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Sandia National Laboratories Compliance Monitoring Parameter Assessment For 2012

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Executive Summary

This document reports the fourteenth annual (2012) derivation and assessment of the Waste Isolation Pilot Plant (WIPP) Compliance Monitoring Parameters (COMPs). The COMPs program is designed to meet certain requirements of the U.S. Environmental Protection Agency's (EPA) long-term disposal regulations (EPA 1993 and 1996). The concept of deriving and assessing COMPs is explained in Sandia National Laboratories (SNL) Activity/Project Specific Procedure, SP 9-8, titled: *Monitoring Parameter Assessment Per 40 CFR 194.42* (SNL 2011).

The WIPP has many monitoring programs, each designed to meet various regulatory and operational safety requirements. The comprehensive WIPP monitoring effort is not under the auspice of one program, but is comprised of many discrete elements, one of which was designed to fulfill the EPA's long-term disposal requirements found at 40 CFR Part 191 Subparts B and C, and the Certification Criteria at 40 CFR Part 194. Monitoring parameters that are related to the long-term performance of the repository were identified in a monitoring analysis.[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 (PA) input parameters.

The Department of Energy (DOE) uses PA to predict the radioactive waste containment performance of the WIPP. COMPs are used to indicate conditions that are not within the PA data ranges, conceptual model assumptions or expectations of the modelers and to alert the project of conditions not accounted for or anticipated. COMPs values and ranges were developed such that exceedance of an identified value indicates a condition that is potentially outside PA expectations. These values were appropriately termed "trigger values." Deriving COMPs trigger values (TVs) was the first step in assessing the monitoring data. TVs were first derived in 1999 and have since been revised. The derivations and revisions are documented in the *Trigger Value Derivation Report* (Wagner and Kuhlman 2010).

This year's COMPs Report is the third derived after the WIPP's second recertification (EPA 2010a). The EPA requested a new PA in support of the second recertification called the Performance Assessment Baseline Calculation (PABC-2009). The PABC-2009 represents the latest compliance baseline.

In the initial Certification Ruling (EPA 1998a), EPA approved 10 COMPs, 2 relating to human activities, 5 relating to geotechnical performance, 2 relating to regional hydrogeology and 1 relating to the radioactive components of the waste. The requirements of 40 CFR § 194.4(b)(3) require the DOE to report any 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. The DOE complies with these EPA requirements by conducting periodic assessments of COMPs that monitor the predicted performance of the repository and reporting any condition adverse to the containment performance. This compliance monitoring program is described in greater detail in DOE's *Compliance Monitoring Implementation Plan for 40 CFR §191.14(b), Assurance Requirements* (MIP; DOE 2007).

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

This 2012 COMPs assessment presents the results and recommendations based on the COMP monitoring data gathered during the annual reporting cycle. This assessment concludes that the current COMP values do not indicate that the repository is performing in a manner other than that represented in the WIPP recertification PAs.

1 Introduction

The WIPP is governed by the EPA's long-term radioactive waste disposal regulations at 40 CFR Part 191 Subparts B and C (EPA 1993) and the WIPP-specific certification criteria at 40 CFR Part 194 (EPA 1996). Monitoring WIPP performance is an "assurance requirement" of these regulations and is intended to provide additional confidence that the WIPP will protect the public and environment (see 40 CFR § 191.14). 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 10 COMPs, which are listed in Section 2.

The COMPs are an integral part of the overall WIPP monitoring strategy. The DOE's *Compliance Monitoring Implementation Plan for 40 CFR §191.14(b), Assurance Requirements* (MIP; DOE 2007) describes the overall monitoring program and responsibilities for COMPs derivation and assessment. This report documents the results of the reporting year 2012 COMPs assessment (July 1st 2011 to June 30th 2012). This period matches the reporting period of the annual report that addresses 40 CFR § 194.4(b)(4) requirements (EPA 2003). This COMPs assessment follows the program developed under the original certification baseline using data and PA results from the current certified baseline, the 2009 recertification's Performance Assessment Baseline Calculation (PABC-2009).

1.1 Monitoring and Evaluation Strategy

The Compliance Monitoring Program is an integrated effort between the Management and Operating Contractor (M&OC), the Scientific Advisor and the DOE Carlsbad Field Office (CBFO). The CBFO oversees and directs the monitoring program to ensure compliance with the EPA monitoring and reporting requirements. The Scientific Advisor (currently Sandia National Laboratories) is responsible for the development and maintenance of the TVs. An observation beyond the acceptable range of TVs represents a condition that requires further actions, but does not necessarily indicate an out-of-compliance condition. This approach assures that conditions that are not consistent with expected repository performance are recognized as early as possible. These 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.

1.2 Reporting Cycle

The types of changes that must be reported to EPA are defined in 40 CFR §194.4. Under 40 CFR § 194.4, changes that differ from the activities or conditions outlined in the latest compliance application are defined as either significant or non-significant based on their potential impact on the compliance baseline and potential impact on containment performance. This part of the rule also identified the timeframe to which the DOE is required to report significant and non-significant changes to the EPA. As such, the CCA states (Section 7.2.1) and subsequent recertification applications state that the results of the monitoring program will be submitted annually (DOE 1996, DOE 2004, DOE 2009). Additionally, the recertification requirements at 40 CFR §194.15(a)(2) also require inclusion of all additional monitoring data, analysis and results in the DOE's documentation of continued compliance as submitted in periodic

Compliance Recertification Applications (CRAs). Monitoring data, the associated parameter values and monitoring information must be reported even if the assessment concludes there is no impact on the repository. The annual monitoring data will be compiled and provided to the DOE to fulfill DOE's monitoring reporting requirements to the EPA. The Scientific Advisor's role in the annual reporting task is to use the monitoring data to derive the COMPs (as necessary), compare the results to repository performance expectations in PA (annually), and to use the new and updated information to make any recommendations for modification to the Compliance Baseline, if merited.

2 Assessment of COMPs

The compliance monitoring program tracks the following 10 COMPs:

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

A periodic 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."

This section summarizes the results of the 2012 assessment. In the following sections, each COMP is evaluated and compared to the applicable TV. This assessment is performed under Specific Procedure SP 9-8 (SNL 2011). A table for each of the 10 COMPs is used to summarize the evaluation and shows the COMP derivation, related PA parameters and FEPs, the current value for the COMPs as applicable and the TV.

2.1 Human Activities COMPs

The CCA identifies 10 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

Table 2.1 summarizes data and TV information related to the COMP Probability of Encountering a Castile Brine Reservoir, as well as its implementation in PA. Monitoring activities for Castile brine encounters have identified no brine encounters during this reporting period. The total number of encounters identified since the CCA is 7. These encounters are detailed in Table 2.2. Data used for the CCA were compiled from drilling record searches for the region surrounding the WIPP. The results of this initial 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; 2 wells, ERDA 6 and WIPP 12, were drilled in support of the WIPP site characterization effort (see DOE 2012a, Table 7 for a complete listing of brine encounters). 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 encounters with pressurized Castile brine. Since the CCA, data have been compiled through August 2012. During this reporting period, no pressurized Castile brine encounters have been reported in the official drilling records for wells drilled in the New Mexico portion of the Delaware Basin (DOE 2012a).

Of the 7 Castile brine encounters recorded since the 1996 CCA, 6 were identified when WIPP Site personnel performing field work talked to area drillers. These encounters were inconsequential to the drilling process. The other encounter was reported by an operator in an annual survey of area drillers. All the new encounters are located in areas where Castile brine is expected to be encountered during the drilling process. Table 2.2 shows all known Castile brine encounters in the vicinity of the WIPP Site since the CCA.

The impacts of brine encounters are modeled in the PA. The CCA used a 0.08 probability of encountering a Castile brine reservoir. In the Performance Assessment Verification Test (PAVT), the EPA mandated a probability range of 0.01 to 0.60 (uniform distribution). The new range did not significantly influence the predicted performance of the repository. This range has been used in all PAs since the original WIPP certification. The mean of this parameter is approximately 0.30. This value is significantly more than the 0.08 used in the CCA which was based on a geostatistical analysis of actual encounters. Results of more than 10 years of monitoring drilling encounters have shown that it is unlikely that further monitoring will show a probability near 0.30. The EPA also determined in their first certification sensitivity analysis that this parameter (PBRINE) does not have a significant impact on PA results (EPA 1998b).

Table 2.1 Probability of Encountering a Brine Reservoir - 2012:

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 – Field observations	0.01 to 0.60 (uniform distribution)

COMP Assessment Process

Analysis of encounters of pressurized brine recorded and reported by industry in the 9-township area centered on WIPP.

Year 2012 COMP Assessment Value - Reporting Period September 2011 to August 2012

No new data reported in State record during the reporting period; no new report from Field Observations. 34 Total Brine Encounters out of 678 boreholes drilled within the monitored area

27 CCA total occurrences before 1996
0 State Record occurrences since 1996
7 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	CCA MASS Attachment 18-6 geostatistical study based on area occurrences. EPA Technical Support Document justified the upper value in their range by rounding up the upper value interpreted from the Time Domain Electromagnetic 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. For this reason and since the parameter is evaluated for significant changes at least once annually, no TV is needed.

(1) Delaware Basin Monitoring Program

Table 2.2. Well Locations Encountering Brine since the CCA[2].

Number	Location	Well Name and Location	Spud Date	Well Information
1	T21S-R31E-Sec 35	Lost Tank “35" - State #4	09/11/2000	Oil Well: Estimated several hundred barrels per hour. Continued drilling.
2	T21S-R31E-Sec 35	Lost Tank “35" - State #16	02/06/2002	Oil Well: At 2,705 ft, encountered 1,000 barrels per hour. Shut-in to get room in reserve pit with pressure of 180 psi. and water flow of 450 barrels per hour. Two days later, no water flow/full returns.
3	T22S-R31E-Sec 2	Graham “AKB” State #8	04/12/2002	Oil Well: Estimated 105 barrels per hour. Continued drilling.
4	T23S-R30E-Sec 1	James Ranch Unit #63	12/23/1999	Oil Well: Sulfur water encountered at 2,900 ft. 35 ppm H_2S was reported but quickly dissipated to 3 ppm in a matter of minutes. Continued drilling.
5	T23S-R30E-Sec 1	Hudson “1" - Federal #7	01/06/2001	Oil Well: Estimated initial flow at 400 to 500 barrels per hour with a total volume of 600 to 800 barrels. Continued drilling.
6	T22S-R30E-Sec 13	Apache “13" - Federal #3	11/26/2003	Oil Well: Encountered strong water flow with blowing gas at 2,850-3,315 ft. 362 ppm H_2S was reported. Continued drilling.
7	T21S-R31E-Sec 34	Jaque “AQJ” - State #7	03/04/2005	Oil Well: Encountered 104 barrels per hour at 2,900 ft. No impact on drilling process.

[2] From DOE 2012a, Table 7

2.1.2 Drilling Rate

Table 2.3 summarizes data and TV information related to the COMP Drilling Rate parameter and its implementation in PA. The drilling rate COMP tracks deep drilling (> 2,150 ft in depth) activities relating to resource exploration and extraction. Boreholes relating to resources include potash and sulfur core-holes, hydrocarbon exploration wells, saltwater disposal wells and water wells drilled in the Delaware Basin. The first drilling rate, reported in the CCA, was determined using an equation provided in 40 CFR Part 194. The drilling rate formula is as follows:

$$D_r = (D_{100} \text{ x } 1{,}000 \text{ yrs}) \div A_{DB} \qquad (1)$$

where

D_r = Drilling Rate (boreholes per km^2 per 10,000 yrs)
D_{100} = Deep boreholes greater than 2,150 ft depth drilled over the last 100 yrs
A_{DB} = Area of the Delaware Basin (23,102 km^2)

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 1996 to June 2012) increases the rate to 67.3 boreholes per square kilometer per 10,000 years (DOE 2012a).

As shown in Table 2.4, the drilling rate has risen from 46.8 holes per square kilometer to 67.3 holes per square kilometer since 1996. As a result of continuing analysis and monitoring, the TV for this COMP was removed (Wagner and Kuhlman 2010). No additional actions are recommended at this time.

Table 2.3 Drilling Rate - 2012:

<table>
<tr><td>COMP Title:</td><td colspan="4">Drilling Rate</td></tr>
<tr><td>COMP Units:</td><td colspan="4">Deep boreholes (i.e., > 2,150 ft deep)/square kilometer/10,000 years</td></tr>
<tr><td colspan="5">Related Monitoring Data</td></tr>
<tr><td>Monitoring Program</td><td>Monitoring Parameter ID</td><td colspan="3">Characteristics
(e.g., number, observation)</td></tr>
<tr><td>DBMP</td><td>Deep hydrocarbon boreholes drilled</td><td colspan="3">Integer per year</td></tr>
<tr><td colspan="5">COMP Assessment Process</td></tr>
<tr><td colspan="5">(Total number of deep boreholes drilled/number of years of observations (100)) x (10,000/23,102) [i.e., over 10,000 years divided by the area of the Delaware Basin in square kilometers]</td></tr>
<tr><td colspan="5">Year 2012 COMP Assessment Value - Reporting Period September 1, 2011 to August 31, 2012</td></tr>
<tr><td colspan="5">(15,558 boreholes on record for the Delaware Basin) Drilling Rate = 67.3 boreholes per square kilometer per 10,000 yrs.</td></tr>
<tr><td colspan="5">Related Performance and Compliance Elements</td></tr>
<tr><td>Element Title</td><td>Parameter Type & ID or Model Description</td><td>Derivation Procedure</td><td>Compliance Baseline</td><td>Impact of Change</td></tr>
<tr><td>Drilling rate</td><td>Parameter LAMBDAD</td><td>COMP/10,000 years</td><td>5.98 E-03 per square kilometer per year (CRA-2009 PABC value)</td><td>Cuttings/cavings releases increase proportionally with the drilling rate. Doubling CRA drilling rate does not exceed compliance limit.</td></tr>
<tr><td colspan="5">Monitoring Data Trigger Values</td></tr>
<tr><td>Monitoring Parameter ID</td><td>Trigger Value</td><td colspan="3">Basis</td></tr>
<tr><td>Deep boreholes</td><td>None</td><td colspan="3">Revision 2 of the TV Derivation Report (Wagner and Kuhlman 2010).</td></tr>
</table>

Table 2.4. Drilling Rates for Each Year since the CCA.

Year	**Number of Boreholes Deeper than 2,150 ft**	**Drilling Rate (boreholes 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[3]	12,219	52.9
2002 (revised)	12,139	52.5
2003	12,316	53.3
2004	12,531	54.2
2005	12,819	55.5
2006	13,171	57.0
2007	13,520	58.5
2008	13,824	59.8
2009	14,173	61.3
2010	14,403	62.3
2011	14,816	64.1
2012	15,558	67.3

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 2012b) and the annual Subsidence Monument Leveling Survey (DOE 2011). Three of the geotechnical parameters lend themselves to quantification: creep closure, displacement of deformation features, and subsidence. In contrast, the extent of deformation and initiation of brittle deformation are qualitative or observational parameters.

[3] In Revision 3 of Delaware Basin Monitoring Annual Report (dated 2002), the drilling rate for 2002 was shown as 52.9, with 12,219 deep boreholes. It was later noted that 80 shallow wells in Texas were listed as being deep. Correcting the classification of the 80 boreholes resulted in a reduction of the drilling rate from 53.9 to 52.5 (DOE 2012a).

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, data to evaluate disposal room closure, 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, rock bolt 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 2012b) summarizes data collected from July 2009 through June 2010.

Subsidence monitoring survey reports are also prepared by the M&OC on an annual basis and present the results of leveling surveys performed in 2010 for nine vertical control loops comprising approximately 15 linear miles traversed over the ground surface of the WIPP site. Elevations are determined for 48 current 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 survey (DOE 2011) summarizes data collected between September and November of 2011.

Comparisons between available geotechnical COMP related data and the TVs allow evaluation of the most recent geotechnical observations for the COMPs program. 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 TVs. Notable deviations are addressed in the GAR and other references, and are reexamined here in the context of COMPs and TVs.

Geotechnical COMPs can be derived from or related to the repository's operational safety monitoring program, which has been implemented 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. Therefore, 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.

2.2.1 Creep Closure

Table 2.5 summarizes data and TV information related to the COMP parameter Creep Closure, and its implementation in PA. 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. With the exception of newly mined openings, rates of closure are relatively constant within each zone of interest and usually range from about 1-5 cm/yr. A closure rate in terms of cm/yr can be expressed as a global or nominal creep rate by dividing the displacement by the room dimension and converting time into seconds. Nominally these rates are of the order of 1×10^{-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 M&OC geotechnical staff to scrutinize the area exhibiting accelerating creep rates.

Extensive GAR data suggest that a possible TV 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. The coalescence of microfractures into an arch-shaped fracture (or macrofracture) that extends into (or intersects) 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 PA assumption confirmation. Therefore, a measured creep rate change over a yearly period constitutes the COMP TV for creep closure. Rate changes are necessarily 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.

