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Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment For 2002

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Parameter Assessment for 2002

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Executive Summary

This document reports the fourth annual (2002) derivation and assessment of the Waste Isolation Pilot Plant (WIPP) Compliance Monitoring Parameters (COMPs). The COMPs program is a requirement of the Environmental Protection Agency (EPA) disposal regulations (EPA 1993 and 1996). The concept of deriving and assessing COMPs is explained in Sandia National Laboratories (SNL) Nuclear Waste Management Program Analysis Plan, AP-069 titled: *An Analysis Plan for Annually Deriving Compliance Monitoring Parameters and their Assessment Against Performance Expectations to Meet the Requirements of 40 CFR 194.42* (SNL 2000a).

The Waste Isolation Pilot Plant has many monitoring programs, each designed to meet various regulatory and operational safety requirements. The comprehensive monitoring effort is not under the auspice of one program, but is comprised of many discrete elements. One element was designed to fulfill the EPA requirements found at 40 Code of Federal Regulations (CFR) Parts 191 and 194. The expected performance of the repository was determined through a Performance Assessment (PA) implemented by SNL, the Scientific Advisor (SA), for the Department of Energy (DOE). Monitoring parameters that are related to the long-term performance of the repository were identified in a Sensitivity Study[1] (since these parameters fulfill a regulatory function, they were termed Compliance Monitoring Parameters so that they would not be confused with similar Performance Assessment parameters).

PA is used to predict repository radioactive waste containment performance for the WIPP. COMPs can indicate conditions that are not within PA expectations and may alert the project of a potential conditions not accounted for or expected. COMPs values and ranges were developed such that exceedance of these values would indicate a condition that is potentially outside PA expectations. These values were appropriately termed "trigger values." Deriving COMPs trigger values was the first step in assessing the monitoring data. Trigger values were derived and documented in the *Trigger Value Derivation Report* (SNL 2002a). In some instances a COMP will not have a trigger value because it has been shown to be insensitive to PA results though EPA's sensitivity analysis (EPA 1998).

As the quantity of information in the monitoring database grows over time, it will become more useful for assessing the monitoring program's performance and usefulness. With each annual assessment and knowledge gained through ongoing activities, the basis for assessing COMPs and assigning trigger values will undergo improvements. The Trigger Value Derivation Report was revised in 2002 to include values for groundwater composition and flow COMPs (SNL 2002a). A monitoring program analysis will be conducted periodically to evaluate the effectiveness of the entire compliance monitoring program.

EPA approved ten COMPs: two relating to human activities, five relating to geotechnical performance, two relating to regional hydrogeology and one relating to the radioactive components of the waste. Existing WIPP monitoring programs are used to gather data and information to develop the COMPs. The EPA also requires the DOE to report any negative condition that would indicate the repository would not function as predicted or a condition that is substantially different from the information contained in the most recent compliance application. Annual assessments of

[1] Attachment MONPAR to Appendix MON in the Compliance Certification Application (DOE 1996) documents the analysis of monitoring parameters. The analysis was performed to fulfill 40 CFR 194.42 requirements.

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COMPs will allow the DOE to monitor the predicted performance of the repository and report any condition adverse to the containment performance. This compliance monitoring program is described in greater detail in DOE's *40 CFR Parts 191 and 194 Compliance Monitoring Implementation Plan* (MIP; DOE 1999).

As outlined in the MIP, the Management and Operating Contractor (M&OC), currently Westinghouse TRU Solutions (WTS), is responsible for implementing the monitoring programs that collect and report the monitoring data. The SA is responsible for assessing these data and compiling the results as they pertain to compliance. The SA is also responsible for making recommendations to improve or change the monitoring programs based on the results. This document reports these results and the recommendations based on the calendar year 2002 COMPs assessment. This assessment concludes that the current COMP values do not indicate a condition adverse to the predicted performance of the repository. However, because Culebra water levels are above expected values at some wells, the project has initiated work in 2001 to revise the current groundwater model. These activities continue and will develop an impact assessment for the first Compliance Recertification Application (CRA) and potentially a new groundwater model for the second recertification. Additionally, the trigger value for the drilling rate COMP will be exceeded within a few years. This condition is expected due to the method by which the drilling rate is calculated (as prescribed by EPA). Last, the process used to assess the actinide COMP is expected to be refined due to a request by EPA for related information in the CRA. In all cases, the monitoring data do not indicate a condition for which the repository will perform in a manner other than that predicted in the PA.

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1 Introduction

The WIPP is governed by the EPA's general radioactive waste disposal regulations at 40 CFR Part 191 (EPA 1993) and the implementing WIPP-specific criteria at 40 CFR Part 194 (EPA 1996). Monitoring WIPP performance is an "assurance requirement" (see 40 CFR 1941.14) of these regulations and is intended to provide additional assurance that the WIPP will protect the public and environment. In the WIPP Compliance Certification Application (CCA; DOE 1996), the DOE made commitments to conduct a number of monitoring activities to comply with the criteria at 40 CFR § 194.42 and to ensure that deviations from the expected long-term performance of the repository are identified at the earliest possible time. These DOE commitments are represented by ten COMPs, which are listed in Section 2.

The COMPs are an integral part of the overall WIPP monitoring strategy. The DOE's MIP (DOE 1999) describes the overall monitoring program and responsibilities for COMPs derivation and assessment. Collecting and reporting data from the WIPP monitoring programs are the responsibilities of the M&OC. SNL, as the SA, uses these monitoring data and observations to derive data values which indicate potential issues (termed "trigger values") for the ten COMPs and evaluate the COMPs against performance expectations for the disposal system. The performance expectations are based on scenarios, conceptual models and computational results using the WIPP PA methodology and its associated codes and parameter values that form part of the DOE's Compliance Baseline. The results of the SA's evaluation are reported to the DOE Carlsbad Field Office (CBFO) via the Office of Regulatory Compliance (ORC). This report documents the results of the reporting year 2002 (September 16th 2001 to September 15th 2002) COMPs assessment.

1.2 Monitoring and Evaluation Strategy

The MIP illustrates the process for evaluation of COMP-related monitoring data and observations (Fig 4.2; DOE 1999). Figure 1.1 (of this document) graphically describes the three basic Compliance Monitoring Program elements which include the trigger value generation and reporting function, the annual COMP reporting cycle and the five-year recertification element. The Compliance Monitoring Program is an integrated effort between the M&OC, the SA and the CBFO. The M&OC operates the monitoring systems at the WIPP site and generates the basic data, while the SA is responsible for generating the COMPs from the basic data and assessing the results. The CBFO oversees and directs the monitoring program to ensure compliance with the EPA monitoring and reporting requirements. The SA is also responsible for the development and maintenance of the trigger values. Exceedance of these values represents a condition that requires further actions, but does not necessarily indicate an out-of-compliance condition. Rather, this approach guarantees that any condition adverse to expected repository performance be recognized as early as possible, before an out-of-compliance condition actually occurs. These out-of-compliance conditions may include data inconsistent with the conceptual models implemented in PA, or invalidation of assumptions and arguments used in the screening of Features, Events and Processes (FEPs) screened into PA.

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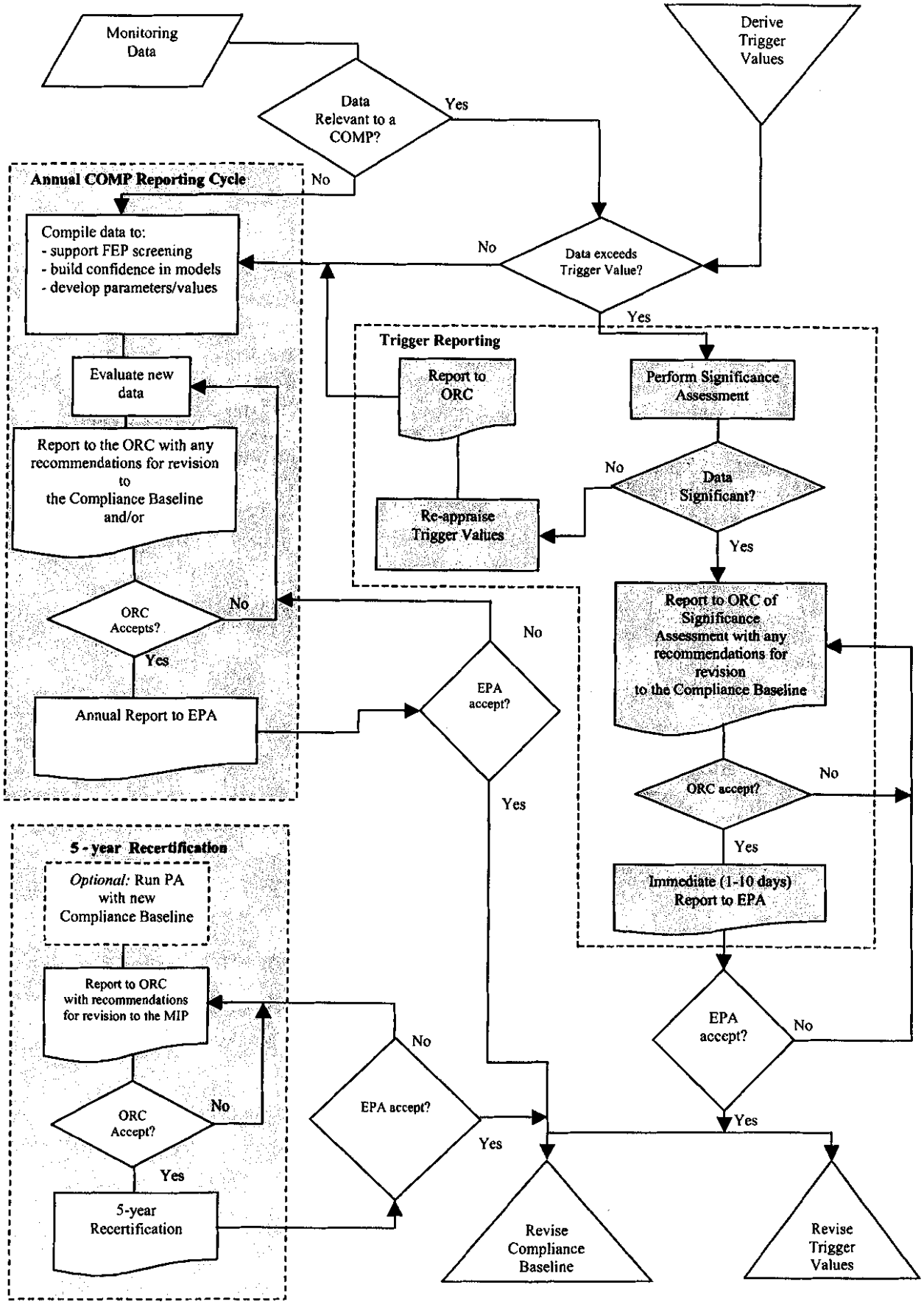

Figure 1.1: Activities Evaluating and Reporting Compliance Monitoring Parameters

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This long-term performance requires that impacts be projected years into the future, based upon data collected in the present. Therefore, this monitoring is not intended to detect operational releases. The WIPP M&OC has operational monitoring programs designed to detect operational releases.

1.3 Annual Reporting Cycle

Reporting results of the annual COMPs assessment is necessary to meet the EPA monitoring requirements. Under 40 CFR §194.4, the DOE is required to report significant, along with non-significant, changes to the EPA. Monitored parameters that change must be reported even if the assessment concludes there is no impact on the repository. Whether or not the monitoring data agree with expectations, as defined by the evaluation, all the data will ultimately be compiled and reported to the DOE to assist in DOE's annual reporting cycle to the EPA. The SA's role in this reporting cycle is to use the monitoring data to derive the COMPs, and to use the new and updated information to make any recommendations for modification to the Compliance Baseline, to monitoring programs, and to trigger values.

2 Assessment of COMPs

The compliance monitoring program tracks the following ten COMPs:

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

In the following section, each COMP is evaluated and compared to the applicable trigger value. This assessment is performed under Analysis Plan AP-069 (SNL 2000a). This section summarizes the results of the 2002 calendar year assessment. An annual review of these COMPs is necessary to meet the intent of 40 CFR §191.14 assurance requirements, which states:

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

Specifically, AP-069 contains five steps to derive trigger values and assess COMPs. Steps 1 and 2 generate a table that maps COMP related data to PA parameters, FEPs screening arguments, conceptual models, model assumptions and the M&OC organization that generates the data used to derive each COMP. Table 2.1 contains this information which was derived using information in the CCA (DOE 1996).

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Table 2.1 Monitoring Parameters

40 CFR 194 Monitoring Parameter	**Responsible Program M&OC/*SA*** (SA in italics)	**Trigger Value(s)**	**Related Performance Assessment Parameter**	**Major FEPs Screening Decisions Related to Monitoring**
Creep Closure and Stresses	Geotechnical Monitoring Program *Rock Mechanics Program*	Greater than 1 order of magnitude increase in the rate.	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*	Greater than 1 m/year increase.	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*	None	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.*

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40 CFR 194 Monitoring Parameter	**Responsible Program M&OC/*SA*** (SA in italics)	**Trigger Value(s)**	**Related Performance Assessment Parameter**	**Major FEPs Screening Decisions Related to Monitoring**
Displacement of Deformation Features	Geotechnical Monitoring Program *Rock Mechanics Program*	Obscured borehole (qualitative)	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.*
Culebra Ground Water Compositions	Ground Water Monitoring Program *Far Field Monitoring Program*	Both duplicate analyses for any major ion falling outside the 95% Confidence Intervals given in Table 4.2 for three consecutive sampling periods.	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 well integrity around the site.*	*Groundwater geochemistry, actinide sorption.*
Change in Culebra Ground Water Flow (Water Level)	Ground Water Monitoring Program *Far Field Monitoring Program*	Comparison to ranges of freshwater heads used in CCA T-Fields (Table 4.1 of Trigger Report)	Culebra transmissivity, fracture & matrix porosity, fracture spacing, dispersivity, & climate Index. *The CCA modeling allowed the water level to rise to the land surface. Can provide information on well integrity around the site.*	*Groundwater flow and recharge/discharge; Infiltration and Precipitation.*
Drilling Rate	Delaware Basin Monitoring Program	53.5 boreholes per square kilometer per 10,000 yrs.	Drilling rate per unit area. *In the CCA the drilling rate was*	*Drilling.*

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40 CFR 194 Monitoring Parameter	Responsible Program M&OC/*SA* (SA in italics)	Trigger Value(s)	Related Performance Assessment Parameter	Major FEPs Screening Decisions Related to Monitoring
	Direct Release Program		*determined to be 46.8 boreholes per square kilometer per 10,000 yrs.*	
Probability of Encountering a Castile Brine Reservoir	Delaware Basin Monitoring Program *Direct Release Program*	None	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.*
Subsidence Measurements	Subsidence Monitoring Program *Rock Mechanics Program*	10 mm/year	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 ground water flow due to mining effects, subsidence baseline.*
Waste Activity	WIPP Waste Information System (WWIS) *PA Methodology*	5.1 Million Curies (RH Only)	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 table WCA-1 in the CCA)*	*Waste characteristics, radiological characteristics, consolidation of waste, actinide source term.*

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2.1 Human Activities COMPs

The CCA identifies ten COMPs that the DOE is required to monitor and assess during the WIPP operational period. Two of these parameters monitor "Human Activities" in the WIPP vicinity which include:

- Probability of Encountering a Castile Brine Reservoir
- Drilling Rate

2.1.1 Probability of Encountering a Castile Brine Reservoir

The CCA data were compiled from record searches of available drilling data from the region surrounding the WIPP. The results of this search recorded 27 drilling encounters with pressurized brine (water) in the Castile Formation. Of these encounters, 25 were hydrocarbon wells scattered over a wide area in the vicinity of the WIPP site; two wells, ERDA 6 and WIPP 12, were drilled in support of the WIPP site characterization effort. The Delaware Basin Drilling Surveillance Program reviews the well files of all new wells drilled in the New Mexico portion of the Delaware Basin each year looking for instances of Castile brine encounters. The program also sends out an annual survey to operators of new wells asking if they encountered pressurized brine during the drilling process. Since the CCA, data have been compiled through August 2002. No pressurized Castile brine encounters have been reported in the drilling records for wells drilled in the New Mexico portion of the Delaware Basin (WID 1999b; WID 2001,WID 2002).

As reported in WID 2001, there were two Castile Brine encounters reported by area drillers to WIPP Site personnel that do not appear in records on file at New Mexico Oil Conservation District (NMOCD) offices. This year there were three additional brine encounters reported to site personnel that do not appear in the records for these wells at the NMOCD offices. Two encounters were located near ERDA 6 northeast of the WIPP Site that reported encountering brine at an initial rate of several hundred barrels per hour. All brine was contained within the drilling pits and therefore did not require reporting to the NMOCD. The third encounter was to the southwest of the WIPP Site reporting an initial rate of 400 to 500 barrels per hour that dissipated in a matter of minutes. Of the five Castile Brine encounters reported to site personnel since 1996, four were identified when WIPP Site personnel were performing field-work and talked to area drillers while the remaining brine encounter was reported through the Area Drillers Annual Survey. All new encounters since 1996 have been in areas where Castile Brine is expected during the drilling process.

The impacts of brine encounters are modeled in the PA. The original assessment included 27 encounters in the WIPP vicinity and determined a 0.08 probability of encountering brine reservoirs. In the Performance Assessment Verification Test (PAVT), the EPA mandated a range of 0.01 to 0.6. Even when the high values within this range were considered, the probability of encountering a brine reservoir did not influence the predicted performance of the repository. Thus, the EPA determined that this parameter (PBRINE, # 3493) does not have a significant impact on PA results (EPA 1998).

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Probability of Encountering a Brine Reservoir - 2002:

Trigger Value Derivation				
COMP Title:	Probability of Encountering a Castile Brine Reservoir			
COMP Units:	Unitless			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
DBMP[1]	NA	Driller's survey – observations	0.08 constant – CCA 0.01 to .60 - PAVT	
COMP Derivation Procedure				
Analysis of encounters of pressurized brine recorded and reported by industry in the 9-township area centered on WIPP.				
Year 2002 COMP Assessment Value				
No new data reported in State record; three occurrences identified by site personnel/surveys. 27 CCA total occurrences before 1996 0 State Record occurrences since 1996 5 Site Personnel/ Drillers Survey occurrences since 1996				
Related Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Probability of Encountering Brine	Parameter PRBRINE ID # 3493	CCA MASS Attachment 18-6 geostatistical study based on area occurrences. EPA TSD justified the upper value in their range by rounding up the upper value interpreted from the TDEM survey, which suggested a 10 to 55% areal extent.	0.08 0.01 to 0.60	Not a sensitive parameter.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
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. Since no value of this parameter can significantly affect the performance of the disposal system predicted by the CCA PA and since the parameter is evaluated at least once annually, no trigger value is needed.		

(1) Delaware Basin Monitoring Program

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2.1.2 Drilling Rate

The drilling rate COMP tracks intrusion activities relating to resource extraction. Drilled boreholes relating to resources include potash and sulfur core holes, hydrocarbon exploration wells, saltwater disposal wells and water wells. The drilling rate that was reported in the CCA was determined using an equation provided in 40 CFR Part 194. The formula is as follows: number of deep holes times 10,000 years divided by 100 years (the latest 100 years, 1896 – 1996 for the CCA value). Deep holes are defined as any resource hole that terminated at a depth equal to or greater than the repository depth. The rate reported in the CCA using this equation was 46.8 boreholes per square kilometer over 10,000 years. Including the time period after the CCA (June 1995 to August 2002) increases the rate to 52.9 boreholes per square kilometer per 10,000 years (WID 2002).

Table 2.2 Drilling Rates for Each Year Since the CCA

Year	Number of Boreholes Deeper than 2,150 feet	DRILLING RATE (BORE HOLES PER SQUARE KILOMETER PER 10,000 YEARS)
1996 (CCA Value)	10,804	46.8
1997	11,444	49.5
1998	11,616	50.3
1999	11,684	50.6
2000	11,828	51.2
2001	12,056	52.2
2002	12,219	52.9

As shown in Table 2.2, the drilling rate has risen from 46.8 holes per square kilometer to 52.9 holes per square kilometer since 1996. The rate will continue to climb because of the method used to calculate the rate. Since the first well drilled in the area occurred 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, increasing 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. A formal assessment of this COMP is planned prior to publishing the 2003 COMPs report.

The trigger value for this COMP is 53.5 and is not based on calculated performance because an order of magnitude change in the drilling rate does not result in an out-of-compliance condition (EEG 1998). However, the FEPs-related assumptions used in the CCA may be affected by increases in the drilling rate. For this reason, a trigger value of 53.5 was chosen so that when this rate was reached, the FEPs-related arguments would be revisited to assure that there is no impact to the original arguments. It should be stated that an exceedance of this trigger value is not an indication of an out-of-compliance condition, but is a point at which further analysis is needed to refine the baseline of the compliance monitoring program.

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Drilling Rate - 2002:

Trigger Value Derivation			
COMP Title:	Drilling Rate		
COMP Units:	Deep boreholes (i.e., > 2,150 feet deep)/square kilometer/10,000 years		
Related Monitoring Data			
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
DBMP	Deep hydrocarbon boreholes drilled	Integer per year	10,640 per 100 years
DBMP	Deep sulfur coreholes drilled	Integer per year	89 per 100 years
DBMP	Deep potash coreholes drilled	Integer per year	19 per 100 years
DBMP	Deep stratigraphic coreholes drilled	Integer per year	56 per 100 years (excluding WIPP test holes)
DBMP	Other deep boreholes drilled	Integer per year	0
COMP Derivation Procedure			
(Total number of deep boreholes drilled/number of years of observations) x (10,000/23,102.1) [i.e., over 10,000 years divided by the area of the Delaware Basin in square kilometers]			
Year 2002 COMP Assessment Value			
(12,219 boreholes on record for the Delaware Basin) Drilling Rate = 52.9 boreholes per square kilometer per 10,000 yrs.			

Related Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Drilling rate	Parameter LAMBDAD #3494	COMP/10,000 years	4.68E-03 per square kilometer per year	23-fold increase over 10,000 years exceeds release limits at 0.1 probability (EEG, 1998). Proportional increase in cuttings/cavings releases.

Monitoring Data Trigger Values		
Monitoring Parameter ID	Trigger Value	Basis
Deep boreholes drilled (derived from the sum of the five monitoring parameters given above)	53.5 boreholes per square kilometer per 10,000 yrs.	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. There is little information 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.

