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# Trigger Value Derivation Report

**Revision 3**

WBS 4.3.1
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# Trigger Value Derivation Report

**WBS 4.3.1**

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|---|---|---|
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# Revision History

## Revision 1

Modifications made in revision 1 of this document include:

The revision reassessed the Trigger Values (TVs) and made minor editorial changes. The Change in Groundwater Composition Compliance Monitoring Parameter (COMP) TV was modified. The TV included the provision that both duplicate analyses for major ions must fall outside of the 95% confidence range for three consecutive samples before the TV is exceeded. The revision also recognized that the Change in Culebra Groundwater Flow COMP results showed the TV being exceeded. Additional groundwater investigations were initiated and a future revision to the TV was expected. No changes were made to the TV. The revision also recognized that the Drilling Rate COMP would be exceeded in a few years and that the TV should be reassessed at that time.

## Revision 2

Modifications made in revision 2 of this document include:

The TVs for the Drilling Rate, Extent of Deformation Features and Displacement of Deformation Features were removed. The assessment period for the Waste Activity TV was revised to be assessed annually. The derivation method for the Change in Culebra Groundwater Flow TV was revised and a new TV was developed. No changes were made to the remaining TVs. Minor editorial changes were also made to the text.

## Revision 3

Modifications made in revision 3 of this document include:

The derivation method for the Culebra Groundwater Composition TV was revised and a new TV was developed. No changes were made to the remaining TVs. Minor editorial changes were also made to the text.

# Preface

This report is the third revision to the trigger value (TV) derivation report last published in 2010 (Wagner and Kuhlman, 2010). TVs are used in the compliance monitoring program as an indicator of conditions that may require further actions should a compliance monitoring program parameter's TV be exceeded. As the Waste Isolation Pilot Plant (WIPP) project knowledge advances with the maturing monitoring program, the basis for TVs may also change. Fifteen years of compliance monitoring results, performance assessment (PA) improvements and new PA results indicate that some of the original monitoring parameter TVs are no longer justified and in some cases are no longer useful. As PA expectations and results change, corresponding TVs must be updated to align them with expected conditions predicted or assumed in the latest baseline PA. Therefore, this TV report is being revised to account for these conditions and assign new TVs where needed.

The evaluations documented in the previous TV revision and repeated in this report were conducted to derive the TVs that are used to support the annual compliance monitoring parameter (COMP) assessment and reporting of compliance-related monitoring data to the Environmental Protection Agency (EPA). The monitoring data are first used by the Scientific Advisor (SA) to derive COMPs which are then evaluated against PA expectations. The concept of deriving and using TVs is explained in Sandia National Laboratories (SNL) Activity/Project Specific Procedure, SP 9-8 titled "Monitoring Parameter Assessment per 40 CFR §194.42" (Wagner 2008). The perceived impact on PA conceptual models was used as the first-order basis for TV derivation. It should be noted that the term "Trigger Value" can represent events, trends, criteria, rates, probabilities, ranges, conditions, or a specific value. In some cases, no specific values are assigned because the monitoring parameters have been proven to be insensitive to the long-term performance of the repository. However, the monitoring parameter may still have an impact on feature, event and process (FEP) screening, modeling assumptions, or some other important repository factor. Because the monitoring program will continue to gather information and experience relating to the WIPP disposal system, periodic assessments of TVs and COMPs have been planned to continue over the WIPP operational period. This third revision revisits TVs to assess the validity and usefulness of the values using the latest information and project knowledge. This assessment results in a more robust monitoring program and is a precursor to the periodic assessment of the entire compliance monitoring program.

The SA is committed to analyze the COMPs annually, as outlined in the DOE's 40 CFR Part 191 and 194 Compliance Monitoring Implementation Plan (DOE 2014a) and SP 9-8 (Wagner, 2008), to determine if the monitoring program output indicates a potentially significant impact on repository performance or unexpected conditions. The annual assessment of each COMP is documented in the records package entitled "Sandia National Laboratories Compliance Monitoring Parameter Assessment (records package ERMS 510062)."

There are ten COMPs used in the compliance monitoring program. These parameters are:

1. Drilling Rate
2. Probability of Encountering a Castile Brine Reservoir

3. Waste Activity
4. Subsidence Measurement
5. Changes in Culebra Groundwater Flow
6. Culebra Groundwater Composition
7. Creep Closure
8. Extent of Deformation
9. Initiation of Brittle Deformation
10. Displacement of Deformation Features

Of these, the following summarizes the TVs that were updated within this revision of the TV report. The remainder of the COMP's TVs were not changed.

***Culebra Groundwater Composition***
The Culebra Groundwater Composition TV has been modified due to the ongoing occurrence of false positive water-quality composition fluctuations. The number of measurements incorporated into the water-quality baseline estimates has been increased by 250%. 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 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 for a given constituent is less than or equal to 0.05 for three consecutive sampling rounds, a TV violation is reported and investigated.

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# 1.0 Compliance Monitoring Parameters

The compliance monitoring program uses ten monitoring parameters and was first described in the Compliance Certification Application (CCA) (DOE 1996). This program continues to monitor the ten monitoring parameters or COMPs. The Trigger Values (TVs) for the ten COMPs were assessed in the first TV determination report. The ten COMPs are:

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

The process for deriving TVs for each COMP is outlined in SP 9-8 and contains five basic steps. These steps are outlined in Appendix A of SP 9-8 (Wagner, 2008), which has been reduced to the following:

**Step 1**
Define the procedure for deriving COMPs.
Define the COMP-related monitoring data characteristics (i.e., what is actually measured/ observed and reported).

**Step 2**
Map COMP-related data to:

- Performance Assessment parameters
- Feature, Event and Process screening arguments
- Conceptual models
- Model assumptions

Define data handling procedures used to process COMP data for Performance Assessment (PA) purposes. Generate COMP Table with the information listed above.

**Step 3**
Use relationships identified in Steps 1 and 2 to identify COMP-related data that were used to support the latest compliance application PA (termed the Compliance Baseline). Define the Compliance Baseline for these COMPs and monitoring data in the context of the PA element(s) derived from them. When reassessing the COMPs, this step should use the latest PA information.

**Step 4**
Use previous project experience (sensitivity analyses, the 40 CFR §194.42 monitoring analysis, etc.) to compile a list of potential impacts that changes in the PA elements identified in Step 2 above have on the predicted performance of the disposal system.

**Step 5**
Derive TVs for COMP-related monitoring data. TVs will represent deviations from the Compliance Baseline determined in Step 3. Exceedance of TVs could lead to either a significant impact on the performance of the disposal system, as determined in Step 4, or may simply indicate variances within modeling assumptions, or conceptual and/or numerical models (not within PA expectations).

**Reassessment of Trigger Value Process**

The original process to derive TVs is also used to reassess the TVs for this third revision of the report. Each step is reviewed to determine if the original conclusions are still valid. If a TV is changed, deviations and justification for the change are documented. It is expected that TVs will be reassessed periodically, which necessitates a method to track the history of TV changes. Table 5.1 (TV Revision Log) documents the TV change history.

# 2.0 Step 1 – Define the Procedure for Deriving COMPs

Define the procedure for deriving each COMP and define the monitoring data characteristics. The CCA (DOE 1996) was originally used to generate the information compiled in Table 1.1.

### Table 1.1 Step 1 COMP Derivation and Data Characteristics Table

| COMP | Procedure for Deriving COMP | Data Characteristics |
|---|---|---|
| Drilling Rate | Using information available from the WIPP Delaware Basin Monitoring Program determine on an annual basis, the total number of deep (> 2,150 feet) boreholes drilled in the Delaware Basin during the 100-year period immediately preceding the current derivation period and calculate a drilling rate based on the area of the Basin and the regulatory time period (i.e., 10,000 years). Specifically, the rate equals the total number of deep boreholes drilled/100 years) x (10,000 years/23,102.1 square kilometers). . | The Delaware Basin Monitoring Program is implemented by the WIPP Management and Operating Contractor (M&O) and collects data from DOE-qualified commercial sources and government agencies including the Midland Map Company, Petroleum Information Incorporated, Whitestar, Bureau of Land Management, Texas Railroad Commission, and the New Mexico Oil Conservation Division. Deep boreholes are defined as those greater than 2,100 feet deep drilled in the Delaware Basin for purposes of hydrocarbon, sulfur and potash evaluation/ exploitation, deep stratigraphic investigations and any other relevant deep boreholes. The Delaware Basin is defined as those surface and subsurface features which lie inside the boundary formed to the north, east and west of the WIPP disposal system, by the innermost edge of the Capitan Reef, and formed, to the south, by a straight line drawn from the southeastern point of the Davis Mountains to the most southwestern point of the Glass Mountains. |
| Probability of Encountering a Castile Brine Reservoir | Using information available from the WIPP Delaware Basin Monitoring Program determine on an annual basis, the number of intercepts of pressurized brine encountered in the Castile Formation in the 9-township area centered on WIPP and reported by industry. | Qualitative probability. As described above, the Delaware Basin Monitoring Program is implemented by the M&O and collects data on drilling activities within the Basin from several sources. The primary source of data for this COMP is from surveys submitted to commercial drillers. Since the drillers are not required to report brine encounters, their responses to the surveys requesting information on brine encounters in the Castile are voluntary. |
| Waste Activity | Waste activity derived from data entered into the WIPP Waste Data System (WDS) by generator sites for all waste shipped to WIPP. Data calls are periodically made to compile the information for ten radionuclides, cellulosics, plastics and rubbers and any other information provided by the generator sites. | Data are a compilation from generator sites. Radionuclide curie content is derived from process knowledge and radioassay. The M&O Data Administrator oversees the data system. Activity is tracked using the WDS. |

