Sandia National Laboratories
Waste Isolation Pilot Plant

Compliance Monitoring Parameter Assessment for 2024

Revision 0

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Information Only

Table of Contents

Executive Summary **4**

1 Introduction **5**

1.1 Monitoring and Evaluation Strategy 5
1.2 Reporting Cycle 6

2 Assessment of COMPs **6**

2.1 Human Activities COMPs 7
2.1.1 Probability of Encountering a Castile Brine Reservoir 7
2.1.2 Drilling Rate 10
2.2 Geotechnical COMPs 12
2.2.1 Creep Closure 15
2.2.2 Extent of Deformation 23
2.2.3 Initiation of Brittle Deformation 25
2.2.4 Displacement of Deformation Features 26
2.2.5 Subsidence 28
2.3 Hydrological COMPs 38
2.3.1 Changes in Culebra Water Composition 38
2.3.2 Changes in Groundwater Flow (Water Level) 47
2.4 Waste Activity COMP 55

3 COMPs Assessment Conclusion **55**

4 References **57**

Information Only

Executive Summary

This document reports the twenty-third annual derivation and assessment of the Waste Isolation Pilot Plant (WIPP) compliance monitoring parameters (COMPs). COMPs were developed as part of a Compliance Monitoring Program, which is designed to meet certain requirements of the U.S. Environmental Protection Agency's (EPA) long-term disposal regulations (U.S. 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 2020).

In the WIPP Compliance Certification Application (CCA; U.S. DOE 1996), the U.S. Department of Energy (DOE) made commitments to conduct several monitoring activities as part of a Compliance Monitoring Program. Monitoring parameters that are related to the long-term performance of the repository were identified in a monitoring analysis (U.S. DOE 1996, Appendix MON, Attachment MONPAR) that was performed to fulfill 40 CFR §194.42 requirements. The results of the analysis were used in the CCA to propose 10 parameters (U.S. DOE 1996, Chapter 7, Table 7-7). Since these parameters fulfill a regulatory function, they were termed COMPs so that they would not be confused with similar performance assessment (PA) input parameters. The DOE uses PA to predict the radioactive waste containment performance of the WIPP. COMPs are used to identify 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 was the first step in assessing the monitoring data. Trigger values were first derived in 1999 and some have since been revised. The derivations and revisions are documented in the *Trigger Value Derivation Report* (Wagner and Thomas 2016).

In the initial Certification Ruling (U.S. 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, in part, by conducting annual assessments of COMPs that monitor the predicted behavior of the repository and reporting any condition adverse to the long-term containment behavior. This compliance monitoring program is described in greater detail in DOE's *Compliance Monitoring Implementation Plan for 40 CFR §191.14(b), Assurance Requirements* (U.S. DOE 2014a).

This 2024 COMPs assessment presents the results and recommendations based on the COMP monitoring data gathered during the most recent annual reporting cycle. This assessment concludes that monitoring results are within expectations and no additional activities are currently warranted.

Information Only

1 Introduction

The Waste Isolation Pilot Plant (WIPP) is subject to the U.S. Environmental Protection Agency's (EPA) long-term radioactive waste disposal regulations at 40 CFR Part 191 Subparts B and C (U.S. EPA 1993) and the WIPP-specific certification criteria at 40 CFR Part 194 (U.S. 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; U.S. DOE 1996), the U.S. Department of Energy (DOE) made commitments to conduct several monitoring activities as part of a Compliance Monitoring Program 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 compliance monitoring parameters (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* (U.S. DOE 2014a) describes the overall monitoring program and responsibilities for COMPs derivation and assessment. This report documents the results of the reporting year 2024 COMPs assessment (for most COMPs data, between July 1, 2023, to June 30, 2024). This period matches the reporting period of the annual report that addresses 40 CFR §194.4(b)(4) requirements (U.S. EPA 1996). This COMPs assessment follows the program developed under the original certification baseline using data and PA results from the current certified baseline, the 2019 Compliance Recertification Application Performance Assessment (CRA-2019 PA).

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 (SNL)) is responsible for annually assessing COMPs and the development and maintenance of the trigger values (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 behavior are recognized as early as possible. These conditions may include data inconsistent with parameters, modeling assumptions or conceptual models implemented within PA, or conditions inconsistent with assumptions and arguments used in the screening of Features, Events and Processes (FEPs) for PA. TVs were first derived in 1999 and some have since been revised. The derivations and revisions are documented in the *Trigger Value Derivation Report* (Wagner and Thomas 2016).

Information Only

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 repository 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 7.2.4) and subsequent recertification applications state that the results of the monitoring program will be submitted annually (U.S. DOE 2019). 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 COMP values, and monitoring information must be reported even if the assessment concludes there is no anticipated impact on repository performance. 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. This document reports the twenty-third annual derivation and assessment of WIPP COMPs.

2 Assessment of COMPs

Monitoring parameters that are related to the long-term performance of the repository were identified in a monitoring analysis (U.S. DOE 1996, Appendix MON, Attachment MONPAR) that was performed to fulfill 40 CFR §194.42 requirements. The results of the analysis were used in the CCA to propose an operational Compliance Monitoring Program using 10 parameters (U.S. DOE 1996, Table 7-7). Since these parameters fulfill a regulatory function, they were termed COMPs so that they would not be confused with similar PA input parameters. The Compliance Monitoring Program tracks the following 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

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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."

In the following sections, each COMP is evaluated and compared to the applicable TV. This assessment is performed under Activity/Project Specific Procedure SP 9-8 (SNL 2020). 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 and 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 and 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 10. 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 up to 1995. The results of this initial search recorded 40 drilling encounters with pressurized brine (water) in the Castile Formation. Of these encounters, 38 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 Table 7 in U.S. DOE 2025a for a complete listing of brine encounters). The Delaware Basin Drilling Surveillance Program (DBDSP) 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 2024. During this reporting period (between September 1, 2023, and August 31, 2024), 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 (U.S. DOE 2025a, Section 2.6).

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Table 2.1. Probability of Encountering a Brine Reservoir – 2024.

COMP Title:	Probability of Encountering a Castile Brine Reservoir
COMP Units:	Unitless
COMP Assessment Process:	Analysis of encounters of pressurized brine recorded and reported by industry in the 9-township area centered on WIPP.
2024 COMP Assessment Value: (Reporting Period September 2023 to August 2024)	No new data reported in the State record during the reporting period. No new report from Field Observations. There have been 40 brine encounters: 30 CCA total occurrences before 1996 0 State Record occurrences since 1996 10 Site Personnel/Drillers Survey occurrences since 1996

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Previous Compliance Baseline Value
DBDSP	NA	Driller's survey – Field observations	0.06 to 0.19 (normal distribution) (U.S. DOE 2014b)

Related Performance and Compliance Elements

Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Current Compliance Baseline	Impact of Change
Probability of Encountering Brine	Parameter PBRINE FEP N2 "Brine Reservoirs"	EPA/DOE Defined Parameters outlined by Zeitler 2019.	4.00E-02 to 5.70E-01 Mean 2.63E-01 (U.S. DOE 2019; Zeitler 2019)	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.

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Table 2.2. Well locations encountering brine since the CCA[(a)].

Number	Location	Well Name and Location	Spud Date	Well Information
1	23S-30E-01	James Ranch Unit #63	12/23/1999	Oil Well: Sulfur water encountered at 2,900 feet H_2S of 35 ppm was reported in the sulfur water but quickly dissipated to 3 ppm in a matter of minutes. Continued drilling.
2	21S-31E-35	Lost Tank 35 State #4	09/11/2000	Oil Well: Estimated several hundred barrels per hour. Continued drilling.
3	21S-31E-35	Lost Tank 35 State #16	02/06/2002	Oil Well: At 2,705 feet, 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 and full returns.
4	22S-31E-02	Graham AKB State #8	04/12/2002	Oil Well: Estimated 105 barrels per hour. Continued drilling.
5	23S-30E-01	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	22S-30E-13	Apache 13 Federal #3	11/26/2003	Oil Well: Encountered strong water flow with blowing air at 2,850-3,315 feet. No impact on the drilling process.
7	21S-31E-34	Jacque AQJ State #7	03/01/2005	Plugged Oil Well: Encountered water flow of 104 barrels per hour at 2,900 feet. No impact on the drilling process.
8	22S-30E-13	Apache 13 Fed #8	08/19/2005	Oil Well: Encountered a severe H_2S water flow.
9	23S-30E-1	James Ranch Unit #108H	12/06/2009	Oil Well: Encountered salt water flow occurred at 2,894 feet.
10	21S-31E-35	Lost Tank 35 State SWD #1	06/28/2013	Salt Water Disposal Well: Encountered H_2S influx from 2,678-3,004 feet then shut in on well.

(a) From Table 7 of U.S. DOE 2025a

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Of the 10 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. All the new encounters are 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 mean of this parameter is approximately 0.30. This value is significantly more than the 0.08 originally used in the CCA which was based on a geostatistical analysis of actual brine 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 (U.S. EPA 1998b).

In the CRA-2014, the DOE included a revision to the PBRINE PA parameter based on new drilling data and a statistical analysis. EPA questioned the justification for this parameter distribution during their review of the CRA-2014 and developed their own parameter distribution (U.S. EPA 2017a). In the Federal Register Notice outlining their recertification decision (U.S. EPA 2017b), the EPA stated that they expect their cumulative distribution function (CDF) for PBRINE to be used as the baseline in future PAs. The EPA CDF equivalent mean, which is 0.26 or approximately the same as the PAVT parameter, is used in the CRA-2019 PA (U.S. DOE 2019; Zeitler 2019). WIPP was initially certified as a 10-panel repository for long-term waste disposal, which served as the design layout and basis for the CRA-2019 PA. Due to operational constraints, not all this volume is available for waste disposal. In March 2024 the DOE submitted the Replacement Panels Planned Change Request (RPPCR) seeking EPA approval of two replacement waste disposal panels. The RPPCR also considered the excavation of up to seven panels beyond the two replacement panels, defined as additional panels, to provide the additional disposal capacity needed to reach the legislated WIPP waste volume limit. After the CRA-2019 PA, a compliance-level calculation known as the RPPCR PA was executed to quantify the long-term performance of the repository with the replacement and additional panels. The EPA's CDF for PBRINE was used for both replacement and additional panels in the RPPCR PA.

2.1.2 Drilling Rate

Table 2.3 summarizes data and TV information related to the COMP Drilling Rate and its implementation in PA. The drilling rate COMP tracks deep drilling (≥ 2,104 feet 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 guidance provided in 40 CFR § 194.33. The drilling rate formula is as follows:

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Table 2.3. Drilling Rate – 2024.

COMP Title:	Drilling Rate
COMP Units:	Deep boreholes (i.e., ≥ 2,104 feet deep) per km^2 per 10,000 years
COMP Assessment Process:	(Total number of deep boreholes drilled/number of years of observations (100)) × (10,000/23,102) [i.e., over 10,000 years divided by the area of the Delaware Basin in km^2]
2024 COMP Assessment Value: (Reporting Period September 1, 2023, to August 31, 2024)	35,661 boreholes on record for the Delaware Basin. Drilling Rate = 153.4 boreholes per km^2 per 10,000 years.

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)
DBDSP	Deep hydrocarbon boreholes drilled	Integer per year

Related Performance and Compliance Elements

Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Drilling rate	Parameter LAMBDAD FEP H1 "Oil and Gas Exploration" FEP H4 "Oil and Gas Exploitation"	COMP per 10,000 years	9.90E-03 per km^2 per year (CRA-2019 value; U.S. DOE 2019)	Cuttings/cavings releases increase proportionally with the drilling rate. Doubling CRA drilling rate does not exceed compliance limit.

Monitoring Data Trigger Values

Monitoring Parameter ID	Trigger Value	Basis
Deep boreholes	None	Revision 2 of the TV Derivation Report (Wagner and Thomas 2016).

$$D_r = \frac{D_{100} \times 10{,}000 \text{ years}}{A_{DB} \times 100 \text{ years}} \quad (1)$$

where

D_r = Deep Drilling Rate (boreholes per km^2 per 10,000 years)
D_{100} = Number of deep boreholes drilled over the last 100 years
A_{DB} = Area of the Delaware Basin (23,102.1 km^2).

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As described in the *Delaware Basin Monitoring Annual Report* (U.S. DOE 2025a, Section 2.4), the EPA revised the drilling rate formula to the following:

$$D_r = \frac{\left[\left(Known\ Deep\ Boreholes\right) + \left(Unknown\ Depth\ Boreholes\right) \times \left(\frac{Known\ Deep\ Boreholes}{Total\ Known\ Depth\ Boreholes}\right)\right] \times \left(10{,}000\ years\right)}{A_{DB} \times 100\ years} \quad (2)$$

where

Unknown Depth Boreholes = Drilling-in-progress or Waiting-on-paperwork Boreholes
= 1,813 (U.S. DOE 2025a, Table 5)

Known Deep Boreholes = Total Deep Boreholes (U.S. DOE 2025a, Table 6) – Unknown Depth Boreholes
= 35,661 – 1,813 = 33,848

Total Known Depth Boreholes = Known Deep Boreholes + Total Shallow Boreholes (U.S. DOE 2025a, Table 4)
= 33,848 + 4,602 = 38,450.

Using these values in the deep drilling rate formula presented in Equation 2 results in a deep drilling rate of 153.4 boreholes per km^2 over 10,000 years (U.S. DOE 2025a, Section 2.4).

The rate reported in the CCA using Equation 1 (with an unadjusted number of deep boreholes) was 46.8 boreholes per km^2 over 10,000 years. Including the time period after the CCA (June 1996 to August 2024) increases the rate to 153.4 boreholes per km^2 per 10,000 years, as shown in Table 2.4. As a result of continuing analysis and monitoring, the TV for this COMP was removed (Wagner and Thomas 2016). No additional actions are recommended currently.

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

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Table 2.4. Drilling rates for each year since the CCA [(a)].

Year	Number of Boreholes	Drilling Rate (boreholes per km^2 per 10,000 years)
1996 (CCA Value)	10,804 Boreholes Deeper Than 2,150 feet	46.8
1997	11,444 Boreholes Deeper Than 2,150 feet	49.5
1998	11,616 Boreholes Deeper Than 2,150 feet	50.3
1999	11,684 Boreholes Deeper Than 2,150 feet	50.6
2000	11,828 Boreholes Deeper Than 2,150 feet	51.2
2001	12,056 Boreholes Deeper Than 2,150 feet	52.2
2002	12,139 Boreholes Deeper Than 2,150 feet	52.5
2003	12,316 Boreholes Deeper Than 2,150 feet	53.3
2004	12,531 Boreholes Deeper Than 2,150 feet	54.2
2005	12,819 Boreholes Deeper Than 2,150 feet	55.5
2006	13,171 Boreholes Deeper Than 2,150 feet	57.0
2007	13,520 Boreholes Deeper Than 2,150 feet	58.5
2008	13,824 Boreholes Deeper Than 2,150 feet	59.8
2009	14,173 Boreholes Deeper Than 2,150 feet	61.3
2010	14,403 Boreholes Deeper Than 2,150 feet	62.3
2011	14,816 Boreholes Deeper Than 2,150 feet	64.1
2012	15,558 Boreholes Deeper Than 2,150 feet	67.3
2013	16,633 Boreholes Deeper Than 2,150 feet	72.0
2014	17,937 Boreholes Deeper Than 2,150 feet	77.6
2015	19,424 Boreholes Deeper Than 2,150 feet	84.1
2016	20,429 Boreholes Deeper Than 2,150 feet	88.4
2017	21,581 Boreholes Deeper Than 2,150 feet	93.4
2018	22,886 Boreholes Deeper Than 2,150 feet	99.1
2019	24,408 Boreholes Deeper Than 2,150 feet	105.7
2020	28,669 Boreholes Deeper Than 2,150 feet	124.1
2021	29,045 Boreholes Deeper Than 2,150 feet	125.7
2022	32,079 Boreholes Deeper Than 2,104 feet	138.9
2023	33,737 Boreholes Deeper Than 2,104 feet	145.5
2024	35,661 Boreholes Deeper Than 2,104 feet	153.4

(a) From Table 6 of U.S. DOE 2025a. Beginning in 2023, a prorated adjustment to the number of deep boreholes was included in the drilling rate equation to account for in-progress boreholes of unknown depth. This table provides the unadjusted number of deep boreholes.

