MON (Attachment 1, MONPAR, Section MONPAR.3.6) for additional detail regarding DOE's analysis of gas generation.

(7) *Temperature distribution.*

Temperature Distribution. Natural geological thermal gradients have been well characterized and are not significant: they will not affect repository performance, either directly by affecting the containers and repository chemistry, or indirectly by altering fluid flow through the Salado or the Culebra. Similarly waste-induced and repository-induced thermal gradients in the repository are not significant: they will not affect repository performance, either directly by affecting the containers and repository chemistry, or indirectly by altering fluid flow through the Salado or the Culebra. Therefore, natural thermal gradients, waste-induced thermal gradients, and repository-induced thermal gradients will not be monitored during the preclosure period or during the postclosure period.

See CCA Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.7 and MONPAR.3.8) for additional detail regarding DOE's analysis of natural temperature distribution.

The criteria state that the DOE is to base decisions regarding disposal system monitoring on "an analysis of the effects of disposal system parameters on the containment of waste in the disposal system and shall include the results of such analysis in any compliance application." The rule goes on to dictate the manner in which the stated analysis will be used in deriving the monitoring program, including the specification that the program consider preclosure monitoring as an integral component of meeting the monitoring requirements.

The DOE has completed the analysis and has designed a monitoring program (including both preclosure and postclosure monitoring techniques) that meets the requirements of 40 CFR § 191.14(b). The program is documented in a manner that addresses the certification criteria of 40 CFR § 194.42, and is described in this section. More detailed information is provided in CCA Appendix MON.

Additional parametric areas of analysis included in MONPAR (Attachment 1 of CCA Appendix MON) are:

- repository chemical conditions,
- shaft seal system,
- radionuclide transport and retardation,
- direct releases, and
- mining.

Table 7-2 is a list of the specific disposal system parameters discussed in CCA Appendix MON, Attachment 1, MONPAR.

As part of the recertification effort, the analysis documented in CCA Appendix MON, Attachment 1, MONPAR was reviewed to determine if changes to PA methods or results of monitoring programs have impacted the conclusions in CCA Appendix MON, Attachment 1, MONPAR. The PA methodology has not changed since the CCA with the exception of additional refinements in Culebra groundwater modeling.

Results of Culebra monitoring have prompted additional groundwater investigations. These investigations are ongoing and involve additional well drilling and hydrological testing. The

Table 7-2. Potentially Significant Disposal System Parameters

NATURAL PARAMETERS	
Impure halite effective porosity	Culebra diffusional porosity
Impure halite permeability	Culebra longitudinal dispersivity
Impure halite pore compressibility	Climate change index
Impure halite far-field pore pressure	Culebra groundwater quantity
Anhydrite permeability	Culebra groundwater flux
Anhydrite pore compressibility	Culebra groundwater spatial distribution
Anhydrite two-phase flow model choice	Culebra groundwater composition
Salado pore shape	Castile brine volume in reservoir
Salado residual brine saturation	Castile brine reservoir volume selection index
Salado residual gas saturation	Castile brine reservoir pressure
Salado brine quantity	Castile brine reservoir permeability
Salado brine flux	Castile brine reservoir rock compressibility
Salado brine spatial distribution	Castile brine composition
Salado brine composition	Castile brine flux
Culebra transmissivity	Castile brine spatial distribution
Culebra advective porosity	Natural temperature distribution
Culebra fracture spacing	
WASTE AND REPOSITORY PARAMETERS	
Closure rates and stresses	Probability factor for types of microbial degradation
Extent of deformation	Gas quantity
Initiation of brittle deformation	Gas composition
Displacement of major deformation features	Choice of oxidation state distribution
DRZ permeability	Solubility of nine radionuclides in Salado brine
DRZ effective porosity	Solubility of nine radionuclides in Castile brine
DRZ brine flux	Humic colloid concentration in Salado brine
DRZ brine quantity	Humic colloid concentration in Castile brine
Waste area residual gas saturation	Clay shaft seal member permeability
Waste area residual brine saturation	Concrete shaft seal member permeability
Brine wicking	Asphalt shaft seal member permeability
Waste area permeability	Shaft DRZ permeability
Backfill porosity	Crushed salt seal component permeability (permeability selection index)
Backfill permeability	
Degree of backfill compaction	Seal residual gas saturation
Backfill reconsolidation	Seal residual brine saturation
Inundated steel corrosion rate with CO_2	Seal pore shape
Inundated steel corrosion rate without CO_2	Waste- and repository-induced temperature distribution
Inundated microbial degradation rate	Salado K_ds for dissolved radionuclides
Humid microbial degradation rate	Culebra K_ds for six dissolved radionuclides
β-factor for microbial degradation process	Salado K_ds for colloidal radionuclides
Drilling rate	Borehole permeability
Waste particle diameter	Borehole plugging pattern (probability index)
Effective shear resistance to erosion	Change in Salado brine flow

Table 7-2. Potentially Significant Disposal System Parameters— Continued

HUMAN-INITIATED PARAMETERS	
Mud pump rate Drill penetration rate Time between intrusions Borehole location Probability of encountering a Castile brine reservoir Borehole diameter	Change in Culebra groundwater flow Probability that mining will occur Mining index for adjusting Culebra transmissivity Waste activity Waste tensile strength

information gathered since the CCA as part of the groundwater monitoring program has been addressed in the implementation of the groundwater conceptual model (see Section 2.2.1.4.1.2, Section 6.4.6.2 and Appendix DATA, Section DATA-11). Culebra groundwater monitoring was derived from the CCA Appendix MON, Attachment 1, MONPAR analysis and has proven to be an important element of the WIPP operational monitoring program. The program continues to monitor Culebra groundwater to ensure that changes to important activities and conditions related to WIPP long-term performance are identified and addressed. Future results of the ongoing investigations may necessitate changes to the monitoring program; however, the current monitoring parameters have not changed.

7.2.1 Monitoring Program Requirements

Requirements for monitoring of a disposal system[1] are included in the final disposal regulations as follows:

> Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring (§ 191.14[b]).

Within this context, monitoring becomes one of several activities to be implemented at the WIPP facility during the active institutional controls period. Monitoring the WIPP disposal system is designed to address significant concerns associated with the performance of the isolation system. The EPA points out that monitoring approaches to address significant concerns should be limited to those that can provide meaningful data in a relatively short period of time (50 FR 38081). In addition, the EPA points out that monitoring must not become a reason to relax the degree of care with which the compliance determination is made. Finally, the EPA specifies that monitoring must not jeopardize the integrity of the disposal system (50 FR 38081).

7.2.2 Monitoring Program Design

The requirements in 40 CFR § 191.14(b) and the criteria in 40 CFR § 194.42 can be translated into five screening criteria for selecting monitoring parameters and for developing monitoring plans. The monitoring plan should

[1] Disposal system means “any combination of engineered and natural barriers that isolate...radioactive waste after disposal” (40 CFR § 191.12).

- address significant disposal system parameters,
- address important disposal system concerns,
- obtain meaningful data in a short time period (50 FR 38081),
- preserve disposal system integrity, and
- be complementary with other regulatory programs.

Each of these screening criteria is discussed below.

7.2.2.1 Significant Disposal System Parameters

In the certification criteria, the EPA states that

> The Department shall conduct an analysis of the effects of disposal system parameters on the containment of waste in the disposal system and shall include the results of such analysis in any compliance application. The results of the analysis shall be used in developing plans for preclosure and postclosure monitoring required pursuant to paragraphs (c) and (d) of this section (40 CFR § 194.42[a]).

The EPA also states that to the extent practicable, preclosure monitoring shall be conducted of significant disposal system parameter(s) as identified by the analysis conducted pursuant to paragraph (a) of this section (40 CFR § 194.42[c]). Though not explicitly stated in the criteria, it is appropriate that the same requirement hold for postclosure monitoring. The EPA defines significant parameters as follows: "A disposal system parameter shall be considered significant if it affects the system's ability to contain waste or the ability to verify predictions about the future performance of the disposal system" (40 CFR § 194.42[c]).

The terms significant, important, and sensitive have been used in the WIPP program to describe parameters with variability that impact the outcome of performance assessment. While these terms are for the most part interchangeable, the term significant is used in this discussion to maintain consistency with the terminology in the 40 CFR Part 194 criteria.

The DOE has conducted the requisite study of parameters that are inputs to the performance assessment. CCA MONPAR (Attachment 1 of Appendix MON) provides a description of the methodology and results of that study. The DOE has implemented the criteria for significance in CCA Appendix MON.

Verification of parameters used in the system performance analysis may occur in one or both of the following ways:

- measurement of physical or chemical conditions to see if they remain consistent with expected conditions or within the range of conditions incorporated into the assumptions and models, and
- measurement of physical and chemical processes that are currently based on professional judgment or regulatory guidance because data are not available.

The DOE considered the major processes and models described in Section 6.4 and the regulations and developed an initial list of potentially significant parameters as discussed in Attachment 1 to CCA Appendix MON (MONPAR). Parameters were screened for inclusion in the list based on the following criteria:

- the parameter represents one or more important aspects of a chemical or physical process or model,
- the parameter represents subjective uncertainty (such as spatial variability in a physical property or process),
- the parameter represents stochastic uncertainty (such as drilling rate), and
- the parameter proved to be moderately to highly sensitive in terms of modeling results in previous preliminary performance assessments.

The parameters identified through this screening process are summarized in Table 7-2 and discussed in CCA MONPAR (Attachment 1 of Appendix MON).

The parameters identified in Table 7-2 are assigned high, medium, and low significance values (EPA 1996c). Those parameters that would significantly affect a release are assigned a HIGH level. Parameters that influence a release are assigned a MEDIUM value. Parameters that are not significant (represent spatial variability or an uncertainty in a given value) are assigned a LOW value. Those that were determined as having a high significance are shown in Table 7-3.

Table 7-3. Disposal System Parameters Determined to be of Highest Significance to Disposal System Performance

Parameter	Significance to Containment	Significance to Verification
NATURAL PARAMETERS		
Salado anhydrite permeability	HIGH	HIGH
Salado brine composition	HIGH	HIGH
Culebra fracture spacing	HIGH	HIGH
Castile brine reservoir volume selection index	HIGH	HIGH
Castile brine reservoir pressure	HIGH	HIGH
Castile brine reservoir permeability	HIGH	HIGH
Castile brine reservoir rock compressibility	HIGH	HIGH
Castile brine reservoir volume selection index	HIGH	HIGH
Castile brine flux	HIGH	HIGH
Castile brine spatial distribution	HIGH	HIGH
Castile brine composition	HIGH	HIGH
WASTE AND REPOSITORY PARAMETERS		
Inundated steel corrosion rate without CO_2	HIGH	HIGH
Choice of oxidation state distribution	HIGH	HIGH
Solubility of nine radionuclides in Salado brine	HIGH	HIGH
Solubility of nine radionuclides in Castile brine	HIGH	HIGH
Humic colloid concentration in Salado brine	HIGH	HIGH
Humic colloid concentration in Castile brine	HIGH	HIGH
Culebra K_ds for dissolved radionuclides	HIGH	HIGH
Crushed salt seal component permeability (permeability selection index)	HIGH	HIGH
HUMAN INITIATED PARAMETERS		
Drilling rate	HIGH	HIGH
Waste particle diameter	HIGH	HIGH
Borehole permeability	HIGH	HIGH
Borehole plugging pattern (probability index)	HIGH	HIGH
Time between intrusions	HIGH	HIGH
Borehole location	HIGH	HIGH
Probability of encountering Castile brine reservoir	HIGH	HIGH
Waste activity	HIGH	HIGH
Effective shear resistance to erosion	HIGH	HIGH

7.2.2.2 Important Disposal System Concern

This criterion is closely tied with the first in that, in the final analysis, the most significant parameters are related to important disposal system concerns. However, the DOE has included this category as a separate criterion to identify any other parameters that, while they are not significant in performance assessment, do describe important disposal system features. For example, the creep properties of the Salado can be considered an important feature of the disposal system, although the parameter analysis identified them as having a minor effect on the outcome of the analysis. Creep properties are identified in CCA Appendix MON (Attachment 1, MONPAR) because they can provide a body of information that allows the DOE to evaluate its conceptual model of Salado creep closure.

In order to select these parameters for further evaluation, the DOE divided the disposal system into five major components: Salado and repository physical properties, Salado and repository hydrological properties, non-Salado hydrological properties, waste properties, and engineered barrier properties. Based on this division, the DOE revisited the list of potentially significant parameters and determined those parameters that were related to a measurable property of the disposal system. Those parameters are shown in Table 7-4.

7.2.2.3 Meaningful Data in a Relatively Short Time

The amount of time available for the DOE to obtain data regarding important disposal system parameters is limited. This period consists of a preclosure period and 100 years of active institutional controls. However, the DOE will continue monitoring programs for as long as needed if meaningful data are collected or are expected.

In screening parameters using this criterion, the DOE applied two qualifications. First, parameters had to be amenable to measurement within the disposal system and, second, parameter changes expected to occur within the first 127 years and affecting long-term disposal system performance had to be predictable. For example, parameters such as the shape of pore spaces cannot be reasonably measured and, therefore, would not become candidates for a monitoring program. Likewise, changes in parameters such as the actual brine concentration within the Salado are likely to be rapid initially and not necessarily diagnostic of the steady state that will exist over most of the regulatory time period.

The results of the screenings of the parameters in Tables 7-3 and 7-4 are given in Table 7-5.

In some cases, the parameter is indicated as a measurable parameter, meaning that it can either be directly monitored or be deduced from a monitoring program. Other parameters are indicated as observed. This means that the parameter represents an event that occurs at unspecified intervals or changes too slowly or too intermittently to be a viable monitoring candidate. For example, displacements of deformation features occur intermittently and can be observed only when they occur, even though other processes leading up to displacement (such as creep) can be monitored.