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2.2 Geotechnical COMPs

The CCA lists ten monitoring parameters that the DOE is required to monitor and assess during the WIPP operational period. Five of these parameters are considered "geotechnical" in nature and include:

- Creep Closure
- Extent of Deformation
- Initiation of Brittle Deformation
- Displacement of Deformation Features
- Subsidence

Data needed to derive and evaluate the geotechnical COMPs are available from the most recent annual Geotechnical Analysis Report (GAR; DOE, 2002a), annual Subsidence Monument Leveling Surveys (DOE, 2001 and 2002b) and results extracted from the geotechnical experimental programs (SNL, 2002b) undertaken cooperatively by the SA and the M&OC to characterize the disturbed rock zone (DRZ). Three of the geotechnical parameters lend themselves to quantification: creep closure, displacement of deformation features and subsidence. In contrast, extent of deformation and initiation of brittle deformation are qualitative or observational parameters.

The WIPP GARs have been available since 1983 and are currently prepared by the M&OC on an annual basis. The purpose of the GAR is to present and interpret geotechnical data from the underground excavations. These data are obtained as part of a regular monitoring program and are used to characterize current conditions, to compare actual performance to the design assumptions, and to evaluate and forecast the performance of the underground excavations during operations. Additionally, the GAR fulfills various regulatory requirements and through the monitoring program, provides early detection of conditions that could affect operational safety, evaluation of disposal room closure to ensure adequate access, and guidance for design changes. Data are presented for specific areas of the facilities including: (1) Shafts and keys, (2) Shaft Stations, (3) Northern Experimental Area, (4) Access Drifts, and (5) Waste Disposal Areas. Data are acquired using a variety of instruments including convergence points and meters, multipoint borehole extensometers, rockbolt load cells, pressure cells, strain gauges, piezometers and joint meters. All of the geotechnical COMPs involve analyses of deformations/displacements, so the most pertinent data derived from the GAR are convergence and extensometer data. The most recent GAR (DOE, 2002a) summarizes data collected from July 2000 through June 2001.

Subsidence monitoring leveling survey reports are also prepared by the M&OC on an annual basis and present the results of leveling surveys performed for ten vertical control loops comprising approximately 18 linear miles traversed over the ground surface of the WIPP site. Elevations are determined for 51 monuments and 14 National Geodetic Survey vertical control points using digital leveling techniques to achieve Second-Order Class II loop closures or better. The data are used to estimate total subsidence and subsidence rates in fulfillment of regulatory requirements. The most recent surveys (DOE, 2001 and 2002b) summarize data collected during September and October 2001 and September and October 2002.

Geotechnical experimental programs conducted jointly by the SA and M&OC are currently underway to characterize the DRZ that develops around underground openings in salt. Data from

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the program will be used primarily for PA and improvements to seal design, but will also provide useful information for characterizing extent of deformation, initiation of brittle deformation and possibly displacement of deformation features. Results from the program are reported as they become available (e.g. SNL 2002b).

Comparisons between available data and the trigger values allow evaluation of the most recent geotechnical observations in the context of the EPA rule. The cited reports and programs provide a good evaluation of all observations where deviations from historical normal occurrences are recorded. This process, as engaged for COMPs assessments, not only focuses attention on monitored parameters, it allows for reassessment of the proposed trigger values. Notable deviations are addressed in the GAR and other references, and are reexamined here in the context of COMPs and trigger values.

Geotechnical COMPs can be derived from or related to the repository's operational safety monitoring program, which is performed to ensure worker and mine safety. By nature, changes in geotechnical conditions evolve slowly, however, they are monitored continuously and reported annually. Since pertinent data from the underground reflect slowly evolving conditions, relationships that correlate to geotechnical COMPs also evolve slowly. Geotechnical conditions warranting action for operational safety will become evident before such conditions would impact long-term waste isolation. Monitoring underground response allows continuing assessment of conceptual geotechnical models supporting certification. In effect, these annual comparisons of actual geotechnical response with expected response serve to validate or improve models.

Annual reviews allow discovery of conditions or trends that lay outside expectations. In principal, the annual geotechnical analysis seeks trends or conditions that are "off normal." At this early stage of the repository history, the WIPP monitoring program is establishing parametric values, rates, conditions or observations that would signal further evaluation. It needs to be re-emphasized that conditions beyond normal or outside expectations do not automatically impact compliance determinations. Conditions differing from expectations alert the geotechnical program to scrutinize incoming data more closely and to make assessments of possible performance impact.

Displacement, deformation, closure, and fracturing evolve slowly. Therefore, annual assessment of the geotechnical COMPs will adequately address conditions that would be of concern for predicting repository performance or that are related to long-term regulatory compliance. This assessment contains the fourth geotechnical monitoring report since disposal operations began. Implementation and evaluation of possible trigger events, features, phenomena, trends, and conditions that would warrant further actions will be refined as experience is gained.

The previous annual assessments of geotechnical COMPs provided the opportunity to review parameters and phenomena in the context of the EPA rule. The geomechanical monitoring program reported in the GAR is implemented primarily for continuous assessment of the underground facilities. Data for interpreting the behavior of underground openings are compared with established design criteria. The SA evaluates these data with respect to performance assessment as required by the EPA rule.

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2.2.1 Creep Closure

The GAR compiles all geotechnical operational safety data gathered from the underground. The most readily quantifiable geomechanical response in the WIPP underground is creep closure. The GAR routinely measures and reports creep deformation, either from rib-to-rib, roof-to-floor, or extensometer borehole measurements. 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. Nominally these rates are of the order of $1x10^{-10}$/s and are quite steady over significant periods. From experience, increases and decreases of rates such as these might vary by 20 percent without undue concern. Therefore, the "trigger value" for creep deformation was set as one order of magnitude increase in creep rate. Such a rate increase would alert the geotechnical staff to scrutinize the area exhibiting accelerating creep rates. Tertiary creep is an expected (eventually) phenomenon and its manifestation would help validate predictive capabilities of the computational models.

Extensive GAR data suggest that possible trigger values could be derived from creep rate changes. The WIPP underground is very stable, relative to most operating production mines, and deformation is steady for long periods. However, under certain conditions creep rates accelerate, indicating a change in the deformational processes. Arching of microfractures to an overlying clay seam might create the onset of the roof beam de-coupling and increase the measured closure rate. Phenomena of fracture coalescence and DRZ growth comprise important elements of compliance confirmation. Therefore, a measured creep rate change over a yearly period constitutes the COMP trigger value for creep closure. Rate changes would necessarily be evaluated on a case-by-case basis since closure is related to many factors such as age of the opening, location in the room or drift, convergence history, recent excavations, and geometry of the excavations.

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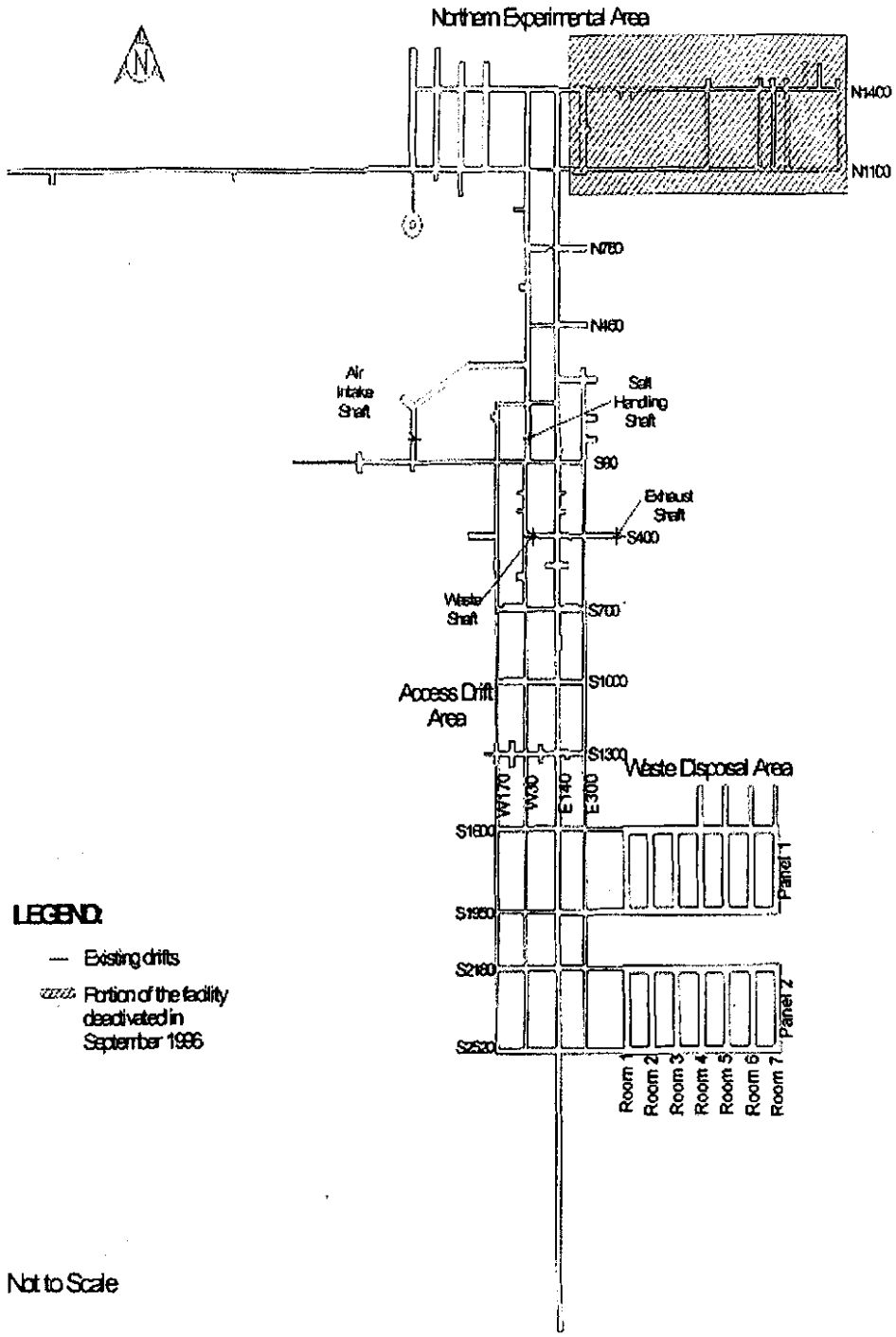

Figure 2.1 Current Configuration of the WIPP Underground (after DOE, 2002a).

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The creep deformation COMP is addressed by examining the deformations measured in specific regions of the underground including: (1) Shafts and Shaft Stations, (2) the Northern Experimental Area, and (3) Access Drifts and Waste Disposal Areas. Figure 2.1 shows the current configuration of the WIPP underground with specific elements and regions annotated for reference. Details of the examination for each of these three regions are discussed below under separate headings.

Shafts and Shaft Stations

The WIPP underground is serviced by four vertical shafts including the following: (1) Salt Handling Shaft, (2) Waste Shaft, (3) Exhaust Shaft, and (4) Air Intake Shaft. At the repository level (approximately 650 meters below ground surface), enlarged rooms have been excavated around the shafts to allow for movement of equipment, personnel, mined salt and waste into or out of the facility. The enlarged rooms are called shaft stations and assigned designations consistent with the shaft they service, e.g., Salt Handling Shaft Station.

Shafts. With the exception of the Salt Handling Shaft, the shafts are configured nearly identically. From the ground surface to the top of the Salado Formation, the shafts are lined with unreinforced concrete. Reinforced concrete keys are cast at the Salado/Rustler interface with the shafts extending through the keys to the Salado. Below the keys, the shafts are essentially "open holes" through the Salado Formation and terminate either at the repository horizon or at sumps that extend approximately 40 meters below the repository horizon. In the Salt Handling Shaft, a steel liner is grouted in place from the ground surface to the top of the Salado. Similar to the three other shafts, the Salt Handling Shaft is configured with a reinforced concrete key and is "open-hole" to its terminus. For safety purposes, the portions of the open shafts that extend through the Salado are typically supported using wire mesh anchored with rock bolts to contain rock fragments that may become detached from the shaft walls. Within the Salado Formation, the shaft diameters range from 3.65 m to 7.0 m.

Data available for assessing creep deformations in the salt surrounding the shafts are derived exclusively from routine inspections and extensometers extending radially from the shaft walls. These data are reported in the GAR. The Salt Handling Shaft, Waste Shaft, and Air Intake Shaft are inspected weekly by underground operations personnel. Although the primary purpose of these inspections is to assess the conditions of the hoisting and mechanical equipment, observations are also made to determine the condition of the shaft walls, particularly with respect to water seepage, loose rock, and sloughing. In contrast to the other three shafts, the Exhaust Shaft is inspected quarterly using remote-controlled video equipment. *Based on these visual observations, all four shafts are in satisfactory condition and have required no significant ground-control support during the reporting period.*

Shortly after its construction, each shaft was instrumented with extensometers to measure the inward movement of the salt at three levels within the Salado Formation. In addition to COMPs assessment, measurements of shaft closure are used periodically as a calibration of calculational models and have been used in shaft seal system design. The approximate depths corresponding to the three instrumented levels are 330 m, 480 m and 630 m. Three extensometers are emplaced at each level to form an array. The extensometers comprising each array extend radially outward from the shaft walls and are equally spaced around the perimeter of the shaft wall. Over the years, some of these extensometers have malfunctioned. As a result, reliable data are not available at some locations.

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Table 2.3 provides a summary of the current (2000-2001) displacement rates of the shaft walls based on extensometer data reported in the GAR. The rates make use of collar displacement measured relative to the deepest anchor for individual extensometers. Rates range from 0.010 in/yr to 0.089 in/yr (0.025 cm/yr to 0.226 cm/yr) and increase with depth, as expected, because of the higher stress levels associated with the overburden at greater depth. Dividing the displacement rates by the typical shaft radius (say 3 m) and expressing the results in units of 1/sec yields creep rates that range from 2.6×10^{-12}/s to 2.4×10^{-11}/s. These creep rates are very low and are typical of rates for stable openings mined from salt. Table 2.3 also gives displacement rates for the previous reporting period (1999 to 2000) and the percentage change in these rates compared to the current rates. In general, the rate changes are small and most are slightly negative indicating the displacement of salt into the shafts is slowing with time. Rather large increases in displacement rates are shown for the 326-m and 477-m levels of the Waste Handling Shaft, but the rates are still considered acceptable. However, deformations at these locations will be monitored closely during the next reporting period. *Based on visual observations and quantitative displacement measurements, creep deformations associated with the WIPP shafts are acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.*

Shaft Station. Shaft station openings are typically rectangular in cross-section with heights ranging from approximately 4 to 6 m and widths ranging from 6 to 10 m. Over the life-time of the individual shaft stations, modifications have been made that have altered the dimensions of the openings. For example, portions of the Salt Handling Shaft Station have been enlarged by removing the roof beam that extended up to anhydrite "b". In the Waste Handling Shaft Station, the walls have been trimmed to enlarge the openings for operational purposes.

The effects of creep on the shaft stations are assessed through visual observations and displacement measurements made using extensometers and convergence points. Because of the modifications made over the years, some of the original instrumentation has been removed or relocated. In addition, some instruments have malfunctioned or been damaged and no longer provide reliable data. Displacement rates available from the GAR for the current reporting period (2000-2001) and the previous reporting period (1999-2000) are summarized in Table 2.3. Creep data are available only for the Salt Handling and Waste Shaft Stations (data for the Air Intake Shaft are reported below under the Access Drift section of this report). Most of the measurements are for vertical closure; however, at least one measurement of horizontal closure is available for both stations. Based on convergence data, current vertical displacement rates range from about 0.348 to 1.887 in/yr (0.88 to 4.8 cm/yr), while current horizontal displacement rates range from about 0.916 to 1.135 in/yr (2.3 to 2.9 cm/yr). Dividing convergence rates by the average room dimension (say 6 m) and expressing the results in units of 1/sec yields vertical and horizontal creep rates of approximately 2×10^{-10}/s. These rates are somewhat higher than those measured in the shafts but are still low and represent typical creep rates for stable openings in salt. An examination of the percentage changes in displacement rates shown in Table 2.3 suggests the current shaft station displacement rates are essentially identical to those measured during the previous reporting period. Based on the extensometer and convergence data, as well as the limited maintenance required in the shaft stations during the last year, *creep deformations associated with the WIPP shaft stations are considered acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.*

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Table 2.3 Summary of Closure Rates for WIPP Shafts and Shaft Stations

Location	Inst. Type[a]	Displacement Rate (in/yr)		Change In Rate (%)
		1999–2000	2000–2001	
Salt Handling Shaft	No extensometers remain functional			
Waste Handling Shaft				
1071 ft (326 m) level, N45W	Ext	0.007	NA[b]	NA
1071 ft (326 m) level, S15W	Ext	0.007	0.010	42.9
1566 ft (477 m) level, N45W	Ext	0.034	0.035	2.9
1566 ft (477 m) level, N75E	Ext	0.027	0.033	22.2
1566 ft (477 m) level, S15W	Ext	0.035	0.036	2.9
2059 ft (628 m) level, N45W	Ext	0.080	0.089	11.3
2059 ft (628 m) level, N75E	Ext	0.080	0.074	-7.5
2059 ft (628 m) level, S15W	Ext	0.095	0.087	-8.4
Exhaust Shaft				
1573 ft (479 m) level, N75E	Ext	0.024	0.020	-16.7
1573 ft (479 m) level, N45W	Ext	0.026	0.023	-11.5
1573 ft (479 m) level, S15W	Ext	0.026	0.023	-11.5
2066 ft (630 m) level, N75E	Ext	0.092	0.087	-5.4
2066 ft (630 m) level, S15W	Ext	0.068	0.062	-8.8
Salt Handling Shaft Station				
E0 Drift – N39 (Vert. CL[c])	CP	2.093	1.887	-9.8
E0 Drift – N39 (Horiz. CL)	CP	1.150	1.135	-1.3
E0 Drift – S18 (Vert. CL)	CP	1.645	1.681	2.2
E0 Drift – S30 (Vert. CL)	CP	1.749	1.772	1.3
E0 Drift – S65 (Vert. CL)	CP	1.352	1.354	0.1
Waste Shaft Station				
S400 Drift – W30 (Vert. CL)	Ext	0.365	0.348	-4.7
S400 Drift – E140 (Vert. CL)	Ext	0.740	0.715	-3.4
S400 Drift – E30 (Horiz. CL)	CP	0.951	0.916	-3.7
S400 Drift – E90 (Horiz. CL)	CP	1.061	1.005	-5.3
Air Intake Shaft Station	Information provided below under access drift discussion			

(a) Instrument Type: Ext = extensometer; CP = convergence point.
(b) NA = Not available
(c) CL = Centerline

Northern Experimental Area

The Northern Experimental Area, defined as all excavations north of the N1100 drift (see Figure 2.1), was constructed in the early 1980's to characterize the site and obtain in situ geotechnical data from underground excavations. During the experiments, the area was heavily instrumented to examine the structural response of the openings. Following completion of the experiments, access to the area was blocked in 1996. As a result, only a few of the instruments (primarily extensometers and convergence meters) remained active and were monitored remotely because of restricted access to the area. During the period from July 1999 to June 2000, portions of the Northern Experimental Area were reopened to assess ground conditions. Following spot bolting, systematic pattern bolting in SPDV Test Room 4 and activation of ventilation, operational use of the area for salt storage was established. Numerous manual convergence measurements were re-established following re-entry and new convergence meters were also installed in some areas;

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however, some measurements were lost when a data logger and some of the existing instrumentation were removed to allow for roof beam removal and vehicular traffic.

A summary of the displacement rates measured along the vertical and horizontal midpoints of the openings in the Northern Experimental Area is provided in Table 2.4 for both the current and previous reporting periods. As shown, displacement rates were determined at 11 locations during the 1999-2000 reporting period and at 37 locations during the 2000-2001 reporting period; however, none of the locations sampled in the 1999-2000 period were also sampled in the 2000-2001 period so changes in displacement rates could not be calculated directly. Instead, changes in rates were inferred from:

(1) Comparison of vertical displacement rates measured during the 1999-2000 period using roof extensometers installed at the centerline of SPDV Room 4 and vertical closure rates measured during the 2000-2001 period using nearby convergence points also installed along the centerline of SPDV Room 4.
(2) Comparison of vertical and horizontal centerline displacement trends observed during 2000-2001 with those observed at the end of 1996 just before access to the Northern Experimental Area was blocked.

Displacement rates for the collar of three roof extensometers (N1325, N1250, and N1175) located along the centerline of SPDV Room 4 were determined during the 1999-2000 reporting period. These rates ranged from 0.590 to 0.913 in/yr with an average rate of 0.739 in/yr. Assuming the roof and floor displacement rates are equal, then the vertical room convergence rate during the 1999-2000 period would be twice the roof rate or 1.478 in/yr. During the 2000-2001 reporting period, displacement rates for three vertical convergence points located along the centerline of SPDV Room 4 were determined. These rates ranged from 1.816 to 1.897 in/yr with an average rate of 1.853 in/yr. Comparing the 1999-2000 and 2000-2001 average rates indicates the vertical displacement rate along the centerline of SPDV Room 4 increased by 25.5% during the current reporting period.

