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Compliance Monitoring, Passive Institutional Controls, and Record Keeping

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ABSTRACT

The WIPP Case Study describes the compliance monitoring program, record keeping requirements, and passive institutional controls that are used to help ensure the Waste Isolation Pilot Plant (WIPP) will safety contain radioactive waste and indicate dangers and location of the wastes. The radioactive components in the waste are regulated by the U.S. Environmental Protection Agency (EPA) while the hazardous components in the waste are regulated by the New Mexico Environment Department (NMED). This paper addresses monitoring relating to radionuclide containment performance, passive institutional controls, and record keeping over a 10,000-year time frame.

Monitoring relating to the hazardous components and the associated regulator are not addressed in this paper. The WIPP containment performance is mandated by release limits set by regulation. Regulations also require the radioactive waste containment performance of the WIPP to be predicted by a "Performance Assessment." The EPA did not base the acceptance of the WIPP solely on predicted containment but included additional assurance measures. One such assurance measure is monitoring, which may be defined as the on-going measurement of conditions in and around the repository. This case study describes the evolution of the WIPP monitoring program as the WIPP project progressed through the planning, site characterization, regulatory promulgation, and eventual operational stages that spanned a period of over 25 years. Included are discussions of the regulatory requirements for monitoring, selection of monitoring

parameters, trigger values used to identify unexpected conditions, assessment of monitoring data against the trigger values, and plans for post-closure monitoring.

The United EPA established the requirements for Passive Institutional Controls (PICs) for disposal sites. The requirements state the a disposal site must be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location. The PIC Task Force assessed the effectiveness of PICs in deterring inadvertent human intrusion and developed a conceptual design for permanently marking the Waste Isolation Pilot Plant (WIPP), establishing records, and identifying other practicable controls to indicate the dangers of the wastes and their location. The marking system should provide information regarding the location, design, contents, and hazards associated with WIPP. This paper discuss these controls including markers, records, archives, and government ownership and land-use restrictions

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Background on the Waste Isolation Pilot Plant

The Waste Isolation Pilot Plant (WIPP) is a U.S. Department of Energy (DOE) facility for the disposal of transuranic (TRU) waste generated through national defense-related activities. WIPP is in southeastern New Mexico, 26 miles (42 km) east of the City of Carlsbad. The site encompasses 16 square miles (41.4 km^2) in a sparsely populated area. Land use in the area surrounding the WIPP land withdrawal area includes livestock grazing, potash mining, and oil and gas production.

The WIPP repository is located 655 m below ground surface in bedded halite of the Permian Salado Formation. Construction of the first shaft began in 1981, and the first seven-room panel of disposal rooms was completed in 1988.

The waste will be disposed in Hazardous Waste Management Units (HWMU). The facility capacity is limited to 6.2 million ft^3 (1.8×10^5 m^3) of contact handled (CH) and remote handled (RH) TRU wastes, many of which are also contaminated with hazardous waste. The CH waste is being stacked in the excavated rooms and the RH waste is to be emplaced in the ribs of the excavated rooms. As each HWMU is filled, the access drifts will be closed to prevent access by personnel and to decrease the potential for release of contaminants. The last HWMU will have space available for acceptance of decontamination waste generated (derived waste) during the execution of this plan.

Descriptions of topography, soils, geology, demography, meteorology, radiological and hazardous materials characteristics, radionuclide inventory, and environmental characteristics are available in the Draft Waste Isolation Pilot Plant Project Technical Baseline for Regulatory Compliance.

The U.S. Environmental Protection Agency (EPA) certified WIPP for operation in 1998. WIPP, operation of which is the responsibility of the Carlsbad Field Office (CBFO), opened to business in March 1999 with the first shipment of waste from Los Alamos National Laboratory (LANL) in northern New Mexico. To date, over 550 shipments, carrying over 18,000 55-gallon (208-L) drums and almost 200 waste storage boxes, have arrived from the DOE's LANL, Hanford, Idaho National Engineering and Environmental Laboratory (INEEL), Rocky Flats, and Savannah River sites.

Section 1: WIPP Compliance Monitoring - Regulatory Requirements, Selection of Parameters, Monitoring Procedures, and Assessment of Data

1. Reasons for Monitoring the WIPP

Initially, the WIPP was self-regulated by the predecessor to the DOE. In 1982, Congress authorized the EPA to promulgate general radioactive waste disposal regulations under the Nuclear Waste Policy Act of 1982. The WIPP disposal regulations went through various stages leading to a 1985 version that was not consistent with other environmental regulations and was remanded. The disposal regulations were revised and finalized in 1993. Congress also required EPA to promulgate criteria for certification of compliance with the EPA's disposal regulations. The criteria regulations were finalized in 1996 (EPA 1996a). Contained in these two regulations were the requirements to monitor the WIPP. Specifically, EPA requires monitoring as an assurance measure intended to provide additional assurance that the repository will perform as expected. In defining the assurance requirements, the EPA determined that the analytical techniques that were to be used in predictive modeling are subject to uncertainties. Because the models are based on the current state of knowledge of highly complex systems, they are also susceptible to imperfect understanding of individual or systematic components. Therefore, the EPA understood that predictive modeling (Performance Assessment) need not provide complete assurance that the containment requirements will be met. "Because of the long time period involved and the nature of the events and processes of interest, there will inevitably be substantial uncertainties in projecting disposal system performance. Proof of the future performance of a disposal system is not to be had in the ordinary sense of the word in situations that deal with much shorter time frames. Instead, what is required is a reasonable expectation, on the basis of the record before the implementing agency, that compliance with §191.13(a) (containment requirements) will be achieved."(EPA, 1993). To address the uncertainty, EPA defined assurance requirements in §191.14 comprising the following six measures:

- Maintain active institutional controls for as long as practicable;
- Monitor to detect substantial and detrimental deviations from expected performance until there are no significant concerns to be addressed by further monitoring;
- Use of permanent markers and passive institutional controls to indicate the dangers of the wastes and their location;
- Use of natural and engineered barriers to isolate the wastes;
- Avoidance of sites containing natural resources; and
- Possibility for removal of waste for a reasonable period of time after disposal.

The monitoring programs discussed below address the second measure listed above.

2. Regulatory Requirements for Monitoring

As the EPA developed their regulations, they expanded their monitoring requirement to include pre- and post-closure monitoring because they concluded that pre-closure monitoring provides a baseline for comparison with future measurements of parameters that are important to the long-term performance of the repository. Additionally, the EPA determined that a monitoring parameter analysis is necessary to determine the important monitoring parameters. They also included a list of parameters that needed to be considered in this analysis. Specifically, the EPA stated in 40 CFR §194.42 (EPA 1996a):

> (a) 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 pre-closure and post-closure 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) Groundwater 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.
>
> (b) For all disposal system parameters analyzed pursuant to paragraph (a) of this section, any compliance application shall document and substantiate the decision not to monitor a particular disposal system parameter because that parameter is considered to be insignificant to the containment of waste in the disposal system or to the verification of predictions about the future performance of the disposal system.
>
> (c) Pre-closure monitoring. To the extent practicable, pre-closure monitoring shall be conducted of significant disposal system parameter(s) as identified by the analysis conducted pursuant to paragraph (a) of this section. 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. Such monitoring shall begin as soon as practicable; however, in no case shall waste be emplaced in the disposal system prior to the implementation of pre-closure monitoring. Pre-closure monitoring shall end at the time at which the shafts of the disposal system are backfilled and sealed.

(d) Post-closure monitoring. The disposal system shall, to the extent practicable, be monitored as soon as practicable after the shafts of the disposal system are backfilled and sealed to detect substantial and detrimental deviations from expected performance and shall end when the Department can demonstrate to the satisfaction of the Administrator that there are no significant concerns to be addressed by further monitoring. Post-closure monitoring shall be complementary to monitoring required pursuant to applicable federal hazardous waste regulations at parts 264, 265, 268, and 270 of this chapter and shall be conducted with techniques that do not jeopardize the containment of waste in the disposal system.

(e) Any compliance application shall include detailed pre-closure and post-closure monitoring plans for monitoring the performance of the disposal system. At a minimum, such plans shall:

(1) Identify the parameters that will be monitored and how baseline values will be determined;
(2) Indicate how each parameter will be used to evaluate any deviations from the expected performance of the disposal system; and
(3) Discuss the length of time over which each parameter will be monitored to detect deviations from expected performance.

3. Selection of Compliance Monitoring Parameters (COMPs)

The primary objective in developing the pre- and post-closure monitoring programs for the WIPP was to meet the regulatory requirements. DOE performed the required monitoring parameter analysis that was documented in Appendix MON of the Compliance Certification Application (CCA: DOE 1996). The DOE considered the major processes and models described in Section 6.4 of the CCA and the results of previous performance assessments and developed an initial list of potentially significant parameters to be subjected to this analysis. Parameters were included in this analysis because they met one or more of the following criteria:

- The parameter represents one or more important aspects of a process or model;
- The parameter represents subjective uncertainty (such as spatial variability in a physical property or process used in modeling results of repository performance);
- The parameter represents stochastic uncertainty (such as drilling rate for consideration of human intrusions);
- The parameter represented subjective or stochastic uncertainty in previous preliminary performance assessment calculations (such as the diameter of the drill bit in the intrusion borehole); and
- The parameter proved to be moderately to highly sensitive in previous preliminary performance assessment calculations.

In the analysis of parameters, the DOE considered the parameters meeting the criteria listed above, together with the properties and processes identified in 40 CFR §194.42(a). Each parameter was considered in the context of scenarios where it may be significant. Three categories of features, events, and processes (FEPs) were screened for scenario construction:

- Natural FEPs;
- Waste- and repository-induced FEPs; and
- Human-initiated events and processes

The monitoring parameter analysis used five criteria in the compliance monitoring parameter (COMPs) selection process:

- Addresses significant disposal system parameters;
- Addresses an important disposal system concern;
- Obtains meaningful data in a short time period;
- Does not violate disposal system integrity; and
- Complements Resource Conservation and Recovery Act (RCRA[1]) programs.

The first criterion listed above pertains to the parameter's effect on "the system's ability to contain waste" and its potential effect on compliance with the regulatory release limits. Containment and compliance are directly related: properties and processes that are significant for waste containment are also significant for compliance with the release limits. Therefore, the

[1] RCRA regulates the hazardous materials (non-radioactive) components in the waste. Examples include hazardous metals, corrosives and volatile organic compounds. RCRA requires that hazardous waste facilities monitor for potential releases.

DOE uses compliance with the release limits as the performance measure to determine which parameters are significant to waste containment in the monitoring parameter assessment. The second criterion pertains to the parameter's effect on "the ability to verify predictions about the performance of the disposal system" and the ability to verify the assumptions used in modeling the system's performance.

The EPA indicated that the monitoring program should be complementary to other monitoring programs at the WIPP, most of which are necessary to meet other regulatory requirements (RCRA for example). As such, DOE used the results of the monitoring parameter analysis and the availability of the existing monitoring data from current WIPP programs to build the pre- and post-closure monitoring programs. Many of the existing programs at that time were in place to ensure compliance with other hazardous materials regulations, mine safety, and ongoing site-characterization activities. The DOE's intent was to develop a pre- and post-closure monitoring program that utilized as many existing data-generation activities as possible without initiating a dedicated program for generation of compliance monitoring data. The pre-closure, post-closure, and all other monitoring programs are described in greater detail in Chapter 7 of the CCA (DOE 1996).

