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SANDIA NATIONAL LABORATORIES
WASTE ISOLATION PILOT PLANT

AP-204
Revision 1

Analysis Plan for the Performance Assessment for the Replacement Panels Planned Change Request

Task 4.4.1.2.1

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Notes for Revision 1

Revision 1 of this analysis plan has been made to provide more detail on the updates to colloid parameters, the Castile brine reservoir model, borehole permeability, and borehole plugging pattern to be included in the RPPCR. The updates to the Castile brine reservoir model involve a change to the BRAGFLO computational grid shown in Figure 3. Clarifications have been made to how the sensitivity analysis will be performed. The PA code GROPECDB, which is used in the SECOTP2D computational loop, has also been added to the list of major codes to be used in the RPPCR.

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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 the placement of waste. For operational reasons, not all of the volume of the ten excavated panels will be used for waste disposal. The DOE plans to excavate two panels, termed replacement panels, to provide an equivalent disposal capability, and may consider excavating up to seven panels beyond the two replacement panels, defined here as additional panels.

This analysis plan describes the models and parameters to be used in the Performance Assessment (PA) for the Replacement Panels Planned Change Request (RPPCR) to quantify the long-term performance of a repository layout that includes nine new (replacement and additional) panels. In addition, the RPPCR will include a number of additional changes to models and parameters to account for new information.

1.1 Summary of Changes from the CRA-2019

The analysis described in this plan uses the models and parameters for the CRA-2019 (DOE, 2019) with the following differences :

Changes related to inventory:

1. Waste inventory parameters will be based on the 2022 Performance Assessment Inventory Report (PAIR) (Van Soest, 2022).
2. Actinide baseline solubilities will be updated in conjunction with the updated inventory parameters and thermodynamic database changes.
3. Uncertainty distributions for each actinide's solubility will be updated in conjunction with the thermodynamic database changes.

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4. Parameters related to microbial and intrinsic colloids will be updated.

Changes related to the replacement and additional panels:

5. The grid for the Salado flow model is modified to accommodate new panels and updates to the Castile brine reservoir model.
6. The grid for computing direct brine releases (DBRs) is modified to account for the new panels.
7. Logic for assigning panel neighbors is extended to account for the new panels.
8. Repository area and volume parameters are updated to account for the new panels.
9. 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 new panels.

Changes related to new information and/or model revisions since the CRA-2019:

10. An update to the iron surface area used for gas generation from iron corrosion in the Salado Flow model.
11. An update to the calculation of waste area pressures at the time of closure.
12. The porosity surface used to represent creep closure of excavations in the Salado is updated to reflect changes in the modeling process and in material models.
13. Model inputs describing the Castile brine reservoir will be updated to account for a recent re-analysis of Castile reservoir data.
14. Permeability of a borehole after plug failure and degradation of borehole materials will be updated to account for a re-analysis of wellbore materials.
15. The model for the oxidation states of actinides is revised.
16. Drilling rates and borehole plugging pattern probabilities are updated to account for new data.
17. Transmissivity fields in the Culebra are updated to account for new data from wells (Bowman, 2022). The new transmissivity fields are computed with different codes (MODFLOW6 and PEST++) than the codes used to compute the transmissivity fields used in the CRA-2019 (MODFLOW2000 and PEST).

Changes related to codes and computing platform:

18. The PRECCDFGF and CCDFGF codes are modified to accommodate new panels and the modified procedure for calculating Culebra releases.
19. The PRELHS code is revised to correct an error (SNL, 2022).
20. The PBRINE parameter distribution is adjusted due to the correction of the error found in the PRELHS code.
21. MODFLOW6 will be used in place of MODFLOW2000 to calculate flow fields in the Culebra.
22. The PRESECOTP2D code is modified to work with MODFLOW6.
23. The PANEL code is changed to implement the revised model for actinide oxidation states.
24. Hardware and software are updated to migrate the PA calculation to a new computational platform (Long, 2020).

The above changes are detailed in Section 2 of this analysis plan.

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1.2 Related Performance Assessments

A performance assessment based on CRA-2019, the Additional Panels Performance Assessment (APPA), considered some but not all of the above changes (Hansen, 2020; Brunell et al., 2021). In particular, the APPA considered items 5, 6, and 7 from the above list, and, in part, items 8 and 18. The APPA also included corrections to actinide baseline solubilities from the CRA-2019 values, which are superseded in the RPPCR. Results of the APPA are summarized in Brunell et al. (2021).

A second performance assessment, the Replacement Panels Performance Assessment (RPPA) was planned and carried out in 2022 in anticipation of submittal of a Planned Change Request (PCR) (Hansen, 2022). The RPPA included the changes described for the APPA as well as: a new inventory (Kicker, 2022); revised actinide baseline solubilities consonant with the new inventory; updates to the repository volume parameters (item 8), iron surface area (item 10), and initial pressure calculation (item 11); and a revised procedure for determining releases through the Culebra (items 9 and 18). Results of the RPPA are summarized in Brunell et al. (2022).

2 *Analysis Approach*

The RPPCR is organized as a sequence of tasks:

1. Review of FEPs and conceptual models.
2. Preparation of inventory and related quantities.
3. Generating a sample of uncertain parameters.
4. Salado flow modeling.
5. Salado transport modeling.
6. Modeling of direct releases.
7. Culebra flow and transport modeling.
8. Calculation of complementary cumulative distribution functions (CCDFs) that quantify potential releases from the repository.
9. Calculation of Culebra travel times.
10. Sensitivity analyses.

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.

For the APPA a FEPs assessment was performed according to SP 9-4, Performing FEPs Baseline Impact Assessments for Planned or Unplanned Changes (Kirkes, 2021). The FEPs assessment found that no changes to FEP screening decisions were warranted. For the APPA, the conceptual models used in the PA were also reviewed to identify those models that are affected by the

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proposed changes (Hansen, 2021). The review concluded that 3 of the 24 conceptual models were affected:

- Disposal System Geometry
- Repository Fluid Flow
- Direct Brine Release

The Additional Panels Performance Assessment (APPA) Changed Conceptual Models Peer Review examined the changes affecting these three conceptual models and concluded that the changed conceptual models provide an adequate and reasonable representation of the repository system (Falta et al., 2021).

The primary differences between the RPPCR and the APPA are:

- the revised inventory and related parameters.
- the procedure for computing releases through the Culebra.
- changes identified as related to new information and revised models since the CRA-2019.

The RPPCR will include an assessment performed according to SP 9-4 to identify if any of these changes affect FEP screening decisions, or conflict with assumptions made in the PA's conceptual models. The results of this assessment will be documented a FEPs assessment report.

A review of conceptual models is not necessary since the RPPCR is quite similar to the APPA, and because the conceptual model changes implemented in the APPA were found adequate by a peer review (Falta et al., 2021).

2.2 Waste Inventory

The inventory for the RPPCR calculation is documented in the Performance Assessment Inventory Report (PAIR) for 2022 (Van Soest, 2022). The PAIR contains updated estimates to the radionuclide content and waste material parameters, scaled to a full repository. To incorporate these changes, parameters for the initial radionuclide, chemical components, waste material inventories and the Waste Unit Factor (WUF) will be updated in an inventory analysis report. The code EPAUNI will be used to calculate the radionuclide concentration in each CH waste stream over time.

