568138

IMPORTANT NOTICE: The current official version of this document is available via the Sandia National Laboratories WIPP Online Documents web site. A printed copy of this document may not be the version currently in effect.

SANDIA NATIONAL LABORATORIES
WASTE ISOLATION PILOT PLANT

AP-177
Revision 0

Analysis Plan for the Assessment of Abandoned Panel Closures in South End of Repository and Lack of Waste Emplacement in Panel 9

Task 4.4.1.2.1

Effective Date: July 13, 2017

Authored by:	Todd R. Zeitler Print Name	[signature] Signature	7/13/2017 Date
Authored by:	Brad A. Day Print Name	[signature] Signature	7/13/17 Date
Reviewed by:	Ramesh Sarathi Print Name Technical Reviewer	[signature] Signature	7/13/2017 Date
Reviewed by:	Shelly R. Nielsen Print Name Quality Assurance Reviewer	Shelly R. Nielsen Signature	7-13-17 Date
Approved by:	Chris Camphouse Print Name Department Manager	[signature] Signature	7-13-17 Date

1 of 20

Table of Contents

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 WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194 by means of performance assessment (PA) calculations performed by Sandia National Laboratories (SNL). WIPP PA calculations estimate the probability and consequence of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure. The DOE updates and submits the results of the WIPP PA calculations to the EPA as part of a recertification process that occurs at five-year intervals following the receipt of the first waste shipment at the site in 1999.

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

The DOE expects to submit a planned change notice (PCN) to the EPA that justifies the decisions to not implement panel closures in Panels 3, 4, 5, and 6 and to not emplace waste in Panel 9. It is anticipated that the PCN will not require PA results as part of the justification; however, the DOE has requested that SNL undertake calculations and analyses to determine the impacts of the proposed changes to the repository configuration on the long-term performance of the facility (USDOE, 2017). This analysis plan outlines the approach that SNL will use to determine the impacts of the operational policy change on the long-term repository performance. Although the analysis is not currently in support of a planned change request (PCR), the analysis will be performed as an Compliance Determination Analysis.

2 Approach

The analysis approach consists of working within the currently approved PA framework (i.e., no consideration is given to conceptual model changes, major code changes, or novel parameter values) to assess the impact of not using ROMPCS in Panels 3, 4, 5, 6 and not emplacing waste in Panel 9. The approach consists of three parts: (1) selection of an appropriate baseline calculation for comparison, (2) assessment and appropriate modification of the current representation of panel closure areas and waste in Panel 9 in the model, and (3) assessment of the impact of the southern area's abandonment on repository performance and regulatory compliance. The following sections describe the approaches to be taken.

2.1 Baseline Calculation Comparison

The CRA-2014 was submitted to the EPA in March 2014 (USDOE, 2014). As part of the recertification application, a PA calculation was performed that included a number of parameter value and computational model changes from the PABC-2009 baseline.[1] During the EPA's completeness review of the CRA-2014, the EPA requested that the DOE perform multiple sensitivity studies of repository performance based on specified parameter changes. The final sensitivity study, CRA14_SEN4, included parameter changes that resulted in increased releases compared to the CRA-2014 results (Zeitler and Day, 2016). At the time of the writing of this document, the EPA has determined that the CRA-2014 is complete and no formal request has been made by the EPA for the DOE to provide a new PA baseline (i.e., through a PABC - Performance Assessment Baseline Calculation - like those performed following CRA-2004 and CRA-2009). Thus, the CRA-2014 PA will become the new baseline. However, it is anticipated that some of the parameter changes investigated in CRA14_SEN4 will become part of the next recertification application performance assessment (CRA-2019). To address the anticipated changes and consider the impact of larger potential releases, the current analysis will primarily use the CRA14_SEN4 analysis for comparison—all changes discussed in this document will be made with CRA14_SEN4 as a reference point.

