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SANDIA NATIONAL LABORATORIES
WASTE ISOLATION PILOT PLANT

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Revision 0

Analysis Plan for the Additional Panels Performance Assessment

Task 4.4.1.2.1

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Authored by:	Clifford Hansen	*Original signed by Shelly R. Nielsen for*	*6-8-2020*
	Print Name	Signature	Date
Reviewed by:	Dwayne Kicker	*Original signed by Shelly R. Nielsen for*	*6-8-2020*
	Print Name Technical Reviewer	Signature	Date
Reviewed by:	Emily Stein	*Original signed by Steve Wagner for Emily Stein*	*6/8/2020*
	Print Name Management Reviewer	Signature	Date
Reviewed by:	Shelly R. Nielsen	*Original signed by Shelly R. Nielsen*	*6-8-2020*
	Print Name Quality Assurance Reviewer	Signature	Date
Approved by:	Steve Wagner	*Original signed by Steve Wagner*	*6/8/2020*
	Print Name Department Manager	Signature	Date

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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. 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.

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 (FEPs) 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.

As currently certified, WIPP includes ten excavated panels for placement of waste. The DOE plans to excavate additional panels for waste disposal. This analysis plan describes the models and parameters to be used to quantify the long-term performance of the repository with the additional panels.

1.1 Baseline for This Analysis

The analysis described in this plan is based on the inventory, models and parameters used for the CRA-2019 (DOE 2019). Since the CRA-2019, the following changes have been made in the WIPP PA which apply to the analysis of additional panels:

1. Actinide solubilities have been corrected (Domski 2020, Kim et. al. 2020).
2. The grid for the Salado flow model is modified to accommodate additional panels.
3. The grid for computing direct brine release (DBR) is modified to account for the additional panels.
4. The procedure for calculating releases due to transport through the Culebra is modified to account for the extended footprint of the repository due to the additional panels.
5. Repository area and volume parameters are updated to account for the additional panels.
6. The CCDFGF code is modified to accommodate additional panels.
7. Logic for assigning panel neighbors is extended to account for the additional panels.

1.2 Additional Panels

The DOE plans to excavate additional volume for waste disposal, comprising nine waste panels (numbered 11 through 19) to the west of the current repository footprint (Figure 1). Panels 11

through 19 will be similar to Panels 1 through 8, except that the abutment pillars (between the waste rooms and the access drift) are increased from 61.0 m (200 ft) to 122 m (400 ft) and the isolation pillars (separating two panels) are increased from 61.0 m (200 ft) to 91.5 m (300 ft).

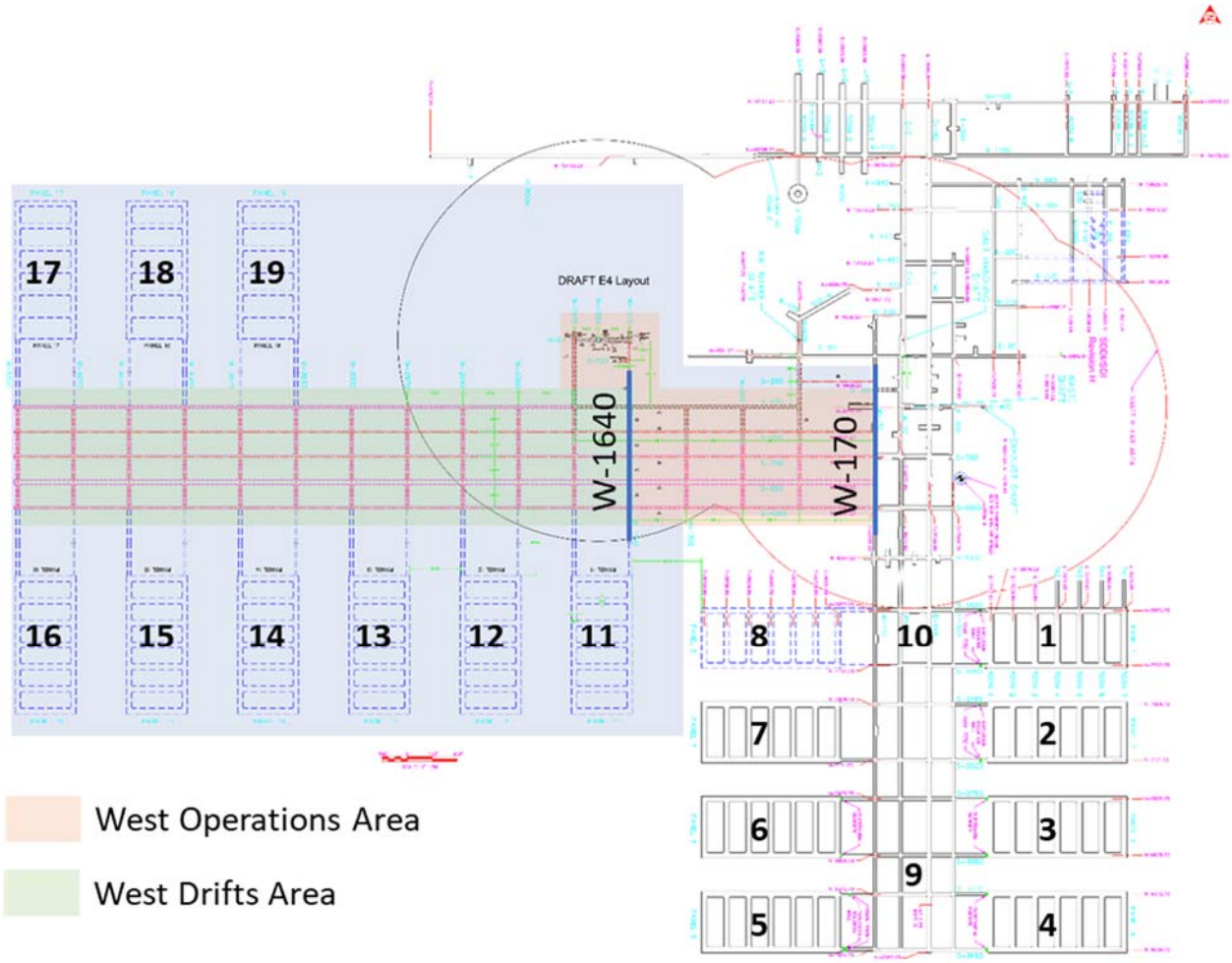

Figure 1. Current Repository Footprint and Proposed Additional Waste Panels (Sjomeling, 2019)

1.3 Panel Closures

Panel closures for the proposed additional panels comprise 100 feet of run-of-mine (ROM) salt in the intake and exhaust drifts, the same as for the waste panels in the current repository.