The creep deformation COMP is addressed by examining the deformations measured in specific regions of the underground including: (1) Shafts and Shaft Stations and (2) Access Drifts and Waste Disposal Areas. Figure 2.1 shows the current configuration of the WIPP underground

Table 2.5 Creep Closure - 2012:

<table>
<tr><td>COMP Title:</td><td colspan="4">Creep Closure</td></tr>
<tr><td>COMP Units:</td><td colspan="4">Closure Rate (s^{-1})</td></tr>
<tr><td colspan="5">Related Monitoring Data</td></tr>
<tr><td>Monitoring Program</td><td>Monitoring Parameter ID</td><td>Characteristics
(e.g., number, observation)</td><td colspan="2">Compliance Baseline Value</td></tr>
<tr><td>Geotechnical</td><td>Closure</td><td>Instrumentation located throughout the underground.</td><td colspan="2">Multi-mechanism deformation creep model developed by Munson and Dawson</td></tr>
<tr><td colspan="5">COMP Assessment Process - Reporting Period July 2010 through June 2011</td></tr>
<tr><td colspan="5">Evaluate GAR for centerline closure rates, compare to previous year’s rate. Account for drift dimensions and convert to creep rate. If closure rate increases by greater than one order of magnitude, initiate technical review.</td></tr>
<tr><td colspan="5">Related Performance and Compliance Elements</td></tr>
<tr><td>Element Title</td><td>Parameter Type & ID or Model Description</td><td>Derivation Procedure</td><td>Compliance Baseline</td><td>Impact of Change</td></tr>
<tr><td>Repository Fluid Flow</td><td>Creep Closure</td><td>Porosity Surface, waste compaction, characteristics, waste properties, evolution of underground setting</td><td>SANTOS, porosity surface calculations</td><td>Provides validation of the creep closure model.</td></tr>
<tr><td colspan="5">Monitoring Data Trigger Values</td></tr>
<tr><td>Monitoring Parameter ID</td><td>Trigger Value</td><td colspan="3">Basis</td></tr>
<tr><td>Creep Closure</td><td>Greater than one order of magnitude increase in closure rate.</td><td colspan="3">The closure rate increase signals potential de-coupling of rock.</td></tr>
</table>

with specific elements and regions annotated for reference. Information used for all geotechnical COMPs is derived from the GAR which has a reporting period ending June 30, 2011. For this reporting period, Panels 1 through 6 had been fully excavated and Panel 7 was ongoing. Figure 2.1 shows all areas mined as of June 30, 2011. At that time, CH waste was being emplaced in Panel 5, Room 1 while RH was being emplaced in Panel 6, Room 7. Panels 1 through waste disposal operations had ceased and the entry drifts had been sealed to prevent access (please note that the reporting period for geotechnical information is through June 2011 such that the reported mining and emplacement activities depicted in Figure 2.1 from the GAR are not as current as the waste activity COMP information, which is through June 30, 2012).

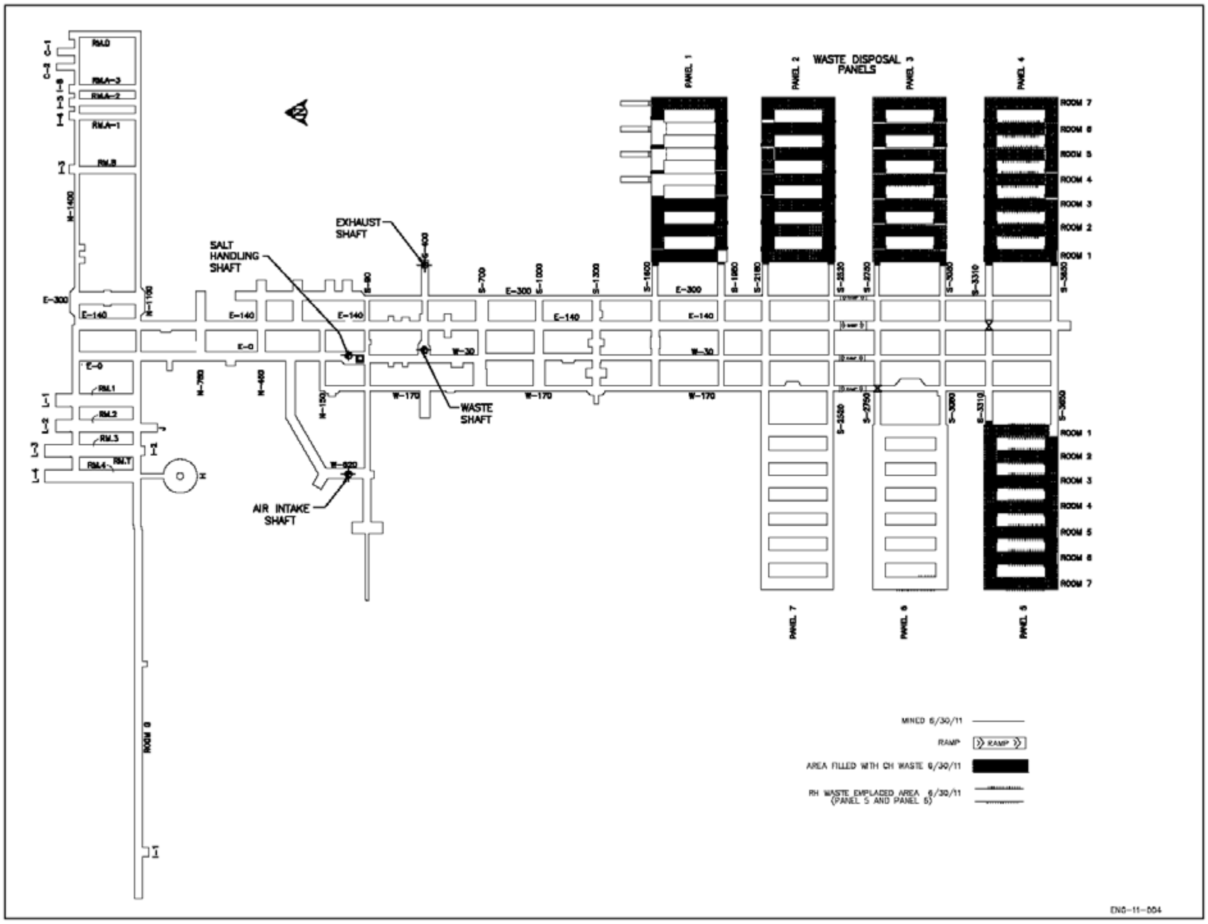


Figure 2.1. Configuration of the WIPP Underground for Geotechnical COMPs (after DOE 2012b; Reporting Period July 2010 through June 2011).

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 m below ground surface), enlarged rooms have been excavated around the Salt Handling and Waste 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).

<u>Shafts.</u> 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 un-reinforced 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 m 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 annually 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. These inspections have focused on salt build-up in the Exhaust Shaft and the impacts this build-up has on power cabling in the shaft. Based on these visual observations, all four shafts are in satisfactory condition and have required only routine ground-control activities during this 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 numerical 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, most of these extensometers have malfunctioned. As a result, reliable data are not available at some locations. The DOE currently has no plans to replace failed instrumentation installed in any of the shafts because monitoring data acquired to date have shown no unusual shaft movements or displacements. It should be noted that no extensometer data was collected from the shafts during the reporting period because of a data logger failure. The type of extensometer used and its compatible data logger are no longer manufactured. DOE does not plan to replace the logger with an alternate because of compatibility and interface issues.

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. In the past, 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. No major modifications were performed at the shaft stations during this reporting period. Ground control, bolt replacement, bolt trimming and cable shoe anchor replacement were performed as routine maintenance.

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, many of the original instrumentation has been removed or relocated. In addition, some instruments have malfunctioned or have been damaged and no longer provide reliable data. Displacement rates from existing and functional instrumentation listed in the GAR for the current reporting period (2010-2011) and the previous reporting period (2009-2010) are summarized in Table 2.6. Most of the measurements are for vertical closure. Based on shaft station convergence data, the current vertical displacement rates range from 0.11 to 2.01 in/yr (0.28 to 5.11 cm/yr). Dividing convergence rates by the average room dimension (approximately 6 meters) and expressing the results in units of 1/s yields vertical creep rates between approximately 1.48 $x10^{-12}$/s to 2.70 $x10^{-11}$/s. These rates 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 2.6 suggests the current shaft station displacement rates (where available) 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.

Table 2.6. Summary of Closure Rates for WIPP Shafts and Shaft Stations.

Location	Inst. Type[(a)]	Displacement Rate (in/yr)[(c)]		Change In Rate (%)
		2009–2010	2010-2011	
Salt Handling Shaft	No extensometers remain functional			
Waste Handling Shaft	No extensometer data available for 2006-2011			
Exhaust Shaft	No extensometer data available for 2006-2011			
Salt Handling Shaft Station				
E0 Drift – S18 (A-E)	CP	1.37	1.85	35
E0 Drift – S18 (B-D)	CP	1.52	2.01	32
E0 Drift – S18 (F-H)	CP	0.92	1.26	37
E0 Drift – S30 (A-C)	CP	1.40	1.88	34
E0 Drift – S65 (A-C)	CP	1.11	1.17	5
Waste Shaft Station				
S400 Drift – W30 (Vert. CL)	Ext	0.27	0.11	-59
S400 Drift – E32 (Vert CL)	Ext	0.29	0.27	-7
S400 – E30 (Vertical)	CP	1.55		NA
S400 – E32 (Horizontal)	CP	1.17	1.26	8
S400 – E85 (Vertical)	CP	1.49		NA
S400 – E85 (Horizontal)	CP	1.16	1.32	14
Air Intake Shaft Station				
S65 Drift – W620 (Vert CL)	Ext	0.29	0.33	14
N95 Drift – W620 (Vert CL)	Ext	0.35	0.01	-97[(d)]

(a) Instrument Type: Ext = extensometer; CP = convergence point.
(b) CL = Centerline
(c) NA = No reading taken during the 2010 – 2011 reporting period
(d) Anchor at maximum range

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. The access drifts are typically rectangular in cross-section with heights ranging from 4.0 m to 6.4 m and widths ranging from 4.3 m to 9.2 m.

During the current reporting period (July 2010 to June 2011), excavation of Panel 6 was completed and Panel 7 mining was ongoing. Panels 3 and 4 were excavated at a slightly higher stratigraphic position (2.4 m) than either Panels 1 or 2. The roof of these panels coincides with Clay G. As such, Panels 1, 2, 7 and 8 will be at the original horizon and Panels 3, 4, 5 and 6 approximately 2.4 m higher in elevation (roof at Clay G). Trimming, scaling, floor milling and rock bolting operations were performed as necessary during the reporting period.

Assessment of creep deformations in the access drifts is made through the examination of extensometer and convergence point data reported annually in the GAR. Table 2.7 summarizes the vertical and horizontal displacement data reported in the most recent GAR (DOE 2012b). The 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% which includes negative values, 0 to 25%, 25 to 50%, etc.). The numbers shown in the tables represent the number of instrumented locations located on the drift vertically or horizontally that fall within the range of the indicated percentage change. In general, convergence rate accelerations continue to be minor in most locations. Other areas that have shown an increase in closure rates can be directly attributed to mining in Panel 7 and associated drifts. The majority of the rate changes for the 2011 COMPs data were low or near zero. For this 2012 report, the majority of the data are still in the lower two ranges. As was done in the 2011 report, the convergence data and extensometer data were combined. The maximum displacement rates corresponding to these data for the current reporting period are given below:

Maximum Vertical Displacement Rates along Access Drifts:

18.80 cm/yr

Maximum Horizontal Displacement Rate along Access Drifts:

10.06 cm/yr

Using a typical average drift dimension of 5 m and the maximum displacement rates shown above, the inferred maximum creep rate is approximately 1.19×10^{-10}/s. This rate is based on the maximum displacement which is not representative of the behavior of the system. This rate is nearly identical to last year's rate of 1.12×10^{-10}/s.

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. High displacement rates observed at a few locations have little effect on safety as geotechnical engineering provides continuous ground-control monitoring and remediation on an as-needed basis.

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 comprising seven rooms (the major north-south access drifts servicing the eight panels will also be used for waste disposal and will make up the ninth and tenth panels). Panel 1 was constructed in the late 1980s, Panel 2 constructed during the 1999-2000 time period, Panel 3 constructed during the 2002-2004 time period and the completion of Panel 4 during 2006. As of June 30, 2011, RH disposal was ongoing in Room 7 of Panel 6 and CH disposal was occurring in Room 1 of Panel. Mining of Panel 7 began April 24, 2010 and was ongoing as of June 30, 2011 (the end of the GAR reporting period). Figure 2.1 shows the state of waste emplacement and mining for the GAR reporting period.

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; the exhaust entry has a height of 3.65 m and a width of 4.30 m while the air intake entry to the panel is 4.0 m by 6.0 m.

Table 2.7. Summary of Changes in Vertical and Horizontal Displacement Rates of the WIPP Access Drifts and Waste Disposal Area Openings.

Location	Number of Instrument Locations Where the Indicated Percentage Change has Occurred					
	Percentage Increase in Displacement Rate for Measurements Made During the 2007-2008 and 2008-2009 Reporting Periods					
	< 0%	0 – 25%	25 – 50%	50 – 75%	75 – 100%	100 – 200%
Access Drifts						
Vertical	28	130	55	15	8	21
Horizontal	7	87	29	8	9	8
Waste Disposal Area						
Panel 3						
Vertical	0	3	1	0	0	0
Panel 4						
Vertical	0	1	4	1	1	0
Panel 5						
Vertical	2	14	13	2	0	0
Panel 6						
Vertical	51	6	3	0	0	0
Panel 7						
Vertical	NA	NA	NA	NA	NA	NA

NA = First year for monitoring. Rates will be available in next reporting period.

Assessment of creep deformation in the waste disposal area is made through the examination of extensometer and convergence point data reported annually in the GAR. Tables 2.6 and 2.7 (presented previously) summarize, respectively, the vertical and horizontal displacement data reported in the most recent GAR (DOE 2012b) for Panel access drifts and Panels 3, 4 and 5. Panel 1, 2 and 3 are closed and are no longer accessible. Convergence points and extensometers were installed in Panel 7 during this reporting period and are currently monitored. No stable data is available from this area. Initial closure rates are high after initial mining. Not enough time has passed since the monitoring points have been installed to derive a reliable yearly rate. Panel 7 data have not been considered in this year's analysis. Each table examines percentage changes between displacement rates measured during the current and previous reporting periods. In addition, extensometer data are based only on displacements of the collar relative to the deepest anchor. Since most control points are vertical for the panels, only the vertical displacement rate is calculated. The maximum displacement rate corresponding to these data are given below.

Maximum Vertical Displacement Rates along Waste Disposal Area:

23.67 cm/yr

Using a nominal disposal-area-opening dimension of 8 m and the maximum displacement rates shown above, the inferred maximum creep rate is approximately 9.38×10^{-11}/s. This rate is less than last year's rate of $1.22x10^{-10}$/s and is consistent with pervious COMPs report rates. Maximum creep rates for the waste disposal areas are all associated with newer excavations. The rate used here was from Panel 6. As noted earlier, the initial rate for Panel 7 listed in the GAR (DOE 2012) were not used in this analysis because they are not representative rates and are as high as 22 in/yr (56 cm/yr). It should be noted that there are no horizontal measurements for Panels 4, 5 and 6. No additional actions are recommended at this time.

2.2.2 Extent of Deformation

Table 2.8 summarizes the data and TV information relating to the COMP parameter Extent of Deformation, as well as its implementation in PA. 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 is related to a conceptual model used in performance determinations. If characteristics could be tracked from inception, the spatial and temporal evolution of the DRZ would provide a validation benchmark for damage calculations.

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. A more in-depth discussion of the condition of the mined areas are found in the "Ground Control Annual Plan for the Waste Isolation Pilot Plant, (DOE 2012c). This document discusses ground conditions and the operational monitoring program that is used to assess these conditions.

The Geotechnical Engineering Department at WIPP has compiled back-fracturing data into a database. The supporting data for the GAR (Volume 2, DOE 2012b) 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 original excavation horizon results in a 2.4 m-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 for PA.

Excavation of Panel 3 raises the waste disposal panels by 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 change will likely alter the typical fracture patterns observed to date and may cause subtle changes in how the DRZ develops. Effects of excavation to Clay Seam G have been evaluated by finite element analyses to assess possible impact to PA (Park and Holland 2003). Their modeling shows that the DRZ does not extend below MB139 at the new horizon, as it does at the original horizon. The rise in repository elevation otherwise causes no discernable change to the porosity surface used in PA. Data provided in the GAR suggest that brittle deformation extends at least 2.4 m (to Clay Seam G where present) 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).

Fracture maps provided in the 2012 GAR were compared to maps in the previous year's report. There were no maps for Panel 4 since there is no longer access to this panel. New maps for Panel 6 were included in the 2011 GAR such that comparisons for this panel can now be made this year. During this reporting period, fractures were mapped in Panel 7 for the first time. A comparison can be made for this panel in next year's report. Panel 5 was also closed this reporting period and was not mapped. Therefore, only Panel 6 can be assessed this year. With the exception of Panel 6, Room 1, all fracture maps for this panel are nearly identical to last year's maps. Room 1 shows new fractures in the S2770 to S3060 area over this reporting period. As discussed in DOE 2012c, this area was identified for additional ground control and was pattern bolted with 12 foot roof bolts.

