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WASTE ISOLATION PILOT PLANT

AP-181
Revision 0

Analysis Plan for the 2019 WIPP Compliance Recertification Application Performance Assessment

Task 4.2.1

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1 Introduction and Objectives

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, has been developed by the U.S. Department of Energy (DOE) for the geologic (deep underground) disposal of transuranic (TRU) waste. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194 by means of performance assessment (PA) calculations performed by Sandia National Laboratories (SNL). WIPP PA calculations estimate the probability and consequence of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure. The models used in PA are maintained and updated with new information as part of an ongoing process. Improved information regarding important WIPP features, events, and processes typically results in refinements and modifications to PA models and the parameters used in them. Planned changes to the repository and/or the components therein also result in updates to WIPP PA models. WIPP PA models are used to support the repository recertification process that occurs at five-year intervals following the receipt of the first waste shipment at the site in 1999.

PA calculations were included in the 1996 Compliance Certification Application (CCA) (U.S. DOE 1996), and in a subsequent Performance Assessment Verification Test (PAVT) (MacKinnon and Freeze 1997a, 1997b and 1997c). Based in part on the CCA and PAVT PA calculations, the EPA certified that the WIPP met the regulatory containment criteria. The facility was approved for disposal of transuranic waste in May 1998 (U.S. EPA 1998). PA calculations were an integral part of the 2004 Compliance Recertification Application (CRA-2004) (U.S. DOE 2004). During their review of the CRA-2004, the EPA requested an additional PA calculation, referred to as the CRA-2004 Performance Assessment Baseline Calculation (PABC) (Leigh et al. 2005), be conducted with modified assumptions and parameter values (Cotsworth 2005). Following review of the CRA-2004 and the CRA-2004 PABC, the EPA recertified the WIPP in March 2006 (U.S. EPA 2006).

PA calculations were completed for the second WIPP recertification and documented in the 2009 Compliance Recertification Application (CRA-2009). The CRA-2009 PA resulted from continued review of the CRA-2004 PABC, including a number of technical changes and corrections, as well as updates to parameters and improvements to the PA computer codes (Clayton et al. 2008). To incorporate additional information which was received after the CRA-2009 PA was completed, but before the submittal of the CRA-2009, the EPA requested an additional PA calculation, referred to as the 2009 Compliance Recertification Application Performance Assessment Baseline Calculation (PABC-2009) (Clayton et al. 2010), be undertaken which included updated information (Cotsworth 2009). Following the completion and submission of the PABC-2009, the WIPP was recertified in 2010 (U.S. EPA 2010).

PA calculations were completed for the third WIPP recertification and documented in the 2014 Compliance Recertification Application (CRA-2014). Following the completion and submission of the CRA-2014, the WIPP was recertified in 2017 (U.S. EPA 2017a).

The Land Withdrawal Act (U.S. Congress 1992) requires that the DOE apply for WIPP recertification every five years following the initial 1999 waste shipment. The results of the analysis described herein will be included in the 2019 Compliance Recertification Application (CRA-2019) to demonstrate regulatory compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194. This document details how SNL will conduct the compliance decision analysis for the CRA-2019 PA. Potential regulatory compliance impacts resulting from changes since the CRA-2014 PA will be determined by way of a comparison of CRA-2019 PA release probabilities to those calculated in the CRA-2014 PA.

Additionally, a separate calculation ("CRA19_CL") will be performed as a sensitivity study that investigates the impact of the assumption of a more rapid closure of open areas in the repository on calculated releases.

2 Approach

The CRA-2019 PA analysis will be used to demonstrate compliance with the containment requirements according to the Certification Criteria in Title 40 CFR paragraph 194. PA calculations will be executed that include changes occurring since the CRA-2014 PA, and results of these calculations will be compared to CRA-2014 PA results.[1] As regulatory compliance impacts will be assessed via a direct comparison to the CRA-2014 PA, the CRA-2019 PA is designed to reproduce the CRA-2014 PA implementation where possible. The CRA-2019 PA will examine all aspects of repository performance that are potentially impacted by changes occurring since the CRA-2014 PA.

The approach used for the CRA-2019 PA will be very similar to that used for the CRA-2014 PA (Camphouse 2013). The CRA-2019 PA includes an analysis of the Features, Events and Processes (FEPs) that may or may not have bearing on the performance of the repository. The FEPs are screened to determine which FEPs will be accounted for in the PA. These "retained" FEPs are formulated into scenarios that will be modeled. Scenarios are modeled using conceptual models that represent the physical and chemical processes of the repository. The conceptual models are implemented through a series of computer simulations and associated parameters that describe the natural and engineered components of the disposal system (e.g., site characteristics, waste forms, waste quantities, and engineered features). The results of the simulations quantify the magnitude and probability of potential releases of radioactive materials from the disposal system to the accessible environment over the 10,000-year regulatory period. The FEPs analysis also provides assurance that the initial FEPs screening performed prior to CRA-2019 PA calculations remains valid following the completion of CRA-2019 PA calculations.

The following sections detail how the CRA-2019 PA will be implemented with particular attention given to how the CRA-2019 PA implementation will differ from that of the CRA-2014 PA.

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[1] CRA-2014 PA calculations were done on the WIPP PA computing cluster running a VMS operating system. WIPP PA codes have since been migrated to a cluster running a Solaris operating system (Kirchner 2012, Kirchner et al. 2014, Kirchner et al. 2015). As part of the migration effort, CRA-2014 PA calculations were rerun on the Solaris system with results saved in the official results database (PA_Results) as Revision 0 (Kirchner et al. 2014). After correcting an error that existed in the version of the DRSPALL code used in the original CRA-2014 PA calculations, CRA-2014 PA calculations were again rerun on Solaris and the results were saved as Revision 1 (spallings releases had increased, but total releases were not substantially changed) (Kirchner et al. 2015). Also, as part of the migration effort, an updated version of the CCDFGF code (version 7.02) was migrated to the Solaris system and the CRA-2014 PA (Rev. 1) results were used as input to updated CRA-2014 calculations, the results of which were saved as Revision 2 (no releases were substantially different from the Rev. 1 results) (Kirchner et al. 2015). The baseline for comparison of CRA-2019 PA results will be the CRA-2014 PA results as calculated on the new WIPP PA Solaris system with the correction to the DRSPALL results and updated version of CCDFGF (i.e., CRA-2014, Rev. 2).

2.1 Changes Since the CRA-2014 PA

Several changes will be incorporated in the CRA-2019 PA relative to the CRA-2014 PA. The modifications included in the CRA-2019 PA include repository planned changes, parameter updates, and refinements to PA implementation. More specifically, changes included in the CRA-2019 PA will include the following:

1. Inclusion of an approach to accommodate the operational decisions to not emplace panel closures in Panels 3, 4, 5, and 6 and to not emplace waste in Panel 9.
2. Inclusion of an approach to accommodate an additional shaft connecting the repository to the surface, as well as an additional mined region in the repository north end to accommodate drifts that lead to the new shaft.
3. Refinement of the gas generation process model to include brine radiolysis.
4. An update to the probability that a drilling intrusion into a repository excavated region will intersect the Castile brine reservoir modeled in BRAGFLO.
5. Refinement to the corrosion rates of steel under humid and inundated conditions.
6. Refinement to the effective shear strength of WIPP waste.
7. Refinement to colloid enhancement parameters associated with actinide mobilization.
8. Refinement to the hydromagnesite to magnesite conversion rate.
9. Removal of two chemical reactions associated with iron sulfidation.
10. Correction to the length of the northernmost panel closure representation in the BRAGFLO grid.
11. Updates to drilling rate and plugging pattern parameters.
12. Updates to WIPP waste inventory parameters.
13. Updates to radionuclide solubilities and their associated uncertainty.
14. An update to the BH_OPEN:RELP_MOD parameter.
15. Introduction of new materials to define properties in some disturbed rock zone areas.
16. Hardware and computational code updates, including two codes that have been qualified for WIPP PA and added to the Software Baseline—those codes were previously qualified and used under Nuclear Waste Management Procedure NP 9-1: Analyses.

These changes are discussed in more detail in the sections that follow. It is intended that all substantial modifications to be included in the CRA-2019 PA are captured in the sections that follow. Additional changes, if they are necessary, will be discussed in the appropriate CRA-2019 PA analysis package, and also fall under the scope of AP-181.

2.1.1 Approach to Abandonment of Panel Closures in the South and No Waste in Panel 9

In February 2014, the WIPP repository was closed and later reopened on a limited basis, which resulted in maintenance delays in the repository. The DOE has proposed an operational policy change at WIPP as a result of the severe ground control issues caused by the maintenance delays. The policy change prohibits personnel access to (with the ultimate goal of withdrawal from) the area in the WIPP underground designated as equivalent Panel 9 (U.S. DOE, 2016). With that change, the planned implementation of run-of-mine salt panel closures (ROMPCS) in Panels 3, 4, 5, and 6 would no longer be possible. Also, waste emplacement in the area designated as Panel 9 would no longer be possible. In response to the operational changes, the DOE requested

that SNL undertake calculations and analyses to determine the impacts of the proposed changes to the repository configuration on the long-term performance of the facility (U.S. DOE, 2017). The approach to modeling the impacts of the operational changes and the results of the Abandonment of Panel Closures in South End of Repository (APCS) analysis are described in Zeitler et al. (2017). This same approach will be taken for CRA-2019 PA calculations and is described briefly below.