7.2.2.4 Preservation of Disposal System Integrity

Disposal system integrity could be compromised by drill holes, conduits, or other entries that are left in place to allow access to monitoring equipment. The requirement to avoid such conditions leads to the conclusion that the only viable monitoring systems are those that can be operated directly during operations, those that can transmit information without cabling (telemetry), and

Table 7-4. Parameters Related to Measurable Disposal System Properties

Parameter	Significance to Containment	Significance to Verification
SALADO PHYSICAL PARAMETERS		
Creep closure and stresses	LOW	LOW
Extent of deformation	LOW	LOW
Initiation of brittle deformation	LOW	LOW
Displacement of major deformation features	LOW	LOW
Natural temperature distribution	LOW	LOW
SALADO HYDROLOGICAL PARAMETERS		
Impure halite pore compressibility	LOW	LOW
Impure halite far-field pore pressure	MEDIUM	MEDIUM
Salado pore shape	MEDIUM	MEDIUM
Impure halite effective porosity	MEDIUM	MEDIUM
Impure halite permeability	MEDIUM	MEDIUM
Anhydrite permeability	HIGH	HIGH
Anhydrite pore compressibility	MEDIUM	MEDIUM
Salado residual brine saturation	MEDIUM	MEDIUM
Salado residual gas saturation	MEDIUM	MEDIUM
Salado brine quantity	LOW	LOW
Salado brine flux	MEDIUM	MEDIUM
Salado brine spatial distribution	LOW	LOW
Salado brine composition	HIGH	HIGH
Salado K_ds for dissolved radionuclides	LOW	LOW
Salado K_ds for colloidal radionuclides	LOW	LOW
Salado change in groundwater brine	LOW	LOW
Natural temperature distribution	LOW	LOW
DRZ permeability	MEDIUM	MEDIUM
DRZ effective porosity	MEDIUM	MEDIUM
DRZ brine flux	MEDIUM	MEDIUM
DRZ brine quantity and spatial distribution	LOW	LOW
NON-SALADO HYDROLOGICAL PROPERTIES		
Culebra transmissivity	MEDIUM	MEDIUM
Culebra advective porosity	MEDIUM	MEDIUM
Culebra fracture spacing	HIGH	HIGH
Culebra diffusional porosity	MEDIUM	MEDIUM
Culebra longitudinal dispersivity	LOW	LOW
Culebra groundwater quantity	LOW	LOW
Culebra groundwater flux	MEDIUM	MEDIUM
Culebra groundwater spatial distribution	LOW	LOW
Culebra groundwater composition	LOW	LOW

Table 7-4. Parameters Related to Measurable Disposal System Properties — Continued

Parameter	Significance to Containment	Significance to Verification
Castile brine reservoir pressure	HIGH	HIGH
Castile brine reservoir permeability	HIGH	HIGH
Castile brine reservoir rock compressibility	HIGH	HIGH
Castile brine reservoir brine volume	HIGH	HIGH
Castile brine flux	HIGH	HIGH
Castile brine spatial distribution	HIGH	HIGH
Castile brine composition	MEDIUM	MEDIUM
Natural temperature distribution	LOW	LOW
Culebra K_ds for six dissolved radionuclides	HIGH	HIGH
Culebra K_ds for humic and actinide-intrinsic colloidal radionuclides	MEDIUM	MEDIUM
Drilling rate	HIGH	HIGH
Effective decay constant for microbes	MEDIUM	MEDIUM
Culebra change in groundwater flow	MEDIUM	MEDIUM
WASTE RELATED PARAMETERS		
Waste area residual gas saturation	MEDIUM	MEDIUM
Waste area residual brine saturation	MEDIUM	MEDIUM
Waste area permeability	MEDIUM	MEDIUM
Brine wicking	MEDIUM	MEDIUM
Inundated steel corrosion rate with CO_2	LOW	LOW
Inundated steel corrosion rate without CO_2	MEDIUM	MEDIUM
Inundated microbial degradation rate	LOW	LOW
Humid microbial degradation rate	LOW	LOW
Gas quantity	MEDIUM	MEDIUM
Gas composition	LOW	LOW
Choice of oxidation state distribution	HIGH	HIGH
Solubility of nine radionuclides in Salado brine	HIGH	HIGH
Solubility of nine radionuclides in Castile brine	HIGH	HIGH
Humic colloid concentrations in Salado brine	HIGH	HIGH
Humic colloid concentrations in Castile brine	HIGH	HIGH
Waste particle diameter	HIGH	HIGH
Effective shear resistance to erosion	MEDIUM	MEDIUM
Waste activity	HIGH	HIGH
Waste tensile strength	HIGH	HIGH
Mud pump rate	LOW	LOW
Drill penetration rate	LOW	LOW

Table 7-4. Parameters Related to Measurable Disposal System Properties — Continued

Parameter	Significance to Containment	Significance to Verification
ENGINEERED BARRIER PROPERTIES		
Shaft DRZ permeability	MEDIUM	MEDIUM
Backfill porosity	LOW	LOW
Backfill permeability	LOW	LOW
Degree of backfill compaction	LOW	LOW
Backfill reconsolidation	LOW	LOW
Clay seal member permeability	MEDIUM	MEDIUM
Concrete seal member permeability	MEDIUM	MEDIUM
Asphalt seal member permeability	MEDIUM	MEDIUM
Seal residual gas saturation	LOW	LOW
Seal residual brine saturation	LOW	LOW
Seal pore shape	LOW	LOW
Long-term borehole permeability	HIGH	HIGH

Table 7-5. Parameters That Can Produce Meaningful Data During Monitoring Period

Parameter	Comment
SALADO PHYSICAL PARAMETERS	
Creep closure and stresses	Can be measured during operations
Extent of deformation	Can be measured during operations
Initiation of brittle deformation	Can be measured during operations
Displacement of deformation features	Can be observed during operations
SALADO HYDROLOGICAL PARAMETERS	
Salado brine composition	Can be measured during operations
NON-SALADO HYDROLOGICAL PROPERTIES	
Culebra groundwater composition	Can be measured for entire period
Castile brine reservoir location	Can be observed for entire period
Drilling rate	Can be observed for entire period
Culebra change in groundwater flow	Can be observed for entire period
WASTE RELATED PARAMETERS	
Waste activity	Can be calculated using measurements made during waste characterization

those that can be used to evaluate parameters using remote sensing techniques. Each is discussed briefly below. Table 7-6 shows the final screening of parameters in order to determine those that are candidates for a monitoring program. Table 7-7 identifies those parameters included in the preclosure and postclosure monitoring programs. The presence of a DRZ surrounding the repository has been

Table 7-6. Parameters That Can Be Measured Without Violating Repository Integrity

Parameter	Comment
SALADO PHYSICAL PARAMETERS	
Creep closure	Direct measurement in open areas of the repository
Extent of deformation	Direct measurement in open areas of the repository
Initiation of brittle deformation	Direct measurement in open areas of the repository
Displacement of deformation features	Directly observed from other open areas of the repository
NON-SALADO HYDROLOGICAL PROPERTIES	
Culebra groundwater composition	Can be measured using existing or additional groundwater surveillance wells
Probability of encountering a Castile brine reservoir	Can be developed based on observations of drilling activity in Delaware Basin
Drilling rate	Can be developed based on observations of drilling activity in Delaware Basin
Culebra change in groundwater flow	Can be determined using existing or additional groundwater surveillance wells
WASTE RELATED PARAMETERS	
Waste activity	Limited to observations during waste characterization activities

Table 7-7. Preclosure and Postclosure Monitored Parameters

Monitored Parameter	Preclosure	Postclosure
Culebra groundwater composition	X	X
Culebra change in groundwater flow	X	X
Probability of encountering a Castile brine reservoir	X	X
Drilling rate	X	X
Subsidence measurements	X	X
Waste activity	X	
Creep closure and stresses	X	
Extent of deformation	X	
Initiation of brittle deformation	X	
Displacement of deformation features	X	

incorporated into performance assessment calculations. The properties of the DRZ have been characterized; they include altered hydrologic properties that are expected to enhance near-field fluid flow both to and from the repository. The initial conditions and enhanced fluid flow are considered moderately significant to disposal system performance. Monitoring the DRZ hydrologic properties would not provide relevant information or verify assumptions used in performance assessment; therefore they will not be monitored during the operational period or during the postclosure period. For more detail regarding DRZ-related parameters, see CCA Appendix MON (Attachment 1, MONPAR, Section MONPAR.3.3).

Composition of Salado brines has been established through investigations. Brine composition is significant and is incorporated into performance assessment calculations. Based on the extensive experimental evidence collected, there is no indication that Salado brine composition will change over the regulatory period; thus it will not be routinely monitored during the operational period or during the postclosure period. For more detail regarding Salado brine composition, see CCA Appendix MON (Attachment 1, Section MONPAR.2.2).

7.2.2.4.1 Evaluation of Monitored Parameters

The preclosure and postclosure parameters identified in Table 7-7 have been evaluated for this CRA (see Appendix DATA) as a part of the plan described in Appendix MON-2004. Significant deviations in expected values of any of these parameters from those ranges of values in the performance assessment models have been and will continue to be evaluated. Where applicable, any new information will be incorporated into the performance assessment conducted for recertification. Parameter values outside of expected ranges will also prompt the evaluation of models and their modification, where appropriate, for use in recertification performance assessment activity.

Culebra groundwater composition, Culebra changes in groundwater flow, Castile brine reservoir encounters, Castile brine reservoir pressure, and drilling rate parameters are evaluated to substantiate that they remain within the range of values assumed in model development and performance assessment. Should there be a significant change outside the assumed range of values used in the 2004 PA models, the DOE will evaluate and, where appropriate, modify models for incorporation into the next performance assessment recertification.

In the unlikely event that subsidence values fall significantly outside the range of values predicted and experienced elsewhere in the Delaware Basin, additional evaluation of the potential effects of such deviations will be conducted. If the evaluation requires changes to models used in the performance assessment, these changes will be made and the revised models incorporated into a future recertification performance assessment.

The waste activity (see Appendix TRU WASTE for a detailed discussion) is monitored to ensure compliance with the requirements of the LWA and that the values are within the range of values used in PA models. New inventory data, including waste activity information, have been incorporated into the 2004 PA; these values are tracked in the preclosure monitoring program. Any significant deviation from the values used in the PA baseline will be addressed by the DOE in a timely fashion to avoid any violation of the compliance certification.

Creep closure and stresses, extent of deformation, initiation of brittle deformation, and displacement of deformation features are all parameters that reflect on the geomechanical nature of the repository. Evaluation of these parameters influence the operational aspects of safe operation of the repository. However, should any of these parameters exhibit properties that are significantly outside the experience and expectations of the information baselines developed to date, the DOE will evaluate the impact on the design of the repository and the design of the shaft seal system.

The EPA will be notified of any deviation that the DOE evaluates as significant with respect to complying with the regulations or the certification of the WIPP as a safe repository.

7.2.2.4.2 Direct Measurement

Direct measurement includes current programs such as the underground geomechanical monitoring program and the groundwater surveillance program. In such cases, the monitoring equipment can be inspected, calibrated, and used with high reliability. Malfunctioning equipment can be easily repaired or replaced. Power requirements are met with portable power units such as rechargeable batteries or generators. In some cases, analog measurements can be made mechanically and recorded in notebooks. In other cases, digital logging equipment is available to record large quantities of data and information. Direct measurement allows for changing the measurement parameters as environmental conditions change. Replicate samples can be taken easily if needed. Unusual conditions can be investigated to provide unambiguous interpretation of data.

7.2.2.4.3 Telemetry Systems

In the early 1970s to the mid 1980s, the U.S. Bureau of Mines and the Mine Safety and Health Administration demonstrated that reliable communications can be established between underground mines and the surface for the purpose of locating and rescuing trapped miners (see Powell 1976; Murphy and Parkinson 1978, p. 42). Low-frequency radio equipment was demonstrated in numerous mine environments and at many depths. The systems evaluated used low-duty cycle transmitters connected to loop antennae powered by miners' cap lamp batteries. Although through-the-earth transmission of signals is feasible, any system that uses this type of telemetry must deal with the following design problems.

First, because the purpose of the telemetry is to obviate the need for cabling to the surface, all power must be self-contained. For the WIPP, this will require extending battery or portable generators beyond the tens of years that can now be achieved for low-duty cycle systems. Second, issues regarding durability must be addressed since the environmental conditions will be severe. Components will have to withstand the brine and gas environments that are predicted, as well as the effects of creep closure and repressurization. Third, reliability will have to be addressed since failed sensors cannot be replaced nor can calibrations be performed or adjustments made. Finally, in addition to the equipment issues, there are concerns about interpreting results in an environment where interference, such as background electromagnetic noise, can only be, at best, poorly characterized. While these issues and concerns can be addressed with technology development programs, it is doubtful that the high cost is justifiable for the limited amount of data that may be obtained from such systems.

7.2.2.4.4 Remote Sensing Systems

The use of remote techniques to determine the characteristics of the earth have been well established. Generally classified as geophysical measurements, these systems look for variations in a parameter within the earth in order to determine geological relationships. Typical parameters that are measured remotely are resistivity, acoustic velocity, magnetism, density, temperature, moisture content, radioactivity, and radiometry (infrared). The general conclusion is that the changes in the repository are too small (in scale), too far from the surface, and too slow to be detectable using remote techniques.

7.2.2.5 Complementary With Other Regulatory Programs Monitoring is performed by the DOE at and near the WIPP site to comply with the requirements of other regulatory programs. This includes groundwater monitoring in support of the Resource Conservation and Recovery Act (RCRA) program for the project. None of the monitoring activities implemented by the DOE in support of 40 CFR Part 191 and Part 194 compliance demonstrations interfere with or contradict monitoring performed for other regulatory programs.

Based on the approach the DOE has taken to monitoring program implementation, the criterion of compatibility with other regulatory programs is met.

7.2.3 Monitoring Program Description

Based on the parameter screening described above and the analysis in CCA Appendix MON, the DOE has selected a monitoring program with the following components:

- preclosure monitoring
  - Geomechanical monitoring parameters until closure:
    Creep closure and stresses,
    Extent of deformation,
    Initiation of brittle deformation, and
    Displacement of deformation features.
  - Waste Characterization monitoring parameters until last waste shipment :

Waste activity

- preclosure and postclosure monitoring parameters (100 years after closure or until DOE can demonstrate that there are no significant concerns to be addressed by further monitoring)
  - groundwater surveillance:

    Culebra groundwater composition,

    Change in Culebra groundwater flow
  - observation of drilling activities (100 years after closure):[2]

    Probability of encountering a Castile brine reservoir, and
    drilling rate.
- postclosure monitoring parameter (100 years after closure or until DOE can demonstrate that there are no significant concerns to be addressed by further monitoring)

- subsidence monitoring.

The rationale for eliminating the volatile organic compound (VOC) monitoring component of the program is described in Section 7.2.3.2. Other changes to this list have been made to more clearly indicate DOE's intent.

Each of these programs is described in the following sections. Individual program plans are included in CCA Appendices GWMP, SMP, and DMP. Relevant information from these CCA appendices has been consolidated into Appendix MON-2004. Consistent with EPA concurrence (EPA letter of March 15, 2002 to DOE; EPA Docket A-98-49, II-B-3, Item 24), CCA Appendices GWMP, SMP, and DMP are not repeated in this recertification application.

Waste monitoring is not discussed in the following sections because it is tracked in the WIPP Waste Information System (WWIS), as described in Chapter 4.0.

7.2.3.1 Geomechanical Monitoring Program

The geomechanical monitoring program at the WIPP facility is an integral part of the DOE's ground control program. Disposal rooms, drifts, and operational area excavations will be monitored to provide confirmation of structural integrity. Geomechanical data on the performance of the repository shafts and excavated areas are currently collected as part of the geotechnical field monitoring program. The results of the geotechnical investigations are reported annually. The report describes monitoring programs and geomechanical data collected during the previous year.

The instrumentation in Table 7-8 is available for use in support of the geomechanical program. The minimum instrumentation for Panels 2 through 8 is one borehole extensometer installed in the roof at the center of each disposal room. The roof extensometers will monitor the dilation of the immediate salt roof beam and possible bed separations along clay seams. Additional instrumentation may be installed as conditions warrant. Panel 1 is more extensively instrumented than subsequent panels because it was the first panel excavated and because it remained open for a relatively long period of time. After the last emplacement of waste in Panel 1, the communication cables from the instrumentation were cut and geomechanical monitoring ceased in the panel**.** In a similar manner, other waste panels will be monitored until each is full and panel seals are emplaced.

Polling of the geomechanical instrumentation will be performed at least once every month. This frequency may be increased to accommodate any changes that may develop. The results from the remotely read instrumentation will be evaluated after each scheduled polling. Documentation of the results are provided annually in the Geotechnical Analysis Report.

The instrumentation system provides for data maintenance, retrieval, and presentation. The instrumentation system cognizant engineer first retrieves the data from the instrumentation system and verifies their accuracy by assuring the measurements were taken in accordance with applicable instructions and procedures. Next, the cognizant engineer reviews the data after each polling to assess the performance of the instrument and the excavation. Data that look anomalous are detected during this polling and are investigated to determine the cause (for

Table 7-8. Instrumentation Used in Support of the Geomechanical Monitoring System

Instrument Type	Features	Parameter Measured	Range
Borehole extensometer	The extensometer provides for monitoring the deformation parallel to the borehole axis. Units suitable for up to five measurement anchors in addition to the reference head.	Cumulative deformation	0-2 inches
Borehole television camera	Closed circuit television may be used for monitoring areas otherwise inaccessible, such as boreholes or shafts.	Video image	N/A
Convergence points and tape extensometers	Mechanically anchored eyebolts to which a portable tape extensometer is attached.	Cumulative deformation	2-50 feet
Convergence meters	Includes wire and sonic meters. Mounted on rigid plates anchored to the rock surface.	Cumulative deformation	2-50 feet
Inclinometers	Both vertical and horizontal inclinometers are used. Traversing type of system in which a probe is moved periodically through casing located in the borehole whose inclination is being measured.	Cumulative deformation	0-30 degrees
Rock bolt load cells	Spool type units suitable for use with rock bolts. Tensile stress is inferred from strain gauges mounted on the surface of the spool.	Load	0-300 kips
Earth pressure cells	Installed between concrete keys and rock. Preferred type is a hydraulic pressure plate connected to a vibrating wire transmitter.	Lithostatic pressure	0-1,000 pounds per square inch
Piezometer pressure transducers	Located in shafts and of robust design and construction. Periodic checks on operability required.	Fluid pressure	0-500 pounds per square inch
Strain gauges	Installed within the concrete shaft key. Suitably sealed for the environment. Two types used—surface mounted and embedded.	Cumulative deformation	0-3,000 microinches per inch (embedded) 0-2,500 microinches per inch (surface)

example, instrumentation problem, error in recording, or changing rock conditions). The data are then processed to calculate various parameters such as the change between successive readings and deformation rates. The results of this assessment are reported to the ground control cognizant engineer and operations personnel. The stability of an open panel excavation is generally determined by the rock deformation rate. Unexpected deformation rates are investigated by Geotechnical Engineering to determine if remediation is needed.