Table 2.8 Extent of Deformation - 2012:

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	Not Established

COMP Assessment Process - Reporting Period July 2010 through June 2011

Extent of deformation is deduced from visual inspections and fracture mapping which are examined yearly for active cross sections. Anomalous growth is determined by yearly 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 of DRZ was originally assigned a constant value of $10^{-15}m^2$ for the CCA; per EPA direction, a uniform distribution from 3.16×10^{-13} to 3.98×10^{-20} m^2 was used for all subsequent PAs	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	None	TV Derivation Report, Revision 2 (Wagner and Kuhlman 2010)

2.2.3 Initiation of Brittle Deformation

Table 2.9 summarizes data and TV information relating to the COMP parameter Initiation of Brittle Deformation, as well as its implementation in PA. Initiation of brittle deformation around WIPP openings is not 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 TVs. In addition, this COMP is not directly related to a PA parameter. 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. The ongoing geotechnical 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 PA calculations. As stated previously, this COMP is qualitative and is not directly related to PA parameters.

Table 2.9 Initiation of Brittle Deformation - 2012:

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	Not Established	
COMP Assessment Process - Reporting Period July 2010 through June 2011				
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	Qualitative COMPs can be subjective and are not prone to the development of meaningful TVs.		

2.2.4 Displacement of Deformation Features

Table 2.10 summarizes data and TV information relating to the COMP parameter Displacement of Deformation Features, as well as its implementation in PA. 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 typically continuous sub-parallel to the surface of the openings and terminating near the 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 Clays G and H. These features are located approximately 2.4 m and 4.5 m respectively, above the roof of Panels 1, 2, 7 and 8. Marker Bed 139 (anhydrite) is located approximately 2 m below the floor of these panels. For Panels 3 through 6, the panels are mined up to Clay G. Clay H is therefore located 2.1 m above the roof of these panels and Marker Bed 139 is located approximately 4.4 m below the panel floors.

Table 2.10 Displacement of Deformation Features - 2012:

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_o	Observational	Not established	
COMP Assessment Process - Reporting Period July 2010 through June 2011				
Observational – Lateral deformation across 209 boreholes in Panels 5,6,& 7.				
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	None	TV Derivation Report Revision 2 (Wagner and Kuhlman 2010)		

Monitoring of these deformation features is accomplished through visual inspection of observation boreholes (OBH) 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 OBHs are 7.6 cm (3 in) in diameter, and many intersect more than one deformation feature. The ages of the OBHs vary from more than 20 years to recent.

The deformation features in OBHs are classified as: 1) offsets, 2) separations, 3) rough spots and 4) hang-ups. Of the four features, offsets are the principle metric for this COMP and are quantified by visually estimating the degree of borehole occlusion created by the offset. 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.

All of the observation holes associated with Panels 1 through 4 are no longer monitored. There are a total of 209 OBHs reported in the GAR. These OBHs are located in the panels, access drifts and the North End of the repository. Based on the current data available from the GAR, 24 OBHs were at least 50% occluded, 7 were 100% occluded. There are 47 accessible holes monitored in Panel 5, and 47 in Panel 6. Panel 6 has the greatest separations that are associated with Clay H and Anhydrite "a." Panel 6 has 19 holes that have fractures associated with anhydrite stringers in the lower portion (first 3 feet) of the roof beam. In Panel 6, 38 of the 47 holes show measurable offset. In panel 7, 16 of the 47 holes showed some offset. In general, panels mined to Clay G show less offsets over time than the other panels as the number of fully occluded OBHs has decreased in the upper panels.

Displacement of deformation features has been useful for implementation of ground control alternatives (i.e., horizon change to Clay G). Displacement features complement observation of brittle deformation initiation and corroborate estimates of the extent of deformation.

2.2.5 Subsidence

Table 2.11 summarizes data and TV information relating to the COMP parameter Subsidence, as well as its implementation in PA. Subsidence is currently monitored via elevation determination of 48 existing monuments and 14 of the National Geodetic Survey’s vertical control points. Approximately 15 miles of leveling was performed in 20011 for 9 control loops (see Figure 2-2). To address EPA monitoring requirements, the most recent survey results (DOE 2011) are reviewed and compared to derived TVs. 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 the local 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 after initial mining. 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 maximal 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 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 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. This year’s measured accuracy ranged from -0.007 to 0.005 ft/mile.

Three monuments have also been included in various annual surveys, but were not included in the current surveys because the monuments no longer exist (last surveyed in 2003, monuments S-17 & S-18 are under a salt pile) or have been physically disturbed (PT-31, last surveyed in 2003). 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 has been following WIPP procedure WP 09-ES4001 (WTS 2002).

Table 2.11 Subsidence - 2012:

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 62 original monitoring monuments	Decimal (meters)	Not Established
SMP	Change in elevation over year	Decimal (meters)	Not Established

COMP Assessment Process – 2012; Data acquired between September through November of 2011
Survey data from annual WIPP Subsidence Monument Leveling are evaluated. Elevations of 48 monitoring monuments in nine loops are compared to determine changes.

Related Performance and Compliance Elements

Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Subsidence	FEP [W-23]	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 (CRA Appendix PA Attachment SCR , Section SCR-6.3.1.4) – 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; DOE 2009).

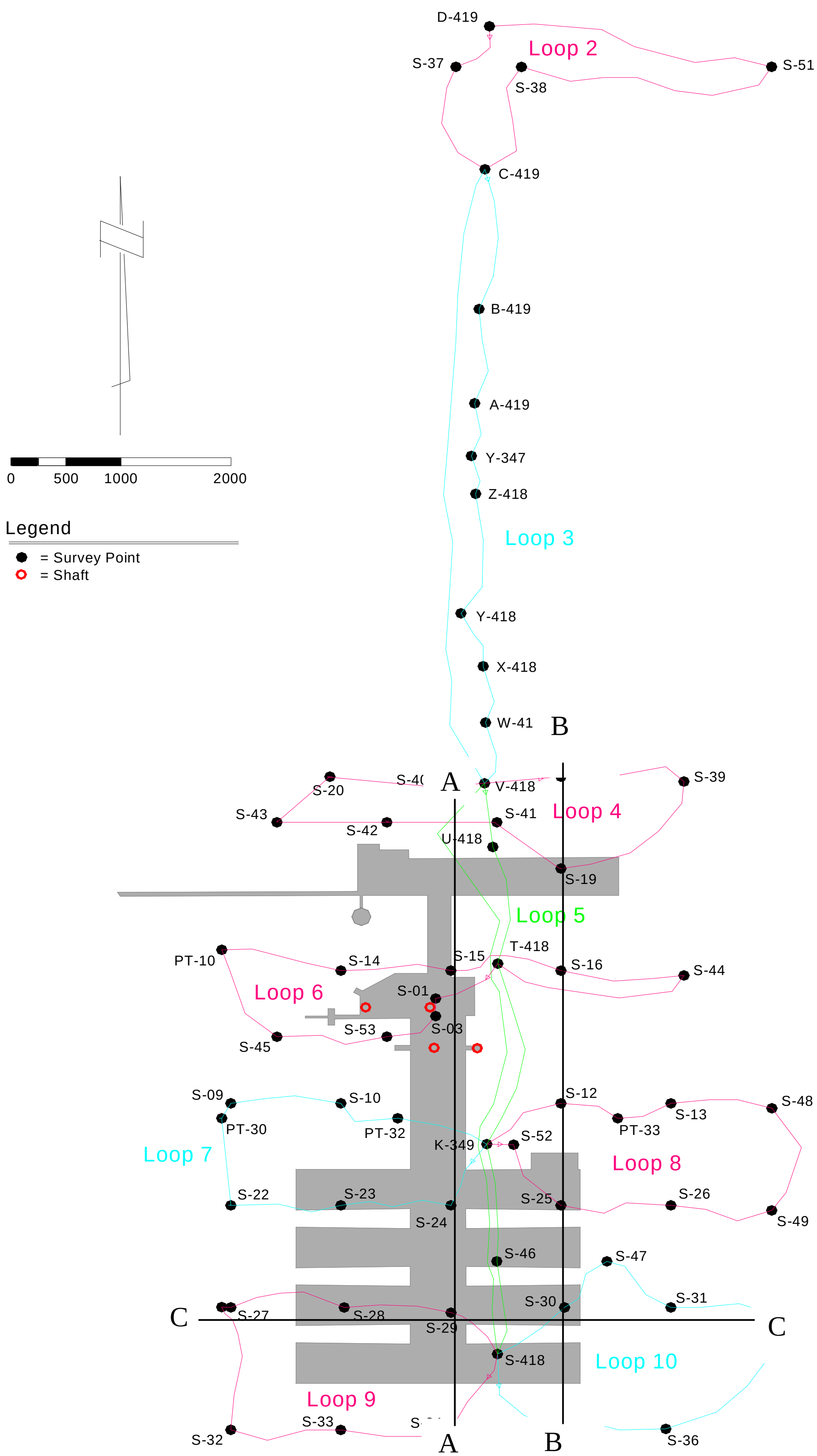
Monitoring Data Trigger Values

Monitoring Parameter ID	Trigger Value	Basis
Change in elevation per year	1.0×10^{-2} m (3.25×10^{-3} ft) per year subsidence	Based on the most conservative prediction by analyses referenced in the CCA.

The current surveys comprise nine leveling loops containing as few as five to as many as ten monuments/control points per loop as shown in Figure 2.2 (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 7,700 ft 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 at 3,423.874 feet for all of the subsidence leveling surveys conducted since 1993. Survey accuracy for all loops was within the allowable limits (DOE 2010). 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 a survey loop.

The adjusted elevations for each monument/control point are plotted as functions of time to assess subsidence trends. Figures 2.3 through 2.7 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) outside the repository footprint of the WIPP underground excavation. As expected, subsidence is occurring directly above the underground openings (Figures 2.3 through 2.6); however the magnitude of the subsidence above the repository is small ranging from about -0.003 ft to -0.35 ft.

Figure 2.2. Monuments and vertical control points comprising WIPP subsidence survey loops.



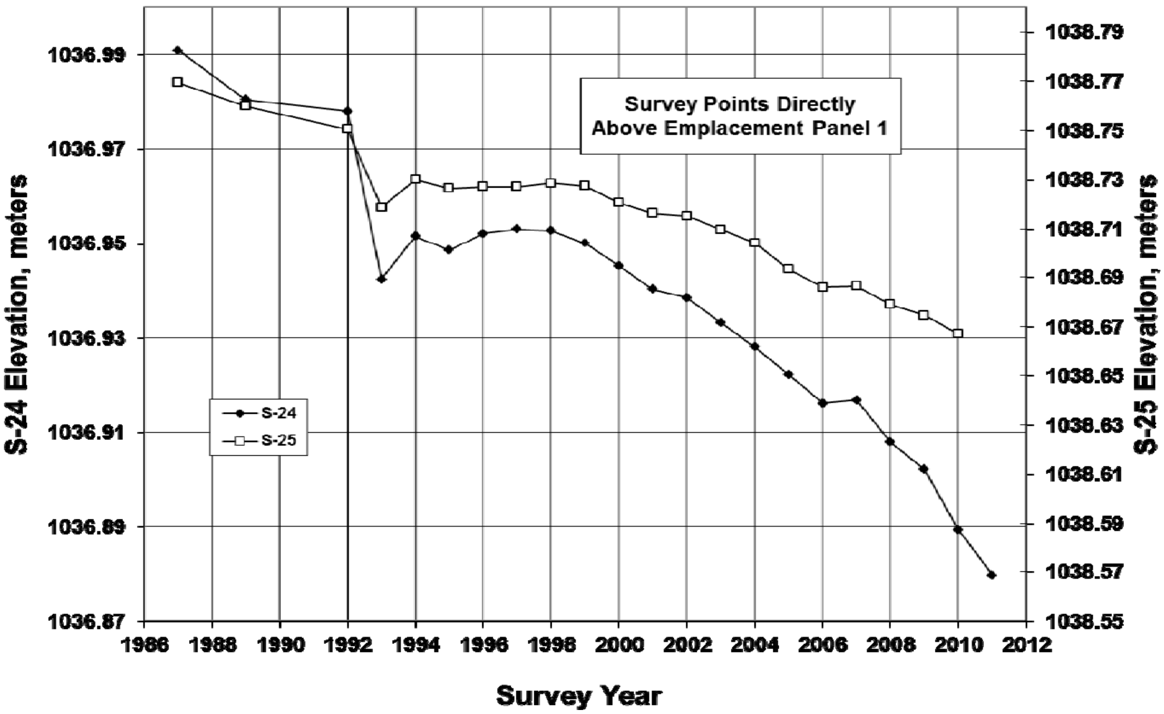


Figure 2.3. Elevations of WIPP monuments S-24 and S-25 located directly above emplacement Panel 1.

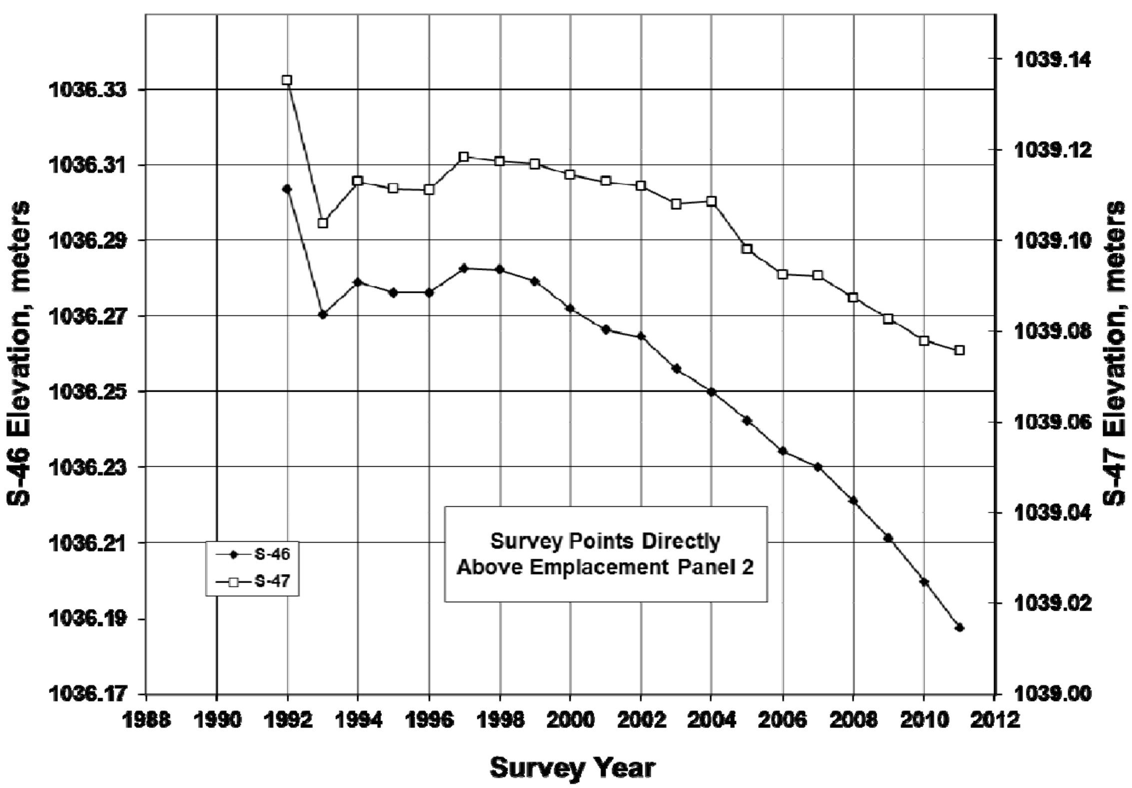


Figure 2.4. Elevations of WIPP monuments S-46 and S-47 located directly above emplacement Panel 2.