Panel closures are represented in PA calculations in the computational grids used by the BRAGFLO code, one grid for Salado flow calculations ("BRAGFLO grid") and one for direct brine release (DBR) calculations ("DBR grid"). In the BRAGFLO grid representation, there are three waste areas: (1) the "waste panel" (WP) represents waste emplaced in Panel 5; (2) the "south rest-of-repository" (SROR) represents waste emplaced in Panels 3, 4, 6, and 9; and (3) the "north rest-of-repository" (NROR) represents waste emplaced in Panels 1, 2, 7, 8, and 10. There are also three panel closure areas (PCS): the "southernmost" PCS representation is between the WP and SROR, the "middle" PCS representation is between the SROR and NROR, and the "northernmost" PCS representation is between the NROR and operations (OPS) area.

2.1.1.1 Properties of Open Panel Closures

In CRA-2014 PA calculations, there were two areas in the BRAGFLO grid that were modeled as "open," the OPS and EXP areas. There is no plan to backfill those areas, so they are assumed to close "naturally" following closure of the WIPP. Although the closure of the OPS/EXP areas is expected to occur gradually over time, in PA calculations, constant porosity and permeability over 10,000 years have been assumed (SNL 1996). In the APCS analysis, material properties for abandoned panel closure areas (i.e., panel closures for Panels 3-6 in the DBR grid and the southernmost panel closure in the BRAGFLO grid) were changed to be those used for the OPS/EXP areas and given a new material name, PCS_NO (Table 2-1). This change is justified in that it was shown to be conservative with respect to releases, and that the properties used for the OPS/EXP areas are the only analogues for open areas used in WIPP PA. Additionally, the DRZ above and below the abandoned panel closure areas retained the properties applied to the DRZ above and below the waste areas and operations and experimental areas (i.e., DRZ_PCS is not invoked at 200 years) (Table 2-2). For the ROMPCS panel closure areas, the same properties used in the CRA-2014 PA were applied.

For the CRA-2019 PA, the parameterization of the abandoned panel closures and associated DRZ areas will be the same as that used in the APCS analysis for the computational grids used in BRAGFLO and BRAGFLO_DBR calculations. The parameter values summarized in **Table 2-1** and Table 2-2 already exist in the Performance Assessment Parameter Database (PAPDB) and will be carried forward for CRA-2019 PA calculations.

Table 2-1: Open Panel Closure Properties for the CRA-2019 PA

Material	Property	Description	Units	Value
PCS_NO	CAP_MOD	Model number, capillary pressure model	(-)	1
PCS_NO	COMP_RCK	Bulk Compressibility	Pa^{-1}	0
PCS_NO	KPT	Flag for Permeability Determined Threshold	(-)	0
PCS_NO	PCT_A	Threshold Pressure Linear Parameter	Pa	0
PCS_NO	PCT_EXP	Threshold pressure exponential parameter	(-)	0
PCS_NO	PC_MAX	Maximum allowable capillary pressure	Pa	1.0E8
PCS_NO	PORE_DIS	Brooks-Corey pore distribution parameter	(-)	0.7
PCS_NO	POROSITY	Effective porosity	(-)	0.18
PCS_NO	PO_MIN	Minimum brine pressure for capillary model KPC=3	Pa	101325
PCS_NO	PRESSURE	Brine far-field pore pressure	Pa	101325
PCS_NO	PRMX_LOG	Log of intrinsic permeability, X-direction	$\log(m^2)$	-11
PCS_NO	PRMY_LOG	Log of intrinsic permeability, Y-direction	$\log(m^2)$	-11
PCS_NO	PRMZ_LOG	Log of intrinsic permeability, Z-direction	$\log(m^2)$	-11
PCS_NO	RELP_MOD	Model number, relative permeability model	(-)	11
PCS_NO	SAT_IBRN	Initial Brine Saturation	(-)	0
PCS_NO	SAT_RBRN	Residual Brine Saturation	(-)	0
PCS_NO	SAT_RGAS	Residual Gas Saturation	(-)	0

2.1.1.2 Redefinition of Panel Adjacency in CCDFGF

An additional piece of the APCS approach is that of "panel reneighboring" in CCDFGF calculations. Some conservativity with respect to releases is built into the APCS approach as a result of the reconsideration of panel adjacencies following intrusions (Zeitler and Day (2017) and Zeitler et al. (2017)). Panel neighbor relationships were modified to correspond to the degree of separation by panel closures instead of merely spatial proximity. The modification is consistent with the definition that panels having one or fewer panel closures between them are considered neighbors. The approach is consistent with the use of panel closures in both the

BRAGFLO and BRAGFLO_DBR grids and the definitions of SROR and NROR. The panel neighboring scheme followed in the APCS analysis will be carried forward for CRA-2019 PA calculations.

2.1.1.3 Removal of Waste from Panel 9

The APCS approach also considered the removal of waste from Panel 9 and relocation of waste to a new panel somewhere north of Panel 8, outside of the current repository configuration. It was shown to be appropriately conservative with respect to releases to continue to model waste within the existing Panel 9 in lieu of adding new waste panel(s) to the north. The conservatism was attributed to the 1-degree (south) dip in the Salado formation, which results in increased brine accumulation due to gravity drainage, increased hydrostatic pressure, and increased gas generation due to corrosion (enabled by the increased availability of brine) at the deeper/south portion of the repository. Previous PA analyses consistently show increasing brine saturations and pressures in the repository when moving from the north to the south. Thus, continuing to model the same mass of waste as if it is located in Panel 9 results in somewhat larger DBR and spallings releases compared to if the same mass was relocated to an arbitrary location further north. In the APCS analysis, this conservatism was greatly enhanced due to the abandonment of panel closures between Panels 3, 4, 5, 6, and 9, which effectively equilibrates the brine pressures and saturations in Panels 3, 4, 5, 6, and 9. The APCS analysis also showed that the potential non-conservative condition of not considering DBRs from both the empty Panel 9 and the hypothetical Panel 9 replacement is more than covered by the conservative assumptions of the panel neighbor redefinitions. For CRA-2019 PA calculations, it is considered to be appropriately conservative with respect to releases to continue to model waste within the existing Panel 9 in lieu of adding new waste panel(s) to the north.

2.1.1.4 Supplemental Calculation for CRA-2019 PA

In the APCS analysis (Zeitler et al. 2017), the decision to use “open” area properties for the abandoned panel closures was shown to substantially increase estimated releases over the CRA14_SEN4 (Zeitler and Day 2016) baseline case due to increased communication between the WP and SROR areas. The increased communication was due to the substitution of an “open” area for the southernmost panel closure area in the BRAGFLO representation, which allowed for greater brine pressures and saturations in the SROR following Castile intrusions, as there was no longer a significant barrier to equilibration with the WP. The saturations resulting from the flooding of Panels 3, 4, 6, and 9 with Castile brine from the borehole in Panel 5 through the abandoned panel closure led to increased gas generation and associated brine pressures in these areas. These conditions contributed to increases in calculated direct brine releases (DBRs) and releases to/from the Culebra and increased pressures led to increased spallings releases.

In discussions between the DOE and EPA subsequent to the APCS analysis, the EPA questioned whether, due to uncertainty in the timing of closure of open areas in the repository (i.e., when the material properties of the open areas might approach the properties of intact halite), the approach to model “open” areas of the repository, including abandoned panel closure areas, as permanently “open” could potentially underpredict releases. As an example, the EPA noted that for the CRA14_SEN3 sensitivity study (Day and Zeitler 2016), in which ROMPCS, OPS, and EXP two-phase flow properties were changed to more closely resemble intact halite (e.g.,

decreased porosity and permeability), estimated total releases increased over the baseline CRA-2014 PA case. However, the assumption made in the APCS analysis of no panel closure emplacement in the south end of the repository, which allowed greater communication among the panels in the south, is what drove releases higher for that analysis. Therefore, an effort to reduce porosity and permeability in all open areas would also serve to return the abandoned panel closure area to having a similar role to that prior to the APCS analysis (i.e., reducing communication among the panels in the south). Reducing the communication between the WP and SROR areas is expected to result in lower brine pressures and saturations in the SROR following Castile intrusions (and thus lower calculated releases) compared to a baseline case that considers an "open" abandoned closure area representation (e.g., the APCS case).

It is expected that the reduction in releases due to the reduction in communication between the WP and SROR areas (as observed for the APCS analysis) would not be less than the nominal increase in releases observed for reduced open area flow properties that limit gas flow to the north and increase pressures by reducing available void space to accommodate gas generation (as observed for the CRA14_SEN3 analysis). Because the APCS and CRA14_SEN3 analyses were based on different baselines (CRA14_SEN4 and CRA-2014 PA, respectively), a direct comparison of releases for an "open vs. closed" comparison has not yet been made. In order to show the impact of the assumed long-term behavior of open areas (i.e., resulting in "open" or "closed" OPS, EXP, and abandoned closure areas), a supplemental calculation will be performed as part of the CRA-2019 PA.

In this supplemental calculation (CRA19_CL analysis), the only differences from the baseline case (CRA19 analysis) will be the properties assigned to three areas (the OPS, EXP, and abandoned panel closure areas) and assignment of the panel neighbor relationships to be consistent with the isolation of panels in the south end of the repository (i.e., reassignment to "pre-APCS" relationships to be consistent with the basis described in Section 2.1.1.2). For the CRA19_CL analysis, OPS, EXP, and abandoned panel closure (southernmost panel closure) areas will have two-phase flow parameters equivalent to those specified for intact halite in order to facilitate modeling the impact of the assumption that rapid closure of open areas results in those areas having material properties more like the low porosity and low permeability Salado formation. Because these parameter values already exist in the PAPDB, no new parameter values will need to be specified for the CRA19_CL analysis.