Table 1 outlines the list of parameters that were considered in the monitoring parameter analysis and an indication of which were selected for inclusion in the monitoring program. Included in the list were the 57 parameters that were considered important to system performance in the Performance Assessment for the CCA, but were too uncertain to assign single values. A range of values was assigned to each of these uncertain parameters, forming the basis for creating the vectors (sets) of parameter values using Latin hypercube sampling (LHS) in the Monte Carlo analysis described in Section 6.1.5 of the CCA. These so-called "PA parameters" did not include things that might change with time (and could therefore be the subject of monitoring), but rather included properties like porosity, permeability, solubility, and fracture spacing. Thus, monitoring could not focus directly on the parameters identified by sensitivity analyses as being most important to system performance (e.g., Helton et al. 1998). Rather, monitoring was focused on observable indicators of system behavior/performance. For the majority of parameters considered, nothing monitorable could be identified.

In addition to parameters related to the behavior of the physical elements of the disposal system (e.g., subsidence, water levels), the WIPP monitoring program also included parameters related to human activities. Human activities may be necessary and/or appropriate to monitor for two principal reasons. First, the human activities occurring near a repository will, in all likelihood, change with time and have the potential to affect the performance of the repository adversely. In the case of the WIPP, for example, the intensity of exploratory drilling for oil and gas around the site has increased significantly since repository construction began. Second, even if human activities do not affect the performance of the repository, they may affect the parameters and processes being monitored around the repository. If the factors affecting monitoring parameters are not known and cannot be accounted for, the utility of monitoring to verify repository performance is severely compromised.

Table 1. Parameters Considered in Development of Monitoring Program.

Parameter	Parameter Type	Selected for Pre-Closure Monitoring?	Selected for Post-Closure Monitoring?
Impure halite Effective porosity Permeability Pore compressibility Far-field pore pressure	Natural Salado Hydrology	N	N
Anhydrite Permeability Compressibility	Natural Salado Hydrology	N	N
Salado Pore shape Residual brine saturation Residual gas saturation	Natural Salado Hydrology	N	N
Brine Quantity Flux Spatial distribution Composition	Natural Salado Hydrology	N	N
Culebra Transmissivity Advective porosity Fracture porosity Fracture spacing Matrix porosity Longitudinal dispersivity Climate change index	Natural Culebra Hydrology	N	N
Groundwater Quantity Flux Spatial distribution	Natural Culebra groundwater	Y	Y
Groundwater composition	Natural Culebra groundwater	Y	Y
Brine Reservoir Volume Pressure Permeability Compressibility Spatial distribution Brine composition	Natural Castile Hydrology	N	N
Natural temperature distribution	Natural Disposal System	N	N

Parameter	**Parameter Type**	**Selected for Pre-Closure Monitoring?**	**Selected for Post-Closure Monitoring?**
Creep Closure Stresses Extent of deformation	Waste and Repository Induced	Y	N
Major Deformation Features Initiation of brittle deformation features Displacement of major deformation features	Waste and Repository Induced	Y	N
DRZ Permeability Effective porosity DRZ brine flux DRZ brine quantity and distribution	Waste and Repository Induced	N	N
Disposal Room Properties Waste area residual gas saturation Waste area residual brine saturation Brine wicking Waste area permeability	Waste and Repository Induced	N	N
Backfill Mechanical Properties Backfill porosity Backfill permeability Degree of backfill compaction Backfill reconsolidation	Waste and Repository Induced	N	N
Gas Generation Inundated steel corrosion rate with and without CO_2 Inundated microbial degradation Humid microbial degradation ß factor for microbial degradation Probability factor for different types of microbial degradation Gas quantity Gas composition	Waste and Repository Induced	N	N
Disposal Room Chemistry Actinide solubility in brines Humics concentrations in brines	Waste and Repository Induced	N	N

Parameter	Parameter Type	Selected for Pre-Closure Monitoring?	Selected for Post-Closure Monitoring?
Shaft Seal System Clay component permeability Concrete permeability Asphalt permeability Shaft DRZ permeability Seal residual gas saturation Seal residual brine saturation	Waste and Repository Induced	N	N
Waste- and Repository-Induced Temperature Distribution	Waste and Repository Induced	N	N
Radionuclide Transport	Waste and Repository Induced	N	N
Drilling Intrusion Drilling rate Probability of encountering a Castile brine reservoir	Human Initiated	Y	Y
Drilling Intrusion Time between intrusions Borehole location	Human Initiated	N	N
Direct Releases Borehole diameter Waste shear strength Waste particle diameter Waste tensile strength Gravity factor for spalling Strength factor for spalling	Human Initiated	N	N
Direct Releases Waste activity	Human Initiated	Y	N
Borehole Properties Borehole permeability Index for selecting type of borehole	Human Initiated	N	N

4. Compliance Monitoring Parameters (COMPs)

The results of the monitoring parameter analysis identified ten parameters for the pre-closure monitoring program. One COMP relates to the radioactive components of the waste, two COMPs relate to human activities, two COMPs relate to regional (far-field) hydrogeology, and five COMPs relate to geomechanical performance. Specifically, the COMPs include the following parameters:

Compliance Monitoring Parameter	Period
1. Waste Activity	Pre-Closure
2. Drilling Rate	Pre- and Post-Closure
3. Probability of Encountering a Castile Brine Reservoir	Pre- and Post-Closure
4. Changes in Culebra Groundwater Flow	Pre- and Post-Closure
5. Changes in Culebra Groundwater Composition	Pre- and Post-Closure
6. Subsidence	Pre- and Post-Closure
7. Creep Closure	Pre-Closure
8. Extent of Deformation	Pre-Closure
9. Initiation of Brittle Deformation	Pre-Closure
10. Displacement of Deformation Features	Pre-Closure

Existing monitoring programs carried out by the WIPP Management and Operating Contractor (MOC; Westinghouse TRU Solutions, LLC) are used to gather data and information to develop the COMPs. The EPA requires the DOE to report any negative condition that would 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. The monitoring programs generate the data for the COMPs on a continuous basis. The WIPP Scientific Advisor (SA; Sandia National Laboratories) assesses the data annually to allow DOE to compare the monitoring parameters to the predicted performance of the repository and report any condition adverse to the containment performance. Table 2 lists the MOC monitoring programs and SA evaluation programs associated with the ten COMPs. The following discusses each of the COMPs contained in the monitoring program.

4.1 RADIOACTIVE COMPONENTS COMP

Waste Activity

The WIPP PA includes waste interactions and influences on repository performance. Because only a fraction of the waste destined for WIPP has so far been generated, the waste inventory used in the PA was a scaled-up estimate based on the existing waste and estimates of future waste generation. The EPA bases the allowable releases from the repository on the total emplaced waste activities. Therefore, it is important to know the actual waste inventory that is emplaced to ensure that any deviations from the expected amounts are accounted for in future assessments. The DOE included the waste activity COMP to monitor waste emplacement assumptions. Ten radionuclides most important to PA are tracked in the monitoring program. These radionuclides include nine component radionuclides that have activities greater than one

Table 2. Monitoring Parameters.

40 CFR 194 Monitoring Parameter	**Responsible MOC and SA Programs** (*SA in italics*)	**Related Performance Assessment Parameter**	**Major FEPs Screening Decisions Related to Monitoring**
Waste Activity	WIPP Waste Information System (WWIS) *PA Methodology*	Radionuclide inventory. *In the CCA, the SA used the Baseline Inventory Report information scaled to the Land Withdrawal Act (LWA) limits of 6.2 million cubic feet for CH TRU waste and 5.1 million curies for RH TRU waste (limits are listed in CCA Table WCA-1)*	*Waste characteristics radiological characteristics, consolidation of waste, actinide source term.*
Drilling Rate	Delaware Basin Monitoring Program *Direct Release Program*	Drilling rate per unit area**.** *In the CCA the drilling rate was determined to be 46.8 boreholes per square kilometer per 10,000 yrs.*	*Drilling.*
Probability of Encountering a Castile Brine Reservoir	Delaware Basin Monitoring Program *Direct Release Program*	Probability of encountering a Castile brine reservoir, reservoir pressure, and volume. *In the CCA, 8% was used; in the Performance Assessment Validation Test, a range of 1 - 60% was used*	*Drilling fluid flow,* *Drilling fluid loss,* *Blowout and brine reservoirs.*
Changes in Culebra Groundwater Flow (Water Level)	Groundwater Monitoring Program *Far Field Monitoring Program*	Culebra transmissivity, dispersivity, and climate index. *The CCA modeling allowed the water table to rise to the land surface, doubling Culebra gradients. Can provide information on Culebra modeling assumptions and well integrity.*	*Groundwater flow and recharge/discharge; infiltration and precipitation.*
Changes in Culebra Groundwater Composition	Groundwater Monitoring Program *Far Field Monitoring Program*	Average Culebra brine composition and matrix distribution coefficient for U (IV,VI), Pu(III,IV), Th(IV), Am(III). *Matrix distribution coefficient is not a sensitive parameter for the CCA PA. Can provide information on Culebra modeling assumptions and well integrity.*	*Groundwater geochemistry, actinide sorption.*

40 CFR 194 Monitoring Parameter	**Responsible MOC and SA Programs** (*SA in italics*)	**Related Performance Assessment Parameter**	**Major FEPs Screening Decisions Related to Monitoring**
Subsidence Measurements	Subsidence Monitoring Program *Rock Mechanics Program*	Not directly related to a PA parameter. *Can provide spatial information on surface subsidence (if any) over the influence area of the underground openings during operations.*	*Changes to groundwater flow due to mining effects, subsidence baseline.*
Creep Closure and Stresses	Geotechnical Monitoring Program *Rock Mechanics Program*	Not directly related to a PA parameter. *Provides a short-term (operational) observation of the deformational properties of halite and anhydrite. Can provide confidence in the CCA creep closure model.*	*Salt creep, room closure, excavation-induced stress changes, changes in stress field, pressurization, consolidation of waste. Data from this monitoring program will be evaluated during recertification.*
Extent of Deformation	Geotechnical Monitoring Program *Rock Mechanics Program*	Not directly related to a PA parameter. *Provides a short-term observation of the extent of deformation. Can provide confidence in the long-term behavior of Disturbed Rock Zone (DRZ) as modeled in CCA and DRZ parameters (e.g., permeability and porosity). Intrinsic shaft DRZ permeability.*	*DRZ, roof falls, consolidation of seal elements, compaction of waste.*
Initiation of Brittle Deformation	Geotechnical Monitoring Program *Seals and Rock Mechanics Programs*	Not directly related to a PA parameter. *Provides related repository observation data on initiation or displacement of major brittle deformation features in the roof or surrounding rock.*	*Disruption due to gas effects.*
Displacement of Deformation Features	Geotechnical Monitoring Program *Rock Mechanics Program*	Not directly related to a PA parameter. *Provides related repository operational data on initiation or displacement of major brittle deformation features in the roof or surrounding rock.*	*Seismic activity, creep closure, consolidation of waste.*

EPA unit at closure (an EPA unit is the allowable number of curies that can be released based on the assumed inventory): ^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{233}U, ^{234}U, ^{90}Sr, and ^{137}Cs. The total activity of the waste at closure and during the entire 10,000-year performance period is dominated by the activities of four emplaced radionuclides: ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{240}Pu. The ^{238}U component is to be tracked as well, because its large mass fraction and low activity dilutes the overall activity of transported uranium species. ^{90}Sr and ^{137}Cs are contained only in the remote-handled waste, decay more quickly, and can only contribute to releases in the first several hundred years or so after closure. The waste destined for WIPP is characterized prior to shipment, which entails determining through assay or knowledge of the process that generated the waste the quantities of these radionuclides. The COMP is determined through a waste acceptance database which is used to determine if the waste meets specific criteria prior to being shipped to WIPP.