**Table 1.1 Step 1 COMP Derivation and Data Characteristics Table (Continued)**

| COMP | Procedure for Deriving COMP | Data Characteristics |
|---|---|---|
| Subsidence Measurement | Using information available from the WIPP Subsidence Monitoring Program, changes in elevation (vertical displacement) are determined from annual leveling surveys performed over a network of monuments located at the ground surface above and around the WIPP surface footprint. For each monument, incremental and total elevation changes are determined for the current year and for the time period since the monument was installed, respectively. Annualized subsidence rates (meters/year) are also determined by dividing the incremental elevation changes by the observation period (i.e., 1 year). | The WIPP Subsidence Monitoring Program is implemented by the M&O and collects data annually through a Second-Order Class II loop survey with a closure accuracy of 8 mm × √km or better. The annual survey includes traverses over ten leveling loops comprising approximately 60 monuments and National Geodetic Survey vertical control points. Elevations are referenced to Monument S-37 located ~ 7,700 ft north of the most northerly boundary of the WIPP underground excavations. Vertical closure errors for each loop are proportioned to the monuments within each loop based on the number of instrument setups and the horizontal distance between adjacent monument points. |
| Changes in Culebra Groundwater Flow | Changes in groundwater flow, both rate and direction, are observed through changes in hydraulic head. Using the information from the WIPP Groundwater Monitoring Program, the depth to water measurements taken monthly in the Culebra wells are corrected for water density and combined with ground surface elevations to derive equivalent freshwater elevations (heads) at the specified well locations. The ensemble average of 100 calibrated Culebra groundwater model realizations are matched to each year's observed heads. The predicted travel times are compared for particles in both the original 100 PA flow model runs and the head-matched ensemble average. | The WIPP Groundwater Monitoring Program is implemented by the M&O and collects water level data at least monthly at all primary wells and quarterly at redundant wells (wells located on the same hydropad as a primary well). Water level measurements are made manually using water-level sounders or with pressure transducers. As part of the Groundwater Monitoring Program, pressure-density surveys are conducted on a routine basis to establish current water densities for use in calculating freshwater heads. The 100 realizations of the Culebra flow model constructed for PA incorporate geologic data, estimated values of transmissivity, and are calibrated to observed large-scale well test results; see (Kuhlman 2010). |
| Culebra Groundwater Composition | Culebra groundwater composition data are derived directly from the WIPP Groundwater Monitoring Program. Major ionic species evaluated include $Na^+$, $Ca^{2+}$, $Mg^{2+}$, $K^+$, $Cl^-$, $SO_4^{2-}$ and $HCO_3^-$. Ion concentrations for these species are reported in units of mg/L. The randomization test is used to determine whether or not an ion concentration treatment group (i.e., sampling round of interest) is statistically significant compared to the ion concentration control group (i.e., sampling rounds 1- 35). For a given sampling round, a p-value is calculated for each constituent, for each well, totaling 42 values. If the p-value is less than or equal to 0.05 for three consecutive sampling rounds, a TV violation will be reported and investigated. | The WIPP Ground Water Monitoring Program, as implemented by the M&O, collects water-quality data on a semi-annual basis from wells WQSP (Water Quality Sampling Program) 1-6. Duplicate analyses are performed on samples recovered for each sampling round. Analyses determine the concentrations of all analytes referenced in the WIPP Hazardous Waste Facility Permit and approximately 20 other chemicals and metals. Analytes include major ion concentrations hazardous chemical and radionuclide concentrations. |

**Table 1.1 Step 1 COMP Derivation and Data Characteristics Table (Continued)**

| COMP | Procedure for Deriving COMP | Data Characteristics |
|---|---|---|
| Creep Closure | Using information available directly from the annual WIPP Geotechnical Analysis Report (GAR), current creep closure rates recorded along monitored WIPP openings (e.g., shafts, experimental areas, waste emplacement rooms and haulage drifts) are compared to the previous year's listed rate. | The WIPP Geotechnical Monitoring Program is implemented by the M&O and collects both geomechanical and hydrological data from an extensive array of instruments. Instrumentation installed for measuring the response of shafts, drifts, and other WIPP openings includes convergence points, convergence meters, extensometers, rockbolt load cells, pressure cells, strain gauges, piezometers and joint meters. Data are acquired both manually and automatically using electronic data acquisition systems. Visual inspection and mapping of exposed surfaces around openings also supplement the quantitative data. Relates to mine operational ground control monitoring. |
| Extent of Deformation | Using information available from the annual WIPP GAR, extent of deformation deduced from borehole extensometers, feeler gauges, and visual inspections are examined yearly for active cross sections Anomalous growth is determined by comparison to previous observations. | As described above, the WIPP Geotechnical Monitoring Program collects both quantitative and qualitative data related to mine operational ground control monitoring issues. Of particular importance to this COMP are the mapping of fractures on exposed surfaces and the projection of these fractures through mapping in observational boreholes. |
| Initiation of Brittle Deformation | Methods and instrumentation needed to quantify the initiation of brittle deformation are not sufficiently advanced to be implemented in the existing WIPP monitoring programs. Therefore, derivation of this COMP is limited to an observational and qualitative assessment of related geotechnical data used to derive other COMPs such as extent of deformation and displacement of deformation features. | Quantitative data for the initiation of brittle deformation is not available from any of the current WIPP monitoring programs; however with time, brittle deformation induces features such as fractures and displacements along deformation features. |
| Displacement of Deformation Features | Using information available from the annual WIPP GAR, displacement of deformation features is derived from measurements of the offsets in observational boreholes drilled normal to common deformation features such as low-angle fractures, clay seams, bedding planes etc. Borehole offset is calculated as the ratio of borehole displacement to the borehole diameter expressed as a percentage. | The WIPP Geotechnical Monitoring Program implemented by the M&O includes visual estimates of borehole offsets where the borehole intersects common deformation features (e.g., low-angle fracture, clay seams, bedding planes etc.). This monitoring is used to assess ground conditions for operational safety. Boreholes are monitored until there is no longer access because of waste emplacement or closure of a panel. Additional boreholes are drilled as new panels are mined. All boreholes are oriented vertically and located in the salt roof. Monitored data relate to mine operational ground control monitoring. |

# 3.0 Step 2 – Map COMPs-Related Data

Step 2 in the process is to map COMP-related data to PA parameters, Feature, Event and Process (FEP) screening arguments, conceptual models, and model assumptions and to define data manipulation procedures used to process COMP data for PA purposes. The results of this step are provided in COMP Table 3.1.

## Table 3.1 COMP Mapping Table

| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter† | | FEP with related Screening Decision† | | Related Modeling Assumption† | | FEP with related Screening text‡ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Geotechnical Monitoring Program (GTMP) | Creep Closure | Elastic properties of halite and anhydrite (e.g., Young's Modulus, shear modulus, Poisson's ratio, specific heat) | N | Mechanical effects of backfill | Y | The amount of creep closure is a function of time, gas pressure, and waste matrix strength | N | Salt creep | Provides validation of the CCA creep closure model. Thermal or backfill effects may be apparent during the operational period |
| | | Creep constitutive model | N | Thermally-induced changes in stress | N | | | Excavation-induced changes in stress | |
| | | Plastic constants for consolidation of the waste/backfill | Y | | | | | Changes in the stress field | |
| | | | | | | | | Pressurization | |
| | | | | | | | | Consolidation of waste | |

† The second column under this heading indicates whether it is likely (Y) or unlikely (N) that the most recent compliance application position on the Parameter, FEP, or Assumption could change due to monitoring program results.

‡ FEPs with related screening text are those FEPs whose screening decision will not be affected by monitoring results, but whose screening discussion in the most recent compliance application may need to be updated in light of any changes related to monitoring results.

§ Parameter is not a COMP but relevant information is being/could be collected as part of the same monitoring program

| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter[†] | | FEP with related Screening Decision[†] | | Related Modeling Assumption[†] | | FEP with related Screening text[‡] | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | Extent of deformation | DRZ parameters (e.g., extent, permeability) | Y | - | - | Drift DRZ has sampled permeability (constant over each realization) | Y | Disturbed rock zone<br><br>Seismic activity (repository-induced) | If the PA DRZ model is modified to account for transient behavior, then this monitoring may have a significant bearing on parameter values and performance assessment |
| | | Intrinsic shaft DRZ permeability | N | | | The shaft is surrounded by a DRZ which heals with time | Y | Roof falls<br><br>Gas explosions | |
| | | | | | | Drift DRZ has constant (very large) size | Y | Underground boreholes<br><br>Consolidation of seals | |
| | Initiation of brittle deformation | Anhydrite fracturing model parameters (e.g., fracture initiation pressure, increment for full fracturing, fracture permeability enhancement) | N | - | - | Initial pressure conditions | N | Disruption due to gas effects | Also has bearing on the behavior of the DRZ (see above for related parameters and FEPs) |
| | | DRZ Properties | Y | | | PA model discretization | N | | |

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| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter† | | FEP with related Screening Decision† | | Related Modeling Assumption† | | FEP with related Screening text‡ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | Displacement of deformation features<br><br>§*Seismic activity* | - | - | Subsidence<br><br>Large-scale rock fracturing<br><br>Fault movement | N<br><br>N<br><br>N | - | | Seismic activity (natural) | Significant subsidence would require development of a new conceptual model |
| | §*Brine sampling and monitoring* | DRZ permeability, effective porosity<br><br>Average Salado brine composition (and source term parameters) | Y<br><br>N | - | - | Initial pressure conditions<br><br>Initial saturation conditions | N<br><br>N | Brine inflow | Sufficient brine samples have been collected to make a change in average brine composition unlikely |

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§ Parameter is not a COMP but relevant information is being/could be collected as part of the same monitoring program

| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter† | | FEP with related Screening Decision† | | Related Modeling Assumption† | | FEP with related Screening text‡ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Ground Water Monitoring Program (GWMP) | Culebra groundwater levels | Culebra transmissivity | N | Density effects on groundwater flow | N | No vertical flow to the Culebra (in the 2-D model) | N | Saturated groundwater flow | Will build confidence in the 3-D groundwater basin modeling of the Rustler. FEPs may only be affected through sudden response to unexpected events. Any adjustments to the 3-D model may also affect PA parameters and assumptions for the other Rustler units |
| | | Fracture and matrix porosity | N | Freshwater intrusion (hydrological effect) | N | Culebra boundary conditions | N | Groundwater recharge | |
| | | Fracture spacing | N | Hydrological response to earthquakes | N | Culebra initial head conditions | N | Groundwater discharge | |
| | | Dispersivity | N | Lake formation | N | | | Infiltration | |
| | | Climate index | N | River flooding | N | | | Changes in groundwater recharge and discharge | |
| | | | | Thermal effects on groundwater flow | N | | | Precipitation | |
| | | | | | | | | Temperature | |