Data needed to derive and evaluate the geotechnical COMPs are available from the most recent annual geotechnical analysis report (GAR) (U.S. DOE 2024a) and the annual subsidence monument leveling survey (U.S. DOE 2025b). 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.

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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 behavior 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) north 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 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 (U.S. DOE 2024a) summarizes data collected from July 2022 through June 2023.

Subsidence monitoring survey reports are also prepared by the M&OC on an annual basis and present the results of leveling surveys performed in 2023 and early 2024 for 14 vertical control loops comprising approximately 23 linear miles traversed over the ground surface of the WIPP site. Elevations are determined for 76 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 (U.S. DOE 2025b) summarizes data collected between August 2023 through February 2024.
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, but it also allows for reassessment of the current 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 that support WIPP certification. In effect, these annual comparisons of actual geotechnical response with expected response serve to validate or improve models.

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The 2024 GAR (U.S. DOE 2024a) reporting period is from July 1, 2022, to June 30, 2023, which is one year earlier than most of the other COMPs reporting periods.

2.2.1 Creep Closure

Table 2.5 summarizes data and TV information related to the COMP 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-related deformation, either from rib-to-rib, roof-to-floor, or extensometer borehole measurements. Except for newly mined openings, rates of closure are relatively constant within each zone of interest and usually range from about 1 to 5 cm per year. Nominally these rates are of the order of 1×10^{-10} per second and are quite steady over significant periods. From experience, increases and decreases of rates such as these might vary by 20% without undue concern.

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 damaged rock zone (DRZ) growth comprise important elements of PA assumption confirmation. Therefore, a measured creep rate of one order of magnitude 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 closure 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 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, 2023. For this reporting period, Panels 1 through 8 have been fully excavated. During this reporting period, the west access drifts are under development supporting the construction and use of Panels 11 and 12. Figure 2.1 shows all areas mined as of June 30, 2023. At that time, waste emplacement had progressed to Room 7 of Panel 8.

Information Only

Table 2.5. Creep Closure – 2024.

COMP Title:	Creep Closure
COMP Units:	Closure Rate (s^{-1})
COMP Assessment Process: (Reporting Period July 2022 through June 2023)	Evaluate GAR for centerline closure rates and 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.

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Geotechnical	Closure	Instrumentation located throughout the underground.	Multi-mechanism deformation creep model developed by Munson and Dawson

Related Performance and Compliance Elements

Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Repository Fluid Flow	Creep Closure FEP W20 "Salt Creep"	Porosity Surface, waste compaction, characteristics, waste properties, evolution of underground setting	SANTOS, porosity surface calculations	Provides validation of the creep closure model.

Monitoring Data Trigger Values

Monitoring Parameter ID	Trigger Value	Basis
Creep Closure	Greater than one order of magnitude increase in closure rate.	The closure rate increase signals potential de-coupling of rock.

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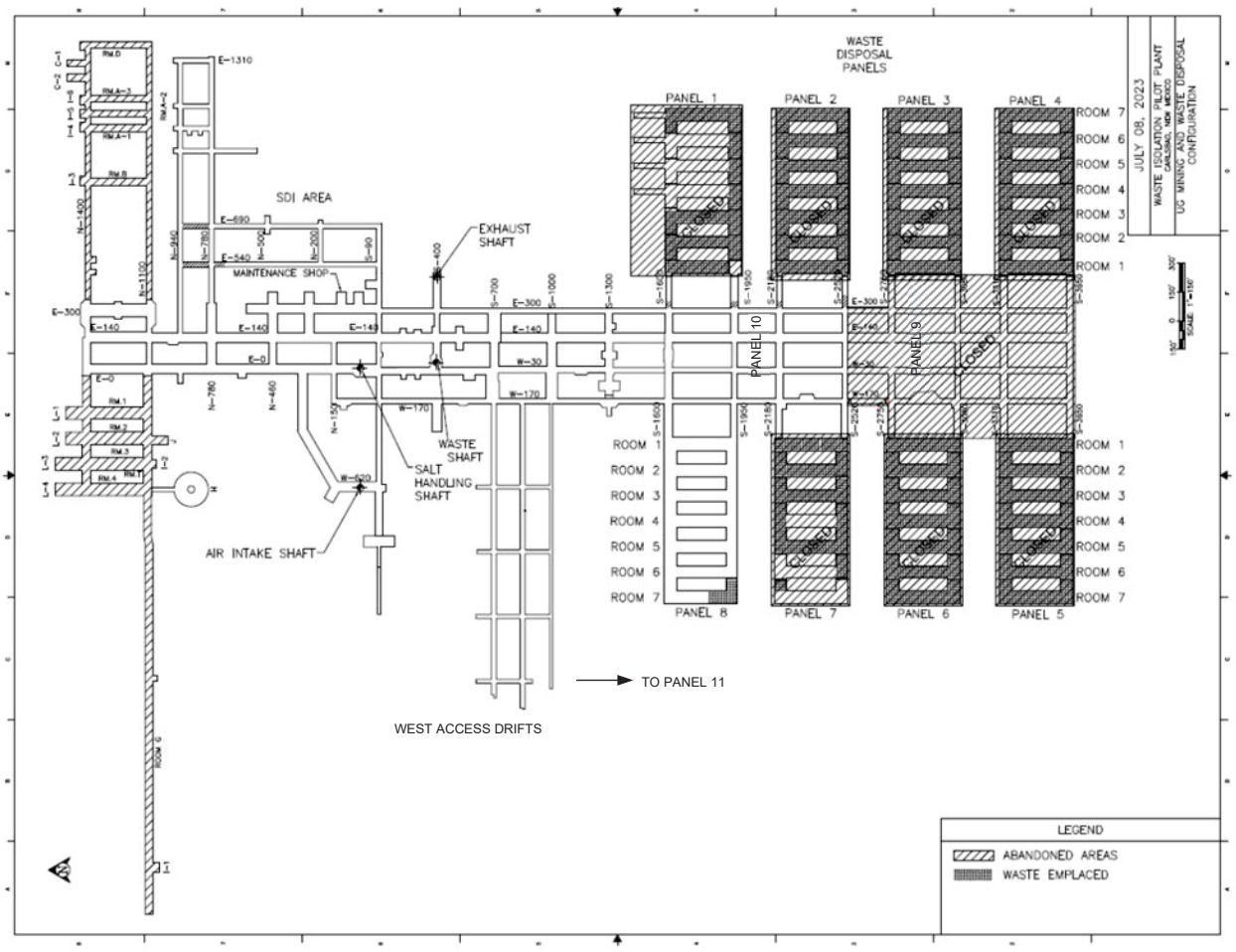

Figure 2.1. Configuration of the WIPP underground for geotechnical COMPs through June 30, 2023 (modified after Figure 1-2 of U.S. DOE 2024a, Volume 1).

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. A fifth shaft to the underground known as a "Utility Shaft" is under construction, but not operational during the reporting period of the GAR. At the repository level (approximately 2,104 feet 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).

Shafts. Except for 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

Information Only

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 to 7.0 m.

Data available for assessing creep-related 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. Piezometers and earth pressure cells were also installed in the shafts during construction to monitor fluid pressure behind the shaft liners and key sections. 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 cabling and (currently not in use) air and water lines 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. During the GAR reporting period, planning continued to develop improvements to the Salt Shaft Pocket loading facility to re-establish it to its original design dimensions. The planned rework of the Salt Pocket is anticipated for future reporting periods.

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.

Shaft Stations. 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 lifetime 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

Information Only

major modifications were performed at the shaft stations during this reporting period. Routine ground control activities were performed during this reporting period.

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 (2022-2023) and the previous reporting period (2021-2022) 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 0.3 to 2.6 inches per year (0.8 to 6.6 cm per year). Dividing convergence rates by the average room dimension (approximately 6 m) and expressing the results in units of 1 per second yields vertical creep rates between approximately 4.03×10^{-11} per second to 3.49×10^{-10} per second. Based on an examination of the displacement rates and the percentage changes in displacement rates from the extensometer and convergence data in Table 2.6, as well as the limited maintenance required in the shaft stations during the last year, creep closure rates associated with the WIPP shaft stations are considered acceptable and meet the TV requiring creep closure rates to change by less than one order of magnitude in a one-year period.

Access Drifts and Waste Disposal Area

During the reporting period of the GAR (ending June 30, 2023), waste emplacement has been completed in Panels 1 through 7. No access is allowed in these areas. Closure data were monitored for the west access drifts, the main access drifts, Panel 7, and Panel 8 at locations where access is allowed. During the reporting period for the GAR, closure monitoring for Panel 7 was limited to two convergence point monitoring stations in the entry drifts leading to the panel, and one remotely monitored extensometer in Room 1.

Waste emplacement continued during the current reporting (July 2022 to June 2023), with waste disposal emplacement proceeding in Room 7 of Panel 8. Mining of Panel 8 started in September of 2013. Mining was interrupted in February 2014 by two separate events: a fire occurred in the WIPP underground, then days later, an unrelated radiological release in the underground occurred. Because of these events, waste emplacement ceased and access to the WIPP underground was restricted for a significant period. Panel 8 mining was completed in 2022.

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, and 7 are at the original horizon and Panels 3, 4, 5, 6, and 8 approximately 2.4 m higher in elevation (roof at Clay G). Note that Panel 8 was originally planned to be mined on the lower horizon, but due to the interruption in mining, which resulted in significant low angle shear and roof separation, it was mined to the upper horizon. Trimming, scaling, floor-milling and rock-bolting operations were performed as necessary during the reporting period. To provide a more stable

Information Only

floor over the expected lifetime of Panel 7, a wide channel was excavated in the floor of the panel to remove stiff bedded polyhalite and a hard anhydride bed. These stiffer beds would resist the lateral stress caused by creep and bow upward into the mined opening. The floor was backfilled with run-of-mine salt to the original floor height.

Table 2.6. Summary of closure rates for WIPP shafts and shaft stations.

Location	Instrument Type[a]	Displacement Rate (inches per year) 2021–2022[b]	Displacement Rate (inches per year) 2022-2023[b]	Change in Rate (%)
Salt Handling Shaft Station				
E0 Drift – S18 (A-E)	CP	2.1	2.1	0
E0 Drift – S18 (B-D)	CP	2.9	2.6	-10
E0 Drift – S18 (F-H)	CP	1.4	1.2	-14
E0 Drift – S30 (A-C)	CP	2.2	2.2	0
E0 Drift – S65 (A-C)	CP	1.5	1.4	-7
Waste Shaft Station[c]				
S400 Drift – E35 (Vert CL)	Ext	0.3	0.3	0
S400 Drift – E10 (A-C)	CP	1.1	1.0	-9
S400 Drift – W20 (A-C)	CP	1.4	1.3	-7
S400 Drift – W30 (A-C)	CP	1.3	1.2	-8
Air Intake Shaft Station[c]				
S90 Drift – W620 (A-C)	CP	1.1	1.1	0
AIS North Brow (Vert CL)	Ext	0.3	0.3	0
AIS South Brow (Vert CL)	Ext	0.3	0.3	0
N20 Drift – W620 (Vert CL)	Ext	0.2	0.5	150

(a) Instrument Type: Ext = extensometer; CP = convergence point.
(b) Data are from the 2024 GAR (U.S. DOE 2024a, Volume 2, Tables 3-1 and 4-1).
(c) CL = Centerline.

Access Drifts. The main access drifts are comprised of four north-south drifts extending southward from near the Salt Handling Shaft to the entries into the waste disposal panels and have several short cross-drifts intersecting these major drifts. The west access drifts are currently being mined and include three east-west drifts extending west from main access drift W-170. During the reporting period of the GAR, the west access drifts were excavated to approximately W-1640, which is the entry drift to Panel 11. The access drifts are typically rectangular in cross-section with heights ranging from 4.0 to 6.4 m and widths ranging from 4.3 to 10.1 m.

Assessment of creep-related deformations in the access drifts is made through the examination of extensometer and convergence point data reported annually in the GAR, including 19 extensometers, 7 wire convergence meters, and 250 convergence points (U.S. DOE 2024a, Volume 2, Table 4-1). Table 2.7 summarizes the vertical and horizontal displacement data reported in the most recent GAR (U.S. DOE 2024a). Table 2.7 examines percentage changes

Information Only

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 that fall within the range of the indicated percentage change. In general, convergence rate accelerations continue to be minor in most locations. Most of the rate changes for the 2023 COMPs data were low or near zero. For this 2024 COMPs report, most of the data are still in the lower two ranges. As was done since the 2014 COMPs report, the convergence data and extensometer data were combined. The maximum displacement rate corresponding to these data for the current reporting period is given below:

> Maximum Vertical Displacement Rates along Access Drifts: 29.0 cm per year (11.4 inches per year).

The maximum access drift displacement rate occurred in the newly mined west access drifts resulting from anticipated initial deformation (Figure 2.2). Using a typical average drift dimension of 5 m and the maximum displacement rates shown above, the inferred maximum vertical creep rate is approximately 18.36×10^{-10} per second. This rate is based on the maximum displacement which is not representative of the behavior of the system. This rate is less than last year's rate of 54.12×10^{-10} per second.

Creep closures associated with the access drifts are acceptable and meet the TV requiring creep closure 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.

Table 2.7. Frequency of occurrence of the percentage increase in displacement rate for measurements made during the 2021-2022 and 2022-2023 reporting periods.

Location	< 0%	0 – 25%	25 – 50%	50 – 75%	75 – 100%	100 – 200%	> 200%
Access Drifts	129	69	13	3	1	1	0
Waste Disposal Area – Panel 7	1	2	0	0	0	0	0
Waste Disposal Area – Panel 8	46	13	1	0	0	0	0

NOTE: Displacement rate change data are from the 2024 GAR (U.S. DOE 2024a, Volume 2, Tables 4-1, 5-1, and 5-2).

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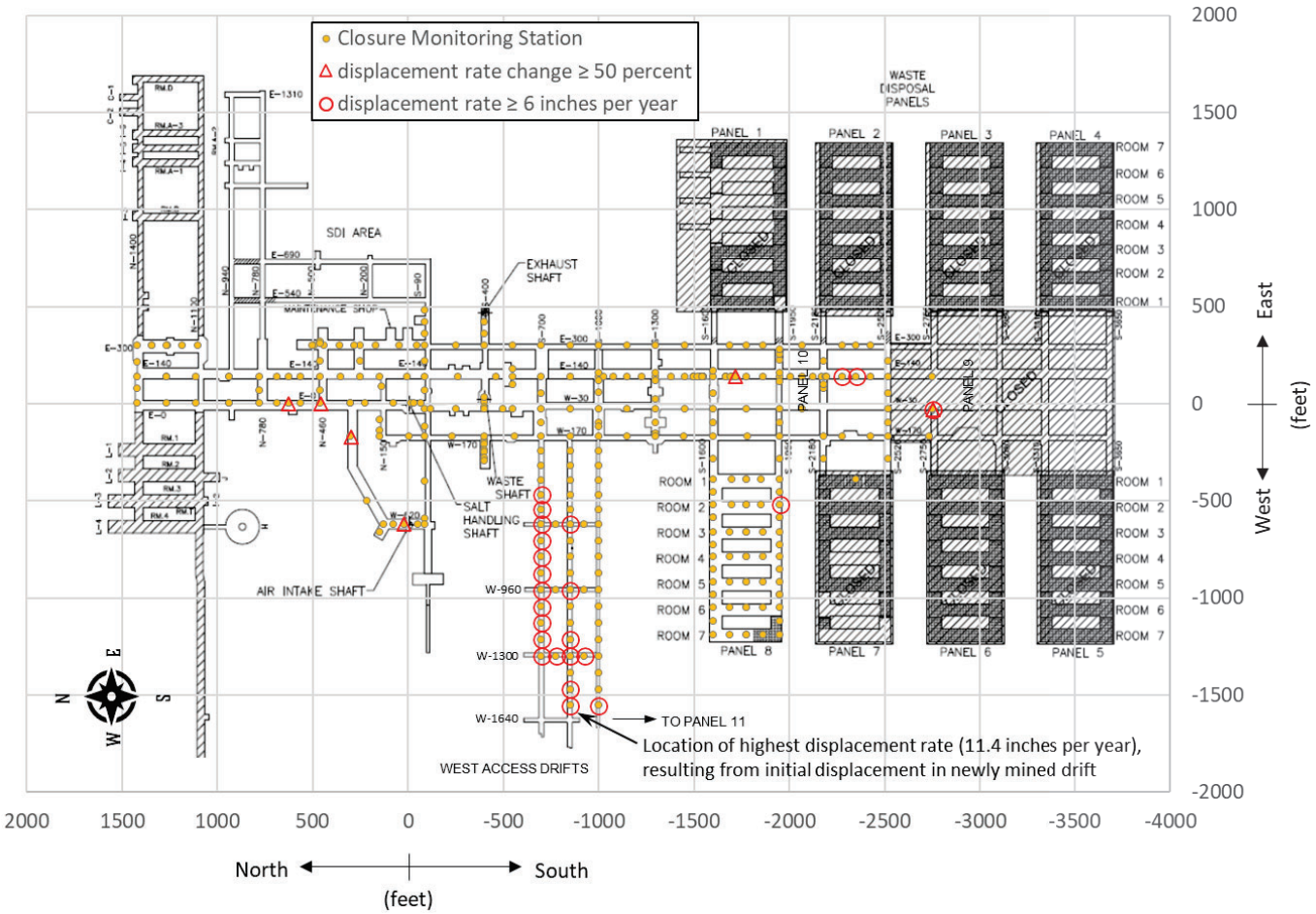

Figure 2.2. Location of closure monitoring stations in the access drifts and waste disposal area, including the identification of stations with the highest closure rates (U.S. DOE 2024a, Volume 1, Figure 1-2 and Volume 2, Tables 3-1, 4-1, 5-1, and 5-2).