1.4 Non-Waste Areas

Five access drifts running east-west connect the new panels with the rest of the repository. Unlike the access drifts in the south that comprise Panel 10, there is no plan to place waste in the west access drifts. There are no plans for panel closures in the drifts that connect the west panels to the operations and experimental areas (Sjomeling, 2019).

1.5 Shafts

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 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 operations area of the repository.

2 Approach

The Additional Panels Performance Assessment (APPA) is organized as a sequence of tasks:

1. Review of FEPs and conceptual models.
2. Generate sample of uncertain parameters.
3. Salado flow modeling.
4. Salado transport modeling.
5. Modeling of direct releases.
6. Culebra flow and transport modeling.
7. Calculation of complementary cumulative distribution functions (CCDFs) that quantify potential releases from the repository.
8. Conduct sensitivity analysis.

Each task is detailed in the subsequent sections. Deviations from the planned approach will be detailed in analysis reports and in revisions to this plan, as warranted.

2.1 Review of FEPs and Conceptual Models

The addition of excavated areas to the west of the repository, and the proposed emplacement of waste in these areas, may affect the screening of FEPs for the PA, and the conceptual models that represent FEPs. The first task in the APPA is to re-examine the FEPs screening decisions and the WIPP PA conceptual models. The assessment will be performed according to SP 9-4, Performing FEPs Baseline Impact Assessments for Planned or Unplanned Changes. The FEPs assessment and the review of conceptual models will be documented in an analysis report.

Because the additional panels represent an extension of the existing repository using similar construction and materials and at the same horizon, it is anticipated that the review will not result in changes to FEP screening decisions or significant change to conceptual models. The remainder of this analysis plan assumes this finding.

2.2 Sample of Uncertain Parameters

For the APPA, no changes are planned that affect parameters considered to be uncertain. Consequently, the APPA will use the same parameter sample as was generated for the CRA-2019.

2.3 Salado Flow

The APPA uses the same conceptual and mathematical models for Salado flow as were used for the CRA-2019. Numerical calculations will be done with the BRAGFLO 7.00 code on a revised grid that accounts for the additional panels.

2.3.1 BRAGFLO Grid

In the CRA-2019 (DOE 2019, Appendix PA) the repository is modeled as comprising ten waste panels with emplaced waste, and additional excavated volumes without waste. Other significant repository features represented in the PA include the panel closures and shafts. Figure 2 displays the computational grid used by the BRAGFLO model to calculate brine and gas flow in the Salado, showing each represented feature.

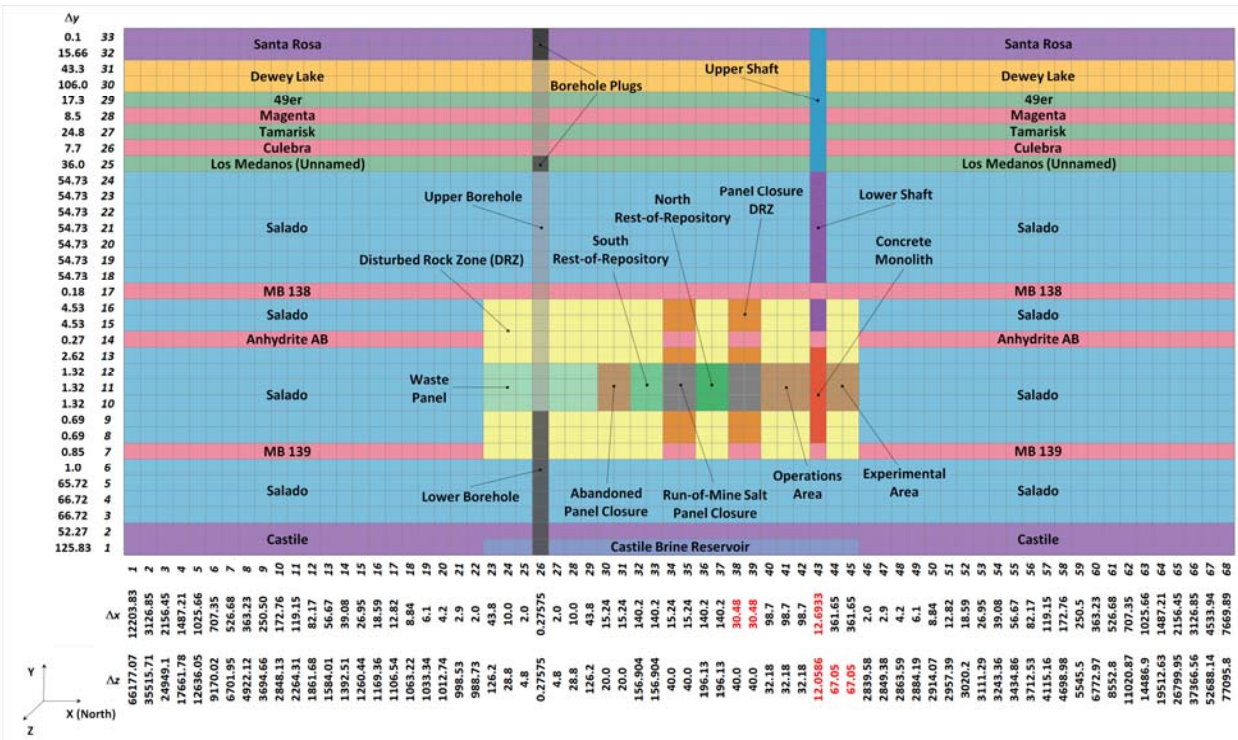

Figure 2. CRA-2019 BRAGFLO grid (DOE 2019, Appendix PA, Figure PA-12)

The additional panels shown in Figure 1 necessitate changes to the computational grid shown in Figure 2. The BRAGFLO model uses a 2D (north-south and vertical) grid that is flared in the east-west direction to account for volumes. This 2D approach enables significant simplifications to the mathematical and numerical models for Salado flow and has been determined to be technically adequate for WIPP PA (Caporuscio 2003). Two-dimensional flaring is used where the flows of primary interest are converging (or diverging), as is the case in the WIPP PA with flows through excavated areas towards boreholes.