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§ Parameter is not a COMP but relevant information is being/could be collected as part of the same monitoring program

| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter[†] | | FEP with related Screening Decision[†] | | Related Modeling Assumption[†] | | FEP with related Screening text[‡] | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | Culebra brine composition | Average Culebra brine composition | N | Changes in groundwater pH | N | Sorption models account for water chemistry | N | Groundwater geochemistry | Will build confidence in the 3-D groundwater basin modeling of the Rustler. The average Culebra brine composition is not used directly in the PA, but changes in estimates of recharge, redox conditions, etc. may be significant |
| | | Matrix distribution coefficient for U(VI) | N | Changes in groundwater Eh | N | Natural actinide concentrations are zero | N | Actinide sorption | |
| | | Matrix distribution coefficient for U(IV) | N | Freshwater intrusion (chemical effect) | N | No vertical flow to the Culebra (in the 2-D model) | N | Groundwater recharge | |
| | | Matrix distribution coefficient for Pu(III) | N | Effects of dissolution | N | Culebra boundary conditions | N | Changes in groundwater recharge and discharge | |
| | | Matrix distribution coefficient for Pu(IV) | N | | | | N | Infiltration | |
| | | Matrix distribution coefficient for Th(IV) | N | | | | | | |
| | | Matrix distribution coefficient for Am(III) | N | | | | | | |
| Delaware Basin Monitoring Program (DBMP) | Drilling rate | Drilling rate projected over a 10,000 year period derived from drilling occurrences over the past 100 years per unit area | Y | Drilling fluid flow | N | Drilling may occur after 100 years according to a Poisson model | N | - | Average rate will change(increase) as more data become available |

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| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter† | | FEP with related Screening Decision† | | Related Modeling Assumption† | | FEP with related Screening text‡ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | Probability of encountering a Castile brine reservoir | Probability of encountering a Castile brine reservoir | Y | Brine reservoirs | N | Probability of intersecting a brine reservoir | N | Drilling fluid flow<br><br>Drilling fluid loss<br><br>Blowouts | FEP screening will only change if probability is reduced to zero |
| | §*Intersected reservoir characteristics* | Reservoir properties<br><br>Castile brine composition (and source term parameters) | N<br><br>N | - | - | - | - | Brine reservoirs<br><br>Drilling Induced Geochemical Changes | Expected that brine composition will not differ significantly from those already sampled |

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§ Parameter is not a COMP but relevant information is being/could be collected as part of the same monitoring program

| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter† | | FEP with related Screening Decision† | | Related Modeling Assumption† | | FEP with related Screening text‡ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | *§Drilling practices*<br><br>*§Borehole plugging activities*<br><br>*§New drilling activities* | Drilling parameters (e.g., bit diameter)<br><br>Borehole plug configurations and permeabilities | N<br><br>N | Oil and gas extraction<br><br>Groundwater extraction<br><br>Liquid waste disposal<br><br>Hydrocarbon storage<br><br>Enhanced oil and gas recovery<br><br>Investigation boreholes | N<br><br>N<br><br>N<br><br>N<br><br>N<br><br>N | Diameter of the intrusion borehole is constant at 12.25 inches<br><br>Future drilling practices will be the same as present<br><br>Plugging practices will be the same as present<br><br>Probability of plugging configurations | N<br><br>N<br><br>N<br><br>N | All FEPs that describe current drilling activity<br><br>Borehole fluid flow<br><br>Waste-induced borehole flow<br><br>Changes in groundwater chemistry due to mining | If plugging practices change, then plugging configuration conceptual model may need revision, and plugging practice for WIPP boreholes may need to be revisited. |
| Subsidence Monitoring Program (SMP) | Subsidence measurement | - | - | Subsidence<br><br>Large-scale rock fracturing<br><br>Oil and gas extraction | N<br><br>N<br><br>N | - | - | Changes in groundwater flow due to mining | Significant subsidence would require development of a new conceptual model |

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‡ FEPs with related screening text are those FEPs whose screening decision will not be affected by monitoring results, but whose screening discussion in the most recent compliance application may need to be updated in light of any changes related to monitoring results.

§ Parameter is not a COMP but relevant information is being/could be collected as part of the same monitoring program

| M&O Program that Generates Data | Monitoring Parameter | Related PA Parameter† | | FEP with related Screening Decision† | | Related Modeling Assumption† | | FEP with related Screening text‡ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| WIPP Waste Information System (WWIS) | Waste activity | Radionuclide inventories | N | - | - | Homogeneous waste distribution | N | Waste inventory | - |
| | | | | | | Specific CH-TRU waste streams based on inventory data and one RH-TRU waste stream based on combined inventory data | N | Heterogeneity of wasteforms | |
| | §*Average waste composition* | Average waste density | N | - | - | - | - | Consolidation of waste | - |
| | | Waste consolidation and permeability parameters | N | | | | | | |
| Environmental Monitoring Program (EMP) | None | - | - | - | - | - | - | - | - |

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‡ FEPs with related screening text are those FEPs whose screening decision will not be affected by monitoring results, but whose screening discussion in the most recent compliance application may need to be updated in light of any changes related to monitoring results.

§ Parameter is not a COMP but relevant information is being/could be collected as part of the same monitoring program

# 4.0 Steps 3, 4, & 5 – Identify COMPs Data, Compile Potential List of Impacts and Derive TVs

A form has been created to aid in the compilation of information derived from steps 3 through 5. This form also standardized the format such that the information presented for each COMP was consistent.

# Drilling Rate:

<table>
<tr><th colspan="5">Trigger Value Derivation</th></tr>
<tr><td>COMP Title:</td><td colspan="4">Drilling Rate</td></tr>
<tr><td>COMP Units:</td><td colspan="4">Deep boreholes (i.e., > 2,150 feet deep)/square kilometer/10,000 years</td></tr>
<tr><th colspan="5">Related Monitoring Data</th></tr>
<tr><th>Monitoring Program</th><th>Monitoring Parameter ID</th><th>Characteristics (e.g., number, observation)</th><th colspan="2">Values used in the CRA-2009 (DOE 2009)</th></tr>
<tr><td>Delaware Basin Monitoring Program (DBMP)</td><td>Deep hydrocarbon boreholes drilled</td><td>Integer per year</td><td colspan="2">13,520 per 100 years – 58.5 boreholes per square kilometer per 10,000 years</td></tr>
<tr><th colspan="5">COMP Derivation Procedure</th></tr>
<tr><td colspan="5">(Total number of deep boreholes drilled/number of years of observations) x (10,000/23,102.1)<br>[i.e., over 10,000 years divided by the area of the Delaware Basin in square kilometers]</td></tr>
<tr><th colspan="5">Related PA Elements</th></tr>
<tr><th>Element Title</th><th>Type and ID</th><th>Derivation Procedure</th><th></th><th></th></tr>
<tr><td>Drilling rate</td><td>Parameter LAMBDAD #3494</td><td>COMP/10,000 years</td><td></td><td></td></tr>
<tr><th colspan="5">Monitoring Data Trigger Values</th></tr>
<tr><th>Monitoring Parameter ID</th><th>Trigger Value</th><th colspan="3">Basis</th></tr>
<tr><td>Deep boreholes drilled per km$^2$ per 10,000 yrs</td><td>None.</td><td colspan="3">PA direct releases are sensitive to drilling rate changes. However only a dramatic and improbable change in drilling rate could affect containment of radionuclides. The sensitivity of changes to the drilling rate was evaluated during the first recertification as part of an analysis that doubled the drilling rate (Kanney and Kirchner 2004). A revised drilling rate is used in each recertification and the associated impacts are accounted for in PA. A rate that is twice what the rate used in the first recertification demonstrates containment compliance. Since changes to the drilling rate are assessed in PA every 5-years and a doubled rate is not expected and has been shown to not impact compliance, the use of a TV is unnecessary.</td></tr>
</table>

## Drilling Rate:

This report does not change the TV for the Drilling Rate COMP.

The drilling rate used in PA is determined according to the method prescribed by the EPA in 40 CFR §194.33, by using an average value determined from the record from the past 100 years. For the CCA, a drilling rate of 46.8 boreholes per square kilometer per 10,000 years was derived. Because the drilling rate that represents the rate for the next 10,000 years is based on the recent drilling that has occurred over the past 100 years, the DOE originally believed that the drilling rate parameter used in PA would not change. The project has since decided a new rate should be used based on the latest 100 years of borehole data. As of August 2010, the drilling rate has increased to 62.3 which is a 33% increase from the CCA value. Because the drilling rate uses a 100-year rolling window, the drilling rate will continue to increase until more wells drop out of the 100-year period than are added. This did not occur until 2011 when the first well drilled in 1911 dropped out (DOE 2008). It is expected that more wells will be added over the thirty-year WIPP operational period than will be removed such that the rate will continue to increase over the lifetime of the monitoring activity.

Although the original drilling rate TV was exceeded in 2004, the exceedance was expected. As discussed above, the drilling rate will continue to rise. Studies have demonstrated that much higher drilling rates are needed to impact compliance (EEG 1998). For example, in response to a request from EPA (EPA 2006), the SA analyzed the impact of drilling rate on repository performance. This analysis shows that even if the drilling rate were doubled relative to that used for the CRA-2004 PA, the disposal system performance would be well within the release limits set by EPA regulations (Kanney and Kirchner 2004). The CRA-2009 recertification PA used a drilling rate of 58.5, (DOE 2009; data cut-off for CRA-2009 is 2007) demonstrating compliance with a higher drilling rate than the CCA.