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. The waste disposal area includes eight disposal panels, each comprising seven rooms (the major north-south access drifts servicing the eight panels may also be used for waste disposal and were initially planned to make up the ninth and tenth panels). Panel 1 was constructed in the late 1980s, Panel 2 was constructed from 1999 to 2000, Panel 3 was constructed from 2002 to 2004, and Panel 4 was completed in 2006. Mining for Panel 5 was completed in February of 2008 and Panel 6 was completed in April of 2010. Mining of Panel 7 began April 24, 2010, and was completed in January of 2013. Panel 8, which began mining in 2013, was completed in 2022. 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 to the panel 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 by 6.0 m.

Information Only

Assessment of creep-related 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 the vertical displacement data reported in the most recent GAR (U.S. DOE 2024a). Panels 1 through 6 were previously closed and are no longer accessible. Panel 5 was closed in 2011 and Panel 6 closed in 2014. Panel 7 closed during the reporting period in 2022. For this year's report, data in the waste disposal area are from Panels 7 and 8. No new convergence points and no new extensometers were installed in either Panel 7 or Panel 8 during this reporting period. Panel 7 includes 2 convergence point monitoring stations in the entry drifts leading to the panel, and 1 extensometer, while Panel 8 includes 49 vertical convergence points and 11 extensometers (U.S. DOE 2024a, Volume 2, Tables 5-1 and 5-2). Table 2.7 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 is provided as follows:

> Maximum Vertical Displacement Rates along Waste Disposal Area: 15.7 cm per year (6.2 inches per year).

The maximum waste disposal area displacement rate was measured in Panel 8. Using a nominal disposal-area-opening dimension of 8 m and the maximum displacement rates shown above, the inferred maximum creep rate is approximately 6.24×10^{-10} per second. This rate is less than last year's rate of 55.70×10^{-10} per second [1]. For the reporting period of the GAR (ending June 30, 2023), the location of the maximum displacement rate in the waste disposal area (in Room 2 of Panel 8) is shown in Figure 2.2.

2.2.2 Extent of Deformation

Table 2.8 summarizes the data and TV information relating to the COMP Extent of Deformation and 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 is found in the *Ground Control Annual Plan*

[1] Last year's maximum rate in the waste disposal area is the result of remotely read extensometer measurements prior to a rockfall in the abandoned area of Panel 7 where ground support was no longer maintained.

Information Only

Table 2.8. Extent of Deformation – 2024.

COMP Title:	Extent of Deformation
COMP Units:	Areal extent (length, direction)
COMP Assessment Process: (Reporting Period July 2022 through June 2023)	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 Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Geotechnical	Displacement	Meters	Not Established

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 FEP W18 "Disturbed Rock Zone"	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 Thomas 2016)

for the Waste Isolation Pilot Plant (U.S. DOE 2023a). This document discusses ground conditions and the operational monitoring program that is used to assess these conditions.

The Geotechnical Engineering Department at WIPP has developed a database that compiles back-fracturing data. The supporting data from past-year GARs contained isometric plots of fractures for active waste panels. 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 Only

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. A comprehensive model and supporting data for model parameters for damage evolution is under development for PA.

Excavation of Panel 3 raises the waste disposal panels by 2.4 m such that the roof of the disposal rooms is coincident with Clay Seam G and the floor is an additional 2.4 m above Marker Bed 139. Additionally, part of the floor in Panel 7 was milled and backfilled with run-of-mine salt to replace the stiff bedded polyhalite and hard anhydride beds. These stiffer beds likely would resist the lateral stress caused by creep closure and bow upward into the mined opening. These changes 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 2007). Their modeling shows that the DRZ does not extend below Marker Bed 139 in the case of both the original horizon and the raised room. The rise in repository elevation causes no discernible change to the porosity surface used in PA. Data provided in past-year GARs 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).

The activities of the WIPP geoscience program during this reporting period included borehole observations and marking of fractures within the mine. Fracture maps are not provided in the 2024 GAR (U.S. DOE 2024a) for comparison to maps in the previous year's report. Similarly, the previous year's GAR did not include fracture mapping.

2.2.3 Initiation of Brittle Deformation

Table 2.9 summarizes data and TV information relating to the COMP Initiation of Brittle Deformation and its implementation in PA. Initiation of brittle deformation around WIPP openings is not directly measured and is therefore a qualitative observational parameter. By nature, 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, growth, and extent of the DRZ are important considerations for the operational period panel closures as well as compliance PA calculations. The activities of the WIPP geoscience program were limited during this reporting period due to logistical issues. No other issues were noted as part of this monitoring.

Information Only

Table 2.9. Initiation of Brittle Deformation – 2024.

COMP Title:	Initiation of Brittle Deformation
COMP Units:	Qualitative
COMP Assessment Process: (Reporting Period July 2022 through June 2023)	Qualitative and pertinent to operational considerations. Captured qualitatively in association with other COMPs

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Geotechnical	Closure	Observational	Not Established

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 Displacement of Deformation Features and its implementation in PA. The displacement of deformation features primarily focuses on those features located in the immediate vicinity of the underground openings. As discussed previously, fracture development is typically continuous semi-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, and 7. Marker Bed 139 (anhydrite) is located approximately 2 m below the floor of these panels. For Panels 3, 4, 5, 6, and 8, 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.

Information Only

Table 2.10. Displacement of Deformation Features – 2024.

COMP Title:	Displacement of Deformation Features
COMP Units:	Length
COMP Assessment Process: (Reporting Period July 2022 through June 2023)	Data from 76 observation boreholes are available for this reporting period.

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Geotechnical	Delta D/D_o	Observational	Not established

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 Thomas 2016)

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. The OBHs are typically 7.6 cm (3 inches) 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 typically classified as either offsets, separations, fractures, or rubble zones. Of these deformation features, offsets are the principal 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.

During the reporting period, 76 boreholes were drilled and/or inspected to identify separations/fractures and lateral displacements in the immediate roof beam (U.S. DOE 2024a, Volume 1, Section 8.1). The inspection of observation boreholes showed roof beam fracture behavior consistent with expectations. No substantial or detrimental deviations from the

Information Only

expected performance of the mined repository were observed during the reporting period of the GAR.

2.2.5 Subsidence

Table 2.11 summarizes data and TV information relating to the COMP Subsidence and its implementation in PA. The 2023 subsidence survey (U.S. DOE 2025b) includes the determination of elevation for 76 of 77 existing monuments, and 14 of the National Geodetic Survey's vertical control points. Approximately 23 miles of leveling was performed in the 2023 subsidence survey for 14 control loops (see Figure 2.3). Five new loops and 29 new monuments were installed in 2023. Construction activities in the vicinity of one monument precluded it from inclusion in the 2023 survey. To address EPA monitoring requirements, the most recent survey results (U.S. DOE 2025b) are reviewed and compared to derived TVs. Because of the low extraction ratio and the relatively deep emplacement horizon (2,104 feet), 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 contact-handled (CH) transuranic (TRU) waste and no backfill (Westinghouse Electric Corporation 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 per year (0.006 feet per year). These predicted rates could be higher or lower depending on mining activities as well as other factors such as time after mining. 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 0.033 feet $\times \sqrt{}$mile or better was achieved in all cases. This year's measured accuracy ranged from < 0.001 to 0.015 feet$\sqrt{}$mile (U.S. DOE 2025b, Table B).

Several monuments have also been included in various annual surveys but were not included in the current surveys because the monuments no longer exist or have been physically disturbed. Table 2.12 lists these monuments. 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 (SIMCO 2023).

The current surveys comprise 14 leveling loops containing as few as 5 to as many as 9 monuments/control points per loop as shown in Figure 2.3. Surveys of Loop 1 benchmarks have been discontinued because only two benchmarks comprise this loop and these benchmarks are redundant to other survey loops. Elevations are referenced to monument S-37 located approximately 7,700 feet north of the most northerly boundary of the WIPP underground excavation. This location is far enough from the WIPP facility to be unaffected by excavation-induced subsidence expected directly above and near the WIPP underground. The elevation of

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Table 2.11. Subsidence – 2024.

COMP Title:	Subsidence
COMP Units:	Change in surface elevation in meters per year
COMP Assessment Process: (Data Acquired Between August 2023 and February 2024)	Survey data from annual WIPP subsidence monument leveling are evaluated. Elevations of 90 monitoring monuments in 14 loops are compared to determine changes.

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Subsidence Monitoring Program (SMP)	Elevation of 62 original monitoring monuments	Decimal (meters)	Not Established
SMP	Change in elevation over year	Decimal (meters)	Not Established

Related Performance and Compliance Elements

Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Subsidence	FEP W23 "Subsidence"	Predictions are of low consequence to the calculated performance of the disposal system – based on Westinghouse Electric Corporation (1994) analysis and EPA treatment of mining.	Maximum total subsidence of 0.62 m (2.0 ft) 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-2019 Appendix SCR, Section SCR-6.3.1.4) – this is within the range of hydraulic conductivity modeled in PA. Predicted WIPP subsidence is below that predicted for the effects of potash mining (0.62 m vs.1.5 m; U.S. DOE 2019).

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.

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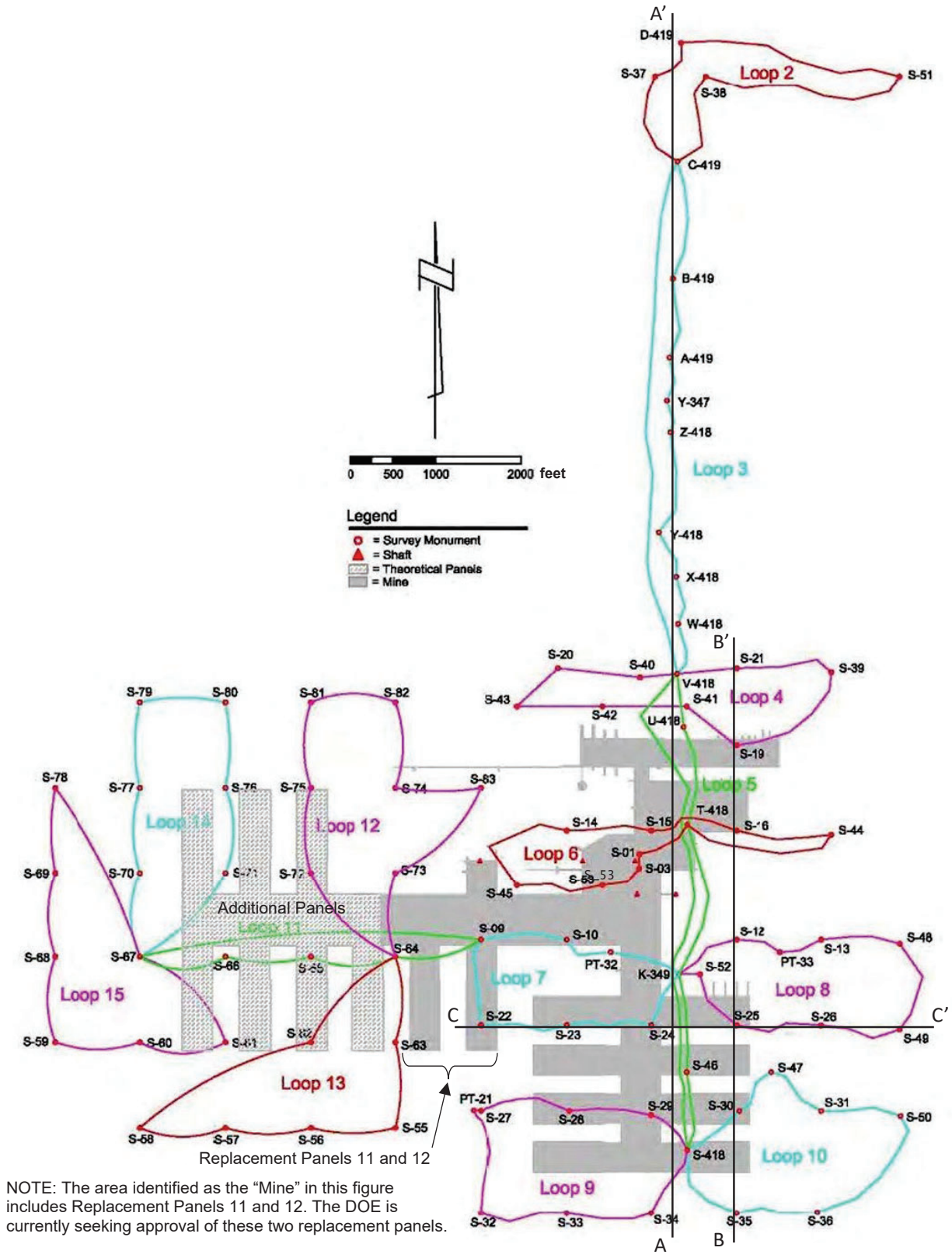

NOTE: The area identified as the "Mine" in this figure includes Replacement Panels 11 and 12. The DOE is currently seeking approval of these two replacement panels.

Figure 2.3. Monuments and vertical control points comprising WIPP subsidence survey loops (modified after Figure 1 of U.S. DOE 2025b).

Information Only

Table 2.12. Monuments no longer surveyed.

Monument	Fate	Date Last Surveyed
S-02	No longer exists	1992
S-11	No longer exists	1992
S-17	No longer exists	2003
S-18	No longer exists	2003
S-54	No longer exists	1992
PT-30	Physically Disturbed	1997
PT-31	Physically Disturbed	2003

S-37 has been fixed at 3,423.874 feet for all subsidence leveling surveys conducted since 1993. Survey accuracy for all loops was within the allowable limits (U.S. DOE 2025b). 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 2.4 through 2.11 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 sixth waste emplacement panel, (4) directly above the eighth waste emplacement panel, (5) near the Salt Handling Shaft, (6) directly above the west access drifts, (7) directly above the north experimental area, and (8) outside the repository footprint of the WIPP underground excavation. As expected, subsidence is occurring directly above the underground openings (Figures 2.4 through 2.9); however, the magnitude of the subsidence above the repository is small ranging from about -0.031 feet (D-419) far north of the repository to -0.784 feet (S-46) directly over the waste panels.

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 2.12 through 2.14 for the following subsidence profiles (shown in plan view in Figure 2.3):

- 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 from Panel 1 through Panel 8.