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Table 2.4 Summary of Closure Rates for Openings in the Northern Experimental Area

Location	Inst. Type[a]	Displacement Rate (in/yr)	
		1999–2000	2000–2001
E140 Drift – N1266, Horiz. CL[b], E. Rib	Ext	NA[c]	0.622
E140 Drift – N1266, Horiz. CL, W. Rib	Ext	NA	0.474
Room L4, Vert. CL, Roof	Ext	0.650	NA
SPDV[d] Room 4 – N1325, Vert. CL, Roof	Ext	0.913	NA
SPDV Room 4 – N1250, Vert. CL, Roof	Ext	0.713	NA
SPDV Room 4 – Center, Horiz. CL, E. Rib	Ext	NA	1.411
SPDV Room 4 – Center, Horiz. CL, W. Rib	Ext	NA	0.480
SPDV Room 4 – N1175, Vert. CL, Roof	Ext	0.590	NA
N1420 – E140 Intersection, Vert. CL,	CP	NA	1.447
E140 Drift – N1266, Vert. CL	CP	NA	2.144
E140 Drift – N1266, Horiz. CL	CP	NA	1.296
N1100 – E140 Intersection, Vert. CL	CP	NA	1.702
N1100 Drift – E80, Vert. CL	CP	NA	0.957
N1100 Drift – E80, Horiz. CL	CP	NA	0.807
N1420 – E0 Intersection, Vert. CL	CP	NA	1.357
E0 Drift – N1266, Vert. CL	CP	NA	0.072
E0 Drift – N1266, Horiz. CL	CP	NA	1.092
E0 – N1100 Intersection, Vert. CL	CP	NA	1.597
N1420 – TR1 Intersection, Vert. CL	CP	NA	2.012
N1100 – TR1 Intersection, Vert. CL	CP	NA	1.592
N1420 Drift – W258, Vert. CL	CP	NA	0.940
N1420 Drift – W258, Horiz. CL	CP	NA	0.735
N1420 – TR2 Intersection, Vert. CL	CP	NA	1.858
N1100 – TR2 Intersection, Vert. CL	CP	NA	1.429
N1420 Drift – W391, Vert. CL	CP	NA	0.925
N1420 Drift – W391, Horiz. CL	CP	NA	0.776
N1420 – TR3 Intersection, Vert. CL	CP	NA	1.467
N1100 – TR3 Intersection, Vert. CL	CP	NA	1.207
N1420 – TR4 Intersection, Vert. CL	CP	NA	2.010
SPDV Room 4 N1325, Vert. CL	CP	NA	1.846
SPDV Room 4 N1325, Horiz. CL	CP	NA	1.413
SPDV Room 4 Center, Vert. CL	CP	NA	1.897
SPDV Room 4 Center, Horiz. CL	CP	NA	1.258
SPDV Room 4 N1175, Vert. CL	CP	NA	1.816
SPDV Room 4 N1175, Horiz. CL	CP	NA	1.114
N1100 TR4 Intersection, Vert. CL	CP	NA	1.168
N1100 Drift – W783, Vert. CL	CP	NA	0.618
N1100 Drift – W783, Horiz. CL	CP	NA	0.462
N1100 Drift – W951, Vert. CL	CP	NA	0.558
N1100 Drift – W1159, Vert. CL	CP	NA	0.583
N1100 Drift – W1347, Vert. CL	CP	NA	0.562
N1420 Drift – E1551, Vert. CL	CM	0.820	NA
N1420 Drift – E1451, Vert. CL	CM	0.809	NA
Room D – N1432, Vert. CL	CM	1.009	NA

(a) Instrument Type: Ext = extensometer; CP = convergence point; CM = convergence meter.
(b) CL = Centerline
(c) NA = Not available
(d) SPDV = Site Preliminary Design Validation

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Table 2.4 – Continued - Summary of Closure Rates for Openings in the Northern Experimental Area

Location	Inst. Type[a]	Displacement Rate (in/yr)	
		1999–2000	2000–2001
Room D – N1266, Vert. CL	CM	0.859	NA
Room D – N1187, Vert. CL	CM	0.859	NA
N1100 Drift – E1620, Vert. CL	CM	0.540	NA
E300 Drift – N1275, Vert. CL	CM	3.061	NA

(e) Instrument Type: Ext = extensometer; CP = convergence point; CM = convergence meter.
(f) CL = Centerline
(g) NA = Not available
(h) SPDV = Site Preliminary Design Validation

In the most recent GAR (DOE, 2002a), the M&OC has plotted the historical displacement trends for all 49 instruments identified in Table 2.4. With the exception of only two instruments (i.e., the roof extensometer in Room L4 and the vertical convergence point located at E0 – N1266), all current displacement rates are approximately the same or slightly less that those measured in 1996 before access to the experimental area was blocked. In contrast, the roof extensometer located in Room L4 shows an increase in displacement rate of approximately 75% from 1996 to the current reporting period. Some of this increase is suspected to be a result of lateral displacement along a clay seam located above the roof. Currently, the displacement rate at E0 – N1266 is approximately 25% higher than it was in 1996. This relatively small increase in displacement rate at one location is not expected to result in any safety or operational problems.

Based on the evaluations of displacement rates conducted under (1) and (2) described above, *creep deformations associated with openings in the Northern Experimental Area are considered acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.* Only two monitored locations showed displacement rate increases and these increases were considered acceptable based on the TVs; however, because limited access to the experimental area has now been restored, these locations will be more closely scrutinized in the future to assess possible roof instability.

Access Drifts and Waste Disposal Area

Access Drifts. The access drifts comprise the four major North-South drifts extending southward from near the Salt Handling Shaft to the entries into the waste disposal panels and several short cross-drifts intersecting these major drifts (see Figure 2.1). Two of the North-South drifts also extend northward to provide access to the Northern Experimental Area. The portions of the four drifts extending to the south provide haulage ways for salt excavated from and waste transported to the waste disposal areas. In addition, the access drifts are used for ventilation. Drift E140 was excavated all the way to the southern boundary of the repository in the early 1980s. Drifts W170, W30, and E300 were developed at approximately the same time as Drift E140, but were terminated at S2180. *During the previous reporting period of the GAR (i.e., July 1999 to June*

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2000), the extension of the three drifts southward to S2520 was completed and other portions of the drifts were trimmed, scaled and milled all in an effort to allow access for mining of Waste Disposal Panel 2. The access drifts are typically rectangular in cross-section with heights ranging from 2.4 m to 6.4 m and widths ranging from 4.3 m to 9.2 m.

Assessment of creep deformations in the access drifts is made through the examination of extensometer and convergence point data reported annually in the GAR. Tables 2.5 and 2.6 summarize, respectively, the vertical and horizontal displacement data reported in the most recent GAR. Each table examines percentage changes between displacement rates measured during the current and previous annual reporting periods and breaks these percentage changes into ranges (e.g, 0 to 25%). Only data from instruments located along the drift centerlines are reported here. In addition, extensometer data are based only on the displacements of the collar relative to the deepest anchor. The numbers shown in the tables represent the number of instrumented locations that fall within the range of the indicated percentage change. For example, data from fifty vertically-oriented extensometers installed in the access drifts were assessed with twelve of these instruments showing percentage changes < 0% (i.e., the rate decreased or slowed), twenty two showing changes between 0 to 25%, eight showing changes between 25 to 50%, five showing changes between 50 and 75%, one showing a change between 75 and 100%, and three showing changes between 100 and 150%. The maximum displacement rates corresponding to these data are given below.

Maximum Vertical Displacement Rates Along Access Drift Centerlines:

10.127 cm/yr – based on extensometer data
11.316 cm/yr – based on convergence point data

Maximum Horizontal Displacement Rate Along Access Drift Centerlines:

3.917 cm/yr – based on convergence point data

Using a typical average drift dimension of 5 m and the maximum displacement rates shown above yields an inferred maximum creep rate of approximately 7×10^{-10}/s. This rate is relatively high so further analyses were performed as described below.

Most (approximately 96% of all data) of the changes in vertical and horizontal displacement rates fall within three categories or subdivisions shown in Tables 2.5 and 2.6, i.e., < 0%, 0 to 25%, and 25 to 50% indicating that current creep deformations in the access drifts are approximately the same as they were for the previous reporting period. The few remaining data show relatively large changes in rate and indicate accelerations of displacement in some locations. As a general rule, accelerations in displacement would be cause for concern; however, a careful examination of these relatively large accelerations in displacement reveals that the extensometers/convergence points associated with these accelerations are, for the most part, located south of S1525 and east of E140 near recent excavations, i.e., the North-South Access Drift extensions and Panel 2 (see Figure 2.1). A few other locations also have exhibited relatively large changes in displacement or closure rates. At several locations near the air intake shaft, the rates have increased approximately 50 to 75%, but these displacement rates appear to be cyclical and are likely caused by temperature and/or humidity changes induced by the fresh air being drawn into the repository seasonally. Another location is E140 – N675 (in the access drift leading to the Northern Experimental Area) where the

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displacement rate has changed by 107%. This higher rate is likely a result of scaling and removal of the roof near this location.

For the most part, creep deformations associated with the Access Drifts are acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period; however, at three locations, the deformation rates have exceeded the TV. Because these high displacement rates have probably been induced by recently completed mining activities and will likely decrease with time, no remedial action is currently required; however, the rates will be carefully monitored during the next reporting period.

Table 2.5 Summary of Changes in Vertical Displacement Rates Measured Along the Centerlines of the WIPP Access Drifts and Waste Disposal Area Openings

Location	Number of Instrument Locations Experiencing the Indicated Percentage Change					
	Percentage Increase in Displacement Rate for Measurements Made During the 1998-1999 and 1999-2000 Reporting Periods					
	< 0%	0 – 25%	25 – 50%	50 – 75%	75 – 100%	100 – 150%
Access Drifts						
Extensometers[a]	12	22	8	5	1	3
Convergence Points	43	70	2	0	0	0
Waste Disposal Area[b]						
Extensometers[a]	14	20	20	3	2	1
Convergence Points	5	30	0	0	0	0

(a) Based on displacement of collar relative to deepest anchor.
(b) Includes instrumentation in Panel 1 only.

Table 2.6 Summary of Changes in Horizontal Displacement Rates Measured Along the Centerlines of WIPP Access Drifts and Waste Disposal Area Openings

Location	Number of Instrument Locations Experiencing The Indicated Percentage Change		
	Percentage Increase in Displacement Rate for Measurements Made During the 1998-1999 and 1999-2000 Reporting Periods		
	< 0%	0 – 25%	25 – 50%
Access Drifts			
Extensometers[a]	0	0	0
Convergence Points	27	26	0
Waste Disposal Area[b]			
Extensometers[a]	2	11	0
Convergence Points	1	22	1

(a) Based on displacement of collar relative to deepest anchor.
(b) Includes instrumentation in Panel 1 only.

Waste Disposal Area: The Waste Disposal Area is located at the extreme southern end of the WIPP facility and is serviced by the access drifts described above. Eventually, the Waste Disposal Area will include eight disposal panels, each comprised of seven rooms (the major north-south access drifts adjacent to the eight panels will also be used for waste disposal and will make up

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ninth and tenth panels). Panel 1 was excavated in the late 1980s and is currently being filled with waste. Excavation of Panel 2 was completed during the previous reporting period (1999-2000). The waste emplacement rooms are rectangular in cross-section with a height of 4 m and a width of 10 m. Entry drifts that provide access into the disposal rooms are also rectangular with heights of 3.65 m and widths of 4.3 m.

Assessment of creep deformations in the waste disposal area is made through the examination of extensometer and convergence point data reported annually in the GAR. Tables 2.5 and 2.6 (presented previously) summarize, respectively, the vertical and horizontal displacement data reported in the most recent GAR for Panel 1. Each table examines percentage changes between displacement rates measured during the current and previous annual reporting periods and breaks these percentage changes into ranges. Only data from instruments located along the drift centerlines are reported here. In addition, extensometer data are based only on displacements of the collar relative to the deepest anchor. The maximum displacement rates corresponding to these data are given below.

Maximum Vertical Displacement Rates Along Waste Disposal Area Centerlines:

5.095 cm/yr – based on extensometer data
8.710 cm/yr – based on convergence point data

Maximum Horizontal Displacement Rates Along Waste Disposal Area Centerlines:

2.540 cm/yr – based on extensometer data
5.448 cm/yr – based on convergence point data

Using a typical disposal-area-opening dimension of 8 m and the maximum displacement rates shown above yields an inferred maximum creep rate of approximately 3.5×10^{-10}/sec. As with the access drift data, maximum creep rates for the waste disposal area are relatively high, so further analyses were performed for this assessment as discussed below.

Similar to the Access Drift data, approximately 95% of all disposal area data indicate changes in vertical and horizontal displacement rates that fall within the < 0%, 0 to 25%, and 25 to 50% subdivisions. The remaining few data show relatively large changes in rate (a 55 to 115% increase) indicating accelerations of displacement. A careful examination of these relatively large accelerations in displacement reveals that the extensometers/convergence points associated with these accelerations are, for the most part, located near the southern portion of Panel 1. Patchet et al., (2001) have conducted three-dimensional modeling to predict the effect of Panel 2 excavation on Panel 1 deformations and have concluded that convergence rates in Panel 1 could increase by as much as 60 to 96 percent which is consistent with the observations. Because the highest displacement rates are probably induced by recent mining activities and will likely decrease with time, no remedial action is currently required; however, the rates will be carefully monitored during the next reporting period.

Creep deformations associated with the Waste Disposal Area are, for the most part, acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period. However, the rate changes at two locations have exceeded the TV. Because these high deformation rates are attributed to recent mining activities, no further evaluation or

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action is warranted; however, the rates will be carefully monitored during the next reporting period.

Deformation rates in Panel 2 are just now being established with vertical closure rates ranging from 1.2 to 7.3 in/yr and horizontal closure rates of 2.0 to 4.5 in/yr. Given the typical dimensions of the disposal rooms, these displacement rates represent vertical and horizontal creep rates ranging between $2x10^{-10}$/s to $13x10^{-10}$/s and $2x10^{-10}$/s to $4x10^{-10}$/s, respectively. These rates are relatively higher and comparable to the current rates observed in Panel 1. The rates are expected to decrease with time and become more or less constant at about $1x10^{-10}$/s. During the next reporting period, changes in annual closure rates will be quantified for Panel 2 instrumentation locations.

Creep Closure:

Trigger Value Derivation				
COMP Title:	Creep Closure			
COMP Units:	Closure Rate (sec^{-1})			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Geotechnical	Closure	Instrumentation throughout the underground.	Munson-Dawson (MD) Constitutive Model	
COMP Derivation Procedure				
Annually evaluate GAR for centerline closure rates, compare to previous year's rate. If closure rate increases by greater than one order of magnitude, initiate technical review.				
Related Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Repository Fluid Flow	Creep Closure	Porosity Surface, waste compaction, characteristics, waste properties, evolution of underground setting	SANTOS, surface porosity calculations	Provides validation of the CCA creep closure model.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Creep Closure	Greater than one order of magnitude increase in closure rate.	The closure rate increase signals potential de-coupling of rock.		

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2.2.2 Extent of Deformation

The extent of brittle deformation can have important implications to PA. As modeled in PA, the 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 performance determination. If characteristics could be tracked from inception, the spatial and temporal evolution of the DRZ would provide a validation benchmark for damage calculations. To this end, a hydrologic profile including permeability and pore pressure is being compiled within the SA Rock Mechanics Program.

Measurements in the GAR 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 de-watering. The extent of deformation quantifies the DRZ, a significant element of performance assessment analyses.

The Geotechnical Engineering Department at WIPP has compiled back-fracturing data into a database. The supporting data for the GAR (Volume 2, DOE, 2002a) consists of plan and isometric plots 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 Clay Seam G. Low angle fractures arch over rooms and asymptotically connect with Clay Seam G. Although the preponderance of monitoring information derives from the roof (back), buckling extends into the floor to the base of Marker Bed 139 which is located about 2 m below the disposal room floors. Fracture mapping thus far is consistent with expectations and tracks stress trajectories derived from computational work. At this time, a comprehensive model and supporting data for model parameters for damage evolution has not been developed and incorporated into PA. Future plans call for the raising of the waste disposal panels by about 2.4 m such that the roof of the disposal rooms will be coincident with Clay Seam G and the floor will be an additional 2.4 m above Marker Bed 139. This planned change will likely alter the typical fracture patterns.

In addition to results presented in the GAR, two activities have been completed under the geotechnical experimental programs being undertaken cooperatively between the SA and the M&OC. These two activities have produced results appropriate for defining the extent of deformation around openings in salt and have been reported recently by Sandia (SNL, 2002b). The activities included cross-hole acoustic velocity measurements and laboratory core analyses as described in Sandia test plans (SNL, 2001a,d, SNL 2000d).

The cross-hole acoustic velocity measurements were conducted in 12 angled boreholes drilled in a corner of the WIPP Q Alcove. Each hole was 10.15 cm in diameter and ~ 6-m deep and was drilled in as nearly a horizontal position as possible, at a 45° angle to the walls forming the alcove corner. The holes were arranged in a 4x3-grid (row x column) pattern with a nominal spacing between holes of one meter. Piezoelectric transducers were used as both the transmitter and receiver of ultrasonic elastic waves. These transducers were moved through the holes to measure cross-hole wave speeds at various distances in from the walls. Near the wall face, wave speeds

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were relatively low because of microfracturing within the salt. Away from the walls, wave speeds increased until undisturbed zones of salt were encountered. Beyond this point, the wave speeds remained constant at about 4.4 to 4.6 km/sec depending on whether the hole was drilled in clean or argillaceous salt. The extent of the DRZ was defined as the depth in the hole at which the wave speeds reach a constant value. Based on these measurements, the extent of the DRZ was approximately one meter or only about one-half the distance determined for holes drilled normal to the walls as reported in the previous COMPs report (SNL 2001c). The geometry of the alcove corner, and in particular, the effect it has on the local stress field, is thought to play the leading role in reducing the extent of the DRZ that developed at this location. A complete description of the investigation is provided by Sandia in a previous report (SNL, 2002b).

Laboratory core analyses were performed on cores recovered from one of the holes (QGU-36) used for the cross-hole acoustic wave tests performed in the corner of the Q Alcove. Analyses included measurement of fracture aperture and spacing, porosity, and microstructural dislocation density. Fracture aperture and spacing are directly relevant to the Extent of Deformation COMP. The cores used to measure fracture aperture and spacing were sliced lengthwise into quarters, impregnated with fluorescent dye, ground flat, mounted on oversized glass plates, and then cut and polished as thick (2-3 mm) sections. Measurements were taken along the centerline of the thick sections (parallel to the core axis). Figure 2.2 plots fracture aperture versus distance from the wall and shows that fractures were observed at depths up to 6 to 7 m; however, the largest fracture apertures (~500 μm) were found within 1 m of the walls, consistent with the ultrasonic velocity measurements. At a depth of approximately one meter, the aperture size was reduced to about 50 to 100 μm and remained at this level to the full depth of the core (i.e., 6 m). Figure 2.2 also shows results of a core analysis performed on cores recovered from a hole (QGU-14) drilled normal to the alcove wall. These results indicate the larger fracture apertures extend into the salt up to 4 m, in contrast to the results shown for the angled borehole. Additional details of the study, including results for porosity and dislocation density, are provided by Sandia (SNL 2002b).

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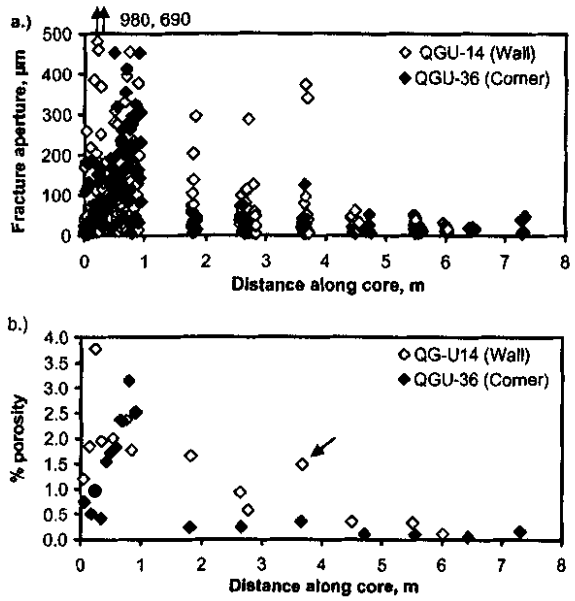
Figure 2.2 Fracture Aperture As a Function Core Length (after SNL 2002b)



Measured fracture apertures (a) and fracture porosity (b) in salt cores extracted from the WIPP DRZ adjacent to a 13-year-old excavation. Coring-induced damage was evident in the sample from 3.7 m in QGU-14 (arrow).

Data provided in the GAR suggest that brittle deformation extends at least 2.4 m (to Clay Seam G) and perhaps as much as 4.5 m (to Clay Seam H) above the roof of the WIPP openings. In addition, brittle deformation extends below the floor of the openings to at least the base of Marker Bed 139 (approximately 2 to 3 m). Recent studies performed under the geotechnical investigation programs have characterized the extent of brittle deformation in the corner of the Q Alcove using ultrasonic velocity measurements and core analyses. The results of these studies indicate that micro- and macrofractures are present 1 m from the walls forming the corner. These combined results are for older openings in which the DRZ and deformational features have matured (essentially a snapshot in time), but provide little information on how brittle deformation evolves with time. Therefore, it is evident that the preliminary trigger value of 1 m of growth per year is neither tractable nor quantitatively meaningful with the current data set. The trigger value for extent of deformation may need to be re-evaluated or other means of monitoring may need to be developed if the current TV is to be retained. Owing to the fact that ground-control is not an issue, the need for immediate re-evaluation of the TV is not essential to underground operations.

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Extent of Deformation:

Trigger Value Derivation				
COMP Title:	Extent of Deformation			
COMP Units:	Areal extent (length, direction)			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Geotechnical	Displacement	Meters	Room geometry	
COMP Derivation Procedure				
Extent of deformation deduced from borehole extensometers, feeler gauges, and visual inspections are examined yearly for active cross sections. Anomalous growth is determined by comparison.				
Related Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
DRZ Conceptual Model	Micro- and macro-fracturing in the Salado Formation	Constitutive model from laboratory and field databases.	Permeability around panel closures was assigned a constant value of $10^{-15}m^2$	DRZ spatial and temporal properties have important PA implications for permeability to gas, brine, and two-phase flow.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Fractures at depth	Growth of 1 m/y[(a)]	Coalescence of fractures at depth in rock surrounding drifts will control panel closure functionality and design, as well as discretization of PA models.		

(a) Trigger value may need to be re-evaluated.

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2.2.3 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 the DRZ are fundamental observational goals of the DRZ investigations currently being conducted under the geotechnical experimental programs, as discussed above. The ongoing cooperative geophysical program will help quantify damage evolution around WIPP openings. Initiation and growth of damaged rock zones are important considerations to operational period panel closures as well as compliance performance assessment calculations. Based on field observations, including the reshaping of Room 7 of Panel 1 for the first receipt of waste, brittle deformation is widely experienced by MB 139 as the floor heaves. Owing to the lithology and structural setting, brittle anhydrite response, as witnessed, is expected. Such observations help quantify modeling assumptions.

No changes to the technical positions are suggested for this COMP. 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.

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Initiation of Brittle Deformation:

Trigger Value Derivation				
COMP Title:	Initiation of Brittle Deformation			
COMP Units:	Qualitative			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Geotechnical	Closure	Observational	Operational and Remedial	
COMP Derivation Procedure				
Qualitative and pertinent to operational considerations. Captured qualitatively in association with other COMPs				
Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Not directly related to PA as currently measured	NA	NA	NA	NA
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Initiation of Brittle Deformation	None[a]	Qualitative COMPs can be subjective and are not prone to the development of meaningful trigger values.		