Changes in drilling rate could affect the assumptions used in assembling the component models of the PA calculation. The original FEP screening process used in the CCA (Section 6.2 and Appendix SCR; DOE 1996) evaluated the impact of interconnections between stratigraphic units created by boreholes. These interconnections were found to be of low consequence for the drilling rates assumed. The finding of low consequence was used to support the models of the Culebra Dolomite Member (Culebra) of the Rustler Formation, Magenta Dolomite Member (Magenta) of the Rustler Formation, and Dewey Lake Redbeds Formation (Dewey Lake). Furthermore, the analysis of climate change effects is predicated on a low consequence associated with abandoned boreholes. Although these assumptions accounted for potential boreholes, the impacts of substantially more boreholes were not assessed. Should the drilling rate increase dramatically, FEP assessments conducted as part of the periodic recertifications would address the impact.

A TV is not needed for the drilling rate during the time period for which monitoring will occur. No drilling will occur over the WIPP site during the operational and active controls period such that any impact of increased drilling on post-closure performance can be assessed in recertification application activities. WIPP PA does not implement the drilling scenario until 100 years after WIPP closure. It is expected that the drilling rate at that time would be less than today's due to the way the rate is calculated (many wells would drop out of the calculation).

# Summary:

The drilling intrusion rate affects repository performance as well as the assumptions made during the development of models of hydrology and climate change. Based on DOE and independent analyses, only a dramatic and improbable change in the drilling rate could affect containment of radionuclides. The sensitivity of hydrologic and climate change assumptions used in low consequence FEP screening decisions have not been assessed for large increases in the drilling rate. However the possibility of any borehole intrusion into the site over the operational and active controls period is zero such that any calculated increase to the drilling rate that impacts the FEP screening decisions would be assessed in the periodic recertifications of the site that occur over the operational period. Therefore, a TV is unnecessary for the drilling rate COMP and has been discontinued.

## Probability of Encountering a Brine Reservoir:

<table>
<tr><th colspan="5">Trigger Value Derivation</th></tr>
<tr><td>COMP Title:</td><td colspan="4">Probability of Encountering a Castile Brine Reservoir</td></tr>
<tr><td>COMP Units:</td><td colspan="4">Unitless</td></tr>
<tr><th colspan="5">Related Monitoring Data</th></tr>
<tr><th>Monitoring Program</th><th>Monitoring Parameter ID</th><th>Characteristics (e.g., number, observation)</th><th colspan="2">Compliance Baseline Value</th></tr>
<tr><td>Delaware Basin Monitoring Program (DBMP)</td><td></td><td>Driller's Survey – observations</td><td colspan="2">0.01 to 0.60</td></tr>
<tr><th colspan="5">COMP Derivation Procedure</th></tr>
<tr><td colspan="5">Analysis of intercepts of pressurized brine recorded and reported by industry in the 9-township area centered on WIPP.</td></tr>
<tr><th colspan="5">Related PA Elements</th></tr>
<tr><th>Element Title</th><th>Type and ID</th><th>Derivation Procedure</th><th>Compliance Baseline</th><th>Impact of Change</th></tr>
<tr><td>Probability of Encountering Brine</td><td>Parameter PRBRINE</td><td>CCA MASS Attachment 18-6 geostatistical study based on area occurrences.<br><br>EPA Technical Support Document (EPA 1998) justified the upper value in their range by rounding up the upper value interpreted from the TDEM survey, which suggested a 10 to 55% areal extent.</td><td>0.08 (CCA Value)<br><br>0.01 to 0.60 (Current Value)</td><td>Not a sensitive parameter.</td></tr>
<tr><th colspan="5">Monitoring Data Trigger Values</th></tr>
<tr><th>Monitoring Parameter ID</th><th>Trigger Value</th><th colspan="3">Basis</th></tr>
<tr><td>Probability of Encountering a Castile Brine Reservoir</td><td>None</td><td colspan="3">After the DOE proposed the brine reservoir probability as a potentially significant in the CCA Appendix MONPAR, the EPA conducted sensitivity analyses that indicate a lack of significant effects on performance from changes in this parameter. Since no value of this parameter can significantly affect the performance of the disposal system predicted by the CCA PA and since the parameter is evaluated at least once annually, no TV is needed.</td></tr>
</table>

## Probability of Encountering a Brine Reservoir:

This report does not change the TV for the Probability of Encountering a Brine Reservoir COMP.

The brine reservoir probability affects the consequences of modeled intrusion scenarios in PA. These scenarios involve the interconnection of a brine reservoir in the Castile Formation with the repository.

The development of the brine reservoir probability used in the PA is described in CCA Appendix MASS, Section 18-6 (DOE 1996). In the CCA, the brine reservoir probability was selected based on an analysis of recorded and reported brine intercepts by the drilling industry in the 9-township WIPP vicinity. This probability was anticipated to be important to the results of the CCA PA, and therefore was proposed for monitoring in CCA Appendix MONPAR.

The EPA conducted an extensive evaluation of the sensitivity of CCDFs to the occurrence of a brine reservoir intrusion, as well as the properties of the brine reservoir, in their Performance Assessment Verification Test (PAVT). The EPA's interpretation of the data on the existence of a brine reservoir led them to require the DOE to change the brine encounter probability (from a constant 0.08 to a sampled value from 0.01 to 0.6). The EPA's PAVT indicated that changes in brine reservoir assumptions can affect the position of CCDFs. However, there is no combination of reservoir intercept probabilities and reservoir properties that can affect the overall compliance of the WIPP. This suggests that no TV for the penetration of a brine reservoir is needed, because the sensitivity of performance predictions to changes in the value is low.

## Summary:

Originally the DOE proposed the probability of encountering a brine reservoir as potentially significant PA parameter (CCA Appendix MONPAR; DOE 1996). The EPA has since conducted analyses that indicate that the probability does not have a significant effect on long-term repository performance. Additionally the EPA required probabilities for this parameter that are higher than the one originally derived from the drilling data. It is not expected that monitoring observations could lead to values higher than what the EPA requires. For these reasons, no TV is needed. Monitoring of the occurrence of brine reservoirs will continue. The information collected will support a current and accurate understanding of human activities in the vicinity of WIPP. These data and information may be considered in support of parameter selection for future PA calculations.

# Waste Activity:

| **Trigger Value Derivation** | | | | |
|---|---|---|---|---|
| **CMPMP Title:** | Waste Activity | | | |
| **CMPMP Units:** | Curies | | | |
| **Related Monitoring Data** | | | | |
| Monitoring Program | Monitoring Parameter ID | Characteristics (e.g., number, observation) | Compliance Baseline Value | |
| WDS | Total emplaced curies for tracked radionuclides, emplaced waste volumes | Curies per container. Container volume. Total curies of ten radionuclides | Inventory cited in the latest Compliance Recertification Application (CRA) | |
| **COMP Derivation Procedure** | | | | |
| Total curie content of the ten monitored actinides emplaced in WIPP for both CH-TRU and RH-TRU waste. *[Total radionuclide inventories reported by WDS]* | | | | |
| **Related PA Elements** | | | | |
| Element Title | Type and ID | Derivation Procedure | Compliance Baseline | Impact of Change |
| Radionuclide inventories | Parameter | Product of waste stream content and volume scaled up to the LWA limits. | Latest CRA Inventory | May affect direct brine releases for those radionuclides that become inventory-limited during a PA simulation. |
| Activity of waste intersected for cuttings and cavings releases. | Parameter | Function of waste stream volumes and activities | - | Cuttings are a significant contributor to releases. Therefore, an increase in activity of intersected waste is potentially significant. |
| WIPP-scale average activity for spallings releases | Parameter | Average of all CH-TRU waste only. | - | Spallings are a significant contributor to releases. Therefore, an increase in average activity of intersected waste is potentially significant. |
| **Monitoring Data Trigger Values** | | | | |
| Monitoring Parameter ID | Trigger Value | Basis | | |
| Total emplaced waste activity for the ten monitored actinides | Actinide values in latest CRA - Section 24 | 40 CFR§194.24 (c) requires a system of controls to confirm important waste limits are not exceeded. Actinide curie values use in baseline PA are used as the waste limit values. | | |
| Total emplaced RH-TRU waste activity | 5.1 million curies | LWA emplacement limit reached. Administrative controls address these limits. | | |

## Waste Activity:

This report does not change the TV for the Waste Activity COMP.

The actinide curie values (which have been decayed to the year 2033) that are used in the latest PA baseline are used as the TVs. Originally, the compliance monitoring assessment would check the actinide values of the emplaced waste against the values used in PA when a panel was half-full. The implementation of the TV has been changed such that the COMP is no longer associated with the extent that a panel is filled with waste. The assessment will now be made annually. The TV associated with the RH waste activity limit of 5.1 million curies has not changed. Monitoring of RH-TRU waste activity will be used to ensure that the WIPP complies with the LWA activity limit of 5.1 million curies and the 250,000 cubic feet RH waste volume limit.

Releases due to cuttings and cavings are calculated by sampling a probability distribution of waste activity based on individual waste stream volumes and activities (Figure 6-31 of the CCA)(DOE 1996). Spalling and direct brine releases are calculated assuming a WIPP-scale average activity and waste distribution. Changes to the activity estimates have a direct influence on PA results such that assuring the values used in PA are representative of the actual values emplaced in the repository is essential. The latest waste information is used in each baseline PA such that changes are accounted for at least every five years. Annual checks on the emplaced waste activities ensure that the waste values used in PA are not exceeded.