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

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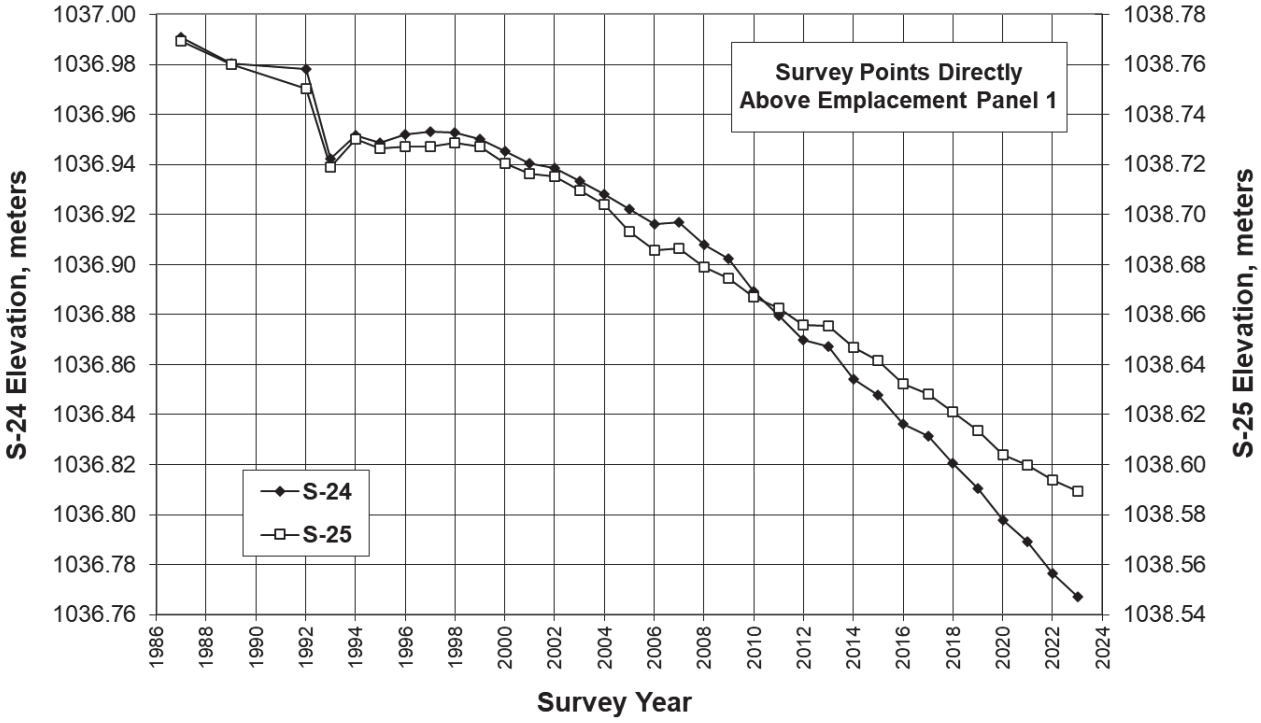

Figure 2.4. Elevations of WIPP monuments S-24 and S-25 located directly above the first emplacement panel.

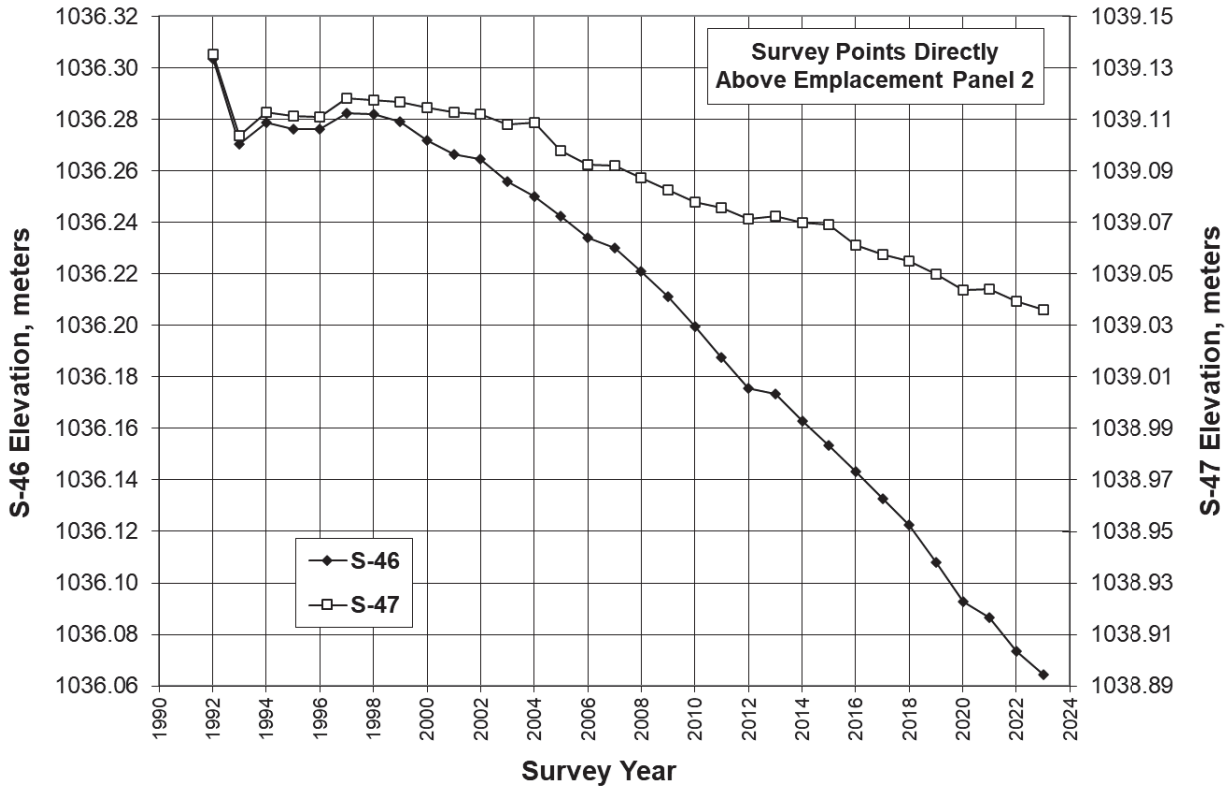

Figure 2.5. Elevations of WIPP monuments S-46 and S-47 located directly above the second emplacement panel.

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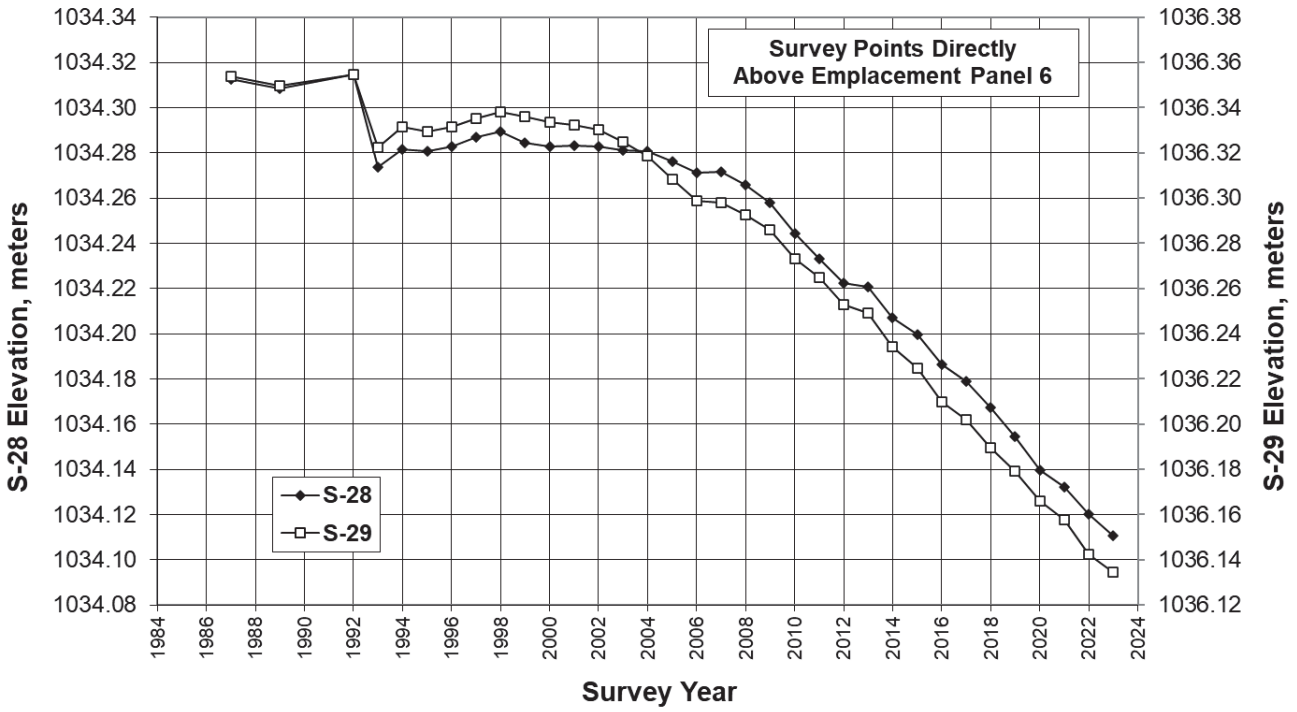

Figure 2.6. Elevations of WIPP monuments S-28 and S-29 located directly above the sixth emplacement panel.

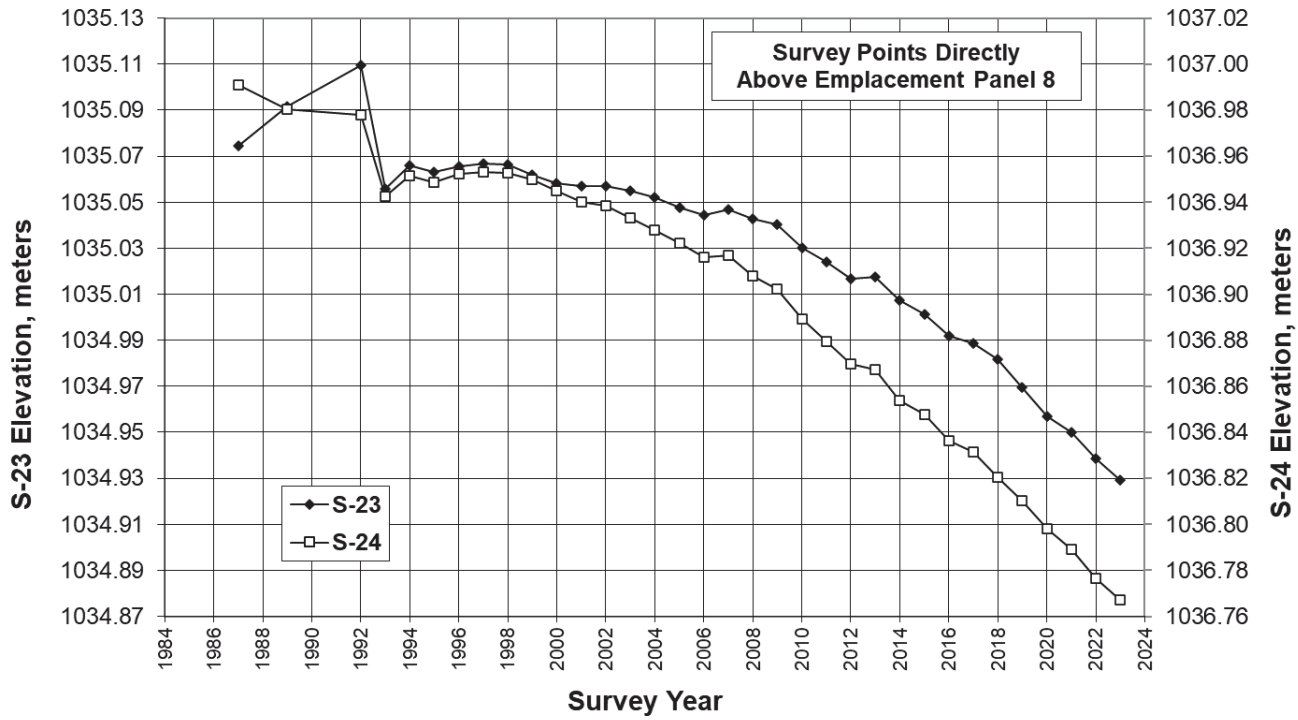

Figure 2.7. Elevations of WIPP monuments S-23 and S-24 located directly above the eighth emplacement panel.

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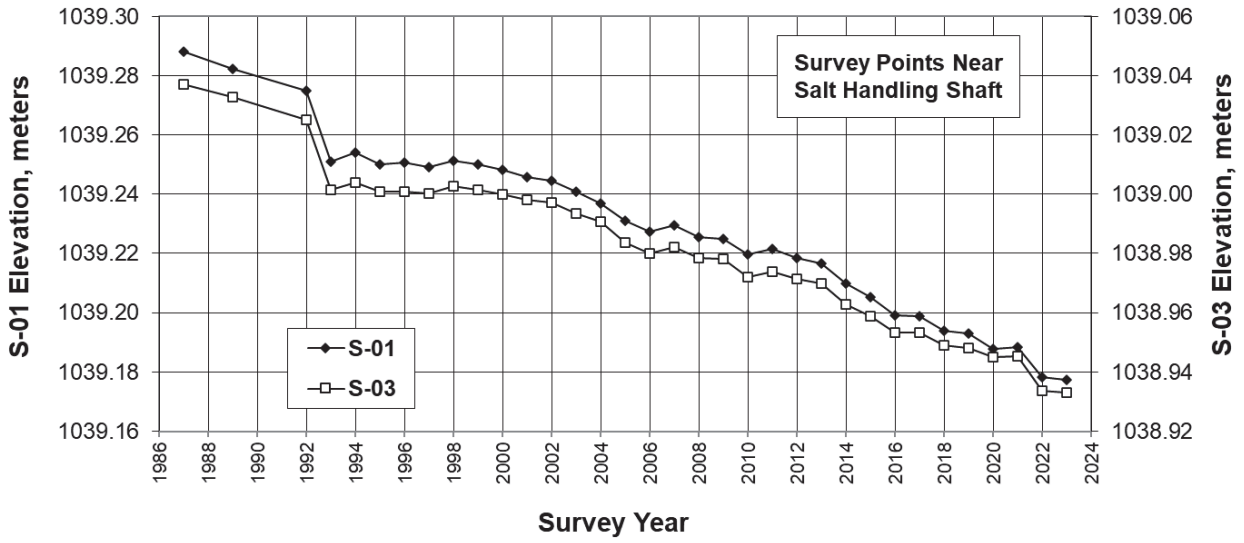

Figure 2.8. Elevations of WIPP monuments S-01 and S-03 located near the Salt Handling Shaft.

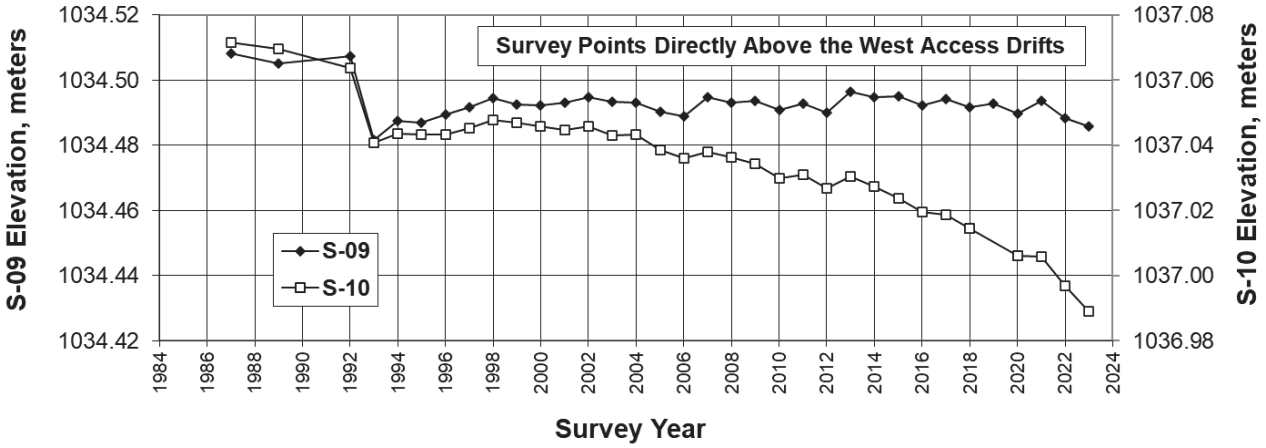

Figure 2.9. Elevations of WIPP monuments S-09 and S-10 located above the west access drifts.