With the additional panels, the repository floor plan assumes an “L” shape rather than the generally linear, north-south geometry in the current repository floor plan. To represent this geometry in a

2D grid, the L shape is unbent to a linear arrangement of panel groups as depicted in Figure 3. Consistent with the Salado Formation's general regional dip to the south-east (Appendix GCR, 1978), a 1% dip from north to south (right to left in Figure 3) is applied to the linear grid.

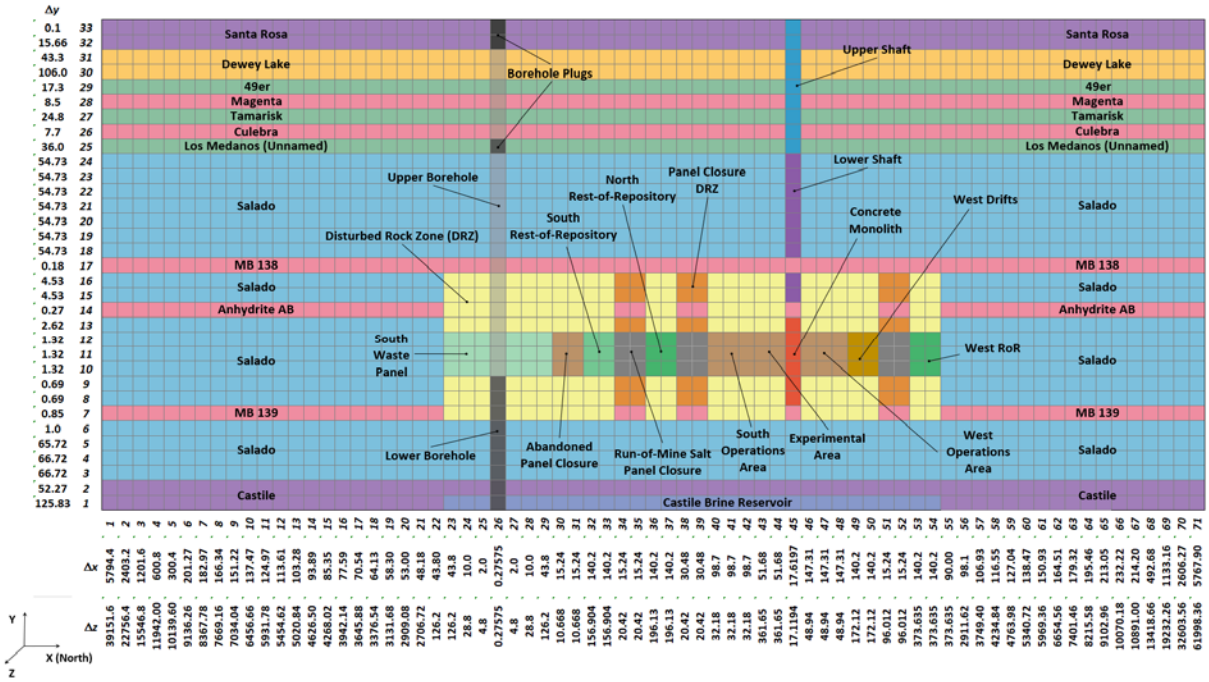

Figure 3. BRAGFLO grid for the APPA

The grid in Figure 3 implements rectangular flaring at two scales: locally around the borehole and regionally to the north and south of the excavated region. The local flaring around the borehole is unchanged from the CRA-2019. The center of regional flaring is moved from the center of the panel closure dividing North Rest-of-Repository from South Rest-of-Repository in Figure 2, to a point at the center of the experimental area in Figure 3, to balance the excavated volumes to the left and right of the regional flaring center. Grid cell dimensions in the Δx direction are adjusted near the excavated region to improve the transition between the local and regional flaring.

The Land Withdraw Boundary (LWB) to the south of the repository is located in the APPA grid between columns 4 and 5; the distance between Waste Panel and the LWB has not changed from the CRA-2019 grid. On the right side of the APPA grid, the LWB is located between columns 67 and 68 at the distance between the proposed west waste panels and the western LWB. The distance between the LWB and the grid domain boundary has been reduced from 20 km in the CRA-2019 grid to 10 km in the APPA grid; the Salado Flow analysis package for the APPA will contain a justification for this change.

The BRAGFLO grid (Figure 3) aggregates waste panels into four waste-bearing areas denoted South Waste Panel (WAS), South Rest of Repository (SRR), North Rest of Repository (NRR), and West Rest of Repository (WRR). Table 1 lists the panels which comprise each waste-bearing area in the BRAGFLO grid. One representative borehole is placed in the grid in the South Waste Panel area. The borehole in the South Waste Panel is considered to be a conservative representation of

an intrusion into any waste panel, as the South Waste Panel tends to have higher saturation, being down dip from other panels.

Table 1. Panel Groups in the APPA

Panel Group	Repository Section	Panels in Panel Group
South Waste Panel (WAS)	South	5
South Rest of Repository (SRR)	South	3, 4, 6, 9
North Rest of Repository (NRR)	South	1, 2, 7, 8, 10
West Rest of Repository (WRR)	West	11, 12, 13, 14, 15, 16, 17, 18, 19

The DOE no longer plans to emplace waste in Panel 9. However, as was done in the CRA-2019, the APPA will model Panel 9 as containing waste to simplify the modeling. The APPA waste inventory will be represented as homogeneous over the volume of the repository; the repository volume (parameter REFCON:VREPOS) will be the volume of 19 waste panels. This treatment of Panel 9 has been shown to be conservative with respect to releases from the repository (Zeitler et. al. 2017). Modeling Panel 9 as having waste places a proportionally greater volume of emplaced waste down-dip from most areas and in a waste area adjacent to the South Waste Panel, which contains the representative borehole.