The evaluation of the performance of the excavation is also performed by Geotechnical Engineering. These evaluations will provide an estimate of the stand-up time of the excavation. If the trend is toward adverse (unstable) conditions, then the results of these assessments are reported to the operations manager to determine appropriate operational responses.

Roof conditions are assessed from observation boreholes and extensometer measurements. Measurements of room closure, rock displacements, and observations of fracture development in the immediate roof beam are used to evaluate the performance of a panel. A summary of the Panel 1 monitoring program was presented to the members of the Geotechnical Experts Panel in 1991, who concurred that the monitoring was adequate to determine deterioration within the rooms and could provide early warning of deteriorating conditions.

The assessment and evaluation of the condition of WIPP excavations is an iterative, continuous process using the data from the monitoring programs. Criteria for corrective action are continually reevaluated and reassessed based on total performance to date. Actions taken are based on these analyses and on planned utilization of the excavation. Because WIPP excavations are in a natural geologic medium, there is inherent variability from point to point. The principle adopted is to anticipate potential ground control requirements and implement them in a timely manner rather than to wait until a need arises.

Both creep closure of the excavation and the development of the DRZ are included in the conceptual model of disposal system performance. Creep closure is discussed in Section 6.4.3.1 and Appendix PA, Attachment PORSURF. The numerical model for predicting creep closure has been developed based on both theoretical considerations and observations. The goal of monitoring is to detect any substantial and detrimental deviations from the expected behavior of Salado halite and to determine the significance of such deviations. Data are analyzed after each round of measurements and results are distributed for use in making ground control decisions. A compilation of data (current and previous) is published annually in the Geotechnical Analysis Report. This compilation is useful determining long-term trends in the behavior of underground openings and can be a diagnostic tool for determining substantial and detrimental deviations from expected performance.

The DRZ is modeled as discussed in Section 6.4.5.3. It is assumed that the DRZ maintains its permeability throughout the model period as shown in Table 6-19. Marker bed (MB) 138 and 139 are modeled to be separate geological units with permeabilities lower than those in the DRZ as shown in Table 6-18. Substantial and detrimental deviations from these expectations may impact repository performance. Consequently, as discussed in Section 4.3 of CCA Appendix GTMP, observations of excavation effects, along with the other geotechnical measurements will be useful to detect deviations in expectations for near-term DRZ development.

7.2.3.2 VOC Confirmatory Monitoring Program

In Docket A-93-02, Compliance Application Review Document No. 42, Section 42.C.5, the EPA concludes:

> The VOC monitoring acts only as a secondary indicator of creep closure because there is not a direct relationship between VOC levels and creep closure rates. While VOC levels might indicate changes in creep closure rates, such changes would be observed earlier and would be better defined by direct geomechanical monitoring, which will be conducted throughout the operation of the WIPP. DOE stated that VOC monitoring will also provide data on gas producing processes (p. 7-58). The DOE did not include gas producing processes as one of the parameters to be monitored, however, because the modeling of gas-producing processes is based on data and assumptions about long-term behavior that will not be applicable during the operational period (p. 7-36).

The EPA indicated that VOC monitoring is not necessary as a secondary indicator of creep closure or to fulfill the requirements of Section 194.42. A planned change per 40 CFR § 194.4(b)(3) was submitted to the EPA in January 2002 requesting removal of CCA Appendix VCMP from the compliance baseline. In March 2002, the EPA approved the request to eliminate CCA Appendix VCMP from the WIPP certification basis. Based on the approval letter, this section and all references to CCA Appendix VCMP are eliminated from future recertification applications.

7.2.3.3 Groundwater Surveillance Program

In the development of the WIPP monitoring programs, potential pathways for release of hazardous constituents to the environment were evaluated. This evaluation indicated no credible release pathway via surface water. Comparisons between data sets are performed using standard statistical tests. The selection of the specific test is dependent upon the relative power of the test and the degree to which the underlying requirements of the test are met. In addition to tests comparing data from distinct locations and times, trend analyses are performed on time series where sufficient data exist.

Citation of the source of the test method or the software used to perform the tests will be made when results are reported. Data and subsequent calculated values are reported in the annual site environmental report.

The two parameters of interest from the groundwater surveillance program are the composition of the Culebra groundwater and water levels. Significant and persistent changes in the composition of the Culebra groundwater are investigated and impacts to the modeling assumptions for long-term performance in Section 6.4.6.2 are evaluated. Large and rapid water-level fluctuations may be diagnostic of nearby human activity such as potash mining and fluid injection and withdrawal. Water-level changes within the groundwater modeling domain in Section 6.4.6.2 that cannot be explained either based on observed trends or on past experience are being investigated and assessed relative to the assumptions made in the regional groundwater flow model (see Appendix DATA, Section DATA-11).

7.2.3.4 Observation of Drilling Activities

As part of the ongoing compliance activities, the DOE has continued to populate and maintain the database of drilling activity within the Delaware Basin. In addition, the DOE has an ongoing program of field checking each well that is drilled within one mile of the WIPP site boundary. Field checking includes verifying the location as listed on the Application for Permission to Drill (APD), monitoring drilling and completion activities, and noting abandonment and plugging. Both the maintenance of the database and the field observation program will be continued throughout the operational period to develop additional statistics on the following parameters:

- drilling rates,
- drilling practices,
- Castile brine reservoirs encountered,

- Castile brine characteristics (where available), and
- plugging practices.

Data collected are addressed as appropriate in the recertification process. Any analyses that indicate parameter values are changing are studied to evaluate the impact of the changes.

Significant changes in drilling practices, such as borehole diameters, plug and abandonment practices, mining techniques, Castile brine occurrence, and injection well use are evaluated for potential impacts on disposal system performance. Any significant deviations are reported to the EPA.

Annual reports of the Delaware Basin Monitoring Program provide the total number of deep boreholes drilled within the Delaware Basin. This information is reported in compliance with 40 CFR § 194.33(b)(3), which specifies the manner in which the frequency of deep drilling events assumed in performance assessments shall be determined. The rule specifies that the DOE shall:

> (i) Identify deep drilling that has occurred for each resource in the Delaware Basin over the past 100 years prior to the time at which a compliance application is prepared.

In addition, the rule specifies that:

> (ii) The total rate of deep drilling shall be the sum of the rates of deep drilling for each resource.

The specification of a 100-year period "prior to the time at which a compliance application is prepared" has had the effect of increasing the deep drilling frequency that must be assumed in performance assessment calculations. This is because significant deep drilling activity did not exist within the Basin in the early part of the 20th century, while the last 10 years has been a period of significant oil drilling activity in the basin. Consistent with this, it is anticipated that the intrusion rate assumed in performance assessments will continue to increase throughout the operational period of the WIPP, as long as drilling continues to occur. The intrusion rate calculated in this manner for the CCA in 1996 is 46.8 deep holes per square kilometer over 10,000 years. Based on current information, this rate is 52.2 deep intrusions per square kilometer over 10,000 years (supporting data are provided in Appendix DATA). The implications of this increased rate of deep drilling are addressed in Chapter 6.0.

7.2.3.5 Subsidence Monitoring

Subsidence monitoring is accomplished with leveling surveys having maximum errors not greater than Second Order, Class II specifications. The relevant subsidence monitoring information presented in CCA Appendix SMP is incorporated into Appendix MON-2004.

Although the CCA indicates that surveys will be performed every 10 years, the surveys are currently performed annually. These surveys will be performed during the operational phase and thereafter in accordance with Appendix MON-2004.

The leveling survey procedures ensure that the data are documented and validated. The data are included in the baseline.

The monitoring program includes the following:

- management of the disposal phase monitoring program,
- maintenance of monitoring procedures and quality assurance/quality control documents,
- performance of all necessary field work,
- maintenance of the subsidence network,
- maintenance (and revision as necessary) of the monitoring schedule,
- maintenance and storage of baseline database,
- review of data and evaluation of performance,
- eventual decommissioning of the disposal system monitoring program, and
- archiving of monitoring data.

Subsidence predictions exist for the WIPP. These will be reevaluated at the time of closure. Subsidence measurements will be used to compare actual subsidence with predictions. Significant deviations between expected subsidence and actual subsidence will be investigated to determine if a substantial and detrimental deviation in the expected performance of the repository is indicated.

7.2.4 Reporting

The results of the DOE's monitoring program are submitted annually. The report includes the results from the previous year, plus any cumulative information that is useful in interpreting the data. The annual report contains a summary assessment of results to ensure that the performance of the repository can be evaluated on a continuous and consistent basis. Other reports, such as those stipulated in 40 CFR § 194.4 (b)(3), are issued when necessary.

Since the submittal of the CCA, the DOE has prepared over 20 annual reports pertaining to geomechanical monitoring, groundwater surveillance, subsidence monitoring, Delaware Basin monitoring, and waste characteristics monitoring. Data resulting from the various monitoring programs are reported in Appendix DATA. These reports are submitted to the EPA with the Annual 194.4(b)(4) Change Report.

7.2.5 Compliance Monitoring Parameter Data Results

In the EPA certification of compliance (63 FR 27354, May 18, 1998), the EPA concurred on the list of 10 compliance monitoring parameters (compliance parameters) that DOE proposed to monitor during the operational period of the project. The 10 compliance parameters are:

- Culebra groundwater composition,
- change in Culebra groundwater flow,
- probability of encountering a Castile brine reservoir,
- drilling rate,
- subsidence measurement,
- waste activity,
- creep closure and stresses,
- extent of brittle deformation,
- initiation of brittle deformation, and
- displacement of deformation features.

These parameters have been continually monitored over a period of several years, most of them before the initial receipt of waste. Existing WIPP monitoring programs gather data and information to develop the compliance parameter values. These programs are described in Appendix MON-2004; data resulting from these monitoring programs are provided in Appendix DATA.

The EPA also requires the DOE to report any negative condition that may indicate the repository will not function as predicted or a condition that is substantially different from the information contained in the most recent compliance application. Annual assessments of compliance parameters allow the DOE to monitor the predicted performance of the repository and report any condition adverse to waste containment.

All monitoring activities performed as part of the compliance parameters program have generated data within expected ranges, except for the changes in Culebra groundwater flow compliance parameter (the drilling rate was changed for PA; however, this parameter is monitored as a regulatory requirement and not to ensure it is within an expected range). For this compliance parameter, data related to water levels in monitoring wells have been recorded that are outside expected ranges. The implications of these unexpected monitoring parameter values are described in Chapters 2.0 and 6.0 of this recertification application.

7.3 Passive Institutional Controls

Passive institutional controls, as opposed to active institutional controls, are controls that once established, can be expected to remain effective with no on-site human support. The DOE will implement passive institutional controls that involve multiple types and multiple levels of passive controls to make human intrusion into the disposal site unlikely. To accomplish this, the DOE intends to use several types of monuments and markers, land ownership, and written notations in land records in numerous locations (see Section XVI of CCA Appendix PIC).

Written documentation will include information on the location, design, and disposal contents and hazards, as well as stipulations on allowable land uses. Components of the passive controls system will be instituted at the site and at remote locations (see CCA Appendix PIC).

As technology advances, this design concept will be revisited over the operational lifetime of the WIPP. If the DOE believes the design can be enhanced, changes will be proposed during the recertification process for EPA approval. The program described in CCA Appendix PIC will fulfill the requirements of 40 CFR Part 191 and satisfy the certification criteria of 40 CFR Part 194.

7.3.1 Requirements for Passive Institutional Controls

The EPA has specified that "[d]isposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable" (40 CFR § 191.14[c]). The EPA then goes on to define passive institutional controls to mean "(1) permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system" (40 CFR § 191.12[e]). The DOE has interpreted this regulatory language to mandate the development and implementation of a system of passive institutional controls consistent with those components listed in the EPA's definition in order to protect the integrity of the disposal system for as long as practicable after disposal.

Guidance is provided by the EPA in 40 CFR § 194.43 on what subject areas must be addressed in order to demonstrate compliance with the regulation. Three subject areas must be addressed: (a) detailed descriptions of the passive institutional controls must be provided, (b) the period of time that the passive institutional controls are expected to endure and be understood must be estimated, and (c) credit for the passive institutional controls in reducing the likelihood of inadvertent human intrusion in performance assessments must be justified for the proposed time period. Additional guidance is provided in EPA (1996b) indicating what documentation is required in the compliance application to address 40 CFR § 194.43(a), the need for rationales to explain the estimates of how long the passive institutional controls are expected to endure and be understood in 40 CFR § 194.43(b), and the limitations of effectiveness and duration of the effectiveness of the passive institutional controls in performance assessment to address 40 CFR § 194.43(c).

In addition, as part of the initial EPA certification decision, the EPA added Condition 4. This condition is applicable to the implementation of the passive institutional controls, and has been included in 40 CFR Part 194 as Appendix A. The appendix provides that not later than the final recertification application submitted before closure of the disposal system, the DOE will provide the following to the EPA:

1. A schedule for implementing passive institutional controls that demonstrates markers will be fabricated and emplaced and other measures will be implemented as soon as possible following closure of the WIPP. The schedule will also describe how testing of any aspect of the conceptual design will be completed before or soon after closure and what changes to the design of passive institutional controls may be expected to result from such testing.

2. Documentation showing that the granite pieces for the proposed monuments and information rooms described in Docket A-93-02, Item II-G-1, may be quarried (cut and removed from the ground) without cracking due to tensile stresses from handling or isostatic rebound; engraved on the scale required by the design; transported to the site, given the weight and dimensions of the granite pieces and the capacity of existing rail cars and rail lines; loaded, unloaded, and erected without cracking based on the capacity of available equipment; and successfully joined.

3. Documentation showing that archives and record centers will accept the documents identified and maintain them in the manner identified in Docket A-93-02, Item II-G-1.

4. Documentation showing that proposed recipients of WIPP information other than archives and record centers will accept the information and make use of it in the manner indicated by the DOE in Docket A-93-02, Item II-G-1, and supplementary information.

7.3.2 Objectives for Passive Institutional Controls

As prescribed by the standards, the objectives of DOE's passive institutional controls for the WIPP are to convey the following:

- location,
- facility design,
- content, and
- hazard.

The passive institutional controls program described within this application will be effective in accomplishing these objectives.

7.3.3 Implementation of the Passive Institutional Controls Program

The DOE began addressing the issue of passive institutional controls in the context of the assurance requirements by convening two panels of experts to identify what future societies might be like (Hora et al. 1991). The panels were convened so that the appropriate types of messages, the contents of the messages, and the types of media for transmitting the messages can be selected and to identify design concepts for the system of markers at the repository footprint (Trauth et al. 1993), which is one of the passive institutional controls. The work of the two panels was completed prior to promulgation of 40 CFR Part 194. To address the issues of the passive institutional controls in addition to the markers at the repository footprint and to incorporate the concept of practicability into the design, the DOE developed a conceptual design, which is included in CCA Appendix PIC. With the promulgation of 40 CFR Part 194, the EPA provided guidance on how credit for the passive institutional controls deterring inadvertent human intrusion can be obtained for use in performance assessment. To address the issue of credit for passive institutional controls, the DOE produced CCA Appendix EPIC.