(a) Recommendation could be considered to add acoustic emissions for brittle monitoring or to replace this parameter with another more directly tied to performance assessment.

2.2.4 Displacement of Deformation Features

The displacement of deformation features primarily focuses on those features located in the immediate vicinity of the underground openings, e.g., mining-induced fractures and lithological units within several meters of the roof and floor. As discussed previously, fracture development is most continuous parallel to the openings and near the upper corners. These fractures tend to propagate or migrate by arching over and under the openings and, thus are designated "low angle fractures" relative to the horizontal axis. Typically, the fractures intersect or asymptotically approach lithologic units such as clay seams and anhydrite stringers. As a result, salt beams are formed. In the roof, the beams are de-coupled from the surrounding formation requiring use of ground support. In the floor, the beams sometimes buckle into the openings requiring floor milling and trimming. Lithologic units of primary interest are Clay G and H, located approximately 2.4 m and 4.5 m respectively, above the roof of a typical opening and Marker Bed 139 (anhydrite), located approximately 2 m below the floor.

Monitoring of these deformation features is accomplished by measuring the offset of observation boreholes drilled from the openings through the feature of interest. In general, these boreholes are aligned vertically (normal to the roof and floor surfaces) because of the location and orientation of the fractures and lithological units of interest. All of the observation holes are 7.6-cm (3-in) in

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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 (32 boreholes were drilled during the current reporting period of the GAR). Essentially all of the observation holes located in Panel 1 were drilled during 1999. Monitoring of deformations features via observation holes drilled in the floors of openings is no longer performed because of crushed-salt infilling of the holes.

The offset(s) in each observation borehole is determined by visually estimating the degree of borehole occlusion. The direction of offset along displacement features is defined as the movement of the stratum nearer the observer relative to the stratum farther from the observer. Typically, the nearer stratum moves toward the center of the excavation. Based on previous observations in the underground, the magnitude of offset is usually greater in boreholes located near the ribs as compared to boreholes located along the centerline of openings.

Currently, nearly 200 observation boreholes have been drilled to monitor displacement along deformation features. Much of the effort of the M&OC during the current GAR reporting period focused on the installation of new observation boreholes in the newly excavated rooms of Panel 2, so limited monitoring data were collected from the observational borehole network. Data that were collected included: (1) initial readings for 22 new observational boreholes drilled in Panel 2; (2) readings for 12 selected boreholes located near Panels 1 and 2; and (3) readings for three boreholes located in the East 140 access drift from S1300 to S1600. Based on the limited data available from the current GAR, only one borehole (OH 138-1, S1505 – E160) was completely occluded (located at Clay G). Offsets in the newly drilled Panel 2 observation boreholes are occurring with closures ranging from 0 to 50%, typically along Clay G. Some holes in Panel 1 are now more than 70% occluded compared to 25% occluded as reported in the previous COMPs report. Lateral movement may be used qualitatively in assessment of modeling techniques, particularly as geotechnical assessments of the effects of raising the repository horizon to Clay G are evaluated.

The TV for displacement of deformation features is the observation of a fully occluded borehole. *Because there are only limited data available from the current GAR, this COMP cannot be adequately assessed during this annual evaluation. However, based on the last COMPs assessment, approximately 10% of all the offsets being monitored meet or exceed the TV and this percentage is expected to grow with time, particularly near Panels 1 and 2 where new excavation has occurred.* Exceedence of the TV, in and of itself, is not necessarily a cause for concern, particularly when the result is having no significant impact on safety or performance given current ground-control techniques. However, in view of the current assessment and the likelihood that many or all of the offsets will exceed the TV in the future, a re-evaluation of the TV for displacement of deformation features may be warranted. The recent excavation and instrumentation of Panel 2 may provide the information needed for the re-evaluation.

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Displacement of Deformation Features:

Trigger Value Derivation				
COMP Title:	Displacement of Deformation Features			
COMP Units:	Length			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Geotechnical	Delta D/D_0	Observational	Not established	
COMP Derivation Procedure				
Observational – Lateral deformation across boreholes.				
Related Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Not directly related to PA	N/A	N/A	N/A	N/A
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Borehole diameter closure	Obscured observational borehole.	If lateral displacement is sufficient to close diameter of observational borehole, technical evaluation of consequences will be initiated.		

2.2.5 Subsidence

Subsidence is currently monitored via elevation determination of 51 existing monuments and 14 of the National Geodetic Survey's vertical control points. To address EPA monitoring requirements, the most recent survey results (DOE 2001 and DOE 2002b) are reviewed and compared to derived trigger values. 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. In contrast, 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 [BEAR; 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 rates would be 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 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. For the current annual subsidence surveys, a Second-Order Class II loop closure accuracy of 8 mm $\times \sqrt{\text{km}}$ (or 0.033 ft $\times \sqrt{\text{mile}}$) or better was achieved in all cases.

Over the years, different data sets have been included in the annual surveys. In general, the data sets have included:

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- 29 monuments surveyed from 1987 to 2002
- 2 monuments surveyed from 1989 to 2002
- 19 monuments surveyed from 1992 to 2002
- 1 monument surveyed from 1993 to 2002
- 14 National Geodetic Survey vertical control points surveyed from 1996 to 2002.

Four other monuments have also been included in various annual surveys, but were not included in the current surveys because the monuments no longer exist or have been physically disturbed. Historically, the surveys were conducted by private companies under subcontract to DOE; however, since 1993, the WIPP M&OC has conducted the surveys using a set of standardized methods. Starting with the 2002 survey, the M&OC was following WIPP procedure, WP 09-ES4001 (WTS 2002).

The current annual surveys comprise nine leveling loops containing as few as five to as many as eleven monuments/control points per loop as shown in Figure 2.3 (Surveys of Loop 1 benchmarks have been discontinued because only two benchmarks comprise this loop and these benchmarks are redundant to other survey loops). Elevations are referenced to Monument S-37 located approximately 7700 feet north of the most northerly boundary of the WIPP underground excavation. This location is considered to be far enough from the WIPP facility to be unaffected by excavation-induced subsidence expected directly above and near the WIPP underground. The elevation of S-37 has been fixed for all of the subsidence leveling surveys conducted since 1993. Survey accuracy for all loops was 0.003 ft or better, which exceeds the Second-Order Class II closure accuracy by more than an order of magnitude. Adjusted elevations are determined for every monument/control point by proportioning the vertical closure error for each survey loop to the monuments/control points comprising the loop. The proportions are based on the number of instrument setups and distance between adjacent points within an individual loop.

The adjusted elevations for each monument/control point are plotted as functions of time to assess subsidence trends. Figures 2.4 through 2.8 provide, respectively, elevations for selected monuments including those located (1) directly above the first waste emplacement panel, (2) directly above the second waste emplacement panel, (3) directly above the north experimental area, (4) near the salt handling shaft, and (5) well outside the repository footprint of the WIPP underground excavation. As expected, subsidence is occurring directly above the underground openings (Figures 2.4 through 2.7); however the magnitude of the subsidence is small ranging from -0.10 feet to -0.18 feet. Most of the observed subsidence has occurred in the time period from 1987 to 1993, but as discussed above, consistent surveying practices were not implemented until 1993 so some of the observed elevation changes may be related to differences in methodology rather than subsidence.

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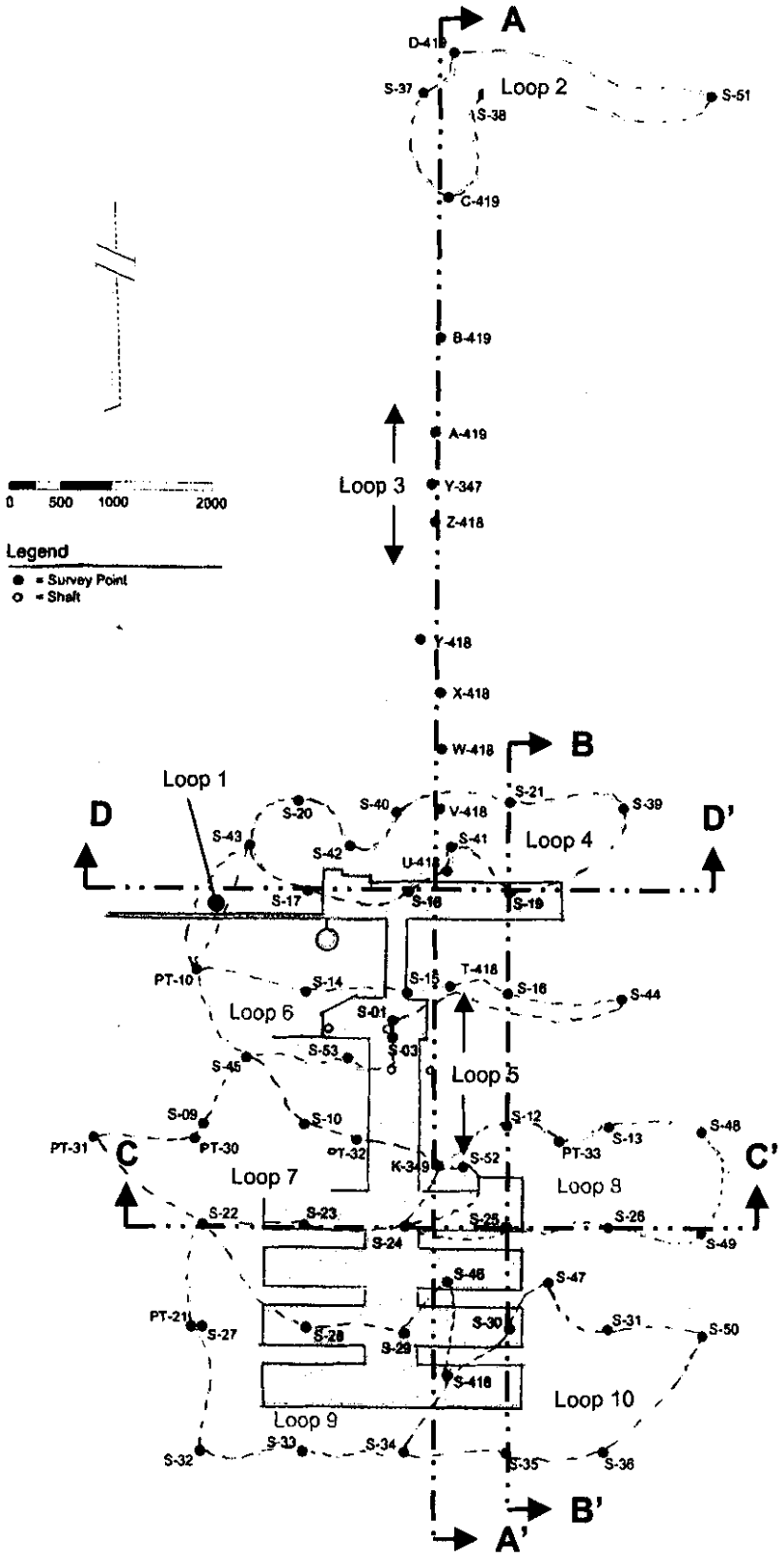

Figure 2.3. Monuments and Vertical Control Points Comprising WIPP Subsidence Survey Loops.

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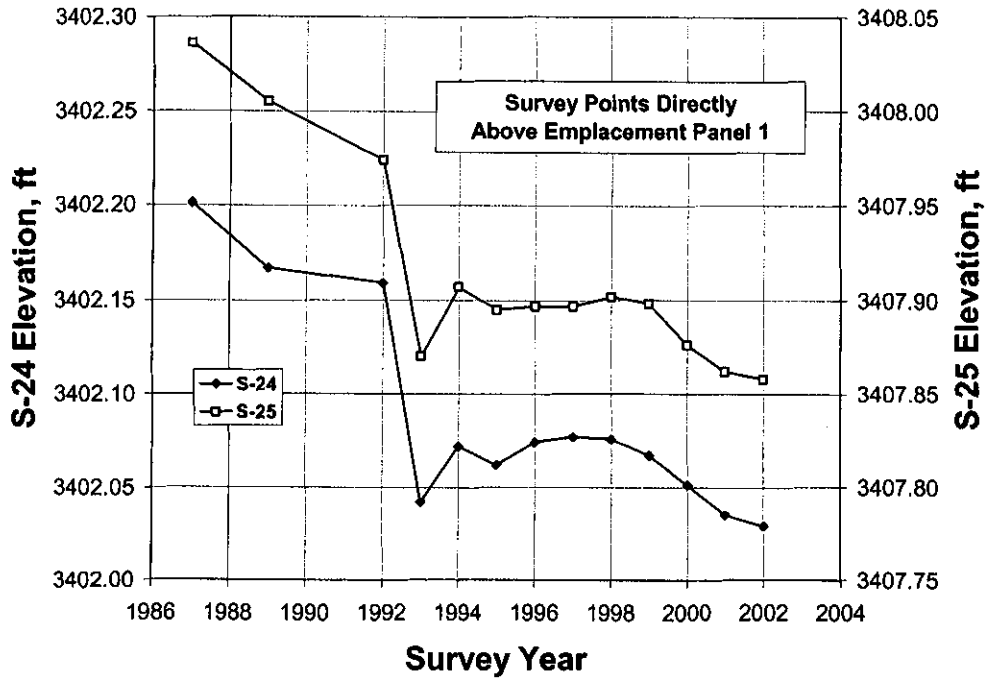

Figure 2.4 Elevations of WIPP Monuments S-24 and S-25 Located Directly Above Emplacement Panel 1.

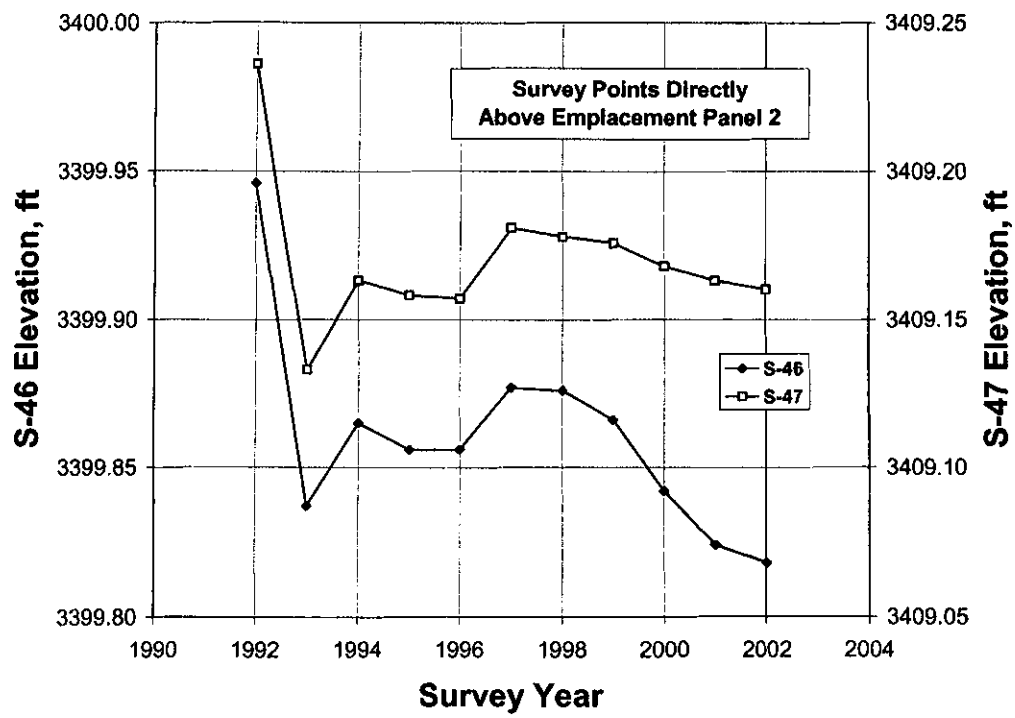

Figure 2.5. Elevations of WIPP Monuments S-46 and S-47 Located Directly Above Emplacement Panel 2.

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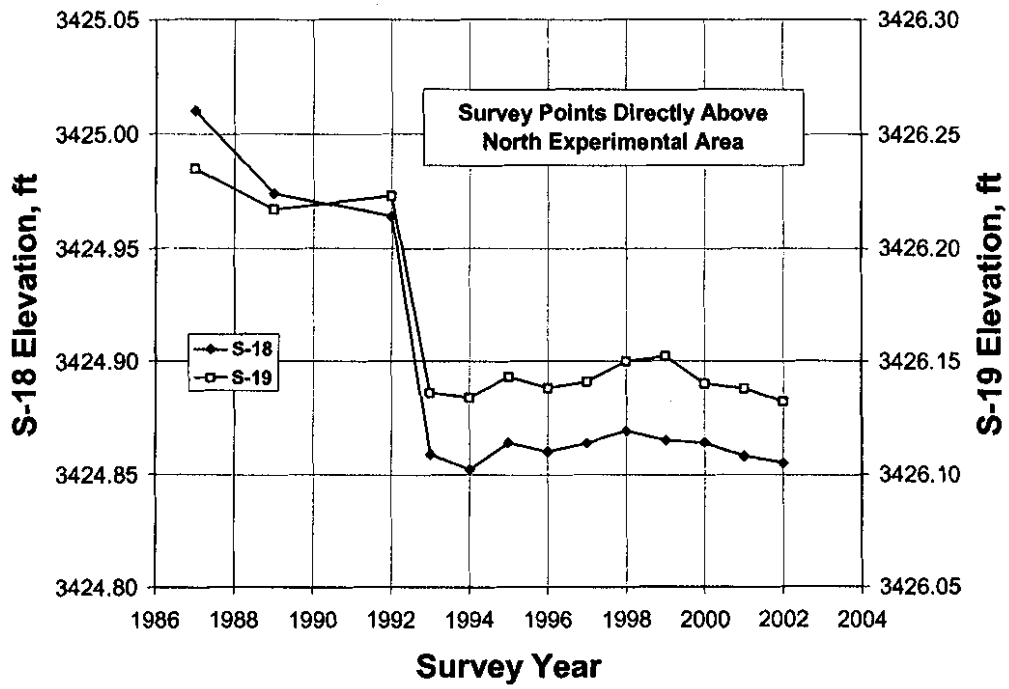

Figure 2.6. Elevations of WIPP Monuments S-18 and S-19 Located Directly Above the North Experimental Area.

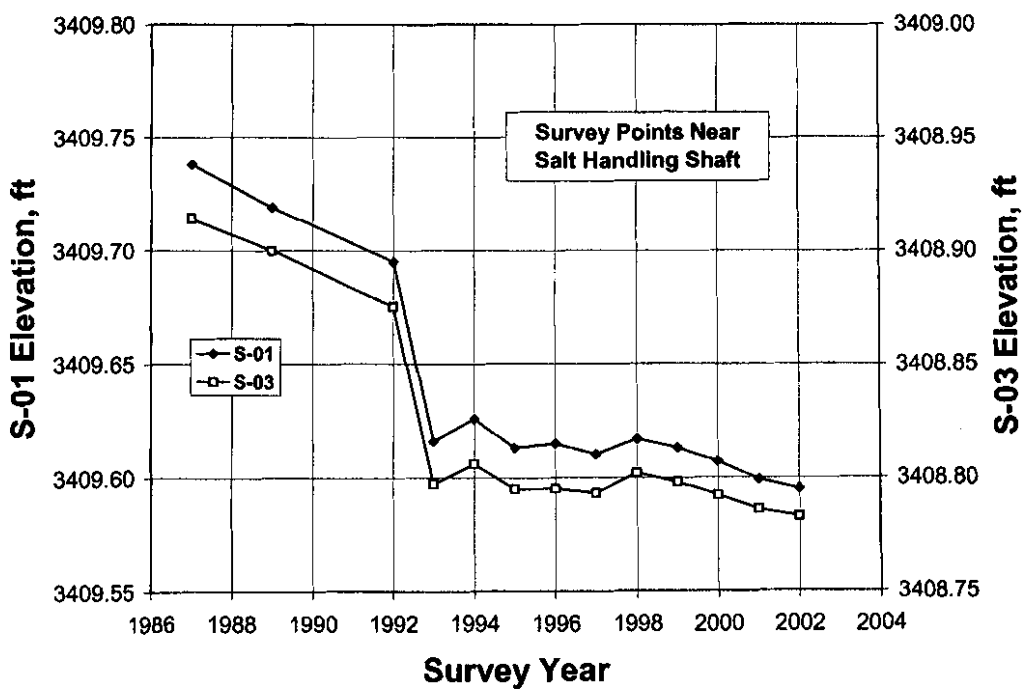

Figure 2.7. Elevations of WIPP Monuments S-01 and S-03 Located Near the Salt Handling Shaft.

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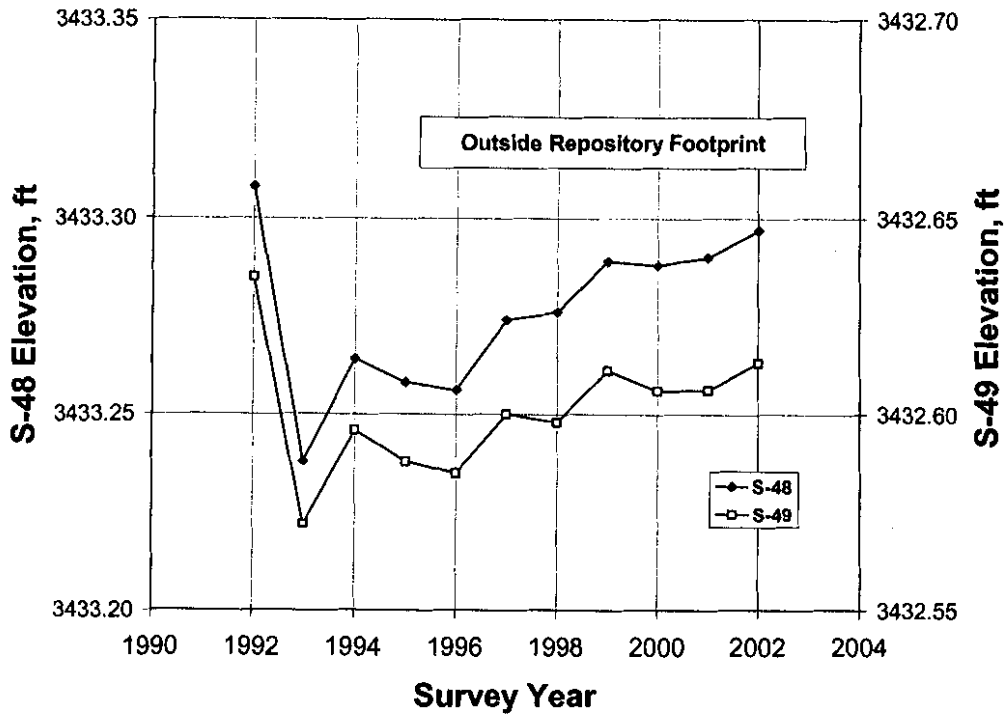

Figure 2.8. Elevations of WIPP Monuments S-48 and S-49 Located Outside the Repository Footprint.