2.2.1 Actinide Solubilities

The solubilities of actinide elements are influenced by the chemical components of the waste and the amount of halite available for reaction. With the new PAIR (Van Soest, 2022), updated information on the amount of various chemical components in the waste is available. With the increased repository volume, the DRZ volume providing halite to the system will also be increased. To incorporate this updated information, parameters used to represent actinide baseline solubilities will be updated in the RPPCR. Uncertainty multipliers for actinide baseline solubilities will be recalculated to account for new information since the CRA-2019 PA, as well as discussions between the DOE and EPA. Development of actinide baseline solubilities and their associated

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uncertainty is described in AP-153 (Brush et al., 2012); details of the analysis for the RPPCR will be documented in the analysis reports described in Section 5.

Radionuclide solubilities are calculated at five integer multiples of the minimum brine volume needed for a DBR event (GLOBAL:DBRMINBV). With the additional repository volume (see Section 2.4.1), the minimum brine volume for a DBR event will be updated (King, 2021c), as was done in the RPPA. In calculating the radionuclide mobilization, the PANEL code uses the minimum brine volume needed for a DBR event.

The CRA-2019 PA used the DATA0.FM4 database for actinide solubilities, but it was later realized that incorrect thermodynamic interaction parameter values resulted in lower actinide (III) solubility values. Analysis showed that correcting the actinide (III) solubility values had no impact on the CCDF of total releases (Kim et al., 2020). The APPA analysis used the DATA0.FM5 thermodynamic database (Domski, 2020) with corrected thermodynamic interaction parameter values. During the completeness review of CRA-2019, additional questions were raised about DATA0.FM4 database. Resolution of these questions may lead to additional changes to the thermodynamic database before calculating actinide solubilities for the RPPCR. Domski (2022) and Domski (2023) describes preparation of the thermodynamic database DATA0.FM6 which will be used to calculate actinide solubilities for the RPPCR.

2.2.2 Updates to Colloid Parameters

To account for new information from experiments conducted by Los Alamos National Laboratories, microbial colloid parameters, PROPMIC and CAPMIC, will be updated for materials AM, NP, PU, TH, and U (Lucchini and Swanson, 2023). To account for a re-evaluation of existing data, intrinsic colloid parameter CONCINT will be updated for materials AM and TH (Lucchini and Swanson, 2023). Actinide oxidation state specific colloid values will not be used for the RPPCR (King, 2022).

2.2.3 Oxidation State Model

In the CRA-2019 PA, Np, Pu, and U actinides were assigned to either a low or high oxidation state (e.g., Pu(III) or Pu(IV)) to reflect epistemic uncertainty in future repository conditions. Each state (low or high) was considered equally likely. The APPA and RPPA took the same approach.

As described in LANL (2022), the binary-state model assumes that all actinides are found in the same low or high oxidation state. In the RPPCR, the oxidation state model will be extended to include more combinations of states, to represent the behavior of the different actinides across a range of redox (oxidation-reduction) potentials. New parameters (property OXCUTOFF for materials NP, PU, and U) will be based on the recommended values from Lucchini and Swanson (2023).

The PANEL code is updated to version 5.02 to implement this extended oxidation state model, and the input files for the BRAGFLO, PANEL and SECOTP2D computations will be updated accordingly. In BRAGFLO, the oxidation state affects the brine radiolysis model; in PANEL, oxidation state affects actinide concentration limits; and in SECOTP2D, oxidation state affects the matrix partition coefficients.

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2.3 Sample of Uncertain Parameters

Uncertain parameters will be sampled with LHS version 3.00. With the migration of LHS to the GNU Fortran compiler on the CentOS platform (Long and King, 2022), the seeded random number generator used by previous versions of LHS is no longer able to produce the same random samples. In order to maintain the same sampling for comparison between analyses, LHS 3.00 has the ability to read in a list of random numbers instead of using a seeded random number generator. For the RPPCR, LHS will read a table of random numbers containing the same values used in the CRA-2019 PA, APPA and RPPA. Keeping the same random numbers enables comparison of the RPPCR to these previous analyses.

Three parameter distributions will be changed for the RPPCR. The distributions for solubility uncertainty for +III and +IV actinides (SOLMOD3:SOLVAR and SOLMOD4:SOLVAR) will be updated based on the updated thermodynamic model and updated literature screening as described in Section 2.2.1. The distribution for the probability of intersecting a pressurized brine pocket (GLOBAL:PBRINE) will be changed as a consequence of correcting an error found in the PRELHS code (SNL, 2022).

2.4 Salado Flow

The RPPCR will consider a repository including both replacement and additional waste panels. The RPPCR uses the same conceptual and mathematical models for Salado flow as were used for the RPPA and the APPA. These models were modified from those of the CRA-2019 . Changes are summarized below and have been deemed appropriate by a peer review (Falta et al., 2021). Numerical calculations will be done with the BRAGFLO 7.01 code on a revised grid that accounts for the new panels.

2.4.1 Replacement and Additional Panels

The DOE plans to excavate two replacement panels to provide disposal volume equivalent to the unused volume in the ten original panels. In the future, the DOE may consider excavating additional waste panels beyond the two replacement panels to provide sufficient repository volume for the statutory limit of waste. This analysis assumes that the repository includes nine new waste panels (two replacement and seven additional, numbered 11 through 19) to the west of the current repository, as illustrated in 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 any two panels) are increased from 61.0 m (200 ft) to 91.5 m (300 ft).

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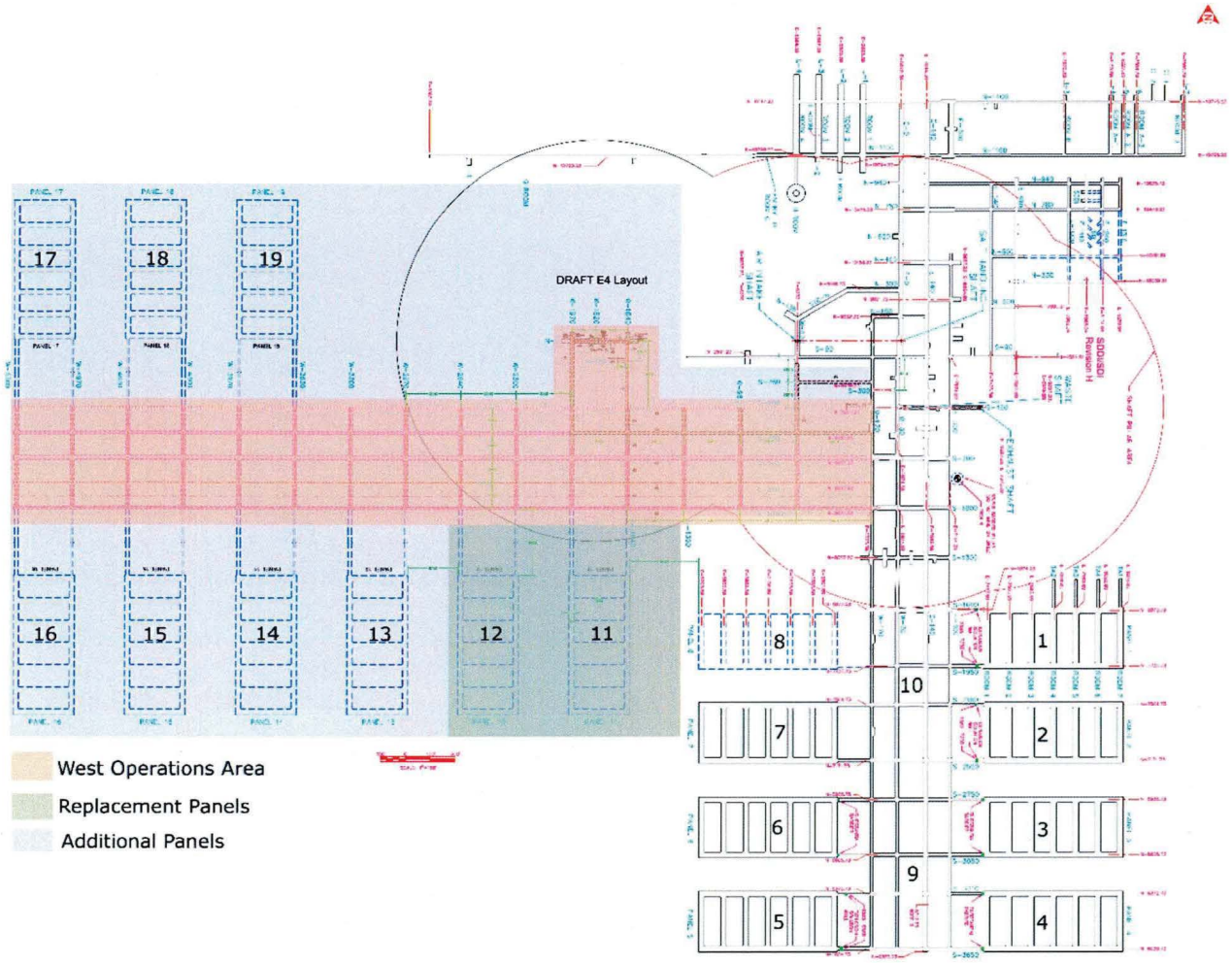