4.2 HUMAN-ACTIVITIES COMPS

The WIPP site is located in the Permian Basin in southeastern New Mexico which is an active oil and gas-producing region and is in the vicinity of several potash mines. Because natural resources are present in and around the WIPP site, DOE must consider the potential consequences of human intrusion of the WIPP repository associated with resource exploitation, once the institutional and societal memory of WIPP is lost. In the WIPP PA, all significant releases of radionuclides from the repository occur as a result of hypothesized human-intrusion scenarios. Thus, two COMPs were selected that relate to the potential for, and consequences of, human activities.

Drilling Rate

The EPA requires that future human activities that could breach the repository be included in repository performance predictions. The EPA also specifically required that drilling activities relating to resource exploitation be included in PA and should include a drilling rate determined from an analysis of historical drilling records within the Delaware Basin (an oil and gas exploitation area in which WIPP is located) over a 100-year period. The analysis calculated that boreholes were drilled to or beyond the repository depth at a rate of 46.8 boreholes per square kilometer per 10,000 years. The EPA reasoned that the activities associated with drilling for oil over the last 100 years would be a surrogate for the potential of future intrusions for unknown resource exploitation. The DOE determined the drilling-rate parameter was important to releases and therefore included monitoring drilling activities in the Delaware Basin in its monitoring program. As such, all State of New Mexico drilling records are monitored as part of the COMPs monitoring program to identify new wells drilled (along with associated activities) in the Delaware Basin to validate the assumptions in the regulations used to predict the potential for future human intrusions into the repository.

Probability of Encountering a Castile Brine Reservoir

Two of the nine deep boreholes drilled during WIPP site-characterization activities encountered pressurized brine in the Castile Formation, which underlies the repository host formation. A time domain electromagnetic survey was performed over the WIPP site and the results suggested that a Castile brine pocket may be located under part of the repository. Studies of well-drilling logs in the WIPP vicinity also indicated that a small percentage of deep boreholes encountered Castile brine. As a result, DOE included human-intrusion scenarios in which one or more drilled boreholes penetrated the repository and a brine reservoir. These scenarios allowed brine to enter the repository through the borehole either initially when a drilling event occurred or in the future when borehole plugs were assumed to degrade. DOE determined in the monitoring parameter analysis that brine encounters were important to prediction of repository performance. DOE performed a statistical analysis based on the historical record of brine occurrences in the Delaware Basin and determined a 0.08 probability that a borehole penetrating the repository would encounter Castile brine. The EPA performed an analysis after DOE's monitoring parameter analysis and determined the DOE should use a range from 0.10 to 0.60 in PA. The PA results were not sensitive to the change in probabilities, showing that the probability of encountering brine is not important to repository performance predictions. However, the DOE included this parameter in the monitoring program based on the previous analysis indications. All drilling records for new wells drilled in the nine townships surrounding the WIPP site are searched for references to brine encounters. Because drillers are not required to note brine encounters in the drilling records they submit to the State unless they necessitate changes in their drilling program, the monitoring program also sends out annual surveys to the drilling companies requesting information on brine encounters and initiates informal communication to elicit information.

4.3 HYDROLOGIC COMPS

Site-characterization activities showed that the Culebra Dolomite Member of the Rustler Formation is the most transmissive saturated water-bearing unit above the repository. The Culebra is included in human-intrusion scenarios in which boreholes have breached the repository. Releases under these scenarios occur after the boreholes have been plugged and abandoned, when the plugs and seals have degraded, allowing interconnection of the repository with the Culebra. The transport of radionuclides in the Culebra to the site boundary is modeled in the WIPP PA. Intensive characterization studies were required to determine the rates and directions of groundwater flow, and to identify and quantify processes affecting transport. The numerical model resulting from these studies assumes that the Culebra is confined and that heads are at steady state on the time scale of human activities at WIPP. Validation of the groundwater model was determined to be important to verify predictions about the future performance of the disposal system in the monitoring parameter analysis. DOE included monitoring both Culebra flow and composition as COMPs in the pre- and post-closure monitoring programs.

Changes in Culebra Groundwater Flow

For the WIPP PA, transmissivity (T) fields for the Culebra were defined by calibrating the model until steady-state heads at 32 wells in the WIPP vicinity fell within ranges defined for each well. Groundwater flow could change in velocity and/or direction from that modeled in the CCA if heads were outside the ranges used for calibration. Because the CCA modeling assumed that hydraulic conditions in the Culebra were at steady state (except for transients introduced by site activities), no changes in heads outside the calibrated ranges are expected. If changes that cannot be attributed to human activities are observed, the validity of the steady-state assumption could be questioned, leading to a revision of the conceptual model. Revising the underlying conceptual model might lead to revision of the numerical model.

Culebra groundwater levels are monitored at 41 well locations on and around the WIPP site. The Culebra groundwater flow COMP involves comparison of Culebra water levels at the 28 of the 32 wells used in T-field calibration that still exist to the ranges used in the T-field calibrations to validate the groundwater model.

Changes in Culebra Groundwater Composition

Culebra water quality is important because of what it implies about the nature of the flow system. Concentrations of major ions (Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3^-) vary widely in Culebra groundwater across the WIPP site, reflecting very slow movement of groundwater and local rock-water equilibrium. The conceptual model for the Culebra presented in the CCA and implemented in PA numerical models is that of a confined aquifer with solute travel times across the WIPP site on the order of tens of thousands of years. In such a system, no changes in water quality at an individual well outside the range of normal analytical uncertainty and noise should be observed during the WIPP operational phase of a few decades duration. If sustained and statistically significant changes in the concentrations of major ionic species were observed, this would imply that water was moving faster through the Culebra than was consistent with our models. Stability of major ion concentrations, on the other hand, is consistent with and supports the PA models. Thus, the evaluation of the groundwater composition COMP focuses on the stability of major ion concentrations.

Six Water Quality Sampling Program (WQSP) wells were established in the Culebra in 1995: three upgradient (north) of the WIPP repository and three downgradient (south) of the repository. These wells were constructed using fiberglass (rather than steel) casing because: (1) the fiberglass is inert relative to the groundwater and does not affect the quality of the samples, and (2) fiberglass casing should have both better longevity and be easier to replace (if necessary) in monitoring wells that may need to be maintained for over a century. Water samples are collected from the six WQSP wells twice a year and analyzed for major and minor ions, hazardous constituents, and radionuclides. The groundwater composition COMP considers only the stability of major ion concentrations. Stability is defined as a condition where the concentration of an ion remains within the 95% confidence interval (C.I.) (mean +/- two standard deviations) established from the baseline measurements at a well (duplicate analyses from ten rounds of sampling), assuming a normal distribution of concentrations.

4.4 GEOMECHANICAL COMPS

Monitoring of the underground has been conducted since the first excavations. Most of the monitoring is performed to characterize the behavior of the mine and to ensure worker safety. Many of the monitored parameters also relate to assumptions used in the PA models. Therefore, the DOE has applied many of the mine safety monitoring parameters to the COMPs monitoring program to validate PA models and assumptions. Specifically, subsidence, creep closure, the extent of deformation, the initiation of brittle deformation, and the displacement of deformation features are monitored in the pre-closure monitoring program.

Subsidence

Effectively monitoring the repository after closure poses many challenges because the techniques must not jeopardize the containment of waste in the disposal system (non-intrusive monitoring techniques) and monitoring for actual releases of radionuclides is not expected to be useful for hundreds of years. Therefore, the DOE proposed subsidence monitoring for a long-term COMP. The WIPP excavations are expected to close over time due to the plastic nature of the salt host rock. The closure causes surface subsidence which can be measured with typical surveying techniques. Data from the subsidence monitoring program during the operational period will be used to validate subsidence predictions and provide baseline information for the post-closure monitoring program.

Subsidence is currently monitored via elevation determination of 51 existing monuments and 14 of the National Geodetic Survey's vertical control points. Because of the low extraction ratio and the relatively deep emplacement horizon (650 m), subsidence over the WIPP is expected to be much lower and slower than over potash mines. Maximum observed subsidence over potash mines near the WIPP is 1.5 m, occurring over a time period of months to a few years. Calculations show that the maximum subsidence predicted directly above the WIPP waste emplacement panels is 0.62 m assuming emplacement of CH-TRU waste and no backfill (Backfill Engineering Analysis Report [WID, 1994]). Further considerations, such as calculations of room closure, suggest that essentially all surface subsidence would occur during the first few centuries following construction of the WIPP, so the average vertical displacement rate over 300 years can be estimated as approximately 0.002 m/yr (0.006 ft/yr). Obviously, these predicted rates could be higher or lower depending on mining activities, as well as on other factors such as time. Because the annual vertical elevation changes are very small, survey accuracy, expressed as the vertical closure of an individual loop times the square root of the loop length, is of primary importance in accurately quantifying subsidence. For the current annual subsidence surveys, a Second-Order Class II loop closure accuracy of 8 mm $\times \sqrt{}$(loop length in km) or better was achieved in all cases.

Creep Closure

The most readily quantifiable geomechanical response in the WIPP underground is creep closure. Creep closure is routinely measured from rib to rib and from roof to floor using convergence meters, and in horizontal and vertical boreholes using multi-point extensometers. Creep closure is monitored in three shafts (14 extensometers), two shaft stations (the openings where the vertical shafts intersect the horizontal mine workings; ten sets of convergence points and two extensometers), the northern experimental area (eight sets of convergence points and seven extensometers), and the disposal area and associated access drifts (155 sets of convergence points and 51 extensometers along the vertical centerlines of openings, and 86 sets of convergence points and 13 extensometers along the horizontal centerlines of openings).

Rates of closure are relatively constant within each zone of interest and usually range from about 1-5 cm/yr. A closure rate in terms of cm/yr can be expressed as a global or nominal creep rate by dividing the displacement by the room dimension and converting time into seconds. These rates are typically of the order of 1×10^{-10}/sec and are quite steady over significant periods.

Extent of Deformation

The extent of brittle deformation can have important implications to PA. As modeled in PA, the disturbed rock zone (DRZ) releases brine to the disposal room while properties of the DRZ control hydrologic communication between disposal panels. Therefore, extent of deformation relates directly to a conceptual model used in PA. Measurements in the WIPP underground include borehole inspections, fracture mapping, and borehole logging. These observations are linked closely to other monitoring requirements concerned with initiation of brittle deformation and displacement of deformation features. These monitoring requirements define characteristics of the DRZ which could validate the baseline conceptual model, its flow characteristics, saturation, and dewatering. The extent of deformation quantifies the DRZ, a significant element of performance assessment analyses.

Initiation of Brittle Deformation

The WIPP underground monitoring program has compiled data on fracturing in the roof (or "back") of excavations into a database. These data are used to plot plan and isometric views of fractures. Fracture development is most continuous parallel to the rooms and near the upper corners. These fractures are designated "low-angle fractures" relative to the horizontal axis. The current excavation horizon results in a 2-meter-thick beam of halite between the roof and an overlying clay seam. Low-angle fractures arch over rooms and asymptotically connect with the clay seam. Fracture mapping thus far is consistent with expectations and tracks stress trajectories derived from computational work. A comprehensive model and supporting data for model parameters for damage evolution has not been developed and incorporated into PA.