# Subsidence Measurement:

<table>
<tr><th colspan="5">Trigger Value Derivation</th></tr>
<tr><td>CMPMP Title:</td><td colspan="4">Subsidence Measurement</td></tr>
<tr><td>CMPMP Units:</td><td colspan="4">Rate of change in surface elevation in meters per year</td></tr>
<tr><th colspan="5">Related Monitoring Data</th></tr>
<tr><th>Monitoring Program</th><th>Monitoring Parameter ID</th><th>Characteristics (e.g., number, observation)</th><th colspan="2">Compliance Baseline Value</th></tr>
<tr><td>SMP</td><td>Elevation of existing monitoring benchmarks</td><td>Decimal (meters)</td><td colspan="2">Values not used in PA.<br>(WIPP Subsidence Monument Leveling Survey – Annual Report)</td></tr>
<tr><td>SMP</td><td>National Geodetic Survey (NGS) results</td><td>Decimal (meters)</td><td colspan="2">Powers (1993)</td></tr>
<tr><td>SMP</td><td>Change in elevation over year</td><td>Decimal (meters)</td><td colspan="2">-</td></tr>
<tr><td>SMP</td><td>Total change in elevation since excavation of the WIPP</td><td>Decimal (meters)</td><td colspan="2">1996 NGS elevation - 1981 NGS elevation (from Powers 1993)</td></tr>
<tr><th colspan="5">COMP Derivation Procedure</th></tr>
<tr><td colspan="5">Subsidence profiles taken along sections crossing relevant portions of the WIPP footprint. Contour plots of the monitoring benchmarks showing [Elevation this year – Elevation last year], and<br>[Elevation this year – Baseline Elevation].<br>Maximum value of (Elevation this year – Baseline Elevation) from the available monitoring benchmarks.</td></tr>
<tr><th colspan="5">Related PA Elements</th></tr>
<tr><th>Element Title</th><th>Type and ID</th><th>Derivation Procedure</th><th>Compliance Baseline</th><th>Impact of Change</th></tr>
<tr><td>Subsidence</td><td>FEP [W23]</td><td>Predictions are of low consequence to the calculated performance of the disposal system – based on Westinghouse (1994) analysis and EPA treatment of mining.</td><td>Maximum total subsidence of 0.62m above the WIPP.</td><td>Predicted subsidence will not exceed existing surface relief of 3 m – i.e., it will not affect drainage.<br>Predicted subsidence may cause an order of magnitude rise in Culebra hydraulic conductivity (CCA Appendix SCR , Section 2.3.4) – this is within the range modeled in the PA. Predicted WIPP subsidence is below that predicted for the effects of potash mining (0.62 m vs.1.5 m; EPA 1996).</td></tr>
<tr><th colspan="5">Monitoring Data Trigger Values</th></tr>
<tr><th>Monitoring Parameter ID</th><th>Trigger Value</th><th colspan="3">Basis</th></tr>
<tr><td>Rate of change in elevation</td><td>1.0 x $10^{-2}$ m per year subsidence</td><td colspan="3">Based on the most conservative prediction by analyses referenced in the CCA.</td></tr>
</table>

## Subsidence Measurement:

This report does not change the TV for the Subsidence Measurement COMP.

Subsidence is expected over the WIPP site due to the mining and eventual closure of the mined void space. Subsidence over the WIPP is expected to be much lower and slower than that observed over potash mines in the region because of the low extraction ratio (pillar to mined room volume) and relative depth. Maximum observed subsidence over these potash mines is 1.5 m, occurring over a time period of months to a few years. EPA took this amount of subsidence into account when specifying its treatment of mining (EPA 1996). Therefore, any predicted subsidence below 1.5 m would not impact the EPA's mining assumptions. Since the WIPP rate is expected to be much lower that above the potash mines, other rates were considered in the TV assessment.

Several subsidence analyses were performed by the project for various reasons to estimate possible subsidence over the WIPP. These analyses could be used to determine possible subsidence rates over the WIPP. Exceedance of the highest rate expected could be used as a TV, however the assumptions used in the analyses and the purpose of the analyses should also be considered in the TV selection.

In one analysis, the maximum subsidence figure calculated for the WIPP assuming emplacement of CH-TRU waste and no backfill is 0.62 m (Backfill Engineering Analysis Report [BEAR], Westinghouse 1994). Maximum subsidence occurs above the waste emplacement panels. Analyses also were made assuming an empty repository, this increases the maximum calculated subsidence to 0.95 m. The majority of the subsidence predictions give no time scales. However, computer modeling in the BEAR predicts subsidence to occur over a time period of 380 years. Assuming the maximum subsidence of 0.95 m for this time period, would result in a subsidence rate of less than 0.003 m per year.

Another subsidence analysis is documented in the Final Safety Analysis Report (FSAR, DOE 1990). This analysis predicts maximum surface subsidence of 12 to 15 inches (0.3 to 0.38 m) over the 35-year operating period. This translates into a subsidence rate of approximately 0.4 inches (0.01 m) per year. Since this is significantly higher than the 0.003 m rate discussed above, this higher rate is considered an acceptable TV for the subsidence COMP.

## Changes in Culebra Groundwater Flow:

| Trigger Value Derivation | | | | |
|---|---|---|---|---|
| **COMP Title:** | Changes in Culebra Groundwater Flow | | | |
| **COMP Units:** | Inferred from water-level data | | | |
| **Related Monitoring Data** | | | | |
| Monitoring Program | Monitoring Parameter ID | Characteristics (e.g., number, observation) | Compliance Baseline Value | |
| Ground Water Monitoring | Head and Topography | Monthly water-level measurements, annual pressure-density surveys. | Indirect | |
| **COMP Derivation Procedure** | | | | |
| Annual assessment from Annual Site Environmental Report (ASER) data. | | | | |
| **Related PA Elements** | | | | |
| Element Title | Type & ID | Derivation Procedure | Compliance Baseline | Impact of Change |
| Groundwater conceptual model Transmissivity Fields (T-Fields) | T-Field | 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). | Appendix T-Fields | Provides validation of the various PA models - T-Field assumptions and groundwater basin model. |
| **Monitoring Data Trigger Values** | | | | |
| Monitoring Parameter ID | Trigger Value | Basis | | |
| Change in Culebra Groundwater Flow | See Figure 4.1 | 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 Land Withdrawal Boundary must fall within the distribution found using the 100 model runs used in the baseline PA. | | |

## Changes in Culebra Groundwater Flow:

This report does not change the TV for the Change in Groundwater Flow COMP.

Groundwater flow in the Culebra is controlled primarily by the distribution of transmissivity and the freshwater head hydraulic gradient. Changes in predicted groundwater flow may result when changes in either or both of these parameters occur. To calculate groundwater travel times and radionuclide releases through the Culebra for PA, a set of transmissivity (T) fields were generated and calibrated to observed heads. These T-fields were generated using "point" values of geologic information, transmissivity and head data obtained from well tests, and water-level measurements at well locations. Boundary conditions (heads) for the model domain were estimated from both hydrologic information about the system (e.g., no-flow boundaries in Nash Draw and low-permeability constant-head boundaries along the Rustler halite margins) and water-level measurements (constant-head boundaries at the north and south ends of the Culebra PA flow model).

The original TV, derived from CCA information, used the ranges of freshwater heads that were used in the calibration of baseline T-fields. For example, Table TFIELD-3 in Appendix TFIELD (DOE 1996) of the CCA lists the undisturbed freshwater heads and uncertainties for 32 wells used in calibration of the CCA baseline Culebra T-fields. At that time, water levels in 26 of those wells were measured monthly as part of the Ground Water Monitoring Program (GWMP). Water levels were expected to remain within the ranges defined for the CCA. If water levels in one or more wells fell outside those ranges, it was thought at the time to mean one of four things. It could mean that the well casing or a packer has failed, and water is entering the Culebra interval of the well from another interval. It could mean that human activities, such as pumping or circulation losses during drilling, are affecting Culebra water levels in nearby wells. It could mean that the undisturbed heads estimated for the CCA are in error. Lastly, it could mean that our conceptual model for the Culebra, which includes an assumption that heads are in a steady-state condition on the time scale of centuries to millennia, is in error. None of these conditions necessarily imply that WIPP is out of compliance with EPA regulations. Groundwater flow directions and rates are controlled by gradients, not by head values, so uniform changes in heads do not necessarily imply (significant) changes in flow. However, prior to the first recertification (termed the CRA 2004), observed water levels fell outside the CCA ranges and triggered an investigation into the cause and possible ramifications. New water level data were used to calculate new T-fields during CRA 2004 activities which defined new freshwater head ranges. Continued monitoring has again observed freshwater heads outside of the new ranges. This condition has been assessed through further investigations. The CRA-2009 PABC revised the Culebra conceptual model and approach used to generate T-fields such that freshwater heads are parameterized as a fixed value, not a range. Therefore, a new TV was necessary.

A failure of the well casing or a packer might be indicated by sudden changes and erratic behavior of the water level. Such a failure would have no long-term impact on WIPP compliance. Changes suspected of being caused by a casing or packer failure have been investigated using methods such as video and/or geophysical logs, isolating and pressurizing different sections of the casing, and imposing a different pressure differential across a packer to verify its integrity.

Most local-scale (e.g., observed in one or two wells) human-induced changes in Culebra heads are likely to be short-term, rarely if ever lasting more than one year. Human-induced changes might take the form of sudden (e.g., between two monthly measurements) rises or drops in water levels, followed by a decay back towards the initial water level. Short-term changes such as this have no impact on WIPP compliance. Changes suspected of being human induced have been investigated by collecting information on human activities in the area such as discharges in potash evaporation ponds and ranch water uses to determine if the activities correlate with or can be modeled to produce the observed changes.

The new TV for assessing change in Culebra groundwater flow involves comparison of the model-predicted travel time for a DTRKMF (Double precision TRacKing with MODFLOW

2000)-predicted particle of water from a point in the Culebra above the center of the WIPP panels to the WIPP Land Withdrawal Boundary (Harbaugh et al. 2000 and Rudeen 2003). If the predicted travel time is outside the distribution predicted as part of the current PA, the heads used to drive the average Culebra model must be investigated to determine the cause of the discrepancy between modeled and predicted travel times and decide if the PA model needs to be revised.

Each year, a model consisting of the ensemble average of calibrated T-fields used in PA analysis is used to match to observed heads from that year. The model input parameters are taken from the calibrated PA model, while the constant-head boundary conditions are adjusted to improve the match between the averaged model and that year's observed heads. Once a best-fit average model is determined, it is used to predict travel time associated with a conservative particle (i.e., a marked water particle without dispersion or retardation) from the location of well C-2737 in the Culebra (above the center of the WIPP panels) to the WIPP Land Withdrawal Boundary. This single travel time from the average flow model with best-fit boundary conditions is compared with the distribution of 100 travel times computed for PA (see red dots in Figure 4.1) to determine whether or not the TV has been exceeded.