The operations area maintains its dimensions as in the CRA-2019 grid but is renamed here as the South Operations area. The volume of the experimental area changes from the CRA-2019 grid. In the CRA-2019, the volume of the additional shaft access drifts is included in the experimental area (Day, 2019). Here, a new West Operations area incorporates all new excavations between drifts W-1640 and W-170 with the volume of the additional shaft access drifts (Figure 1). A new area named West Access Drifts includes the volume of the access drifts for the waste panels west of W-1640. Compared to the CRA-2019 grid, the x- and z-dimensions of the experimental area are swapped so that the experimental area offers little impedance to flow between the west and south areas of the repository, while maintaining the experimental area's excavated volume.

As in the CRA-2019, the planned fifth shaft will be combined with the four existing shafts into a single shaft feature in the BRAGFLO grid for the APPA. The SHFT14 analysis (Camphouse 2014) showed minimum impact to the long-term repository performance from representing the additional shaft in this manner.

2.3.2 Scenarios for Salado Flow Modeling

The Salado flow model computes two-phase (brine and gas) spatially and temporally varying pressure, saturation and flow in both undisturbed and disturbed conditions. Disturbed conditions are modeled by imposing a borehole representing a drilling intrusion in the BRAGFLO grid. Table 2 lists the intrusion scenarios and their characteristics; the intrusion scenarios for the APPA are unchanged from the CRA-2019.

Table 2. Intrusion Scenarios for the Additional Panel PA

Scenario	Description
E0	Undisturbed repository
E1	Drilling intrusion that intersects a brine reservoir in the Castile
E2	Drilling intrusion that does not intersect a brine reservoir in the Castile
E1E2	Multiple intrusions into the same waste panel with at least one E1 intrusion

For the APPA a representative borehole is placed in the south half of the repository as indicated in Figure 3. The BRAGFLO scenarios for the APPA are unchanged from the CRA-2019 as indicated in Table 3.

Table 3. BRAGFLO Modeling Scenarios for the Additional Panel PA

Scenario	Description
S1-BF	Undisturbed repository
S2-BF	E1 intrusion at 350 years in South Waste Panel
S3-BF	E1 intrusion at 1,000 years in South Waste Panel
S4-BF	E2 intrusion at 350 years in South Waste Panel
S5-BF	E2 intrusion at 1,000 years in South Waste Panel
S6-BF	E2 intrusion at 1,000 years; E1 intrusion at 2,000 years in South Waste Panel

2.4 Salado Transport

Models to estimate transport in the Salado are implemented in the PANEL and NUTS codes. The PANEL code simulates radionuclide decay and mobilization in brine, resulting in time-dependent mobilized concentrations in the waste panels. The NUTS code simulates radionuclide decay and advective transport in the Salado formation for the E0, E1 and E2 scenarios, using the same 2D grid as BRAGFLO. A second usage of PANEL is to compute radionuclide transport to the Culebra in the E1E2 intrusion scenario.

2.4.1 Radionuclide Mobilization

The PANEL code calculates mobilized radionuclide concentration as the sum of the dissolved and colloidal contributions for 13 elements (Am, Cf, Cm, Cs, Np, Pa, Pb, Pm, Pu, Ra, Sr, Th and U) and their isotopes inside the waste panels during the 10,000-year regulatory period. Except as noted below, these calculations are the same in the APPA as in the CRA-2019.

The CRA-2019 PA used the DATA0.FM4 database for actinide baseline solubilities, but it was later realized that incorrect thermodynamic interaction parameter values resulted in lower actinide (III) baseline solubility values (Domski, 2020). Analysis showed that correcting the actinide (III) baseline solubility values had no impact on the CCDF of total releases (Kim, 2020). The APPA will use DATA0.FM5, the WIPP thermodynamic database (Domski, 2020) with corrected thermodynamic interaction parameters.

The PANEL code calculates mobilized radionuclide concentrations for the radionuclide mass and brine volumes with direct access to the representative borehole (Figure 3).

Using Am-241 for illustration, the radionuclide mass is computed in the PANEL code from the repository inventory as

AM241:INVCHD × INVSCALE × NUMPANEL

where AM241:INVCHD is the mass of Am-241 in the contact-handled (CH) inventory and INVSCALE and NUMPANEL are ALGEBRACDB variables. Conceptually, INVSCALE is the fraction of radionuclide inventory in a single waste panel. For the CRA-2019, the value of INVSCALE was determined by dividing the volume of a single panel (parameter REFCON:VPANLEX) by the total volume of the ten waste panels (parameter REFCON:VREPOS). For the APPA, the value of REFCON:VREPOS will be changed to the volume of 19 waste panels. Although the DOE does not plan to place waste in Panel 9, REFCON:VREPOS will be the total volume of 19 panels to be consistent with the BRAGFLO grid (Figure 3) in which Panel 9 is modeled as having waste. For the APPA, the value for INVSCALE will be computed as the volume of a standard panel (parameter REFCON:VPANLEX) divided by the 19-panel value for the parameter REFCON:VREPOS. The ALGEBRACDB variable NUMPANEL is the maximum number of waste panels with direct access to the representative borehole. For the CRA-2019, NUMPANEL was set to 5 (for the connected group comprising Panels 3, 4, 5, 6 and 9); this same value will be used for the APPA.

Mobilized radionuclide concentrations are computed for each of a set of brine volumes. In the CRA-2019, single-panel brine volumes (ALGEBRACDB variable PANDFVOL) were calculated by ALGEBRACDB as

PANDFVOL = GLOBAL:DBRMINBV × INVSCALE × BRINEFAC

where the parameter GLOBAL:DBRMINBV is the minimum repository brine volume for a DBR release and BRINEFAC was 1, 2, 3, 4 and 5. The ALGEBRACDB variable PANDFVOL is multiplied in the PANEL code by NUMPANEL to obtain the volume of the waste panels with direct access to the representative borehole. In the CRA-2019, the value of GLOBAL:DBRMINBV was based on a 10-panel repository, INVSCALE was the ratio of one panel volume to the volume of a 10-panel repository, and NUMPANEL was set to 5 (for the connected group comprising Panels 3, 4, 5, 6 and 9). For the APPA, the value of GLOBAL:DBRMINBV will be the same as for the CRA-2019 to maintain consistency with the baseline solubilities for the CRA-2019 which are not being changed for the APPA. A value for PANDFVOL will be calculated as

PANDFVOL = GLOBAL:DBRMINBV × 0.10514829 × BRINEFAC

where 0.10514829 is the ratio of the volume of a representative panel (parameter REFCON:VPANLEX) to the volume of the 10-panel repository, i.e., the CRA-2019 value of parameter REFCON:VREPOS. The variables BRINEFAC and NUMPANEL will have the same values as for the CRA-2019.