Elevations of survey points located directly above Waste Emplacement Panel 1 were stable during the 1994 to 1998 surveys, as shown in Figure 2.4. However, when the excavation of Panel 2 was initiated in 1999, the elevations of the survey points above Panel 1 began to decrease with time in a nearly linear manner. These higher rates of subsidence were anticipated because the excavation of Panel 2 caused a redistribution of stress in the salt around Panel 1, leading to higher creep rates in the salt and higher convergence rates of panel rooms. Based on three-dimensional modeling conducted by Patchet et al. [2001], the convergence rates within Panel 1 were predicted to increase by as much as 60 to 96 percent as a result of the mining of Panel 2. A manifestation of these higher convergence rates is higher subsidence rates at the surface, particularly above Panel 1. Higher subsidence rates were also expected directly above Panel 2 because of the excavation. Figure 2.5 shows that the elevations of the survey points located above Panel 2 also began to decrease immediately following the initiation of Panel 2 excavation in 1999. With the completion of the Panel 2 excavation in October 2000, subsidence rates of survey points located above both Panel 1 and Panel 2 slowed as indicated by the 2002 survey results shown in Figures 2.4 and 2.5.

As time passes, subsidence is expected to be most pronounced directly above the WIPP underground excavations and will be minimal away from the repository footprint. Early results suggest this pattern is already occurring, as shown in Figures 2.9 through 2.12 for the following subsidence profiles (shown in plan view in Figure 2.3):

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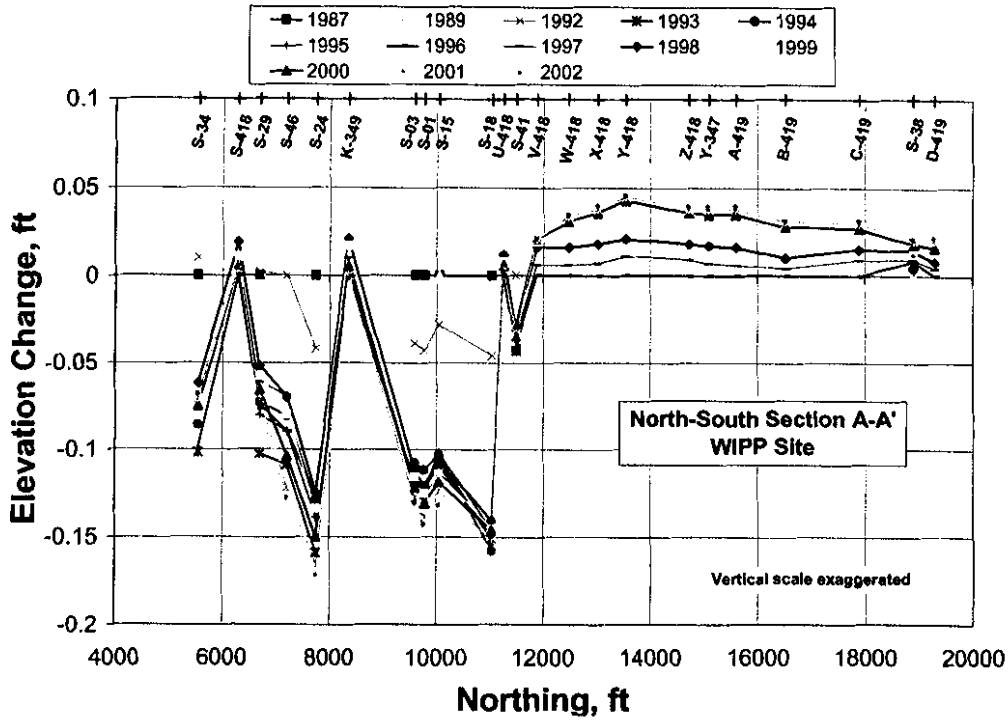

Figure 2.9. North-South Subsidence Profile A-A′.

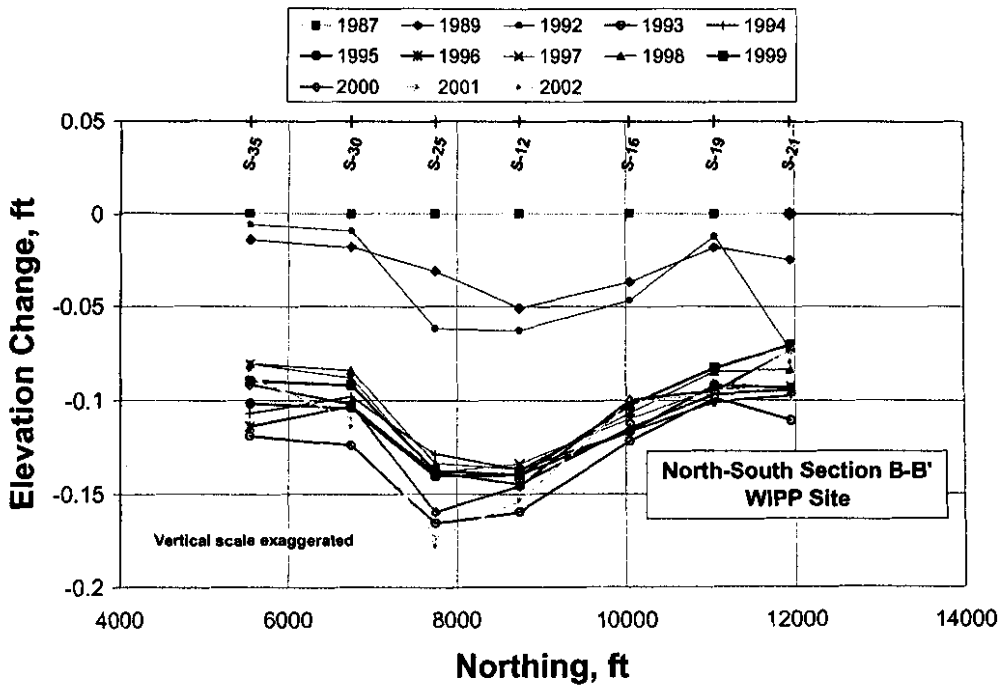

Figure 2.10 North-South Subsidence Profile B-B′.

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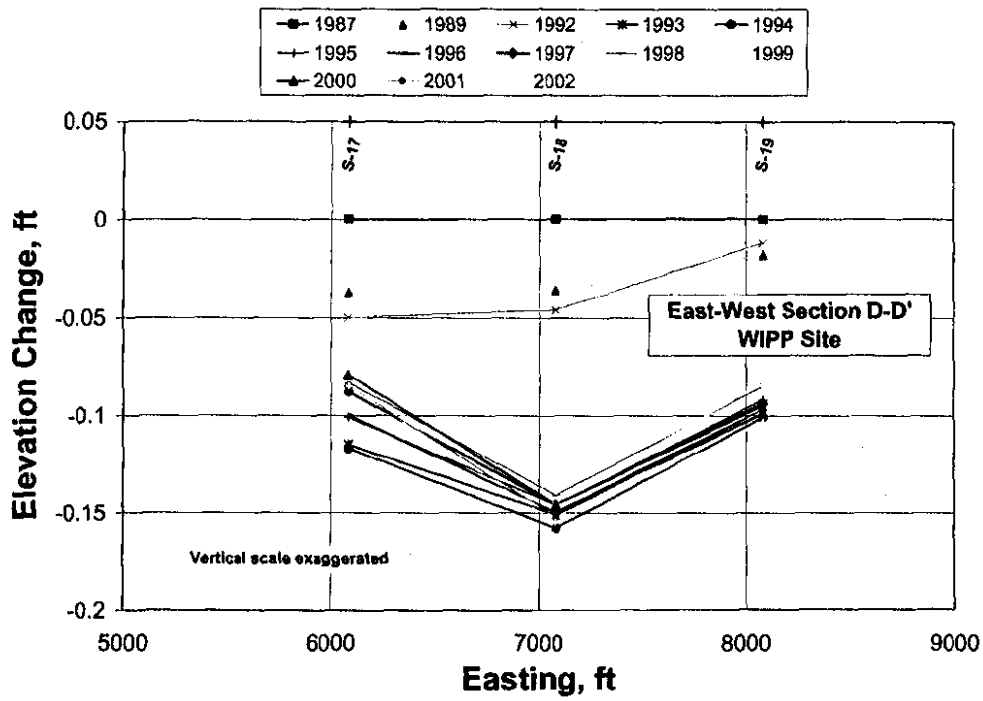

Figure 2.11 East-West Subsidence Profile C-C′.

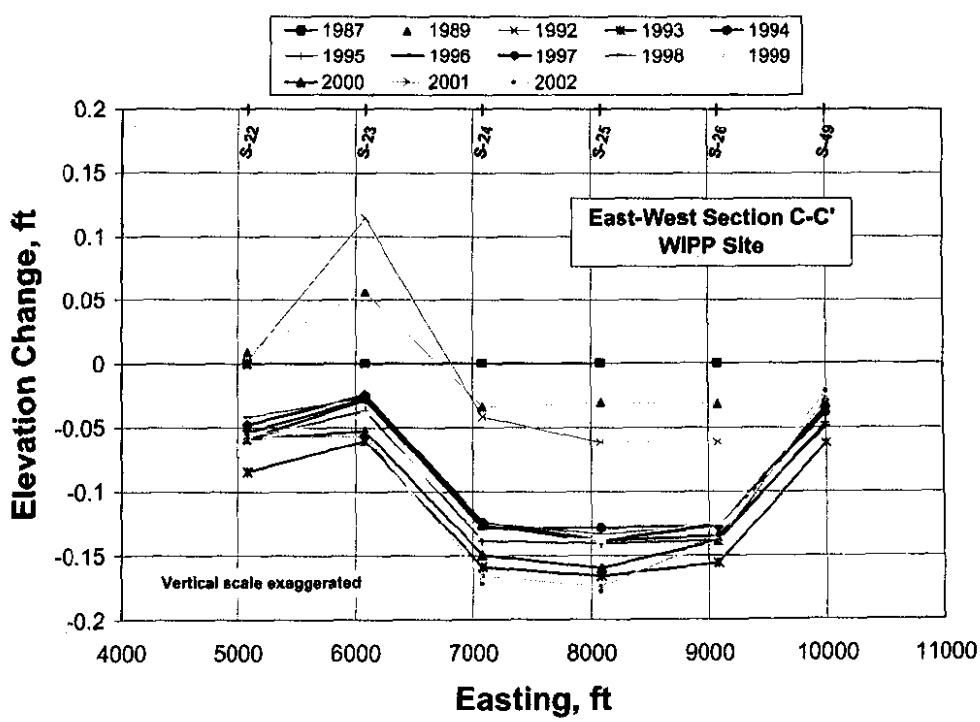

Figure 2.12 East-West Subsidence Profile D-D′.

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- Section A-A′, North-South section extending through the WIPP site
- Section B-B′, North-South section extending from the north experimental area through the south emplacement panels
- Section C-C′, East-West section extending through Panel 1
- Section D-D′, East-West section extending through the north experimental area.

The elevation changes of individual monuments shown in these figures are referenced to the elevations determined from the annual surveys that first incorporated the monument so, in some cases, direct temporal comparisons between pairs of monuments cannot be made. For example, only 29 monuments were included in the 1987 survey, while 50 and 65 monuments were included in the 1992 and 1996 surveys, respectively. Although direct comparisons cannot always be made, several observations are possible including:

1. The measured elevations of the monuments located between the Reference Monument, S-37, and the northern boundary of the WIPP footprint (Figure 2.9) appear to be increasing with time rather than remaining constant, as would be expected in an area unaffected by underground operations. This observation could suggest that the ground surface is actually rising with time or that the reference monument (i.e., S-37) is settling. *Since the elevation of the reference monument has not been verified recently, it is recommended that the elevation of this monument be accurately determined during the next annual survey to investigate the cause for the "observed" elevation rises north of the repository footprint.*
2. The most significant subsidence (approximately – 0.16 to –0.18 ft) occurs directly above the north experimental area (Monument S-18) and also above Panel 1 (Monuments S-24 and S-25), with slightly less subsidence near the Salt Handling Shaft (Monuments S-01 and S-03).
3. The highest subsidence rates measured for the 2000-2001 surveys were 4.9×10^{-3} m/yr, 4.3×10^{-3} m/yr, and 1.4×10^{-2} m/yr at Monuments S-24, S-25, and PT-32, respectively. For the 2001-2002 surveys, these rates decreased to 1.8×10^{-3} m/yr, 1.2×10^{-3} m/yr, and 2.7×10^{-3} m/yr.
4. The effects of subsidence extend away from the repository footprint approximately 1,000 to 1,500 ft (e.g., S-26, see Figures 2.3 and 2.12).
5. Generally, changes in elevation were largest for the 1992-1993 surveys but then were smaller in subsequent annual surveys. Exceptions are in the Panel 1 and Panel 2 areas where current data (2001-2002 annual surveys) suggest subsidence magnitudes have now exceeded their 1992-1993 levels probably as a result of the Panel 2 mining activities. These higher magnitudes were expected and are not considered detrimental to repository performance.

Furthermore, total subsidence and subsidence rates are small, and are approximately at the resolution level of the survey accuracy. These minor amounts of subsidence and low subsidence rates are expected and are well within normal ranges. *Based on the survey data available, subsidence rates of the ground surface at the WIPP are low, and with the exception of one point (i.e., PT-32), meet the TV requiring rates to be less than 1×10^{-2} m/yr. For the 2000-2001 surveys,*

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the subsidence rate of PT-32 exceeded the TV by 40%, but the rate for the 2001-2002 surveys decreased and is now below the TV. Therefore, no impact assessment is considered necessary; however, the subsidence rates for this point will be carefully monitored during future surveys.

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Subsidence:

Trigger Value Derivation			
COMP Title:	Subsidence		
COMP Units:	Change in surface elevation in meters per year		
Related Monitoring Data			
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Subsidence Monitoring Leveling Survey (SMP)	Elevation of 51 monitoring monuments	Decimal (meters)	—
SMP	National Geodetic Survey (NGS) results	Decimal (meters)	—
SMP	Change in elevation over year	Decimal (meters)	—
SMP	Total change in elevation since excavation of the WIPP	Decimal (meters)	—
COMP Derivation Procedure			
Survey data from annual WIPP Subsidence Monument Leveling are evaluated. Elevations of 51 monitoring monuments are compared to determine annual change.			

Related Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Subsidence	FEP [W2.023]	Predictions are of low consequence to the calculated performance of the disposal system – based on WID (1994) analysis and EPA treatment of mining.	Maximum total subsidence of 0.62 m above the WIPP.	Predicted subsidence will not exceed existing surface relief of 3 m – i.e., it will not affect drainage. Predicted subsidence may cause an order of magnitude rise in Culebra hydraulic conductivity (CCA Appendix SCR , Section 2.3.4) – this is within range modeled in the PA. Predicted WIPP subsidence is below that predicted for the effects of potash mining (0.62 m vs.1.5 m; EPA 1996).

Monitoring Data Trigger Values		
Monitoring Parameter ID	Trigger Value	Basis
Change in elevation per year	1.0×10^{-2} m per year subsidence	Based on the most conservative prediction by analyses referenced in the CCA.

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2.3 Hydrological COMPs

The CCA lists ten monitoring parameters that the DOE is required to monitor and assess during the WIPP operational period. Two of these parameters are considered "Hydrological" in nature and include:

- Changes in Culebra Water Composition
- Changes in Culebra Groundwater Flow

The SA has reviewed the data collected by the M&OC in 2001 under the Groundwater Surveillance Program (GSP). The GSP has two components:

- The Water Quality Sampling Program (WQSP)
- The Water-Level Monitoring Program (WLMP)

WQSP and WLMP data are reported in the Waste Isolation Pilot Plant 2001 Site Environmental Report (DOE, 2002c) and WLMP data are also reported in monthly memoranda from the M&OC to the SA.

2.3.1 Change in Culebra Water Composition

Water Quality Sampling Program
Under the WQSP, WTS collected water samples twice (sampling rounds 12 and 13) in 2001 from seven wells, denoted WQSP-1 through WQSP-6 and WQSP-6a. WQSP-1 through WQSP-6 are completed to the Culebra Dolomite Member of the Rustler Formation and WQSP-6a is completed to the Dewey Lake Redbeds. Flow and transport in the Dewey Lake are not modeled in PA because FEP screening showed them to be unimportant. Nevertheless, the Dewey Lake water quality is monitored because it might help to increase the understanding of the Dewey Lake hydrology. The water samples were analyzed in duplicate for major and minor elements and hazardous constituents per the WIPP Ground Water Monitoring Program Plan (GWMP; WID 1999a).

The Culebra is not a source of drinking water, so Culebra water quality is not of concern in an immediate health sense. Instead, Culebra water quality is important because of what it implies about the nature of the flow system. Solute concentrations differ widely among wells across the WIPP site, reflecting local equilibrium, diffusion, and perhaps most importantly, slow transport. 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 (Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3^-) 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 SA's models. Thus, this evaluation of the water-quality data focuses on the stability of major ion concentrations.

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In this evaluation, 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, assuming a normal distribution of concentrations. The baseline was revised in 2000, expanding from the first five rounds of sampling in the WQSP wells to the first ten rounds of sampling, which were performed between 1995 and 2000 before the first receipt of RCRA-regulated waste at WIPP. The baseline data are presented in the WIPP Resource Conservation and Recovery Act Background Quality Baseline Report (Crawley and Nagy, 1998) and in Addendum 1 to that report (IT Corporation, 2000). For the purposes of this evaluation, a small number of measurements have been eliminated from the baselines for WQSP-3, 5, 6, and 6a. The reasons for eliminating these values are discussed in detail in the third annual COMPs assessment report (SNL, 2001c). The elimination of these values is always conservative in that it reduces the "stable" range of concentrations for the affected parameters.

A charge-balance error, defined as the difference between the positive and negative charges from the ions in solution divided by the sum of the positive and negative charges, was also calculated for each analysis (Freeze and Cherry, 1979). Charge-balance errors are useful in evaluating the reliability of an analysis because water must be electrically neutral. Charge-balance errors are rarely zero because of inherent inaccuracy in analytical procedures, but a reliable analysis should not have a charge-balance error exceeding five percent (Freeze and Cherry, 1979). Charge-balance errors in excess of five percent imply either that the analysis of one or more ions is inaccurate (most common) or that a significant ion has been overlooked (rare). The variation between the values obtained for the "sample" and "duplicate" analyses of individual ions is also considered. Generally speaking, this variation should be less than ten percent. Greater variation indicates a potential problem with one or both analyses. Analytical results and charge-balance errors for rounds 12 and 13 of sampling are presented in Table 2.7 with the 95% confidence intervals derived from the baseline data.

In the 1999 COMPs Assessment Repost (SNL 2000b), it was noted that round 7 potassium concentrations exceeded the 95% confidence intervals (from five rounds of sampling) at WQSP-1, 2, 4, 5, and 6a. In the 1999 COMPs Assessment Report (SNL 2000b), it was noted that all potassium concentrations from rounds 8 and 9 from all seven WQSP wells exceeded the same 95% confidence intervals. In the 2000 COMPs Assessment Report (SNL 2000c), it was noted that the potassium concentrations in all of the WQSP wells except WQSP-6a continue to be high. In the case of WQSP-3, potassium concentrations from rounds 1 through 7 appear to constitute a separate population from the concentrations from rounds 8 through 10, with no overlap of the 95% confidence intervals (1200 to 1730 versus 2060 to 3150 mg/L). Potassium concentrations from rounds 11 through 13 from WQSP-3 fall within the 95% confidence interval derived from rounds 8 through 10. A similar situation is seen at WQSP-4 with respect to potassium, except the two populations are comprised of rounds 1 through 6 and 7 through 10 with slight overlap of the 95% confidence intervals (627 to 805 versus 784 to 1600 mg/L). Potassium concentrations from rounds 11 through 13 from WQSP-4 fall within the 95% confidence interval derived from rounds 7 through 10. Thus, the potassium analyses remain problematic. The greatest variation between concentrations of an ion between rounds 12 and 13 is potassium in WQSP-3, WQSP-6, and WQSP-6a (see Table 2.7). The reason for this variation is uncertain at this time.

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Table 2.7. Rounds 12 and 13 Ion Concentration and Baseline 95% Confidence Intervals.