Displacement of Deformation Features

Monitoring the displacement of deformation features is accomplished by measuring the offset of features (e.g., the contact between a halite layer and an anhydrite layer) in boreholes drilled from the mine openings through the feature of interest. In general, these boreholes are aligned vertically (normal to the roof and floor surfaces). Currently, 142 observation boreholes are located throughout the WIPP underground. All of the holes are 7.6-cm (3-in) in diameter and many intersect more than one deformation feature. The ages of the observation holes vary from more than 17 years to less than one year. The offset (or offsets) in each observation borehole is determined by visually estimating the degree of borehole occlusion. Currently, 225 offsets are monitored in the 142 boreholes.

5. Trigger Values

To help ensure that the project would detect an adverse condition prior to an out-of-compliance condition arising, the DOE developed the trigger value concept. Values or ranges were assigned to COMPs data that would indicate a condition that is outside PA expectations or represent a point at which further analysis is necessary to determine the potential impact the data may have on WIPP containment performance. The perceived impact on PA conceptual models (i.e., whether an observation would be inconsistent with our conceptual understanding of a process or condition) was used as the first-order basis for these trigger values. "Trigger Values" can represent events, trends, criteria, rates, probabilities, ranges, conditions, or a specific value. For some COMPs, no specific trigger values are assigned because the long-term performance of the repository is not sensitive to the monitoring parameters. There are also cases where the monitoring parameter does not directly affect performance, but may have an impact on Features, Events, and Processes (FEPs) or their screening arguments (FEPs are the building blocks for the modeled scenarios in the WIPP PA) or modeling assumptions. The EPA does not require such a system to be used in the pre- and post-closure monitoring program. However, the DOE believed trigger values are an important part of a complete program.

The DOE used a five-step process to derive the COMPs trigger values. The first step defines the COMP-related monitoring data characteristics (i.e., what is actually measured/observed and reported). The second step maps the COMPs-related data to PA elements which include: PA parameters, FEPs screening arguments, conceptual models, and model assumptions. The third step uses relationships identified in Steps 1 and 2 to identify COMPs-related data that were used to support the Compliance Certification Application (CCA) PA. This step also defines the CCA Compliance Baseline for these COMPs and monitoring data in the context of the PA element(s) derived from them. The next step uses previous project experience (sensitivity analyses, CCA monitoring analysis, etc.) to determine the potential impact that changes in the PA elements identified in Step 2 would have on the performance of the disposal system. In the last step, PA principal investigators (PIs) knowledgeable in the PA topical areas relating to each COMP determine if it is appropriate for the COMP to have a trigger value and if so, derive trigger values for each COMP and/or related monitoring data. In this step, the PIs may also determine if the trigger value will represent deviations from the Compliance Baseline determined in Step 3, whether the trigger value could lead to significant impacts on the performance of the disposal system, as determined in Step 4, or simply indicate variances with operative conceptual and/or numerical models. The derivation of trigger values is documented in Sandia National Laboratories records (SNL 2000a and 2000b). Trigger values were assigned to seven of the ten COMPs. Table 3 details the trigger values for each COMP.

The trigger value concept was created by DOE to be used as a diagnostic tool for the compliance monitoring program. It is not intended to identify regulatory-related out-of-compliance conditions or indicate actual releases. The EPA has stated that monitoring for releases would not likely be productive since even poorly performing geologic repositories are unlikely to allow for releases to the accessible environment for hundreds of years. The monitoring would most certainly not detect a release of radionuclides for several times the length of time the United States of America has existed (EPA 1996b). Trigger values are intended to indicate conditions that are important to PA elements such as data outside the range of related values used in the PA calculations. Trigger values are also used to indicate when additional investigations are needed to ensure the performance of the repository is within expectations. An example for this is the trigger value that is assessed when a panel is half full. At this trigger point, the actual emplaced actinide quantities and waste stream information are compared to the assumptions used in the PA calculations to determine if the emplaced waste could potentially affect PA predictions or if additional investigations or calculations are needed to identify the true impact on the predicted repository performance.

No specific actions necessarily occur if a trigger value is exceeded. Instead, an investigation will be initiated to determine the cause of the unexpected value, and an assessment will be made of the possible impact on compliance. Other actions may follow, as appropriate, from that assessment. In some cases, the trigger value may simply be revised.

Table 3. COMP Trigger Values.

Monitoring Parameter (COMP)	Trigger Value	Notes
Waste Activity	CH – ½ panel full evaluation RH – 5.1 million curies	Check that PA assumptions about waste activity will remain valid as remainder of panel is filled and verify random emplacement assumptions. LWA emplacement limit reached. Administrative controls address these limits.
Drilling Rate	53.5 boreholes/km^2/10,000yrs	CCA direct releases are sensitive to drilling rate changes, however only a dramatic and improbable change in drilling rate could affect containment of radionuclides. The sensitivity of FEP-screening decisions to changes in drilling assumptions has not been evaluated to date. Little information is available upon which to justify the choice of a trigger value based on FEP-screening decisions. A change of drilling rate greater than 10% (i.e., greater than 53.5 boreholes per square kilometer per 10,000 years) is considered prudent as a trigger value to revisit the low-consequence assumptions associated with the effects of abandoned boreholes on fluid flow and climatic changes used to construct the performance assessment calculations.
Probability of Encountering a Castile Brine Reservoir	None	After the DOE proposed the brine reservoir probability as potentially significant in the CCA Appendix MONPAR, the EPA conducted analyses that indicate a lack of significant effects on performance from changes in this parameter. Because no value of this parameter can significantly affect the performance of the disposal system predicted by the CCA PA and because the parameter is evaluated at least once annually, no trigger value has been assigned.
Changes in Culebra Groundwater Flow	Head ranges used for CCA transmissivity field calibration	Annual comparisons with ranges of undisturbed steady-state freshwater heads used to calibrate Culebra T fields for CCA. Revision to a gradient-based trigger value is being considered.
Change in Culebra Groundwater Composition	Yet to be defined	Will probably involve major ion concentrations observed to be outside of 95% confidence intervals (defined from 10 rounds of baseline sampling) for a minimum of 2 to 3 consecutive sampling rounds.
Subsidence	1×10^{-2} m/yr	Based on the most conservative prediction by analyses referenced in the CCA.
Creep Closure	Greater than one order of magnitude increase in the closure rate	An increase in closure rate signals a potential de-coupling of rock.
Extent of Deformation	Growth of 1 m/ year[(a)]	Coalescence of fractures at depth in rock surrounding drifts will control panel closure functionality and design, as well as discretization of PA models.
Initiation of Brittle Deformation	None	Qualitative COMPs can be subjective and are not prone to the development of meaningful trigger values.
Displacement of Deformation Features	Obscured observational borehole	If lateral displacement is sufficient to close diameter of observational borehole, technical evaluation of consequences will be initiated.

6. COMPs Assessment for Calendar Year 2000

The monitoring data collected by the DOE's MOC are assessed annually by the SA for a report the DOE is required to give to the EPA. This assessment is reported to the Office of Regulatory Compliance (ORC) of the DOE Carlsbad Field Office (CBFO). A flow chart illustrating the activities involved in assessing COMPs is shown in Figure 1. The following provides a summary of the COMPs assessment performed for calendar year 2000 data (SNL, 2001) as an example of the manner in which COMPs are evaluated and compared to trigger values.

Waste Activity

Only a limited amount of waste has been emplaced in the WIPP as of September 2001. A total of 10,851 55-gallon (208-L) drums, 137 Standard Waste Boxes (SWBs), one 85-gallon (322-L) over-pack, and 161 dunnage drums of Contact-Handled (CH) TRU are currently stored at WIPP. No Remote-Handled (RH) waste has been emplaced in WIPP. Panel 1 is currently filled to 16.5% of its total waste capacity. As discussed in the Trigger Value Derivation Report (SNL, 2000b), Waste Activity COMPs assessments are not performed until half of a panel is filled since small quantities do not yield statistically valid assessments. There are no trigger values for CH activity, only RH. There are no recognized reportable issues associated with this COMP. No changes to the monitoring program are recommended.

Drilling Rate

Since the CCA, the drilling rate has risen from 46.8 boreholes/km^2/10,000 years to 52.2 boreholes/km^2/10,000 years. Based on the trend line, the trigger value of 53.5 boreholes/km^2/10,000 years could be exceeded within one or two years. However, indications from data collected in the past several months are that drilling activity in the Delaware Basin is tapering off. By using the current method for calculating drilling rates that is based on a rolling 100-year window, the rate to be determined in the next several years cannot decrease even if all drilling activity were to stop. Because the first well was drilled in the area in 1911, it will be 2011 before one well is dropped from the count and 2014 before the next well is dropped from the count. In the meantime, numerous wells will have been added, driving up the drilling rate. For this reason, other methods and approaches are being investigated to derive a more meaningful trigger value. Some of the approaches that may be considered include using a rate change as the trigger indicator or using a different rate calculation that uses all data and more than a 100-year window for the COMP.

Probability of Encountering a Castile Brine Reservoir

A total of 27 Castile brine encounters had been reported at the time of the CCA. Since that time, no further encounters have been reported in drilling records submitted to the State of New Mexico in 2000. However, two brine encounters were reported to WIPP site personnel by area drillers that were not reported in the state drilling records or in the annual surveys.