2.4.2 Models for Salado Transport

The models for Salado transport for the APPA are the same as for the CRA-2019 (DOE 2019, Appendix PA).

The NUTS code simulates advective transport of radionuclides in the Salado for the E0, E1 and E2 intrusion scenarios, using the 2D BRAGFLO grid (Figure 3 for the APPA). NUTS takes as input inventories of 5 lumped radionuclides, effective solubility limits (mobilized concentrations in the absence of inventory limits) calculated by PANEL, and transient brine flow fields calculated by BRAGFLO. It returns radionuclide mass fluxes which are summed to calculate cumulative radionuclide release up the shafts or boreholes to the Culebra and through the marker beds to the land withdrawal boundary. Transport calculations are performed with intrusion times of 350 and 1000 years (in Table 3) as well as other intrusion times (100, 3000, 5000, 7000 and 9000 years).

The PANEL code is used to calculate cumulative radionuclide release through a borehole to the Culebra for the E1E2 scenario. This scenario assumes a sequence of two intrusions: an E2 followed by an E1 intrusion that admits Castile brine to the repository. To calculate cumulative radionuclide release, PANEL integrates the product of brine flow rate from the BRAGFLO S6-BF scenario and time-dependent mobilized radionuclide concentration. Transport calculations are performed with E1 intrusion times of 100, 350, 1000, 2000, 4000, 6000, and 9000 years. The PANEL code internally shifts brine flow times from BRAGFLO S6-BF scenario (E1 intrusion at 2000 years) to get brine flows for other E1 intrusion times.

2.5 Direct Releases

Direct releases of radionuclides to the surface following a drilling intrusion include direct brine releases (DBRs), spallings, cuttings, and cavings. Direct releases are calculated by models for each process applied to several direct release scenarios that vary with time of intrusion, intrusion location relative to previous intrusions, and the type of previous intrusions.

2.5.1 Direct Brine Release

In the CRA-2019, DBR volumes were calculated for the scenarios listed in Table 4 using the BRAGFLO_DBR code on a horizontal grid (Figure 4) at each of three representative boreholes: Lower (L), Middle (M), and Upper (U). The Lower intrusion was modeled as occurring in Panel 5 and represents a subsequent intrusion into the same panel as the previous intrusion (all previous intrusions are modeled as occurring in panel 5, as indicated in Figure 4). The Middle intrusion was modeled as occurring in Panel 3 and represents a subsequent intrusion into a panel adjacent (i.e., no intervening panel closure) to a panel with a previous intrusion. The Upper intrusion was modeled as occurring in Panel 10 and represents a subsequent intrusion into a panel with no previous intrusions in its adjacent panels, but with previous intrusions into non-adjacent panels (i.e., with intervening panel closures). A full description of the approach to calculating DBR volumes is provided in Bethune (2019).

Table 4. Direct Brine Release Scenarios in the CRA-2019

Scenario	Previous intrusion type and time	DBR intrusion times (yr)
S1-DBR	None	100, 350, 1000, 3000, 5000, 10000
S2-DBR	E1 intrusion at 350 yr (S2-BF)	550, 750, 2000, 4000, 10000
S3-DBR	E1 intrusion at 1000 yr (S3-BF)	1200, 1400, 3000, 5000, 10000
S4-DBR	E2 intrusion at 350 yr (S4-BF)	550, 750, 2000, 4000, 10000
S5-DBR	E2 intrusion at 1000 yr (S5-BF)	1200, 1400, 3000, 5000, 10000

For the APPA, the direct brine release conceptual models are unchanged from the CRA-2019 (DOE 2019, Appendix PA) and the DBR scenarios will be the same as the CRA-2019 (as listed in Table 4). The grid for calculating direct brine releases (Figure 5) is adjusted to create a new panel group with a new representative borehole that is used to estimate DBR volumes from intrusions into the proposed additional waste panels. The DBR grid for the APPA retains the geometry used in the CRA-2019 (Figure 4) with 10 notional "panels," termed here DBR panels, but the interpretation of each DBR panel is different in the APPA (Figure 5).