2.2 Abandonment of Panel Closures in South End of Repository

Prior to submittal of the CRA-2014, the PCS-2012 analysis investigated the replacement of the plan for "Option D" panel closures with a plan for run-of-mine salt panel closures (ROMPCS) (Camphouse, 2012). Following a federal rulemaking that supported the use of the ROMPCS (USEPA, 2014), panel closures were represented by ROMPCS in the CRA-2014 PA. The proposed plan change, that considers not emplacing ROMPCS in Panels 3, 4, 5, 6 and not emplacing waste in Panel 9, will be evaluated in an Abandonment of Panel Closures in the South (APCS) analysis.

2.2.1 Representation of Panel Closures in the BRAGFLO AND BRAGFLO_DBR Grids

Panel closures are represented in PA calculations in the computational grids used by the BRAGFLO code. BRAGFLO calculates subsurface brine/gas flow in the repository and the surrounding area over a 10,000-year period using a two-dimensional, "flared" vertical cross section representation of the repository and surrounding area. In this grid representation (Figure 1), there are three waste areas: (1) the "waste panel" (WP) represents waste emplaced in Panel 5; (2) the "south rest-of-repository" (SROR) represents waste emplaced in Panels 3, 4, 6, and 9; and (3) the "north rest-of-repository" (NROR) represents waste emplaced in Panels 1, 2, 7, 8, and 10. There are also three panel closure areas (PCS): the "southernmost" PCS representation is between the WP and SROR, the "middle" PCS representation is between the SROR and NROR, and the "northernmost" PCS representation is between the NROR and operations (OPS) area.

---

[1] In 2012, the PCS-2012 PA investigated changes to the panel closure properties associated with replacing Option D closures with run-of-mine salt closures (Camphouse, 2012). Because that PA was approved by the EPA in a federal rulemaking, it could be considered to be the PA baseline immediately prior to submission of the CRA-2014. However, the CRA-2014 made comparisons to the PABC-2009 as a baseline.