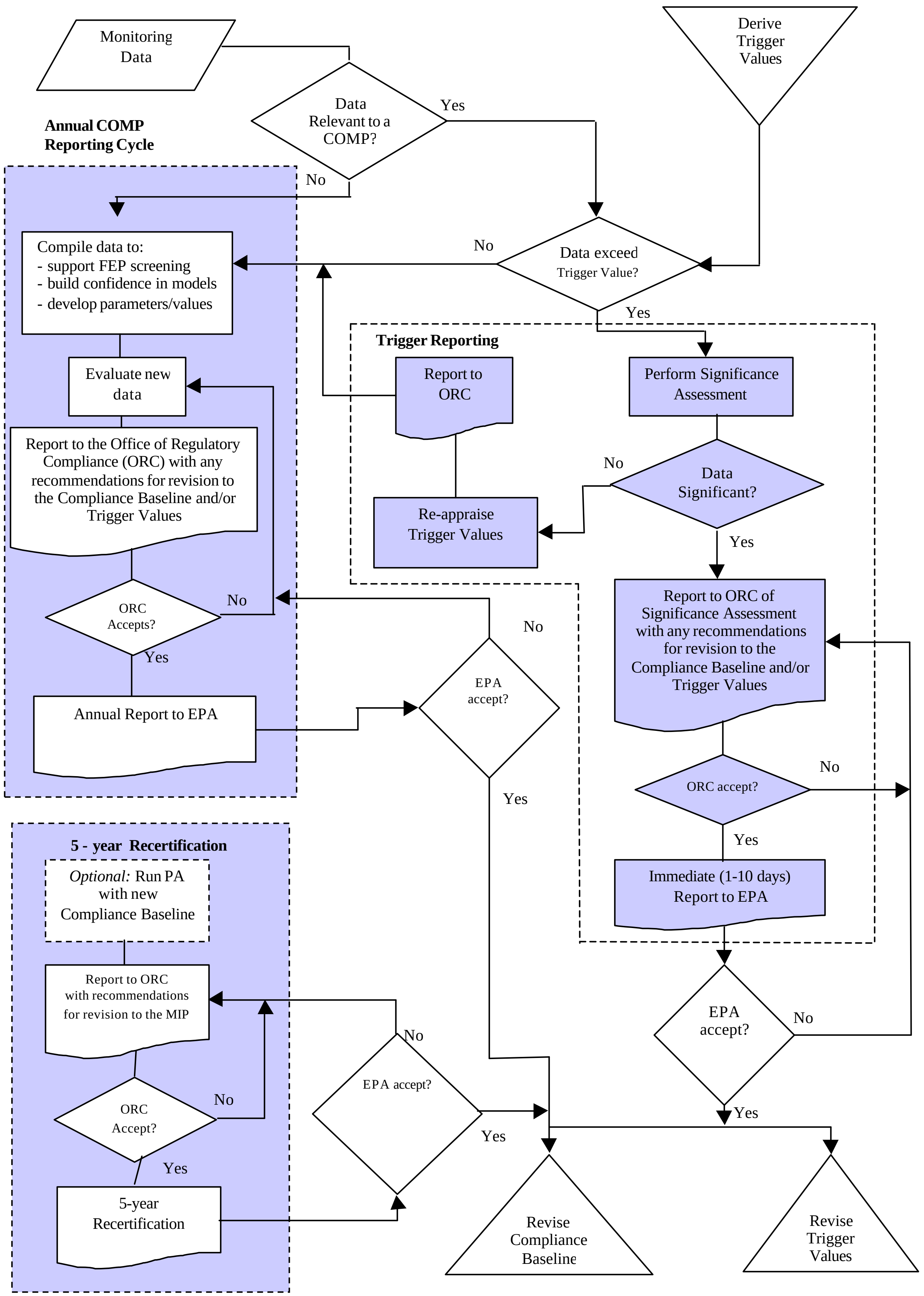

Figure 1. Activities Evaluating and Reporting Compliance Monitoring

Changes in Culebra Groundwater Flow

Water levels were monitored in 28 of the 32 Culebra wells used for CCA T field calibration in 2000. Heads in 17 wells were higher than the CCA ranges, although this conclusion is not certain for 11 of the wells until the results of new pressure-density surveys are available. Heads in seven wells were within the CCA ranges. Heads in four wells were affected by casing and/or packer problems and, therefore, not considered representative of Culebra conditions. Sandia has initiated a comprehensive investigation to determine the cause(s) for the changes in water levels in the Culebra.

Changes in Culebra Groundwater Composition

Two rounds of sampling (Rounds 10 and 11) were conducted in the six WQSP Culebra wells during 2000. All major ion concentrations were within the 95% confidence intervals (CI's) established from the baseline sampling rounds except:

- WQSP-1: 1 Round 10 Ca value high
- WQSP-2: 1 Round 10 Ca value and both Round 11 K values high
- WQSP-3: both Round 10 HCO_3 values high
- WQSP-4: 1 Round 11 Na value low
- WQSP-5: 1 Round 10 Na value low
- WQSP-6: 1 Round 10 and 1 Round 11 Mg values high

Duplicate analyses are performed for all samples, so the single values outside the 95% CI's probably represent analytical error compared to the duplicate values that were within the 95% CI's. In the case of the Round 10 analyses falling outside the 95% CI's, the conclusion of analytical error is supported by the Round 11 values lying within the 95% CI's. Special attention will be paid to the ions whose Round 11 values lay outside the 95% CI's in subsequent sampling rounds. We conclude that no significant changes in groundwater composition have occurred.

Subsidence

The maximum subsidence observed at the ground surface is 0.05 m. The maximum subsidence rate in 2000 was 0.006 m/yr (occurred at only one benchmark) compared to a trigger value of 0.01 m/yr. The subsidence "trough" currently extends 300 to 460 m from the repository footprint (vertical projection of excavations to the surface).

Creep Closure

In the shafts and shaft stations, creep rates in 2000 were about the same as in 1999. In the Northern Experimental Area, creep rates were lower than in 1999 except at one location where the halite beds in the roof may be separating from the overlying anhydrite beam. In the access drifts and waste-disposal area, most creep rates are within ±20% of 1999's rates. Some locations have seen more than a 40% increase over 1999's rate, but none have exceeded 100%. These rate increases are attributed to the mining of Panel 2 in 2000.

Extent of Deformation

Brittle deformation extends upward at least 2 m (possibly as much as 4.5 m), downward approximately 2-3 m, and laterally 1 to 2 m (possibly out to 4 to 6 m). We are unable to determine a rate of change because data are available from only a "mature" opening, essentially representing a single snapshot in time, although a mine-by experiment with acoustic-velocity measurements may provide useful data. For PA, we need to correlate the extent of deformation with permeability. The trigger value for this COMP (growth of 1 m/yr) may need to be reevaluated.

Initiation of Brittle Deformation

Initiation of brittle deformation around WIPP openings is not being directly measured and is therefore a qualitative observational parameter. By definition, qualitative COMPS can be subjective and are not prone to the development of well-defined trigger values. Brittle deformation eventually leads to features that are measured as part of geotechnical monitoring requirements, such as the extent and displacement of deformation features. Initiation of brittle deformation is expected to begin immediately upon creation of an opening. Initiation and growth of damaged rock zones are important considerations to operational period panel closures as well as compliance performance assessment calculations. Because initiation of brittle deformation is not readily quantifiable within the geotechnical monitoring system currently deployed at the WIPP, either additional monitoring techniques could be suggested (such as acoustic emission) or another parameter could be identified for monitoring.

Displacement of Deformation Features

This COMP involves visual observation in boreholes (7.6-cm diameter) drilled normal to features such as bedding contacts and fractures where differential movement is causing the features to slide past one another, gradually occluding the borehole. A total of 225 features are being observed in 142 boreholes. A percentage occlusion is estimated visually at regular intervals. To date, 23 features (about 10%) have fully occluded the boreholes (i.e., exceeded TV) and eight more have 75% occlusion. Fully occluded boreholes are typically about ten years old. Fully occluded boreholes have not compromised the safety of WIPP openings and existing ground control measures are adequate. Because occlusion depends on borehole diameter and the time when the borehole was drilled relative to the age of the excavations, the TV may need to be revised.

Conclusions

The only COMP showing values outside the expected ranges pertains to changes in Culebra groundwater flow, for which 17 of 28 wells showed anomalous water levels. An investigation into the causes and impacts of these changes is underway. Other COMPs are being re-evaluated in terms of their suitability and/or meaningfulness as monitoring parameters. Some COMPs may be deleted from the monitoring program, or replaced with more suitable parameters. Trigger values might also be revised.

7. Post-Closure Monitoring Activities

Post-closure monitoring is required by the EPA and serves an assurance role. Post-closure monitoring will demonstrate that the disposal system is continuing to behave as predicted, contributing to technical and societal confidence in the repository.

The DOE proposed a post-closure monitoring program in the CCA that would represent a program that would be put in place if the site were to be closed at the time of the application. The proposed post-closure monitoring program represents a continuation of the operational monitoring program, including the five of the ten COMPs that can continue to be monitored after closure of the repository. However, the DOE recognized that many advancements in technology and the state of knowledge of the site, as well as regulatory changes, would occur during the thirty-five year operational lifetime of the WIPP that could make parts or all of the proposed monitoring program obsolete. Thus, the DOE stated that a closure review study would be performed during the late operational phase of the WIPP that assesses the condition of the facility at closure. The study will:

- Evaluate the post-closure monitoring plan, the data generated during the operational and closure phases, and regulatory requirements at the closure date;
- Update the post-closure monitoring program;
- Evaluate the necessity for continued monitoring and determine the appropriate repository parameters to be monitored; and
- Revise the post-closure monitoring schedule to account for any necessary changes based on the study findings.

The DOE has established six criteria that any post-closure monitoring system must meet:

- The system design shall be as human-independent as possible;
- The system must endure the conditions posed by the natural environment;
- The system must be cost-effective;
- The system must not require unreasonably large support facilities;
- The system shall require minimal maintenance and power requirements; and
- All components susceptible to vandalism shall be secured from public access.

The design of the post-closure monitoring program will depend in part on the data obtained during pre-closure monitoring. Current plans are to monitor:

- Drilling activities
- Groundwater levels and composition
- Surface subsidence
- Environmental radiological concentrations

The specific technologies to be used for post-closure monitoring are unknown at the present time. The pre-closure monitoring programs are continually evaluating new measurement techniques and instruments, and adopting those that are most practical. This practice is expected to continue for the duration of the project.

Monitoring of groundwater levels and composition will continue for a minimum of 30 years after closure. Radiological monitoring of biota and sediments will be performed for two years after decontamination and decommissioning (D&D), and of soil, surface water, and airborne particulates for five years after D&D. Monitoring of other parameters will continue for as long as practicable during the period of active institutional control (=100 years), and/or until the DOE can demonstrate to EPA that there are no significant concerns to be addressed by further monitoring.

The post-closure monitoring program will also have to be responsive to societal concerns at the time of closure.

8. Summary and Conclusions

The WIPP monitoring program is driven by regulatory requirements from EPA. Monitoring is conducted to detect deviations from expected performance. Monitoring parameters (COMPs) were selected either because they affect the system's ability to contain waste or the ability to predict the future behavior of the system. COMPs were also selected to build on existing WIPP monitoring programs. Ten COMPs were selected: one related to waste activity, two related to human intrusion, two related to far-field hydrology, and five related to geomechanics. Trigger values were defined for most COMPs to indicate a condition that merits further investigation, not necessarily an out-of-compliance condition. Trigger values can represent events, trends, criteria, rates, probabilities, ranges, conditions, or a specific value and may be tied directly to performance or to FEPs screening and modeling assumptions. COMP values are compared to Trigger Values no less often than annually. COMPs and trigger values are expected to evolve with time as additional data are collected and the utility of the information collected is assessed.

Monitoring data are reported annually and with each Compliance Recertification Application as evidence that the repository system is behaving as predicted in PA. Monitoring data may be used to re-evaluate and improve models. Where deviations from expected performance are observed, monitoring data may be used to revise the PA's conceptual and numerical models.

A post-closure monitoring program will be defined at the time of repository closure, based on the condition of the facility at closure and the regulatory requirements at that time. At a minimum, the post-closure monitoring program will include monitoring of drilling activities, groundwater levels and composition, subsidence, and environmental radiological surveillance. Post-closure monitoring must continue throughout the period of active institutional control of the site or until the DOE can demonstrate to the EPA Administrator "that there are no significant concerns to be addressed by further monitoring."

Section 2: WIPP Passive Institutional Controls and Recording Keeping

1. Introduction

The United States Environmental Protection Agency (EPA) established the requirements for Passive Institutional Controls (PICs) in 40 CFR §191.14(c). Specifically, 40 CFR §191.14(c) requires that:

> "Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location."

In 1994, the Department of Energy (DOE) created a task force to comply with 40 CFR §191.14(c), regarding the proposed PICs. The PIC Task Force assessed the effectiveness of PICs in deterring inadvertent human intrusion. The PIC Task Force developed a conceptual design for permanently marking the Waste Isolation Pilot Plant (WIPP), establishing records, and identifying other practicable controls to indicate the dangers of the wastes and their location.