Table 2-2: Material Properties to be Used for Operations, Experimental, and Panel Closure Areas from 0 to 10,000 yr in CRA14, CRA19, and CRA19_CL Analyses

Model Area	CRA14	CRA19	CRA19_CL
Northernmost and Middle Panel Closure Areas	PCS_T1 (0-100 yr), PCS_T2 (100-200 yr), PCS_T3 (200-10,000 yr)	PCS_T1 (0-100 yr), PCS_T2 (100-200 yr), PCS_T3 (200-10,000 yr)	PCS_T1 (0-100 yr), PCS_T2 (100-200 yr), PCS_T3 (200-10,000 yr)
Southernmost Panel Closure Area	PCS_T1 (0-100 yr), PCS_T2 (100-200 yr), PCS_T3 (200-10,000 yr)	PCS_NO	S_HALITE
Operations Area	OPS_AREA	OPS_AREA	S_HALITE
Experimental Area	EXP_AREA	EXP_AREA	S_HALITE

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2.1.2 Additional Shaft and Associated Drifts

In the wake of the 2014 radiological release event at the WIPP site, a modified ventilation system is planned that will provide sufficient airflow necessary for the resumption of increased-rate disposal operations in the future. The primary components of the modified ventilation system are an additional shaft in the north end of the repository and associated drifts to connect the additional shaft to the experimental area of the repository.

There are four shafts currently located in the repository north end, namely a salt handling shaft, an exhaust shaft, a waste shaft, and an air intake shaft. In WIPP PA, these shafts are combined into a single shaft that captures the combined impacts of all of them. The additional, planned shaft will be combined with the four existing shafts in the CRA-2019 PA. Additionally, mined volume in the repository north end will be modified in the repository representation so as to include the additional drifts created to access the new shaft. A similar approach was employed for the SHFT14 analysis that accompanied a planned change notice (PCN) submitted to the EPA in 2017 (Camphouse 2014). That analysis showed minimum impact to the long-term repository performance from representing the additional shaft and drifts. The shaft and drift dimensions assumed for the SHFT14 analysis were based on a preliminary design, while the dimensions assumed for the CRA-2019 PA are based on a more recent design. Updated model dimensions for the shaft and experimental area representations to be used in the BRAGFLO Salado grid were derived by Zeitler (2019a) and are summarized below in Table 2-3 and Table 2-4.

Table 2-3: BRAGFLO Grid Cell X- and Z-Dimensions for Shaft Representation (CRA-2014 and CRA-2019)

Analysis	X-Dimension (m)	Z-Dimension (m)	Area (m^2)	Length (m)	Volume (m^3)
CRA-2014	10	9.5	95	658.56	62563
CRA-2019	12.6933	12.0586	153.06	658.56	100802

Table 2-4: BRAGFLO Grid Dimensions for Experimental Area (CRA-2014 and CRA-2019)

Analysis	One-Cell Dimension			Full Dimension			Volume (m^3)
	X-Dim (m)	Y-Dim (m)	Z-Dim (m)	X-Dim (m)	Y-Dim (m)	Z-Dim (m)	
CRA-2014	361.65	1.32	51.68[a]	723.3	3.96	51.68[a]	148011
CRA-2019	361.65	1.32	67.05	723.3	3.96	67.05	192053

[a] – Three EXP cells in the CRA-2014 PA had a *z*-dimension of 51.68 m and three had *z*-dimension of 51.67 m.

2.1.3 Brine Radiolysis as Part of Gas Generation Process Model

A recent scoping analysis has identified a need to include radiolytic gas generation in WIPP PA (Day 2019). Therefore, brine radiolysis will be included in the CRA-2019 PA as part of the gas generation process model. The implementation and associated assumptions are described in detail in Day (2019) and parameterization implications are summarized below.

The total radiolytic H_2 generation rate is due to contributions from one or more decaying radionuclides in the waste area. The hydrogen generation rate due to radiolysis of radionuclides in solution and due to a fractional contribution from the wetted solid form of the radionuclides is dependent upon the following variables:

GDEPFAC = energy deposition probability for wetted solid radionuclides [-]

DECAYNRG = disintegration energy of radionuclide [MeV]

GH2AVG = average "G" value for H_2 [molecule/eV]

SRADO2 = stoichiometric coefficient for O_2 from radiolysis [mol O_2/mol H_2]

An inventory assessment as part of the CRA-2019 PA (see Section 3) will determine which radionuclides are to be considered to participate in radiolysis based on the relative amount of decay heats compared to the overall inventory heat production. For those selected radionuclides, new DECAYNRG parameters (Table 2-5) will be implemented in CRA-2019 PA to support the radiolysis and decay calculations—parameter values will be described in the Inventory Analysis Report. The source for the GLOBAL:GH2AVG parameter is an experimentally-derived value from Reed et al. (1993). Justifications for the GLOBAL:GDEPFAC and GLOBAL:SRADO2 parameter recommendations are provided by Day (2019).

Table 2-5: Radionuclide Radiolysis and Decay Parameters for the CRA-2019 PA

Material	Property	Description	Units	Value
To be determined via inventory analysis	DECAYNRG	Radionuclide disintegration energy	MeV	To be assigned as part of inventory analysis
GLOBAL	GH2AVG	Average G-value for H_2	molecules/eV	0.014
GLOBAL	GDEPFAC	Energy deposition probability for wetted solid radionuclides	(-)	Uniform Distribution from [0 - 0.5]
GLOBAL	SRADO2	Stoichiometric coefficient for O_2 from radiolysis	mol O_2/mol H_2	0

2.1.4 Refinement to the Probability of Encountering Pressurized Brine

The WIPP PA parameter GLOBAL:PBRINE (hereafter PBRINE) is used to specify the probability that a drilling intrusion into the excavated region of the repository encounters a region of pressurized brine below the repository. Development of the distribution for PBRINE

used prior to the CRA-2014 PA was the result of an analysis of TDEM data (Rechard et al. 1991, Peake 1998). A framework that provided a quantitative argument for refinement of the PBRINE parameter was developed for the CRA-2014 PA (Kirchner et al. 2012). The refinement of PBRINE resulted from a re-examination of the TDEM data while also including a greatly expanded set of drilling data for locations adjacent to the WIPP site than were available when the original analysis was performed in 1998. The EPA has since created a revised distribution for the PBRINE parameter based on a reexamination of the original TDEM data and recommended its use in the CRA-2019 PA. The resulting cumulative distribution for PBRINE is described in detail in U.S. EPA (2017b) and summarized in Zeitler (2019b) (Table 2-6). The DOE has agreed to use of the U.S. EPA-identified distribution in the CRA-2019 PA. The EPA previously directed this distribution for use by the DOE as part of the CRA14_SEN4 sensitivity study (Zeitler and Day 2016) and the distribution thus already exists in the PAPDB as version 4 of the PBRINE parameter.

Table 2-6: GLOBAL:PBRINE Distribution for the CRA-2019 PA

Material	Property	Description	Units	Value
GLOBAL	PBRINE	Prob. that Drilling Intrusion In Excavated Area Encounters Pressurized Brine	(-)	Cum. distribution as summarized in U.S. EPA (2017b) and Zeitler (2019b)

2.1.5 Refinement to the Corrosion Rates of Steel

The interaction of steel in the WIPP with repository brines will result in the formation of H_2 gas due to anoxic corrosion of the metal. Two steel corrosion rates will be updated for the CRA-2019 PA, STEEL:CORRMCO2 (hereafter CORRMCO2) and STEEL:HUMCORR (hereafter HUMCORR).

For the CRA-2014 PA, experimental results from Roselle (2013) were used to determine an updated parameter distribution for CORRMCO2, which represents the anoxic steel corrosion rate for brine-inundated steel in the absence of microbially produced CO_2. Subsequent to the submittal of the CRA-2014, the EPA requested that the DOE reconsider the subset of the Roselle data to be included in the CORRMCO2 distribution. As a result, a new, cumulative distribution for CORRMCO2 was developed (Zeitler and Hansen 2015). Later, in their technical support document (TSD) on chemistry-related issues, the EPA recommended an adjustment of the Zeitler and Hansen (2015) distribution for the CRA-2019 PA via an increase by a factor of two (U.S. EPA 2017c) and the DOE has agreed to the adjustment by a factor of two. The resulting cumulative distribution for CORRMCO2 is described in detail in Zeitler (2018a) and will be used in the CRA-2019 PA (Table 2-7).

For the CRA-2014 PA, experimental results from Roselle (2013) were used to determine that HUMCORR, which represents the humid corrosion rate of steel should maintain a value of zero. Subsequent to the submittal of the CRA-2014, the EPA requested that the DOE reconsider the subset of the Roselle data to be used for development of the STEEL:HUMCORR parameter. As a result, a cumulative distribution for HUMCORR was developed (Zeitler and Hansen 2015b)

and later revised based on a updated estimate of the CO_2 level expected in the repository, which itself is recalculated each time the thermodynamic database is revised (Zeitler and Hansen 2015c). In order to avoid recalculation of the HUMCORR distribution each time the thermodynamic database is revised in the future, a CO_2 level that is expected to bound future predicted CO_2 levels was selected and used to again revise the HUMCORR distribution (Zeitler 2018b). The cumulative distribution described in Zeitler (2018b) will be used in the CRA-2019 PA (Table 2-7).