Well I.D.	Sample	Cl^- Conc. (mg/L)	SO_4^{2-} Conc. (mg/L)	HCO_3^- Conc. (mg/L)	Na^+ Conc. (mg/L)	Ca^{2+} Conc. (mg/L)	Mg^{2+} Conc. (mg/L)	K^+ Conc. (mg/L)	Charge Balance Error (%)
WQSP-1	Round 12	37000/36000	4900/4800	51/52	19170/17460	1854/1794	**1255**/1180	**767/745**	**-5.8**
	Round 13	35900/36100	4730/4720	50/52	18450/17430	1828/1795	**1262/1270**	**896/871**	**-5.5**
	95% C.I.	31100-39600	4060-5600	45-54	15850-21130	1380-2030	940-1210	322-730	
WQSP-2	Round 12	35000/36000	5200/5600	48/50	19790/21340	1651/1715	**1199/1188**	**706/768**	-0.9
	Round 13	34900/34800	5160/5060	46/48	20910/21060	1689/1676	**1175/1193**	**841/856**	1.1
	95% C.I.	31800-39000	4550-6380	43-53	14060-22350	1230-1730	852-1120	318-649	
WQSP-3	Round 12	130000/130000	7200/7200	34/32	68300/71100	1310/1300	2120/2040	2180/2190	**-6.9**
	Round 13	131000/129000	7460/7190	32/34	81600/74400	1537/1430	2455/2312	3035/2862	-1.1
	95% C.I.	113900-145200	6420-7870	23-51	62600-82700*	1090-1620	1730-2500	2060-3150*	
WQSP-4	Round 12	54900/**52100**	6470/6380	40/38	35000/34200	1520/1650	1050/1060	1020/1090	1.6
	Round 13	55300/55000	6300/6130	36/34	34100/33170	1470/1505	1093/1134	1221/1245	-0.8
	95% C.I.	53400-63000	5620-7720	31-46	28100-37800	1420-1790	973-1410	784-1600*	
WQSP-5	Round 12	16100/15700	4890/4800	46/46	9756/9712	1011/1029	425/437	474/505	-2.6
	Round 13	15600/14800	4690/4470	46/44	**10600**/10200	1090/1080	**545/545**	452/454	3.5
	95% C.I.	13400-17600	4060-5940	42-54	7980-10420*	902-1180	389-535	171-523	
WQSP-6	Round 12	**5140/5170**	4600/4720	42/42	4320/4330	663/687	212/231	208/204	0.5
	Round 13	**4970/4820**	4500/4510	46/44	4090/4230	672/688	**234/236**	**278/282**	1.9
	95% C.I.	5470-6380*	4240-5120*	41-54	3610-5380*	586-777	189-233*	113-245	
WQSP-6a	Round 12	536/505	1900/1830	104/106	260/255	570/**540**	150/146	7.20/7.50	-3.7
	Round 13	**414/411**	1900/1870	102/102	*302/267*	622/620	**186**/169	7.55/7.59	**5.1**
	95% C.I.	433-764*	1610-2440	97-111	253-354	554-718	146-185	1.8-9.2	

Bold signifies outside 95% confidence interval
Italics signifies sample and duplicate analyses differ by more than 10%
*see text for baseline definition

WQSP-1

Concentrations of all major ions were within the 95% confidence intervals for round 12 sampling at WQSP-1 except for magnesium and potassium. Magnesium concentrations in round 12 were the highest observed at WQSP-1. One analysis was above the 95% confidence interval and the duplicate was near the upper 95% confidence interval (Table 2.7). Potassium concentrations in round 12 were also the highest observed at WQSP-1. Both the analysis and the duplicate are above the 95% confidence interval. However, the resulting charge-balance error was an unacceptable –5.8% indicating an overabundance of anions. For round 13, the results were similar to those for round 12 except that both magnesium and potassium were observed to be higher than in round 12. Still, for round 13, an unacceptably high charge-balance error of –5.5% existed again indicating an overabundance of anions. While there are some questions regarding the potassium concentration at WQSP-1, at the present time, the water quality is believed to be stable.

WQSP-2

Concentrations of all major ions were within the 95% confidence intervals for round 12 sampling at WQSP-2 except for both magnesium and potassium analyses. Magnesium concentrations in round 12 were the highest observed at WQSP-2. Both the analysis and the duplicate were above

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WQSP-6

For round 12 at WQSP-6, all ion concentrations were within the 95% confidence intervals except for chloride, which were the lowest observed (Table 2.7). The chloride concentrations were also low in round 13 with the magnesium and potassium concentrations being above the 95% confidence interval for both analyses and potassium concentrations being the highest observed in the WQSP well analyses. The charge-balance errors for rounds 12 and 13 were an acceptable 0.5% and 1.9%, respectively. At the present time, the water quality is believed to be stable at WQSP-6.

WQSP-6a

For round 12 at WQSP-6a, all ion concentrations were within the 95% confidence intervals expect for the duplicate analysis for calcium, which was below the 95% confidence interval (Table 2.7). The charge-balance error for round 12 was an acceptable –3.7%. For round 13, all ion concentrations were within the 95% confidence intervals except for one magnesium analysis, which was above the 95% confidence interval and both chloride analyses, which were the lowest observed in the WQSP well analyses. The charge-balance error for round 13 was an unacceptable 5.1%, which may be a result of the lower than normal chloride results. At the present time, the water quality is believed to be stable at WQSP-6a.

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the 95% confidence interval (Table 2.7). Potassium concentrations in round 12 were also above the 95% confidence interval for both the analysis and the duplicate. The charge-balance error for round 12 is an acceptable –0.9%. For round 13, the results were similar to those for round 12 in that both magnesium and potassium concentrations were above the 95% confidence intervals. Magnesium concentrations were slightly lower than observed in round 12, however, potassium concentrations were the highest observed. The charge-balance error for round 13 sampling was an acceptable 1.1%. Round 13 marks the third consecutive sampling in which the observed potassium concentrations are above the 95% confidence interval with no evidence that the analysis is in error, which means that the trigger value has been achieved. SNL is currently investigating these results and some possible reasons for the high potassium concentrations are discussed above. The preliminary results suggest that a new (higher) population for potassium concentration is being experienced, as identified in rounds 8 through 10 for WQSP-3. Therefore, the baseline and associated 95% confidence interval for potassium may need to be adjusted for WQSP-2. The SA is currently evaluating possible sources of the increased potassium levels that are being observed in several of the WQSP wells. Otherwise, at the present time, the water quality is believed to be stable at WQSP-2.

WQSP-3

For round 12 and 13 sampling at WQSP-3, all potassium concentrations were above the 95% confidence interval (Table 2.7). As discussed above, potassium concentrations from rounds 1 through 7 appear to constitute a separate population from the concentrations from rounds 8 through 10, with no overlap of confidence intervals (1200 to 1730 mg/L versus 2060 to 3150 mg/L). Therefore, the potassium concentrations from rounds 12 and 13 are consistent with analytical results since round 8, but not before. For round 13 sampling, all other ion concentrations were within the 95% confidence intervals. The charge-balance error for round 12 was an unacceptable –6.9% probably due to relatively low reported sodium concentration. The charge-balance error for round 13 was an acceptable –1.1%. At the present time, the water quality is believed to be stable at WQSP-3.

WQSP-4

For rounds 12 and 13 sampling at WQSP-4, potassium concentrations were again high (Table 2.7). As discussed above, potassium concentrations from rounds 1 through 6 appear to constitute a separate population from the concentrations from rounds 7 through 10, with only slight overlap of the 95% confidence intervals (627 to 805 mg/L versus 784 to 1600 mg/L). Therefore, potassium concentrations from rounds 12 and 13 are consistent with analytical results since round 7, but not before. All other ion concentrations from round 12 were within the 95% confidence intervals except the chloride duplicate, which was low. The charge-balance error was an acceptable 1.6% for round 12 reported values. All ion concentrations from round 13 were within the 95% confidence intervals, and the charge-balance error was an acceptable –0.8%. At the present time, the water quality is believed to be stable at WQSP-4.

WQSP-5

For round 12 at WQSP-5, all ion concentrations were within the 95% confidence intervals (Table 2.7). The charge-balance error for round 12 was an acceptable –2.6%. For round 13, all ion concentrations were within the 95% confidence intervals except for one analysis for sodium, which was the highest observed value, as well as both analyses for magnesium. The charge-balance error for round 13 was an acceptable 3.5%. At the present time, the water quality is believed to be stable at WQSP-5.

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Change in Groundwater Composition - 2002:

Trigger Value Derivation				
COMP Title:	Groundwater Composition			
COMP Units:	Various – mg/L pCi/L			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Groundwater Monitoring	Composition	Semi-annual chemical and radionuclide analysis	RCRA Background Water Quality Baseline	
COMP Derivation Procedure				
Annually evaluate ASER data and compare to previous years and baseline information				
Related Performance and Compliance Elements				
Element Title	Type & ID	Derivation Procedure	Compliance Baseline	Impact of Change
Groundwater conceptual model, brine chemistry, actinide solubility	Indirect	Conceptual models	Indirect – The average Culebra brine composition is not used.	Provides validation of the various CCA models, potentially significant with respect to flow, transport, and solubility and redox assumptions.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Change in Culebra groundwater composition	Both duplicate analyses for any major ion falling outside the 95% confidence interval (see Table 2.7) for three consecutive sampling periods	The 95% confidence interval for a particular analyte defines the range of concentrations that 19 out of 20 analyses, on average, should fall within. Therefore, trigger values should not be set so that a single analysis falling outside the 95% confidence interval is significant. In addition, analysis of solutes in the concentrated brines of the Culebra is not a routine procedure, and occasional analytical errors are to be expected, particularly when a new laboratory is contracted to perform the analyses (SNL2002a).		

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2.3.2 Changes in Groundwater Flow (Water Level)

Assessment of the COMP "Changes in Groundwater Flow" involves trigger values derived from the steady-state freshwater heads estimated for Culebra flow modeling in the CCA. The Culebra transmissivity (T) fields that were subsequently used to simulate the transport of radionuclides through the Culebra were considered calibrated when, among other things, the modeled heads at 32 wells fell within the ranges of uncertainty estimated for steady-state freshwater heads at those wells. If monitoring shows that heads at these wells are outside the ranges used for T-field calibration (hereafter called the "CCA range"), the cause(s) and ramifications of the deviations must be determined.

The freshwater head is the elevation of the column of freshwater (density = 1.0 g/cm^3) that would exert the same pressure at the midpoint of the Culebra as that exerted by the column of fluid actually in the well. Thus, once the ground-surface elevation at a well site is surveyed, determination of freshwater head requires two sets of information:

1) The height of the water column in the well above the midpoint of the Culebra.
2) The density of the water in that water column.

Under the WLMP in 2001, WTS made monthly water-level measurements in 41 Culebra wells, and quarterly in 17 "redundant" Culebra wells located on the same drilling pads as eight of the wells monitored monthly. Pressure-density surveys were performed in 29 Culebra wells in 1987 (Crawley, 1988). Fluid-density data from other wells come from water samples collected over a range of years. WTS began an annual program of pressure-density surveys in all of the monitoring wells in 2000. Table 2.8 gives the results available at the current time (DOE, 2002c).

Water levels were also measured in wells completed in horizons other than the Culebra. These other horizons are not currently monitored as COMPs and do not have trigger values. The water-level measurements in these units do, however, provide information used in the development of our conceptual model of site hydrology. Water levels in the Magenta Member of the Rustler Formation were measured monthly in 16 wells. Water levels in the Los Medanos Member of the Rustler Formation and across the Rustler-Salado contact were measured monthly in one well. Monthly water levels were measured in two Dewey Lake wells, two Bell Canyon wells and in one well in the Forty-niner Member of the Rustler Formation.

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Table 2.8 Pressure Density Survey Results

Well I.D.	Date	Formation	Density (g/cm^3)
AEC-7	2000	Culebra	1.0888
DOE-1	5/18/01	Culebra	1.093
DOE-2	2000	Culebra	1.0554
H-1	2000	Culebra	1.0197
H-2b2	2000	Culebra	1.0117
H-3b1	10/9/01	Culebra	1.0051
H-3b2	6/4/01	Culebra	1.0334
H-4b	6/4/01	Culebra	1.0154
H-5b	10/8/01	Culebra	1.0981
H-6b	5/16/01	Culebra	1.0371
H-9b	6/13/01	Culebra	1.000
H-11b4	6/11/01	Culebra	1.061
H-12	2000	Culebra	1.0833
H-14	2000	Culebra	1.0421
H-17	6/11/01	Culebra	1.14
H-19b0	6/5/01	Culebra	1.0620
H-19b4	2000	Culebra	1.0661
H-19b5	2000	Culebra	1.07
H-19b7	2000	Culebra	1.0612
P-15	2000	Culebra	1.0133
P-17	2000	Culebra	1.0912
WIPP-19	2000	Culebra	1.0556
WIPP-22	2000	Culebra	1.0699
WIPP-21	2000	Culebra	1.0759
DOE-2	7/11/01	Magenta	1.0553
H-5c	10/8/01	Magenta	1.0045
H-6c	9/26/01	Magenta	1.003
H-11b2	5/31/01	Magenta	1.070
H-14	7/9/01	Magenta	1.0294
H-15	7/9/01	Magenta	1.0294
H-18	7/11/01	Magenta	1.0294
WIPP-18	7/12/01	Magenta	1.0423

Culebra Data

Table 2.9 provides a comparison of Culebra water levels in feet above mean sea level (ft AMSL) from December 2000 to December 2001 at the 41 wells monitored monthly (DOE, 2002c). Water levels in 29 of the wells rose in 2001. In all but three of those wells, water levels rose by less than two feet. Water levels rose by 28.43-feet in CB-1, by 2.97-feet in WIPP-25, and by 6.63-feet in WIPP-30. The high and changing heads in CB-1 appear to reflect a problem with the well (perhaps plugged perforations combined with a leaking packer) and are not thought to reflect conditions in the Culebra. In May, 2002, the water level in CB-1 was reduced via pumping. The

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water level in CB-1 continues to be monitored and remeidial actions are being considered. In January, 2001, the P-15 well was discovered to have holes in the casing near the surface, confirming the hypothesis given in the previous COMPs Assessment Report (SNL 2001c). As a result, P-15 was moved to the plugging and abandonment priority list. The water rose 1.61-feet in P-18, continuing a trend dating back to 1977. The speculation remains that the casing in P-18 may not be well cemented, and that the measured water levels reflect leakage from horizons above the Culebra.

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Table 2.9. Summary of 2001 Culebra Water-Level Changes and Freshwater Heads

Well I.D.	12/00 W.L. (ft AMSL)	12/01 W.L. (ft AMSL)	2001 Change (ft)	12/01 FWH (ft AMSL)	CCA Range (ft AMSL)	Outside CCA Range??
AEC-7	3038.22	3038.29	0.07	3061.25	3055.1-3060.4	Y
CB-1	3245.85	3274.28	28.43	3287.21	2986.9-2991.5	Y
DOE-1	2975.04	2976.71	1.67	3005.19	2992.5-3013.8	N
DOE-2	3040.80	Recompleted to Magenta well (April 2001)			3061.7-3071.5	N/A
ERDA-9	3007.53	3008.60	1.07	3024.05	N/A	N/A
H-1	3035.57	Plugged and Abandoned (February 2001)			3017.1-3030.2	N/A
H-2b2	3036.63	3037.60	0.97	3039.95	3033.8-3040.0	N
H-3b2	2997.81	2998.94	1.13	3010.29	2995.1-3007.5	Y
H-4b	3000.30	3001.07	0.77	3004.66	2988.2-2992.1	**Y**
H-5b	3028.30	3028.57	0.27	3073.47	3060.4-3069.6	Y
H-6b	3051.70	3052.50	0.80	3064.68	3054.5-3061.0	Y
H-7b2	2997.56	2997.54	-0.02	2997.45	2994.1-2996.1	**Y**
H-9b	2990.20	2991.31	1.11	2991.56	2973.4-2977.7	**Y**
H-10b	2994.49	2994.70	0.21	3026.81	3015.4-3029.9	N
H-11b4	2983.61	2984.65	1.04	3004.75	2990.2-3003.3	Y
H-12	2968.94	2969.63	0.69	3006.88	2993.1-3001.0	Y
H-14	3008.98	Recompleted to Magenta well (April 2001)			3007.9-3021.0	N/A
H-15	2961.86	Recompleted to Magenta well (April 2001)			3005.2-3019.4	N/A
H-17	2960.56	2961.97	1.41	3011.20	2985.9-2991.8	Y
H-18	3059.60	Recompleted to Magenta well (April 2001)			3055.4-3067.3	N/A
H-19b0	2988.52	2989.73	1.21	3011.50	N/A	N/A
P-15	3015.89	3015.60	-0.29	3016.38	3008.5-3013.8	**Y**
P-17	2983.47	2983.35	-0.12	2997.53	2981.0-2985.6	Y
P-18	3162.44	3164.05	1.61	3235.74	N/A	N/A
WIPP-12	3031.51	3032.15	0.64	3068.95	3062.7-3070.2	N
WIPP-13	3057.57	3057.08	-0.49	3067.64	3059.1-3068.2	N
WIPP-18	3033.55	Recompleted to Magenta well (April 2001)			3048.9-3062.7	N/A
WIPP-19	3038.93	3039.83	0.90	3077.62	N/A	N/A
WIPP-21	3015.17	3016.10	0.93	3040.25	N/A	N/A
WIPP-22	3029.15	3030.12	0.97	3061.19	N/A	N/A
WIPP-25	3057.46	3060.43	2.97	3057.36	3043.6-3050.2	**Y**
WIPP-26	3021.71	3021.40	-0.31	3021.53	3013.1-3014.8	**Y**
WIPP-27	3081.22	3082.10	0.88	3088.19	3075.5-3080.1	**Y**
WIPP-29	2967.37	2967.06	-0.31	2970.23	N/A	N/A
WIPP-30	3061.22	3067.85	6.63	3074.91	3060.4-3067.6	**Y**
WQSP-1	3053.00	3053.61	0.61	3070.29	N/A	N/A
WQSP-2	3059.11	3059.45	0.34	3079.19	N/A	N/A
WQSP-3	3011.21	3011.42	0.21	3068.49	N/A	N/A
WQSP-4	2986.23	2987.17	0.94	3012.10	N/A	N/A
WQSP-5	3001.69	3002.59	0.90	3009.64	N/A	N/A
WQSP-6	3014.19	3015.51	1.32	3019.23	N/A	N/A

Bold **Y** signifies determination is independent of density uncertainty
NA = not applicable; data from well not used in CCA T-field calibration

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Water levels decreased in six wells in 2001. In all of these wells, the water levels decreased by less than one foot. In April 2001, DOE-2 was recompleted as a Magenta well ,effectively eliminating the speculated packer problem identified in the 2000 COMPs Assessment Report (SNL 2000c).

Table 2.9 also compares the December 2001 freshwater heads to the CCA ranges for the 22 (28 wells were compared in the 2000 COMPs Assessment Report (SNL 2000c) but six of these wells were recompleted as Magenta monitoring wells) wells used in the generation of the CCA T fields that were monitored in 2001. Freshwater heads in 17 of the 22 wells appear to be outside the CCA ranges at the end of 2001, all higher than expected. The heads at CB-1 and P-15 can be discounted for the reasons discussed above, leaving 15 wells with unexpectedly high freshwater heads.

For eight of these 15 wells (AEC-7, H-3b2, H-5b, H-6b, H-11b4, H-12, H-17, and P-17), freshwater heads could be within the CCA range if a lower fluid density was used to convert the measured water levels to freshwater heads. The fluid densities used to calculate the freshwater heads in Table 2.9 are the most current available from the WTS annual program of pressure-density surveys. Therefore, the SA is of the opinion that the heads in these eight wells exceed the respective CCA ranges that were used in the generation of the T fields.

For the remaining seven of the 15 wells (H-4b, H-7b2, H-9b, WIPP-25, WIPP-26, WIPP-27, WIPP-30), the measured water levels exceed the CCA range before being converted to freshwater head. In these cases, conversion to freshwater head using any feasible fluid density can only increase the deviation from the CCA range. WIPP-25, WIPP-26, and WIPP-27 are located in Nash Draw where they may be affected by discharge of effluent from potash mines and mills. Changes in heads in Nash Draw might then propagate to the other wells, but at the present time this is only speculation. WIPP-30 is in close proximity to the Nash Draw boundary as well as the identified northern Salado dissolution tongue, both of which make it susceptible, although probably to a lesser degree, to the same influences as WIPP-25, WIPP-26, and WIPP-27. Several of these 15 wells are on or near the offsite-transport pathways through the Culebra modeled for the CCA.

Considering the potential impact that these Culebra heads in excess of the respective CCA ranges might have on CCA compliance calculations, the cause(s) of the change needs to be understood. The SA began an investigation of possible causes of the high heads in 2000 (SNL 2001b). Recently, the SA began formalizing an integrated hydrology program plan, in conjunction with both WTS and the DOE CBFO, that outlines the path forward with respect to this investigation. The plan calls for the completion of a number of strategically placed new Culebra wells as well as several wells replacing Culebra wells that have been lost to deterioration. The new wells will be sited in order to investigate possible sources of the rising Culebra heads as well as to fill gaps in existing Culebra information. It is anticipated that this integrated hydrology program plan will be completed by December 2002.

Data from Other Units

Table 2.10 provides a comparison of water levels from units other than the Culebra from December 2000 to December 2001. Water levels in the Magenta changed by less than 1 foot in all wells except H-3b1, H-10a, and WIPP-25 in 2001. Well H-1 was plugged and abandoned in February 2001 after unsuccessful attempts were made to repair leaking casing. Water level rises associated with the leaking casing in H-1 propagated to H-2b1 and H-3b1, where water levels rose

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by approximately 2.1 feet and 0.6 feet, respectively, in 2000. Following the plugging and abandonment of H-1 in February, 2001, the prior trends significantly subsided, resulting in a 0.65-foot rise in H-2b1 and a 1.16-foot water level decline in H-3b1. The packer separating the Culebra and the Magenta in WIPP-25 was replaced in 2000, causing water-level fluctuations from which the well may still be recovering. Seven new Magenta wells were monitored in 2001. Six of these wells (DOE-2, H-11b2, H-14, H-15, H-18, and WIPP-18) were recompleted to Magenta wells. One well (C-2737) was a new Magenta well added to the monitoring well network.

Table 2.10 Summary of 2001 Water-Level Changes in Units Other than the Culebra.

Well I.D.	12/00 W.L. (ft AMSL)	12/01 W.L. (ft AMSL)	2001 Change (ft)
Magenta Wells			
C-2737	Completed March 2001	3144.96	N/A
DOE-2	Completed April 2001	3058.12*	N/A
H-1	3229.17	P&A February 2001	N/A
H-2b1	3146.54	3147.19	0.65
H-3b1	3151.71	3150.55	-1.16
H-4c	3143.93	3144.33	0.40
H-5c	3156.91	3157.29	0.38
H-6c	3064.40	3064.84	0.44
H-8a	3027.07	3026.83	-0.24
H-10a	3160.18	3162.18	2.00
H-11b2	Completed April 2001	3127.85*	N/A
H-14	Completed April 2001	3102.73*	N/A
H-15	Completed April 2001	3113.26*	N/A
H-18	Completed April 2001	3077.51*	N/A
WIPP-18	Completed April 2001	3113.12*	N/A
WIPP-25	3048.23	3050.54	2.31
Dewey Lake Wells			
H-3d	3073.01	3073.96	0.95
WQSP-6a	3198.25	3198.11	-0.14
Los Medanos Wells			
H-8c	2979.12	2979.22	0.10
Forty-niner Wells			
H-3d	3089.45	3091.64	2.19
Bell Canyon Wells			
AEC-8	3026.09	3043.70	17.61
CB-1	3014.65	3014.66	0.01

N/A = not available
* = measured by SNL

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Water levels were stable within one foot in both of the Dewey Lake wells and in the Los Medanos/Rustler-Salado well (H-8c). The water level in the Forty-niner well, H-3d, increased by 2.19 feet in 2001.

The Bell Canyon water level in AEC-8 increased by 17.61 feet in 2001, continuing a rise of unknown origin dating back to 1993. The cause of this rise is currently under investigation. Water-level monitoring of the Bell Canyon began again in well Cabin Baby-1 (CB-1) in September 1999 after a 13-year hiatus. The water level was stable in 2001. At the end of 2001, the water level was approximately five feet lower than it had been in 1986, which may be attributed to differences in the density of the fluid in the well related to drilling-brine contamination.