In February 1996, the Environmental Protection Agency (EPA) published 40 CFR 194, *Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations*. 40 CFR §194.43 states the criteria for PICs as:

(a) Any compliance application shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location, design, and contents of the disposal system. Such measures shall include:

(1) Identification of the controlled area by markers that have been designed, and will be fabricated and emplaced to be as permanent as practicable;

(2) Placement of records in the archives and land record systems of local, State, and Federal governments, and international archives, that would likely be consulted by individuals in search of unexploited resources. Such records shall identify:

(i) The location of the controlled area and the disposal system;

(ii) The design of the disposal system;

(iii) The nature and hazard of the waste;

(iv) Geologic, geochemical, hydrologic, and other site data pertinent to the containment of waste in the disposal system, or the location of such information; and

(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.

(3) Other passive institutional controls practicable to indicate the dangers of the waste and its location.

(b) Any compliance application shall include the period of time passive institutional controls are expected to endure and be understood.

(c) The Administrator may allow the Department to assume passive institutional control 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.

The EPA requires the use of passive institutional controls (PICs) to discourage future generations from inadvertently intruding into the WIPP waste repository and the contiguous 16 sections. The controls are to include markers, records, archives, and government ownership and land-use restrictions. The PIC Task Force determined that the marking system should provide information regarding the location, design, contents, and hazards associated with WIPP. In November 1990, EPA stated that "...permanent markers will be necessary in fact, they are required under 40 CFR 191 subpart B".

2. Passive Institutional Controls

2.1 PURPOSE

The purpose of PICs is to communicate to potential intruders:

(1) information about the existence and location of the repository,
(2) the wastes buried there,
(3) the nature of the hazard the wastes represent, and
(4) the goal of not disturbing the disposal system.

The distinction between active and passive controls is in the nature of the deterrence. PICs differ from Active Institutional Controls (AICc) in that the warning, rather than an institution, is the deterrent. A fundamental assumption about nuclear-waste disposal is that if future generations have and understand the appropriate information, they will not intrude into the repository or disturb the remainder of the disposal system. With the use of PICs, the danger to the larger area outside the repository footprint is of impacting groundwater flow and possibly affecting radionuclide transport from the disposal facility toward the biosphere.

Documentation for PIC requirements is given in:
(1) 40 CFR 191: “Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste, Final Rule”, Dec. 1993.
(2) 40 CFR194: “Criteria for the Certification and Re-certification of WIPP’s Compliance with the 40 CFR Part 191 Disposal Regulations” Feb. 1996.

2.2 REQUIREMENT FOR PASSIVE INSTITUTIONAL CONTROLS

Passive Institutional Controls (PICs) are required by the EPA regulation 40 CFR §191.14 (c) which states:

> "Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location." (50FR38086c/EPA, 1985)

In §191.12, the EPA defines PICs as

> "(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." (50 FR 38085c/EPA, 1985)

DOE developed a WIPP-specific 40 CFR Part 194 (EPA, 196c) that establishes the requirement for PICs and the permission for the Performance Assessment (PA) to take advantage of the PICs to reduce drilling and mining frequencies. DOE may take credit for the PICs in deterring inadvertent human intrusion into the WIPP facility and disposal system in the Performance Assessment (PA) calculations for the Compliance Certification Application (CCA). DOE supports this action by indicating that EPA intended for the implementing agency to take credit for the effectiveness of PICs in deterring inadvertent human intrusion:

> "The Agency [EPA] believes that the most productive consideration of inadvertent intrusion concerns those realistic possibilities that may be usefully mitigated by repository design, site selection, or use of passive institutional controls (although passive institutional controls should not be assumed to completely rule out the possibility of intrusion)." (50 FR 38089a/EPA, 1985)

and

> "Not allowing passive institutional controls to be taken into account to some degree when estimating the consequences of inadvertent human intrusion could lead to less protective geologic media being selected for repository sites." (50 FR 38080b,c/EPA, 1985*)*

Concurrently, §194.26 establishes requirements on the use of expert judgment and indicates that expert judgment would probably be used to assess the effectiveness of PICs in inadvertent human intrusion into the disposal system.

2.3 CRITERIA FOR PASSIVE INSTITUTIONAL CONTROLS

40 CFR §194.43(a) applies to and requires a description of the proposed PICs:

> "Any compliance application shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location, design, and contents of the disposal system. Such measures shall include: (1) Identification of the controlled area by markers that have been designed and will be fabricated and emplaced to be as permanent as practicable." (61FR5243c/EPA,1996c)

In addition, §194.43(b) requires that an assessment of the term of effectiveness of the PICs must be undertaken:

> "Any compliance application shall include the period of time passive institutional controls are expected to endure and be understood." (61 FR 5243c/EPA, 1996c).

2.4 REASONABLE-EXPECTATION REQUIREMENT FOR PICs

WIPP’s compliance with the disposal standards will be determined by “reasonable expectation” as given in the Supplementary Information to 40 CFR 191.

"The containment requirements call for a 'reasonable expectation' that their various quantitative tests be met. This phrase reflects the fact that unequivocal numerical proof of compliance is neither necessary nor likely to be obtained. A similar qualitative test, that of 'reasonable assurance,' has been used with NRC regulations for many years.”

Because the effectiveness of the PICs are an integral part of the PA calculation used to address the Containment Requirements, the reasonable-expectation requirement also applies to the estimation of the effectiveness of PICs. DOE interprets the reasonable-expectation language as meaning that absolute proof of the longevity of a marker, a records system, or a message is neither achievable nor required to take credit for PICs in the PA calculations.

2.5 DESIGN REQUIREMENTS/CRITERIA FOR PERMANENT MARKER SYSTEM

Design requirements were developed for DOE Carlsbad Area Office (CAO) by Westinghouse based upon applicable regulations and "Expert Judgment on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant." (Trauth et al., 1993)

2.5.1 Guiding Principles

The guiding principles for the conceptual design of the permanent marker system include:

(1) The site is marked

(2) Message(s) are truthful and informative

(3) Multiple components exist within a marker system

(4) Multiple means of communication (e.g., language, pictographs, scientific diagrams) are provided

(5) Multiple messages with differing levels of complexity between messages are inscribed on individual marker system elements

(6) Materials with little recycle value are used

(7) Compliance with international standards of marking locations and contents of nuclear waste repositories

These principles have been followed to the extent practicable with the exception of the last. The last principle is not achievable at this point in time since no international standards exist.

2.5.2 Permanent Marker System Design Requirements

The Permanent Marker System design requirements were developed for DOE Carlsbad Area Office (CAO) by Westinghouse based upon applicable regulations.

(1) The marking system should provide a reasonable expectation that the site will be uniquely marked and such marking will be the most permanent practicable. The system must also provide for marking the controlled (withdrawn) area. It is recognized that experience gained during the first 100 years may result in marker system modifications to improve the endurance capability of the system.
BASIS: Title 40 CFR Part 191, 40 CFR 194: The period of regulatory interest is 10,000 years.

(2) The site must be marked in such a manner as to provide reasonable assurance that the marker's purpose cannot be mistaken or its intended message misinterpreted. The

system should include a combination of surface and subsurface markers
BASIS: Expert panel judgment to account for possible removal of surface markers and effects of erosion for uncovering subsurface markers

(3) The marking system must include the concept of "defense in depth" which implies redundancy by way of its physical design and message delivery concepts
BASIS: Expert panel judgment and a common design philosophy of the nuclear electric generating station industry.

(4) Materials comprising the marking system should have as little intrinsic value as is reasonable to minimize the likelihood of future generations salvaging the material for recycling purposes
BASIS: Expert panel judgment.

(5) The marking system on the surface should encompass the grade level equivalent of the entire waste storage footprint (waste filled panels and drifts) but not exceed the footprint by more than 10% in area
BASIS: Engineering judgment.

(6) The message delivery components should provide a means of communicating with reasonable expectation the what, when, who, why, and how essentials of the WIPP program to future generations and should include an assortment of symbolic, pictographic, linguistic, narrative, diagrammatic, scientific, and astronomic messages
BASIS: Expert judgment.

(7) The marker system should be constructible with available technology and its construction should be cost effective
BASIS: Engineering judgment in response to the Title 40 CFR 191 requirement to provide the most permanent markers practicable.

(8) Information regarding the location, design, contents, and hazards associated with the WIPP should be archived domestically and internationally so as to be accessible by individuals or organizations having an interest in exploiting potential resources at the WIPP site.
BASIS: Expert judgment.

2.5.3 Permanent Marker System Design Criteria

Design criteria for the Permanent Marker System were developed based upon the Design Guidelines and Requirements. The following design criteria were established:

2.5.3.1 Provide a system for marking the disposal area footprint on the surface through use of berms and monuments:

(1) Berms
(a) Berm dimensions should be a minimum of 30M (100 feet) at the base and a minimum 10M (33 feet) high. Berms should be massive enough to withstand

human and natural forces and accommodate a roadway during construction.

(b) Berm slope should be at least 1.3 horizontal to 1.0 vertical. Slopes are designed to minimize erosion.

(c) Berm should be mechanically packed. Packing provides a mores stable structure and minimizes slumping.

(d) Berm should provide a dielectric or magnetic anomaly when compared to the local surface characteristics.

(e)Configuration of the berm marker should provide for observation of the entire marked area from any point on top of the berm adjacent to the marked area.

(f) To the extent practicable local material should be used for the majority of the berm structure.

(2) Monuments

(a) Granite is the material of choice for the monuments. (Also, basalt was suggested, however, no source of large basalt monoliths were identified

(b) Monuments should be at least 7.5M (25 feet) high. Monuments should be high enough to prevent being covered migrating sand dunes.

(c) Monuments should include a minimum 20 tons continuous mass (no bonding materials between components for individual monuments). This is sufficiently massive to withstand the effects of vandalism and possible removal.

(d) The total number of perimeter marking monuments should be a power of 2. This will allow for the future reconsruction of the original monument configuration if necessary.

(e) The spacing between monuments should be such that an average individual standing adjacent to one monument will be able to see the monuments on either side.

(f) To the degree practicable, monument material should be relatively unaffected by anticipated environmental and climatic conditions, minimizing these effects.

(g) The monument messages shall be engraved to a depth of at least 1cm. Birkeland, 1984 reports weathering rinds of granitic rocks in the Central Sierra Nevada, CA at 1.7 mm at a 10,000-20,000 year estimated age.

2.5.3.2 Subsurface Warning Markers will be placed throughout the footprint of the disposal area.

(1) Granite is the material of choice for the subsurface warning markers.

(2) Warning markers shall be less than 0.6M (2 feet) in the longest dimension providing sufficient size to carry a warning message.

(3) Marker material should be inert with respect to the local environmental conditions at the depth at which they are buried to minimize potential marker degradation from chemical attack.

(4) Burial depth should be greater than deep plowing/tilling or that expected to be dug by amateur archaeologists. This should minimize loss due to inadvertent uncovering or vandalism.

(5) The warning message shall be written in Spanish, English, Russian, Chinese, French, Arabic, and Navajo, with the distribution of the seven languages evenly spread among all the buried warning markers.

(6) Marker spacing should be such that their discovery has a high probability under conditions currently anticipated to be created by drilling crews and professional archaeologists. However, spacing should be random to minimize excessive loss through vandalism and/or souvenir collection efforts.

2.5.3.3. Provide for detailed complex information storage:

(1) Structures for the permanent storage of detailed and complex information relating to the repository location, contents, and associated hazards shall be constructed.

(2) Buried and surface structures shall be provided. Provide a reasonable expectation that complex information is available through redundancy and varying locations.