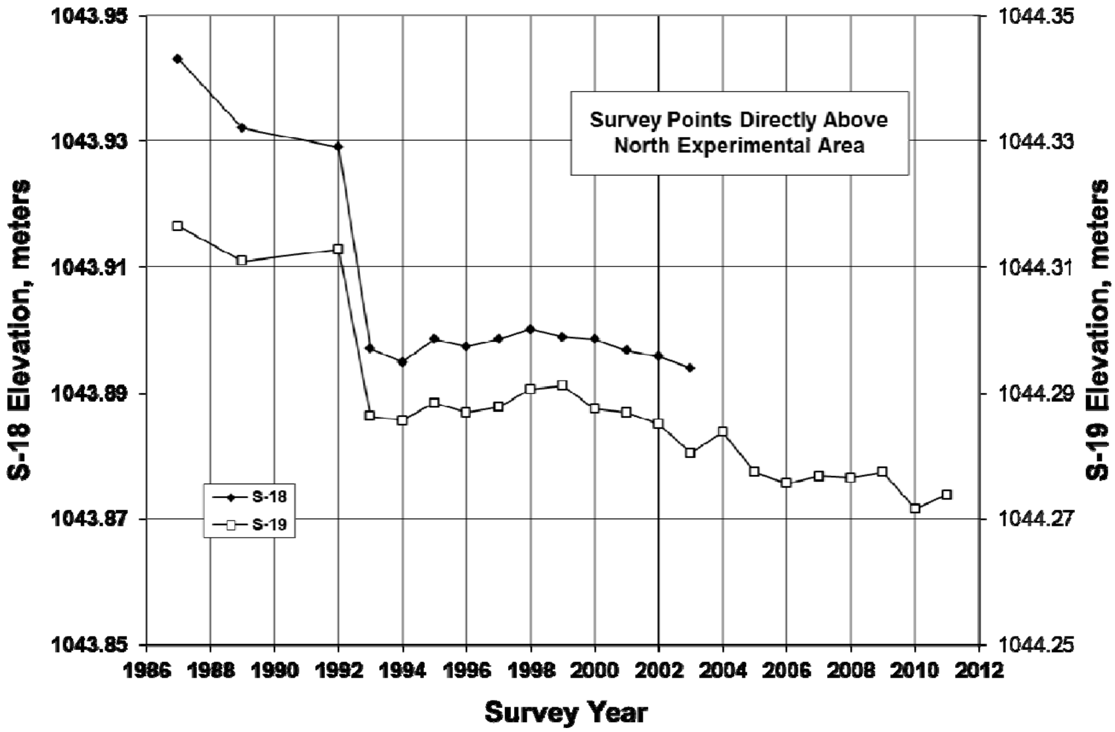


Figure 2.5. Elevations of WIPP monuments S-18 and S-19 located directly above the north experimental area.

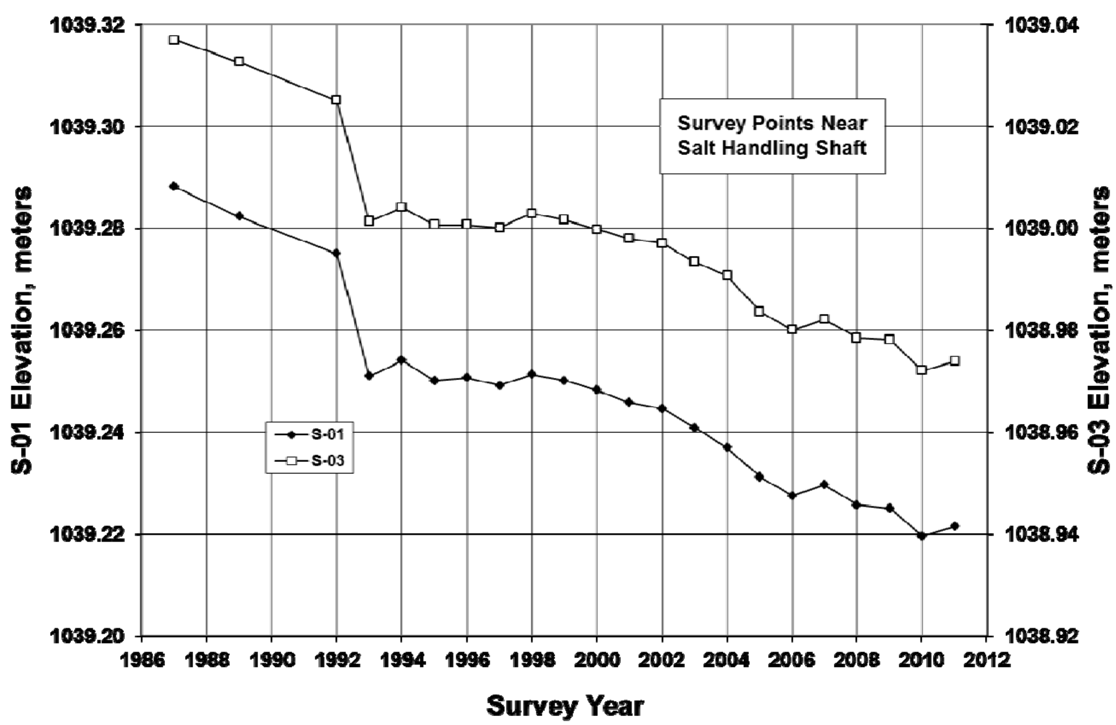


Figure 2.6. Elevations of WIPP monuments S-01 and S-03 located near the Salt Handling Shaft.

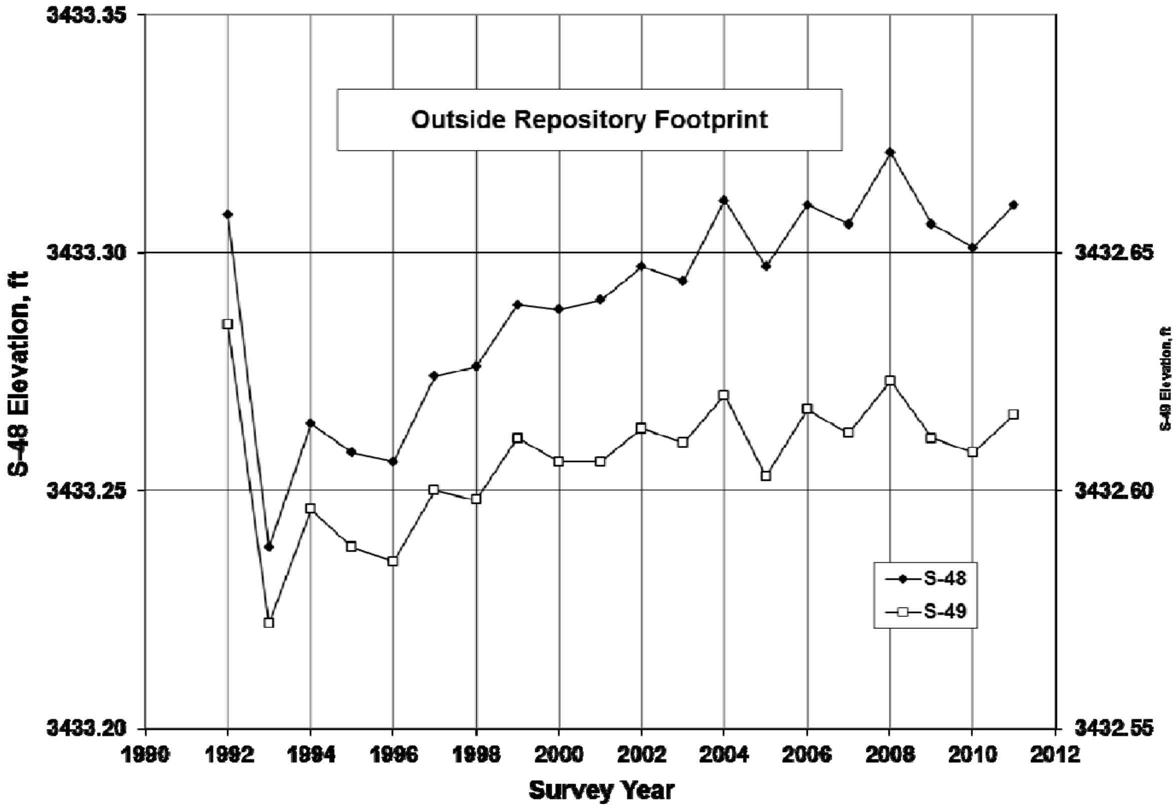


Figure 2.7. Elevations of WIPP monuments S-48 and S-49 located outside the repository footprint.

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 2.8 through 2.10 for the following subsidence profiles (shown in plan view in Figure 2.2):

- 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

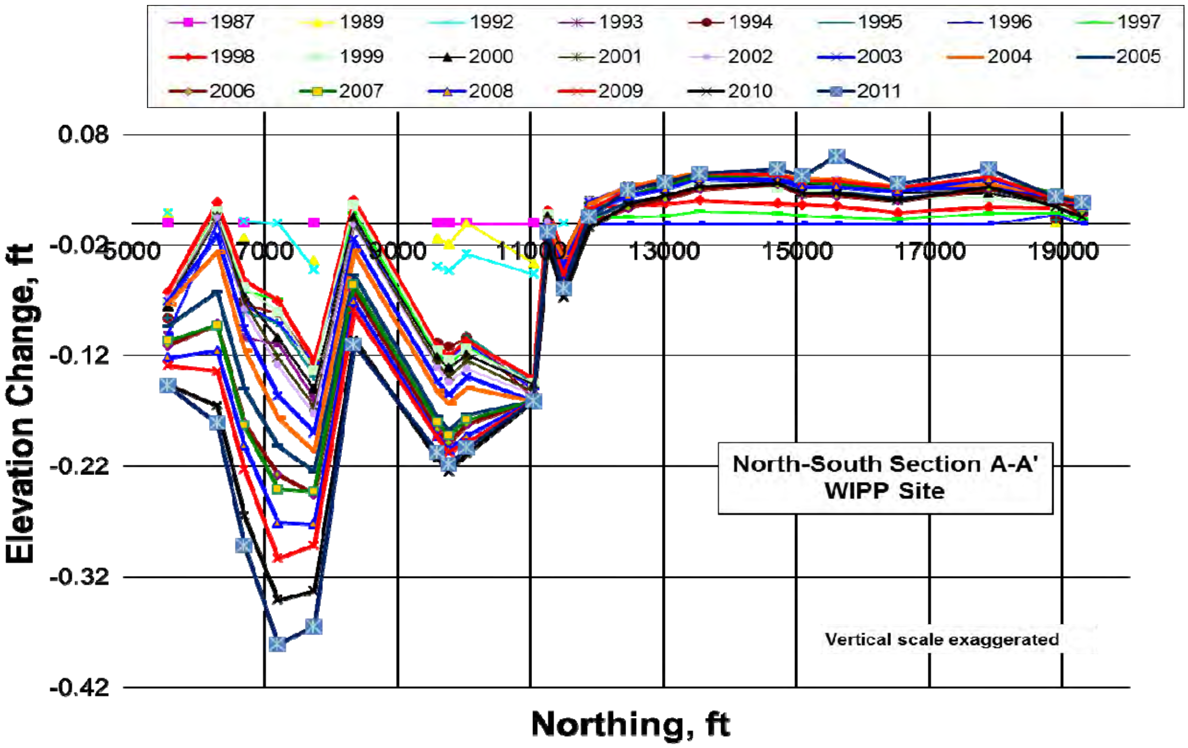


Figure 2.8. North-South subsidence profile A-A'.

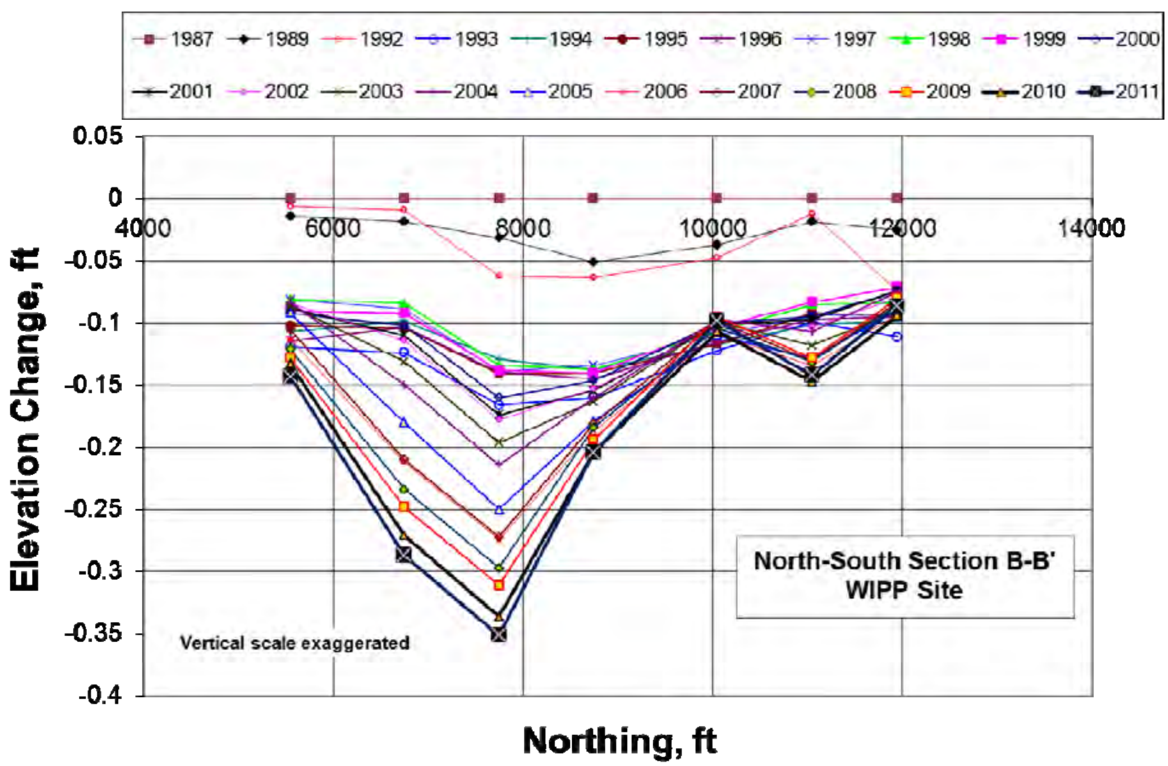


Figure 2.9. North-South subsidence profile B-B'.

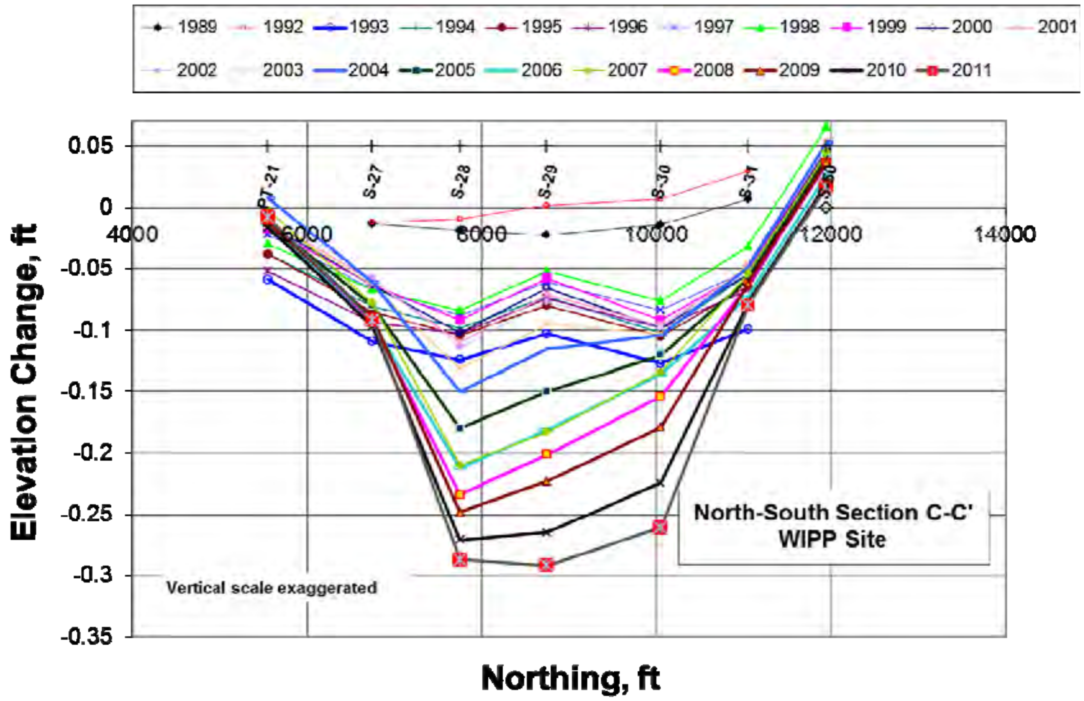


Figure 2.10. East-West subsidence profile C-C′.

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 monuments were included in the 1992 surveys and more that 60 for all surveys since 1996. Although direct comparisons cannot always be made, several observations for this reporting period are possible including:

1. The most significant total subsidence (greater than - 0.25 ft) occurs above the waste panels (Monuments S-23, S-24, S-25, S-29, S-30, S-46 and PT-32). This subsidence trend is centered over Panels 1 and 2 while the maximum subsidence of 0.341 was over Panel 2 (S-46).
2. The highest subsidence rates measured for the 2010-2011 surveys correspond to benchmarks located generally over the newer panels (e.g., S-24, S-28, S-29 and S-46) which had a rate of approximately -1.1×10^{-2} to -8.2×10^{-3} m/yr. Only monuments over the Experimental Area and Waste Panels showed any appreciable subsidence rate (approximately $+/-1 \times 10^{-3}$ m/yr) with the higher rates located directly over the Waste Panels.
3. The effects of subsidence extend away from the repository footprint approximately 1,000 to 1,500 ft (e.g., S-26, see Figures 2.2 and 2.10).

Furthermore, total subsidence and subsidence rates are small, and are approximately at the resolution level of the survey accuracy. The highest subsidence rates are seen above the mined panels and have increased since the mining of Panels 4 through 7. Based on the latest survey data, subsidence rates of the ground surface at the WIPP have exceeded the 1×10^{-2} m/yr TV. As this is the second occurrence no additional activities are recommended at this time. If this trend continues, a determination will be made if additional actions are necessary.