Table 2-7: Iron Corrosion Parameters for the CRA-2019 PA

Material	Property	Description	Units	Value
STEEL	CORRMCO2	Inundated corrosion rate for steel without CO2 present	m/s	Cum. distribution as summarized in Zeitler (2018a)
STEEL	HUMCORR	Humid corrosion rate for steel	m/s	Cum. distribution as summarized in Zeitler (2018b)

2.1.6 Refinement to the Effective Shear Strength of WIPP Waste

WIPP PA includes scenarios in which human intrusion results in a borehole intersecting the repository. During the intrusion, drilling mud flowing up the borehole will apply a hydrodynamic shear stress on the borehole wall. Erosion of the wall material can occur if this stress is high enough, resulting in a release of radionuclides being carried up the borehole with the drilling mud. The WIPP PA parameter BOREHOLE:TAUFAIL (hereafter TAUFAIL) is used to represent the effective shear strength for erosion of WIPP waste.

For the CRA-2014 PA, experimental results from Herrick et al. (2012) were used to determine an updated parameter distribution for TAUFAIL (Herrick 2013). Subsequent to the submittal of the CRA-2014, the EPA requested that the DOE reconsider the subset of the Herrick data to be included in the TAUFAIL distribution, including lowering the lower bound of the distribution. The resulting cumulative distribution for TAUFAIL is described in U.S. EPA (2017d) and summarized in Zeitler (2019b). The DOE has agreed to its use in the CRA-2019 PA. The EPA previously directed this distribution for use by the DOE as part of the CRA14_SEN4 sensitivity study (Zeitler and Day 2016) and the distribution thus already exists in the PAPDB as version 7 of the TAUFAIL parameter.

Table 2-8: BOREHOLE:TAUFAIL Update for the CRA-2019 PA

Material	Property	Description	Units	Value
BOREHOLE	TAUFAIL	Effective shear strength for erosion	Pa	Uniform distribution as summarized in U.S. EPA (2017d) and Zeitler (2019b)

2.1.7 Refinement to Colloid Enhancement Parameters

Based on new laboratory and literature data since the CRA-2014 PA, it is expected that new parameter recommendations will be made to colloid enhancement parameters used to calculate mobilized radionuclide concentrations. Work is currently being done by SNL under AP-167 (Mariner 2014) related to updates to humic colloid parameters. Additionally, there is ongoing work being performed at Los Alamos National Laboratory (LANL) that may result in new parameter recommendations for intrinsic, mineral, and microbial colloids. Potential colloid enhancement parameter updates to be incorporated into the CRA-2019 PA are summarized in Table 2-9.

Table 2-9: Colloid Enhancement Parameters for the CRA-2019 PA

Material	Property	Description	Units	Value
PHUMOX3, PHUMOX4	PHUMSIM	Proportionality Constant, Humic Colloids, Salado Brine	(-)	To be assigned based on SNL colloid analysis
PHUMOX3, PHUMOX4	PHUMCIM	Proportionality Consant, Humic Colloids, Castile Brine	(-)	To be assigned based on SNL colloid analysis
AM, NP, PU, TH, U	CAPMIC	Maximum Concentration of Actinide on Microbe Colloids	moles/L	May be updated based on LANL colloid analysis
AM, NP, PU, TH, U	PROPMIC	Moles of Actinide Mobilized on Microbe Colloids per Moles Dissolved	(-)	May be updated based on LANL colloid analysis
AM, NP, PU, TH, U	CONCINT	Actinide Concentration with Mobile Actinide Intrinsic Colloids	moles/L	May be updated based on LANL colloid analysis
AM, NP, PU, TH, U	CONCMIN	Actinide Concentration with Mobile Mineral Fragment Colloids	moles/L	May be updated based on LANL colloid analysis

2.1.8 Refinement to Hydromagnesite Conversion Rate

For the CRA-2014 PA, the reaction of hydromagnesite to form magnesite was included along with an associated reaction rate, parameterized as WAS_AREA:HYMAGCON (hereafter HYMAGCON), derived by Clayton (2013). Subsequent to the submittal of the CRA-2014, the EPA requested that the DOE revise the distribution for HYMAGCON. A revised distribution was provided to the EPA by the DOE, but the EPA has recommended a different distribution for the CRA-2019 PA (U.S. EPA 2017c). The uniform distribution to be used for HYMAGCON in

the CRA-2019 PA is described in U.S. EPA (2017c) and summarized in Zeitler (2019b) (Table 2-10). The DOE has agreed to its use in the CRA-2019 PA.

Table 2-10: WAS_AREA:HYMAGCON Update for the CRA-2019 PA

Material	Property	Description	Units	Value
WAS_AREA	HYMAGCON	Rate of conversion of hydromagnesite to magnesite	mol kg^{-1} sec^{-1}	Uniform distribution as summarized in U.S. EPA (2017c) and Zeitler (2019b)

2.1.9 Removal of Iron Sulfidation Reactions

For the CRA-2014 PA, the sulfidation reactions with iron and iron hydroxide were included as part of the repository brine and gas production/consumption calculations. Subsequent to the submittal of the CRA-2014, the EPA requested that the DOE remove these chemical reactions from WIPP PA by setting the appropriate stoichiometric coefficients (i.e., REFCON:STCO_31, REFCON:STCO_32, REFCON: STCO_35, REFCON:STCO_36, REFCON:STCO_43, and REFCON:STCO_46) to zero. The request to remove iron sulfidation reactions from WIPP PA and the impact to WIPP PA parameters for the CRA-2019 PA is described in U.S. EPA (2017c) and summarized in Zeitler (2019b) (Table 2-11). The EPA previously directed the definition of zero values for these stoichiometric coefficients for use by the DOE as part of the CRA14_SEN4 sensitivity study (Zeitler and Day 2016) and thus these values already exist in the PAPDB as version 2 of the respective parameters. The DOE has agreed to their use in the CRA-2019 PA.

Table 2-11: Iron Sulfidation Stoichiometric Coefficient Parameter Updates for the CRA-2019 PA

Material	Properties	Description	Units	Value
REFCON	STCO_31, STCO_32, STCO_35, STCO_36, STCO_43, STCO_46	$FeOH_2$ and metallic Fe sulfidation stoichiometric coefficients	(-)	0

2.1.10 Correction to Length of Northernmost Panel Closure Representation

Three separate panel closure areas are modeled in BRAGFLO. The “northernmost” panel closure area separates the operations area from the “north rest of repository” (NROR) waste area, the “middle” panel closure separates the NROR from the “south rest of repository” (SROR), and the “southernmost” panel closure separates the SROR from the waste panel.

As part of the DOE/EPA completeness determination discussions for CRA-2014, an error in the length of the northernmost panel closure was identified by the DOE—the northernmost panel closure in the BRAGFLO grid should represent the length of two panel closures. This is done to

represent the combined blockage corresponding to the set of panel closures directly north of Panel 10 and the set of closures between the operations and experimental areas. Thus, the northernmost panel closure should have been 200 ft. (60.96 m) long, rather than 100 ft. (30.48 m) long, as had been used in the BRAGFLO model for the CRA-2014 PA (DOE 2015). A PA calculation was done to examine the impact of doubling the length of the northernmost panel closure and negligible changes to the pressures and saturations in the waste areas were found (Zeitler 2015). The correction to the BRAGFLO grid will be made for the CRA-2019 PA via changes in grid cell *x*-dimensions for the two columns of cells that contain the representation of the northernmost panel closures (Table 2-12).

Table 2-12: BRAGFLO Grid Cell X-Dimensions for Northernmost Panel Closure Representation (CRA-2014 and CRA-2019)

Analysis	One-Cell Length (m)	Full Length (m)
CRA-2014	15.24	30.48
CRA-2019	30.48	60.96

2.1.11 Updates to Drilling Rate and Plugging Pattern Parameters

WIPP regulations require that current drilling practices be assumed for future inadvertent intrusions. The DOE continues to survey drilling activity in the Delaware Basin in accordance with the criteria established in 40 CFR 194.33. Local well operators are surveyed annually to provide the WIPP project with information on drilling practices, Castile brine encounters, etc. Survey results through September 2018 are documented in the 2018 Delaware Basin Monitoring Annual Report (DBMAR) (DOE 2018).

Drilling parameters will be updated for the CRA-2019 PA to include information assembled through September 2018. The 2018 DBMAR indicates a drilling rate of 99.0 boreholes per km^2 over 10,000 years, resulting in a value for WIPP PA parameter GLOBAL:LAMBDAD of 9.90×10^{-3} boreholes per km^2 per year for the CRA-2019 PA, a notable increase to the value of 6.73×10^{-3} specified for this parameter in the CRA-2014 PA.

Borehole plugging pattern parameters will also be updated based on data contained in the 2018 DBMAR. The DBMAR reports six types of plugging patterns (summarized in Table 9 of the DBMAR), which have historically been translated into three unique plugging patterns for PA purposes. This same translation scheme (i.e., type VI is the same as a full plug, types II and IV are the same as a two-plug, and types I, III, and V are the same as a three-plug configuration) will be used for the parameterization of the GLOBAL:ONEPLG, GLOBAL:TWOPLG, and GLOBAL:THREEPLG parameters for the CRA-2019 PA (see SNL 2010 for a description of the use of the plugging pattern parameters in WIPP PA).