Figure derived from Sjomeling, (2019).

Figure 1. Current Repository Footprint, Replacement Panels and Additional Waste Panels

2.4.1.1 Panel Closures

Panel closures for the new 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. The analysis assumes that there are no panel closures in the drifts that connect the west panels to the operations and experimental areas (Sjomeling, 2019).

2.4.1.2 Non-Waste Areas

Five access drifts running east-west connect the new panels with the rest of the repository. This analysis assumes that no waste is emplaced in the west access drifts.

2.4.1.3 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, an upgraded ventilation system is planned that will provide sufficient

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airflow necessary for the resumption of increased-rate disposal operations in the future. The primary components of the upgraded ventilation system include 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. The additional shaft will be represented in the repository modeled in the RPPCR.

2.4.2 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.

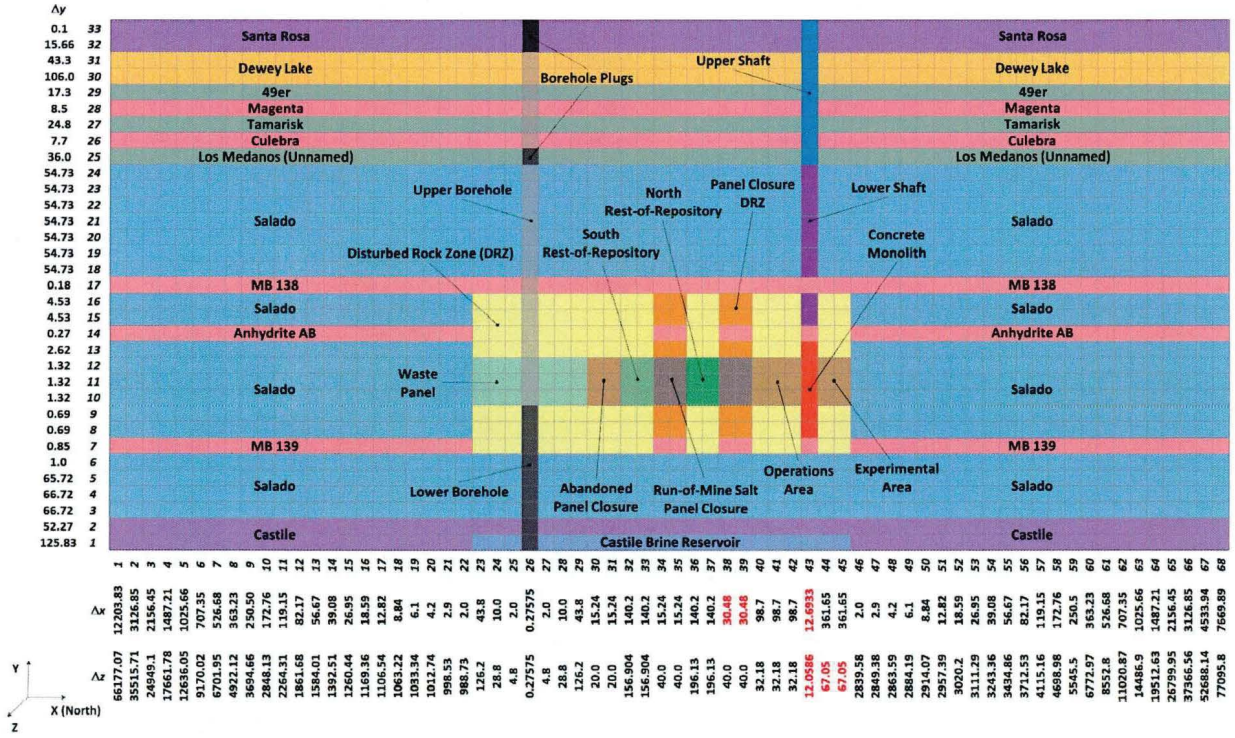


Figure 2. CRA-2019 BRAGFLO Grid (DOE, 2019, Appendix PA, Figure PA-12)

The replacement and 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 adequate and reasonable for WIPP PA (Caporuscio et al., 2003; Falta et al., 2021). 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 western 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.

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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.