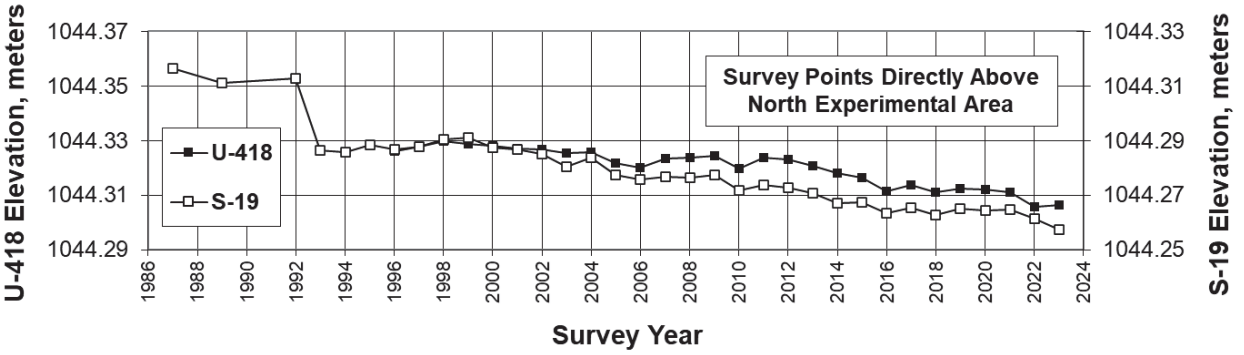

Figure 2.10. Elevations of WIPP monuments S-19 and U-418 located directly above the north experimental area.

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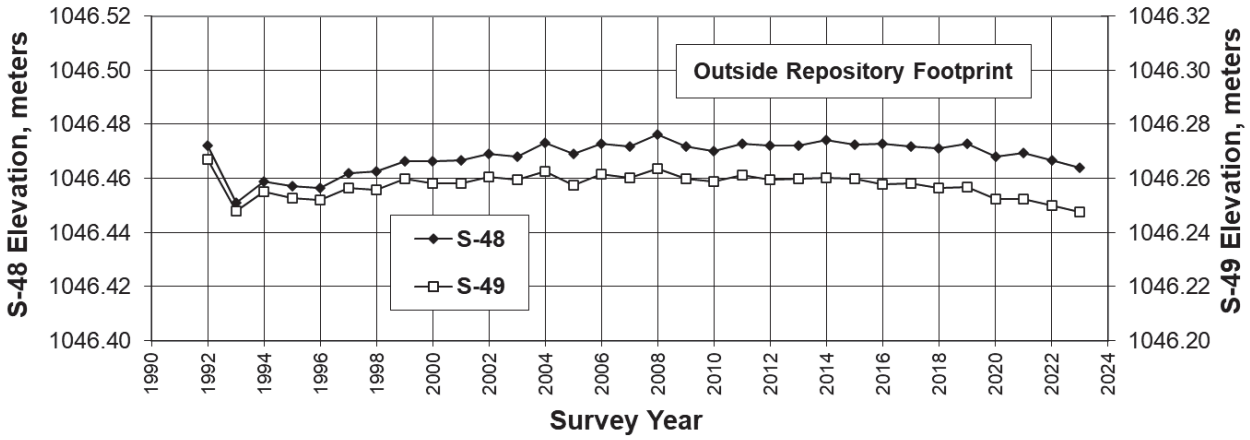

Figure 2.11. Elevations of WIPP monuments S-48 and S-49 located outside the repository footprint.

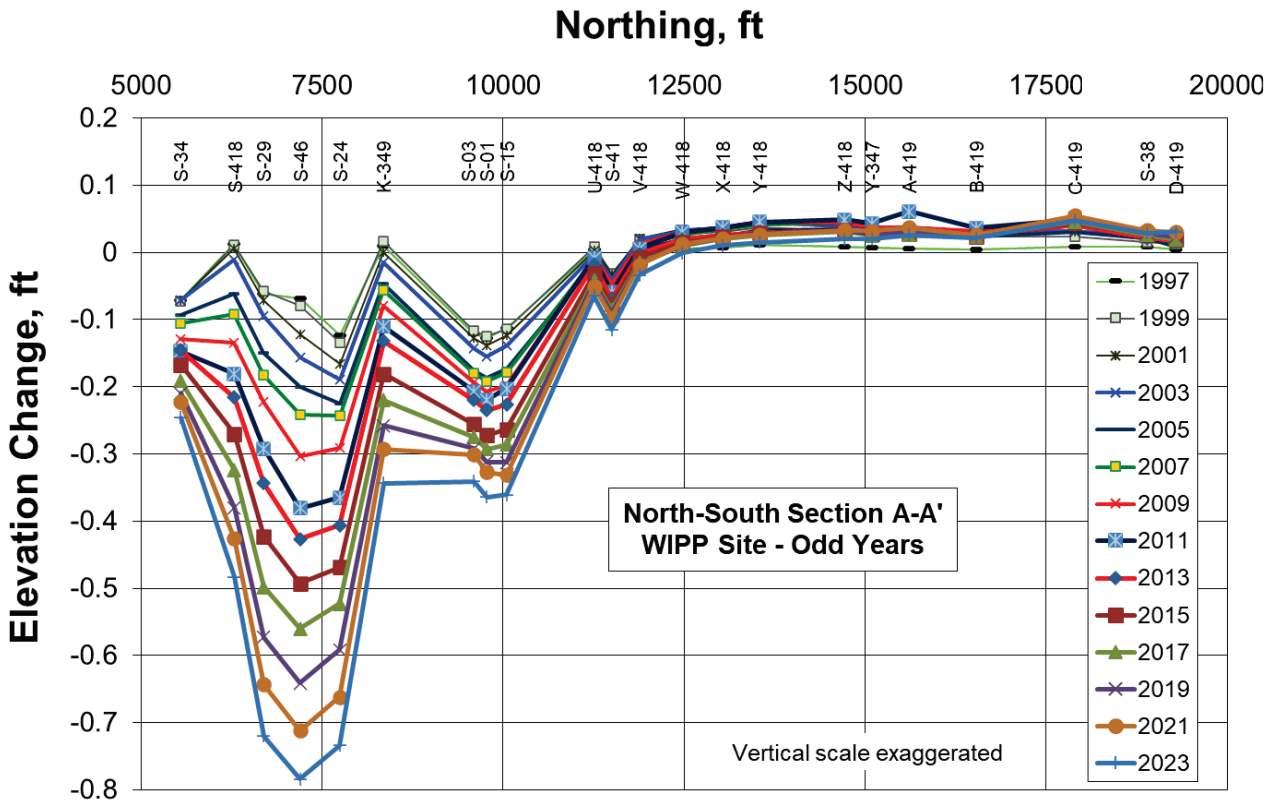

Figure 2.12. North-south subsidence profile A-A' in Figure 2.3.

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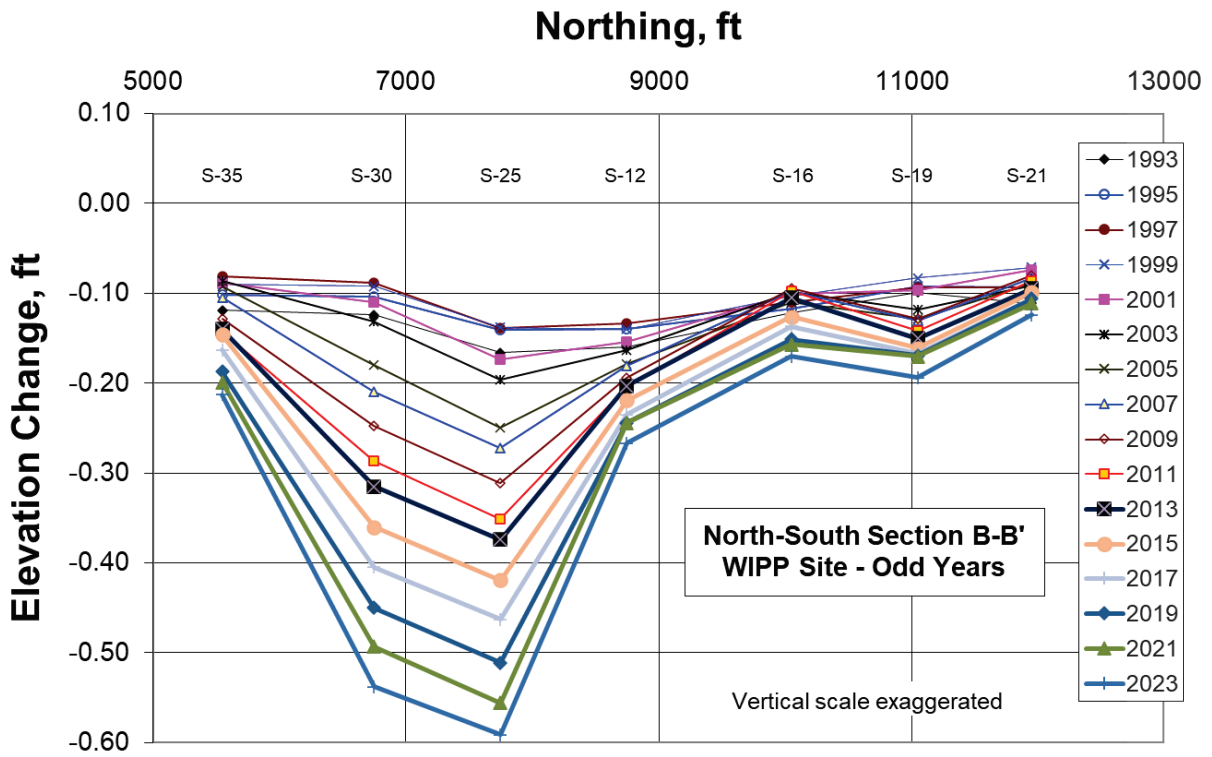

Figure 2.13. North-south subsidence profile B-B’ in Figure 2.3.

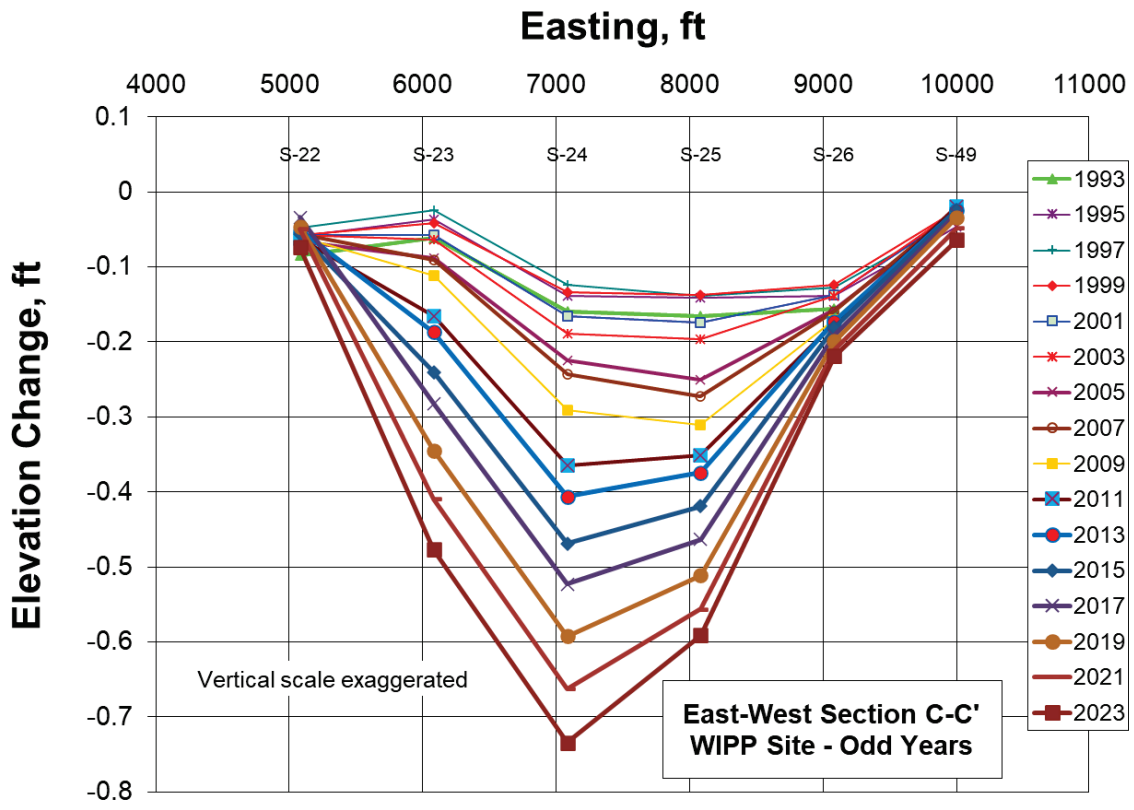

Figure 2.14. East-west subsidence profile C-C’ in Figure 2.3.

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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 than 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 feet) occurs above mine workings including the waste panels (monuments S-01, S-03, S-12, S-14, S-15, S-23, S-24, S-25, S-28, S-29, S-30, S-34, S-46, S-47, S-52, S-418, PT-32, and K-349). The maximum subsidence of 0.784 feet is over Panel 2 (S-46). This trend is the same as last year's results.

2. Only monuments over the north experimental area, the west access drifts, and the waste panel areas show any appreciable subsidence rate with the higher rates located directly over the waste panels. The highest subsidence rates measured for the 2023 surveys correspond to benchmarks located generally over the center of the repository (e.g., S-23, S-24, S-28, S-29, S-46, and PT-32) with a maximum rate for this period of -9.75×10^{-3} m per year. This rate does not exceed the TV.

3. The effects of subsidence extend away from the repository footprint approximately 1,000 to 1,500 feet (e.g., S-38, see Figures 2.3 and 2.12).

Total subsidence and subsidence rates are small. The highest subsidence rates are seen directly above the mined panels and have increased since the mining of Panels 4 through 8. Based on the 2023 survey data and comparing to the 2022 survey data, no monuments exceeded the 1×10^{-2} m per year TV this reporting period. However, exceedance of the TV has occurred several times since subsidence was monitored. The TV is based on several analyses of potential subsidence over the WIPP site. The largest rate was chosen from these analyses and is derived from the total subsidence calculated over a 35-year period. The TV assumes that this rate is constant over a 35-year period whereas the monitoring data show a gradual increase in rate over time. Considering the WIPP subsidence data since 2001, overall subsidence rates [(2)] remain below the TV for all monuments. As such, exceedance of the TV in a few monuments over a few years does not indicate this behavior is unexpected. No action is necessary in response to this year's subsidence data.

[2] For each monument, the overall subsidence rate = (current elevation – 2001 elevation) / number of years since 2001.

Information Only

2.3 Hydrological COMPs

As stated in previous sections, the CCA lists 10 monitoring parameters that the DOE is required to monitor and assess during the WIPP operational period (U.S. DOE 1996). 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 M&OC under Waste Isolation Pilot Plant Groundwater Protection Program (U.S. DOE 2014c), which is comprised of two components:

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

WQSP and WLMP data are reported in the Waste Isolation Pilot Plant Annual Site Environmental Report (ASER) for 2023 (U.S. DOE 2024b). Additionally, WLMP data are reported in monthly memoranda from the M&OC to the scientific advisor.

2.3.1 Changes in Culebra Water Composition

2.3.1.1 Water Quality Sampling Program (WQSP)

Table 2.13 summarizes the data and TVs relating to the COMP Change in Culebra Water Composition, as well as its implementation in PA. Under the current WQSP, six wells are sampled by the M&OC, all completed to the Culebra Dolomite Member of the Rustler Formation (Figures 2.15 and 2.16). 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 hydraulically 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 the most transmissive and laterally extensive saturated zone in the WIPP vicinity and 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.