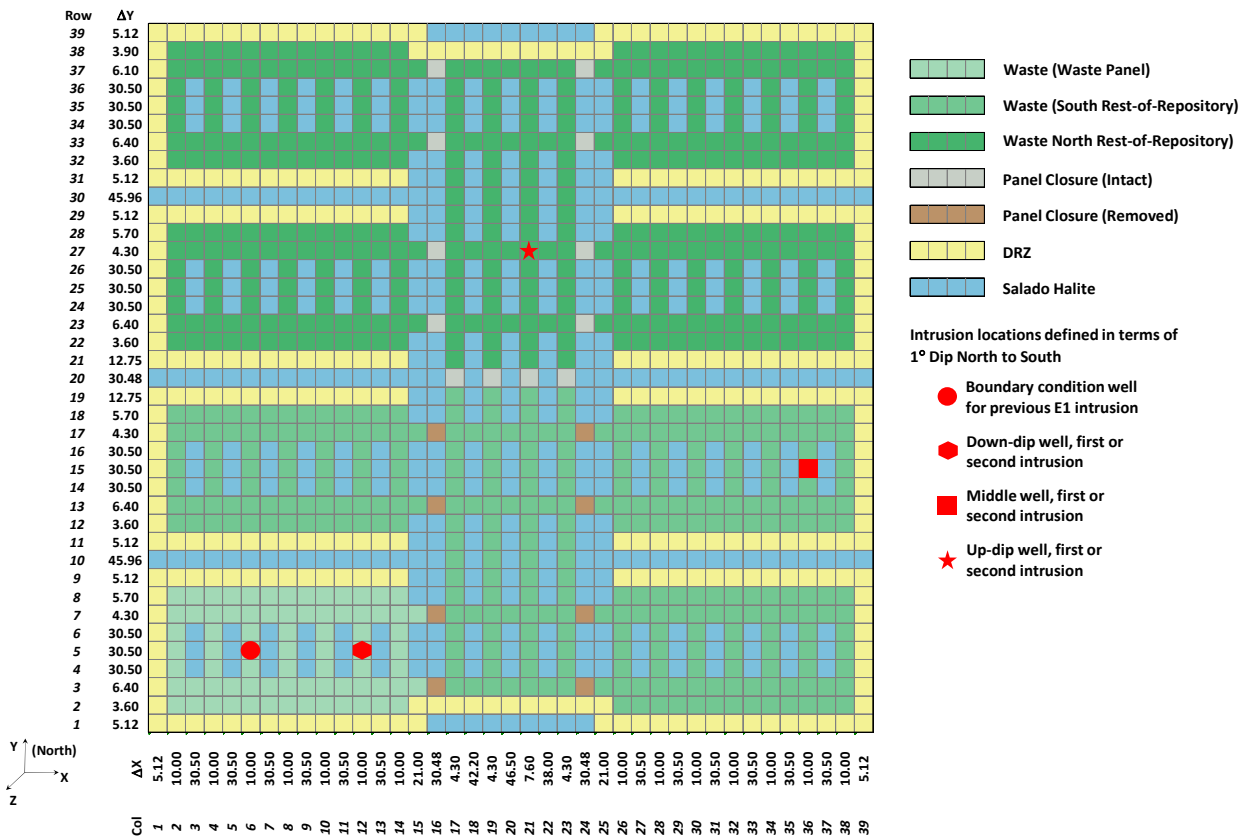

Figure 4. BRAGFLO_DBR grid for the CRA-2019

Initial conditions for a DBR panel (Figure 5) are taken from the panel groups in the BRAGFLO grid (Figure 3), and releases are separately calculated for four representative boreholes (lower, middle, upper and other, Figure 5):

- The lower (L) borehole is located in DBR Panel 5 and initial conditions for the DBR panel containing this borehole are taken from the South Waste Panel (WAS) region of the BRAGFLO grid.
- The middle (M) borehole is located in DBR Panel 3 and initial conditions for the group of DBR panels containing this borehole (comprising DBR Panels 3, 4, 6 and 9) are taken from the South Rest of Repository (SRR) region of the BRAGFLO grid.
- The upper (U) borehole is located in Panel 2 and initial conditions for the group of DBR panels containing this borehole (comprising DBR Panels 2, 7 and the south half of DBR Panel 10) are taken from the North Rest of Repository (NRR) region of the BRAGFLO grid.
- The other (O) borehole is located in DBR Panel 1 and initial conditions for the group of DBR panels containing this borehole (comprising DBR Panels 1, 8 and the north half of DBR Panel 10) are taken from the West Rest of Repository (WRR) region of the BRAGFLO grid.

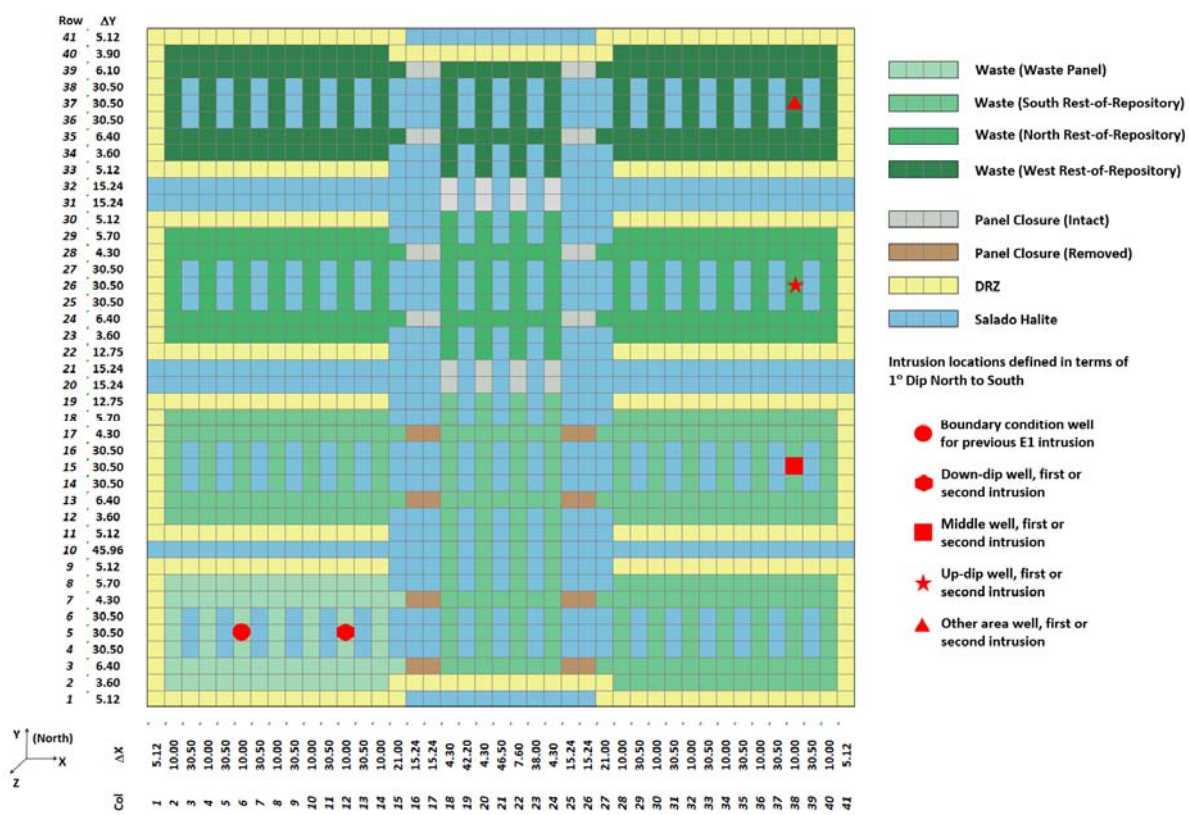

Figure 5. BRAGFLO_DBR grid for the Additional Panels PA

A new panel closure is added to the grid to separate DBR Panel 10 into south and north areas. This panel closure does not represent a new physical feature in the repository; rather, it is placed in the DBR grid to represent the panel closures that separate the south half of the repository from the

proposed west half. To improve numerical results, all panel closures are represented by two grid cells rather than the single cell used in the CRA-2019 DBR grid.