2.3 Hydrological COMPs

As stated in the previous sections, the CRA-2009 lists 10 monitoring parameters that the DOE is required to monitor and assess during the WIPP operational period (DOE 2009). Two of these parameters are considered hydrological in nature and include:

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

The Scientific Advisor has reviewed the data collected by the MOC during 2011 under the *Strategic Plan for Groundwater Monitoring at the Waste Isolation Pilot Plant* (GMP) (DOE 2003), which comprises 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 Annual Site Environmental Report (ASER) for 2011 (DOE 2012d). Additionally, WLMP data are also reported in monthly memoranda from the MOC to the Scientific Advisor.

2.3.1 Changes in Culebra Water Composition

2.3.1.1 Water Quality Sampling Program (WQSP)

Table 2.12 summarizes data and TV information relating to the COMP parameter Change in Culebra Water Composition, as well as its implementation in PA.

Under the current WQSP, six wells are sampled by the MOC, all completed to the Culebra Dolomite Member of the Rustler Formation (Figures 2.11 and 2.12). All the WQSP wells are located within the WIPP Land Withdrawal Boundary (LWB). WQSP-1, 2, and 3 are situated hydraulically up-gradient (north) of the WIPP surface facilities and WQSP-4, 5, and 6 are situated down-gradient (south) of the WIPP surface facilities. Previously, the Dewey Lake Formation well WQSP-6A was also sampled, but beginning with sampling round 32, this well is no longer included and is therefore no longer discussed in this section.

The Culebra is modeled for PA because it is the most transmissive, lowest freshwater hydraulic head, saturated water-bearing zone in the WIPP vicinity. Because of this, it is considered the most likely groundwater release pathway for potential future inadvertent human intrusion of the repository. The Culebra is not a source of drinking water for humans and therefore water quality degradation is not of concern. Understanding Culebra water quality is important because it is a key component in understanding the entire flow system.

Table 2.12 Change in Groundwater Composition - 2012:

<table>
<tr><td>COMP Title:</td><td colspan="4">Groundwater Composition</td></tr>
<tr><td>COMP Units:</td><td colspan="4">mg/L</td></tr>
<tr><td colspan="5">Related Monitoring Data</td></tr>
<tr><td>Monitoring Program</td><td>Monitoring Parameter ID</td><td colspan="2">Characteristics (e.g., number, observation)</td><td>Compliance Baseline Value</td></tr>
<tr><td>Groundwater Monitoring</td><td>Composition</td><td colspan="2">Annual chemical analysis</td><td>RCRA Background Water Quality Baseline</td></tr>
<tr><td colspan="5">COMP Derivation Process – Data acquired in two rounds, March-May (round 32) and September-November (round 33) 2011</td></tr>
<tr><td colspan="5">Annually evaluate ASER data and compare to previous years and baseline information</td></tr>
<tr><td colspan="5">Related Performance and Compliance Elements</td></tr>
<tr><td>Element Title</td><td>Type & ID</td><td>Derivation Procedure</td><td>Compliance Baseline</td><td>Impact of Change</td></tr>
<tr><td>Groundwater conceptual model, brine chemistry, actinide solubility</td><td>Indirect</td><td>Conceptual models</td><td>Indirect – The average Culebra brine composition is not used.</td><td>Provides validation of the various CRA models, potentially significant with respect to flow, transport, and solubility and redox assumptions.</td></tr>
<tr><td colspan="5">Monitoring Data Trigger Values</td></tr>
<tr><td>Monitoring Parameter ID</td><td>Trigger Value</td><td colspan="3">Basis</td></tr>
<tr><td>Change in Culebra groundwater composition</td><td>Both duplicate analyses for any major ion falling outside the 95% confidence interval (see Table 2.13) for three consecutive sampling periods</td><td colspan="3">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, TVs 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 (SNL 2002).</td></tr>
</table>

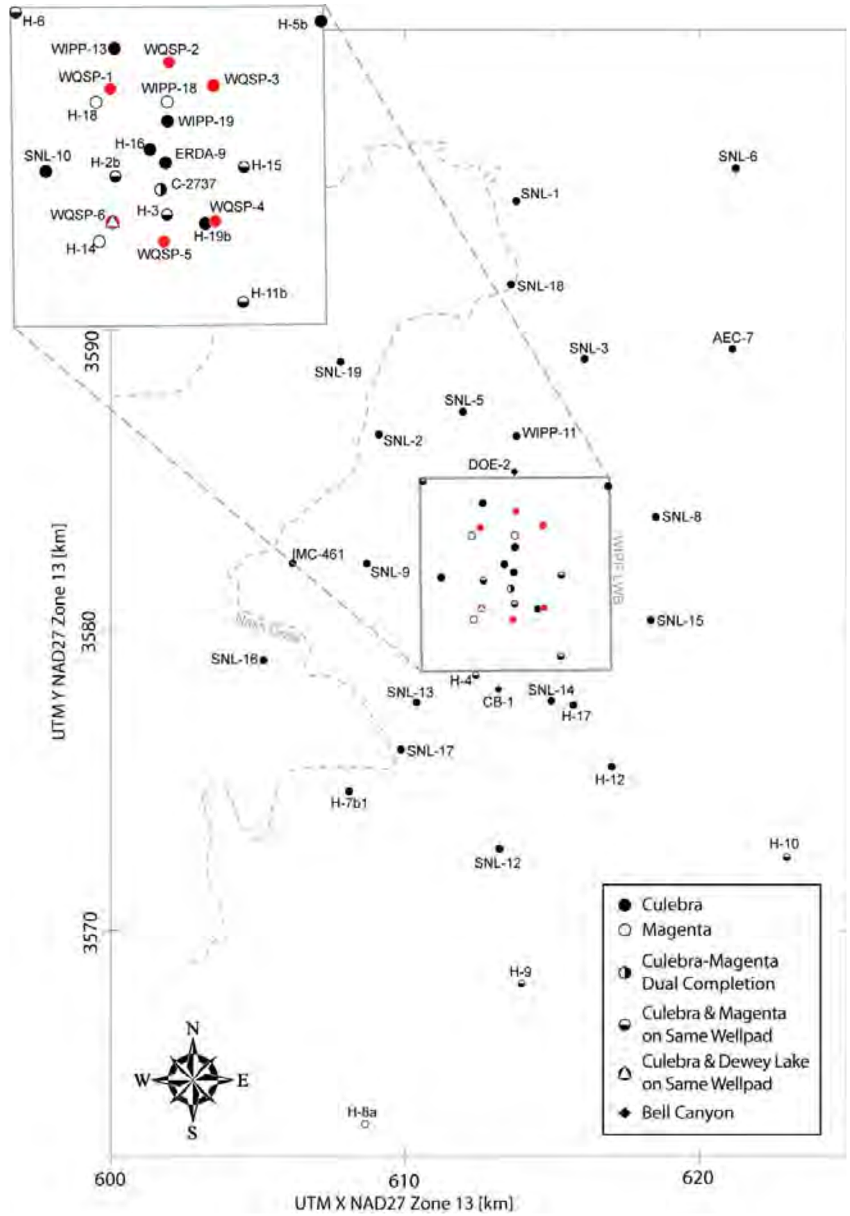


Figure 2.11. Map showing locations of WQSP wells (red) in relation to the WIPP LWB and the rest of the groundwater-monitoring network.

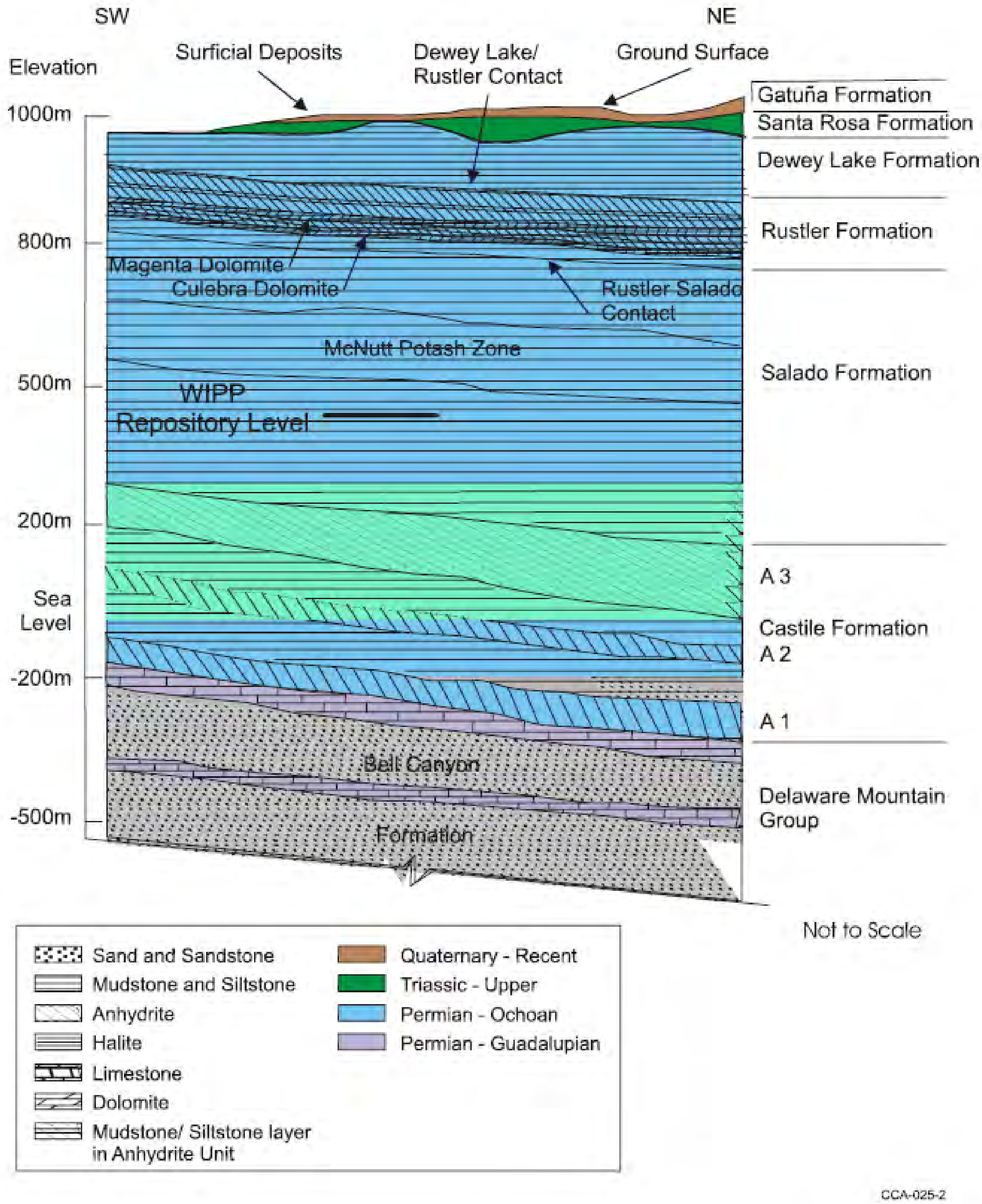


Figure 2.12. Generalized Stratigraphic Cross Section at the WIPP Site.

Solute concentrations in Culebra waters differ widely among wells across the WIPP site, reflecting local equilibrium, diffusion, and, perhaps most importantly, slow regional transport rates. The conceptual model for the Culebra was presented in the CRA-2009 (DOE 2009) and is implemented in the PA hydrological models. The conceptual model consists of a confined groundwater flow system with natural-gradient solute travel times across the WIPP site on the order of thousands to 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 are expected. If sustained, representative, and statistically significant changes in the concentrations of major ionic species (Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3^-) are observed, this condition could imply that groundwater movement through the Culebra is quicker than what is predicted by the PA models. Stability of major ion concentrations, on the other hand, is consistent with and supports the Scientific Advisor's Culebra transport conceptual model. Thus, this evaluation of the water-quality data focuses on the stability of major ion concentrations.

2.3.1.1.1 Water Quality Sampling

Two water samples (a primary and a duplicate) were collected from each WQSP well twice per year, in the spring and again in the fall. Water sampling procedures are outlined in the GMP (DOE 2003) and are summarized here. After this year's round of water quality sampling, the DOE will change the sampling frequency to once a year (annual for rounds past 33).

Serial and final samples are collected using a submersible pump (each well has its own dedicated pump) that is set at the mid-formation level. Serial samples are collected at regular intervals during pumping and they are analyzed in a mobile field laboratory to determine when water chemistry has stabilized. Stabilization parameters include temperature, Eh, pH, specific gravity, specific conductance, alkalinity, chloride, divalent cations, and total iron. Final samples are collected in the appropriate containers for each particular analysis when water quality parameters have stabilized to within ±5% of their field parameter averages. Once collected, final samples are placed in coolers and delivered to the analytical laboratory within a day of collection.

2.3.1.1.2 Laboratory Analysis

The MOC collects samples to be analyzed for volatiles, total organic halogens, total organic carbon, semi-volatiles, metals, and general chemistry. For this report, only the results from the metals and general chemistry analyses are discussed, as they provide the necessary information for assessment of the COMP. In the field, the general chemistry samples are not preserved, metals samples are preserved with nitric acid, and neither sample is filtered. In the lab, samples are analyzed using a variety of published, lab-standard methods. Samples are analyzed for major cations (i.e., Na^+, Ca^{2+}, Mg^{2+}, K^+), major anions (i.e., Cl^-, SO_4^{2-}, HCO_3^-), and other constituents not discussed here.

For sampling rounds 7 through 26, TraceAnalysis, Inc. of Lubbock, TX was responsible for analysis of the water samples submitted by the MOC. In 2008, the analytical contract was awarded to Hall Environmental Analysis Laboratory (HEAL) of Albuquerque, NM, who began analysis with round 27.

2.3.1.1.3 Data Analysis

The results of the WQSP analyses are compared to baseline results in order to determine stability, where concentration of a given ion remains within its baseline-established 95% confidence interval (CI; mean ± two standard deviations). Confidence interval calculations assume concentrations follow a normal distribution. The original baseline included the initial five rounds of WQSP well sampling conducted between July 1995 and September 1997 (Crawley and Nagy 1998). The baseline was revised in 2000, expanding from the first five to the first ten rounds of sampling, which were performed between July 1995 and May 2000 (the first receipt of RCRA-regulated waste at WIPP). The baseline data are presented in the *WIPP Resource Conservation and Recovery Act Background Groundwater 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, and 6. The reasons for eliminating these values are discussed in detail in the COMPs assessment report for data collected in the year 2000 (SNL 2001). The elimination of these values is always conservative; it reduces the "stable" range of concentrations for the affected parameters. The 95% CIs derived from the baseline data (SNL 2002) are presented in Table 2.13.

Using the baseline analysis described above, a Trigger Value (TV) for Culebra groundwater composition has been defined. The TV occurs when both primary and duplicate analyses for any major ion fall outside the 95% CI for three consecutive sampling periods. Should the TV be reached, the project will first evaluate the sampling and analytical procedures to ensure the adequacy of the sampling. If the change appears to accurately reflect Culebra conditions, the Scientific Advisor will investigate what effects the changes might have on Culebra model conceptualization. The model will be revised to be consistent with the new information if appropriate.

Table 2.13. Rounds 32 and 33 major ion concentrations and charge-balance errors, with a baseline 95% CI defined for each major ion.