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Table 2.13. Change in Groundwater Composition – 2024.

COMP Title:	Groundwater Composition
COMP Units:	mg/L (concentration data); unitless (p-value, level of marginal significance)
COMP Derivation Process:	Annually evaluate ASER data and compare to previous years and baseline information

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
Ground Water Monitoring	Composition	Annual chemical analyses	Ion concentration data (i.e., sampling rounds 1-35) reported in the WIPP ASER. Expanded from the original Resource Conservation and Recovery Act (RCRA) Background Water Quality baseline (i.e., sampling rounds 1-10).

Related Performance and Compliance Elements

Element Title	Type & ID	Derivation Procedure	Compliance Baseline	Impact of Change
Groundwater conceptual model and brine chemistry	Indirect	Conceptual models	Indirect	Provides validation of the various PA models, potentially significant with respect to groundwater flow and transport

Monitoring Data Trigger Values

Monitoring Parameter ID	Trigger Value	Basis
Change in Culebra Groundwater Composition	The p-value for a major ion is less than or equal to 0.05 for three consecutive sampling rounds.	Annual comparison of major ion concentrations for a sampling round-of-interest (i.e., treatment group) against a sampling rounds 1-35 inclusive baseline (i.e., control group) with the randomization test. Hypothesis tested: If the p-value is less than or equal to 0.05, the treatment group is statistically significant compared to the control group.

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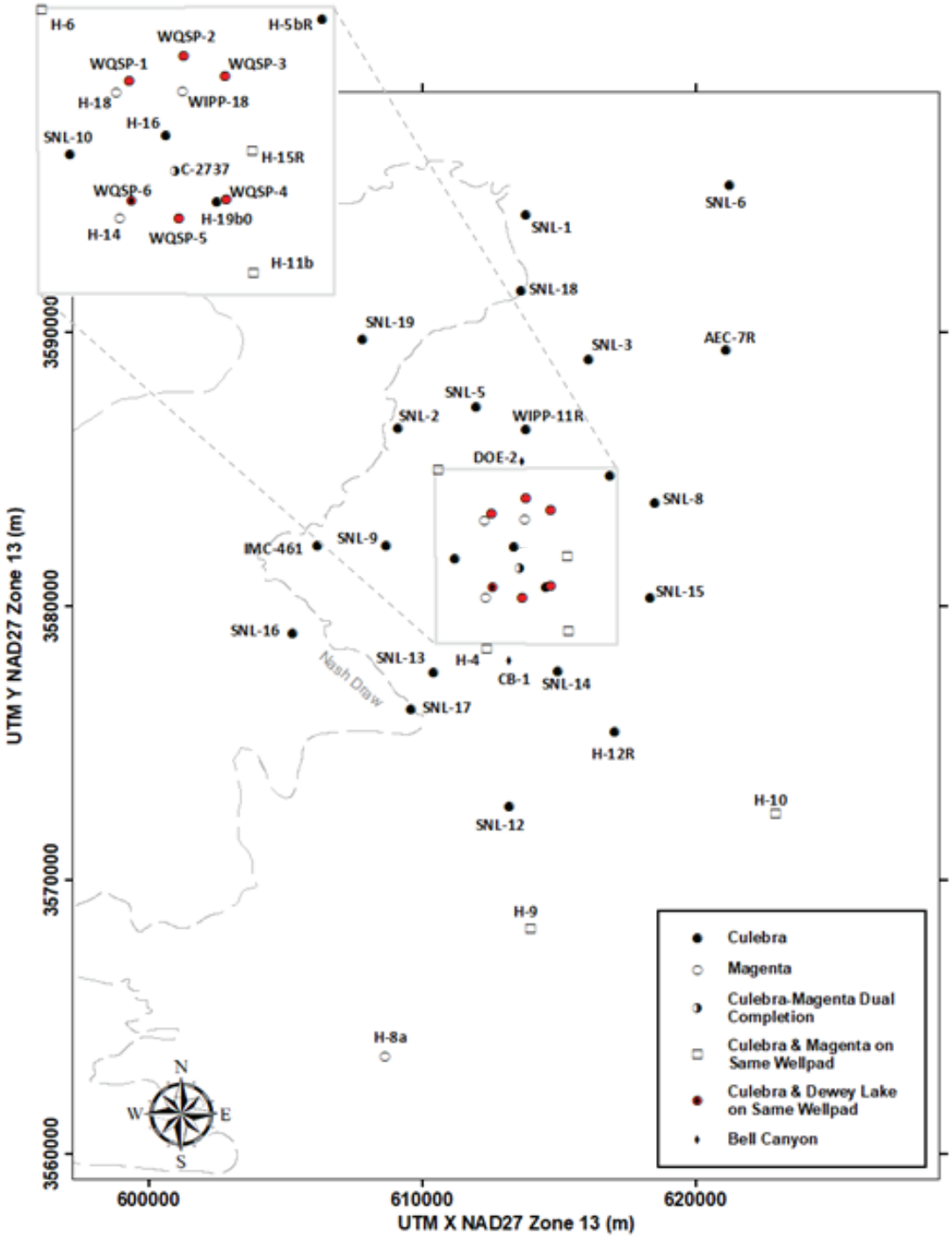

Figure 2.15. Map showing the locations of WQSP wells (red) in relation to the WIPP LWB and the groundwater monitoring network.

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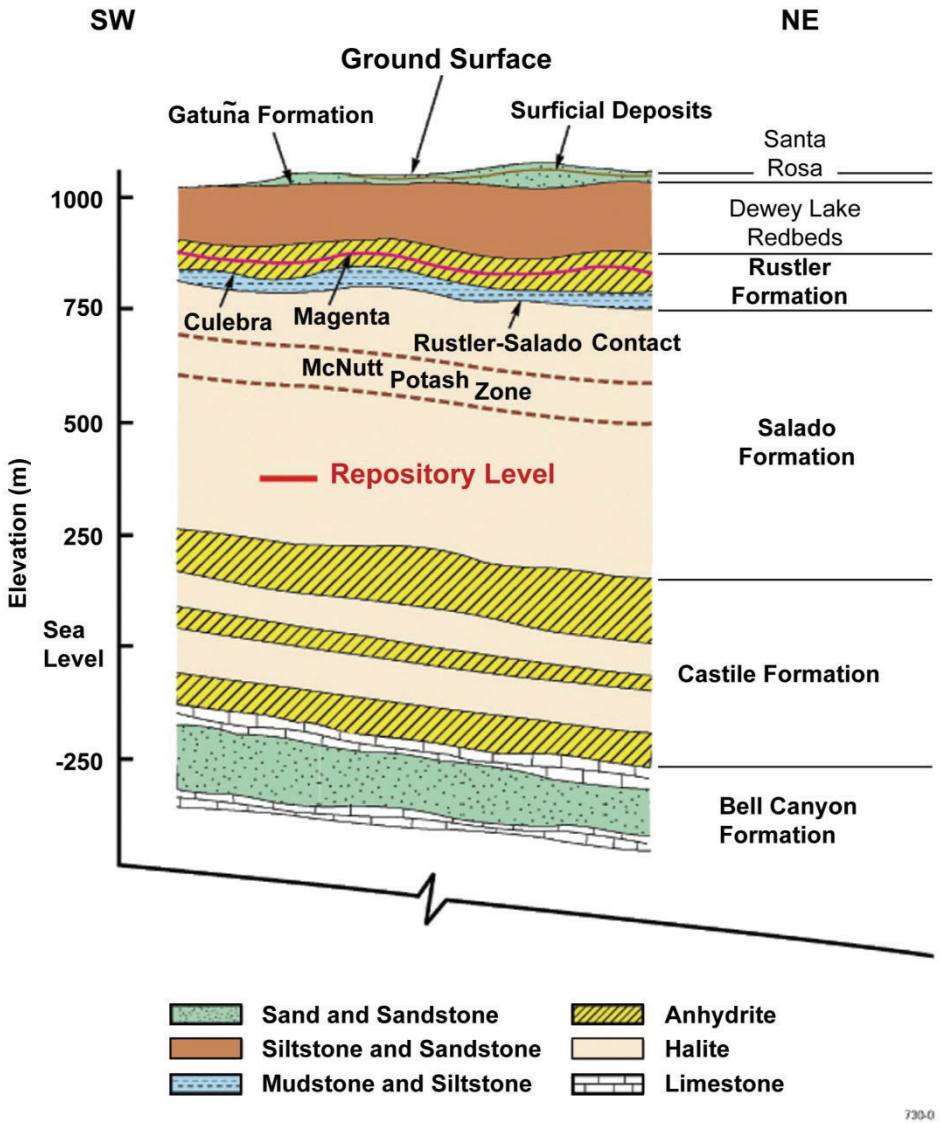

Figure 2.16. Generalized stratigraphic cross section at the WIPP site.

Solute concentrations in Culebra waters differ widely among wells across the WIPP site, a reflection of local compositional equilibrium, diffusion, and, perhaps most importantly, slow regional transport rates. The Culebra conceptual model for T-Fields was presented in the CRA-2014 (Appendix TFIELD: U.S. DOE 2014b) 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. Stability of major ion concentrations (Na+, Ca2+, Mg2+, K+, Cl-, SO42-, HCO3-) is consistent with and supports the Scientific Advisor's conceptual model of solute transport in the Culebra. If sustained, representative, and statistically significant changes in the concentrations of major ionic species are observed, this condition could imply that groundwater movement through the Culebra is quicker than what is

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predicted by the PA models. Thus, this evaluation of the water-quality data focuses on the stability of major ion concentrations.

2.3.1.1.1 Water Quality Sampling

Currently, two water samples (a primary and a duplicate) are collected from each WQSP well once per year. Round 45 conducted in 2023 is the twelfth year of annual sampling; rounds 2–33 (1996–2011) included two sampling rounds per year. Water sampling procedures are outlined in the Groundwater Protection Plan (U.S. DOE 2014c) and are summarized here.

Serial and final samples are collected using a submersible pump (each well has its own dedicated pump) set mid-formation. Serial samples are collected at regular intervals during pumping and are analyzed in a mobile field laboratory to determine when water chemistry has stabilized. Stabilization parameters include temperature, pH, specific gravity, and specific conductance. 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 M&OC 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 (including Na+, Ca2+, Mg2+ and K+), major anions (including Cl-, SO42- and HCO3-), 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 M&OC. 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. Wagner and Thomas (2016) modified the Culebra Groundwater Composition TV due to the ongoing occurrence of false positive water-quality composition fluctuations. Compared to Wagner and Thomas (2015), the number of measurements incorporated into the water-quality baseline estimates is 250% larger. Evaluation of the Culebra Groundwater Composition TV no longer rests upon assumptions about the underlying statistical distribution of the ion concentration data. The randomization test is used to determine whether or not the treatment

Information Only

group (i.e., sampling round of interest) is statistically significant compared to the control group (i.e., sampling rounds 1-35). For a given sampling round, a p-value is calculated for each major constituent, for each well, totaling 42 values. If the p-value (Table 2.13) for a given constituent is less than or equal to 0.05 for three consecutive sampling rounds, a TV violation is reported. 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.

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.

In addition to the comparison of species concentrations with trigger values, a charge-balance error (CBE) was also calculated for each analysis. 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 major ion has been overlooked. The percent difference between the results of primary and duplicate sample analysis for each individual ion is also considered. In general, this difference should be < 10%; large variability can indicate a problem with one or both analyses. The method used to calculate the percent difference is given below (Equation 2). Analytical results and CBE for round 45 are presented in Table 2.14.

$$Percent\ Difference = \frac{|primary - duplicate|}{(primary + duplicate)/2} \quad (2)$$

2.3.1.2 Results

WQSP results for sampling round 45 are reported in the 2023 ASER (U.S. DOE 2024b). The reported major ion concentrations are listed in Table 2.14. Sampling round 45 was conducted between March and October 2023 with analyses performed by HEAL. In the following subsections, anomalous values given in Table 2.14 (identified with either bolded or italicized fonts) are discussed.

2.3.1.2.1 WQSP-1

All ion concentrations in WQSP-1 water samples resulted in a p-value greater than 0.05. The CBE for the primary analysis was below -5% and the duplicate analysis was within the tolerated ± 5% range. The primary and duplicate sample chemistries were within 10% of each other.

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Table 2.14. Round 45 major ion concentrations and charge-balance errors, with p-value defined for each major ion for each well.

Well	Round 45	Ca^{2+} (mg/L)	Cl^- (mg/L)	HCO_3^- (mg/L)	K^+ (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	SO_4^{2-} (mg/L)	CBE (%)
WQSP-1	primary	1,870	38,000	51.36	506	1,180	19,500	4,460	**-5.14%**
	duplicate	1,890	37,100	51.40	515	1,190	19,800	4,820	-3.66%
	% diff	1.06%	2.40%	0.08%	1.76%	0.84%	1.53%	7.76%	
	p-value	0.064	0.922	0.482	0.322	0.391	0.950	0.390	
	TV violated?	No	No	No	No	No	No	No	**Yes**
WQSP-2	primary	1,550	37,100	47.88	489	1,080	21,200	5,250	-2.46%
	duplicate	1,560	35,900	47.92	495	1,080	21,800	5,380	0.10%
	% diff	0.64%	3.29%	0.08%	1.22%	0.00%	2.79%	2.45%	
	p-value	0.826	0.991	0.614	0.432	0.562	0.252	0.241	
	TV violated?	No	No	No	No	No	No	No	No
WQSP-3	primary	1,440	106,000	37.48	1,480	2,360	79,900	6,790	**9.37%**
	duplicate	1,440	102,000	37.08	1,480	2,370	82,000	8,800	**11.70%**
	% diff	0.00%	3.85%	1.07%	0.00%	0.42%	2.59%	**25.79%**	
	p-value	0.835	**0.005**	0.313	0.228	0.509	0.410	0.908	
	TV violated?	No	No	No	No	No	No	**Yes**	**Yes**
WQSP-4	primary	1,700	56,000	41.28	820	1,300	38,000	7,300	3.71%
	duplicate	1,700	54,000	39.76	830	1,300	39,000	7,700	**6.27%**
	% diff	0.00%	3.64%	3.75%	1.21%	0.00%	2.60%	5.33%	
	p-value	0.163	0.192	0.329	0.488	0.180	0.051	0.408	
	TV violated?	No	No	No	No	No	No	No	**Yes**
WQSP-5	primary	1,070	14,500	49.08	332	565	11,200	4,750	**7.87%**
	duplicate	1,100	15,000	49.00	329	568	11,300	5,280	**5.97%**
	% diff	2.76%	3.39%	0.16%	0.91%	0.53%	0.89%	**10.57%**	
	p-value	0.452	0.172	0.501	0.563	**0.001**	**0.005**	0.541	
	TV violated?	No	No	No	No	**Yes**	No	**Yes**	**Yes**
WQSP-6	Primary	680	4,420	50.76	157	213	4,250	4,350	**5.32%**
	duplicate	693	4,470	50.80	157	212	4,350	4,280	**6.34%**
	% diff	1.89%	1.12%	0.08%	0.00%	0.47%	2.33%	1.62%	
	p-value	0.940	**0.000**	0.127	0.301	0.851	0.922	0.086	
	TV violated?	No	No	No	No	No	No	No	**Yes**

2.3.1.2.2 WQSP-2

All ion concentrations in WQSP-2 water samples resulted in a p-value greater than 0.05. The CBE for the primary and duplicate analyses were both within the tolerated ± 5% range. The primary and duplicate sample chemistries were within 10% of each other.

2.3.1.2.3 WQSP-3

All ion concentrations in WQSP-3 water samples resulted in a p-value greater than 0.05 except for chloride. This is not a TV violation because this has not occurred three times in a row. The CBE for the primary and duplicate analyses were both outside the tolerated ± 5% range. The primary and duplicate sample chemistries were within 10% of each other.