In addition, the DOE has developed new information pertaining to the permanent markers portion of the passive institutional controls program and furthered the planning process since the development and submittal of the CCA. This material is documented in the following reports:

1. Permanent Markers Testing Program Plan, Waste Isolation Pilot Plant (DOE 2000) – This document presents DOE plans for the program to test reference designs and alternative permanent markers materials, physical configurations, and locations. The markers testing program will develop information useful in materials selection and in the development of final designs. Testing will help to determine the effectiveness and durability of selected and alternative materials and design configurations. The testing plan provides the following information:

   Program Overview – Implementing the testing program will require performing a series of general activities, such as literature reviews and a survey and assessment of existing markers, the development of some testing methods, and the performance of both laboratory and field-scale tests. The coordination and integration of these activities is described.

   Testing Rationale – The rationale for the testing process is described. The testing rationale links individual marker systems, applicable design criteria, and testing objectives and issues. The testing objectives and issues are, in turn, addressed by the performance of specific tests and analyses.

   Tests Specification – Specific tests appropriate to address individual testing objectives and issues are identified for those cases where an appropriate method currently exists. Cases are identified where no method currently exists.

   Detailed Test Plans – Information that must be addressed in detailed test and analysis plans is identified in the plan. These plans must be developed before testing begins and will address topics such as test objectives, management of the testing activity, specific test methods, data quality objectives, data management, reporting, quality assurance (QA) provisions, and others.

   Evaluation of Results – The general manner in which testing and analyses results will be evaluated in the markers systems design process is described.

   Program Organization – The organization of the testing and analysis program in a sequential progression of activities and the general schedule of testing activities are described in the plan.

   QA – QA provisions applicable to the implementation of the testing program are described.

2. Contractor Report, Permanent Markers Monument Survey, Waste Isolation Pilot Plant (John Hart and Associates, P.A. 2000a) – The DOE is currently investigating alternative materials for the construction of permanent markers. One of the important considerations is the ability of the marker material to be inscribed with warning messages and the durability of these messages over very long time frames. In the CCA,

the DOE provides details regarding the implementation of the permanent markers program. An important objective of the program is to optimize the design of the marker systems by evaluating alternative configurations and materials and aiding in the development of final designs. A related activity identified in the CCA is the survey of monuments within 150 miles of the WIPP site to obtain any information useful in the selection of marker materials and the development of marker designs. This report documents the results of a survey performed in the summer of 2000. The objective of this survey was to collect and compile information relevant to the assessment of the durability of ancient inscriptions made on various rock types. Conclusions are provided related to the durability of various rock types, the effects of aspect, the rates of erosion of inscriptions, the effects of inscription form, and the importance of contrast in color and texture in regard to inscription legibility. Recommendations based on study observations and related to the longevity of inscriptions on various rock types are provided. These include:

Rock Types – Rocks of hardness and durability suitable for use as WIPP permanent markers are available within a few hundred miles of the WIPP site. Basalt and sandstone are the most abundant, so one or both of these should be selected for further evaluation. Intrusive igneous rocks that are susceptible to exfoliation should not be used.

Form of Inscriptions – To the extent consistent with the necessary written and symbolic warnings and messages, inscriptions should be as large as possible, with groove widths several times the largest mineral particle size. Unless the rock is very fine-grained, like basalt, it probably will not be practical to inscribe letters smaller than about 25mm minimum plan dimension or less than 5mm deep.

Additional Studies – Given the consistent findings over the 16 sites included in this survey, it is anticipated that additional monument (petroglyph) surveys would not be useful. However, studies on material properties of rock and man-made materials would be useful, with emphasis on surface hardness, methods to create and preserve color contrast, and the effects of rock texture on inscribability and inscription durability.

3. Contractor Report, Permanent Markers Materials Analysis, Waste Isolation Pilot Plant (John Hart and Associates P.A., 2000b) – This report documents assessments of marker materials included in the reference design as well as potential alternative materials. The permanent markers will be constructed of materials that will be selected through an evaluation process. Candidate materials identified in the CCA reference designs will be evaluated against performance criteria. The evaluations are being performed using methods identified in the Permanent Markers Testing Program Plan. Information obtained from literature reviews is provided in this report and has been used to refine the evolving candidate materials lists. The literature review also provides information supporting preliminary evaluations of the candidate materials. This information is also of value in planning laboratory and field tests that will provide additional information necessary to make final marker material selections.

4. Contractor Report, Ancient Cementitious Materials (John Hart and Associates, P.A. 2000c) – The current reference design for WIPP permanent markers calls for granite as the primary construction material for the large surface markers, small surface markers, buried storage rooms, and the information center. Although the reference design specifies granite, the DOE has committed to evaluate alternative materials in an effort to optimize final designs. One potential alternative material is concrete. Accordingly, a literature review was performed to investigate instances in which man-made cementitious materials have survived for very long time periods. The intent of this effort was to determine and document, when possible, the attributes of cementitious materials that contribute to their survival for long periods.

   This literature review showed that cementitious materials used nearly 9,000 years ago have survived intact to the present day. Concretes that have survived over such long periods have been some form of pozzolanic concrete. Results suggest that the blending of ancient and modern concrete technologies may provide a durable, long-lasting concrete meeting the DOE goal to mark the WIPP site for a very long time.

7.3.3.1 Definition of Passive Institutional Design Appropriate for the WIPP

In deciding which passive institutional controls are appropriate for the WIPP, the DOE was guided by the regulatory language in 40 CFR § 191.14(c) that states that the controls should be practicable. The DOE is expected to address the components of the passive institutional controls listed in the definition of 40 CFR § 191.12(e). The components of the passive institutional controls for the WIPP consist of (1) monuments that define the boundary of the withdrawal area, (2) markers at the footprint of the repository that consist of monuments that identify the outer boundary of the subsurface facility, a berm surrounding the repository footprint, an information center on the surface at the center of the repository footprint, a buried room halfway between the information center and the berm, a buried room halfway between the berm and the hot cell, and randomly spaced buried markers distributed across the repository footprint, (3) sets of records distributed to national and international archives, (4) sets of records distributed to records centers locally, nationally, and internationally (both those of a general nature and those specializing in land and resource use), (5) government control and land-use restrictions, and (6) other means of communication, such as encyclopedias, dictionaries, textbooks, and various maps and road atlases. CCA Appendix PIC contains a detailed description of the designs of each of these components.

Trauth et al. (1993) examined a variety of configurations and materials in concluding that a system comprised of natural materials incorporating massive structures with messages provided in an enduring configuration offered the best system for permanently marking the site. The permanent marker system incorporates these concepts and thus is the best system of passive institutional controls for permanently marking the repository. The use of archives and national publications as described in CCA Appendix PIC is the most extensive means of widespread distribution of the WIPP information. Use of radio or television is transient and will not provide the long-term societal memory.

7.3.3.1.1 Markers

Two groups of experts, the Futures Panel and the Markers Panel, were established to examine the issues involved with designing an effective system of permanent markers. Hora et al. (1991) incorporates judgments of the Futures Panel and discusses the underlying physical and societal factors that would influence society and the likely modes of human intrusion at the WIPP site.

The Hora et al. report was an important reference and source of information for the preparation of Trauth et al. (1993). Trauth et al. (1993) reports the results of the Markers Panel, which considered various concepts of marking the site and conveying to future generations information regarding the presence of dangerous waste material and the potential consequence of intrusion into the waste repository. CCA Appendix PIC (Section I) is a modification of the ideas developed by this panel.

CCA Appendix PIC sets forth the permanent markers system for the WIPP facility. This system involves the use of surface monuments, small subsurface warning markers, buried rooms, and large earthen structures marking the WIPP repository footprint on the surface. CCA Appendix EPIC (Section EPIC.6) indicates the period of time during which passive institutional controls will be effective.

The surface monuments are large monuments erected on the surface at both the repository footprint and the controlled area boundaries. To facilitate fabrication and shipping of the monuments, each monument will consist of two separate stones connected by a tendon joint. The large monuments will be engraved with Level II and III messages and Level IV pictographs, as described in CCA Appendix PIC (Section IV).[3] Figures 7-10 and 7-11 provide the

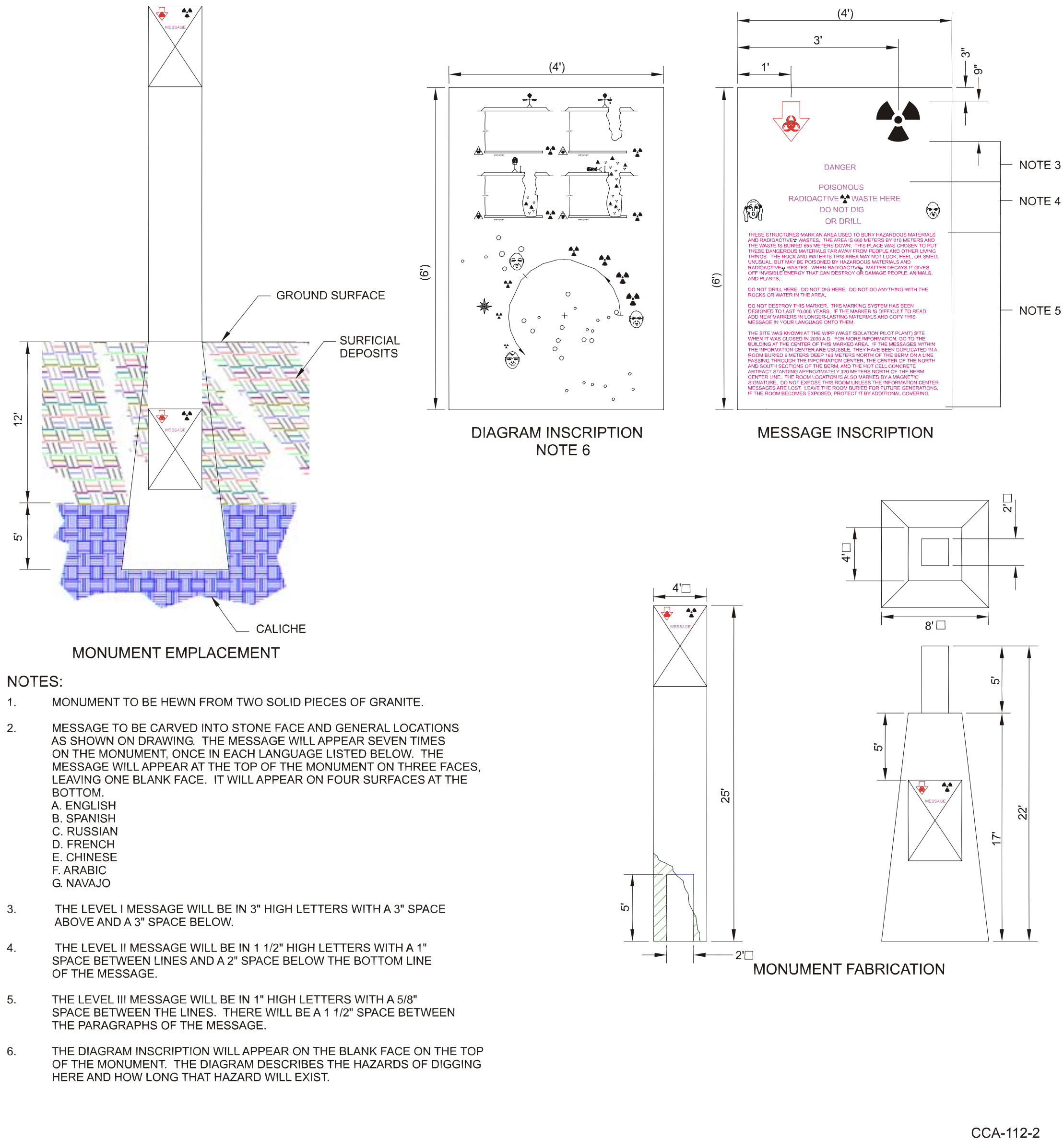


Figure 7-10. Repository Footprint Perimeter Monument Configuration

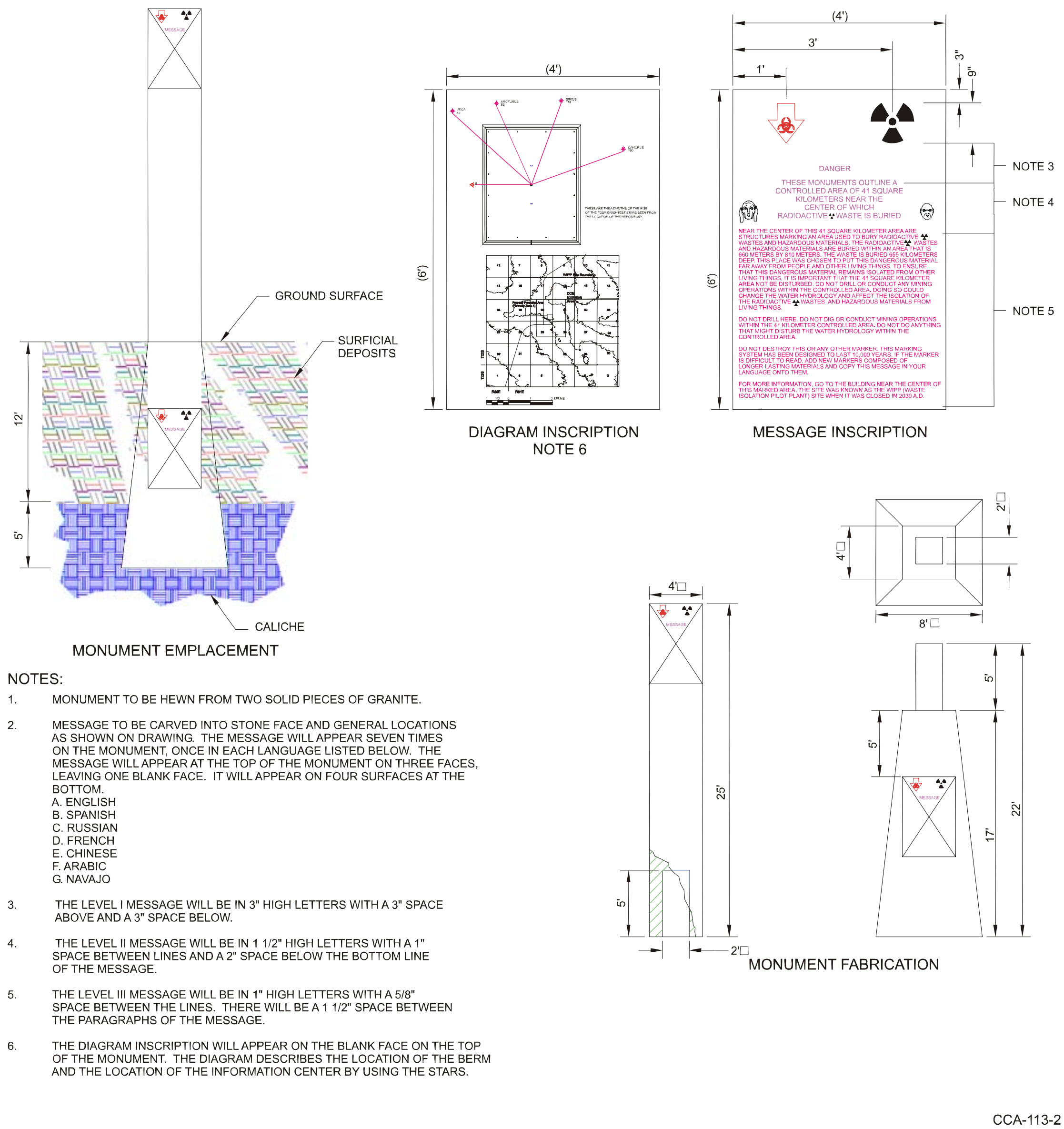


Figure 7-11. Controlled Area Perimeter Monument Configuration

dimensional characteristics of the large monuments. The monuments intended for marking the controlled area boundaries will differ from the monuments marking the repository footprint. Each footprint monument will be inscribed with the Level II and III messages in seven languages, the six official United Nations languages (English, French, Spanish, Chinese, Russian, and Arabic), and Navajo. The controlled area boundary monuments will be inscribed with warning messages. Trauth et al. (1993, Appendix F) discusses in some detail the selection of these languages by the Markers Panel.