Well	Round	Cl^- (mg/L)	SO_4^{2-} (mg/L)	HCO_3^- (mg/L)	Na^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	K^+ (mg/L)	CBE (%)
WQSP-1	32	**41000/40000**	4570/4770	51.3/51.5	20100/19900	1710/1690	1120/1100	*498/596*	**-7.8%**
	33	36000/38000	4950/4900	52.8/50.8	20500/20900	1850/1790	1170/1150	489/499	-2.1%
	CI	31100-39600	4060-5600	45-54	15900-21100	1380-2030	939-1210	322-730	
WQSP-2	32	35000/34500	5760/5620	47.8/48.0	21500/20000	1690/1670	1110/**1130**	484/533	-0.4%
	33	38000/38500	5580/5680	50.7/49.1	21700/20100	1580/1610	1080/1090	465/483	-4.7%
	CI	31800-39000	4550-6380	43-53	14100-22300	1230-1770	852-1120	318-649	
WQSP-3	32	**158000/153000**	**8490/8880**	32.6/33.2	76000/71000	1470/1520	2390/2460	**1420/1470**	**-13.1%**
	33	**151000/146000**	**8170/7920**	33.4/33.5	*80000/71000*	1570/1520	2400/2460	**1500/1470**	**-9.5%**
	CI	114000-145000	6420-7870	23-51	62600-82700[c]	1090-1620	1730-2500	2060-3150[a]	
WQSP-4	32	**68300/66000**	7610/7650	39.8/39.8	36500/33700	1620/1550	1260/1200	**763/731**	**-8.7%**
	33	60400/60300	6950/7120	39.9/39.8	36800/35100	1560/1570	1170/1180	**734/743**	-2.6%
	CI	53400-63000	5620-7720	31-46	28100-37800	1420-1790	973-1410	832-1550[b]	
WQSP-5	32	15900/15300	5480/5580	48.0/48.1	9310/9330	1110/1120	480/480	297/312	-4.5%
	33	15000/16200	5090/5200	47.4/47.6	**10500**/9970	1100/1130	478/478	300/306	0.0%
	CI	13400-17600	4060-5940	42-54	7980-10400[c]	902-1180	389-535	171-523	
WQSP-6	32	**5060/5080**	4490/4510	48.2/46.8	4290/4280	714/730	222/223	167/162	1.5%
	33	5500/**5120**	4900/4740	49.3/48.5	4410/4420	706/680	200/202	141/143	-0.8%
	CI	5470-6380[c]	4240-5120[c]	41-54	3610-5380[c]	586-777	189-233[c]	113-245	

Bold denotes analyses returning values outside the 95% CI or a charge-balance error ≥5%
Italics denotes sample and duplicate analyses differ by >10%
[a] baseline defined from rounds 8-10
[b] baseline defined from rounds 7-10
[c] baseline definition excludes anomalous values

In addition to the baseline comparison, a charge-balance error (CBE) was also calculated for each analysis using the average of the primary and duplicate sample. The CBE is 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. CBE is useful in evaluating analysis reliability because water must be electrically neutral. CBE is rarely zero because of inherent inaccuracy in analytical procedures, but a reliable analysis should not have a CBE exceeding ±5% (Freeze and Cherry 1979). A CBE in excess of ±5% implies either the analysis of one or more ions is inaccurate, or a significant ion has been overlooked. The variation between the results of primary and duplicate sample analysis for each individual ion is also considered. Generally speaking, this variation should be <10%; large variability can indicate a problem with one or both analyses. Analytical results and CBE for rounds 32 and 33 are presented in Table 2.13.

2.3.1.2 Results

WQSP results for sampling rounds 32 and 33 conducted in 2011 are reported in the 2012 ASER (DOE 2012d). The reported major ion concentrations are listed in Table 2-13. Sampling round 32 was conducted between March and May and round 33 was conducted between September and November. Both rounds of samples were analyzed by HEAL. In the following subsections, we describe any anomalous values given in Table 2.13 with either bolded or italicized fonts.

2.3.1.2.1 WQSP-1

In rounds 32 the chloride values (for both samples) were outside the 95% CI. The difference between the round 32 primary and duplicate sample potassium ion concentrations was 17.9%. The CBE for round 32 was -7.8%.

2.3.1.2.2 WQSP-2

For round 32, the duplicate magnesium sample concentration was above its 95% CI, but the average of the primary and duplicate samples was not.

2.3.1.2.3 WQSP-3

Sulfate, chloride, and potassium ion concentrations measured in both samples were above the 95% CI for rounds 32 and 33. Round 33 sodium ion concentrations differed by 11.9% between the sample and duplicate. Both sampling rounds had large CBE, round 32 was -13.1% and round 33 was -9.5%.

2.3.1.2.4 WQSP-4

For round 32, both samples' chloride ion concentrations were outside the 95% CI. Both rounds' potassium ion concentrations were above the 95% CI for both primary and duplicate samples. The CBE in round 32 was -8.7%.

The potassium ion concentration in rounds 27 through 33 were all below the lower 95% CI of 832 mg/L, and therefore exceed the trigger value. Potassium is one of the minor cations, and this deviation is not a significant event warranting further investigation at this time.

2.3.1.2.5 WQSP-5

Sodium ion concentration in the primary round 33 sample was above the 95% CI, while the average of the primary and duplicate samples was not.

2.3.1.2.6 WQSP-6

Round 32 chloride ion concentration was below the 95% CI. The duplicate sample chloride ion concentration in round 33 was also below the 95% CI. The average of the primary and duplicate samples in round 33 was also below the 95% CI.

2.3.1.3 Assessment of Culebra Water Quality Data

Four of the 12 calculated CBEs for the two rounds were >±5%. All the analyses with larger CBEs are negative (more anions than cations), and most are associated with analytes that have anomalously high or low concentrations. All the anomalous CBEs can be linked to high chloride ion concentrations (WQSP-1 rounds 32, WQSP-3 both rounds, and WQSP-4 round 32). Both rounds at WQSP-3, and WQSP-4 round 32 also had anomalously low potassium ion concentrations, which compounds the effects of the high chloride ion concentration effects on the overall CBE.

A common method of assessing water-quality stability is through the use of Piper diagrams, which illustrate relative proportions of three cation and three anion concentrations (four cations are treated by lumping sodium and potassium together). By plotting the ion ratios for every round, we can visually assess water quality trends. Piper diagrams of Culebra water chemistry (Figure 2.13) over the course of the WQSP (now 15+ years) show that the groundwater is relatively stable, with results for each well continually plotting within relatively small envelopes.

The Piper diagrams illustrate that WQSP-4 does not show significant deviation, even though the potassium ion concentration has been below the lower 95% C.I. for six sampling rounds. This is due to the small contribution that the potassium ion has to overall water chemistry.

Full assessment of the Culebra water-chemistry results shows that it is stable and that the Culebra wells only have one minor analyte (K^+) in violation of a TV. Based on review of CBEs calculated for each WQSP well sampled, the analytical results appear to be generally reliable, although CBE are consistently negative but not as large as those reported last year. Any variability observed in the data suggesting instability can be attributable to analytical problems. As mentioned in last year's COMPs report (SNL 2011), it is believed that the majority of analytical problems can be linked to the high salinity (i.e., TDS) observed in Culebra brines. The sensitive analytical equipment used in environmental labs requires that samples be diluted up to 10,000 times in order for samples to be run without harming the machine. Dilution of the samples introduces both human and analytical error, which can cause results to be less precise, especially for constituents that make up a small portion of the overall charge balance.

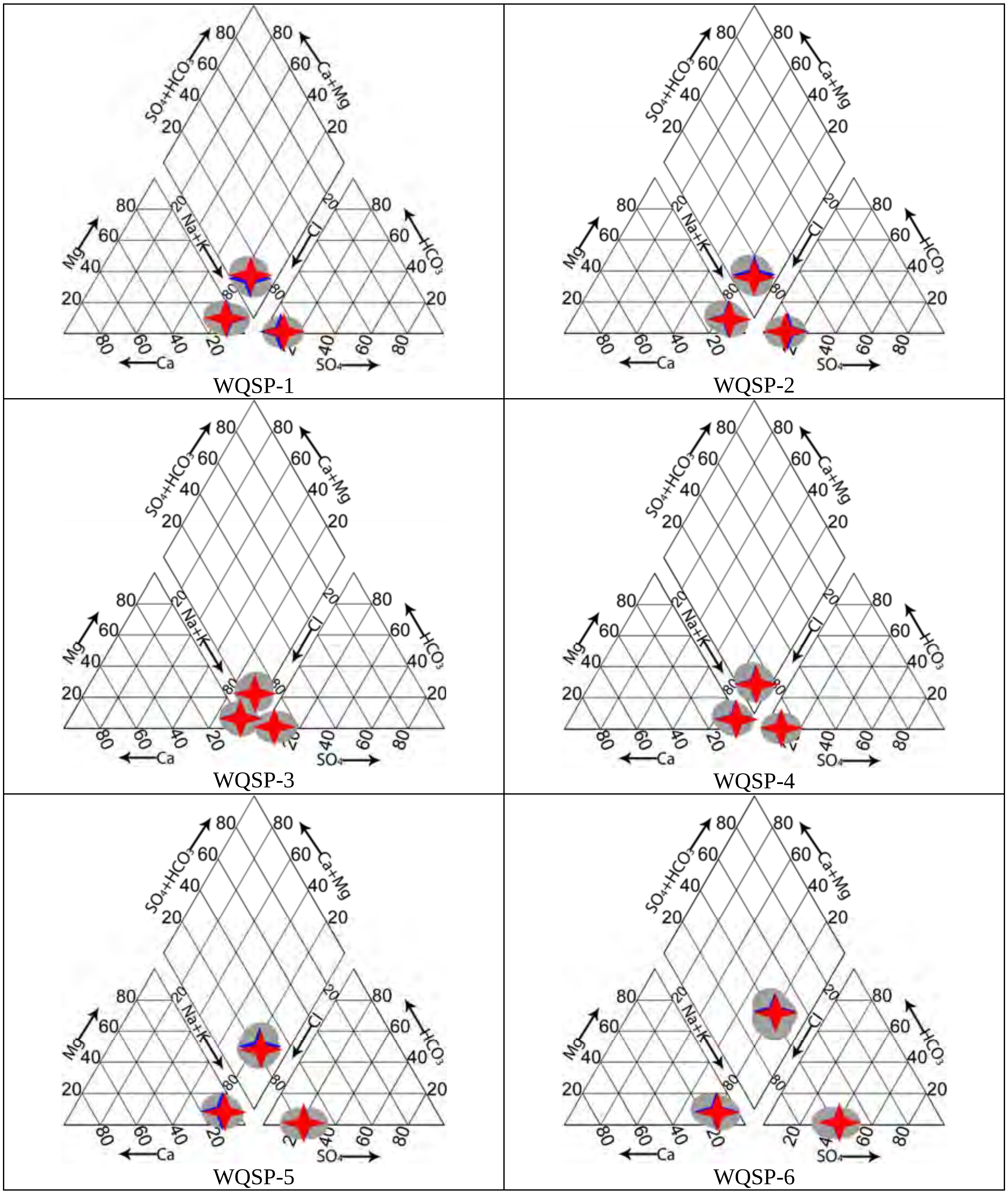


Figure 2.13. Piper diagrams of data collected from WQSP-1 through WQSP-6. The plots show both historical data (gray areas) and results from rounds 32 (blue star) and 33 (red star).

2.3.2 Changes in Groundwater Flow (Water Level)

Table 2.14 summarizes data and TV information relating to the COMP parameter Change in Groundwater Flow, as well as its implementation in PA. Assessment of the COMP for the Culebra involves comparisons of two sets of modeling results. The baseline model results are derived from the ensemble of models used in PA for CRA-2009 PABC (e.g., Hart et al., 2009; Kuhlman, 2010a), while annual model results are adjusted to best fit freshwater heads observed in 2011 (DOE 2012d).

The Dewey Lake, Magenta, and Bell Canyon are not currently monitored as COMPs, do not have PA flow models, and therefore do not have TVs. The water-level measurements in these units do, however, provide information used in the development of the conceptual model of overall site hydrology.

2.3.2.1 Water Level Monitoring Program (WLMP)

In 2011, the MOC made monthly water-level measurements in all of the WIPP non-shallow subsurface water (SSW) monitoring network wells (see Figure 2-14 and Table 2.15), or quarterly in any redundant wells (i.e., six of the seven H-19b wells). As of August 2011, the WIPP monitoring network consisted of 65 wells (including one dual-completion Magenta-Culebra well), see Table 2-15. There were 49 wells with completions to the Culebra Member of the Rustler Formation, 13 to the Magenta Member of the Rustler Formation, two to the Bell Canyon Formation, and one to the Dewey Lake Formation. Since the last COMPs report, the dual-completion well H-9c was plugged back to only the Magenta, while the replacement well H-9bR was drilled to the Culebra on the same pad.

Table 2.14 Changes in Groundwater Flow - 2012:

COMP Title:	Changes in Culebra 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 - Data acquired between December 2010 and December of 2011				
Annual assessment from ASER data.				
Related PA Elements				
Element Title	Type & ID	Derivation Procedure	Compliance Baseline	Impact of Change
Groundwater conceptual model, Transmissivity fields	T-Fields	Computer codes are used along with groundwater data to generate transmissivity fields for the Culebra on a regional scale. A summary of the conceptualization, implementation and calibration of the Culebra T-fields is given in Kuhlman (2010b).	Attachment T-FIELDS to Appendix PA.	Validates assumptions used in T-Field modeling and the groundwater Basin model.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Change in Culebra Groundwater Flow	PA Compliance Baseline range; see Table 2.15	Model-predicted travel time in the Culebra is compared to the distribution found in PA, for an ensemble-average model with best-fit boundary conditions to the current year's observed freshwater heads. The travel time from the center of the WIPP panels to the WIPP LWB must fall within the distribution found using 100 model runs used in the baseline PA.		

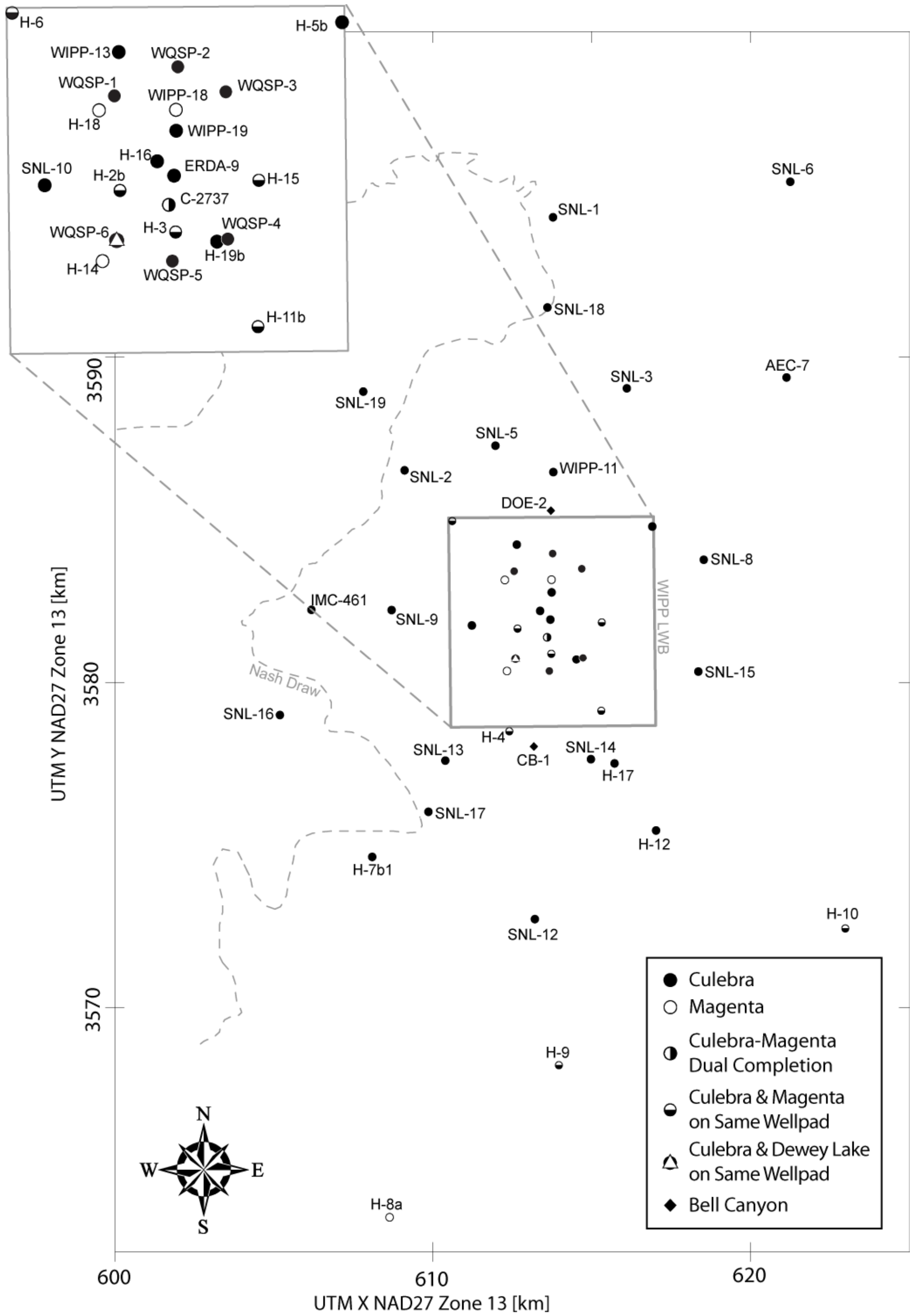


Figure 2.14. Map of the WIPP area showing well pad locations discussed in this section (See Table 2.15 for listing of wells at each well pad).