(3) The structural material shall be inert and sufficiently durable to provide a high degree of protection for the stored information. The buried storage room will be constructed of granite.

(4) Stored written records, tables, figures, graphs, maps, and diagrams shall be engraved in stone or man-made materials having the durability to retain the engraved information over extended periods of time. and engineering judgment based upon ancient analogues of stone structures (e.g. Stonehenge, the Pyramids, the Acropolis).

(5) Entry to buried structures shall be designed to preclude removal of the stored information by curious individuals. Removal should require a concerted effort by a well financed and technically competent organization.

(6) Concrete for encasement of radar reflectors and berm stairway shall be in accordance with the Building Code requirements for Reinforced Concrete (ACI-318, latest edition) with special emphasis on durability, (ACI-201.2, Guide to Durable Concrete).

2.5.4 Permanent Marker System Message Criteria

Five levels of messages will be used in the Permanent Marker System as including:

(1) Message Level I: This level indicates that the site is manmade. The message itself is in the physical form of the marker system and the effort expended in constructing it.

(a) Message Level I includes: the earthen berm, granite monuments, and information center

(b) Physical size should convey the concept that the structure is a manmade facility, which required a significant amount of effort to build.

(2) Message Level II: This level not only conveys the cautionary information that something manmade is here,but also it is dangerous.

(a) The Level II mesage is a 3-part message:

i. Part 1: large "DANGER" caution:

1. contains graphic symbols of danger, defined as waste that is both poisonous and radioactive.

2. In the message, the Trefoil symbol is used in association with the trms "radioactive" and "radioactivity"

3. The Biohazard symbol is used with the Terfoil on the monuments and the small subsurface warning markers

ii. **Part 2: Caution not to dig or drill beacuse of radioactive waste.**

iii. Part 3: facial expressions showing horrorand terror and/or a face showing tha something is nauseating and poisonious.

(b) This message is carried in seven languages uniformly distributed among the subsurface warning markers. Each marker has the message in a single language.

(c) The level II message is engraved in granite on each footprint perimeter monument in seven languages.

(3) Message Level III: This message level conveys basic information that tells what, why, when, where, who, and how. This message is engraved on the footprint perimeter monument markers. This message provides more information on

(a) What is buried, size of the area in which digging or drilling should be prohibited, and at what depth the radioactive waste is located,

(b) When the repository, WIPP, was closed and the intent was to preserve the warning information for 10,000 years,

(c) A request to update the message and/or the marker system to add long lasting material and/or messages written in languages more current to the times.

(d) In addition, Message Level II and III will contain two additional diagrams on the perimeter monument, which are intended to mitigate the effects of language changes. These diagrams convey a cautionary message of

(i) Pictorially conveying the danger of digging or drilling into the repository
(ii) Provide a method to determine how long WIPP has been closed and convey the decreasing nature of the danger over a period of thousands of years.

(4) Message Level IV: This level, given in 7 languages, provides the most comprehensive and complex message located at the WIPP site   The message gives a detailed written record of the WIPP Repository. It should include maps, diagrams, figures and tables. This message will be housed in the Information Center, in a room buried within the berm in controlled area outside the repository footprint. The Information Center will be constructed of solid granite walls embedded 1.5m into compacted caliche for support. The Level IV message, in seven languages, will be engraved on the walls. In addition it will also contain a message containing the location of the controlled area buried Storage Room.

(a) It describes the potential leakage path for radioactive material through ground water should deep drilling occur

(b) It specifies the disease cancer as the potential human impact from radiation poisoning and explains that cancer is a long term result

(c) It specifies the particular radioactive isotopes, their individual quantities, and the hazardous chemicals which were originally buried It identifies that the U.S. Government was responsible for this long term solution of isolating waste derived from its nuclear weapons making activities

(d) It describes why the Salado formation was chosen as the repository site

(e) It describes the general layout of the repository and the original configuration of the emplaced waste

(f) It gives an explanation of the diagram showing the four brightest stars at the time of burial of the waste including their azimuth angles to provide an independent means for future generations to determine when the waste was buried

(g) It provides an explanation of the diagram showing the precession of the north celestial pole through constellations and the diminution of the radioactive waste with time

(h) It provides an equivalency of the year of [i]WIPP closure with five other calendar dates

(i) It provides an explanation of the diagrams associated with the Level IV message

(j) It urges the reader to check the other locations around the world where radioactive wastes are buried for consistency with the markings used at the

WIPP and the basic criteria used for establishing the message character and protection of the message

(5) Message Level V: This is an archival message stored at various state, federal, and international archives. This message is more detailed than the message stored at the site as it contains a complete “rulemaking” record. A less detailed version of this record addressing location, design, hazards, test/experiment results, and pertinent site data will be located in record centers at the local, state, and federal level.

2.6 INADVERTENT HUMAN INTRUSION

2.6.1 Definition

Inadvertent human intrusion includes any activity that disrupts the disposal systems. These intrusions include drilling and mining for natural resources, both exploration and development.

2.6.2 Area of Concern

“The most speculative potential disruptions of a mined geologic repository are those associated with inadvertent human intrusion." (50 FR 38088c/EPA, 1985)

Title 40 CFR §194.33(a) states that:

> “Performance assessments shall examine deep drilling and shallow drilling that may potentially affect the disposal system during the regulatory time frame." (61 FR 5242b/EPA, 1996c).

This means that "human intrusion" is not limited to events that actually penetrate the repository, but includes a broader list including shallow drilling and excavation mining. By this definition, human intrusion (drilling) must be considered to occur anywhere in the Withdrawal Area- within the footprint or within the Withdrawal Area outside the repository footprint. EPA states that PICs may reduce the likelihood of inadvertent human intrusion, that is PICs may be useful in deterring these other activities, as well as drilling and mining for natural resources.

2.6.3 Deterring Inadvertent Human Intrusion

The requirement for PICs is to protect against the inadvertent human intrusion:

The EPA has included provisions in 40 CFR 194.33(b)(1) that limit consideration of intrusion into the disposal system to inadvertent drilling:

> "Inadvertent and intermittent intrusion by drilling for resources (other than those resources provided by the waste in the disposal system or engineered barriers designed to isolate such waste) is the most severe human intrusion scenario." (61 FR 5242b/EPA, 1996c)

This provision allows for the assumption that the message of the PICs is to be directed at discouraging those efforts to locate and exploit natural resources. Under this assumption, individuals locating and conducting drilling operations will avoid intruding into the repository and disturbing the disposal system if warning messages against intruding and disturbing are correctly conveyed to future generations. If, however, a potential intruder realizes that a drilling or mining activity may intersect the repository or the Withdrawal and understands the associated risks, but decides to intrude anyway, the intrusion is not inadvertent. Intentional intrusions are not to be considered in the PA calculations."

2.7 OFFSITE ARCHIVAL STORAGE OF WIPP INFORMATION

2.7.1 Definition of Archive

An archive is "a place in which public records or historical documents are preserved". This definition implies control of the environment, control of access to the records and documents, and control/selection of the storage medium. A significant part of the overall plan to provide PIC is the distribution of important information remote from the repository for preservation. This information will be broader in scope and more extensive in volume than that available within the permanent marker system at the repository footprint location or record centers and should be widely distributed in a number of locations including some locations worldwide.

2.7.2 Type of WIPP Information to be Archived

The archived WIPP material should include information that is important to defining the location, design, content, and hazards associated with the WIPP. The documentation addressing the details of the WIPP site is extensive and quite voluminous.

2.7.3 WIPP Summary Document

The DOE will develop a WIPP summary document to ensure that access to the most pertinent location, potential hazards of intrusion, and land use restrictions information is readily available, This document will be distinctively bound. The receiving archive will be requested to locate and catalog this summary volume such that it is readily available to the general public with particular emphasis on availability to potential natural resource investigators, historians, and archaeologists.

2.7.4 Multiple Languages

These summary documents will be prepared and translated into the six recognized United Nations languages. The receiving archive will determine which language version shall be archived.

2.7.5 Media for Archiving WIPP Documents

The initial form of the information should be on archival quality paper. Paper will be specified to meet or exceed the requirements of National Archives and Records Administration (NARA) Bulletin Number 95-7 (Bechtold, 1996) or ANSI/NISO Z39.48-1992 (or latest version), Permanence of Paper for Documents and Libraries to ensure that the stored records will have a maximum opportunity of surviving for thousands of years. In addition, offset printing using an oxidizing, carbon black ink with a buffered fountain solution (pH >5.5) or equivalent will be specified.

Careful consideration should be given to the implications of permitting electronic storage technologies as archival storage mediums. No experience with the long term storage capabilities of the electronic technologies exist today. In addition, the equipment to read back these technologies could be lost in the future as new products become available.

2.7.6 Specific Documents to be Archived

Specific documents that should be included in the archived information portfolio to address the requirements of the regulations include:

(1) The Final Safety Analysis Report (FSAR) and the addenda that describes the disposal phase of the WIPP.

(2) The Final Environmental Impact Statement for WIPP and the Supplement(s) to the Environmental Impact Statement

(3) The No-Migration Variance Petition and the No-Migration Determination for Disposal

(4) The Resource Conservation and Recovery Act (RCRA) Permit

(5) The Certification of Demonstration of Compliance with Title 40 CFR 191

(6) Environmental and ecological background data collected during the pre-operational phase of WIPP and summaries of data collected during the disposal and decommissioning phases of WIPP

(7) Records of the waste containers contents and disposal locations within the WIPP repository

(8) Drawings defining the construction and configuration of the repository and shafts

(9) Drawings, procedures, and the design report(s) describing how the waste was emplaced; how the rooms, drifts, and panels were closed; and how the shafts were backfilled and sealed.

(10) Detailed maps describing the exact location of the repository

(11) Design, drawings, specifications, (etc.) for Permanent Markers.

2.7.7 Locations for Archival

Locations for this information should include public funded organizations which may be more likely to expend the resources necessary to preserve the documents in well controlled environments. However, the most likely strategy for long-term protection of the information is through widespread distribution. The DOE will strive to reach agreements for accepting and archiving the provided documents with the following facilities/organizations:

(1) National Archives and Records Services

(2) The State Archives of New Mexico and Texas

(3) The national archives of the nations worldwide which possess nuclear weapons and/or operate nuclear power generating

(4) The archives of the United Nations

(5) The national archives of the world nations which possess natural gas and/or petroleum resources and are not included in the list of nations have nuclear weapons/nuclear power plants

2.7.8 Proper Storage and Retrievability

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 DOE will provide to the various archival locations. As described above, the paper used to print the submitted documents will be archival quality.

2.7.8 Length of Intended Preservation

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 United States 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.

2.8 DISTRIBUTION OF RECORDS OF THE KNOWLEDGE OF WIPP TO RECORDS CENTERS AND OTHER ENTITIES

2.8.1 Definition and Purpose of Record Centers

Record centers are locations that would generally permit freer access by members of the public and not normally exercise the degree of environmental control and information medium selection to be found in modern archives. Many of the centers would also not receive the same quantity of information allocated to archives.

In that the record centers normally serve a more functional nature than do archives for individuals explicitly interested in resource exploitation rather than historical or archeological information, a smaller volume of documentation will be provided. Information provided to these record centers should be focused on location, design, and hazards information.