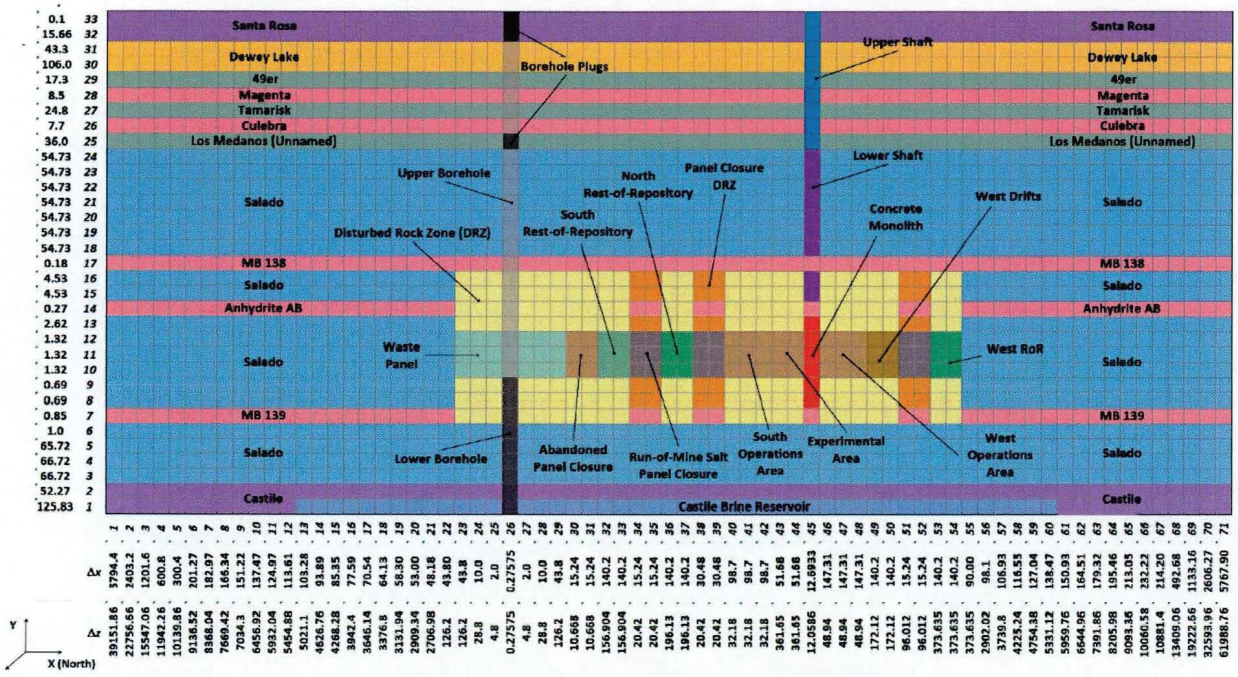


Figure 3. BRAGFLO Grid for the RPPCR

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 RPPCR grid between columns 4 and 5; the distance between the Waste Panel and the LWB has not changed from the CRA-2019 grid. On the right side of the RPPCR grid, the LWB is located between columns 67 and 68 at the distance between the proposed western 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 RPPCR grid.

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 downdip from other panels.

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Table 1. Panel Groups in the RPPCR

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 RPPCR will model Panel 9 as containing waste to simplify the modeling. The RPPCR waste inventory will be represented as homogeneous over the volume of the repository. 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 downdip and in a waste area adjacent to the South Waste Panel, which contains the representative borehole. The repository volume parameter (REFCON:VREPOS) will be the volume of 19 waste panels.

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 drifts to the new panels and the additional shaft access drifts (Figure 1). 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 RPPCR. The SHFT14 analysis (Camphouse, 2014) showed minimum impact to the long-term repository performance from representing the additional shaft in this manner.

For the APPA, the major assumptions used in the BRAGFLO grid for the Salado flow model (Figure 3) were reviewed by the APPA Changed Conceptual Models Peer Review. The peer review panel found the assumptions to be well justified and the model adequate and reasonable for its intended application (Falta et al., 2021). The RPPA used the same Salado Flow grid as the APPA, except for one correction to the shaft dimensions. In the APPA the shaft was mistakenly given the dimensions 17.1194 m by 17.6197 m. In the RPPA grid, the shaft dimensions were corrected to 12.6933 m by 12.0586 m giving a cross sectional area of 153.06 m^2 as specified by Zeitler (2019). Due to the correction to the shaft dimensions, the far-field Salado flaring was updated using the same methodology as was used to set the APPA grid flaring.

The Castile brine reservoir representation in the BRAGFLO grid has also been updated for the RPPCR. The modeled porosity of the Castile brine reservoir in BRAGFLO is determined by the sampled bulk compressibility value and the range of desired reservoir pore volumes. In CRA-2019, the grid volume of the Castile brine reservoir was only slightly larger than the maximum pore volume of the Castile brine reservoir leading to porosities ranging from 0.1842 to 0.9208. For the RPPCR, the grid volume of the Castile brine reservoir has been expanded, in conjunction

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with an update to the range of Castile brine reservoir pore volumes, so the modeled porosity and productivity ratio is more physically realistic (Section 2.4.6).

2.4.3 Iron Surface Area

For CRA-2019, the total surface area of iron-based metals for gas generation was calculated based on an estimated iron surface per drum, and an optimal loading of drums in the repository. The same approach was used in the APPA.

For the RPPCR, the total iron surface area is calculated with an estimated surface area per kilogram of iron inventory (REFCON:FESAPKG), as outlined in King (2021a). This approach was used in the RPPA. The CRA-2019 parameters REFCON:ASDRUM, REFCON:DRROOM, and REFCON:VROOM are not used in the RPPCR.

2.4.4 Initial Pressure

In CRA-2019, the pressure in the waste areas at repository closure was set to 128,039 Pa. The 26,714 Pa increase over atmospheric pressure is to account for the early-time rapid biodegradation of cellulose, plastic, and rubber (CPR). The pressure increase is a function of CPR inventory and repository volume as calculated by Nemer et al. (2005). For the APPA the initial pressure was set at 115,610 Pa, which is less than in the CRA-2019 due to the additional storage volume. However, changes to the CPR inventory since the Nemer et al. (2005) calculation were not incorporated. To facilitate setting of the initial pressure parameter, a new parameter (WAS_AREA:EGRATMIC) for the moles of gas generated per kilogram of CPR inventory has been defined (King, 2021b). This parameter will be used in the Salado flow ALGEBRACDB step to calculate the initial waste area pressure. This same approach was used in the RPPA.

2.4.5 Porosity Surface

As described in AP-197 (Reedlunn, 2022) the disposal room porosity model is being revised to incorporate an improved geomechanical model for the Salado materials, an improved waste constitutive model, and updates to the gas generation model within the room porosity calculations, consonant with changes to the gas generation model in the Salado flow calculations. The revised disposal room porosity model will be run to generate a new porosity surface (a table of disposal room porosity vs. time parameterized by pressure) that is used by the BRAGFLO code to determine porosity of waste-filled regions.

2.4.6 Castile Brine Reservoir

Gross and Gjerapic (2022) report a re-analysis of data from two wells (WIPP-12 and ERDA-6) which produced brine from the Castile. They found that observed brine flow and well pressures were better modeled using a two-domain hydrogeologic model for the Castile. Their fitted model predicts a somewhat smaller upper bound for the Castile reservoir pore volume than was used in the CRA-2019 PA. Docherty (2023) further looked into the Castile reservoir model representation in BRAGFLO, recommending the extended representation shown in Figure 3. With this updated grid volume and the maximum pore volume from Gross and Gjerapic (2022), the modeled porosity based on the sampled rock compressibility (CASTILER:COMP_ROCK) will be updated.

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2.4.7 Borehole Permeability

Permeability of a borehole after plug failure and degradation of borehole materials (material BH_SAND, properties PRMX_LOG, PRMY_LOG, PRMZ_LOG) was modeled between $10^{-16.3}$ and 10^{-11} m^2 in CRA-2019. Gjerapic et al. (2023) recommended a new upper bound for this distribution of 10^{-14} m^2. The RPPCR will use this recommendation, sampling the borehole permeability between $10^{-16.3}$ and 10^{-14} m^2.

2.4.8 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 RPPCR are unchanged from the CRA-2019.

Table 2. Intrusion Scenarios for the RPPCR

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

Table 3. BRAGFLO Modeling Scenarios for the RPPCR

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

2.5 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.

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2.5.1 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. As noted in Section 2.2, these calculations are revised from those done for the CRA-2019 PA with new base solubilities, new uncertainty distributions for solubilities, new parameters for colloids, and a modified model for actinide oxidation states.

2.5.2 Models for Salado Transport

The models for Salado transport for the RPPCR 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). 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.

2.6 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.

For the RPPCR, the direct brine release conceptual models are the same as in the RPPA and APPA. These models were modified from those of the CRA-2019. Changes are summarized below and have been deemed appropriate by a peer review (Falta et al., 2021).

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2.6.1 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., separated by one or no 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 more than one 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 RPPCR, 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 RPPCR retains the 10 notional "panels," termed here DBR panels, used in the CRA-2019 (Figure 4) but the interpretation of each DBR panel is different in the RPPCR (Figure 5). The approach taken in the RPPCR is the same as in the APPA and the RPPA.