Although the translation scheme remains the same as for the CRA-2014 PA, the DOE has made a change to the physical area over which plugging pattern data are collected. The DBMAR states that the new dataset "more accurately represents plugging techniques and activities used in the vicinity of the WIPP and is consistent with the provisions of 40 CFR 194.33(c)(1) and the future states assumptions of 40 CFR 194.25" (DOE 2018). As a result, the plugging pattern

dataset is somewhat different than in previous versions of the DBMAR. Because of the substantial and potentially impactful changes of the drilling parameters, comparison values from the CRA-2014 PA are also presented in Table 2-13.

Table 2-13: Drilling Rate and Plugging Pattern Parameters for the CRA-2019 PA

Material	Property	Description	Units	CRA-2014 Value	CRA-2019 Value
GLOBAL	LAMBDAD	Drilling rate per unit area	km^{-2} yr^{-1}	6.73×10^{-3}	9.90×10^{-3}
GLOBAL	ONEPLG	Probability of having Plug Pattern 1 (full plug)	(-)	0.04	0.403
GLOBAL	TWOPLG	Probability of having Plug Pattern 2	(-)	0.594	0.331
GLOBAL	THREEPLG	Probability of having Plug Pattern 3	(-)	0.366	0.266

2.1.12 Updates to WIPP Waste Inventory Parameters

The Performance Assessment Inventory Report (PAIR) - 2018 (Van Soest 2018) was released on December 20, 2018. The PAIR-2018 contains updated estimates to the radionuclide content and waste material parameters, scaled to a full repository, based on inventory information collected up to December 31, 2017. In order to incorporate this update to the inventory into the CRA-2019 PA, the parameters for the initial radionuclide, chemical component and waste material inventories will be updated. In addition, parameters which are calculated based on the initial radionuclide inventories, such as the Waste Unit Factor (WUF) and the initial lumped radionuclide inventories, will be updated as well. Inventory parameters to be updated in the CRA-2019 PA are listed in Table 2-14.[2] Along with the parameter updates shown in Table 2-14, the analysis of the radionuclides that dominate potential releases will be updated.

[2] The SM147:INVCHD and SM147:INVRHD parameters, which represent initial inventories of the ^{147}Sm radionuclide in CH and RH waste, respectively, are new for the CRA-2019 PA. The ^{147}Sm radionuclide inventory with time continues to be calculated in the PANEL code, but an initial inventory of ^{147}Sm had not been previously defined.

Table 2-14: Inventory Parameter Updates for the CRA-2019 PA

Materials	Properties	Description	Value
AM241, AM243, CF252, CM243, CM244, CM245, CM248, CS137, NP237, PA231, PB210, PM147, PU238, PU238, PU240, PU241, PU242, PU244, RA226, RA228, SM147, SR90, TH229, TH230, TH232, U233, U234, U235, U236, U238	INVCHD and INVRHD	WIPP-Scale Initial Radionuclide Inventory (in Curies)	To be assigned as part of inventory analysis
AM241L, TH230L, PU238L, U234L, PU239L	INVCHD and INVRHD	WIPP-Scale Initial Lumped Radionuclide Inventory (in Curies)	To be assigned as part of inventory analysis
BOREHOLE	WUF	Waste Unit Factor	To be assigned as part of inventory analysis
NITRATE, SULFATE	QINIT	WIPP-Scale Amounts of Nitrate and Sulfate (in moles)	To be assigned as part of inventory analysis
WAS_AREA	IRONCHW, IRONRHW, IRNCCHW, IRNCRHW, CELLCHW, CELLRHW, CELCCHW, CELCRHW, CELECHW, CELERHW, PLASCHW, PLASRHW, PLSCCHW, PLSCRHW, PLSECHW, PLSERHW, RUBBCHW, RUBBRHW, RUBCCHW, RUBCRHW, RUBECHW, RUBERHW	Waste Material Parameters (in kg)	To be assigned as part of inventory analysis

The PAIR-2018 also includes information on the volume and radionuclide content for each waste stream. This information is used to generate the probability of encountering a waste stream and the normalized release as a function of time for each waste stream. Waste stream information is

stored in the input files for WIPP PA code EPAUNI. These input files will be updated in the CRA-2019 PA to reflect the most current waste stream information.

2.1.13 Updates to Radionuclide Solubilities

The solubilities of actinide elements are influenced by the chemical components of the waste. With the release of the PAIR-2018 (Van Soest 2018), updated information on the amount of various chemical components in the waste is available. To incorporate this updated information, parameters used to represent actinide solubilities will be updated in the CRA-2019 PA. Additionally, uncertainty ranges and probability distributions for actinide solubilities will be recalculated based on experimental results that have been published in the literature since the CRA-2014 PA, as well as the discussions between the DOE and EPA. Details of the development of radionuclide solubilities and their associated uncertainty for the CRA-2019 PA are contained in AP-153 (Brush et al. 2012) and will be expanded upon in the baseline solubility analysis report that will be generated for CRA-2019. Table 2-15 lists solubility parameters that will be updated in the CRA-2019 PA.

Table 2-15: Solubility Parameter Updates for the CRA-2019 PA

Materials	Properties	Description	Value
SOLMOD3, SOLMOD4, SOLMOD5	SOLCOH, SOLSOH, SOLCOH2, SOLSOH2, SOLCOH3, SOLSOH3, SOLCOH4, SOLSOH4, SOLCOH5, SOLSOH5	Actinide Baseline Solubilities in Castile and Salado Brines	To be assigned as part of solubility analysis
SOLMOD3, SOLMOD4	SOLVAR	Actinide Solubility Uncertainties	To be assigned as part of solubility uncertainty analysis

2.1.14 Update to BH_OPEN:RELP_MOD Parameter

A minor error in the BRAGFLO code related to the calculation of capillary pressure was discovered, as detailed in software problem report (SPR) 18-002, and determined to have an insignificant effect on repository performance results (Day 2018). It is noted that one of the SPR 18-002 corrections also prompts the necessity to revise a BRAGFLO input parameter for the relative permeability and capillary pressure function that is used to model an open borehole (BH_OPEN:RELP_MOD). The RELP_MOD parameter will be revised from 5 (the value used in the CRA-2014 PA) to 11 for the CRA-2019 PA to resolve the issue where the code correction resulted in a positive capillary pressure within the open borehole under RELP_MOD=5, which is both physically unrealistic and numerically unstable. The use of RELP_MOD = 11 for the BH_OPEN material is consistent with the relative permeability and (zero) capillary pressure implemented for other “open” repository areas such as the operations and experimental areas.

Table 2-16: BH_OPEN:RELP_MOD Parameter Value for the CRA-2019 PA

Material	Property	Description	Units	Value
BH_OPEN	RELP_MOD	Model number, relative permeability model	(-)	11

2.1.15 New Materials to Define Properties in DRZ Surrounding OPS, EXP, and Panel Closure Areas

As part of their review of the CRA-2014, the EPA directed multiple sensitivity studies that investigated impacts of parameter changes to the OPS, EXP, and panel closure areas and their associated disturbed-rock zones (DRZs), while leaving the DRZ surrounding the waste panel unchanged. To facilitate those analyses, new material names were used that introduced flexibility in specifying material properties independently across areas for which material properties in the CRA-2014 PA were identical. The flexibility of managing material properties by using these new material names will be preserved in the CRA-2019 PA. This subsection describes the new materials (DRZ_OE_0, DRZ_OE_1, DRZ_PC_1, DRZ_PC_0, and CAVITY_5) and the sources for the associated property values that already exist in the PAPDB due to their use in the sensitivity studies. To be clear, while material names representing these areas of the BRAGFLO grid have changed since the CRA-2014 PA, properties for those areas have not changed (one exception is the DRZ surrounding the abandoned southernmost panel closure area, which will have DRZ_0 and DRZ_1 properties (Section 2.1.1.1)).

In the CRA-2014 PA, the DRZ surrounding the waste, OPS, and EXP areas were given identical properties in BRAGFLO calculations via the DRZ_0 and DRZ_1 materials. In the CRA14_SEN2 study (Day 2016), to isolate the parameter modifications for the DRZ surrounding the OPS and EXP areas, the new materials DRZ_OE_0 and DRZ_OE_1 were introduced to represent the DRZ surrounding only the OPS and EXP areas in the -5 to 0 y and 0 to 10,000 y timeframes, respectively (the DRZ_0 and DRZ_1 materials continued to represent the DRZ surrounding the waste areas). In the CRA14_SEN4 sensitivity study (Zeitler and Day 2016), the properties of the DRZ surrounding the OPS and EXP areas were not changed from the CRA-2014 PA values, but the flexibility of isolating potential changes to the DRZ surrounding the OPS and EXP areas was preserved by maintaining the DRZ_OE_0 and DRZ_OE_1 materials and assigning values used in the CRA-2014 PA for the DRZ_0 and DRZ_1 materials, respectively.

For the CRA-2019 PA, the DRZ_OE_0 and DRZ_OE_1 materials will be used with parameter values equal to those used in the CRA-2014 PA for the DRZ_0 and DRZ_1 materials, respectively. Because the DRZ_OE_0 and DRZ_OE_1 materials did not exist for the CRA-2014 PA, the CRA-2019 PA will use the values defined in the sensitivity studies, as described above and summarized in Table 2-17.