The monuments will be quarried from granite and shipped by rail to the WIPP site. Each monument base will be soundly founded by excavating into the near-surface caliche. After emplacing the base monument, the excavation will be backfilled and the upper monument will be placed over the base tendon.

The small warning marker is shown in Figure 7-12. The Level II messages placed on the small subsurface warning markers will be in the seven languages previously listed. However, each marker will have the message in only one of the seven languages. Warning markers will be placed throughout the repository footprint and within the berm. The warning markers will be made of a diversity of durable materials, such as granite, aluminum oxide, and fired clay, thus improving the likelihood that at least some of the markers will endure for thousands of years.

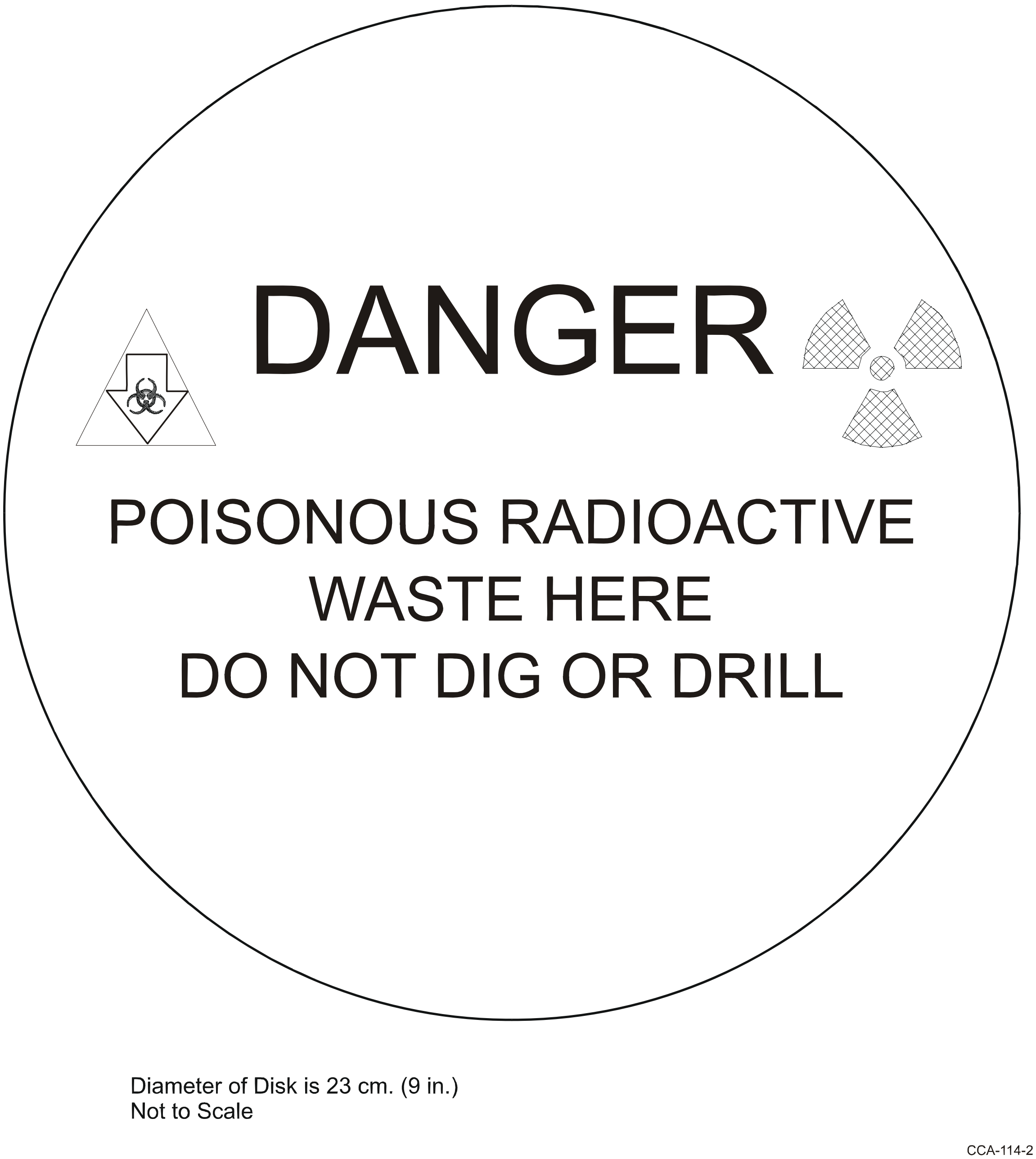


Figure 7-12. Small Buried Warning Marker

The small buried warning markers will be randomly spaced in locations and at depths to provide a reasonable expectation of discovery by any organized exploration effort, but to discourage organized efforts at collecting the markers. The current petroleum industry practice in the Delaware Basin is to remove surface soil down to the caliche layer over an area sufficiently large to set up a drilling rig and dig a mud pit. Nominally, this area is 50,000 ft^2 (4,648 m^2). By placing the small warning markers above the caliche at intervals of a few feet, several of the warning markers should be unearthed during any soil clearing operation.

The inclusion of a berm in Figure 7-13 in the permanent marker design is based upon the following criteria (see CCA Appendix PIC, Section VII, for more detail).

- The surface footprint of the repository should be essentially outlined by some enduring structure.
- The structure should be sufficiently massive to provide reasonable expectation that it will endure for thousands of years.
- The structure's profile should minimize the likelihood that it can become buried by shifting sands or that characteristics of the profile may lead to fabrication stresses affecting the ability of the structure to retain its configuration.
- The structure should be constructable without the need for sophisticated equipment or processes.

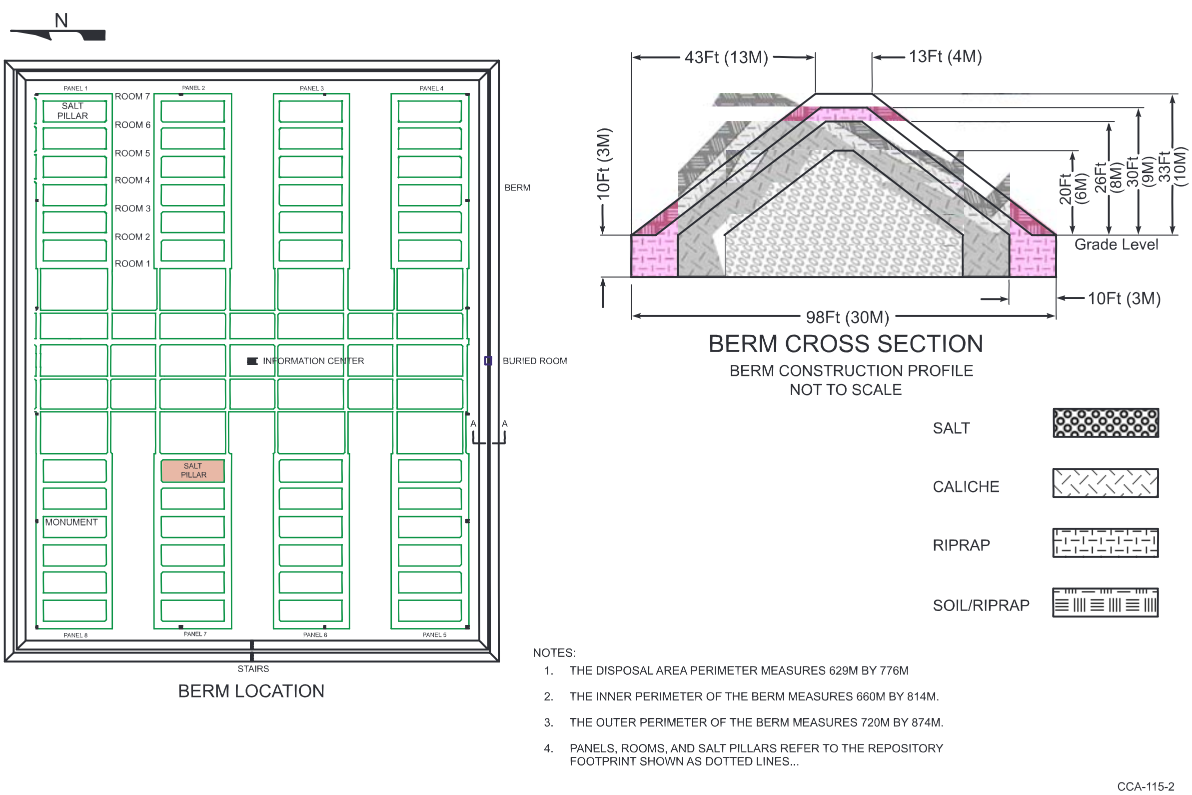


Figure 7-13. Berm Construction

- The construction materials should be reasonably available to the WIPP site and have little intrinsic value.
- The cost should not be disproportionately high for the advantages that the alternative provides.
- To the extent practicable, the nature of the structure should lend itself to testing over a period of two to five decades.

The berm is proposed to encompass the repository footprint. Figure 7-13 also depicts the reference design berm cross section.

As reported in John Hart and Associates, P.A. (2000b), the permanent markers will be constructed of materials selected through an evaluation process. Candidate materials identified in the CCA reference designs will be evaluated against performance criteria. The evaluations will be performed using methods identified in the Permanent Markers Testing Program Plan (DOE 2000).

A variety of earth materials that occur on or close to the WIPP site are available for use in the construction of the berm including native soils and caliche. Salt, excavated from the WIPP underground and stockpiled on site, may not be a good material for use in the berm. Its solubility and low strength make it an unreliable material to form the core of the berm, and use at shallower locations in the berm, while structurally of less consequence, nevertheless may not be feasible because of the closer proximity to infiltrating groundwater and the resulting increased risk of dissolution.

The berm design shown in Figure 7-13, including materials of construction, will be refined through the ongoing design-development process and finalized prior to its construction. Final design specifications will be provided to the EPA for approval prior to construction.

To provide a distinctive magnetic signature for the berm, large permanent magnets or other magnetically distinct materials buried at intervals in the berm will be used. These materials are intended to produce a detectable signature with current airborne detection equipment. The magnetic signal's geometric form will provide strong indication that it could only have been humanly engineered. This magnetic signature should motivate any organization capable of magnetic surveying to further investigate this anomaly prior to initiating drilling activities.

Similarly, to provide a distinctive radar-reflective signature unique from the surrounding terrain, DOE will consider the use of radar-reflective trihedrals for placement within the top layer of the berm.

Another aspect of the marker system includes on-site buried storage rooms containing the Level IV message and associated diagrams. These rooms will be designed to endure for a similar time period as the permanent marker system and will be buried (see CCA Appendix PIC). The design characteristics contributing to this longevity will be the material and environmental conditions associated with construction and location. The rooms will be made of granite with a minimum number of joints. Individual walls, the floors, and the roofs will comprise single granite slabs joined only at the edges. The configuration minimizes the risk of failure caused by chemical interactions between the construction material and the environment. The message texts contained within the buried storage rooms will be engraved on the walls. To provide redundancy, additional granite slabs engraved with the message text and the diagrams will be held in place against the interior walls. Although some damage could be inflicted by vandals, the granite composition of the message-carrying materials will provide the greatest opportunity for preventing complete destruction of the information contained within the buried rooms.

In addition to the buried storage rooms, an information center, as described in CCA Appendix PIC (Section VII), will be located on the surface, providing access to the same information that is contained in the buried rooms. Details regarding the location of one of the buried storage rooms and identical information will be contained in the information center.

7.3.3.1.2 Records

A significant part of the overall system will be the archiving of important information at sites remote to the repository. The archived material will include information that defines the location, design, content, and hazards associated with the WIPP. The amount of information will be more extensive than that available within the permanent marker system at the repository location. Information will be preserved using practicable materials and techniques at record centers and archives throughout the world. CCA Appendix EPIC (Section EPIC.6) provides justification for a period of time that materials placed in archives and records centers are expected to endure and be understood.

Although DOE has not yet established the specific archival files, examples of the types of documents that will be archived include the following. The specific requirements of 40 CFR § 194.43 (a)(2) are listed and responsive documents are indicated in parentheses.

- (i) The location of the controlled area and the disposal system (detailed maps describing the exact location of the repository, Safety Analysis Report, the Final Environmental Impact Statement (FEIS) for WIPP and the supplement(s) to the FEIS, the RCRA Permit, the last compliance recertification application (CRA))

- (ii) The design of the disposal system (Safety Analysis Report, the FEIS for WIPP and the supplement(s) to the FEIS, the RCRA Permit, the last CRA, drawings defining the construction and configuration of the repository and shafts, design information for the passive institutional controls)

- (iii) The nature and hazard of the waste (Safety Analysis Report, the FEIS for WIPP and the supplement(s) to the FEIS, the RCRA Permit, the last CRA, records of the waste container contents and disposal locations within the WIPP repository)

- (iv) Geologic, geochemical, hydrologic, and other site data pertinent to the containment of waste in the disposal system, or the location of such information (Safety Analysis Report, the FEIS for WIPP and the supplement(s) to the FEIS, the RCRA Permit, the last CRA, environmental and ecological background data collected during the preoperational phase of WIPP and summaries of data collected during the disposal and decommissioning phases of WIPP)

- (v) The results of tests, experiments, and other analyses relating to backfill of excavated areas, shaft sealing, waste interaction with the disposal system, and other tests, experiments, or analyses pertinent to the containment of waste in the disposal system, or the location of such information. (Safety Analysis Report, the FEIS for WIPP and the supplement(s) to the FEIS, the RCRA Permit, the last CRA, drawings, procedures, and design reports describing how the waste was emplaced, and how the repository was decommissioned, closed and sealed)

The National Archives will be one organization responsible for the permanent storage of this information. As discussed in CCA Appendix PIC, the information will also be distributed to appropriate organizations such as the following for long-term safekeeping:

- federal and state government agencies,
- federal, state, tribal, and local archives and libraries,
- local and state and record repositories (for example, the Eddy County Clerk New Mexico)
- national archives and libraries of nations that possess nuclear weapons and nuclear energy or produce natural gas and oil resources, and
- professional and technical societies.

The archival and record centers identified in CCA Appendix PIC as planned recipients of information were selected based upon one or more of the following criteria:

- representing an international location in a nation which had citizens engaged in the oil and gas exploration and exploitation industry,
- representing an international location in a nation which had the potential to generate radioactive waste,
- representing a local governmental organization frequented by individuals engaged in the oil and gas exploration and exploitation industry,
- representing a National Archival location,
- representing a Regional Library, or
- is a public funded location.

The DOE intends to submit WIPP records to over 100 archives nationally and internationally as identified in CCA Appendix PIC. The final number of archive recipients will depend upon the agreements reached between DOE and the facilities. The initial submittal of these records will occur after closure and decommissioning of the WIPP. Since this time frame is decades into the future and thus significant changes will occur to some or all of the archives as well as some of the governments, the DOE has not attempted to identify the practices employed by each archive and repository for maintaining records and making them accessible to the public. However, the National Archive-Rocky Mountain Region practices are described and are representative of the National Archives and its regional facilities. The state of New Mexico Archive and the Canadian National Archive were also contacted and their practices are similar to those employed by the U.S. National Archives. There are also international standards for the organization and operation of archives that enable the world's archives to function similarly in many aspects of the practices governing maintenance of records and access to the records by members of the public.

To ensure the proper storage and retrievability of archived material, the DOE archivist will develop a filing code system specifically for the WIPP material. This system will be a part of the overall document submittal the DOE will provide to the various archival locations. In the development of the filing code system and communications with worldwide archives, it is expected that differing cultural issues will be addressed in order that the DOE gain acceptance of the information from as many archives as possible.