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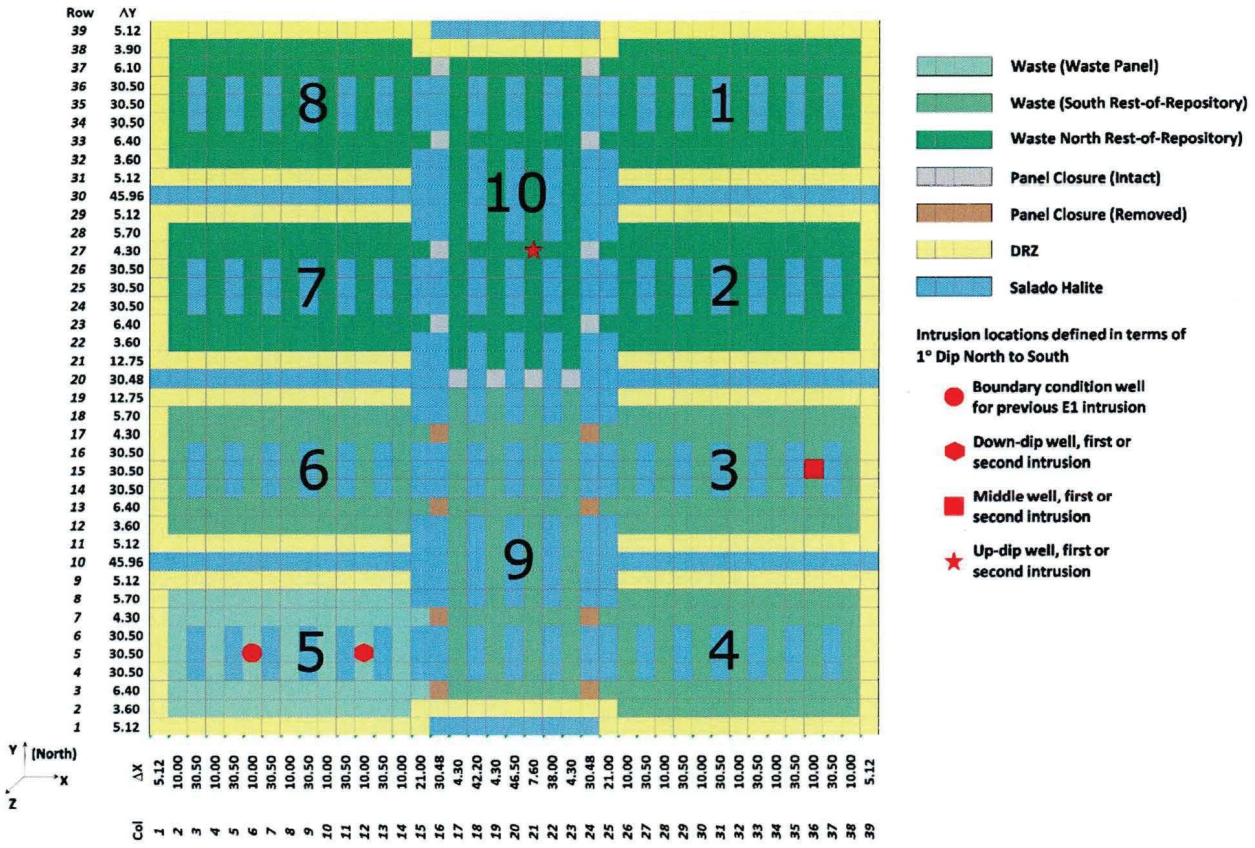


Figure 4. BRAGFLO_DBR Grid for the CRA-2019.

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.

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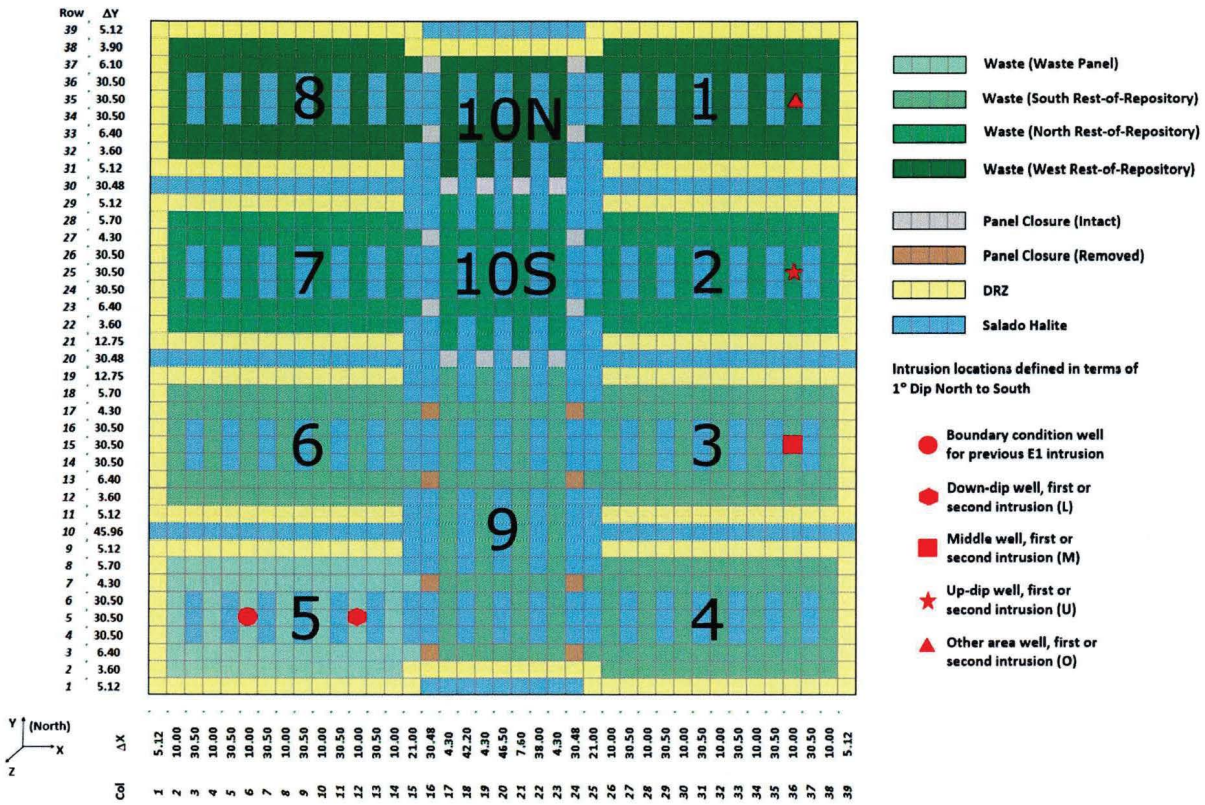


Figure 5. BRAGFLO_DBR Grid for the RPPCR.

Analyses have shown 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 (Shumaker, 2021). 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 assumptions and DBR model were reviewed by the APPA peer review panel. The peer review panel found the assumptions used to be justified, and the DBR model was found to be adequate and reasonable for its intended purpose (Falta et al., 2021).

2.6.2 Representative Boreholes for Direct Brine Releases

DBRs from an intrusion into the repository are modeled by results of the DBR scenarios (Table 4); and the representative borehole for an intrusion is determined as shown in Table 5. The representative borehole for a DBR from an intrusion into the repository with undisturbed conditions is determined by the intruded panel. After the initial intrusion, DBRs for a subsequent intrusion are based on the distance between the panel containing the subsequent intrusion and the nearest panel with a previous E1 intrusion. If no previous E1 intrusion has occurred, releases are determined by the nearest panel with an E2 intrusion. The distances between panels are specified by the panel groups indicated in Table 6, in order of nearest to farthest: Same, Connected, Adjacent, and Non-Adjacent. The representative borehole associated with each distance is identified in Table 5.