Changes in Groundwater Flow - 2002:

Trigger Value Derivation				
COMP Title:	Changes in Groundwater Flow			
COMP Units:	Inferred from water-level data			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Groundwater Monitoring	Head and Topography	Monthly water-level measurements; annual pressure-density surveys.	Indirect	
COMP Derivation Procedure				
Annual assessment from ASER data.				
Related PA Elements				
Element Title	Type & ID	Derivation Procedure	Compliance Baseline	Impact of Change
Groundwater conceptual model, Transmissivity fields	NA	NA	NA	Provides validation of the various CCA models - T-field assumptions and groundwater basin model.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Change in Culebra Groundwater Flow	CCA range; see Table 2.9	Annual comparisons with ranges of undisturbed steady-state freshwater heads used to calibrate Culebra T fields for CCA.		

2.4 Waste Activity

A significant amount of Panel 1 has been utilized as of September 15, 2002. According to current schedules, waste emplacement will be completed in Panel 1 by early 2003. However, the entire panel will not be utilized as originally planned. Figure 2.12 details waste emplacement in Panel 1 where waste has been placed in Room 7 and only in one access way of Rooms 4, 5 and 6. Waste

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has been emplaced in Room 3 as shown. Waste is currently placed in Room 2 with the remaining placements shown in Figure 2.12. Underutilizing the panel eliminated approximately 30% of the available area. As such, this panel's waste activity assessment will not be representative of other panels in the repository.

As of September 15, 2002, a total of 32,777 containers (representing 7,342 m^3) of CH TRU are currently stored at WIPP of which 275 are SWBs and the remainder 55-gallon drums. A total of 554 dunnage 55-gallon drums have also been emplaced. No RH waste has been emplaced in WIPP. Totals for actinide content (listed in grams and curries), number of drums/SWBs, and kilograms of cellulosics, plastics and rubber (CPR) emplaced in Panel 1 are found in Appendix A of this document.

Other issues have arisen that impacts this year's waste activity COMPs assessment. EPA has provided guidance to DOE (EPA 2002) directing them to include (in the CRA) an assessment of random versus non-random waste emplacement based on emplacement practices and current emplacement schedules. Also, EPA indicated that new experimental data and information relating to actinide solubilities must be addressed in this assessment. EPA has also directed DOE to include the most recent 40 CFR 194.4(b)(4) information in the CRA (COMPs reports are a part of the 194.4(b)(4) report). Therefore, a complete assessment of the actinide COMP must be included in the CRA and the impacts of non-random emplacement must be assessed. This assessment is likely to identify a new actinide COMP assessment process. A comparison of the tracked actinides the total repository inventory used in the CCA is detailed in Table 2.11. A map of the ten tracked actinides is graphically detailed in Figures 2.13 to 2.20. Each bar represents a top view of a room if all the waste were lined up in a straight room. This information will be included and assessed in the EPA directed non-random assessment. EPA has requested this information be included in the CRA (planned for completion in October 2003). No other assessment has been made at this time.

As discussed in the Trigger Value Derivation Report, 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 at this time. A detailed assessment will be provided in the CRA. A new actinide COMPs assessment process may be evaluated prior to the first COMPs assessment after the CRA in October 2004.

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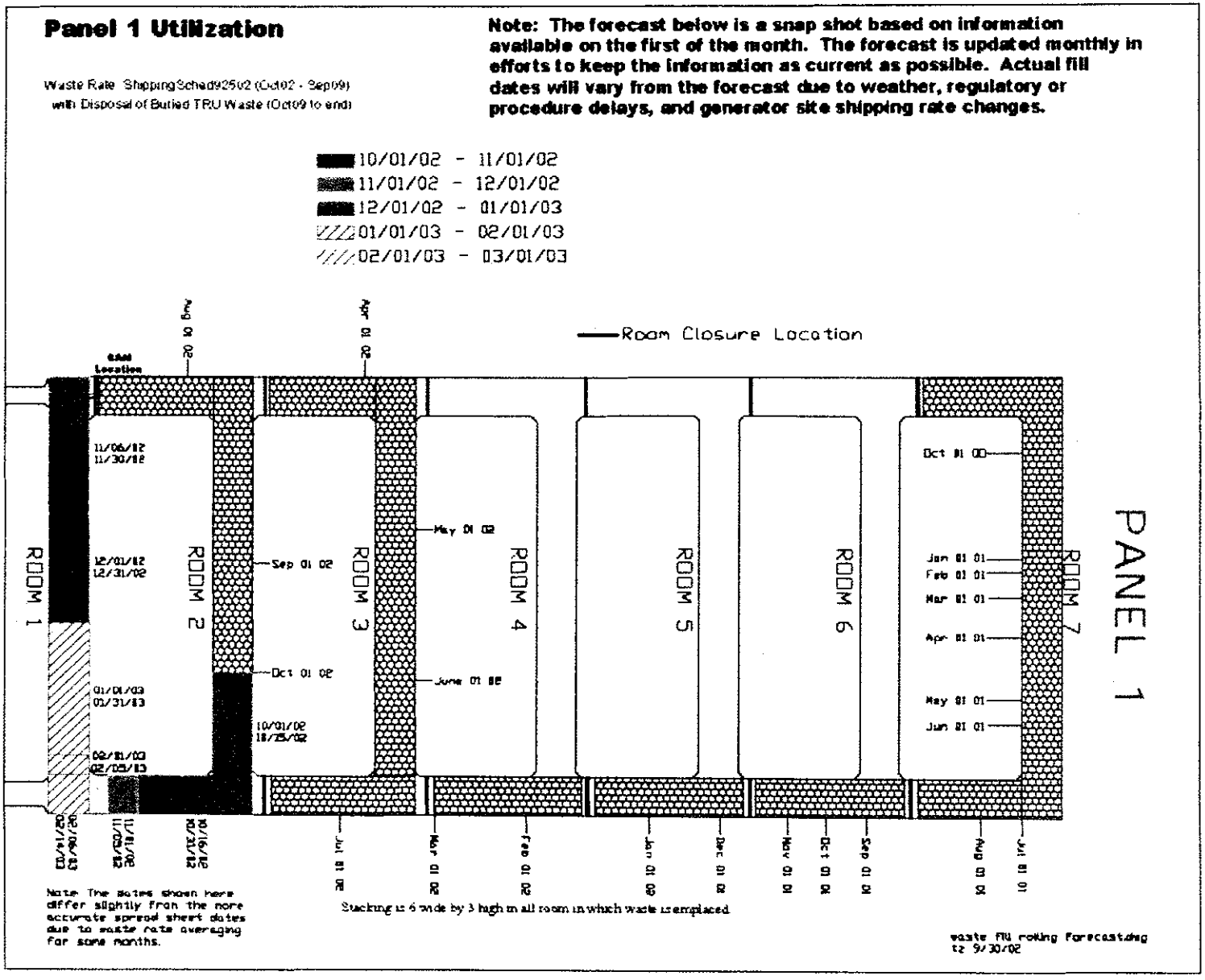

Figure 2.12 Panel 1 Utilization

Table 2.11 Comparison of Panel 1 Inventory to CCA Repository Inventory

Radionuclide (CCA Table 4-10)	CCA Total Inventory at Closure (Curies)	Non-decayed Panel 1 Inventory (Curies)
Am^{241}	4.48×10^{5}	1.16×10^{5}
Pu^{238}	2.61×10^{6}	5.53×10^{3}
Pu^{239}	7.95×10^{5}	1.34×10^{5}
Pu^{240}	2.15×10^{5}	3.03×10^{4}
Pu^{242}	1.17×10^{3}	2.88
U^{233}	1.95×10^{3}	2.45×10^{-1}
U^{234}	5.08×10^{2}	1.17
U^{238}	50.1	6.13
Sr 90	2.16×10^{5}	0
Cs^{137}	2.24×10^{5}	3.21×10^{-4}

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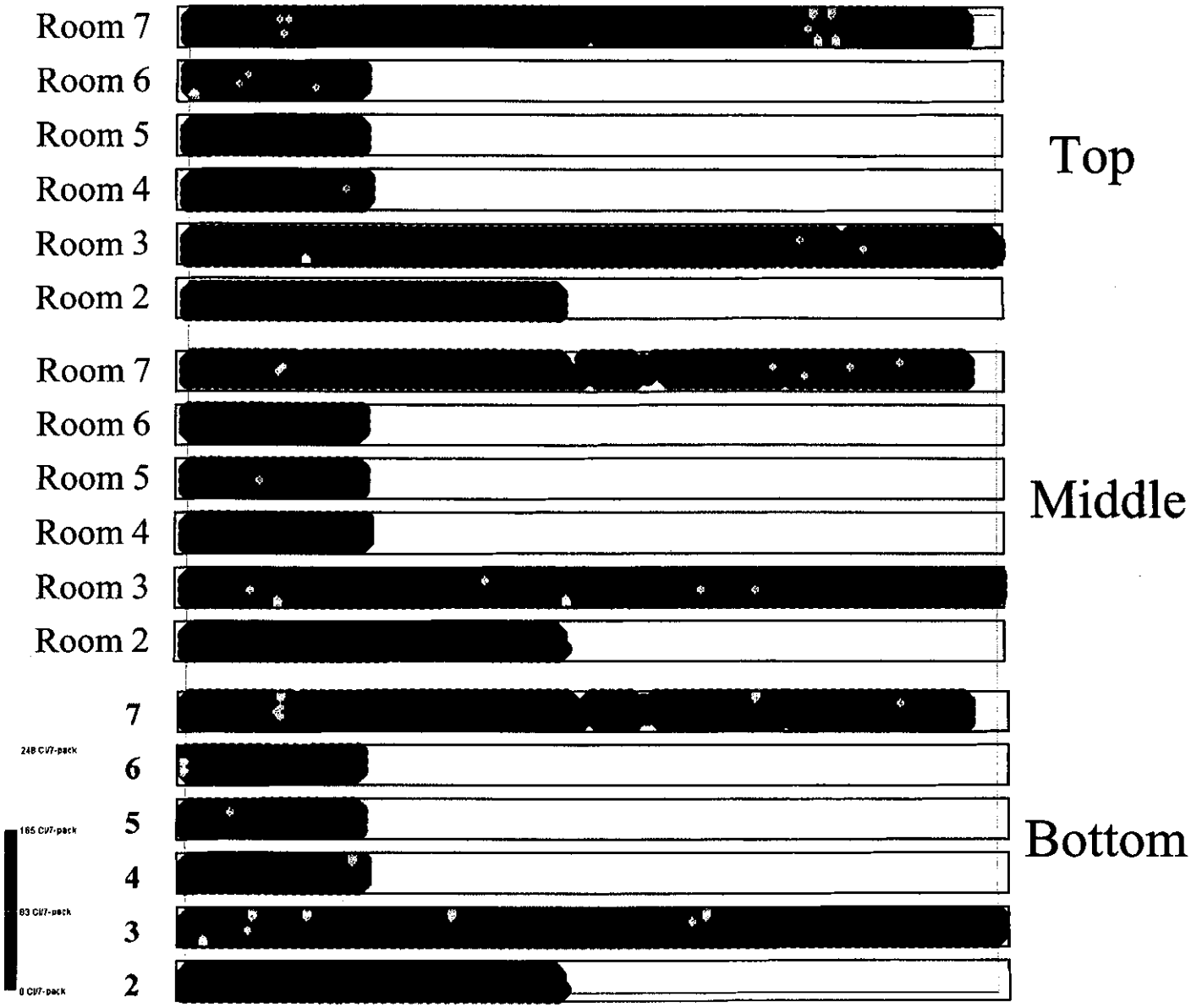

Figure 2.13 Am 241 Concentration Map for Panel 1

INFORMATION ONLY

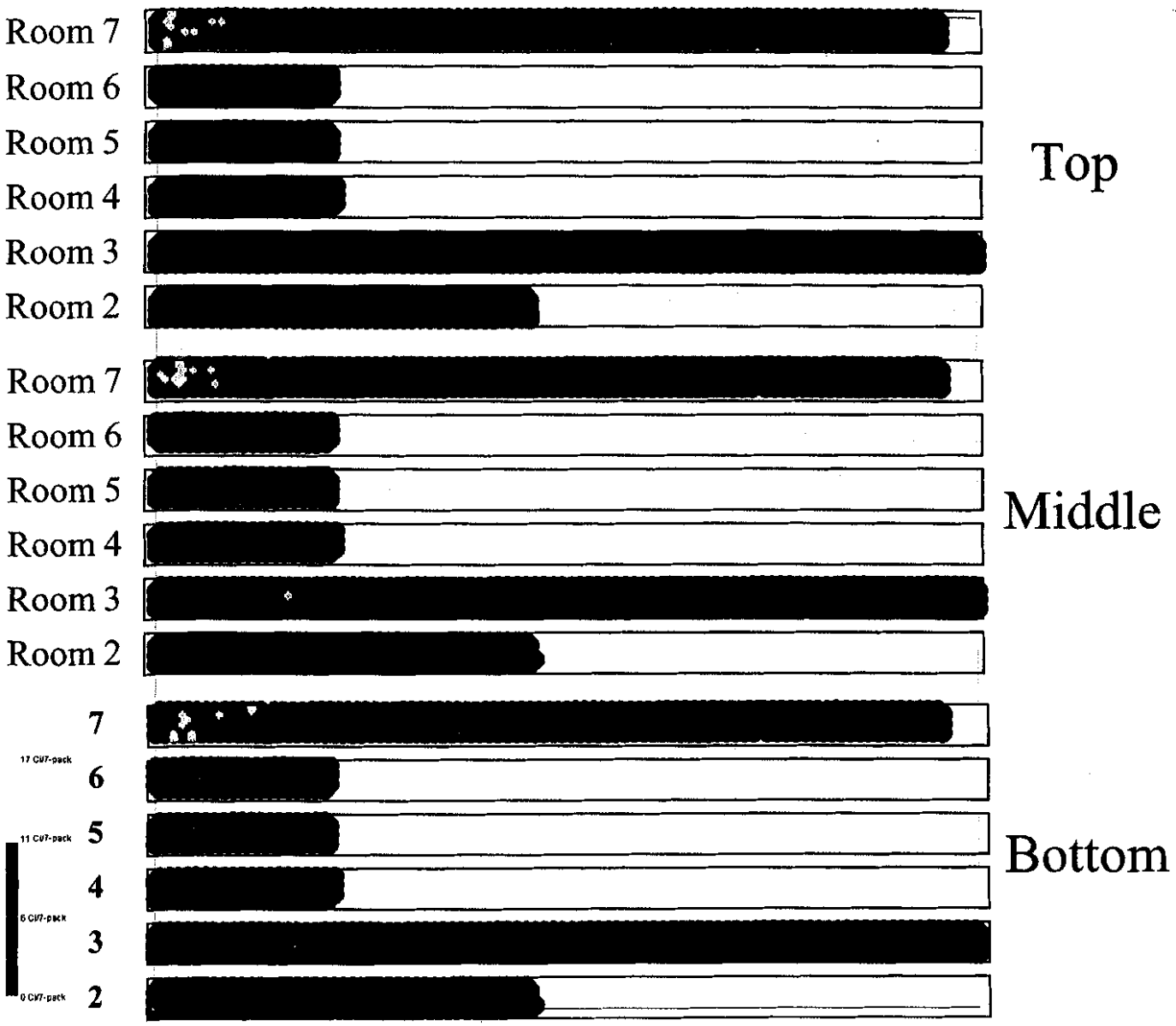

Figure 2.14 Pu 238 Concentration Map for Panel 1

INFORMATION ONLY

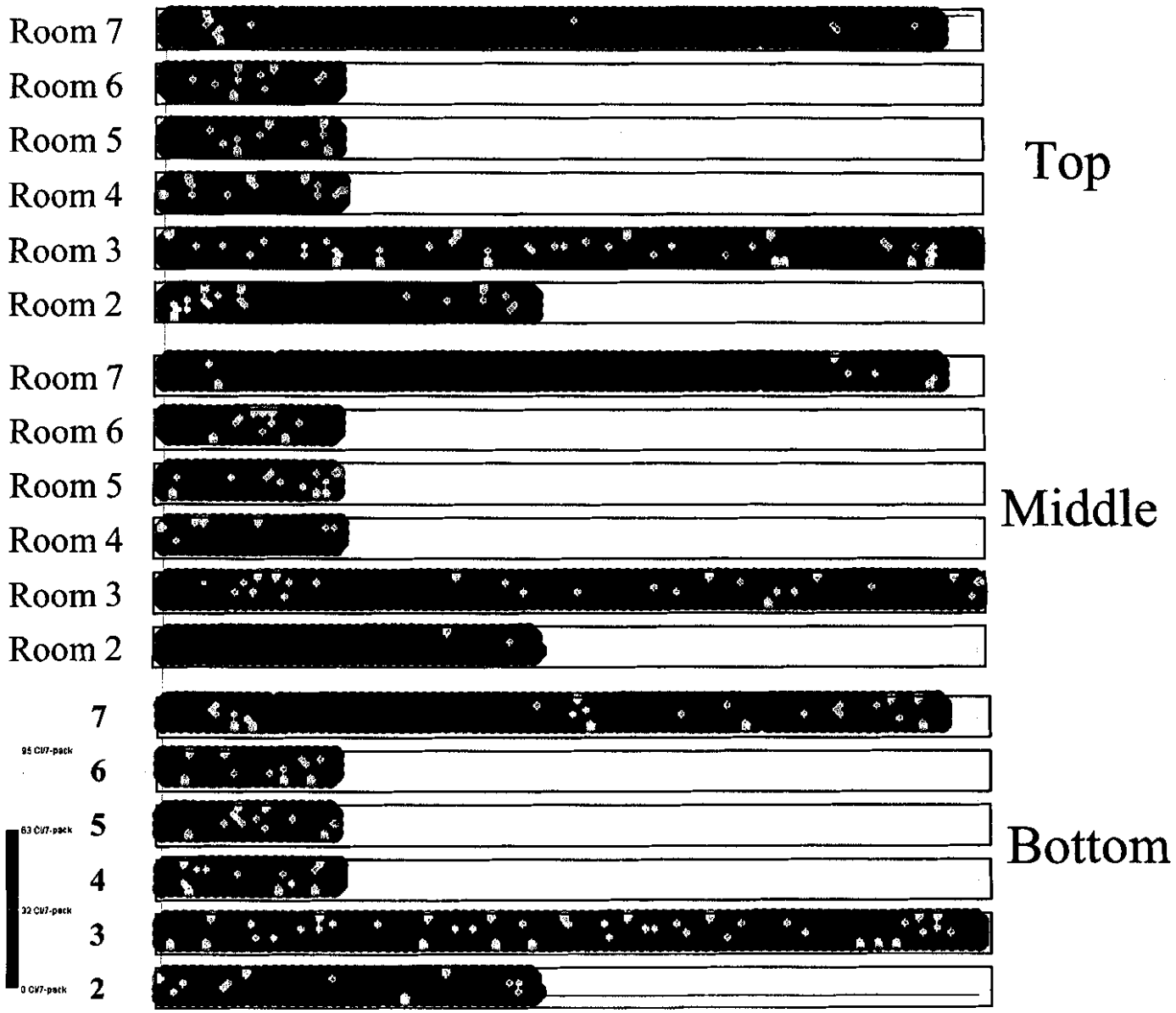

Figure 2.15 Pu 239 Concentration Map for Panel 1

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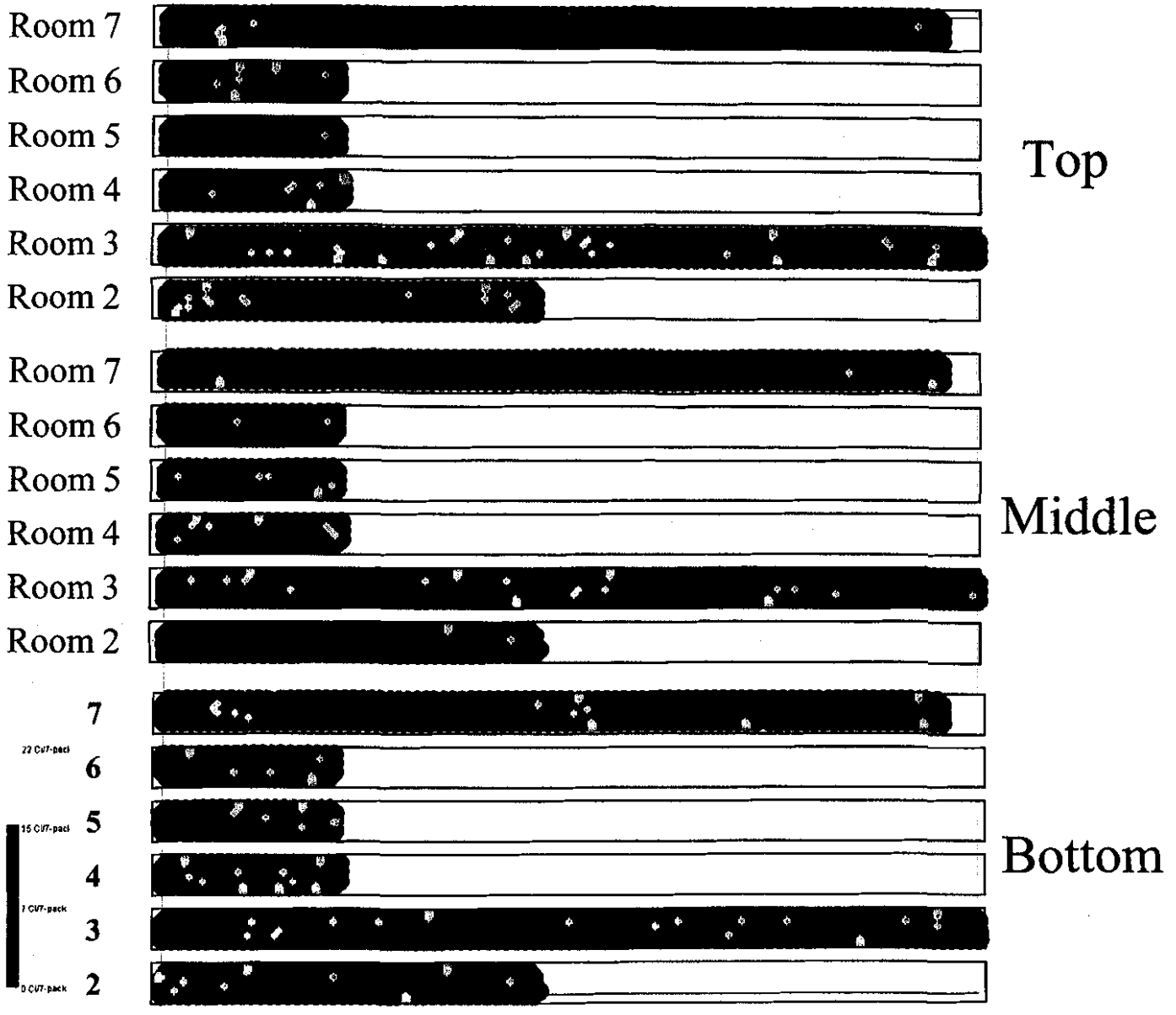