Preliminary analysis showed that direct brine release volumes are primarily determined by the conditions in the intruded panel; other areas in the DBR grid have little to no effect on DBRs. Thus, DBRs resulting from boreholes in the waste panels comprising the NRR or WRR can be reasonably represented by the DBRs from an intrusion into e.g. Panel 1, since the waste panel volumes are similar. The analysis package for DBRs will contain analysis to justify this representation.

2.5.2 Panel Groups and Neighbors

The CRA-2019 classified panels into one of three groups as determined by the number of panel closures separating each waste panel from Panel 5: same, adjacent, and non-adjacent (Brunell, 2019).

For the APPA the panel neighbor groups are extended to same, connected, adjacent, and non-adjacent which requires a change from CCDFGF v7.04. Two panels are connected if there are no intervening panel closures, e.g., Panels 4 and 5 are connected. Two panels are adjacent if both panels are in the same half of the repository (i.e., south or west) but are separated by one or more intervening panel closure; e.g., Panels 1 and 5 are adjacent. Two panels are non-adjacent if the panels are in different halves of the repository. The path between panels is traced through excavated areas only.

The same panel group comprises Panel 5. Conditions in the same panel group are used to estimate releases from an intrusion into a previously intruded panel. The connected group comprises Panels 3, 4, 5, 6, and 9; conditions in this panel group are used to estimate releases from intrusions into a panel that has no previous intrusion but is not separated by a panel closure from a panel with a previous intrusion. The adjacent panel group comprises Panels 1, 2, 7, 8 and 10. Conditions in the adjacent panel group are used to calculate releases from an intrusion into a panel that has no previous intrusions, no connected panel has a previous intrusion, and previous intrusions have occurred in adjacent panels. The non-adjacent panel group comprises the proposed additional waste panels numbered 11 through 19. Conditions in the non-adjacent panel group are used to estimate releases from an intrusion into a panel without a previous intrusion, and that is separated by two or more panel closures from all panels with previous intrusions.

The CCDFGF code simulates random sequences of drilling intrusions. Each intrusion is placed in one of the waste panels using the probabilities listed in Table 5. When a new intrusion occurs, previous intrusions in the same, connected and adjacent panels determine the conditions for calculating releases from the new intrusion; Table 5 summarizes the panel neighbor scheme for the APPA.

Table 5. Panel Neighbors in the APPA

Intruded Panel	Intrusion Probability	Connected Panels	Adjacent Panels
1	0.053662264	-	2 through 10
2	0.053662264	-	1, 3 through 10
3	0.053662264	4, 5, 6, 9	1, 2, 7, 8, 10
4	0.053662264	3, 5, 6, 9	1, 2, 7, 8, 10
5	0.053662264	3, 4, 6, 9	1, 2, 7, 8, 10
6	0.053662264	3, 4, 5, 9	1, 2, 7, 8, 10
7	0.053662264	-	1 – 6, 8, 9, 10
8	0.053662264	-	1 – 7, 9, 10
9	0.042154636	3, 4, 5, 6	1, 2, 7, 8, 10
10	0.045586876	-	1 through 9
11	0.053662264	-	12 – 19
12	0.053662264	-	11, 13 – 19
13	0.053662264	-	11 – 12, 14 – 19
14	0.053662264	-	11 – 13, 15 – 19
15	0.053662264	-	11 – 14, 16 – 19
16	0.053662264	-	11 – 15, 17 – 19
17	0.053662264	-	11 – 16, 18 – 19
18	0.053662264	-	11 – 17, 19
19	0.053662264	-	11 – 18

2.5.3 Representative boreholes for direct brine releases

DBR from an intrusion into the repository are modeled by results of the DBR scenarios (Table 5); and the representative borehole for an intrusion is determined as shown in Table 6. The representative borehole for DBR from an intrusion into the repository with undisturbed conditions is determined by the intruded panel. After the initial intrusion, DBR for a subsequent intrusion are based on the representative borehole associated with the nearest panel with an E1 intrusion, or if no E1 intrusion has occurred, by the nearest panel with an E2 intrusion. Distance between panels is specified by the panel groups (Table 5) which, in order of nearest to farthest, are same, connected, adjacent and non-adjacent.

Table 6. Use of Representative Boreholes for DBR

Representative Borehole	Initial Intrusion: Intruded Panel	Subsequent Intrusion: Nearest Panel Group
Lower	5	Same
Middle	3, 4, 6, 9	Connected
Upper	1, 2, 7, 8, 10	Adjacent
Other	11 – 19	Non-adjacent

2.5.4 Spallings

Spalling releases are calculated by combining a spalling volume obtained by interpolation on a table of single borehole spalling volumes with a time-dependent radionuclide concentration in the solid waste calculated by the code PANEL. The APPA will use the table of single borehole spallings volumes from the CRA-2019 as none of the changes since the CRA-2019 affect the calculation of these volumes. The spalling release volume for an intrusion is determined by interpolating the table to the pressure in the intruded panel at the intrusion time. The panel conditions for spallings are determined using the scenarios for DBR release volumes. The DBR release scenario is determined by the borehole location and the type and distance to any previous intrusions as described in Section 2.5.3. The pressure in the intruded panel is estimated by interpolating the initial conditions for DBR releases to the intrusion time using the DBR calculation cases listed in Table 4.

2.5.5 Cuttings and Cavings

For the APPA, cutting and cavings releases will be estimated using the CRA-2019 models with no changes (DOE 2019, Appendix PA). Cuttings and cavings release volumes are calculated by multiplying a borehole diameter by the repository height; cuttings and cavings releases are then calculated by multiplying 1/3 of the release volume with the time-dependent radionuclide concentration (calculated by the code PANEL) in each of three randomly selected waste streams. The probability of selecting a waste stream is equal to the waste stream's volume fraction in the inventory.

2.6 Culebra Flow and Transport

Radionuclides may be transported to the Culebra via boreholes or through the shaft. Models and codes for transport to the Culebra are the same as in the CRA-2019. However, the proposed additional panels necessitate a change to the location of the modeled releases into the Culebra. In the CRA-2019 releases into the Culebra are modeled to occur at a single point above the centroid of the waste panels in the existing repository. The predominate regional flow in the Culebra is to the south. However, the proposed additional panels extend westward towards areas affected by potash mining, where enhanced transmissivity can draw flow toward the western delineation of the land withdrawal boundary. Locations of releases into the Culebra will be revised as necessary to account for the possibility of transport through the Culebra towards the mining-impacted region to the west.