To reduce the possibility that future archivists may destroy the provided documents, each volume containing documents will be labeled with a warning that the intent of providing the archived material is to ensure its preservation for the 10,000-year regulatory time frame stipulated in the U.S. Government's regulations controlling the disposal of transuranic waste. It is recognized that the federal government may incur some long-term financial obligations to the archival locations to ensure retention. Within two years following the distribution of archival material and at least every 15 years thereafter during the active institutional controls period, the DOE will conduct audits of selected archival locations to verify retention and retrievability of the historical documents.

As an example of how an archive will handle archived information, the National Archive will use the indexing system provided by the DOE in organizing the WIPP material submitted for archiving and public use. Upon receipt of the material in boxes, the archive staff will examine the documents; remove staples, paper clips, rubber bands, and other miscellaneous materials that may damage or are otherwise incompatible with the records over an extended period of time; enclose any damaged material in individual protective covers; place the records in acid-free boxes; and store those boxes in an environmentally controlled vault. The individual boxes are labeled with coded alpha-numeric designations that tie the contents back to the agency submitting the documents, the year in which the documents were received, and the general content of the documents. Finding aids, content indices, or significant word lists are developed to aid researchers in identifying the material desired. The coded number will also provide information relative to whether or not the documents may be destroyed after a given amount of time. Many government documents are scheduled to be destroyed after 30 years. Other documents are preserved indefinitely.

Title 36 CFR Part 1254, Availability of Records and Donated Historical Materials, regulates the manner in which archival material within the National Archive system is made available to members of the public. In general, researchers must register each day that they enter a research facility and may be required to provide identification. The researcher must sign for the documents received and again may be required to show identification. The researcher is not permitted to leave the room without notifying the room attendant and placing all documents in their proper containers. Documents must be returned to the research room attendant prior to the room closing. Documents may not be used where there is food, drink, or the presence of ink. Only pencils may be used in the room containing original documents. If the researcher requires copies of documents, the appropriate document must be marked with a paper tab provided by the archive. No paper clips or rubber bands may be used on the documents. The room attendant will provide the copying services for the researcher. Documents must be maintained in order by the researcher; however if the documents become disordered, the room attendant must perform the re-ordering function and not the researcher. Upon exiting a research room, the researcher must present for examination any article that could contain documents.

In addition to the national and state archives, Indian tribes and pueblos (for example, Navajo, Mescalero Apache, and Zuni) were contacted to determine the extent of any archival activity. Only the Zuni were establishing a limited internal archive. Other groups forward archive worthy materials to federal storage facilities. The DOE will continue to work with key nations, tribes, and pueblos to establish pertinent agreements and to ensure that appropriate WIPP records are distributed for archiving and reference purposes.

Finally, the International Atomic Energy Agency (IAEA), with the DOE as a current participatory through the agency of its Scientific Advisor, is developing a procedure for the archiving of records pertinent to the disposal of radioactive waste in deep geological repositories. The procedure, published in July 1999, is titled Maintenance of Records for Radioactive Waste Disposal (IAEA 1999). The DOE embraces this effort.

7.3.3.2 Implementation of Programs to Collect Information

Prior to implementing the passive institutional controls, a testing program will determine whether the specific messages proposed can be expected to convey the intended warnings and information across cultures and whether the proposed media for transmitting the messages will endure to the degree anticipated in the development of the conceptual model. The testing to be conducted will address the refinement of the messages, diagrams, and the method of presentation. As recommended in Trauth et al. (1993), the translated versions of the message text should be evaluated by presentations to groups indigenous to the countries whose language is represented in the message. This process should provide input into how comprehensible the messages are and provide information regarding any idiom changes that may be necessary in the translated versions. When considering that the messages were developed by educated individuals residing in the U.S., it is prudent that the effectiveness of the messages to convey their intended content to a broader cross-section of individuals be thoroughly tested. The testing therefore should include cross-cultural groups in evaluating the effectiveness of conveying the intended messages through diagrams and pictures as well as script. The DOE will continue to develop and review the details of a testing program to ensure that a comprehensive effort is made to test the final written and pictograph message comprehensibility. For those components that include either large volumes of various materials (for example, the berm) or the movement of heavy objects (for example, the sections of granite in the monuments), procedures will be tested for transporting the material and constructing the specified designs. The testing programs are described in CCA Appendix PIC. See CCA Appendix EPIC for a discussion of the durability of materials to be used to construct passive institutional controls.

7.3.3.3 Passive Institutional Controls Timelines

The DOE has prepared a tentative schedule of the implementation of the passive controls program. The schedule is shown in Figure 7-14. The following is provided as a brief expansion of the timelines provided in Figure 7-14.

- 1996 – 2083 Design and Test Permanent Marker Concepts and Materials. During this period the testing and monitoring described in CCA Appendix PIC related to the permanent marker components, materials, and communication concepts are conducted.
  - 2004-2009 Construct Test Markers. During this period, the DOE will install prototype markers for testing. The types of prototype markers and their materials of construction will be based on results of screening tests.

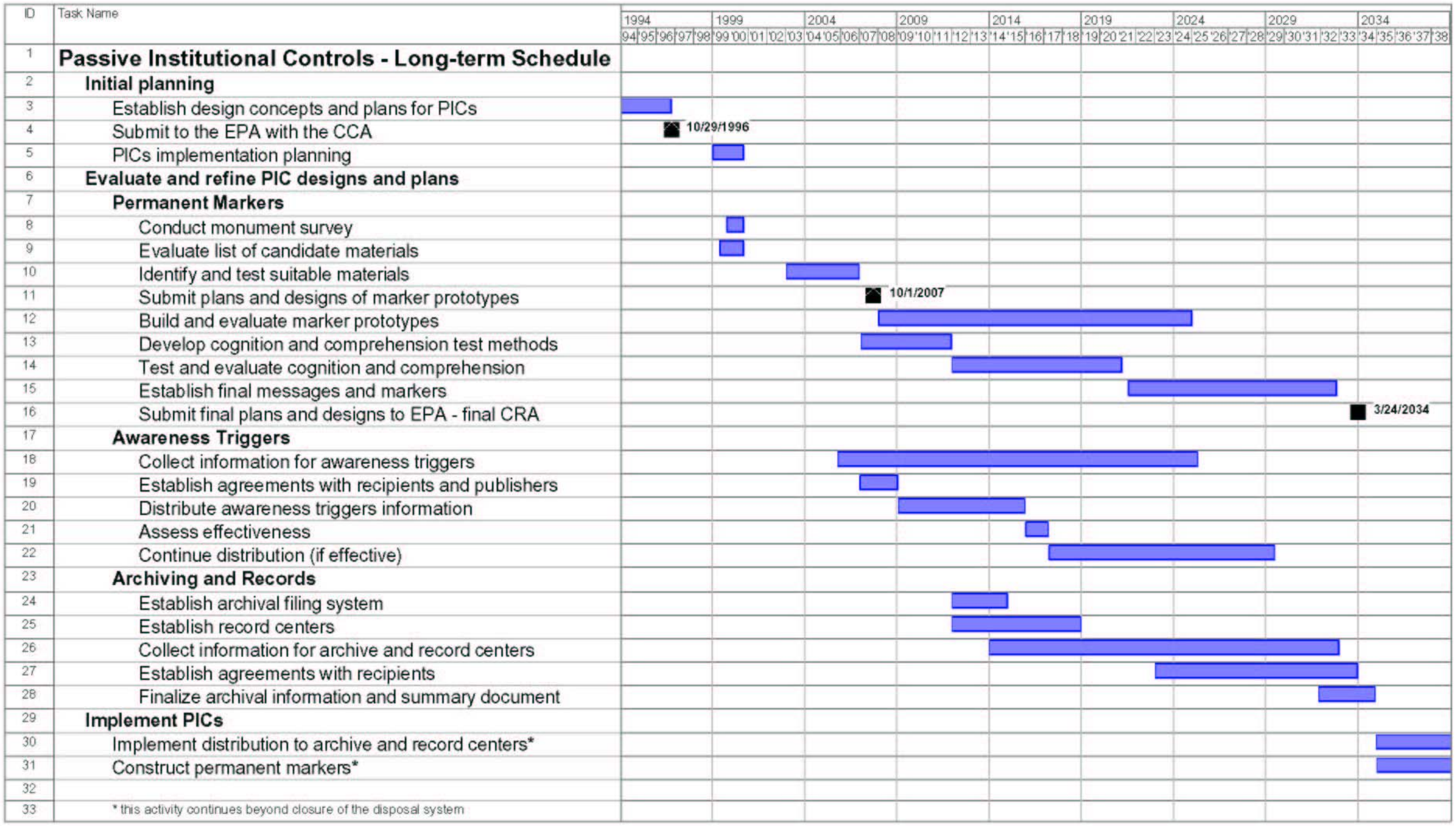


Figure 7-14. Passive Institutional Controls - Long Term Schedule 2007-2083

Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2004

- Monitor Performance of Prototype Markers. During this period, the DOE will monitor the performance of the test structures to develop information for use in the final design.

- 2018 – 2023 Test Message Comprehension. The DOE will gain operational experience for any information that may affect the composition of the intended messages, both narrative and pictogram, and then conduct testing for comprehension by populations indigenous to the countries represented by the languages used in the messages.

- 2083 – 2090 Final Design. During this period, the DOE will complete the final design of the permanent marker system.

- 2090 – 2093 Construct Permanent Marker System. During the period, the permanent marker system will be constructed including installation of messages.

- 1999 – 2093 Implement Information Collection and Establish Archival and Record Center Agreements. During this period the actions required to implement record keeping and record storage aspects of PICs are conducted. Individual actions and associated timelines are:

• 2004 Establish Filing System. The DOE will establish the filing system under which the record center and archival information will be assembled. Completion of the system by 2004 will support the information collection program.

- 2003 – 2033 Collect Operational Information. Collect the information relative to WIPP operation, including decommissioning, which will be included in the promulgated documentation.

- 2033 – 2090 Collect Active Control Period Information and Marker Configuration. Collect the information relative to WIPP active controls and the results of testing of the permanent marker system components and communication concepts.

- 2023 – 2034 Establish Agreements with Recipients. During this period the DOE will communicate with the planned document recipients to develop general agreements with respect to language translation, scope of translated material, format in which the material will be provided, and any financial support required to achieve acceptance by each recipient. Beginning about 2023 when most of the documentation should have been developed, this effort should start. The DOE expects two to three years to establish the agreements and another five to eight years for translation, with completion about the time that decommissioning and decontamination are finished. This provides for the incorporation of information related to decommissioning and decontamination.

- 2033 – 2034 Develop Summary Document. The DOE will develop the WIPP summary document to be provided for ease of public access and understanding of the WIPP.

- 2035 Promulgate Information Accumulated Through WIPP Closure and Decommissioning. The DOE will make a distribution of documents accumulated through the final closure, decontamination, and decommissioning of the WIPP.

- 2023 – 2033 Establish Agreements and Submit Information to Publishers. During this period, the DOE will establish agreements with map makers and text publishers including financial support and provide hazard, history, and location information to be included on maps and various text materials.

- 2083 – 2093 Finalize Archival Information. During this period, the DOE will develop the final additions to the planned submittal, which include information describing the WIPP history during the first 50 to 60 years following closure and the final configuration of the permanent marker system.

- 2093 Promulgate Archival & Records Center Information. The DOE will make the distribution of the final portion of the archived information nationally and internationally.

In a letter dated May 16, 2002 from Dr. Ines Triay to Mr. Frank Marcinowski, the DOE proposed to the EPA changes regarding the submittal of detailed plans and drawings depicting the permanent marker prototypes. The request includes a proposed revised schedule, as detailed in Table 7-9.

The EPA responded to the DOE request in a letter dated November 7, 2002, from Mr. Marcinowski to Dr. Triay (EPA Docket A-98-49, Category IIB-3, Item 41). The EPA response states that the schedule changes proposed by the DOE are insignificant with respect to the Certification Decision (63 FR 27396, May 18, 1998). The EPA also concluded that the DOE plans for testing provide significant details to support the need for additional testing time. As such, the EPA determined that the DOE may proceed with the proposed changes. In addition, the EPA provided the following comments related to the implementation of the passive institutional controls program. These comments serve as guidance to the DOE.

1. The Permanent Markers Testing Program Plan is a welcome development. The EPA appreciates the thoroughness of DOE's approach to this topic, especially the inclusion of references to the Quality Assurance Program Document. The use of reference standards and established quality processes, as well as a methodical approach to testing, will be important factors in demonstrating to the EPA that any future changes to the conceptual design have an adequate technical basis.

2. The DOE is obligated to execute site markers as described in the CCA and subsequent DOE correspondence (February 7, 1997, letter from G. Dials to R. Trovato; Air Docket A-93-02, Item II-I-07). If the DOE determines that the original marker design (including location, number, materials, and configuration) should be altered or

Table 7-9. Activities Related to the Implementation of the Permanent Markers Program

Activity	Reference Event	Original Timeframe	Current Status	Proposed Timeframe
Stone Monument Survey	First five years of operations	1999-2004	Completed	N/A
Identification of suitable source material	First five years of operations	1999-2004	Pending decisions on changes to design and material selection	2007
Submit plans for the test marker system	1st CRA submittal	2003	Proposed change to submit prior to second CRA	2007
Construct and test berm and test markers	Second five years of operations	2004-2009	Pending proposed change and testing program	2008
Monitor performance of test berm and test markers	After construction	2007-2083	Pending proposed change and testing program	2009 - until closure
Testing comprehension of marker messages submittal of testing plans to EPA	Fourth CRA submittal	2018	No change	N/A
Develop final design of markers	Upon termination of testing program	2083-2090	Final design to be submitted with the final CRA	2033 (anticipated)
Finalized Translated Messages	Prior to building of final permanent markers	N/A	Finalized messages will be submitted with the final CRA	2033 (anticipated)

improved, the Department must notify the EPA and receive the Agency's approval before proceeding.

Certain changes (such as different component materials or dimensions) may be possible without modifying the certification, as long as the design itself remains essentially the same. However, the introductory section of the proposal (page 2) states, "DOE plans to re-examine whether…all of the components of the permanent marker system proposed in the CCA are needed." Elimination of one or more components may require modification.

3. Condition 4 of the Certification Decision requires the DOE to show that PICs will be implemented "as soon as possible following closure of the WIPP." DOE's change notice states that all measures in their final form will be presented in the last recertification application before site closure (approximately 2033). Throughout the operational phase of the WIPP, the DOE should present information in each recertification application showing progress with regard to testing and implementation of all PICs (markers, archived records, etc.).

4. Based on conclusions reached by John Hart and Associates, the DOE suggests that "portions of the permanent marker system originally conceptualized…are impractical" (page 1 of the introductory section). Concerns about the specific design of the surface granite monoliths led us to require further information about the monoliths in Section(a)(2) of Condition 4 of the WIPP Certification. Nevertheless, the EPA explicitly concluded in the Certification Decision that the proposed marker system – including the salt-core based berm – was practicable. To justify a departure from the markers that were proposed, the DOE would be expected to provide an adequate technical basis showing that an alternative is likely to be more durable and effective as a marker. EPA believes that further testing and analysis of materials (e.g., basalt), processes (e.g., granite exfoliation), and configurations (e.g., salt core of the berm) should be done before DOE concludes that certain features of the marker system are impractical.

7.3.4 Effectiveness of Passive Controls in Reducing the Rate of Human Intrusion

The EPA raises the issue of the expected ability of the passive institutional controls to convey information to future societies in two areas. In the context of the assurance requirement in which no assumptions can be made to limit the uncertainty of the future states of societies, the EPA states

> Any compliance application shall include the period of time passive institutional controls are expected to endure and be understood. (40 CFR § 194.43[b])

In the context of credit for passive institutional controls in deterring inadvertent human intrusion for use in performance assessments, the EPA goes on to state that

> The Administrator may allow the Department to assume passive institutional controls credit, in the form of reduced likelihood of human intrusion, if the Department demonstrates in the compliance application that such credit is justified because the passive institutional controls are expected to endure and be understood by potential intruders for the time period approved by the Administrator. Such credit, or a smaller credit as determined by the Administrator, cannot be used for more than several hundred years and may decrease over time. In no case, however, shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely (40 CFR § 194.43[c]).