Table 2.15 August 2011 Non-SSW[1] WIPP Groundwater Monitoring Network

Well	Pad[2]	Completion[3]
AEC-7	AEC-7	CUL
C-2737	C-2737	CUL/MAG DUAL
CB-1	CB-1	BC
DOE-2	DOE-2	BC
ERDA-9	ERDA-9	CUL
H-2b1	H-2b	MAG
H-2b2		CUL
H-3b1	H-3	MAG
H-3b2		CUL
H-4b	H-4	CUL
H-4c		MAG
H-5b	H-5b	CUL
H-6bR	H-6	CUL
H-6c		MAG
H-7b1	H-7b1	CUL
H-8a	H-8a	MAG
H-9bR	H-9	CUL
H-9c		MAG
H-10a	H-10	MAG
H-10c		CUL
H-11b2	H-11b	MAG
H-11b4		CUL
H-12	H-12	CUL
H-14	H-14	MAG
H-15R	H-15	CUL
H-15		MAG
H-16	H-16	CUL
H-17	H-17	CUL
H-18	H-18	MAG

Well	Pad[2]	Completion[3]
H-19b0	H-19b	CUL
H-19b2		CUL REDUN
H-19b3		CUL REDUN
H-19b4		CUL REDUN
H-19b5		CUL REDUN
H-19b6		CUL REDUN
H-19b7		CUL REDUN
IMC-461	IMC-461	CUL
SNL-1	SNL-1	CUL
SNL-2	SNL-2	CUL
SNL-3	SNL-3	CUL
SNL-5	SNL-5	CUL
SNL-6	SNL-6	CUL
SNL-8	SNL-8	CUL
SNL-9	SNL-9	CUL
SNL-10	SNL-10	CUL
SNL-12	SNL-12	CUL
SNL-13	SNL-13	CUL
SNL-14	SNL-14	CUL
SNL-15	SNL-15	CUL
SNL-16	SNL-16	CUL
SNL-17	SNL-17	CUL
SNL-18	SNL-18	CUL
SNL-19	SNL-19	CUL
WIPP-11	WIPP-11	CUL
WIPP-13	WIPP-13	CUL
WIPP-18	WIPP-18	MAG
WIPP-19	WIPP-19	CUL
WQSP-1	WQSP-1	CUL
WQSP-2	WQSP-2	CUL
WQSP-3	WQSP-3	CUL
WQSP-4	WQSP-4	CUL
WQSP-5	WQSP-5	CUL
WQSP-6	WQSP-6	CUL
WQSP-6a		DL

[1] SSW wells and piezometers monitor the Santa Rosa / Dewey Lake Formation contact at the WIPP facilities
[2] Pad names used in Figure 2.14
[3] Well completions codes are as follows:
CUL: Culebra Member of the Rustler Formation
MAG: Magenta Member of the Rustler Formation
BC: Bell Canyon Formation
DL: Dewey Lake Formation
DUAL: dual-completion well
REDUN: redundant well (quarterly water levels)

2.3.2.2 Culebra Groundwater Flow Results and Assessment

Assessment of Culebra data involves the interpretation of freshwater head data in the context of the hydrogeologic knowledge about the WIPP area. If heads change significantly in wells, this may be due to an underlying change in flow Culebra flow patterns. At the request of the New Mexico Environment Department (NMED), the Scientific Advisor uses the ensemble-average of the 100 calibrated Culebra groundwater flow model runs developed for PA to create the baseline transmissivity (T) field. This ensemble-average T field is used to produce the freshwater head potentiometric surface map each year for the ASER. Each year the boundary conditions of the ensemble-averaged model are adjusted to best fit the observed freshwater head values from that year. The ensemble-averaged T field and the adjusted boundary conditions are used as inputs to the MODFLOW model (Harbaugh et al. 2000) that computes the heads which are then contoured and presented in the ASER.

The Culebra PA model is a single-layer groundwater flow model that incorporates information about aquifer parameters (e.g., T, storativity, and anisotropy) and is based upon a peer-reviewed conceptual model of Culebra geology (Section 8.2 of EPA 2010b). The model is calibrated to both steady-state freshwater head and transient pumping test drawdown data. The contour map shown in Figure 2.17 shows the area immediately around the WIPP land withdrawal boundary, and indicates that flow is generally from north to south, which is consistent with previous results, and that the gradient is steepest across the area including the WIPP surface facilities, caused by a region of low Culebra T.

The contour map is created according to SNL specific procedure SP 9-9, and the results of following the procedure along with detailed narrative descriptions are given in the analysis report *Analysis Report for Preparation of 2011 Culebra Potentiometric Surface Contour Map, Revision 2* (Kuhlman 2012). This material is summarized in the 2012 ASER, Section 6.2.5 (DOE 2012d).

2.3.2.3 Culebra Freshwater-Head Results and Assessment

Table 2.15 shows the August 2011 freshwater heads reported in the 2012 ASER and used in the development of the Culebra contour map given in the 2012 ASER (DOE 2012d). The particle shown as a blue arrow in Figure 2.16 begins where the Culebra intersects the WIPP waste-handling shaft and continues to the WIPP LWB, as required by NMED. The travel time for this particle in the boundary-calibrated ensemble-average flow field (5,826 years) is compared to the distribution of 100 travel times computed for the CRA-2009 PABC. The fastest travel time from the ensemble of 100 fields is less than 3,000 years (see red dots in Figure 2.15), therefore the ensemble-average travel time falls inside the predicted CRA-2009 PABC range. The particles illustrated in Figures 2.16 and 2.17 are released from the point in the Culebra corresponding to the center of the WIPP waste panels underground (the same location as well C-2737).

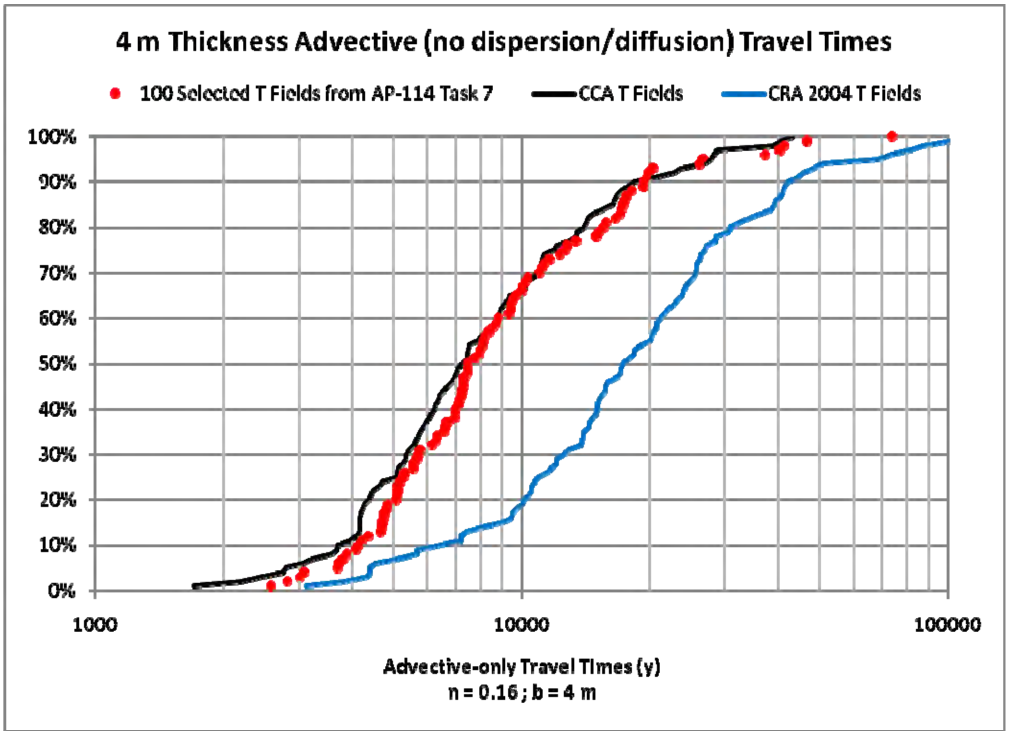


Figure 2.15. Distribution of Particle Travel Times from C-2737 (Center of Waste Panels) to WIPP LWB for CCA (black line), CRA-2004 (blue line), and CRA-2009 PABC (red dots). Figure from Hart et al. (2009).

In UTM NAD27 Zone 13 coordinates (meters), the waste-handling shaft is located at the (X, Y) location (613579, 3582079), while the center of the waste panels is (613597, 3581401). The distance between these two points is 678 meters, mostly in the north-south direction; the difference can be seen by comparing the location of the tail of the blue arrow and the location of C-2737 in Figure 2.17. The particle trace in the ensemble-average flow field has a length of 4,092 meters.

The ensemble average transmissivity (T) field used to compute the contour map for the ASER is by construction much smoother than any of the 100 stochastically generated fields it is averaged from. This smoothness of the input T field results in a smoother and relatively faster particle trace; compare the particle traces in Figure 2.17 (smoothed average field) and Figure 2.18 (original T fields from PA).

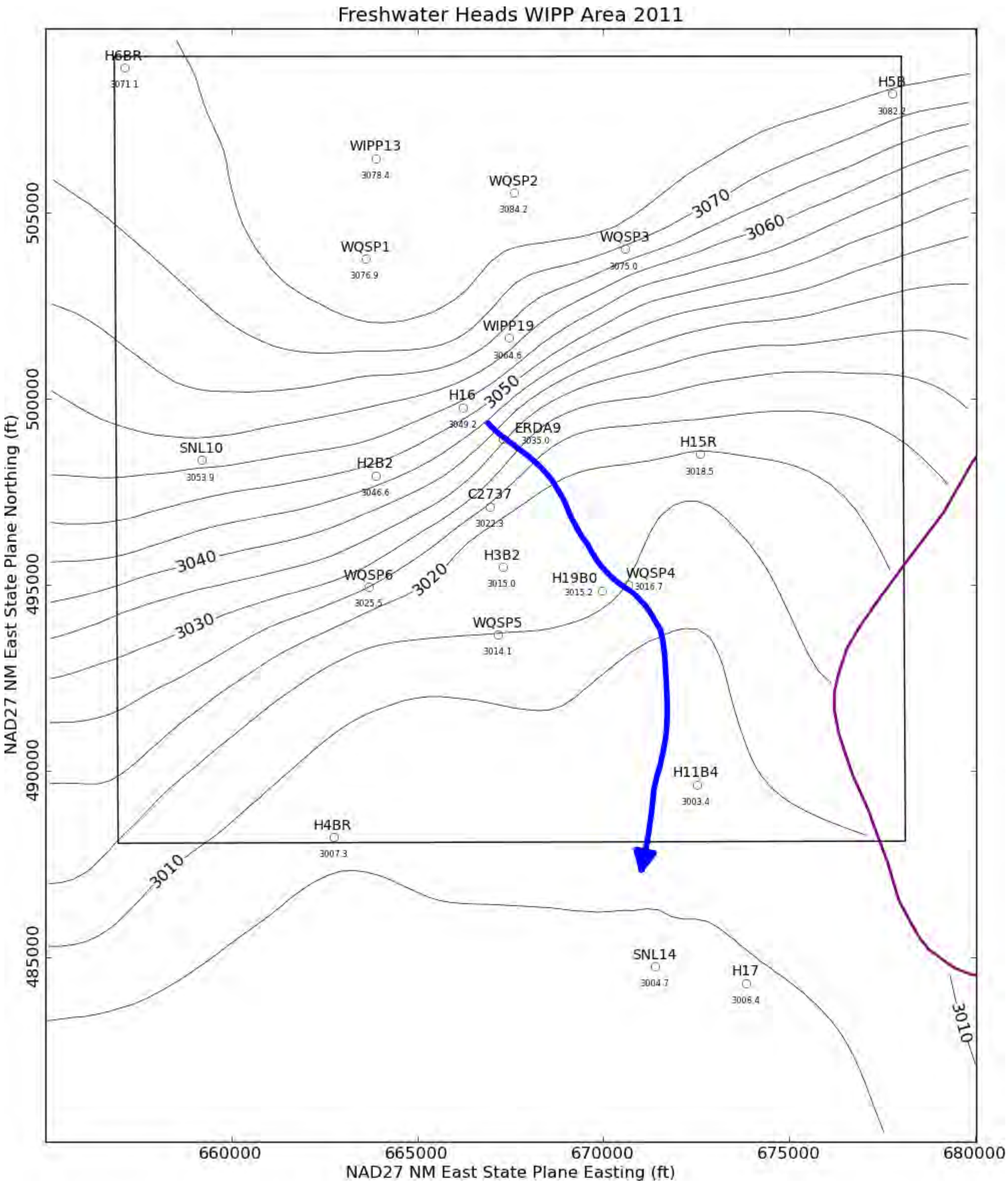


Figure 2.16. August 2011 modeled Culebra potentiometric surface of the immediate WIPP vicinity (DOE 2012d) generated using ensemble average distributed aquifer parameters from the SNL Culebra flow model used in performance assessment baseline calculation for CRA-2009; see Kuhlman (2010b).

Table 2.16. Summary of August 2011 Culebra freshwater heads.

Culebra Well	Measurement Date	Adjusted Freshwater Head [m AMSL]	Specific Gravity
AEC-7	8/9/11	934.14	1.078
C-2737 (PIP)	8/10/11	921.20	1.027
ERDA-9	8/10/11	925.08	1.072
H-02b2	8/10/11	928.60	1.013
H-03b2	8/10/11	918.98	1.043
H-04bR	8/9/11	916.62	1.018
H-05b	8/9/11	939.44	1.093
H-06bR	8/9/11	936.07	1.037
H-07b1	8/8/11	913.91	1.006
H-09bR	8/8/11	912.93	1.000
H-10c	8/9/11	922.94	1.091
H-11b4	8/9/11	915.45	1.051
H-12	8/9/11	917.92	1.107
H-15R	8/10/11	920.02	1.119
H-16	8/10/11	929.41	1.037
H-17	8/9/11	916.96	1.136
H-19b0	8/10/11	919.03	1.068
I-461	8/8/11	927.64	1.005
SNL-01	8/8/11	939.96	1.028
SNL-02	8/8/11	936.19	1.009
SNL-03	8/9/11	939.23	1.028
SNL-05	8/8/11	937.09	1.008
SNL-06	8/9/11	953.83	1.233
SNL-08	8/9/11	930.44	1.094
SNL-09	8/9/11	930.85	1.018
SNL-10	8/8/11	930.83	1.009
SNL-12	8/8/11	915.18	1.005
SNL-13	8/8/11	920.09	1.023
SNL-14	8/9/11	915.82	1.046
SNL-15	8/9/11	912.27	1.228
SNL-16	8/8/11	916.97	1.009
SNL-17	8/8/11	916.13	1.004
SNL-18	8/8/11	937.18	1.006
SNL-19	8/8/11	936.21	1.006
WIPP-11	8/9/11	939.53	1.037
WIPP-13	8/10/11	938.28	1.044
WIPP-19	8/10/11	934.08	1.051
WQSP-1	8/10/11	937.82	1.049
WQSP-2	8/10/11	940.06	1.047
WQSP-3	8/10/11	937.27	1.147
WQSP-4	8/10/11	919.49	1.078
WQSP-5	8/10/11	918.69	1.028
WQSP-6	8/10/11	922.17	1.016

[1] PIP (production injection packer) indicates water levels measured in C-2737, a dual-completed well.
[2] SNL-06, SNL-13, and SNL-15 are currently not representative of undisturbed conditions in the Culebra; water levels in these well are predicted to continue to rise for the foreseeable future.

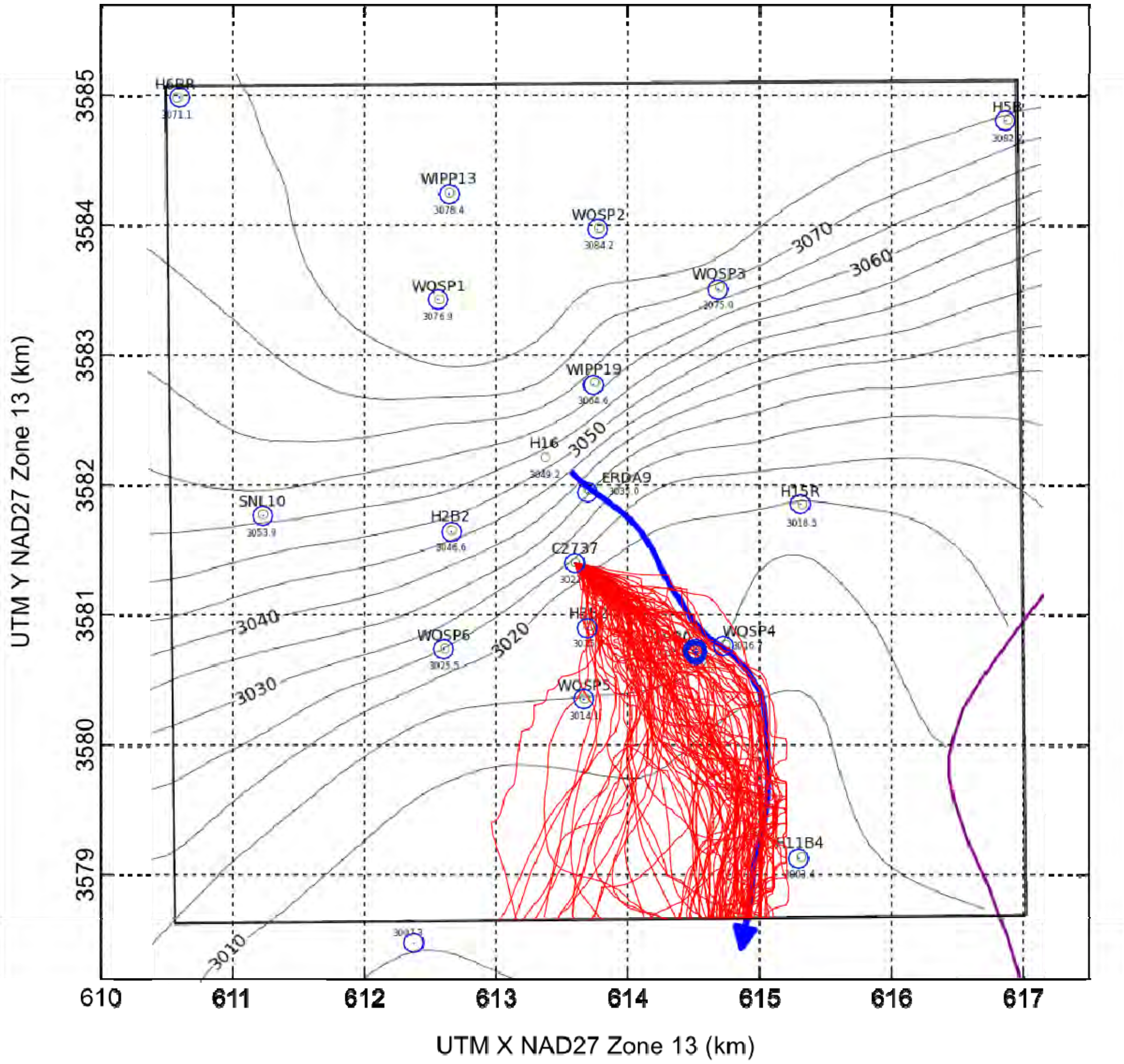


Figure 2.17. Distribution of 100 particle traces (red lines) from C-2737 (center of waste panels) to WIPP LWB (heavy black line) for CRA-2009 PABC. Figure is combination of contours and blue contour from 2012 ASER (DOE 2012d), and individual realization particle traces from CRA-2009 PABC (Kuhlman, 2010a). Culebra monitoring wells are indicated with blue or green circles.