Table 2-17: DRZ_OE_0 and DRZ_OE_1 Parameter Values for the CRA-2019 PA

Material	Material for which Property Values are Equivalent (CRA-2014 and CRA-2019)	Properties	Analysis from which Defined Property Values Will be Used
DRZ_OE_0	DRZ_0	KPT, PC_MAX, PO_MIN, PORE_DIS, RELP_MOD	CRA14_SEN2
DRZ_OE_0	DRZ_0	CAP_MOD, COMP_RCK, PCT_A, PCT_EXP, POROSITY, PRMX_LOG, PRMY_LOG, PRMZ_LOG, SAT_IBRN, SAT_RBRN, SAT_RGAS	CRA14_SEN4
DRZ_OE_1	DRZ_1	KPT, PC_MAX, PO_MIN, PORE_DIS, RELP_MOD	CRA14_SEN2
DRZ_OE_1	DRZ_1	CAP_MOD, COMP_RCK, PCT_A, PCT_EXP, POROSITY, PRMX_LOG, PRMY_LOG, PRMZ_LOG, SAT_IBRN, SAT_RBRN, SAT_RGAS	CRA14_SEN4

In the CRA14_SEN3 study (Day and Zeitler 2016), to isolate the parameter modifications for the DRZ surrounding the panel closure areas, the new materials DRZ_PC_0 and DRZ_PC_1 were introduced that represented the DRZ surrounding panel closure areas in the -5 to 0 y and 0 to 10,000 y timeframes, respectively. In the CRA14_SEN4 sensitivity study (Zeitler and Day 2016), the properties of the DRZ surrounding the panel closure areas were not changed from the CRA-2014 PA values, but the flexibility of isolating potential changes to the DRZ surrounding the panel closure areas was preserved by maintaining the DRZ_PC_0 and DRZ_PC_1 materials and assigning values used in the CRA-2014 PA for the DRZ_0 and DRZ_1 materials, respectively (one caveat is that the DRZ_PC_1 material properties were only used for the 0 to 200 y timeframe, while the DRZ_PCS material properties were used for the 200 to 10,000 y timeframe, as in the CRA-2014 PA).

For the CRA-2019 PA, the DRZ_PC_0 and DRZ_PC_1 (0 to 200 y timeframe) materials will be used with parameter values equal to those used in the CRA-2014 PA for the DRZ_0 and DRZ_1 materials, respectively. Because the DRZ_PC_0 and DRZ_PC_1 materials did not exist for the CRA-2014 PA, the CRA-2019 PA will use the values defined in the sensitivity studies, as described above and summarized in Table 2-18.

Table 2-18: DRZ_PC_0 and DRZ_PC_1 Parameter Values for the CRA-2019 PA

Material	Material for which Property Values are Equivalent (CRA-2014 and CRA-2019)	Properties	Analysis from which Defined Property Values Will be Used
DRZ_PC_0	DRZ_0 (-5 to 0 y)	KPT, PC_MAX, PO_MIN, PORE_DIS, RELP_MOD	CRA14_SEN3
DRZ_PC_0	DRZ_0 (-5 to 0 y)	CAP_MOD, COMP_RCK, PCT_A, PCT_EXP, POROSITY, PRMX_LOG, PRMY_LOG, PRMZ_LOG, SAT_IBRN, SAT_RBRN, SAT_RGAS	CRA14_SEN4
DRZ_PC_1	DRZ_1 (0 to 200 y)	KPT, PC_MAX, PO_MIN, PORE_DIS, RELP_MOD	CRA14_SEN3
DRZ_PC_1	DRZ_1 (0 to 200 y)	CAP_MOD, COMP_RCK, PCT_A, PCT_EXP, POROSITY, PRMX_LOG, PRMY_LOG, PRMZ_LOG, SAT_IBRN, SAT_RBRN, SAT_RGAS	CRA14_SEN4

The CRA14_SEN3 sensitivity study (Day and Zeitler 2016) investigated changes to panel closure properties. For the CRA-2014 PA, the panel closure system was, along with the shaft area, part of the CAVITY_4 material used in the -5 to 0 y time frame, but was separated from CAVITY_4 for the CRA14_SEN3 analysis. The startup material used for the panel closure system was a new material, CAVITY_5, and that material will continue to be used for the CRA-2019 PA, in order to preserve flexibility in assigning startup material properties to panel closure areas independently of the shaft area. For the CRA14_SEN3 analysis, the CAVITY_4 and CAVITY_5 materials had different property values, but for the CRA-2019, the property values for these two materials will be identical. Because the CAVITY_5 material did not exist for the CRA-2014 PA, the CRA-2019 PA will use the values defined in the sensitivity studies, as described above and summarized in Table 2-19.

Table 2-19: CAVITY_5 Parameter Values for the CRA-2019 PA

Material	Material for which Property Values are Equivalent (CRA-2014 and CRA-2019)	Properties	Analysis from which Defined Property Values Will be Used
CAVITY_5	CAVITY_4	KPT, PC_MAX, PO_MIN, PORE_DIS, PRESSURE	CRA14_SEN3
CAVITY_5	CAVITY_4	CAP_MOD, COMP_RCK, PCT_A, PCT_EXP, POROSITY, PRMX_LOG, PRMY_LOG, PRMZ_LOG, RELP_MOD, SAT_IBRN, SAT_RBRN, SAT_RGAS	CRA14_SEN4

2.1.16 Hardware and Computational Code Updates

Calculations for the CRA-2014 PA were performed on the WIPP PA Alpha Cluster, which consisted of HP AlphaServer hardware running the OpenVMS operating system (Long 2013). WIPP PA codes were later migrated to the WIPP PA Solaris Cluster, which consists of Intel hardware running the Solaris operating system (Kirchner 2012, Kirchner et al. 2014, Kirchner et al. 2015). The migration process consisted of recompilation, retesting, and requalification of codes, as well as rerunning of the CRA-2009 PABC and CRA-2014 PA calculations for verification. Subsequent to the migration of codes to the Solaris system, additional code changes have been made and documented to account for bug fixes, added functionality, and the addition of two codes to the Software Baseline that were previously qualified and used under Nuclear Waste Management Procedure NP 9-1: Analyses (SCREEN_NUTS and CCDFVECTORSTATS). The CRA-2019 PA will be run on the WIPP PA Solaris Cluster using code versions listed in Section 4.

2.2 FEPs Re-assessment

An assessment of the FEPs baseline will be conducted to determine if the FEPs basis remains valid in consideration of changes introduced by the CRA-2019 PA. This will include an assessment of whether the results of the CRA-2019 PA calculations support the initial FEPs screening. Results of this FEPs assessment will be documented in a separate report.

2.3 Calculation Methodology

2.3.1 Rationale

The aim of the CRA-2019 PA is to quantify regulatory compliance impacts associated with changes made since the CRA-2014 PA. Impacts will be determined by a direct comparison of

CRA-2019 PA and CRA-2014 PA results. As seen in Section 2.1, changes incorporated into the CRA-2019 PA include planned changes as well as parameter and implementation changes. The approach taken in the CRA-2019 PA is to assess the combined impact when all of these changes are included in the PA. As discussed in Section 2.1.1.4, a supplemental calculation will investigate the hypothesis that representing open areas of the repository (i.e., "open" panel closure, experimental, and operations areas) as having been closed from early times will lead to lower estimated releases from the repository. The primary CRA-2019 PA calculation (CRA19 analysis) and supplemental calculation (CRA19_CL analysis) are now discussed.

2.3.1.1 Primary CRA-2019 PA Calculation (CRA19 Analysis)

The first and primary analysis considered in the CRA-2019 PA will be used to compare the changes made relative to the CRA-2014 PA. The name given to this analysis is CRA19. All of the changes described in Section 2.1, apart from those discussed in Section 2.1.1.4 relative to the supplemental calculation, will be included in the CRA19 calculation. Three replicates will be executed for the CRA19 analysis, with results being compared to those obtained in the CRA-2014 PA (see Footnote 1 on page 7). The CRA19 analysis is the defining analysis associated with the CRA-2019 PA and the analysis to be used to ascertain regulatory compliance.

2.3.1.2 Supplemental CRA-2019 PA Calculation (CRA19_CL Analysis)

With the results of the CRA19 analysis in hand, the material property changes described in Section 2.1.1.4 will be added to the set of baseline changes implemented in the CRA19 analysis so that the impact of the early, "tight" closure of the OPS, EXP, and panel closure areas can be determined. The addition of these changes, and their potential impact on regulatory compliance, will be captured in the CRA19_CL (for CRA-2019 **CL**osure) analysis. Thus, the CRA19_CL analysis will incorporate all changes included in case CRA19 as well as refinements to material properties in the OPS, EXP, and open panel closure areas.

Three replicates will be executed for the CRA19_CL analysis and impacts of the changes described in Section 2.1.1.4 will be assessed via a direct comparison of CRA19_CL results to CRA19 results.