Flow and transport of radionuclides in the Culebra will be estimated using the same models as in the CRA-2019.

2.7 Calculation of CCDFs for Releases

The conceptual structure of the APPA remains the same as for the CRA-2019. For each element in a sample of uncertain parameters, many 10,000-yr futures are randomly generated. Each future comprises a sequence of simulated drilling and mining intrusions. For each intrusion, direct releases are tabulated using output from the models described above, and over the course of the entire future, releases through the Salado and Culebra to the land withdrawal boundary are

recorded using output from the Salado and Culebra transport models. The total of these various releases at the end of the 10,000-yr period yields one data point for total releases; the collection of total release data points over all futures comprises the data that forms one complementary cumulative distribution function (CCDF) of releases. The code CCDFGF generates the random futures and estimates the CCDFs. A formal definition of this conceptual structure is found in Appendix PA of DOE, 2019.

For APPA the CCDFGF and PRECCDFGF codes will need to be modified from the code versions for the CRA-2019. Specifically, CCDFGF will also need to be modified to extend the panel grouping as described in Section 2.5.2, and both codes will need to be modified to accept results for four representative boreholes. CCDFGF and PRECCDFGF may also need to be modified to accumulate results for multiple release points into the Culebra.

2.8 Sensitivity Analysis

The APPA will include a sensitivity analysis to quantify the influence of uncertain parameters on the uncertainty in select outputs from the PA models, to include:

- Pressure and saturation in the excavated areas.
- Brine flow in the borehole.
- Releases by cuttings, cavings, spallings, direct brine release and by Salado or Culebra transport.
- Total releases.

The sensitivity analysis will be done using the code STEPWISE.

3 Parameters

For the APPA several parameters related to repository areas and volumes will be updated to account for the proposed additional panels, including:

- REFCON:ABERM – Area of the berm placed over waste panels.
- REFCON:AREA_CH – Area for Contact Handled (CH) waste disposal.
- REFCON:FVW – Fraction of repository volume occupied by waste.
- REFCON:VREPOS – Excavated storage volume of the repository.
- REFCON:AREA_RH – Area for Remote Handled (RH) waste disposal.
- REFCON:FVRW – Fraction of RH waste disposal volume occupied by waste.

Parameters for baseline actinide solubilities will be updated as described in Domski (2020). Updates to parameters will follow Nuclear Waste Management Procedure NP 9-2, Parameters.

In addition, the ALGEBRACDB variable INVSCALE – the ratio of the volume of a single panel to the volume of all waste panels the repository – will be updated to account for the proposed additional panels.

4 Reports and Documentation

Several reports will be generated as a result of this analysis plan. Each set of calculations discussed in Section 2 for the APPA 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-2019 PA calculations; and
2. analysis of results relevant to the long-term performance of the repository. The analysis will include comparisons of APPA analysis results with the CRA-2019 PA.

A record of the run control will be created for the APPA. 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 APPA will also fall under AP-185.

5 Tasks

The tasks, responsible personnel, and estimated task schedule are summarized below in Table 7.

Table 7: Task List and Estimated Schedule for the APPA

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
1	CCDFGF Code Modifications	AP-185	8/4/2020	Brunell
2	Input Files Prepared	AP-185	9/10/2020	Bethune, Brunell, Kicker, Kim, King, and Zeitler
3	Input File Review	AP-185	9/24/2020	Hansen
4	Parameter Entry	NP 9-2	9/10/2020	Long
5	PA Calculations	AP-185	10/6/2020	Long
6	Analysis Reports		12/23/2020	Hansen
6a	FEPs Re-assessment	SP 9-4	5/28/2020	Kirkes
6b	Salado Flow: BRAGFLO	AP-185	11/03/2020	King
6c	Actinide Mobilization and Salado Transport: NUTS & PANEL	AP-185	11/03/2020	Kim
6d	Culebra Flow and Transport: MODFLOW and SECOTP	AP-185	11/03/20	Bethune
6e	Direct Brine Release: BRAGFLO_DBR	AP-185	11/03/20	King

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
6f	Summary Report, including direct releases, CCDFs for normalized releases, and sensitivity analysis	AP-185	12/23/2020	Brunell, Hansen, Kicker, King, Zeitler
6g	Run Control Document	AP-185	12/23/2020	Long

6 Software

The major WIPP PA codes to be used for this analysis are listed in Table 8. The execution of these codes for the analysis described herein comprises a compliance decision calculation. These codes will be executed on the WIPP PA Sun Blade Cluster, which is described in Table 9. Additionally, we may utilize COTS (Commercial off-the-shelf) software such as Matlab®, Sigma Plot®, Excel®, Access®, or Python, running on workstations. The use of any COTS application will be verified per NP 9-1 Appendix C as appropriate.

DRSPALL v1.22 and MERGESPALL v1.01 will not be run for the APPA. Instead, output results from a previous analysis (Kirchner et al. 2014, Kirchner et al. 2015) will be used as input to the APPA calculations. The inputs to these codes are the same for the APPA as for the previous analysis.

Table 8. Codes to be Used for the APPA

Code	Version	Executable	Build Date
ALGEBRACDB	2.36	algebracdb	9/11/12
BRAGFLO	7.00	bragflo	8/14/18
CCDFGF	TBD*	ccdfgf	2/4/20
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	2.07	nuts	2/22/19
PANEL	5.00	panel	2/18/19
POSTBRAG	4.02	postbrag	1/10/13
POSTLHS	4.11	postlhs	6/2/16
PREBRAG	9.00	prebrag	8/16/18
PRECCDFGF	TBD*	preccdfgf	9/9/13
PRELHS	2.44	prelhs	10/11/16

Code	Version	Executable	Build Date
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

*- CCDFGF version 7.04 and PRECCDFGF version 2.01 are currently the baseline versions of the codes. It is anticipated that changes to both codes will be needed for the APPA.

Table 9. 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
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

Node	Hardware Type	CPU	Operating System	# CPUs
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

7 Special Considerations

None.

8 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*.
- FEPs assessment will be conducted according to SP 9-4, *Performing FEPs Impact Assessment for Planned or Unplanned Changes*.
- 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.*

9 References

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