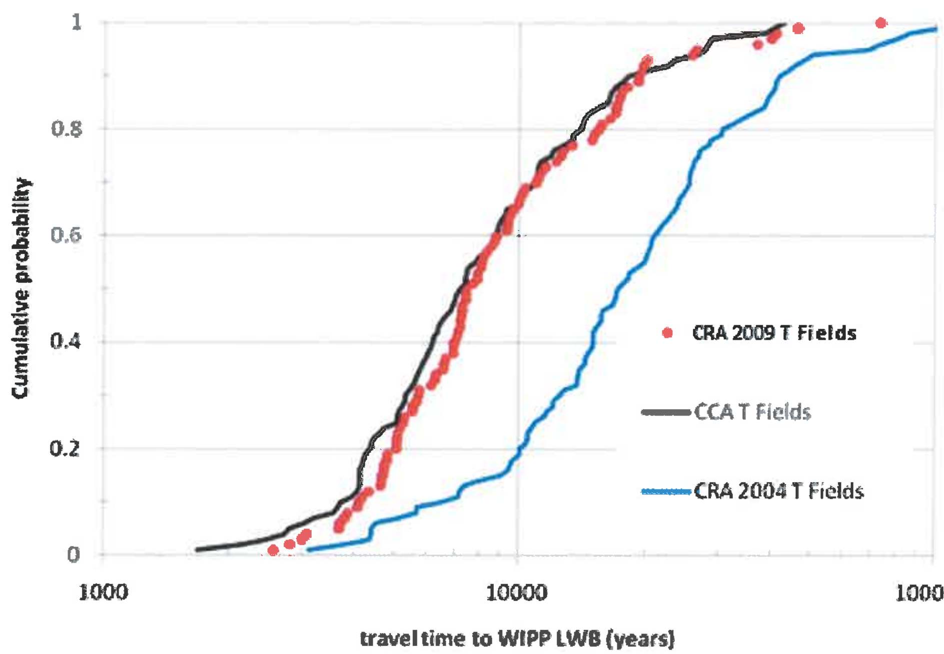


**Figure 4.1 Distribution of travel times from above the center of the WIPP panels to the WIPP Land Withdrawal Boundary.**

# Culebra Groundwater Composition:

| Trigger Value Derivation | | | | |
|---|---|---|---|---|
| **COMP Title:** | Culebra Groundwater Composition | | | |
| **COMP Units:** | mg/L (concentration data); unitless (p-value, level of marginal significance) | | | |
| **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). | |
| **COMP Derivation Procedure** | | | | |
| Annually evaluate ASER data and compare to baseline information. | | | | |
| **Related PA 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. | | |

# Culebra Groundwater Composition:

This report revises the TV for the Culebra Groundwater Composition COMP.

Culebra groundwater composition is not a parameter that directly affects repository performance or compliance. However, the stability of groundwater composition on the timescale of the WIPP operational period is implicit in the steady state, confined, two-dimensional model of the Culebra used for PA compliance calculations. Therefore, significant changes in groundwater composition would indicate the need to revise the conceptual and, possibly, numerical models used to simulate groundwater flow and solute transport in the Culebra.

In the Beauheim et al. (2000) formulation of the Culebra Groundwater Composition TV, it was decided that major ion concentrations for a given sampling round for Culebra wells WQSP (Water Quality Sampling Program) 1-6 would be compared to a range associated with baseline mean concentrations. The baseline mean concentrations were calculated with the first ten rounds of water-quality sampling, spanning July 1995 to May 2000 (see IT Corporation 1998, 2000). Stability was assumed the condition where the concentration of a given ion (i.e., chloride, sulfate, sodium, bicarbonate, calcium, magnesium, or potassium) remained within the range defined as the baseline mean concentration ± two standard deviations (Beauheim et al, 2000). The values reported in Table 4.1 were thought to represent the range of concentrations that 19 out of 20 future analyses (i.e., 95%) should, on average, fall within. The TV definition for Culebra Groundwater Composition was formalized by Beauhiem et al. (2002) as the condition where both the primary and duplicate analyses for any of the major ions fell outside the determined range for three consecutive sampling rounds.

**Table 4.1 Ion concentration ranges defined by the baseline mean concentration ± two standard deviations (source: Beauhiem et al., 2002).**

| Well | $Cl^-$ (mg/L) | $SO_4^{2-}$ (mg/L) | $HCO_3^-$ (mg/L) | $Na^+$ (mg/L) | $Ca^{2+}$ (mg/L) | $Mg^{2+}$ (mg/L) | $K^+$ (mg/L) |
|---|---|---|---|---|---|---|---|
| WQSP-1 | 31100-39600 | 4060-5600 | 45-54 | 15850-21130 | 1380-2030 | 940-1210 | 322-730 |
| WQSP-2 | 31800-39000 | 4550-6380 | 43-53 | 14060-22350 | 1230-1730 | 852-1120 | 318-649 |
| WQSP-3 | 113900-145200 | 6420-7870 | 23-51 | 62600-82700 | 1090-1620 | 1730-2500 | 682-2940 |
| WQSP-4 | 53400-63000 | 5620-7720 | 31-46 | 28100-37800 | 1420-1790 | 973-1410 | 364-1450 |
| WQSP-5 | 13400-17600 | 4060-5940 | 42-54 | 7980-10420 | 902-1180 | 389-535 | 171-523 |
| WQSP-6 | 5470-6380 | 4240-5120 | 41-54 | 3610-5380 | 586-777 | 189-233 | 113-245 |

The Wagner and Thomas (2016) Compliance Monitoring Parameter Assessment was conducted with water-quality data sampled in the spring of 2014 (i.e., sampling round 36). For sampling rounds 28-36 and 27-36, respectively, the WQSP-3 sulfate and potassium ion concentrations fell outside the tolerated range, violating the TV. Additonally, in sampling rounds 27-36, the WQSP-4 potassium ion concentrations fell outside the tolerated range, violating the TV. Visual inspection of piper diagrams constructed for the data for each well over the 36 sampling rounds demonstrated that the three violations did not warrant a revision to the models used to simulate groundwater flow and solute transport in the Culebra. As noted by Wagner and Kuhlman (2014), an updated Culebra Groundwater Composition TV is needed to mitigate the continued occurrence of false positives.

Twenty-five rounds of water-quality sampling data (i.e., rounds 11 to 35) are available to extend the sample size with which to update the ion concentration ranges reported in Table 4.1. Simply extending the sample size and employing the revised ion concentrations, however, would still require the Beauheim et al. (2000) assumption that the data follow a normal distribution (i.e., that the baseline mean concentration ± two standard deviations represents the range of concentrations that 95% of future analyses should fall within). As part of this trigger derivation report, the ion concentration data for each constitutent, for each well, including sampling rounds 1 to 35, were evaluated for normality and log-normality with the Shapiro-Wilk test (Shapiro and Wilk, 1965). More than 50% of the datasets fail the statistical test for normality and log-normality.

To provide a more robust assessment of Culebra groundwater composition as part of the COMPs, this trigger derviation report establishes the consistent use of a non-parametric method known as the randomization test (Ernst, 2004) for all wells and analytes. Non-parametric methods, including the randomization test, generate reference distributions by calculating a chosen statistic for all combinations of the data (Ernst, 2004). The primary advantage of the randomization test is that no assumption about the distribution of groundwater composition is needed to make comparisions between the sampling round-of-interest and the baseline group of samples.

Seven steps are required to employ the randomization test:

1) Establish the control and treatment groups.
2) Select the test statistic.
3) Calculate the test statistic with the control group and treatment group (i.e., threshold).
4) Find all combinations of the control and treatment groups.
5) Calculate the test statistic for all combinations.
6) Count the number of combinations whose test statistic meet or exceed the threshold criteria.
7) Calculate the p-value to determine if the treatment group is statistically significant compared to the control group.

To implement the randomization test as the basis for the Culebra Groundwater Composition TV, the control and treatment groups are established with all historic data from sampling rounds 1-35 (excluding the anomalous data identified by Beauheim et al. [2002]) and the sampling round-of-interest (i.e., round 36 or later), respectively. Both groups include the concentration values for the primary and duplicate samples. For simplicity, the difference in arithemetic means between the treatment and control groups is used as the test statistic (Ernst, 2004). Although geometric means are commonly employed with concentration data, the arithmetic mean was chosen here because none of the concentration data exhibit variability spanning more than a factor of four. On average, the minimum and maximum concentration values for each well, for each constitutent, do not vary by more than a factor of two. Furthermore, because the arithmetic mean will not dampen the effect of possible future outlier concentrations, the arithmetic mean-based approach will always provide a more risk-averse (i.e., lower) p-value than the geometric mean-based approach. The threshold criteria, which will change for each new treatment group that is associated with the annual Culebra Groundwater Composition assessment, is calculated with the difference in means test statistic. All combinations of the control and treatment group are found. For a given consitutent, there are approximately 2,500 combinations. For each combination, the test statistic is calculated. After the number of combinations whose test statistic meet or exceed the threshold criteria is known, the p-value is calculated as the number of violations divided by the number of combinations. The hypothesis tested with the p-value follows as: If the p-value is less than or equal to 0.05, the treatment group (i.e., the current sampling round-of-interest) is statistically significant compared to the control group. The Python script used to conduct steps one through seven (`wqsp_database.py`) and most the most up-to-date WQSP data (`wqsp-data.txt`) are available in the WIPP version control system in the repository `/nfs/data/CVSLIB/WIPP_EXTERNAL/tv/TV_rev3`.

Under the revised Culebra Groundwater Composition TV, three consective sampling periods exhibiting a p-value less than or equal to 0.05 consitutes a violation. Figure 4.2 shows that the three ongoing TV violations reported in Wagner and Thomas (2016) are no longer violations when interepreted with the revised TV. The sampling round 36 p-values for sulfate in WQSP-3, potassium in WQSP-3, and potassium in WQSP-4 are 0.056, 0.259, and 0.254, respectively. When all of the sampling round 36 data is re-evaluated with the new TV definition, two of the 42 tests (i.e., six wells multiplied by seven consitutents) indicate the treatment group is statistically significant. The sampling round 36 p-values for chloride in WQSP-3 and WQSP-5 are 0.03 and 0.028, respectively. Concentration histories and test statistic histograms for the two statistically significant sampling round 36 cases are shown in Figure 4.3. These results do not constitute a third consecutive offense of the Culebra Groundwater Composition TV. Concentration data from sampling round 37, which was collected in 2015, have not yet been evaluated as part of the annnual COMPs report. However, when the sampling round 37 data is evaluated with the new TV definition, no consecutive offense is observed and, therefore, no possibility of violation exists. Figure 4.3 shows that the statistically significant sampling round 36 cases are statistically insignificant for sampling round 37.