2.8.2 Record Centers

The record centers should include various Federal and State libraries/agencies and commercial mapping agencies to ensure that the [ii]WIPP location and drilling or mining restrictions are identified on widely distributed maps used by almost all public and private organizations. These Federal and State Libraries/agencies include:

(1) The New Mexico and Texas State Libraries

(2) The City Libraries of population centers exceeding 15,000 within 150 miles of the [iii]WIPP site

(3) The U.S. Nuclear Regulatory Commission

(4) The 53 Federal Regional Depository Libraries

(5) The state libraries of the remaining 48 states

(6) Bureau of Land Management

(7) U.S. Geological Survey

(8) Library of Congress

(9) Defense Mapping Agency

(10) International Boundary Commission

(11) Federal Highway Administration

(12) New Mexico State Highway Department Planning and Research Division, Cartography Section

(13) One-Call System of notification of underground utilities

(14) The local office of the Bureau of Land Management

(15) The local office of the Bureau of Mines

(16) The local office of the Bureau of Reclamation

(17) The Federal records center in Denver, Colorado

(18) The Hobbs and Artesia offices of the New Mexico Oil Conservation Division (OCD)

(19) Supporting University Libraries (i.e., New Mexico Tech, New Mexico State University, University of New Mexico, and Texas A&M)

2.8.3 Quantity of Documents

It is intended that the quantity of documents provided to record centers be significantly reduced from that provided to archives. However, the information regarding design, location, hazards, and land use restrictions will still require a significant amount of storage shelf space. As with archival documentation, information provided to record centers will contain the admonition to preserve these records for the regulatory time frame. The record centers will be provide with a copy of the WIPP summary document. The receiving record centers will be requested to locate and catalog this summary volume such that it is readily available to the general public with particular emphasis on availability to potential natural resource investigators, historians, and archaeologists.

2.8.4 Other Entities

To ensure wide spread location information of the [iv]WIPP site and the hazards associated with the emplaced waste, detailed maps and descriptions of the hazardous material will be sent to national and international professional societies of cartographers and geographers. Weitzburg 1982 suggests the following organizations and societies receive this location and hazards information:

(1) The American Congress on Surveying and Mapping

(2) The American Society of Cartographers
(3) The Commission for the Geological Map of the World
(4) The International Cartographic Association
(5) The American Geographical Society
(6) The Association of American Geographers
(7) The International Geographical Union
(8) The Society of Women Geographers
(9) The American Geological Institute
(10) The American Geophysical Union
(11) The American Society of Professional Geographers
(12) The National Geographic Society
(13) The Federal Aviation Administration
(14) Mining, Oil, and Gas Professional Organizations
(15)

The actual distribution of the information will depend on agreements worked out between the DOE and these organizations and societies.

Many of the members of these various organizations are employed in secondary and college education providing an opportunity for this information to become more widely disseminated among students during their formal education. In addition, companies providing energy and resource related data to commercial ventures active in the Delaware Basin should receive location and hazardous record information. Examples of such companies include:

(1) Midland Map Company of Midland, Texas

(2) Petroleum Information Corporation of Midland, Texas
(3) Tobin Data Graphics of Austin, Texas
(4) Dwight's Energy Data of Denver, Colorado

Location and hazards information should be submitted to various Federal and State of New Mexico mapping agencies to ensure that the WIPP location and drilling or mining restrictions are identified on widely distributed maps used by almost all public and private organizations. These agencies include:

(1) Bureau of Land Management

(2) U.S. Geological Survey

(3) Defense Mapping Agency

(4) International Boundary Commission

(5) Federal Highway Administration

(6) New Mexico State Highway Department Planning and Research Division, Cartography Section

(7) One-Call System of notification of underground utilities

2.9 SUMMARY

In May of 1996, a three-member panel of experts was convened to conduct an independent peer review of the PIC systems. They reviewed two documents, the *Effectiveness of Passive Institutional Controls in Reducing Inadvertent Human Intrusion into the Waste Isolation Pilot Plant for Use in Performance Assessments* (WIPP/CAO-96-3168) and the *Passive Institutional Controls Conceptual Design Report.* The peer review panel determined that the marker system was 100 percent reliable with no uncertainty, and that the records/archives controls are highly reliable with no uncertainty.

3. Record Keeping

3.1 BACKGROUND

The purpose of record keeping is to retain the knowledge of WIPP for future generations. One way to accomplish this is to engrave written records, tables, figures, graphs, maps, and diagrams in stone or man-made materials. This information will be in three different storage rooms at the site; two above-ground and one below-ground. In addition to the storage rooms at the site, specific documents will be stored in several different record centers and archives around the world. Records such as the final safety analysis report, the final environmental impact statement, drawings defining the construction of the facility, and detailed maps showing the exact location of the repository will be sent to such places as the U.S. National Archives and Records Administration (NARA), the archives of the United Nations, and the state libraries of all 50 states.

3.2 RECORD-KEEPING REQUIREMENTS

The three main regulatory agencies are NARA, the EPA, and the State of New Mexico. Other stakeholders include the states where the waste now resides, the states the waste travels through, and any Native American reservation the waste travels through. NARA has the final authority on all government records. As such, NARA approval must be obtained before destroying any government record. The State of New Mexico regulates the handling and disposition of hazardous waste at the WIPP under a Permit issued pursuant to the Resource Conservation and Recovery Act (RCRA). The RCRA permit contains many requirements on what records must be created, where they are stored, and the minimum length of time they must be kept. The Environmental Protection Agency regulates the handling and disposition of radioactive waste. The EPA was the government organization that certified that the WIPP could dispose of radioactive waste in a safe manner. In addition to approving the WIPP PIC system, the EPA also has many requirements on what records must be created.

3.2.1 Requirements for WIPP Records Management

Requirements for WIPP records management are given in the DOE Carlsbad Area Office (CAO) Quality Assurance Program Document (QAPD). The QAPD describes the CAO QA program. The document was generated DOE Carlsbad Area Office and all CAO participants must comply. The QAPD specifies requirements for generating, indexing, classifying, and receiving QA records, as well as the storage, preservation, safekeeping, and disposition of QA records.

3.2.2 Other Records Management Activities

Sandia National Laboratories (Sandia) has their own written procedures for processes involving WIPP records. These procedures are NP 17-1, “Records”, and SP 17-1, “Records Center Operations”. These procedures comply with the QAPD, as shown in the NWMP QA Procedures Matrix.

In addition to the stated regulatory requirements, Sandia also sends a monthly report of all newly received records to EEG, including the record and package numbers, titles, authors, and number of pages. This is not a requirement, but is done as a courtesy to the stakeholder. Also, the public has access to SNL’s WIPP records through the Freedom of Information Act. Any member of the public can make a FOIA request. The design of the records system allows for easy searching and retrieval by the Records Staff of requested documents.

3.2.3 New Mexico Stakeholders

According to *40 CFR Part 194 Final Rule*, the EPA held public hearings in Carlsbad, Albuquerque, and Santa Fe during the certification process. Additionally, EPA held meetings with the following stakeholders: New Mexico Attorney General’s Office, New Mexico Environmental Evaluation Group, Concerned Citizens for Nuclear Safety, Citizens for Alternatives to Radioactive Dumping, and Southwest Research and Information Center. All relevant public comments were taken into consideration by the EPA during the certification process. Any concerns that citizens or other stakeholders had about records management and WIPP could have been addressed at this time.

3.3 DESCRIPTION OF THE WIPP RECORD-KEEPING PROGRAM

The final authority over government records is U.S. National Archives and Records Administration (NARA). Volume 44 of the United States Code (44 USC Chapter 21) gives NARA the responsibility for the control of all federal records. NARA requires all federal agencies to follow 36 Code of Federal Regulations (CFR) Subchapter B. This CFR section establishes the regulations for the creation, maintenance, and disposition of all federal records. NARA establishes the life span of federal records by issuing approved record schedules.

There are two types of records in government: permanent and temporary. Permanent records are those deemed so valuable to national history that they are sent to NARA 25 years from the date of creation, or sooner if necessary. NARA accepts full responsibility for stewardship of the records. Temporary records are everything else, and can be destroyed as directed in accordance with an approved records inventory and disposition schedule (RIDS).

At the WIPP, records are generated either on paper or by machine. Records are kept by the record generator until no longer needed for current business use or the instructions for disposition call for them to be transferred to the Carlsbad Field Office (CBFO) Records Holding Facility (RHF). Currently, only paper records are accepted at the RHF. If possible, electronic records are printed and transferred to the RHF. Other electronic records handling procedures are being worked out through the installation of an electronic data management system.

After receipt at the RHF, records with a retention period of more than five years are microfilmed. The microfilm is stored in two locations sufficiently remote from each other to preclude destruction of both sets as a result of a single event such as fire or natural disaster. Records sent to the RHF are indexed and the index is scanned into an electronic retrieval system (ERS). The ERS is used to determine the location of records for retrieval purposes.

To date, no WIPP records have been transferred to any federal records centers, although many have been designated as permanent records and will eventually be turned over to NARA. Temporary records are routinely destroyed according to the date of the approved RIDS accompanying them to the CBFO RHF.

The WIPP is currently researching electronic records management systems to determine the best system available for handling electronic records.

3.4 PROPOSED RECORDS SYSTEM

For each waste container received at WIPP, there are about 3000 sheets of paper documenting the type of waste, the waste stream from which it originated, age, and composition. In addition to the basic waste data, quality assurance records documenting the training and qualifications of the waste handlers are also necessary to ensure the waste has been responsibly managed.

The amount of paper generated for the waste is formidable. It will likely be needed for litigation for many years to come, making retrieval of the records from storage critically important. Not all records are paper—some are radiographs, video and magnetic tapes, and other machine-readable media. All of these will require specialized storage. Although the most logical approach would be to send all these records to WIPP for retention, no budget or mission scope has been assigned to the site to facilitate records acceptance and maintenance.

Two of the sites shipping waste to WIPP are scheduled for closure in 2006: Rocky Flats in Colorado and all Ohio sites (shipping waste via Savannah River). The records for the WIPP waste from these sites will be orphaned when the sites close. Rocky Flats estimates they have 22,400 boxes of records, some classified. In addition, Hanford, Savannah River, and INEEL all want to send their waste records to WIPP as they send the waste here.

CBFO has proposed a non-paper-based records management system to handle the substantial amount of WIPP-related records projected to come to Carlsbad. Using the most current technology available to provide both analog and digital copies of the records, the CBFO will not require the huge amounts of storage currently needed for paper-based records. A 4-drawer file cabinet can be reduced to the size of a 4-inch (10.2-cm) microfiche film cartridge, decreasing the necessary floor space by an order of magnitude. The cost of this technology is estimated to be $0.005/page, and given the current expectation of 375 million pages (WIPP-related records only), all records could be made available electronically for $1.8M. CBFO has located a vendor with the necessary capabilities and experience to build and maintain an electronic database with full OCR text search.

CBFO personnel agree that the most logical place for WIPP-related records is Carlsbad, near the site where the waste will be entombed. The records should be located in town, since taking them to the site for the projected 25 years of operation will present its own problems when the site is remediated and all buildings removed starting in 2025. It makes no sense to build a big facility to house records that have a longer retention period than the lifespan of the facility in which the records will reside.

The advantages to the Department of such a facility in Carlsbad are clear: cheaper land acquisition, several commercial buildings immediately available for occupancy which could be renovated to meet the new National Archives and Records Administration standards, an available pool of workers who wish to stay in the area, a lower cost of living, access by air and highway, FedEx and other overnight courier services, and a DOE facility requiring long-term monitoring and oversight already present and fully supported by the community.

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