To limit the speculation about the state of future society, the EPA has provided additional guidance by stating that "EPA expects that the DOE will establish a framework of assumptions for passive institutional controls that is a prudent extrapolation of the future state assumptions established in 194.25" (EPA 1996b, p. 61) and by providing for the existence of certain societal "common denominators" based on "patterns of human behavior that may be detected throughout history and around the world" (EPA 1996b, p. 61).

Section 7.3.4.1 addresses the issue of how long the passive institutional controls are expected to endure and be understood in the context of the Assurance Requirement (40 CFR § 194.43[b]) and Section 7.3.4.2 addresses the issues of how long these controls are expected to endure and be understood and the resulting credit in deterring inadvertent human intrusion in performance assessment calculations (40 CFR § 194.43[c]).

7.3.4.1 Expected Effectiveness

The passive institutional controls in the Conceptual Design Report (DOE 1994) were developed from the recommendations of the Markers Panel convened in 1991, modifying them for reasons such as constructability or resource requirements. The Markers Panel developed fundamental principles of long-term communication making only the most minimal assumptions about what future societies would be like (for example, they will be human beings similar to what we are today). No assumptions were made about what languages they might be speaking or how technologically sophisticated they might be. Because no assumptions were made about language or technology, the Markers Panel developed strategies that attempt strategies to communicate with individuals in a variety of means and in a systems approach whereby the various components reinforce and supplement the other messages.

Without assumptions about technological sophistication, messages will be provided in various levels of complexity, ranging from the most basic marker of human construction rather than a natural phenomenon, to the entire written record of information about the repository and its certification. Because it is not known what languages will be spoken in the future, the markers will include non-linguistic means of communication, such as pictures of humans, star charts, and the periodic table of the elements. In this way, the design of the markers responds to the EPA's requirement for the "most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location" (40 CFR § 191.14[c]). While the Markers Panel focused its efforts on the repository footprint, based on the 40 CFR 191 definition of human intrusion, the entire withdrawal area will be identified by on-site passive institutional controls to satisfy criteria in 40 CFR § 194.43. Because of the requirement for records and archives, plans have been made to place materials within the existing governmental and scientific systems of recordkeeping.

In addressing the issue of credit for passive institutional controls in performance assessment calculations, the DOE examined historical analogues for the controls components (see CCA Appendix EPIC, Chapter 5). Certain design characteristics of these historical analogues have survived destruction from both societal turmoil and natural processes. By designing the PICs to mimic and enhance these design characteristics, the DOE believes that the passive institutional controls for the WIPP will be capable of surviving at least as long as the historical analogues. Based on the characteristics of the markers, these components have the capability of lasting in excess of several thousand years. This conclusion is consistent with the conclusions of both teams of the Markers Panel whose estimates were based on basically the same design characteristics for the markers and on a wide variety of future states of society. The multiple copies of the records in the records centers and archives, the selection of highly durable materials (that is, archival paper and carbon-black ink), and the fact that the records will have value in the economic and health areas suggest that at least some copies of the records have a high probability of surviving for many hundreds to thousands of years.

The Markers Panel concluded that the messages proposed have a high probability (greater than 0.70) of being understood by all potential levels of technology for at least 2,000 years (Team A estimated at least 5,000 years). Although the Markers Panel considered only the messages on the markers, the same information, both text and pictographs, will be included in the records in records centers and archives. As a result, the DOE concludes that these records will be interpretable for as long as the documents survive.

7.3.4.2 Credit Taken in Performance Assessment Calculations

In addition to their use for compliance with the assurance requirements, credit for passive institutional controls may be used in PA calculations. In 40 CFR § 194.43(c), EPA allows credit in the form of reduced likelihood of human intrusion. The Preamble to 40 CFR 194 limits any credit for passive institutional controls in deterring inadvertent human intrusion to 700 years after disposal**.** During the certification process, the DOE sought passive institutional controls credit in the CCA based on the conclusions of a designated task force. CCA Appendix EPIC documents the basis for this credit. For the performance assessment calculations in the CCA, the passive institutional controls were considered to be 0.99 effective in deterring inadvertent human intrusion over the entire withdrawal area for 700 years.

However, the EPA performance assessment verification test (PAVT) calculations did not include credit for passive institutional controls (63 FR 27396). In the certification decision (EPA 1998), the EPA concluded its discussion on this matter as follows:

> However, EPA's final decision today applies only to the credit proposal in the CCA and should not be interpreted as a judgement on the use of PICs credit in PAs generally. In the future, DOE may present to EPA additional information derived from an expert elicitation of PICs credit. Any future PICs credit proposals will be considered in the context of a modification rulemaking, and will be subject to public examination (63 FR 27396).

In this recertification application, the DOE claims no credit for the effectiveness of passive institutional controls. As indicated by the EPA, the DOE may claim such credit in future recertification applications.

7.4 Multiple Barriers

The WIPP facility has incorporated multiple natural and engineered barriers, including plugs, seals, and backfill into its design. As a part of the DOE's program to evaluate multiple barriers, an Engineered Alternatives Task Force (EATF) evaluated optional additional engineering measures for the WIPP facility. The findings of the task force are summarized in the *Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives* (DOE 1991). A more recent study, the Engineered Alternatives Cost/Benefit Study, updated the 1991 EATF activity and augmented it with more in-depth and comprehensive analyses of the relative benefits and detriments of the alternatives. Benefits and detriments at the waste generation and storage sites were evaluated in this study as well as those at the WIPP. (This study is included in CCA Appendix EBS.)

Beyond the requirements contained in 40 CFR § 191.14(d) relating to multiple barriers, 40 CFR § 194.44 has imposed certification criteria upon the DOE with regard to engineered barriers. The following sections provide a discussion of the manner in which the DOE has complied with the multiple barrier requirement of 40 CFR § 191.14(d) and an overview of the manner in which the engineered barrier criteria of 40 CFR § 194.44 have been met. A detailed discussion of the cost and benefit analysis dictated in 40 CFR § 194.44 is provided in CCA Appendix EBS.

7.4.1 Requirements for Multiple Barriers

By requiring the use of both natural and engineered barrier types as the assurance requirement, the EPA intends to ensure that the impacts of the failure of any single barrier type will be minimized.

In the LWA, Congress mandated that the Secretary will use both natural and engineered barriers. Waste form modifications may be used at the WIPP to isolate waste after disposal to the extent necessary to comply with the final disposal regulations. Therefore, the disposal system design involving the Salado as a natural barrier and the shaft seals as engineered barriers complies with this assurance requirement as indicated by the compliant complementary cumulative distribution functions (CCDFs) shown in Section 6.5.

7.4.2 Objectives for Multiple Barriers

The primary objective for the implementation and the use of multiple barriers at the WIPP facility is to help guard against unexpectedly poor performance from one type of barrier. This is accomplished by a design that includes multiple types of barriers.

7.4.3 Implementation of Multiple Barriers

The baseline design for the WIPP facility includes the concept of multiple barriers for isolation and containment of waste. Barriers that are part of the design include natural barriers (for example, hydrological, geological, and geochemical conditions) and engineered barriers (for example, borehole plugs, shaft seals, panel closures, and backfill). The effectiveness of these barriers is modeled in the performance assessment to demonstrate the ability of the disposal system to meet EPA standards.

Although the DOE plans to apply multiple engineered systems to aid in waste isolation, the EPA specified in the WIPP certification that only MgO backfill meets the regulatory definition of an engineered barrier.

Section 194.44(a) provides a criterion for certification for the analysis of the cost and benefits of various engineered barrier options. The text in the following subsections describes the DOE program that meets the engineered barrier requirements.

7.4.3.1 Engineered Alternatives Cost and Benefit Study

To fulfill the benefit and detriment evaluation criterion contained in 40 CFR § 194.44(b), the DOE published *Engineered Alternatives Cost/Benefit Study; Final Report* (DOE 1995) (see CCA Appendix EBS). The EPA's criterion for this cost and benefit study is as follows:

> In selecting any engineered barrier(s) for the disposal system, the Department shall evaluate the benefit and detriment of engineered barrier alternatives, including but not limited to: cementation, shredding, supercompaction, incineration, vitrification, improved waste canisters, grout and bentonite backfill, melting of metals, alternative configurations of waste placements in the disposal system, and alternative disposal system dimensions. The results of this evaluation shall be included in any compliance application and shall be used to justify the selection and rejection of each engineered barrier evaluated. (40 CFR § 194.44[b])

The primary purpose of this cost and benefit study was to provide the DOE with information for use in selection or rejection of additional engineered barriers that provide assurance in the performance calculations. The current facility baseline, as represented in performance assessment, provides sufficient multiple barriers to obtain compliance with the requirements of 40 CFR § 191.14(d) as described in Sections 6.4.4 (Shaft Seal Engineered Barriers), 6.4.5 (The Salado Formation Natural Barrier), and 6.5 (Performance Assessment Results).

The approach used in the study was to screen potential engineered alternatives compiled from previous studies, the ten technologies specified in 40 CFR § 194.44(b), and input elicited from stakeholders. The screening process used a working group composed of technical professionals from various related fields to compare the proposed engineered alternatives to the established definition of an engineered alternative and then to determine if those alternatives that meet the definition also meet regulatory and technological feasibility criteria. The outputs of the screening process were

- a list of engineered alternatives that did not meet the definition or screening criteria, along with the justification for their rejection, and

- a list of engineered alternatives retained for further consideration.

The screening process evaluated 111 proposed engineered alternatives and screened out all but 54 (see CCA Appendix EBS, Section 2.2.2). The 54 alternatives retained were then subjected to a DOE management-level assessment to determine the set of alternatives that would be retained for full analysis through the study. The basis for this assessment was to:

- develop a set of alternatives that address important WIPP performance issues, such as reducing the solubility of actinides in brine and improving the strength of the waste,

- analyze those alternatives that have high technical feasibility (that is, those alternatives that have been subjected to bench-scale testing at the least), and

- assess those alternatives that have a high likelihood of being permitted in a reasonable amount of time.

This assessment resulted in the selection of 18 alternatives for full analysis through the study. The screening process, including this DOE management-level assessment, was included in the scope of an independent peer review done on the study to address the requirements of 40 CFR § 194.27(a)(3). The peer review panel concluded that the entire screening process was reasonable and acceptable. Details of the peer review are found in CCA Appendix PEER (Section 3.2).

The 18 alternatives finally selected for further study consisted of nine basic alternatives and nine variations. The 18 alternatives were compared to the criteria in 40 CFR § 194.44(c):

> (i) The ability of the engineered barrier to prevent or substantially delay the movement of water or waste toward the accessible environment;

(ii) The impact on worker exposure to radiation both during and after incorporation of engineered barriers;

(iii) The increased ease or difficulty of removing the waste from the disposal system;

(iv) The increased or reduced risk of transporting the waste to the disposal system;

(v) The increased or reduced uncertainty in compliance assessment;

(vi) Public comments requesting specific engineered barriers;

(vii) The increased or reduced total system costs;

(viii) The impact, if any, on other waste disposal programs from the incorporation of engineered barriers (for example, the extent to which the incorporation of engineered barriers affects the volume of waste);

(ix) The effects on mitigating the consequences of human intrusion. (40 CFR § 194.44[c][1])

In addition to the criteria listed above, CCA Appendix EBS includes analyses that evaluated

- existing waste that is already packaged,
- existing waste that is not yet packaged,
- existing waste that is in need of repackaging, and
- to-be-generated waste.

All 18 alternatives met the intent of these criteria. This process is further described in Section 2 and Appendix O of CCA Appendix EBS. The variations originated in the screening process, details of which can be found in Sections 2.2 and 2.3.1 of CCA Appendix EBS.

For comparison, the baseline was considered to be the WIPP facility with no additional engineered barriers beyond shaft seals and panel closures. The 18 final engineered alternatives, along with a brief description of each, are listed below.

- **Supercompact Organics and Inorganics.** Solid organic and inorganic wastes are sorted to remove items that cannot be compacted. Sorted waste is precompacted in 35-gallon (132.6-liter) drums and then supercompacted. Usually, the contents of four supercompacted drums are placed in a 55-gallon (208-liter) drum. Sludges are not processed.

- **Shred and Compact Organics and Inorganics.** Solid organics and inorganics are shredded and compacted in 55-gallon (208-liter) drums using a mechanical shredder and a low-pressure compactor. Sludges are not processed.

- **Plasma Processing of All Wastes.** All wastes are processed through a mechanical shredder and the input waste stream is controlled to ensure a suitable metal to nonmetal ratio. The waste is processed through a plasma arc centrifugal treatment system and placed into 55-gallon (208-liter) drums.

- **Sand Plus Clay Backfill.** A mixture of medium-grained sand and granulated clay is used as backfill. The mixture is placed around the waste stack and between the drums, filling the void space between drums and unmined host salt in waste emplacement panels. A fifty percent void space is assumed.

- **Salt-Aggregate (Grout) Backfill.** A salt-aggregate grout mixture is used as backfill to fill the void spaces between drums and unmined host salt in waste emplacement panels. This backfill consists of a cementitious-based, salt-aggregate grout with crushed salt aggregate and is pumped around the waste stack and between the drums filling the void spaces. A twenty percent void space is assumed.

- **Cementitious Grout Backfill.** A cementitious grout backfill consisting of ordinary Portland cement, sand, and fresh water is pumped around the waste stack and between the drums filling the void space. A twenty percent void space is assumed.

- **Supercompact Organics and Inorganics, Salt-Aggregate and Grout Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.1 meters) wide, and 300 feet (91.4 meters) long.

- **Supercompact Organics and Inorganics, Clay-Based Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meter) high, 33 feet (10.1 meter) wide, and 300 feet (91.4 meter) long.

- **Supercompact Organics and Inorganics, Sand and Clay Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meter) high, 33 feet (10.1 meter) wide, and 300 feet (91.4 meter) long.

- **Supercompact Organics and Inorganics, CaO Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meter) high, 33 feet (10.1 meter) wide, and 300 feet (91.4 meter) long.

- **Salt Backfill with CaO.** A backfill of commercially available granulated lime and crushed salt is placed around the waste stacks and between the drums filling the void space. A fifty percent void space is assumed.

- **Enhanced Cement Sludges, Shred and Add Clay-Based Materials to Organics and Inorganics, No Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Sand and Clay Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A mixture of medium-grained sand and granulated clay is used as backfill. The mixture is placed around the waste stack and between the drums filling the void space between drums and unmined host salt in waste emplacement panels. A fifty percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Cementitious Grout Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A cementitious grout backfill consisting of ordinary Portland cement, sand, and fresh water is pumped around the waste stack and between the drums filling the void space. A twenty percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Salt Aggregate Grout Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A salt-aggregate grout mixture is used as backfill to fill the void spaces between drums and unmined host salt in waste emplacement panels. This backfill consists of a cementitious-based, salt-aggregate grout with crushed salt aggregate and is pumped around the waste stack and between the drums filling the void spaces. A twenty percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Clay-Based Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A backfill consisting of commercially available pelletized clay is placed around the waste stack and between the drums, filling the void space. A fifty percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, CaO and Salt Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A backfill of commercially available granulated lime and crushed salt is placed around the waste stacks and between the drums filling the void space. A fifty percent void space is assumed.

- **Clay-Based Backfill.** A backfill consisting of commercially available pelletized clay is placed around the waste stack and between the drums, filling the void space. A fifty percent void space is assumed.

The product from the evaluation of each factor evaluated was integrated into a quantifiable result called a performance vector. This vector expresses the performance of each engineered alternative relative to the baseline. The results of the factor analyses are presented in detail in CCA Appendix EBS (Section 5.4).