A charge-balance error (CBE), in addition to the comparison of species concentrations, will continue to be 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. A reliable analysis should not have a CBE exceeding ± 5% (Freeze and Cherry 1979). A CBE in excess of ± 5% implies either the analysis of one or more ions is inaccurate, or a significant ion has been overlooked. The variation between the results of primary and duplicate sample analysis for each individual ion is also considered. Generally speaking, this variation should be <10%; large variability can indicate a problem with one or both analyses and should prompt a follow-up discussion with the laboratory conducting the analyses.

In summary, the Culebra Groundwater Composition TV has been modified due to the ongoing occurrence of false positives. The number of values incorporated into the concentration baselines has been increased by 250%. Evaluation of the Culebra Groundwater Composition TV will no longer rest upon assumptions about the statistical distribution of the ion concentration data. The randomization test will now be used to determine whether or not the treatment group (i.e., sampling round of interest) is statistically significant compared to the control group (i.e., sampling rounds 1-35). The control group will be static, but the treatment group will change each year. For a given sampling round, a charge-balance error and p-value will be calculated for each constituent, for each well. If the p-value is less than or equal to 0.05 for three consecutive sampling rounds, a TV violation will be reported and investigated.

(a) (b)

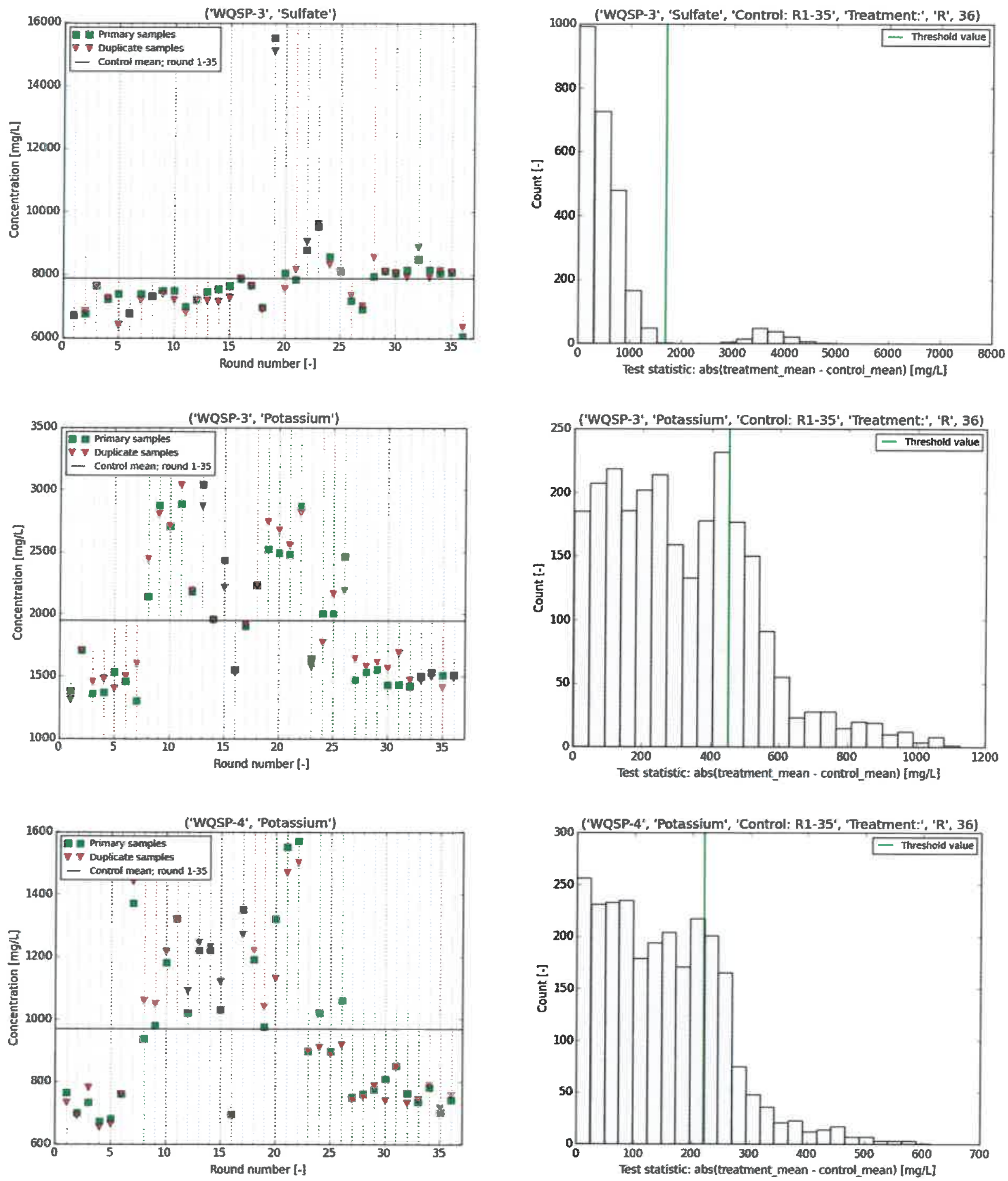


**Figure 4.2 (a) Concentration history for sulfate in WQSP-3, potassium in WQSP-3, and potassium in WQSP-4. (b) Histogram of test statistic values calculated for sulfate in WQSP-3, potassium in WQSP-3, and potassium in WQSP-4. Vertical line (green if statistically insignificant, red if statistically significant) indicates the absolute difference between the mean of sampling rounds 1-35 and sampling round 36.**

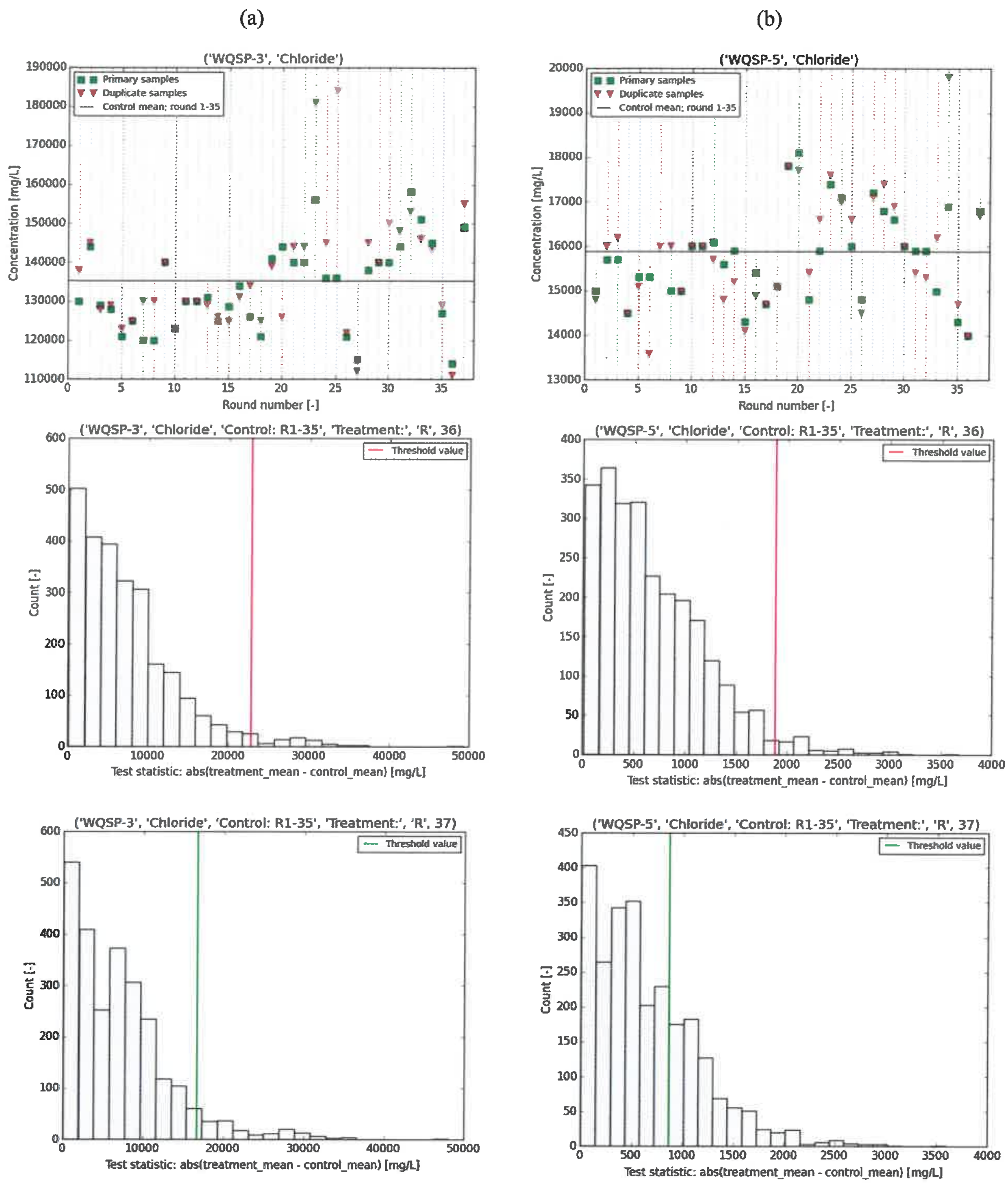


**Figure 4.3 (a) Concentration history (sampling rounds 1-37) and histograms of test statistic values for sampling rounds 36 and 37 for chloride in WQSP-3. (b) Concentration history (sampling rounds 1-37) and histograms of test statistic values for sampling rounds 36 and 37 for chloride in WQSP-5. Vertical line (green if statistically insignificant, red if statistically significant) indicates the absolute difference between the mean of sampling rounds 1-35 and sampling rounds 36 and 37.**

## Geotechnical COMPs

Geotechnical COMPs are directly related to the repository's operational safety monitoring program performed to ensure mine safety. By nature, changes in geotechnical conditions evolve slowly; however, they are monitored on a continual basis. Since these geotechnical changes correlate to geotechnical COMPS, changes to these COMPS also evolve slowly. For most instances, a geotechnical condition that warrants action for operational safety will occur before data on the same condition would impact long-term repository performance predictions. For these reasons, an annual assessment of the geotechnical COMPs will adequately address conditions that would be a concern for predicting repository performance. Future assessments will evaluate possible trigger events, features phenomenon, trends, and conditions that would warrant further actions related to predicting long-term performance of the repository. Examples and the rationale for development of these TVs are described below.