2.3.2 Code Execution

As described above, all planned changes, parameter changes, and implementation refinements will be incorporated in the CRA19 analysis, the defining analysis of the CRA-2019 PA. Additionally, a supplemental analysis, CRA19_CL, will be undertaken to examine the sensitivity of the repository response to a specific set of material properties applied to the OPS, EXP, and panel closure areas. The only differences between the CRA19 and CRA19_CL analyses will be due to the material properties assigned to the OPS, EXP, and panel closure areas, as well as assignment of panel neighbor relationships to be consistent with the isolation of panels in the south end of the repository. The material properties used in the CRA19_CL analysis will be identical to those used in the CRA19 analysis, with the exception of those discussed in Section 2.1.1.4 and summarized in **Table 2-2**. For simplicity in run control execution, no output from the CRA19 analysis will be used in the CRA19_CL analysis. Identical code versions will be executed for each analysis. The STEPWISE code will not be executed for the CRA19_CL

analysis. The sequence of code execution used in the CRA-2019 PA for each of the CRA19 and CRA19_CL analyses is now described.

2.3.2.1 Code Execution for CRA19 Analysis

The CRA19 analysis will consist of a full set of PA compliance calculations. That is, three replicates, with each replicate consisting of 100 vectors, will be produced for the CRA19 analysis. The structure of the calculations that will be performed for the CRA19 analysis is listed below.

Parameter Sampling: LHS

Three replicates of 100 vectors each will be created using the computer code LHS. The random seeds and parameter ordering from the CRA-2014 PA will be used for the CRA19 analysis in the CRA-2019 PA. Use of the CRA-2014 PA random seeds and ordering will result in identical sampled values for sampled parameters that have no changes to distributions between the CRA-2014 PA and CRA19 anlaysis. This approach enables comparison of CRA19 and CRA-2014 PA results on a vector-by-vector basis. The codes PRELHS version 2.44 and LHS version 2.44 will be used for the CRA19 analysis.

Salado Flow: BRAGFLO

The two-phase flow code BRAGFLO simulates the brine and gas flow in and around the WIPP repository and incorporates the effects of disposal room closure, gas generation, brine consumption, and inter-bed fracturing in response to gas pressure. The results of BRAGFLO scenarios S1-BF to S5-BF are used as input for the subsequent calculation of Salado radionuclide transport, DBRs, and spallings releases. BRAGFLO scenario S6-BF is used in the calculation of radionuclide transport to the Culebra. The scenarios modeled in BRAGFLO are listed in Table 2-20.

Table 2-20: WIPP PA BRAGFLO Scenarios

Scenario	No. of Drilling Intrusions	Time of Intrusion (Years)	Castile Brine Pocket Encountered?
S1-BF	0 (Undisturbed)	NA	NA
S2-BF	1	350	Yes
S3-BF	1	1,000	Yes
S4-BF	1	350	No
S5-BF	1	1,000	No
S6-BF	2	1,000 and 2,000	Only at 2,000 y

Three BRAGFLO replicates will be executed for the CRA19 analysis, with each replicate consisting of 100 vectors over 6 scenarios (see Table 2-20). The codes PREBRAG version 9.00, BRAGFLO version 7.00, and POSTBRAG version 4.02 will be used for the CRA19 analysis.

Direct Solids Releases: DRSPALL and CUTTINGS_S

Updated waste inventory information included in the CRA19 analysis will change cuttings and cavings releases as compared to the CRA-2014 PA. Repository pressures will be affected by other changes implemented since CRA-2014 PA, including the addition of radiolytic gas generation and changes to iron corrosion rates. Changes in repository pressures will impact spallings results. Consequently, direct solids releases for the CRA19 analysis will differ from those found in the CRA-2014 PA due to differences in repository pressures calculated by BRAGFLO as well as updated inventory information. Spallings volumes from a single borehole intrusion are calculated by code DRSPALL at initial repository pressures of 10, 12, 14, and 14.8 MPa. DRSPALL results (i.e., spallings volumes) that were generated at these pressures in calculations performed as part of the migration of computational codes to the Solaris system using DRSPALL version 1.22 (which were based on calculations performed to replicate PABC-2009 calculations; i.e., PABC09, Rev. 1) will be used in the CRA19 analysis (Kirchner et al. 2015). DRSPALL version 1.22 corrected an error found in previous versions (Kicker et al. 2015).

The CRA19 analysis will use the same procedure as was used for the CRA-2014 PA to interpolate between these DRSPALL volumes to calculate spallings volumes corresponding to a particular drilling intrusion. The initial repository pressure for a given scenario, time, location, and vector will be retrieved from the BRAGFLO results, and CUTTINGS_S will use this initial pressure to calculate a spallings volume for each scenario, time, location, and vector combination by interpolating between DRSPALL results. CUTTINGS_S version 6.03 will be used to calculate direct solids releases for three replicates in the CRA19 analysis.

Actinide Mobilization: PANEL

WIPP PA code PANEL calculates quantities of actinides mobilized by colloids and as dissolved species in WIPP brines. PANEL uses actinide solubilities from the WIPP parameter database, and these parameters will be updated for the CRA19 analysis (see Table 2-15). Three replicates of PANEL calculations will be executed for the CRA19 analysis. Although PANEL version 4.04 is currently the baseline version of the code, it is anticipated that version 5.00 will be available for use in the CRA-2019 PA.

Salado Transport: NUTS and PANEL

Changes incorporated into the CRA19 analysis impact waste concentrations in brine as well as repository conditions found with BRAGFLO. The WIPP radioisotope mobilization and decay code NUTS is used to simulate the transport of radionuclides through the Salado Formation for scenarios S1-BF through S5-BF. Three replicates of NUTS calculations will be executed for the CRA19 analysis. Although NUTS version 2.06 is currently the baseline version of the code, it is anticipated that version 2.07 will be available for use in the CRA-2019 PA.

Based on drilling event characteristics, intrusions are classified as no change (not significantly changing repository behavior), an E1 type (where a region of pressurized brine is encountered) or an E2 type (where pressurized brine pocket is not encountered). Radionuclide transport to the Culebra for the E2E1 intrusion combination (BRAGFLO scenario S6-BF) is calculated by running the PANEL code in “intrusion mode” (PANEL_INT). Three replicates of PANEL_INT

calculations will be performed for the CRA19 analysis using the same procedure that was used in the CRA-2014 PA PANEL_INT calculations. Although PANEL version 4.04 is currently the baseline version of the code, it is anticipated that version 5.00 will be available for use in the CRA-2019 PA.

Direct Brine Releases: BRAGFLO

In addition to its role as a tool used to simulate brine and gas flow in and around the WIPP repository, BRAGFLO is also used in PA to calculate DBR volumes. As the changes incorporated in the CRA19 analysis will impact pressure and brine saturation in waste-containing repository regions, DBR calculations consisting of three replicates will be performed as part of the CRA19 analysis. Conditions required for the initiation of a DBR release will remain unchanged from the CRA-2014 PA, and the DBR volumes will be calculated for the same scenarios and times (see Table 2-21). The codes PREBRAG version 9.00, BRAGFLO version 7.00, and POSTBRAG version 4.02 will be used for the CRA19 analysis.

Table 2-21: PA Intrusion Scenarios Used in Calculating Direct Brine Releases

Scenario	Conditioning (or 1st) Intrusion Time (year) and Type	Intrusion Times – Subsequent (year)
S1-DBR	None	100, 350, 1000, 3000, 5000, 10000
S2-DBR	350, E1	550, 750, 2000, 4000, 10000
S3-DBR	1000, E1	1200, 1400, 3000, 5000, 10000
S4-DBR	350, E2	550, 750, 2000, 4000, 10000
S5-DBR	1000, E2	1200, 1400, 3000, 5000, 10000

Culebra Flow and Transport: MODFLOW and SECOTP2D

Culebra flow and transport calculations will be identical to those found in the migration of computational codes to the Solaris system (Kirchner et al. 2014, Kirchner et al. 2015) because their parameters and conceptual models are not impacted by any of the updates or corrections implemented in the CRA19 analysis. Consequently, the Culebra flow and transport results from the code migration using SECOTP2D version 1.43 (which were based on calculations performed to replicate PABC-2009 calculations; i.e., PABC09, Rev. 1) will be used for the CRA-2019 PA.

CCDF Construction: CCDFGF

The CRA19 analysis will include calculation of CCDFs of individual vectors for total normalized releases, cuttings and cavings releases, spallings releases, DBRs, and releases from the Culebra. Mean CCDFs for each release pathway will be calculated for three replicates in the CRA19 analysis. The 95% confidence limit on the mean will also be calculated. The codes EPAUNI version 1.19, PRECCDFGF version 2.01 and CCDFGF version 7.03 will be used for the CRA19 analysis. The baseline version of the CCDFGF code has changed from CRA-2014 in order to allow for a more flexible method of modeling drilling intrusions into panels with regard to repository configuration (WIPP PA 2010, Kirchner et al. 2015). EPAUNI input files will be

updated in the CRA-2019 PA to include new waste stream information contained in the PAIR-2018 (Van Soest 2018).

Sensitivity Analysis: STEPWISE

The CRA19 analysis will implement sensitivity analyses for CCDFGF release results based on LHS-sampled parameters. Sensitivity analyses will be conducted in a manner consistent with those employed for the CRA-2014 PA. Specifically, global sensitivity analyses will be conducted on the results from CCDFGF using the linear regression code STEPWISE version 2.22.

2.3.2.2 Code Execution for Case CRA19_CL

As discussed in Section 2.1.1.4 and summarized in **Table 2-2**, the CRA19_CL analysis is an extension of the CRA19 that includes changes to OPS, EXP, and panel closure material properties for the BRAGFLO code run for both Salado flow and DBR calculations. Although, changes to these parameters do not impact the entire code execution chain used for the CRA19 analysis, for simplicity in run control execution, no output from the CRA19 analysis will be used in the CRA19_CL analysis. Identical code versions will be executed for each analysis. The STEPWISE code will not be executed for the CRA19_CL analysis.