Information Only

2.3.1.2.4 WQSP-4

All ion concentrations in WQSP-4 water samples resulted in a p-value greater than 0.05. The CBE for the primary analysis was within the tolerated ± 5% range but the duplicate analysis was above 5%. The primary and duplicate sample chemistries were within 10% of each other.

2.3.1.2.5 WQSP-5

All ion concentrations in WQSP-5 water samples resulted in a p-value greater than 0.05 except for magnesium and sodium. The magnesium value is a TV violation because this has occurred more than three times in a row. The sodium value is not a TV violation because this has not occurred three times in a row. The remaining ion concentrations in WQSP-5 water samples resulted in a p-value greater than 0.05. The CBE for the primary and duplicate analyses were both above the tolerated ± 5% range. The primary and duplicate sample chemistries were within 10% of each other, except for sulfate which had a difference greater than 10%.

2.3.1.2.6 WQSP-6

All ion concentrations in WQSP-6 water samples resulted in a p-value greater than 0.05 except for chloride. This is not a TV violation because this has not occurred three times in a row. The CBE for the primary and duplicate analyses were both above the tolerated ± 5% range. The primary and duplicate sample chemistries were within 10% of each other.

2.3.1.3 Assessment of Culebra Water Quality Data

A common method of visually assessing water-quality stability is through the use of Piper diagrams, which illustrate the relative proportions of three cation and three anion concentrations (four cations are treated by combining sodium and potassium together). By plotting the ion ratios for every round (including outliers thrown out in the calculation of confidence intervals presented in Table 2.13), we can visually assess water quality trends. Piper diagrams of Culebra water chemistry (Figure 2.17) over the course of the WQSP (now 20+ years) show that the groundwater is quite stable, with results for each well continually plotting within relatively small envelopes.

As shown in Table 2.14, CBEs were calculated for the primary and duplicate samples for WQSP 1-6. As mentioned in a previous COMPs report (SNL 2012), 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 within the calibration range of the instrument. Dilution of the samples introduces error, which can cause results to be less precise. The number of CBEs outside of tolerance increased this year from 6 to 7; this also is similar to the number of CBEs outside of tolerance reported between 2018-2021. Sandia National Laboratories will continue to monitor the CBE trend and contact the M&OC and HEAL to review the laboratory-based protocols if the number of out of tolerance CBEs greatly increases. If future analyses

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reveal a trend of out of compliance CBEs, SNL may investigate the possibility of evaluating additional constituents or the occurrence of ion complexation as part of the CBE calculation.

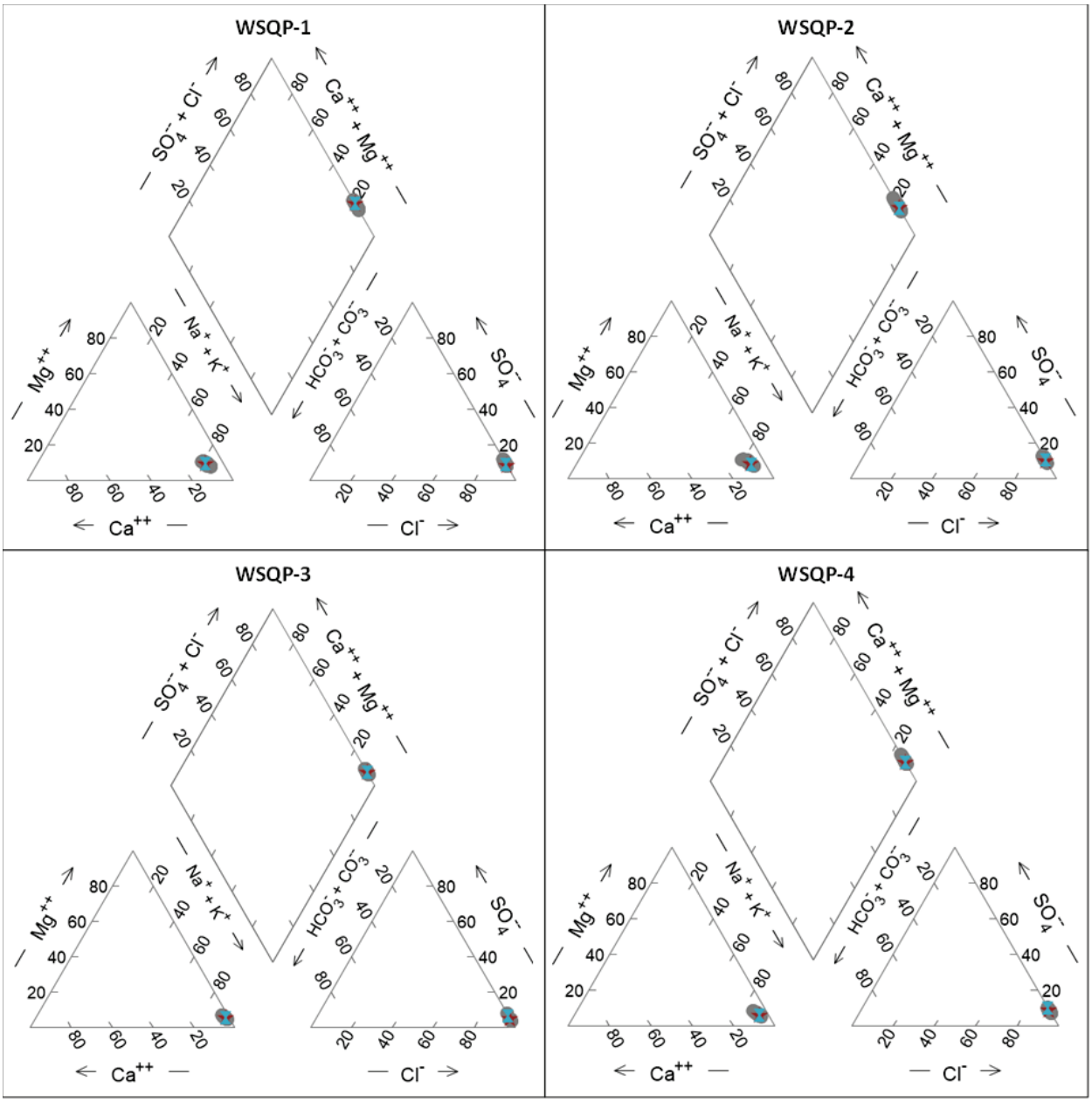

Figure 2.17. Piper diagrams of all data collected from WQSP-1 through WQSP-4. The plots show both historical data (gray) and results from Round 45 (red diamonds and blue hourglasses).

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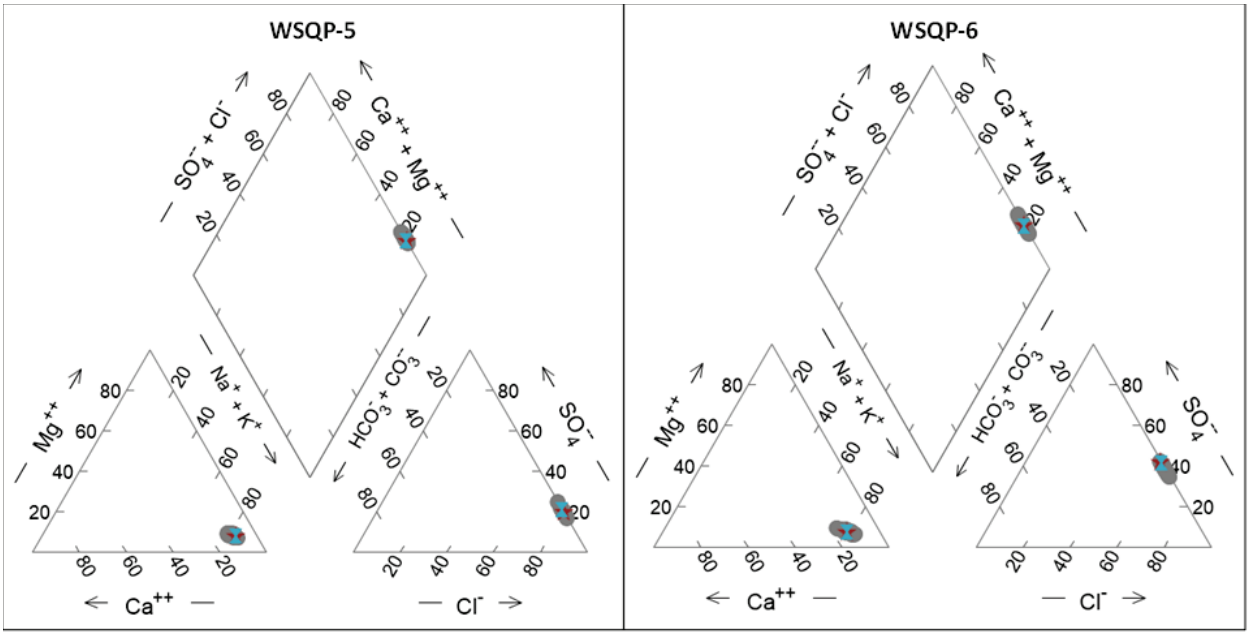

Figure 2.17 cont. Piper diagrams of all data collected from WQSP-5 through WQSP-6. The plots show both historical data (gray) and results from Round 45 (red diamonds and blue hourglasses).

2.3.2 Changes in Groundwater Flow (Water Level)

Table 2.15 summarizes data and TV information relating to the COMP 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-2014 (e.g., Hart et al. 2009; U.S. DOE 2014b), while annual model results are adjusted to best-fit freshwater heads observed in 2023 (U.S. DOE 2024b).

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 2023 the M&OC made monthly water-level measurements in all the WIPP non-perched anthropogenic water (PAW) monitoring network wells (see Figure 2.15 and Table 2.17), or quarterly in any redundant wells (i.e., six of the seven H-19b wells). As of December 2023, the WIPP monitoring network consisted of 57 monitoring wells (including one dual-completion Magenta/Culebra well, see Table 2.16). There were 42 wells with completions in the Culebra Member of the Rustler Formation (hereafter referred to as Culebra), 13 with completions to the

Information Only

Magenta Member of the Rustler Formation (hereafter referred to as Magenta), two with completion to the Bell Canyon Formation, and one to the Dewey Lake Formation.

Table 2.15. Data and TV information for Changes in Groundwater Flow – 2024.

COMP Title:	Changes in Culebra Groundwater Flow
COMP Units:	Inferred from water-level data
COMP Derivation Procedure: (Data acquired between December 2022 and December of 2023)	Annual assessment from ASER 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

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 (2010).	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	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.

Information Only

Table 2.16. December 2023 non-PAW WIPP groundwater monitoring network.

Well	Pad[1]	Completion[2]
AEC-7R	AEC-7	CUL
C-2737	C-2737	CUL/MAG DUAL
CB-1	CB-1	BC
DOE-2	DOE-2	BC
H-2b1	H-2b	MAG
H-3b1	H-3	MAG
H-4bR	H-4	CUL
H-4c	H-4	MAG
H-5bR	H-5	CUL
H-6bR	H-6	CUL
H-6c	H-6	MAG
H-8a	H-8a	MAG
H-9c	H-9	MAG
H-9bR	H-9	CUL
H-10a	H-10	MAG
H-10cR	H-10	CUL
H-11b2	H-11b	MAG
H-11b4R	H-11b	CUL
H-12R	H-12	CUL
H-14	H-14	MAG
H-15R	H-15	CUL
H-15	H-15	MAG
H-16	H-16	CUL
H-18	H-18	MAG
H-19b0	H-19b	CUL
H-19b2	H-19b	CUL REDUN
H-19b3	H-19b	CUL REDUN
H-19b4	H-19b	CUL REDUN
H-19b5	H-19b	CUL REDUN
H-19b6	H-19b	CUL REDUN
H-19b7	H-19b	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-11R	WIPP-11	CUL
WIPP-18	WIPP-18	MAG
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	WQSP-6	DL

[1]Pad names used in Figure 2.15
[2]Well completion codes are as follows:
BC: Bell Canyon Formation
CUL: Culebra Member of the Rustler Formation
MAG: Magenta Member of the Rustler Formation
DL: Dewey Lake Formation
DUAL: dual-completion well
REDUN: redundant well (quarterly water levels)

Information Only

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 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-2000 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., transmissivity, storativity, and anisotropy) and is based upon a peer-reviewed conceptual model of Culebra geology (Section 8.2 of U.S. EPA 2010). The model is calibrated to both steady-state freshwater heads and transient pumping test drawdown data. The contour map shown in Figure 2.18 shows the area immediately around the WIPP LWB, 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 Preparation of Culebra Potentiometric Surface Contour Maps, and the results of following the procedure along with detailed narrative descriptions are given in the Analysis Report: Analysis Report for Preparation of the 2023 Culebra Potentiometric Surface Contour Map (Akara 2024). This material is summarized in the 2023 ASER, Section 6.2.5 (U.S. DOE 2024b).

2.3.2.3 Culebra Freshwater-Head Results and Assessment

Table 2.17 shows the 2023 freshwater heads reported and used in the development of the Culebra contour map given in the 2023 ASER (U.S. DOE 2024b). The particle track shown as a black dotted arrow in Figure 2.18 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 (6,583 years) is compared to the distribution of 100 travel times computed for the CRA-2014 PA. The ensemble-average travel time also falls inside the predicted CRA-2009 Performance Assessment Baseline Calculation (PABC) range (see red points in Figure 2.19). Please note that CRA-2009 and 2014 PA are all based on the same 100 T-fields. The estimated flow velocity of 0.60 m/yr is similar to the reported 2022 velocity of 0.73 m/yr, and the 2021 reported flow velocity of 0.67 m/yr. Since the flow model has the ensemble hydraulic conductivity and anisotropy fields as inputs, the freshwater head contours and particle track take into account the variability of aquifer

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conditions across the site that are consistent with the calibration data used to derive the T-fields.

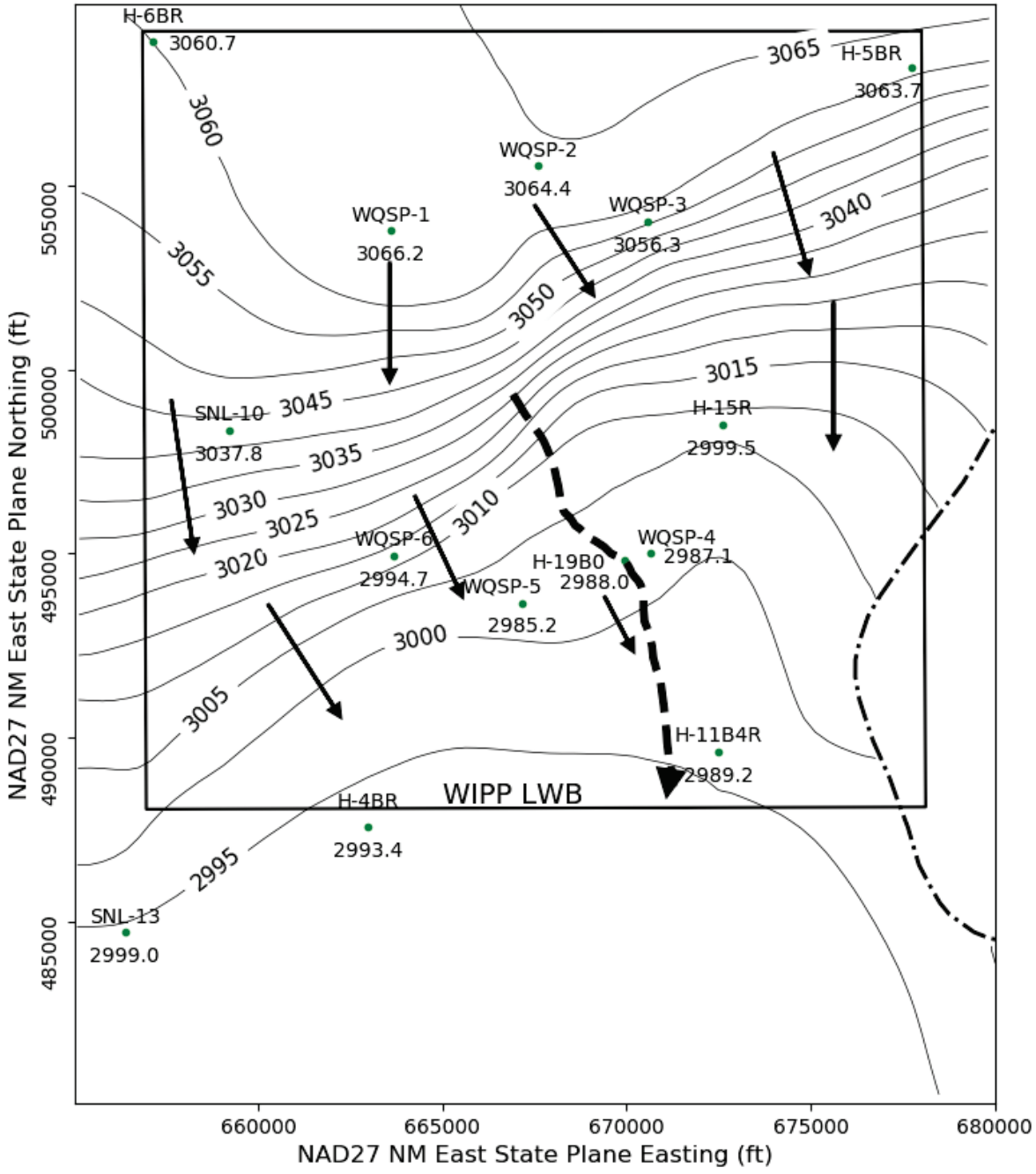

Figure 2.18. The 2023 modeled Culebra potentiometric surface of the immediate WIPP vicinity (Akara 2024) generated using ensemble average distributed aquifer parameters from the SNL Culebra flow model used in CRA-2014 and CRA-2019 PA (U.S. DOE 2014b, U.S. DOE 2019).