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Table 5. Use of Representative Boreholes for DBR

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

2.6.3 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 RPPCR the panel neighbor groups are extended to same, connected, adjacent, and non-adjacent. 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, e.g., Panels 1 and 11 are non-adjacent. The path between panels is traced through excavated areas only. The panel neighboring is the same as in the APPA and the RPPA.

As discussed in Section 2.6.2, the panels are grouped according to their relative location within the repository for the purposes of interpolating releases from calculations for specific DBR scenarios. The lower panel group comprises Panel 5. Conditions in the lower panel group are used to estimate releases from an intrusion into a previously intruded panel. The middle group comprises Panels 3, 4, 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 upper panel group comprises Panels 1, 2, 7, 8 and 10. Conditions in the upper 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 other panel group comprises the proposed new waste panels numbered 11 through 19. Conditions in the other panel group are used to estimate releases from an intrusion into a panel without a previous intrusion, and that is in a different half of the repository than all panels with previous intrusions (i.e., the south section vs. the west section).

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 6. 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 6 summarizes the panel neighbor scheme for the RPPCR. Panels not designated as same, connected, or adjacent are defined as non-adjacent.

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Table 6. Panel Neighbors in the RPPCR

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

2.6.4 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 contact-handled (CH) waste. The RPPCR 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.

2.6.5 Cuttings and Cavings

For the RPPCR, cutting and cavings releases will be estimated using the CRA-2019 models with no changes (DOE, 2019, Appendix PA). If the borehole intersects contact-handled waste, cuttings and cavings release volumes are calculated by multiplying the eroded 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 in each of three randomly

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selected CH-waste streams. The probability of selecting a waste stream is equal to the waste stream's volume fraction in the inventory.

If the borehole intersects remote-handled waste, cuttings and cavings release volumes are calculated by multiplying the eroded borehole diameter by the remote handled waste height of 0.509 m (Parameter REFCON:HRH). Cuttings and cavings releases are then calculated by multiplying the release volume with the time-dependent radionuclide concentration in a randomly selected RH-waste stream.

2.7 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. The Culebra flow and transport calculations from the CRA-2009 PABC were used in the CRA-2019 PA, and are fully described in Kuhlman, (2010).

For the RPPCR, three aspects of Culebra flow and transport modeling are revised:

- Transmissivity fields for flow in the Culebra are re-calculated.
- Flow fields are calculated using MODFLOW6 in place of MODFLOW2000.
- Additional source locations are used to model radionuclide transport through the Culebra.

2.7.1 Transmissivity Fields

Bowman (2022) describes the analyses to be carried out to produce updated transmissivity fields for modeling flow in the Culebra. Transmissivity fields were last computed for the CRA-2009 PABC (Kuhlman 2010); these fields were used in the CRA-2019 PA as well as in the APPA and RPPA. The updated transmissivity fields will account for new information since the CRA-2009 PABC and use updated versions of the relevant codes: MODFLOW2000 is replaced by MODFLOW6 and PEST is replaced with PEST++. The code PRESECOTP2D will be updated to version 1.25 for the RPPCR to accept the MODFLOW6 output file format. The resulting transmissivity fields will be documented in an analysis report answering to AP-203 (Bowman, 2022).

2.7.2 Culebra Flow Fields

Transmissivity fields in the Culebra are used to compute flow fields in the Culebra. In the RPPCR, the MODFLOW6 code will be used for this calculation. The flow fields used for the CRA-2019 PA were those developed for the CRA-2009 PABC, which were calculated using MODFLOW2000. In the RPPCR, new flow fields will be calculated using the new transmissivity fields. Flow fields will be calculated for the same partial mining and full mining scenarios that were used in the CRA-2009 PABC flow calculations.

2.7.3 Culebra Release Points

In each transport simulation, 1 kg of each of ^{241}Am, ^{239}Pu, ^{234}U, and ^{229}Th is released during the first 50 years after repository closure and the mass fraction reaching the LWB is tabulated over time. In the CRA-2019 PA and the APPA, all radionuclides were introduced into the Culebra at a

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single location over the centroid of the current ten waste panels. For the RPPA, a total of four release locations were used to represent the spatial extent of the proposed replacement and additional waste panels. The predominant regional flow in the Culebra is to the south. However, the proposed new panels extend westward into areas affected by potash mining in the full-mining scenario, where enhanced transmissivity can draw flow toward the western delineation of the land withdrawal boundary.

For the RPPCR, Culebra transport calculations will include releases into the Culebra at four locations to account for the potential for westward transport above the new panels (Figure 6), as was done in the RPPA. Kushnereit et al. (2020) calculated the particle tracks of a conservative tracer released into the Culebra at points distributed across the western repository region for partial and full mining flow fields from the CRA-2019. The particle tracking analysis was used to define groups of waste panels with similar particle transport direction, travel distance and travel time. For each group a release point is located in the Culebra at the centroid of the group's panels.

Four panel groups were identified (Bethune and Brunell, 2022):

- Group 1 comprises Panels 1 through 10. Discharge to the Culebra from an undisturbed repository, from boreholes in Panels 1 through 10, and through the shafts will be modeled with a release point near the centroid of the existing repository, as was done for CRA-2019. The release point for Group 1 is labeled CRP 1.
- Group 2 is composed of Panels 11, 12, and 13, which are characterized by particle tracks with predominately southward flow and shorter travel distances and times to the land withdrawal boundary relative to Group 3. The release point for Group 2 panels is labeled CRP 2.
- Group 3 is composed of Panels 14 and 19, which are characterized by having particle tracks that predominately flow to the south and east, but with longer travel distances and times to the land withdrawal boundary relative to Group 2. The release point for Group 3 panels is labeled CRP 3.
- Group 4 is composed of Panels 15, 16, 17, and 18, which are characterized by having a relatively high percentage of particle tracks that exit the western land withdrawal boundary in the full-mining scenario. Waste panels in Group 4 are all at least partially inside the full-mining region. The release point for Group 4 panels is labeled CRP 4.