Code execution for the CRA19_CL will be identical to that described in Section 2.3.2.1 for the CRA19 analysis. Results of the CRA19_CL analysis will be compared to results of the CRA19 analysis. Results from execution of the BRAGFLO and CCDFGF codes will be compared, as well as other codes as deemed needed to explain observed differences.

2.4 Reports and Documentation

Several reports will be generated as a result of this analysis plan. Each set of calculations discussed in Section 2.3 for the CRA19 analysis will be documented in an analysis report. These reports will include:

1) discussion of any implementation changes (parameters, modeling assumptions, etc.) relative to the corresponding CRA-2014 PA calculations; and
2) analysis of results relevant to the long term performance of the repository. The analysis will include comparisons of CRA19 analysis results with the CRA-2014 PA.

Additionally, results from execution of the BRAGFLO and CCDFGF codes for the CRA19_CL analysis will be documented in the respective analysis reports. A summary report describing the major results of the CRA-2019 PA will also be written.

A record of the run control will be created for the CRA-2019 PA. This document will contain:

1. A description of the hardware platform and operating system used to perform the calculations.
2. A listing of the codes and versions used to perform the calculations.
3. A listing of the scripts used to run each calculation.
4. A listing of the input and output files for each calculation.
5. A listing of the library or file directory where each file is stored.

6. File naming conventions.

Additional analyses, calculations, and documentation performed as part of the regulatory review and approval process for the CRA-2019 PA will also fall under AP-181.

3 Tasks

The tasks, responsible personnel and estimated task schedule are summarized below in Table 3-1.

Table 3-1: Task List and Estimated Schedule for the CRA-2019 PA

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
1	**Preparation Tasks**			
1a	Inventory Analysis	AP-181	3/26/19	Kicker
1b	Solubility Analysis	AP-153	3/1/19	Domski
1c	Colloid Parameter Analysis	AP-181	4/3/19	Sarathi
2	**Parameter Entry**			
2a	Inventory Parameters	NP 9-2	4/12/19	Long
2b	Solubility Parameters	NP 9-2	4/12/19	Long
2c	Colloid Parameters	NP 9-2	4/12/19	Long
2d	Other Parameters	NP 9-2	4/12/19	Long
3	**Code Run Environment Preparation**			
3a	Run Control Script Update	AP-181	3/15/19	Long
4	**Calculation Preparation**			
4a	Input Files Prepared	AP-181	3/15/19	Bethune, Brunell, Day, Kicker, Sarathi, Zeitler
4b	Input Files Reviewed	AP-181	3/16/19	Zeitler
5	**Calculations (Case CRA19)**			
5a	Parameter Sampling: LHS	AP-181	4/19/19	Long
5b	Salado Flow: BRAGFLO	AP-181	4/19/19	Long
5c	Cuttings & Cavings: CUTTINGS_S	AP-181	4/19/19	Long
5d	Direct Brine Releases: BRAGFLO	AP-181	4/19/19	Long
5e	Actinide Mobilization: PANEL	AP-181	4/19/19	Long

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
5f	Salado Transport: NUTS & PANEL	AP-181	4/19/19	Long
5g	Solid Normalized Releases: EPAUNI	AP-181	4/19/19	Long
5h	CCDF Construction: CCDFGF	AP-181	4/19/19	Long
5i	Sensitivity Analysis: STEPWISE	AP-181	4/19/19	Long
6	**Calculations (Case CRA19_CL)**			
6a	Parameter Sampling: LHS	AP-181	4/26/19	Long
6b	Salado Flow: BRAGFLO	AP-181	4/26/19	Long
6c	Cuttings & Cavings: CUTTINGS_S	AP-181	4/26/19	Long
6d	Direct Brine Releases: BRAGFLO	AP-181	4/26/19	Long
6e	Actinide Mobilization: PANEL	AP-181	4/26/19	Long
6f	Salado Transport: NUTS & PANEL	AP-181	4/26/19	Long
6h	CCDF Construction: CCDFGF	AP-181	4/26/19	Long
9	**Analysis & Documentation**			
9a	Inventory Analysis Report	AP-181	3/26/19	Kicker Sarathi
9b	FEPs Re-assessment	SP 9-4	6/3/19	Kirkes
9c	Parameter Sampling: LHS	AP-181	6/7/19	Zeitler
9d	Salado Flow: BRAGFLO	AP-181	6/7/19	Day
9e	Cuttings & Cavings: CUTTINGS_S	AP-181	6/7/19	Kicker
9f	Direct Brine Releases: BRAGFLO	AP-181	6/7/19	Bethune
9g	Actinide Mobilization: PANEL	AP-181	6/7/19	Sarathi
9h	Salado Transport: NUTS & PANEL	AP-181	6/7/19	Sarathi
9i	Solid Normalized Releases: EPAUNI	AP-181	6/7/19	Kicker
9j	CCDF Construction: CCDFGF	AP-181	6/7/19	Brunell
9k	Sensitivity Analysis: STEPWISE	AP-181	6/7/19	Zeitler
9l	Run Control Document	AP-181	6/7/19	Long
9m	Summary Report	AP-181	7/8/19	Zeitler

4 Software and Hardware

The major WIPP PA codes to be used for this analysis are listed in Table 4-1. These codes will be executed on the WIPP PA Solaris Cluster, the components of which are listed in Table 4-2. Additionally, COTS software, such as MATLAB®, Python, Excel®, or Access®, may be utilized. The use of COTS applications will be verified per NP 9-1 Appendix C as appropriate.

DRSPALL v1.22 and MERGESPALL v1.01 will not be run for the CRA-2019 PA. Instead, the DRSPALL v1.22 and MERGESPALL v1.01 output results from a previous run associated with the migration of codes to the Solaris system (Kirchner et al. 2015) will be used as input to the CRA-2019 PA calculations. Similarly, PRESECOTP2D v1.23, POSTSECOTP2D v1.05, and SECOTP2D v1.43 will not be rerun for the CRA-2019 PA. Instead, the PRESECOTP2D v1.23 and SECOTP2D v1.43 output results from a previous run associated with the migration of codes to the Solaris system (Kirchner et al. 2014) will be used as input to the CRA-2019 PA calculations. In all cases, the changed inputs to the CRA-2019 PA would not have changed the results of running these codes.

Table 4-1: WIPP PA Codes to be Used for the CRA-2019 PA

Code	Version	Executable	Build Date
ALGEBRACDB	2.36	algebracdb	9/11/12
BRAGFLO	7.00	bragflo	8/14/18
CCDFGF	7.03	ccdfgf	5/3/17
CCDFVECTORSTATS	1.01	ccdfvectorstats	3/20/18
CUTTINGS_S	6.03	cuttings_s	1/15/13
EPAUNI	1.19	epauni	9/12/16
GENMESH	6.10	genmesh	1/12/15
ICSET	2.23	icset	9/11/12
LHS	2.44	lhs	6/2/15
MATSET	9.24	matset	10/11/16
NUTS	2.06*	nuts	3/27/13
PANEL	4.04**	panel	9/26/12
POSTBRAG	4.02	postbrag	1/10/13
POSTLHS	4.11	postlhs	6/2/16
PREBRAG	9.00	prebrag	8/16/18
PRECCDFGF	2.01	preccdfgf	9/9/13
PRELHS	2.44	prelhs	10/11/16
RELATE	1.45	relate	9/11/12
SCREEN_NUTS	1.02	screen_nuts	2/7/18
STEPWISE	2.22	stepwise	7/2/13
SUMMARIZE	3.02	summarize	10/31/12

*- Although NUTS version 2.06 is currently the baseline version of the code, it is anticipated that version 2.07, which corrects a minor error, will be available for use in the CRA-2019 PA.
**- Although PANEL version 4.04 is currently the baseline version of the code, it is anticipated that version 5.00, which addresses a number of known issues, will be available for use in the CRA-2019 PA.

Table 4-2: WIPP PA Solaris Cluster Compute Nodes

Node	Hardware Type	CPU	Operating System	# CPUs
BEP	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
BLS	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
DC5	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
GD	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24

Node	Hardware Type	CPU	Operating System	# CPUs
GFD	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
IRON	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
LZ	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
PF	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
VH	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
ZP	Oracle/SUN X6270 m2	x86 (GenuineIntel 206C2 family 6 model 44 step 2 clock 3458 MHz)	Oracle Solaris 11	24
BC	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
BOS	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
CHI	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
FOG	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
HP	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
JA	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
ML	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
RE	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
UH	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
ZZ	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
SAN	Dell PowerEdge R820	x86 (GenuineIntel 206D7 family 6 model 45 step 7 clock 2400 MHz)	Oracle Solaris 11	64

5 Special Considerations

None

6 Applicable Procedures

All applicable WIPP QA procedures will be followed when conducting these analyses.

- Training of personnel will be conducted in accordance with the requirements of NP 2-1, *Qualification and Training*.
- Analyses will be conducted and documented in accordance with the requirements of NP 9-1, *Analyses*.
- All software used will meet the requirements laid out in NP 19-1, *Software Requirements* and NP 9-1, as applicable.
- The analyses will be reviewed following NP 6-1, *Document Review Process*.
- All required records will be submitted to the WIPP Records Center in accordance with NP 17-1, *Records*.
- New and revised parameters will be created as discussed in NP 9-2, *Parameters*.

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