Information Only

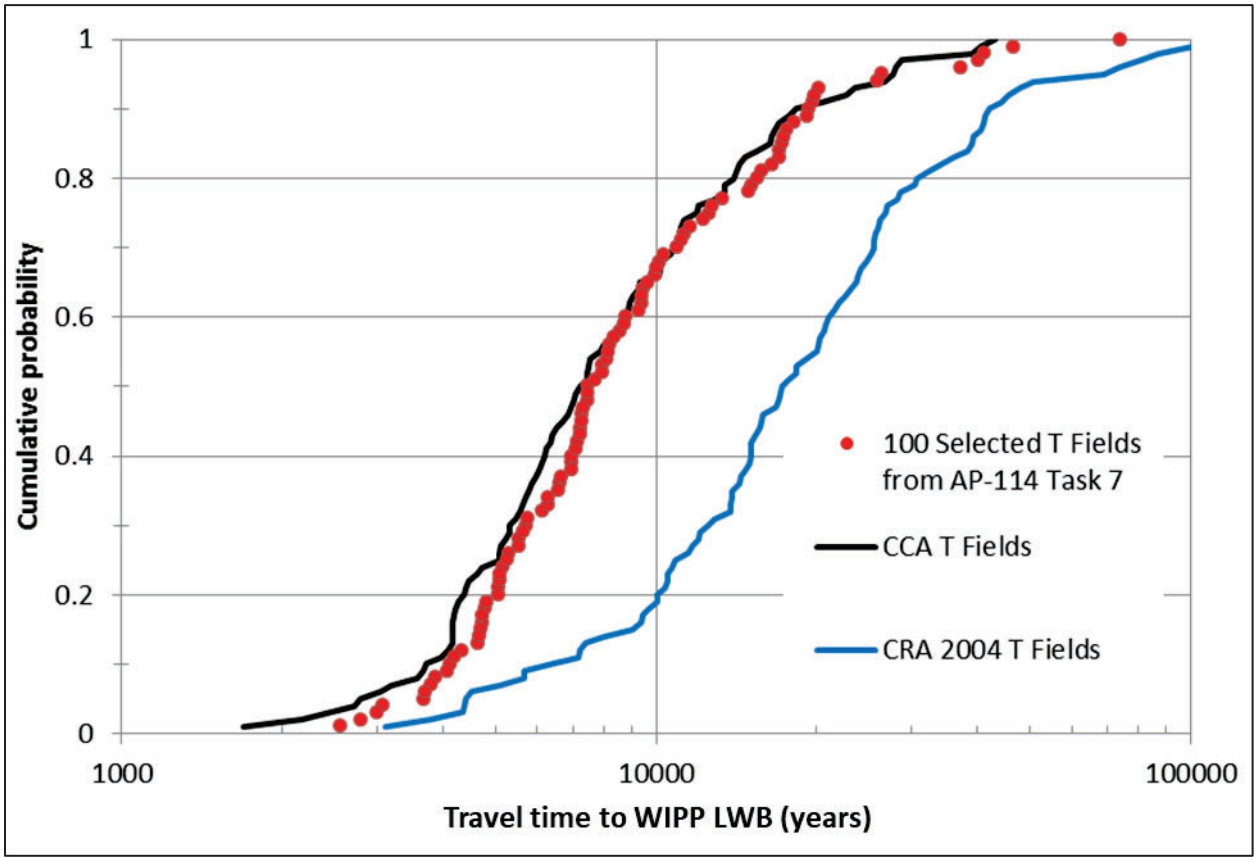

Figure 2.19. Distribution of particle travel times from the center of the WIPP waste panels to WIPP LWB for CCA (black line), CRA-2004 (blue line), and CRA-2009 PABC (red points). Figure from Hart et al. (2009).

Table 2.17. Summary of 2023 Culebra freshwater heads (Akara 2024).

Well	Measurement Date	Freshwater Head (ft. AMSL)	Specific Gravity
AEC-7R	12/5/2023	3061.08	1.072
C-2737	12/6/2023	2976.12	1.027
H-4bR	12/4/2023	2993.41	1.021
H-5bR	12/5/2023	3063.68	1.091
H-6bR	12/6/2023	3060.69	1.040
H-9bR**	12/4/2023	2971.92	1.004
H-10cR	12/4/2023	3039.37	1.092
H-11b4R	12/4/2023	2989.16	1.080
H-12R**	12/4/2023	3004.20	1.105
H-15R	12/6/2023	2999.50	1.127
H-16**	12/6/2023	2944.20	1.033
H-19b0	12/4/2023	2988.04	1.067

Information Only

Well	Measurement Date	Freshwater Head (ft. AMSL)	Specific Gravity
IMC-461	12/6/2023	3033.24	1.004
SNL-1	12/5/2023	3073.29	1.034
SNL-2	12/5/2023	3060.99	1.009
SNL-3	12/5/2023	3069.12	1.027
SNL-5	12/5/2023	3061.63	1.008
SNL-6*	12/5/2023	3485.85	1.263
SNL-8	12/5/2023	3054.93	1.092
SNL-9	12/6/2023	3044.29	1.017
SNL-10	12/6/2023	3037.82	1.005
SNL-12	12/4/2023	2986.89	1.014
SNL-13	12/4/2023	2999.01	1.027
SNL-14	12/4/2023	2986.24	1.048
SNL-15*	12/4/2023	3120.85	1.230
SNL-16	12/4/2023	3006.89	1.020
SNL-17	12/4/2023	3001.82	1.001
SNL-18	12/5/2023	3061.92	1.002
SNL-19	12/5/2023	3061.56	1.006
WIPP-11R	12/6/2023	3064.93	1.025
WQSP-1	12/6/2023	3066.20	1.056
WQSP-2	12/5/2023	3064.35	1.033
WQSP-3	12/5/2023	3056.31	1.141
WQSP-4	12/6/2023	2987.11	1.070
WQSP-5	12/6/2023	2985.16	1.024
WQSP-6	12/6/2023	2994.70	1.010

* Water levels have not fully recovered from original drilling
** Water levels impacted by oil field activities and shaft activities

2.3.2.4 Interpretation/Summary of the 2023 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 with low flow velocities across the WIPP modeling domain (Hart et al. 2009). The basis of the assessment of the groundwater flow COMP is the computed travel time and potentiometric surface map of the Culebra (Figure 6.4 of U.S. DOE 2024b). The map was generated using the Culebra flow model developed by the Scientific Advisor for performance assessment associated with CRA-2014 and CRA-2019 PA and Culebra Heads from December 2023 and is consistent with the historical general north to south gradient.

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The ensemble-averaged model predicted travel time for a particle of 6,583 years currently falls within the range modeled for 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.

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 2.18) 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.

Table 2.18. Summary of 2018 to 2023 water-level changes in non-Culebra units.

Well	Formation	Feb 2018 Water Level Elevation (m AMSL)	Feb 2019 Water Level Elevation (m AMSL)	Feb 2020 Water Level Elevation (m AMSL)	Feb 2021 Water Level Elevation (m AMSL)	Feb 2022 Water Level Elevation (m AMSL)	Feb 2023 Water Level Elevation (m AMSL)	2023-2022 Water Level Change (m)
C-2737	Magenta	961.65	962.03	961.89	961.50	960.93	959.85	**-1.08**
H-2b1	Magenta	959.32	959.93	960.27	960.20	960.01	959.64	-0.37
H-3b1	Magenta	962.36	962.69	962.47	962.04	961.50	960.98	-0.52
H-4c	Magenta	959.71	959.8	959.55	959.09	958.58	958.32	-0.26
H-6c	Magenta	936.12	936.07	935.84	935.37	934.93	934.20	**-0.73**
H-8a	Magenta	923.1	922.98	922.88	922.66	923.62	924.28	**0.66**
H-9c	Magenta	955.71	956.09	957.87	959.31	959.61	959.57	-0.04
H-10a	Magenta	948.54	948.1	947.78	947.64	947.63	947.57	-0.06
H-11b2	Magenta	959.41	959.62	959.3	958.94	958.62	958.39	-0.23
H-14	Magenta	957.6	957.76	957.78	957.58	957.42	957.16	-0.26
H-15	Magenta	966.26	965.67	964.67	964.23	963.59	962.94	**-0.65**
H-18	Magenta	963.47	963.72	963.8	963.65	963.40	963.05	-0.35
WIPP-18	Magenta	964.69	964.86	964.53	963.94	963.29	962.71	-0.58
WQSP-6A	Dewey Lake	973.99	974.01	973.91	974.01	973.96	974.06	0.1
CB-1	Bell Canyon	926.33	927.86	929.14	930.31	931.61	932.74	**1.13**
DOE-2	Bell Canyon	935.47	935.68	935.85	935.99	936.17	936.39	0.22

Bold = absolute changes in water level ≥ 0.61 m (2.0 ft)
NA = well not accessible for water level measurement

February 2023 was chosen as the period for reporting water level data from non-Culebra units to make a consistent year to year comparison. Water-level changes in the Magenta ranged from -1.08 to 0.66 m, with four wells experiencing water-level change ≥ 0.61 m (2.0 ft). Continuous pressure measurements confirm that the changes in water level in well C-2737, H-6c, and H-15 are gradual and not the result of a transient process; however, H-8a is from a transient process and the water level returned to the 02/2022 level by 09/2023.

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Water-levels in the Bell Canyon well CB-1 increased 1.13 m between February 2021 and February 2022. Continuous pressure measurements confirm that the changes in water level in well CB-1 are gradual and not the result of a transient process. Water levels in DOE-2, the other Bell Canyon well, are no longer increasing.

2.4 Waste Activity COMP

Table 2.19 summarizes data and TV information relating to the COMP 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, 2024. A comparison of the tracked actinides and the total expected repository inventory used in the CRA-2019 is detailed in Table 2.20. No other activity-related assessment has been made at this time.

There are no TVs for CH-TRU activity, only remote-handled (RH) TRU waste activity. The TV for RH-TRU waste is the regulatory limit of 5.1 million curies. The total curies of RH waste for the period ending June 30, 2024, is 2.4×10^4 curies, well below the TV. There are no recognized reportable issues associated with this COMP. No changes to the monitoring program are recommended currently. A detailed waste inventory assessment has been provided in the CRA-2019 (U.S. DOE 2019).

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-2019 (U.S. DOE 2019) contains the results of the most recent PA submitted to the EPA that has been reviewed and certified[3]. Therefore, the CRA-2019 represents the latest compliance baseline. 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.

[3] WIPP was initially certified as a 10-panel repository for long-term waste disposal, which served as the design layout and basis for the CRA-2019 PA. Due to operational constraints, not all this volume is available for waste disposal. In March 2024 the DOE submitted the Replacement Panels Planned Change Request (RPPCR) seeking EPA approval of two replacement waste disposal panels. The RPPCR also considered the excavation of up to seven panels beyond the two replacement panels, defined as additional panels, to provide the additional disposal capacity needed to reach the legislated WIPP waste volume limit. After the CRA-2019 PA, a compliance-level calculation known as the RPPCR PA was executed to quantify the long-term performance of the repository with the replacement and additional panels.

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Table 2.19. Waste Activity – 2024.

COMP Title:	Waste Activity
COMP Units:	Curies
COMP Assessment Process: (Reporting Period July 1, 2023, to June 30, 2024)	Total curie content of emplaced CH-TRU and RH-TRU waste. Total radionuclide inventories are reported by the Waste Data System (WDS).
COMP Assessment Value:	A comparison of emplaced and PA waste parameters is found in Table 2.20.

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
WDS	Radionuclide activity per container and volume	Curies, volume	TRU waste inventory for the 2019 Compliance Recertification Application (Van Soest 2018)

Related Performance and Compliance Elements

Element Title	Type and ID	Derivation Procedure	Compliance Baseline	Impact of Change
Radionuclide inventories	Parameter FEP W2 "Waste Activity"	Product of waste stream content and volume scaled up to the Land Withdrawal Act limits. (U.S. Congress 1992)	Table 6-1 of Van Soest 2018	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 FEP W84 "Cuttings" FEP W85 "Cavings"	Function of waste stream volumes and activities	Van Soest 2018	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 FEP W86 "Spallings"	Average of all CH-TRU waste only.	Van Soest 2018	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 Thomas 2016)
Total emplaced RH-TRU waste activity	5.1 million curies	LWA emplacement limit reached. Administrative controls address these limits.

Information Only

Table 2.20. Comparison of tracked radionuclide inventory to the CRA-2019 inventory.

Radionuclide [a]	Non-Decayed Total Activity as of June 30, 2023 (curies) [b]	Non-Decayed CH Inventory as of June 30, 2024 (curies) [c]	Non-Decayed RH Inventory as of June 30, 2024 (curies) [c]	Non-Decayed Total Activity as of June 30, 2024 (curies) [d]	CRA-2019 Total Inventory at Closure (2033) (curies) [e]
^{241}Am	2.838E+05	2.938E+05	6.731E+02	2.945E+05	1.14E+06
^{137}Cs	1.450E+04	2.658E+01	1.449E+04	1.451E+04	2.51E+05
^{238}Pu	5.370E+05	5.538E+05	8.014E+02	5.546E+05	9.65E+05
^{239}Pu	3.614E+05	3.825E+05	4.157E+02	3.829E+05	8.74E+05
^{240}Pu	8.949E+04	9.445E+04	2.913E+02	9.474E+04	3.19E+05
^{242}Pu	3.032E+01	3.087E+01	3.835E-01	3.125E+01	1.64E+02
^{90}Sr	7.753E+03	1.365E+02	7.629E+03	7.766E+03	1.97E+05
^{233}U	2.304E+01	2.752E+01	3.848E-01	2.790E+01	1.27E+02
^{234}U	9.725E+01	1.006E+02	1.232E-01	1.007E+02	4.87E+02
^{238}U	2.007E+01	2.312E+01	3.929E-02	2.316E+01	4.23E+01
Total	**1.294E+06**	**1.325E+06**	**2.430E+04**	**1.349E+06**	**3.75E+06**

(a) Radionuclides requiring quantification are identified in Table 4-10 of U.S. DOE 1996.
(b) 2023 total activity for emplaced radiological activity inventory from Table 3 of U.S. DOE 2023b.
(c) Calculated using 2023 COMPs data and 2024 reporting period data for emplaced radiological activity inventory from Table 3 of U.S. DOE 2024c.
(d) 2024 total activity for emplaced radiological activity inventory from Table 3 of U.S. DOE 2024c.
(e) CRA-2019 inventory from Table 6-1 of Van Soest 2018.

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