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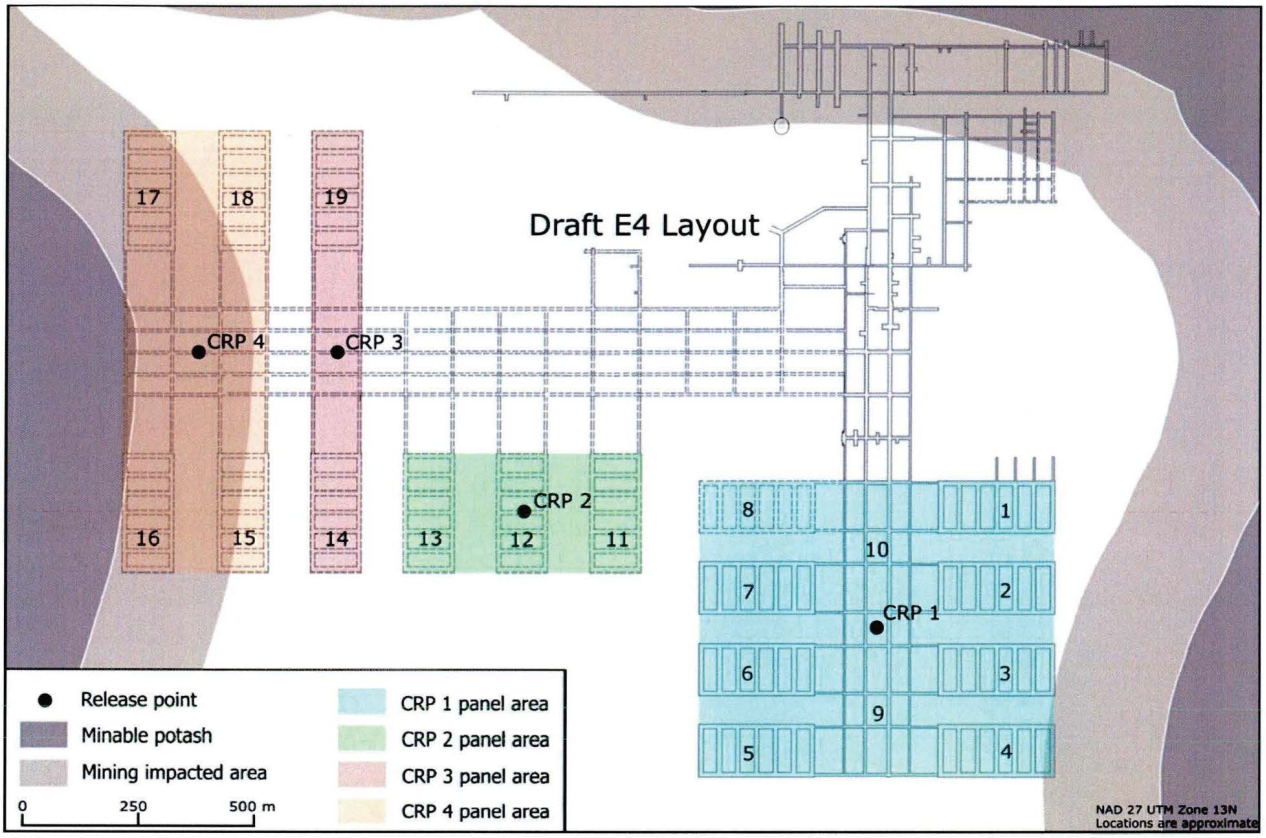


Figure 6. Culebra release point locations

2.8 Calculation of CCDFs for Releases

The conceptual structure of the RPPCR 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 the CRA-2019, PRECCDFGF v 2.01 and CCDFGF v 7.03 were used. For the APPA, PRECCDFGF was modified to v2.02 and CCDFGF was modified to v.7.05 to accept results for four representative boreholes (Section 2.6.2) and to extend the panel adjacency relationships (Section 2.6.3). Both codes were modified (PRECCDFGF v 3.00 and CCDFGF v 8.00) for the RPPA calculation to accumulate results for multiple release points into the Culebra (Section 2.7). The RPPCR will use RPPA versions of these codes migrated to the updated computational platform (PRECCDFGF v 3.01 and CCDFGF v8.01).

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2.8.1 Drilling Rates and Plugging Pattern Probabilities

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 August 2022 are documented in the 2022 Delaware Basin Monitoring Annual Report (DOE 2022). The drilling rate (GLOBAL:LAMBDAD) will be updated based on DOE (2022).

For CRA-2019, only wells within the designated potash area (DPA) were used for determining the plugging pattern of wells modeled in the performance assessment. This approach was criticized by the EPA in their review of the CRA (EPA, 2022b). An alternative approach using a nine-township area surrounding the WIPP site was proposed (Day, 2023) and found acceptable by the EPA (Santillan, 2023). The probability of one-, two- and three-plug wellbore plugging patterns, will be updated for the RPPCR with the data from Day (2023). Analysis to translate from data in Day (2023) to PA parameters is documented in Brunell (2023).

2.9 Hardware Changes

Calculations for the CRA-2019 PA were performed on the WIPP PA Solaris Cluster, which consisted of Intel hardware running the Solaris operating system (Long, 2019). WIPP PA codes have been migrated to the WIPP PA HPC/Linux Cluster, which consists of Dell PowerEdge C6420 hardware running CentOS7 (Long, 2020; Long and King 2022). The RPPCR will be run on the WIPP PA HPC/Linux Cluster using the code versions listed in Section 6.

3 Summary of Parameter Changes

Table 7 lists parameters changes relative to the CRA-2019. A complete list of changed parameters with values will be published in the Summary Report (Table 8). Updates to parameters will follow Nuclear Waste Management Procedure NP 9-2, Parameters.

Table 7. Summary of Parameter Changes for the RPPCR

Material(s)	Property(s)	Description
Parameters related to inventory		
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 of contact- and remote-handled waste
AM241L, TH230L, PU238L, U234L, PU239L	INVCHD and INVRHD	WIPP-scale initial lumped radionuclide inventory of contact- and remote-handled waste

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Material(s)	Property(s)	Description
BOREHOLE	WUF	Waste Unit Factor
NITRATE, SULFATE	QINIT	WIPP-scale amounts of nitrate and sulfate
WAS_AREA	IRONCHW, IRNCCHW, CELLCHW, CELCCHW, CELECHW, PLASCHW, PLSCCHW, PLSECHW, RUBBCHW, RUBCCHW, RUBECHW	Mass of iron, cellulose, plastic and rubber in contact-handled (CH) waste materials, waste container (packaging) materials, and waste emplacement materials
WAS_AREA	IRONRHW, IRNCRHW, CELLRHW, CELCRHW, CELERHW, PLASRHW, PLSCRHW, PLSERHW, RUBBRHW, RUBCRHW, RUBERHW	Mass of iron, cellulose, plastic and rubber in remote-handled (RH) waste materials, waste container (packaging) materials, and waste emplacement materials
Parameters related to actinide mobilization		
SOLMOD3, SOLMOD4, SOLMOD5	SOLCOH, SOLSOH, SOLCOH2, SOLSOH2, SOLCOH3, SOLSOH3, SOLCOH4, SOLSOH4, SOLCOH5, SOLSOH5	Actinide baseline solubilities in Castile and Salado brines
SOLMOD3, SOLMOD4	SOLVAR	Actinide solubility multiplier
AM, NP, PU, TH, U	PROPMIC CAPMIC CONCINT	Microbial and intrinsic colloid parameters
NP, PU, U	OXCUTOFF	Probability of low oxidation state

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Material(s)	Property(s)	Description
Parameters related to repository dimensions		
REFCON	VREPOS	Excavated storage volume of the repository
REFCON	ABERM	Area of the berm placed over waste panels
REFCON	AREA_CH	Area for contact-handled (CH) waste disposal
REFCON	FVW	Fraction of the repository volume occupied by waste
Parameters related to the Salado flow model		
CAVITY1	PRESSURE	Initial pressure in the representative waste panel
CAVITY2	PRESSURE	Initial pressure in waste-filled regions other than the representative waste panel
WAS_AREA	EGRATMIC	Moles of gas generated per kilogram of cellulose from early-time rapid CPR biodegradation.
REFCON	FESAPKG	Iron surface area per kilogram of iron inventory
CASTILER	PRESSURE	Initial pore pressure of a Castile brine reservoir
CASTILER	PRMX_LOG, PRMY_LOG, PRMZ_LOG	Permeability (log base 10) of Castile reservoir
CASTILER	COMP_RCK	Bulk compressibility of Castile reservoir host rock
BH_SAND	PRMX_LOG PRMY_LOG PRMZ_LOG	Permeability (log base 10) of degraded borehole material
Parameters related to boreholes and direct releases		
GLOBAL	LAMBDAD	Drilling rate per unit area
GLOBAL	ONEPLG	Probability of having Plug Pattern 1 (full plug)
GLOBAL	TWOPLG	Probability of having Plug Pattern 2
GLOBAL	THREEPLG	Probability of having Plug Pattern 3