2.3.2.4 Interpretation/Summary of the 2010 Culebra Data

As mentioned previously, change in Culebra groundwater flow would be manifested as a change in gradient and/or flow velocity, which would be observed through changes in freshwater head measured in observation wells. In general, the freshwater potentiometric gradient of the Culebra is and has been from north to south and flow velocities are low across the WIPP modeling domain (Hart et al., 2009). The basis of this year's assessment of the groundwater flow COMP is the computed travel time and potentiometric surface map of the Culebra (Figure 6.11; DOE 2012d). The map was generated using the Culebra flow model developed by the Scientific Advisor for performance baseline calculations associated with CRA-2009 PABC and Culebra heads from August 2011.

The ensemble-model predicted travel time for a particle currently falls within the range modeled for PA, although it is near the faster end of the distribution because of the smoothness of the averaged field, compared to the stochastically generated individual fields used in PA. The travel time indicates that the current observed freshwater heads are consistent with the model used in PA, and therefore they do not violate the TV defined last year.

2.3.2.5 Results and Assessment of Data from Other Units

Assessment of water-level changes from other hydrologic units present in the WIPP vicinity (Table 2.17) is important for confirming the conceptual model of overall site hydrology. Water-level measurements for the Magenta Member of the Rustler Formation provide information about confinement of and connectivity to the underlying Culebra Member.

For consistency with the time period chosen for reporting previous water levels, August 2011 was chosen as the time period for reporting water level data from other (non-Culebra) units. Water-level changes in the Magenta ranged from -8.56 to 2.22 m, with five wells experiencing water-level changes $\geq$ 0.61 m (2.0 ft). Aside from recovery due to Scientific Advisor pumping and sampling activities, water levels in wells are largely stable. The water levels in H-02b1 and H-04c are 8.56 and 0.71 meters lower than 2010 because the wells are recovering from water quality testing activities in early 2011. The water level in H-08c is 1.73 m higher than 2010 because the well is slowly recovering from pumping in 2010, approaching the pre-pumping water levels seen in 2008 and 2009. The water level in H-14 is 1.11 m higher than 2010 because the well is slowly recovering from pumping in 2009. The water level in H-15 rose 2.22 m since 2010, and has been rising steadily since the well was re-completed in 2008.

The water level was stable in WQSP-6A. This well is completed to the middle of the Dewey Lake Formation (Table 2.17). Water levels in DOE-2 are stable, while water levels in CB-1 have continued to slowly rise (0.98 m in the last year). This rise has continued since 2008 swabbing activities cleaned out foreign water and subsequently changed wellbore water densities significantly (Table 2.17).

Table 2.17. Summary of 2008-2011 water-level changes in units other than the Culebra.

Well Name	Dec 2008 Water Level Elevation (m AMSL)	Dec 2009 Water Level Elevation (m AMSL)	Dec 2010 Water Level Elevation (m AMSL)	Aug 2011 Water Level Elevation (m AMSL)	2011-2010 Water Level Change (m)
Magenta Wells					
C-2737	958.33	958.06	958.22	958.35	0.13
H-02b1	958.10	958.24	958.25[a]	**949.69**	**-8.56**
H-03b1	959.10	958.59	958.95	959.12	0.17
H-04c	959.34	959.49	959.49[a]	**958.78**	**-0.71**
H-06c	935.62	935.80	935.91	936.07	0.16
H-08a	922.71	922.78	920.37	**922.10**	**1.73**
H-09c	956.44	956.68	956.7[b]	956.39	-0.31
H-10a	982.17	981.95	948.6	948.71	0.11
H-11b2	956.45	956.69	956.78	956.97	0.19
H-14	953.65	946.77	955.05	**956.16**	**1.11**
H-15	952.75	954.55	955.78	**958.00**	**2.22**
H-18	960.18	960.08	961.03	961.46	0.43
WIPP-18	960.05	960.10	959.89	960.11	0.22
Dewey Lake Well					
WQSP-6A	974.45	974.44	974.36	974.29	-0.07
Bell Canyon Wells					
CB-1	915.65	917.35	918.41	**919.39**	**0.98**
DOE-2	934.41	934.71	934.73	934.88	0.15

[a] March 2010 water level; no December water level due to Scientific Advisor sampling activities
[b] September 2010 water level; no December water level due to drilling and plugging activities
Bold = absolute changes in water level ≥ 0.61 m (2.0 ft)

2.4 Waste Activity

Table 2.18 summarizes data and TV information relating to the COMP parameter Waste Activity, and its implementation in PA. The reporting period for the waste activity COMP started at first waste receipt and ended on June 30, 2012. A comparison of the tracked actinides and the total repository inventory used in the PABC-2009 is detailed in Table 2.19. No other activity-related assessment has been made at this time.

There are no TVs for CH activity, only RH. The TV for RH is the regulatory limit of 5.1 million Curies. The total curies of RH waste for the period ending June 30, 2012 is 7.19×10^3 Curies, well below the TV. There are no recognized reportable issues associated with this COMP. No changes to the monitoring program are recommended at this time. A detailed waste inventory assessment has been provided in the CRA-2009 (DOE 2009).

Table 2.18 Waste Activity - 2012:

COMP Title:	**Waste Activity**		
COMP Units:	Curies		
Related Monitoring Data			
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Waste Data System (WDS; formerly the WWIS), BIR	Radionuclide activity per container and volume	Curies , volume	TRU Waste Inventory for the 2009 Compliance Recertification Application Performance Assessment Baseline Calculation (Crawford et al. 2008)
COMP Assessment Process - Reporting Period July 1, 2011 to June 30, 2012			
Total curie content of emplaced CH-TRU and RH-TRU waste. *[Total radionuclide inventories reported by the WDS]*			
Year 2012 COMP Assessment Value			
A comparison of emplaced and PA waste parameters is found in Table 2.19.			

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 Land Withdrawal Act limits. (U.S. Congress 1992)	Table 5-6 of Crawford et al. 2008	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	Crawford et al. 2008; see also Figure 6-30 of the CRA-2004 (DOE 2004)	Cuttings are a significant contributor to releases. 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.	Crawford et al. 2008	Spallings are a significant contributor to releases. An increase in average activity of intersected waste is potentially significant.

Monitoring Data Trigger Values		
Monitoring Parameter ID	Trigger Value	Basis
Waste emplacement records	None	Administrative controls address waste limits. TV Derivation Report, Revision 2 (Wagner and Kuhlman 2010)
Total emplaced RH-TRU waste activity	5.1 million curies	LWA emplacement limit reached. Administrative controls address these limits.

Table 2.19. Comparison of tracked radionuclide inventory to the PABC Inventory (from WRES 2012 and Crawford et al. 2008).

Radionuclide (CCA Table 4-10)	Non-Decayed Total Activity as of June 30, 2011	Non-Decayed CH Inventory as of June 30, 2012	Non-Decayed RH Inventory as of June 30, 2012	Non-Decayed Total Activity as of June 30, 2012	PABC Total Inventory at Closure (2033)
^{241}Am	2.190E+05	2.296E+05	4.794E+02	2.301E+05	4.72E+05
^{137}Cs	3.659E+03	7.886E+00	8.106E+03	8.114E+03	8.95E+04
^{238}Pu	3.470E+05	4.417E+05	5.575E+02	4.423E+05	1.47E+06
^{239}Pu	3.039E+05	3.159E+05	2.199E+02	3.161E+05	5.13E+05
^{240}Pu	7.465E+04	7.780E+04	1.964E+02	7.800E+04	1.45E+05
^{242}Pu	1.900E+01	2.389E+01	3.079E-01	2.420E+01	7.59E+01
^{90}Sr	2.645E+03	1.520E+01	5.335E+03	5.350E+03	8.04E+04
^{233}U	6.033E+00	6.161E+00	3.032E-01	6.464E+00	2.07E+02
^{234}U	6.386E+01	8.036E+01	5.563E-01	8.092E+01	3.09E+02
^{238}U	1.415E+01	1.687E+01	3.021E-02	1.690E+01	2.73E+01
Total	**9.510E+05**	**1.065E+06**	**1.490E+04**	**1.080E+06**	**2.77E+06**

3 COMPs Assessment Conclusion

The operational period monitoring program designed to meet the Assurance Requirements of 40 CFR § 191.14 and the terms of WIPP certification was initiated in 1999. This monitoring program is useful to further validate the assumptions and conceptual models that are used to predict WIPP performance and identify conditions that could potentially cause radioactive release above the limits established in 40 CFR § 191.13. Since releases above these limits cannot occur during the operational period of WIPP, the monitoring program looks at other potential performance indicators of the disposal system and compares these data to PA performance expectations. Specifically, 10 monitoring parameters are assessed and compared to PA expectations and assumptions. The CRA-2009 (DOE 2009) contains the results of the most recent PA submitted to the EPA for compliance purposes. The PABC-2009 was used in EPA's 2010 certification decision and became the new compliance baseline PA (EPA 2010a). The results of this year's COMP assessment conclude that there are no COMPs data or results that indicate a reportable event or condition adverse to predicted performance. In instances where TVs have been exceeded, further investigations or activities will be pursued and if necessary, the results will be captured in the next revision to the TV report.

4 References

Crawford, M.E., D. Guerin, S. Lott, B. McInroy, J. McTaggart and G. Van Soes. 2008. Persormance Assessment Inventory Report – 2008. LA-UR-09-02260, INV-PA-08 Revision 0, Los Alamos National Laboratory, Carlsbad Operations, April 2008.

Crawley, M.E., and M. Nagy. 1998. *Waste Isolation Pilot Plant RCRA Background Groundwater Quality Baseline Report*. DOE/WIPP 98-2285. Albuquerque, NM: IT Corporation for Westinghouse Electric Corporation.

DOE (U. S. Department of Energy). 2012a. *Delaware Basin Monitoring Annual Report*, DOE/WIPP-12-2308, September 2012.

DOE (U. S. Department of Energy). 2012b. *Geotechnical Analysis Report for July 2010 – June 2011*, DOE/WIPP-12-3484, Volume 1 & 2, May 2012.

DOE (U.S. Department of Energy). 2012c. *Ground Control Annual Plan for the Waste Isolation Pilot Plant*, Revision 10, DOE/WIPP-023212, April 2012.

DOE (U.S. Department of Energy). 2012d. *Waste Isolation Pilot Plant Annual Site Environmental Report for 2011*. DOE/WIPP 12-3489, September 2012.

DOE (U. S. Department of Energy). 2011. *WIPP Subsidence Monument Leveling Survey 2011*, DOE/WIPP-12-2293, December 2011.

DOE (U. S. Department of Energy). 2009. *Title 40 CFR Part191 Compliance Recertification Application for the Waste Isolation Pilot Plant*, DOE/WIPP-09-3424, March 2009.

DOE (U.S. Department of Energy). 2007. *Compliance Monitoring Implementation Plan for 40 CFR §191.14(b), Assurance Requirements*, DOE/WIPP-99-3119, Revision 5, December 2007.

DOE (U. S. Department of Energy). 2004. *Title 40 CFR Part191 Compliance Recertification Application for the Waste Isolation Pilot Plant*, DOE/WIPP 2004-3231, March 2004.

DOE (U.S. Department of Energy). 2003. *Strategic Plan for Groundwater Monitoring at the Waste Isolation Pilot Plant*, DOE/WIPP-03-3230, February 2003.

DOE (U.S. Department of Energy). 1996. *Title 40 CFR Part191 Compliance Certification Application for the Waste Isolation Pilot Plant*, DOE/CAO 1996-2184, October 1996.

EPA (U.S. Environmental Protection Agency). 2010a. 40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance With the Disposal Regulations: Recertification Decision; Final Rule." Federal Register, Vol. 75, No. 222, p. 70684, November, 18 2010, Office of Radiation and Indoor Air, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 2010b. Technical Support Document for Section 194.23, Review of the 2009 Compliance Recertification Performance Assessment Baseline Calculations, EPA-HQ-OAR-2009-0330. Office of Radiation and Indoor Air, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 2003. Letter from Frank Marcinowski, Director of Radiation Protection Division to Ines Triay, Manager of Carlsbad Field Office, August 8, 2003.

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

EPA (U.S. Environmental Protection Agency). 1998b. Technical Support Document for Section 194.23: Sensitivity Analysis Report, May 1998. Office of Radiation and Indoor Air, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1996. 40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR part 191 Disposal Regulations; Final Rule. *Federal Register*, Vol. 61, No. 28 pp. 5224-5245, February 9, 1996. Office of Radiation and Indoor Air, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1993. 40 CFR Part 191: Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuels, High Level and Transuranic Radioactive Wastes: Final Rule. *Federal Register*, Vol. 58, No.242, pp. 66398-66416, December 20, 1993. Office of Radiation and Indoor Air, Washington, D.C.

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc. 604 p.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald. 2000. MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model -- User Guide to Modularization Concepts and the Ground-Water Flow Process. Open-File Report 00-92. Reston, VA: U.S. Geological Survey.

Hart, D.B., R.L. Beauheim, and S.A. McKenna. 2009. Analysis Report for Task 7 of AP-114: Calibration of Culebra Transmissivity Fields. October 30, 2009. ERMS 552391. Sandia National Laboratories WIPP Records Center, Carlsbad, NM.

IT Corporation. 2000. *Addendum 1, Waste Isolation Pilot Plant RCRA Background Groundwater Quality Baseline Update Report*. Prepared for Westinghouse Electric Corporation, Carlsbad, NM.

Kuhlman, K.L. 2012. Analysis Report for Preparation of 2011 Culebra Potentiometric Surface Contour Map, Revision 2, ERMS 557633, Sandia National Laboratories, Carlsbad, NM.

Kuhlman, K.L. 2010a. Analysis Report for the CRA-2009 PABC Culebra Flow and Transport Calculations, ERMS 552951,Sandia National Laboratories, Carlsbad, NM.

Kuhlman, K.L. 2010b. Development of Culelbra T Fields for CRA-2009 PABC, ERMS 553276, Sandia National Laboratories, Carlsbad, NM.

Park, B-Y and J. F. Holland. 2003. *Structural Evaluation of WIPP Disposal Room Raised to Clay Seam G*. SAND2003-3409. Sandia National Laboratories, Albuquerque NM.

SNL (Sandia National Laboratories). 2011. *Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment (for Year 2011)*. ERMS 556779. Carlsbad, NM: Sandia National Laboratories.

SNL (Sandia National Laboratories). 2002. *Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment Report for 2002*, ERMS 524449. Sandia National Laboratories, Carlsbad, NM, November 2002.

SNL (Sandia National Laboratories). 2001. *Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment* [for Year 2000], Sandia National Laboratories, Carlsbad, NM, October 2001, ERMS 519620.

U.S. Congress. 1992. Waste Isolation Pilot Plant Land Withdrawal Act. Public Law 102-579, October 1992. 102nd Congress, Washington, D.C.

Wagner S.W. and K.L. Kuhlman. 2010. Trigger Value Derivation Report, ERMS 554605. Carlsbad, NM: Sandia National Laboratories.

WID (Waste Isolation Division), Westinghouse. 1994. Backfill Engineering Analysis Report, IT Corporation for WID.

WRES (Washington Regulatory and Environmental Services) 2012. Annual Change Report 2011/2012, WP 12-0335, October 2012.

WTS (Westinghouse TRU Solutions). 2002. Subsidence Survey Data Acquisition Report, WP 09-ES4001, June 2002.