Figure 2.16 Pu 240 Concentration Map for Panel 1

INFORMATION ONLY

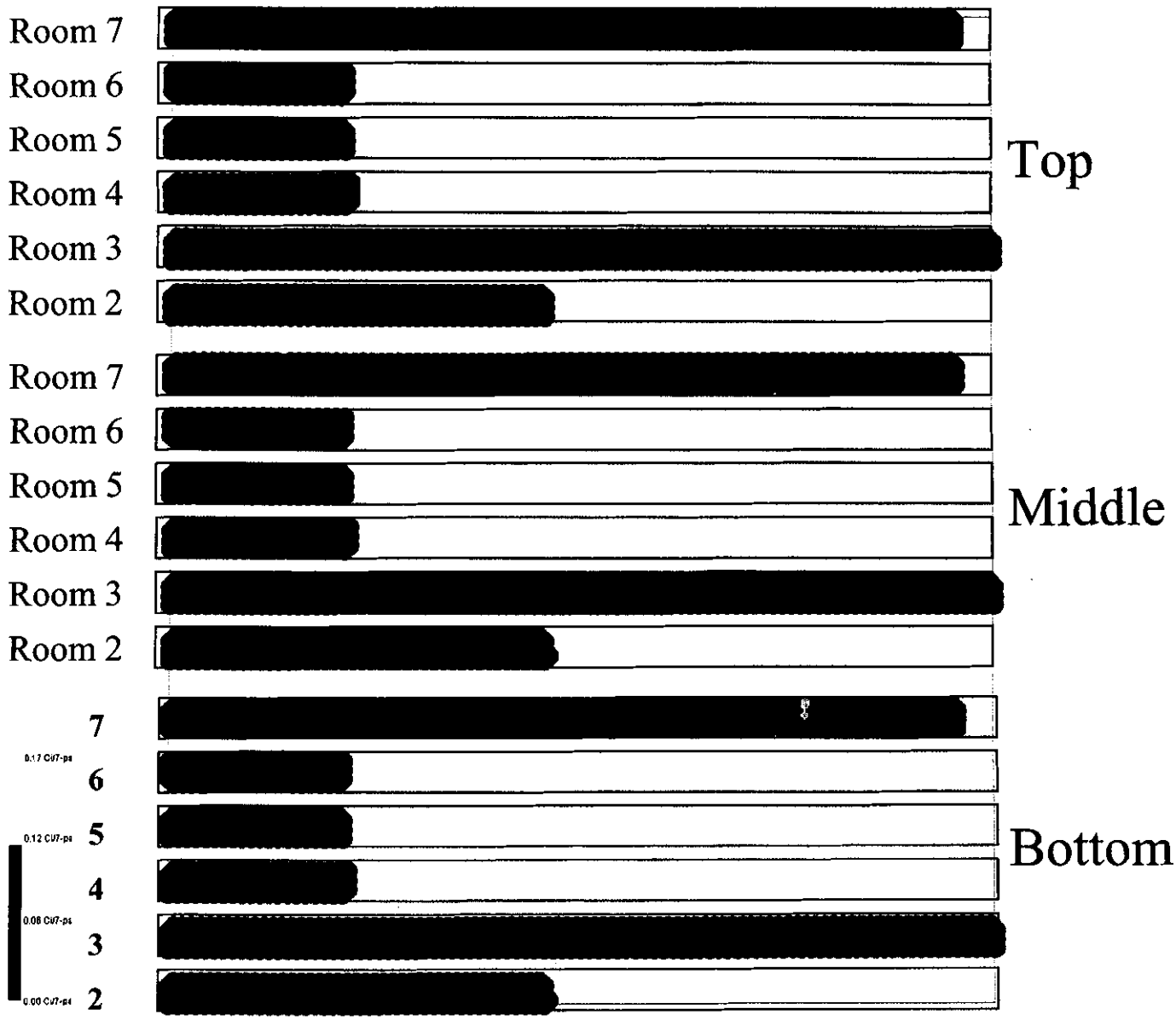

Figure 2.17 Pu 242 Concentration Map for Panel 1

INFORMATION ONLY

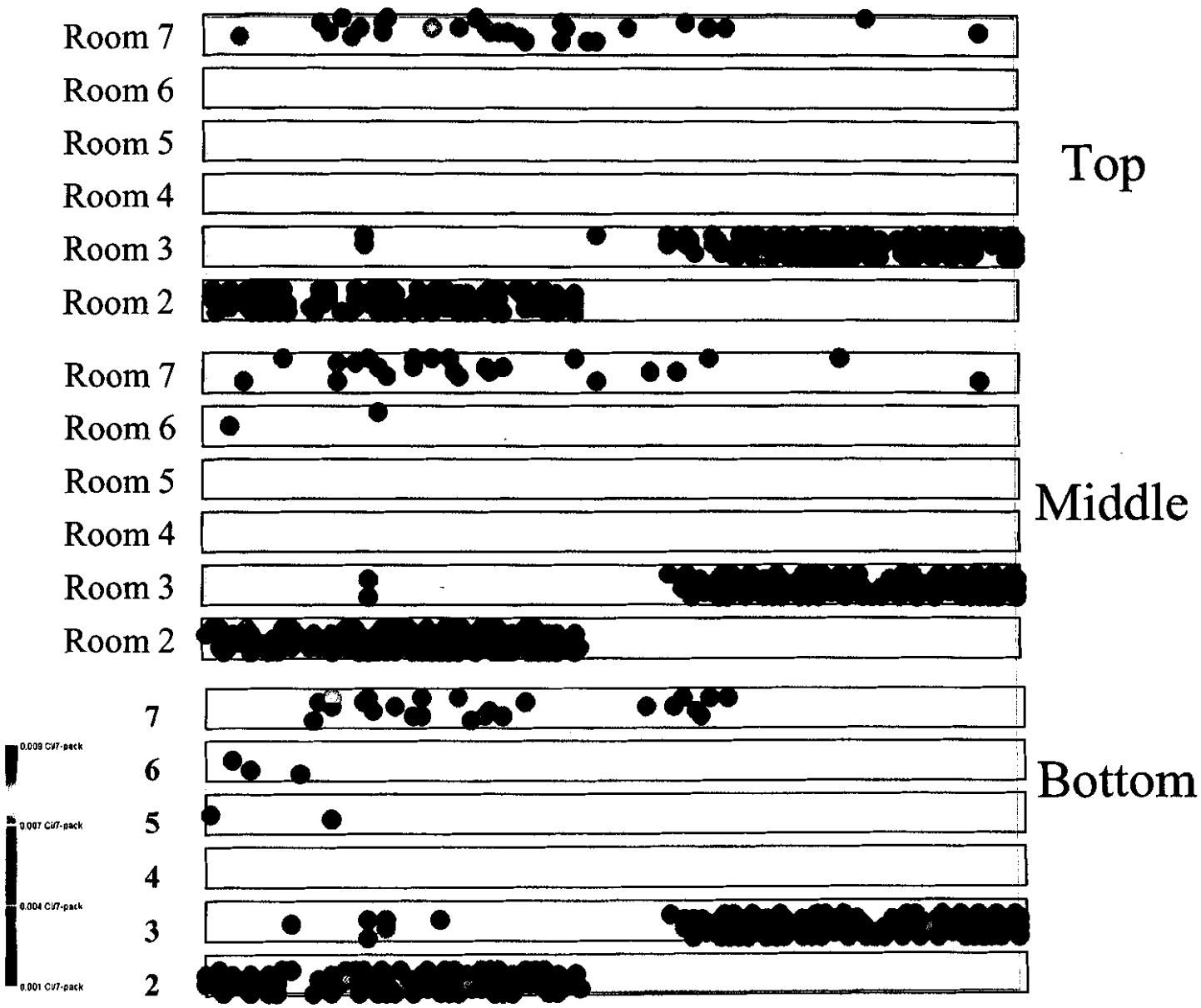

Figure 2.18 Concentration Map for U 233

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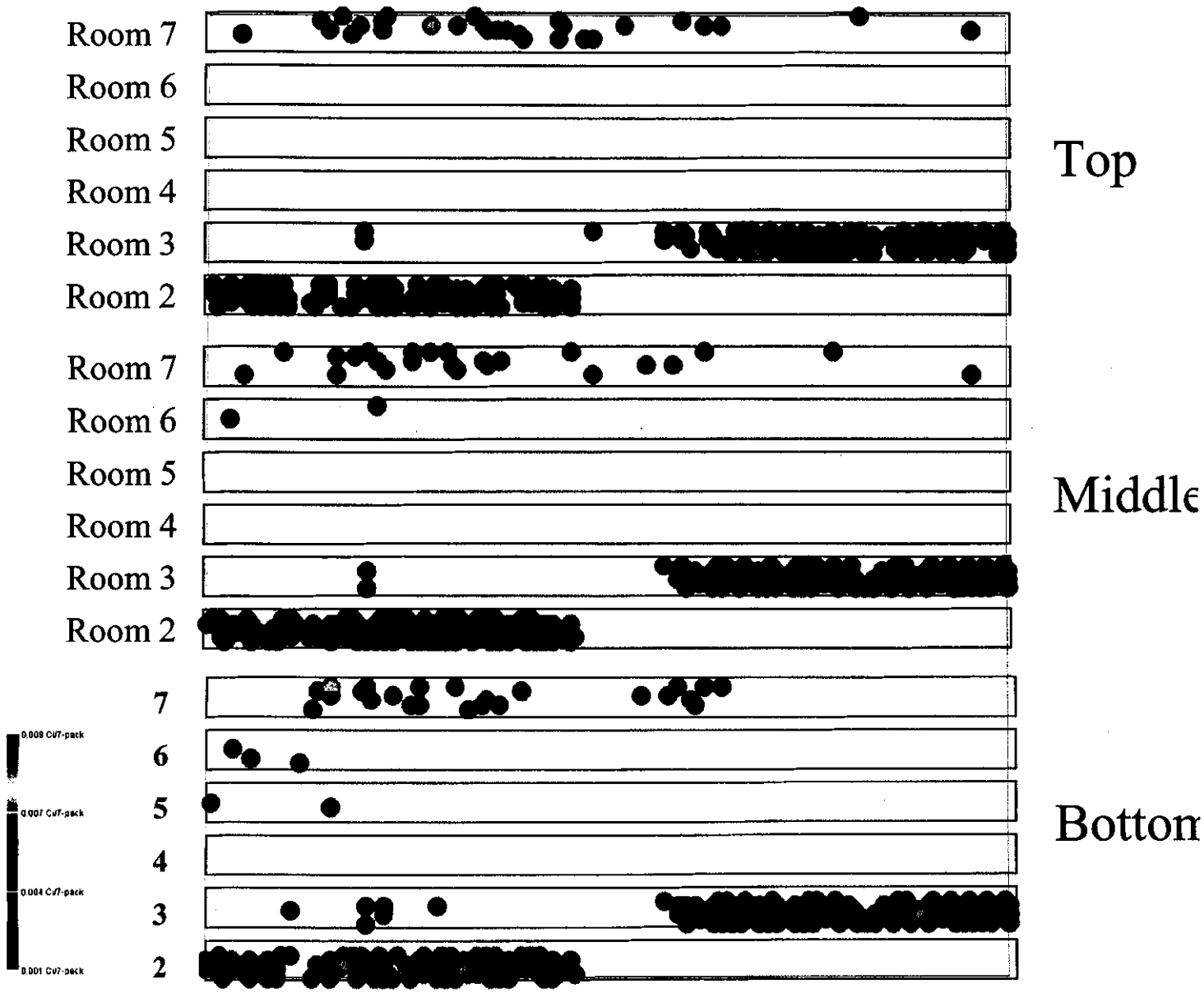

Figure 2.19 U 234 Concentration Map for Panel 1

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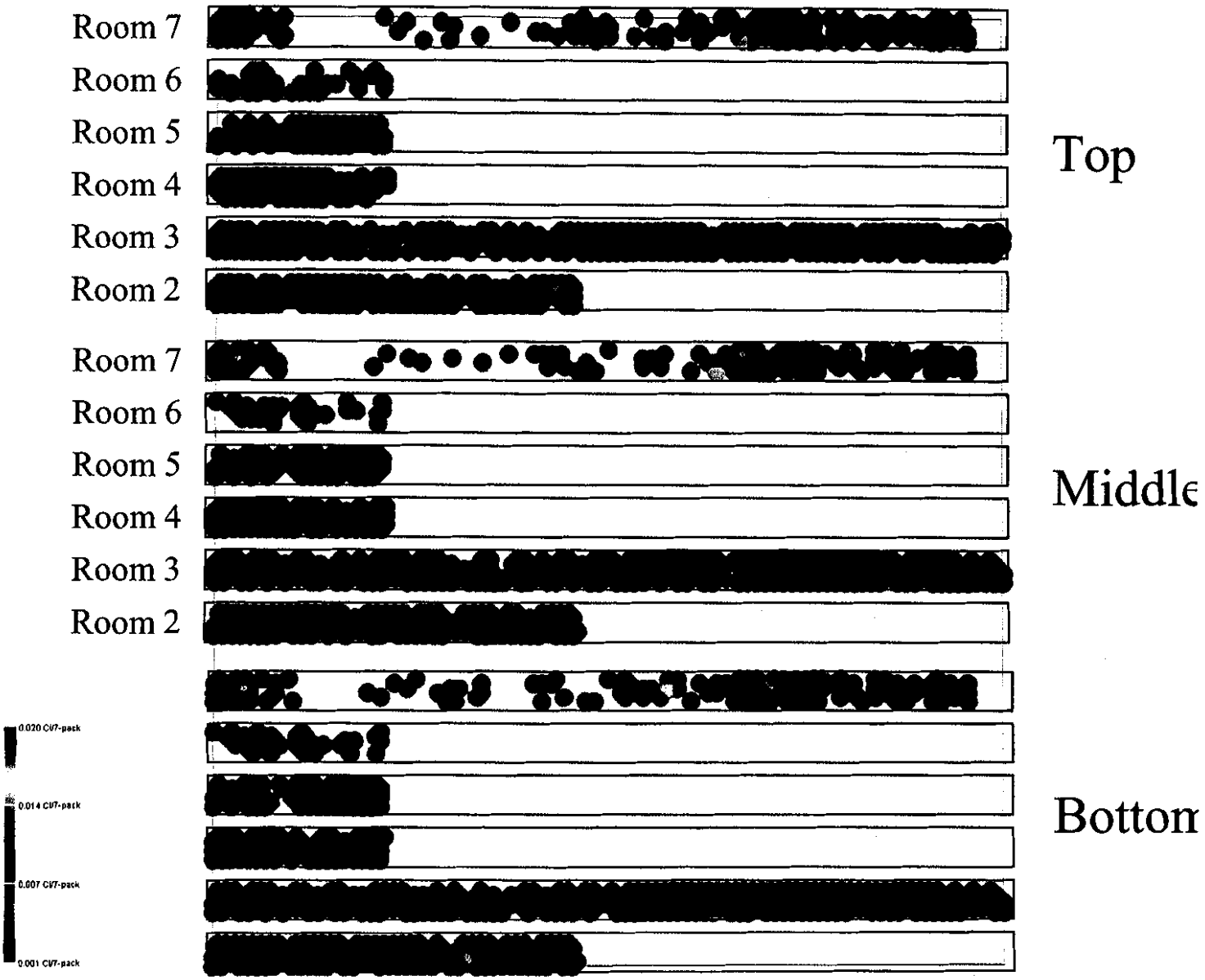

Figure 2.20 U 234 Concentration Map for Panel 1

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Waste Activity - 2002:

Trigger Value Derivation			
COMP Title:	Waste Activity		
COMP Units:	Curies		
Related Monitoring Data			
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
WWIS	Radionuclide activity per container and volume	Curies per container. Container volume.	Appendix P of CCA Appendix BIR (DOE 1996) by waste stream.
Waste emplacement records	Location of waste in panels	Coordinates and number of containers (or volume in cubic meters).	None.
COMP Derivation Procedure			
Map of waste activity distribution in each panel. Total curie content of emplaced CH-TRU and RH-TRU waste. *[Total radionuclide inventories reported annually by WWIS]*			
Year 2002 COMP Assessment Value			
Comparison of emplaced and PA waste parameters made in Table 2.11. No RH has been emplaced. Actinide totals and CPR totals are found in Appendix A of this document. EPA letter (EPA 2002) directed DOE to evaluate waste emplacement in the CRA. Results of these ongoing activities will be used to redefine the COMP assessments process.			

Element Title	Type and ID	Derivation Procedure	Compliance Baseline	Impact of Change
Radionuclide inventories	Parameter	Product of waste stream content and volume scaled up to the LWA limits.	Table PAR-41 and Table 4-8 of the CCA.	May affect direct brine releases for those radionuclides that become inventory-limited during a PA simulation.
Activity of waste intersected for cuttings and cavings releases.	Parameter	Function of waste stream volumes and activities	Figure 6-31 of the CCA	Cuttings are a significant contributor to releases. Therefore, an increase in activity of intersected waste is potentially significant.
WIPP-scale average activity for spallings releases	Parameter	Average of all CH-TRU waste only.	NA	Spallings are a significant contributor to releases. Therefore, an increase in average activity of intersected waste is potentially significant.

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Monitoring Data Trigger Values		
Monitoring Parameter ID	Trigger Value	Basis
Waste emplacement records	Panel half-full	Check that PA assumptions about waste activity will remain valid as remainder of panel is filled and verify random emplacement assumptions.
Total emplaced RH-TRU waste activity	5.1 million curies	LWA emplacement limit reached. Administrative controls address these limits.

3 COMPs Assessment Conclusion

The WIPP became operational in 1999 when it received its first shipment of TRU waste. This event initiated the operational period monitoring program designed to meet the assurance requirements of the EPA radioactive waste certification decision. This monitoring program was designed to further validate the assumptions and conceptual models that were used to predict WIPP performance. The monitoring program was intended to identify conditions that could potentially cause radioactive release above the allowable 40 CFR 191 release limits. Since releases above these limits cannot occur during the operational period of WIPP, the monitoring program looks at monitorable aspects of the disposal system and compares them to performance expectations. Ten monitoring parameters are assessed and compared annually to these expectations and assumptions. The results of this year's assessment are documented in this report and, with the exception of the Culebra ground water monitoring wells, the SA concludes that there are no COMPs data or results that indicate a reportable event or condition adverse to predicted performance. As originally reported in the 2001 COMPs assessment, freshwater heads in several Culebra wells continue to be above the ranges used in the CCA. An investigation program has been initiated by the SA to assess long-term changes in the Culebra water levels. The general investigation approach is described in the SNL test plan titled, *Examining Culebra Water Levels* (SNL 2001b). Preliminary findings indicate that Culebra water levels are generally rising across the entire monitoring region. Water-level data compiled from various sources and dating back to 1977 indicate that regional water levels were rising when Culebra monitoring began and that this trend continues today.

INFORMATION ONLY

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 INFORMATION ONLY

Compliance Certification Application
Relevant Parameters
(3/1/99 to 9/30/02)

Waste Inventory

Nuclide Inventory (Totals)

Nuclide	Curies	Kilograms
Ac-227	.000364301	.000000005
Am-241	117,431.687332641	33.842854103
Am-243	.004804696	.000023856
Co-60	.000000347	.000000000
Cs-137	.000341240	.000000005
K-40	.000028697	.005080900
Na-22	.000005343	.000000000
Np-237	.400094525	.561145756
Pa-231	.000504015	.000010432
Pu-238	5,643.735048802	.326283918
Pu-239	137,599.222223313	2,187.581699356
Pu-240	30,994.337561017	134.759430327
Pu-241	436,768.214415104	4.200638568
Pu-242	2.954618670	.744373594
Ra-226	.000007878	.000000008
Sr-90	.000000000	.000000000
Th-230	.000024100	.000001180
Th-232	.000002607	.023646000
U-233	.272687633	.027939262
U-234	1.263625338	.199934911
U-235	.122022990	55.718339813
U-238	6.529802722	19,204.484470494
Total:	728,448.745515980	21,622.475872488

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Appendix A

2002 WWIS COMPs Waste report

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Materials Inventory
CPR

Waste Material	Tons
Cellulose	682.134
Plastic	337.688
Rubber	2.701
Total:	1,022.523

Materials Inventory
Metals

Metal	Tons
Ferrous	2,742.476
Non-Ferrous	34.237
Total:	2,776.713

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Compliance Certification Application
Relevant Parameters
(3/1/99 to 9/30/02)

Total Inventory
Containers, Volumes, and Weights by Generator Site and Container type

EMPLACED WASTE CONTAINERS:

Site	Shipments	Container Type	Containers	Weight(kg)	Volume(m3)
C1	16	55 GAL DRUM	672	39142.40	141.12
IN	509	55 GAL DRUM	13661	2388941.34	2868.81
IN	3	SWB - USED TO OVERPACK 4 - 55 GAL. DRUMS IN GOOD CONDITION	8	9106.78	15.04
LA	1	55 GAL DRUM	28	1535.00	5.88
LA	25	SWB	141	57194.00	265.08
RF	101	55 GAL DRUM	3072	202452.34	645.12
RF	569	55 GALLON PIPE OVERPACK - 12 INCH PIPE OVERPACK	15680	2482536.14	3292.80
RF	30	SWB	172	135262.98	323.36
RL	12	55 GAL DRUM	467	32289.60	98.07
SR	7	55 GAL DRUM	294	17412.40	61.74
		Totals:	34195	5365872.98	7717.02

EMPLACED DUNNAGE CONTAINERS:

Site	Shipments	Container Type	Containers	Weight(kg)	Volume(m3)
IN	226	55 GAL DRUM	516	14964.00	108.36
RF	15	55 GAL DRUM	36	1044.00	7.56
RL	1	55 GAL DRUM	2	58.00	.42
		Totals:	554	16066.00	116.34

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