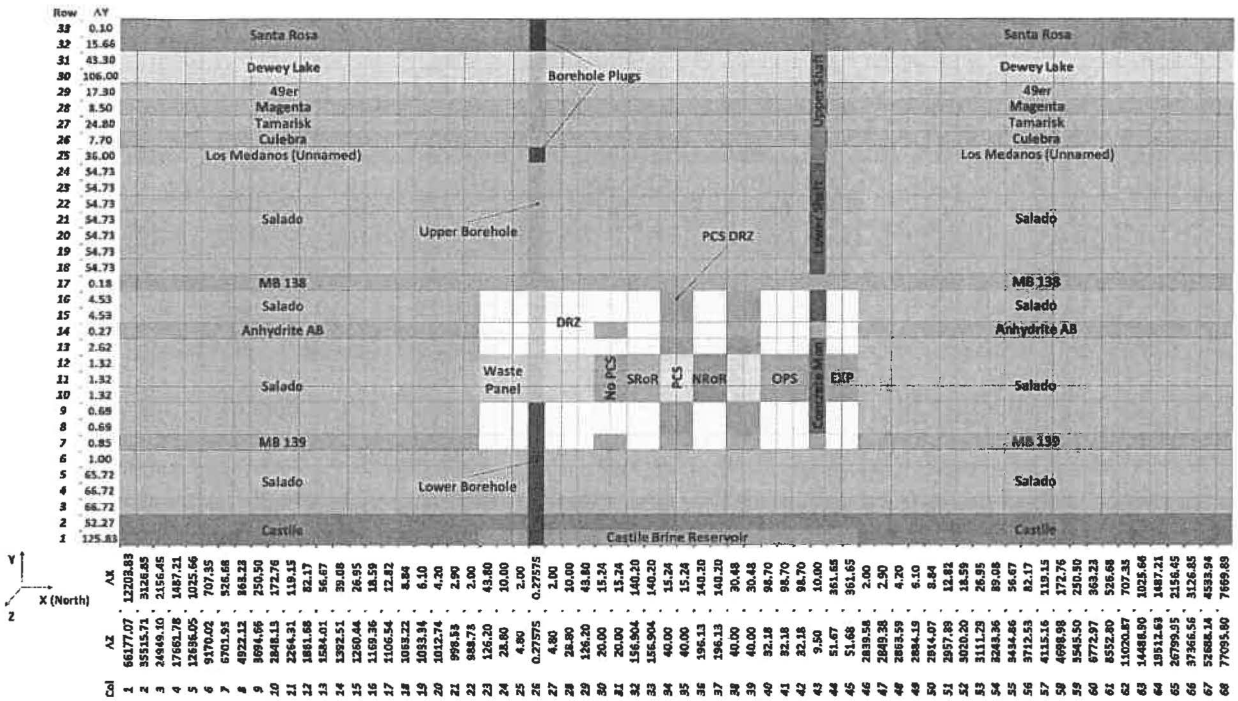

Figure 1 - BRAGFLO "flared" grid to be used for APCS.

The southernmost panel closure represents a single set of two panel closures (one for each panel entrance) for Panel 5, with a caveat described below. The middle panel closure represents the four closures in the drifts between Panels 9 and 10. The northernmost panel closure represents the four closures in the drifts between Panel 10 and the OPS area as well as the four closures in the drifts between the OPS and experimental (EXP) areas.[2]

This lumping of panels and panel closures essentially distills the lateral flow paths available to any individual panel in the repository down to two – the path between a panel and the surrounding formation, and the path between a panel and the "rest-of-repository." Panel 5 has been conservatively selected to represent a single waste panel as the WP in WIPP PA. Another consequence of this lumping is that individual panel closures within the SROR and NROR areas (e.g., between Panels 3 and 9 or between Panels 1 and 10) are not explicitly represented in the BRAGFLO grid. Instead, the panel closure for Panel 5 (i.e., the southernmost panel closure) is a proxy for panel closures between any two adjacent panels in the SROR and NROR areas. Finally, this lumping also applies to modeling wellbore intrusion scenarios where initial intrusions into Panel 5 are explicitly modeled and conservatively used to represent initial intrusions into other panels.

A different grid (Figure 2), the "DBR grid," is used for BRAGFLO direct brine release (DBR) calculations. The DBR grid represents a smaller portion of the repository than the BRAGFLO grid—it represents, in a two-dimensional planar view, the individual waste panels and their immediate surroundings, including individual panel closures for each waste panel.

[2] For CRA-2014, the northernmost panel closure was incorrectly represented as 30.48 m long, which is equivalent to the length of a single drift closure. In CRA14_SEN4, the representation was corrected to 60.96 m in order to represent the length of two drift closures.

BRAGFLO_DBR calculates flow between the repository and the surface over a 3.5 day period, with different simulations starting at different specified times within the 10,000-year regulatory period. While the ten waste panels are represented individually in the DBR grid, the saturation and pressure values for each panel are initialized to averaged saturation and pressure values taken from the BRAGFLO grid; the averaged WP values are mapped to Panel 5, the averaged SROR values are mapped to Panels 3, 4, 6, and 9, and the averaged NROR values are mapped to Panels 1, 2, 7, 8, and 10.