**Creep Closure:**

This report does not change the TV for the Creep Closure COMP.

The annual Geotechnical Analysis Report (GAR; e.g., Westinghouse 2001) compiles all geotechnical operational safety data gathered from the underground. The GAR reports routine measurements of creep deformation, either from rib-to-rib, roof-to-floor, or extensometer borehole measurements. Rates of closure are relatively constant and slow ($5 \times 10^{-10}$ $s^{-1}$), such that upward trends could be readily observed at no risk to operational personnel or to safety. Extensive GAR data suggest that possible TVs could be derived from creep rate changes. The WIPP underground is essentially stable relative to most operational mines, and deformation is steady for long periods of time. However, under certain conditions, creep rates accelerate which indicates a structural change to the deformation processes. Arching of microfractures to an overlying clay seam might create the onset of the roof beam de-coupling, and increase the measured closure rate. Therefore, a measured creep rate change which occurs over a yearly period would constitute the COMP TV for creep closure on a case-by-case basis since this rate is directly related to factors such as age of the opening, location in the room or drift, convergence history, recent excavations, and geometry of the excavations.

**Initiation of Brittle Deformation:**

This report does not change the TV for the Initiation of Brittle Deformation COMP.

The Initiation of Brittle Deformation around WIPP openings cannot be directly measured and is therefore a qualitative observational parameter. By definition, qualitative COMPs can be subjective and are not prone to the development of well-defined TVs. Initiation of brittle deformation manifests quantitatively in COMPs related to deformational extent and displacement of deformational features. WIPP geotechnical personnel possess historical knowledge of the WIPP underground, and continually assess deformation features, assess roof bolt behaviors, and perform caliper fracture mapping. These assessments are reported in the GAR and will be used along with information from the other geotechnical COMPs in the annual assessments to ensure that there are no conditions that could impact repository performance, or predicted behavior.

**Extent of Deformation:**

This report does not change the TV for the Extent of Deformation COMP.

The extent of deformation is quantifiable as it defines spatial and temporal evolution of the DRZ. Derivation of this COMP is made from yearly comparisons of room and drift surface fracture mapping provided in the annual GARs. A qualitative TV was originally applied using a change of more than 1 m/yr in fracture length. The results from this COMP cannot be directly applied to the current conceptual model's numerical implementation such that observed changes in fracture lengths do not indicate a condition outside of PA expectations. The fracture depth into the host rock is related to DRZ assumptions, however the surface fracture lengths do not correlate to depth. For this reason, applying a TV to this COMP is not an indicator of unexpected behaviors and has been discontinued.

**Displacement of Deformation Features:**

This report does not change the TV for the Displacement of Deformation Features COMP.

The displacement of deformation features largely occurs vertically via crack openings and is associated laterally along clay seams. Extensive deformational features may include occlusion of observational borehole diameters. This parameter is not currently associated with a PA parameter or modeling assumption. Data related to this COMP could be used in the future if the creep closure model is further refined. Observational borehole monitoring data are currently used to assess ground control in an effort to ensure adequate operational safety. A TV related to PA parameters or assumptions is not practical and is unnecessary. Therefore, the TV has been discontinued.

## Creep Closure:

| **Trigger Value Derivation** | | | | |
|---|---|---|---|---|
| **COMP Title:** | Creep Closure | | | |
| **COMP Units:** | Closure Rate ($sec^{-1}$) | | | |
| **Related Monitoring Data** | | | | |
| Monitoring Program | Monitoring Parameter ID | Characteristics (e.g., number, observation) | Compliance Baseline Value | |
| Geotechnical | Closure | Instrumentation is throughout the underground. | Munson-Dawson (MD) Constitutive Model | |
| **COMP Derivation Procedure** | | | | |
| Annually evaluate GAR for centerline closure rates, compare to previous year's rate. If closure rate increases by greater than one order of magnitude, initiate technical review. | | | | |
| **Related PA Elements** | | | | |
| Element Title | Type & ID | Derivation Procedure | Compliance Baseline | Impact of Change |
| PA Grid | Creep Closure | Porosity Surface<br>Waste Compaction Characteristics<br>Waste Properties<br>Evolution of underground setting | MD Model | Provides validation of the CCA creep closure model. |
| **Monitoring Data Trigger Values** | | | | |
| Monitoring Parameter ID | Trigger Value | Basis | | |
| Creep Closure | Greater than one order of magnitude increase in closure rate. | Closure rate increase signals potential de-coupling of rock. | | |

# Extent of Deformation:

## Trigger Value Derivation

| | |
|---|---|
| **COMP Title:** | Extent of Deformation |
| **COMP Units:** | Areal extent (length, direction) |

### Related Monitoring Data

| Monitoring Program | Monitoring Parameter ID | Characteristics (e.g., number, observation) | Compliance Baseline Value |
|---|---|---|---|
| Geotechnical | Displacement | Meters | Room geometry |

**COMP Derivation Procedure**

Extent of deformation deduced from borehole extensometers, feeler gauges, and visual inspections are examined yearly for active cross sections. Anomalous growth is determined by comparison.

**Related PA Elements**

| Element Title | Type and ID | Derivation Procedure | Compliance Baseline | Impact of Change |
|---|---|---|---|---|
| PA Grid | DRZ (shaft, drift and panel closure) | Constitutive model from laboratory and field databases. | See DOE 2014b for DRZ parameter values | 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 | Fracture coalescence at depth in rock surrounding drifts are important to closure performance and DRZ assumptions however surface observations do not correlate well with fracture depth. |

# Initiation of Brittle Deformation:

| **Trigger Value Derivation** | | | | |
|---|---|---|---|---|
| **COMP Title:** | Initiation of Brittle Deformation | | | |
| **COMP Units:** | Qualitative | | | |
| **Related Monitoring Data** | | | | |
| Monitoring Program | Monitoring Parameter ID | Characteristics (e.g., number, observation) | Compliance Baseline Value | |
| Geotechnical | Closure | Observational | Operational and Remedial | |
| **COMP Derivation Procedure** | | | | |
| Qualitative and pertinent to operational considerations. Captured qualitatively in association with other COMPs | | | | |
| **Related PA Elements** | | | | |
| Element Title | Type and ID | Derivation Procedure | Compliance Baseline | Impact of Change |
| Not directly related to PA | 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 conducive to the development of meaningful TVs. | | |

# Displacement of Deformation Features:

| **Trigger Value Derivation** | | | | |
|---|---|---|---|---|
| **COMP Title:** | Displacement of Deformation Features | | | |
| **COMP Units:** | Length | | | |
| **Related Monitoring Data** | | | | |
| Monitoring Program | Monitoring Parameter ID | Characteristics (e.g., number, observation) | Compliance Baseline Value | |
| Geotechnical | Delta $D/D_o$ | Observational | Not established | |
| **COMP Derivation Procedure** | | | | |
| Observational – Lateral deformation across boreholes., | | | | |
| **Related PA Elements** | | | | |
| Element Title | Type and ID | Derivation Procedure | Compliance Baseline | Impact of Change |
| Not directly related to PA | NA | NA | NA | NA |
| **Monitoring Data Trigger Values** | | | | |
| Monitoring Parameter ID | Trigger Value | Basis | | |
| Borehole diameter closure | None | Impact assessed as part of operational safety program. Not a PA parameter | | |

# 5.0 Conclusions

This report is the third revision of the *Trigger Value Derivation Report* and documents a reassessment of the values determined in the last revision of the report. SP 9-8 was used for this reassessment. TVs are to be used as a tool for the annual COMPs assessment process described in SP 9-8 (Wagner, 2008). The COMPs program is expected to evolve over the WIPP operational period. Changes to the compliance monitoring program are expected to include new monitoring parameters and assessment practices which will likely result in further changes to the TV concept.

The assessment made in this report modified one COMPs TV.

A summary of the TVs and the modification made by each revision of this report is shown in Table 5.1 below.

**Table 5.1**
**Trigger Value Revision Log**

| COMP | Rev 0. Trigger Value | Rev 1. Trigger Value | Rev 2. Trigger Value | Rev 3. Trigger Value |
|---|---|---|---|---|
| Probability of Encountering a Castile Brine Reservoir | None | No Change | No Change | No Change |
| Drilling Rate | 53.5 boreholes per $km^2$ per 10K yrs. | No Change – Correction made in "Basis" of TV, 10% changes to 15%, TV was not changed. | TV Deleted | No Change |
| Waste Activity | Panel half-full 5.1 million curies | No Change | Changed to annual assessment | No Change |
| Subsidence | $1.0 \times 10^{-2}$ m per year subsidence | No Change | No Change | No Change |
| Changes in Culebra Groundwater Flow | See Table 4.1 | No Change | Predicted travel time are compared to the distribution predicted by the current PA | No Change |
| Culebra Groundwater Composition | Not assigned in Rev. 0 | Both duplicate analyses for any major ion falling outside the 95% C.I.s given in Table 4.2 for three consecutive sampling periods | No Change | A p-value, derived with randomization test, for any major ion is less than or equal to 0.05 for three consecutive sampling rounds. |
| Creep Closure | Greater than one order of magnitude increase in closure rate. | No Change | No Change | No Change |
| Extent of Deformation | Growth of 1 m/year | No Change | TV Deleted | No Change |
| Initiation of Brittle Deformation | None | No Change | No Change | No Change |
| Displacement of Deformation Features | Occluded borehole | No Change | TV Deleted | No Change |

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