The Engineered Alternatives Cost/Benefit Study (CCA Appendix EBS) was useful to the DOE, as it identified engineered barriers that could be used to improve long-term repository performance. Specifically, the advantages of a backfill that chemically altered the pH of brine in the disposal room were identified in CCA Appendix EBS (Section 3.1) as providing significant benefit in reducing the quantity of mobile actinides. Alkaline earth oxides (such as calcium oxide [CaO]) are known to readily react with water to form hydroxides. These hydroxides are free to react with carbonic acid that may form in the disposal room. The reaction buffers the brines to a pH that reduces the amount of actinide in solution. After further analysis, which is documented in CCA Appendix BACK and discussed in CCA Appendix SOTERM, the DOE selected magnesium oxide (MgO) as the backfill material that provided the desired long-term benefit while minimizing the operational impacts associated with the more caustic CaO. The beneficial effects of MgO backfill are now included in the WIPP performance assessment calculation. Relevant discussions can be found in Sections 3.3.3 and 6.4.3.4. Additional related information developed since the preparation of the CCA is provided in Appendix BARRIERS.

7.4.3.2 Incorporation into Repository Design

In its guidance to implementation of the certification criteria in 40 CFR § 194.44(d), the EPA requested that the DOE describe how engineered barriers are incorporated into the repository. The purpose of this section is to identify the location of these descriptions and the location of the analysis that evaluates the performance of the engineered barriers.

Shaft seals delay the movements of radionuclides toward the accessible environment through the shafts. These shaft seals are described in detail in CCA Appendix SEAL and are summarized in Section 3.3.2. Analysis of the effectiveness of shaft seals is included in CCA Appendix SEAL (Section 8) and Section 6.4.4. Panel closures prevent the movement of radionuclides toward the accessible environment by limiting the magnitude of releases that can occur during certain human intrusion events. The design of panel closures is described in CCA Appendix PCS, summarized in Section 3.3.2, and their role in the repository model is discussed in Section 6.4.3. More recent related information is provided in Appendix BARRIERS**.** Backfill substantially delays the movement of radionuclides toward the accessible environment by limiting, through chemical means, the amount of actinides that can be dissolved in brines that enter the repository. The placement of backfill is described in Section 3.3.1, and its design and functions are described in CCA Appendix SOTERM and Appendix PA, Attachment SOTERM. Actinide mobility is discussed in Section 6.4.3. Borehole plugs are used to limit the volume of water that could be introduced to the repository from overlying water-bearing zones and to limit the volume of contaminated brine that could be released to the accessible environment. Borehole plug design is addressed in Section 3.3.4. In addition, parameter values selected to implement the various engineered components into the PA model are described in Appendix PA, Attachment PAR. Borehole plugs, as described in Section 3.3.4, are also included to mitigate the potential for contaminant migration.

The EPA concluded in its certification that the use of MgO backfill meets the regulatory intent of the engineered barriers portion of the regulation. The certification decision (EPA 1998) includes the following regarding engineered barriers:

> The EPA finds that DOE complies with Section 194.44. The EPA found that DOE conducted the requisite analysis of engineered barriers and selected an engineered barrier designed to prevent or substantially delay the movement of water or radionuclides toward the accessible environment. The DOE provided sufficient documentation to show that MgO can effectively reduce actinide solubility in the disposal system. The DOE proposed to emplace a large amount of MgO around waste drums in order to provide an additional factor of safety and thus account for uncertainties in the geochemical conditions that would affect CO_2 generation and MgO reactions (63 FR 27397).

Since the certification, the DOE has performed additional MgO-related analyses. These analyses are reported in Appendix BARRIERS.

7.5 Resource Considerations

The EPA discourages the location of repositories in areas in which valuable natural resources are present, through the assurance requirements in 40 CFR § 191.14(e). This assurance requirement states that

> Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas, valuable geologic formations, and ground waters that are either irreplaceable because there is no reasonable alternative source of drinking water available for substantial populations or that are vital to the preservation of unique and sensitive ecosystems. Such places shall not be used for disposal of the wastes covered by this part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future (40 CFR § 191.14[e]).

The purpose of the requirement is to provide assurance that site selection actions further reduce the likelihood of future intrusion into the repository by giving preference to those sites without currently recognized resources.

In promulgating 40 CFR 194, the EPA provided for a clear manner in which to assess compliance with this requirement, stating that

> If performance assessments predict that the disposal system meets the containment requirements of § 191.13 of this chapter, then the Agency will assume that the requirements of this section and § 191.14(e) of this chapter have been fulfilled (40 CFR § 194.45).

Section 6.5 demonstrates compliance with 40 CFR § 191.13, including resource considerations, and hence compliance with 40 CFR § 194.14(e). The EPA further provides, in its guidance to 40 CFR Part 194, that the DOE

- document that the effects of mining and drilling over the regulatory time frame have been incorporated into performance assessments according to the requirements of § 194.32, § 194.33, and § 194.43;
- document that performance assessments incorporate the effects on the disposal system of any activities that occur in the vicinity of the disposal system or are expected to occur in the vicinity of the disposal system soon after disposal, according to the requirements of § 194.32; and
- document whether the results of performance assessments demonstrate compliance with the containment requirements of § 191.13.

The DOE has satisfied the EPA criteria concerning resource evaluation. This information is documented in Section 6.5.2. The mean CCDFs in Figure 6-36 incorporate both the effects of mining inside the controlled area (see Section 6.4.6.2.3 for a description of the mining conceptual model) and the effects of intermittent and inadvertent drilling (see Section 6.4.7 for a discussion of the drilling conceptual model). In addition, the impacts of resource development outside the controlled area were considered in the development of disposal system conceptual models.

7.5.1 Resource Considerations Prior to 40 CFR Parts 191 and 194

The WIPP site selection occurred prior to promulgation of 40 CFR Parts 191 and 194. Resource considerations were included in the site selection process for the WIPP and are documented in the WIPP FEIS (DOE 1980) and CCA Appendices GCR and IRD. The objective of the program for demonstrating compliance with the resource considerations requirement is to document the rationale used in the decision-making process.

7.5.2 Implementation of Resource Considerations

Resource considerations were included in the site selection process for the WIPP and are documented in the WIPP FEIS (DOE 1980, Section 7.3.7). The FEIS describes a four-step decision-making process that was applied to siting the repository. This process is summarized below:

- Step 1 – Bedded salt was selected as the most promising geologic medium, and geographic regions that contain extensive bedded salt formations were identified. This was accomplished by gathering and evaluating existing information concerning rock types and their geographic distribution. Desirable criteria were identified and the most favorable regions were identified.

- Step 2 – A literature review was performed to narrow the number of regions identified in Step 1. Once a region was selected, candidate sites within the region were chosen. Selection criteria were used to compare the sites. Those sites that satisfied the most criteria were selected for further evaluation. Resource-conflict considerations were applied on a broad scale at this stage of the process.

- Step 3 – The candidate sites identified in Step 2 were subjected to further investigations covering geology, hydrology, archaeology, demography, and biological resources. The results of all the site evaluations were compared, and the site that best met the selection criteria was selected for additional site characterization. At this stage, the types and quantities of natural resources present at the site were considered in detail.

- Step 4 – In this final step, a detailed system analysis was performed. This analysis addressed the specific geologic environment, the waste forms, the disposal facility design, and the potential failure modes with respect to radiation safety and environmental impact.

Based upon the above process, the DOE concluded that the favorable characteristics of the WIPP site (good hydrological characteristics, salt medium, moderate depth, salt thickness, low population density, lack of significant economic conflicts, and others) uniquely qualified it for a repository for defense waste. These characteristics also compensate for any increased likelihood of future disturbance. CCA Appendix IRD provides further analysis of compliance with the resource disincentive requirement. Section 2.3.1 provides a summary of known and inferred resources in the vicinity of the WIPP. CCA Appendix DEL contains resource-development-related information used in the conceptual model of disposal system performance.

7.6 Waste Removal

Removal of the waste any time after emplacement is possible. Because the repository was initially mined to provide access to the repository rooms, access to the waste can be accomplished using similar mining technologies. Location and removal are also possible using similar equipment modified to operate remotely. A remote retrieval demonstration was conducted at the WIPP in April 1992.

7.6.1 Requirements for Waste Removal

With the promulgation of 40 CFR Part 194, and in particular 40 CFR § 194.46, the EPA specifies the criteria for demonstrating compliance with this requirement. Specifically, the EPA mandates that "any compliance application shall include documentation which demonstrates that removal of waste is feasible for a reasonable period of time after disposal." The EPA states that this documentation should "include an analysis of the technological feasibility of mining the sealed disposal system, given technology levels at the time a compliance application is prepared."

In promulgating its disposal regulations, the EPA stated that "any current concept for a mined geologic repository meets this requirement without any additional procedures or design features" (EPA 1985, 50 FR 38082).

Because the WIPP facility is a mined repository, no additional actions other than documentation to meet this assurance requirement are necessary. The rationale for this assurance requirement is to preclude use of some disposal technologies that would not allow future generations to recover the wastes, should they decide to do so. According to the EPA, recovery need not be easy or inexpensive but only possible (EPA 1985). CCA Appendix WRAC describes a feasible system for waste removal using available mining technologies.

7.6.2 Implementation of Waste Removal

After determining the existing repository condition, the mining and waste removal operations will be designed to minimize the amount of contamination and exposure to allow limited human access for assessments, equipment retrieval, and repairs. Any radiological work will be performed using standard industry practices and approved procedures.

Radiological sampling activities will be planned and implemented so that recovered wastes can be handled. Packaging the removed waste and any decontamination of containers can be accomplished with standard automation techniques. Plans and procedures will ensure that the amount of additional contaminated material produced during the actual waste removal is minimized.

The removal concept is composed of the following five phases.

Phase 1 – Planning and permitting.

Phase 2 – Initial above ground setup and shaft sinking.

Phase 3 – Underground excavation and facility setup of underground ventilation, radiation control, packaging areas, decontamination areas, maintenance, remote control center, and personnel support rooms.

Phase 4 – Waste location and removal operations, including mining waste removal, packaging, package surveying and decontamination, transportation to surface, staging for off-site transportation, and off-site transportation.

Phase 5 – Closure and D&D of the facility.

Each of the five phases is summarized below and described in detail in CCA Appendix WRAC (Section 5).

7.6.2.1 Planning and Permitting

A decision to remove waste will initiate the planning and permitting phase. Permitting requirements will be based on governing regulations at the time removal is authorized. The planning and permitting program will identify all permits and research the available technologies at that time to determine available removal techniques and the condition of the repository. After initial research is completed, a plan will be drafted to itemize and schedule all removal activities.

7.6.2.2 Initial Above Ground Setup and Shaft Sinking

Above ground support buildings will house the exhaust fans and filters, administration, operations and maintenance facilities, control center waste staging and decontamination areas, the warehouse (containers), and others, as deemed necessary.

7.6.2.3 Underground Excavation and Facility Setup

After the shafts are completed, drifts will be run and ventilation paths will be established using air control regulators. Support rooms will be excavated for maintenance, control rooms, and packaging areas. Air locks will be constructed to provide the necessary level of control and separation. All equipment required for removal, packaging, and related support equipment will be installed.

Excavation will be in two stages. Initial excavation will not contact waste, but will mine support rooms and haulage drifts that provide ventilation and access to the waste. The second stage will remove the waste.

7.6.2.4 Waste Location and Removal Operations

The waste removal will be performed in separate operations. The waste will be removed by mining the area where the waste was emplaced. The mined waste will be transported to the packaging areas. The waste can be removed many ways using standard equipment. CCA Appendix WRAC (Sections 6 and 7) contains a brief description and feasibility of using various mining techniques for waste removal. An appropriate level of radiological controls will be used, depending upon the radioactivity of the mined waste.

7.6.2.5 Closure and D&D of the Facility

After waste is removed from the repository, the facility will be decommissioned according to the current regulations at that time.

REFERENCES

40 CFR Part 191 Disposal Regulations; Final Rule." *Federal Register,* Vol. 61, No. 28, pp. 5224 – 5245, February 9, 1996. Office of Radiation and Indoor Air, Washington, D.C.

Hora, S.C., von Winterfeldt, D., and Trauth, K.M. 1991. *Expert Judgment on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*. SAND90-3063. Sandia National Laboratories, Albuquerque, NM.

International Atomic Energy Agency (IAEA). 1999. Maintenance of Records for Radioactive Waste Disposal. IAEA-TECDOC-1097, Vienna, Austria.

John Hart and Associates, P.A. 2000a. Contractor Report, Permanent Markers Monument Survey, Waste Isolation Pilot Plant, Carlsbad, NM.

John Hart and Associates, P.A. 2000b. Contractor Report, Permanent Markers Materials Analysis, Waste Isolation Pilot Plant, Carlsbad, NM.

John Hart and Associates, P.A. 2000c. Contractor Report, Ancient Cementitious Materials, Waste Isolation Pilot Plant, Carlsbad, NM.

Murphy, John N., and Parkinson, H.F. 1978. *Underground Mine Communications*, Proceedings of the IEEE, Vol. 66, No. 1, pp. 26 – 50, January 1978.

New Mexico Bureau of Mines and Mineral Resources (NMBMMR). 1995. *Final Report Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site*. Vol. I, Ch. I-III, December 22, 1994.

Powell, J.A. 1976. *An Electromagnetic System for Detecting and Locating Trapped Miners*, U.S. Bureau of Mines Report of Investigations, RI 8159, U.S.B.M, Pittsburgh, PA.

Trauth, K.M., Hora, S.C., and Guzowski, R.V. 1993. *Expert Judgment on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*. SAND92-1382. Sandia National Laboratories, Albuquerque, NM.

U.S. Environmental Protection Agency (EPA). 1985. "40 CFR Part 191: Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule." *Federal Register*, Vol. 50, No. 182, pp. 38066 – 38089, September 19, 1985. Office of Radiation and Air, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1988. Test Methods for Evaluating Solid Waste. Volume 1A through 1C and Volume 2. Field Manual Physical Chemical Methods (3rd Edition). Report EPA/SW-846, September 1988, National Technical Information Service, Springfield, VA.

U.S. Department of Energy (DOE). 1980. *Final Environmental Impact Statement, Waste Isolation Pilot Plant*. DOE/EIS-0026. Vols. 1 and 2. Assistant Secretary for Defense Programs. Washington, D.C.

U.S. Department of Energy (DOE). 1990. *Final Safety Analysis Report*. WP 02-9, Rev. 0, May 1990. Westinghouse Electric Corporation, Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy (DOE). 1991. *Draft Report: Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task Force*. DOE/WIPP 91-007, Rev. 0. Westinghouse Electric Corporation, Carlsbad, NM.

U.S. Department of Energy (DOE). 1994. *Permanent Marker Conceptual Design Report* Draft. Rev. 2, November 1994. U.S. Department of Energy, Carlsbad, NM.

U.S. Department of Energy (DOE). 1995. *Engineered Alternatives Cost/Benefit Study; Final Report*. DOE/WIPP 95-2135. U.S. Department of Energy, Carlsbad, NM.

U.S. Department of Energy (DOE). 1999. 40 CFR Parts 191 and 194 Compliance Monitoring Implementation Plan (MIP), Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy (DOE). 2000. Permanent Markers Testing Program Plan, Waste Isolation Pilot Plant, Carlsbad, New Mexico, DOE/WIPP 00-3175, Carlsbad Area Office, Carlsbad, NM.

U.S. Environmental Protection Agency (EPA). 1996a. “40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant’s Compliance with the EPA (U.S. Environmental Protection Agency). 1996b. *Compliance Application Guidance for 40 CFR Part 194.* EPA 402-R-95-014, March 29, 1996. Office of Radiation and Indoor Air, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1996c. Docket A-93-02, Item II-I-01, Enclosure 1).

U.S. Environmental Protection Agency (EPA). 1997. Docket A-93-02, Item II-I-07, Enclosure 1c).

U.S. Environmental Protection Agency (EPA). 1998. “40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant’s Compliance With the Disposal Regulations: Certification Decision; Final Rule.” Federal Register, Vol. 63, No. 95, pp. 27396, May 18, 1998. Office of Radiation and Indoor Air, Washington, D.C.

INDEX