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Material(s)	Property(s)	Description
GLOBAL	DBRMINBV	Minimum volume of brine in the repository required for a direct brine release
GLOBAL	PBRINE	Probability that a borehole intersects pressurized brine in the Castile

4 Analyses

4.1 Sensitivity Analysis

The RPPCR will include sensitivity analyses to quantify the influence of uncertain parameters and select intermediate outputs on the uncertainty in select outputs from the PA models, which include:

- Pressure and saturation in the excavated areas for assumed intrusions (BRAGFLO scenarios).
- Brine flow in the borehole for assumed intrusions (BRAGFLO scenarios).
- Radionuclide transport to the Culebra for assumed intrusions at select times (NUTS scenarios).
- Radionuclide transport through the Culebra from each release point resulting from placement of unit masses at simulation start (SECOTP2D scenarios).

In addition, sensitivity analyses will be done on mean values of CCDFs for each release type (cuttings, cavings, spallings, direct brine release and Culebra transport) and on total releases. The sensitivity analysis will be done using the code STEPWISE.

In the sensitivity analysis of Culebra transport, the explanatory variables will include the DTRKMF output travel times for conservative particles tracked through the Culebra from each release point to the LWB in the no-mining, full-mining, and partial-mining scenarios. Travel times will be used in sensitivity analyses to quantify the importance of the T-field selection to uncertainty in mass transport. If travel times are highly correlated among release points, travel times for one release point will be retained in the sensitivity analysis while the others will be dropped. The T-field selection index (GLOBAL:TRANSIDX) will be excluded from the sensitivity analysis because, being an index, TRANSIDX should have no monotonic relationship to releases.

4.2 Comparison with previous PAs

Results from the RPPCR will be compared with corresponding results from the CRA-2019 PA. In addition, RPPCR results will be compared with results from the RPPA, and with the APPA as appropriate, to aid in explaining the differences between the RPPCR PA and the CRA-2019 PA.

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4.3 Comparison with EPA's analysis

Results from the RPPCR will be compared with a separate analysis conducted by the EPA, termed the CRA19-COMB (see Section 4.6 of EPA, 2022a). EPA's analysis employed several assumptions and models that are different from those in the CRA-2019 or planned for the RPPCR; for example, EPA's analysis assumes that all radionuclides are in the low oxidation state.

5 Tasks and Schedule

The tasks, responsible personnel, and estimated task schedule are summarized in Table 8. Calculations described in Section 2 will be carried out and documented in analysis reports. Analysis 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. Analyses will include comparisons of RPPCR analysis results with the CRA-2019 PA and the RPPA. Analyses will also describe the uncertainty of the results and provide a sensitivity analysis to determine the input uncertainty that primarily impacts the uncertainty in the results.

A record of the run control will be created for the RPPCR. 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 RPPCR will also fall under this analysis plan.

Table 8: Task List and Estimated Schedule for the RPPCR

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
1	Mining modifier run control scripts completed	AP-204	2/28/2023	Bethune
2	PBRINE justification memo	NP 9-1	6/23/2023	Zeitler
3	Inventory Analysis Report	NP 9-1	3/28/2023	Kicker
4	FEPs analysis report	SP 9−4	5/31/2023	Kirkes
5	Input Files Prepared	AP-204	5/19/2023	Bethune, Brunell, Docherty, Kicker, Kim, King, and Zeitler

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Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
6	Input File Review	AP-204	6/09/2023	Hansen
7	Parameter Data Entry and QA Review	NP 9-2	6/15/2023	Long
8	Main PA Calculations	AP-204	6/23/2023	Long
9	Analysis Reports	NP 9-1	9/26/2023	Hansen
9.1	Parameter Sampling	AP-204	9/26/2023	Zeitler
9.2	EPA Unit	AP-204	9/26/2023	Kicker
9.3	Salado Flow	AP-204	9/26/2023	King
9.4	Cuttings, Cavings, and Spallings	AP-204	9/26/2023	Kicker
9.5	Actinide Mobilization and Salado Transport	AP-204	9/26/2023	Kim, Docherty
9.6	Culebra Flow and Transport	AP-204	9/26/2023	Bethune
9.7	Direct Brine Release	AP-204	9/26/2023	Docherty, King
9.8	CCDF Construction	AP-204	9/26/2023	Brunell, Zeitler
9.9	Run Control Document	AP-204	9/26/2023	Long
10	Summary Report	NP 9-1	10/17/2023	Bethune, Brunell, Docherty, Hansen, Kicker, Kim, King, Long, Zeitler

6 Software

The major WIPP PA codes to be used for the RPPCR are listed in Table 9. The execution of these codes for the analysis described herein comprises a compliance decision calculation. These codes will be executed on the WIPP PA HPC/Linux Cluster. The WIPP PA HPC/Linux Cluster consists of the login node FWM, and 24 Dell PowerEdge C6420 compute nodes running CentOS 7. Additionally, we may utilize COTS (commercial off-the-shelf) software such as Matlab®, Sigma Plot®, Excel®, Access®, or Python, running on individual workstations. The use of any COTS application will be verified per NP 9-1 Appendix C as appropriate.

DRSPALL and MERGESPALL will not be run for the RPPCR. Instead, output results from a previous analysis (Kirchner et al., 2014; Kirchner et al., 2015) will be used as input. The inputs to these codes would be the same for the RPPCR as for the previous analysis.

Table 9. Codes to be Used for the RPPCR

Code	Version	Executable	Build Date
ALGEBRACDB	2.37	algebracdb	8/17/2020
BRAGFLO	7.01	bragflo	9/17/2020
CCDFGF	8.01	ccdfgf	7/28/2022

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Code	Version	Executable	Build Date
CCDFVECTORSTATS	1.02	ccdfvectorstats	8/19/2020
CUTTINGS_S	6.04	cuttings_s	11/13/2020
DTRKMF	1.02	dtrkmf	1/13/2021
EPAUNI	1.20	epauni	8/19/2020
GENMESH	6.11	genmesh	8/20/2020
GROPECDB	2.14	gropecdb	6/16/2020
ICSET	2.24	icset	8/20/2020
LHS	3.00	lhs	11/1/2021
MATSET	9.25	matset	9/8/2020
MODFLOW6	6.2.2	modflow6	5/16/2022
NUTS	2.08	nuts	11/16/2021
PANEL	5.02	panel	8/16/2022
POSTBRAG	4.03	postbrag	9/8/2020
POSTSECOTP2D	1.06	postsecotp2d	8/17/2020
POSTLHS	4.12	postlhs	9/17/2020
PREBRAG	9.01	prebrag	8/20/2020
PRECCDFGF	3.01	preccdfgf	7/28/2022
PRELHS	2.46	prelhs	8/29/2022
PRESECOTP2D	1.25	presecotp2d	1/25/2023
RELATE	1.46	relate	8/20/2020
SCREEN_NUTS	1.03	screen_nuts	8/19/2020
SECOTP2D	1.44	secotp2d	8/20/2020
STEPWISE	2.23	stepwise	10/28/2020
SUMMARIZE	3.03	summarize	8/17/2020

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*.

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- 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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