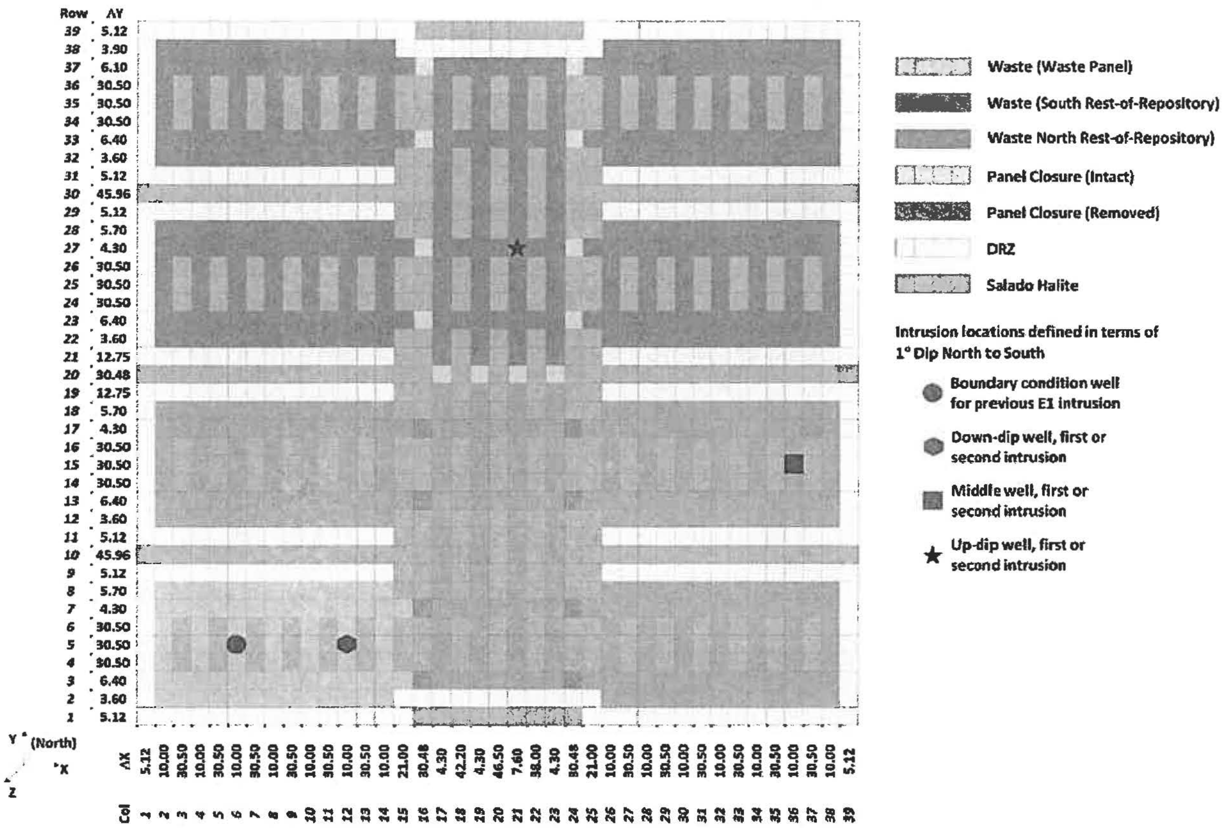

Figure 2 - BRAGFLO_DBR grid to be used for APCS.

For the planned changes to the configuration of panel closures, both the BRAGFLO "flared" grid and the DBR grid are impacted. Abandonment of the Panel 5 panel closure in the BRAGFLO grid entails representing the southernmost panel closure with material properties that are more transmissive than the ROMPCS. In the DBR grid, each abandoned panel closure (i.e. for Panels 3, 4, 5, and 6) is similarly treated with an alternate material specification. However, due to lumping in the BRAGFLO grid, these changes have broader implications. Removing the southernmost panel closure conceptually represents removing the panel closures between any two adjacent panels in the SROR. Also, since values from the BRAGFLO "flared" grid are mapped onto the DBR grid as initial conditions, the pressure and saturation values mapped to the panels in the SROR will be calculated assuming no adjacent panel closures. Removal of adjacent panel closures will allow faster pressure equilibration between panels (i.e., less isolation of panels), which is expected to result in increased calculated releases (see Section 2.2.4 below). This is considered to be a change that is conservative with respect to releases. In this analysis, the southernmost panel closure in the BRAGFLO grid and panel closures for Panels 3, 4, 5, and 6 in the DBR grid will be assumed not to exist.

2.2.2 Properties of Open Panel Closures

Because the abandoned panel closures areas will lack backfill or run-of-mine salt, the modeling of the material properties applied to those areas must be re-examined. In current PA calculations, there are two areas in the BRAGFLO grid that are modeled as "open," the OPS and EXP areas. There is no plan to backfill those areas, so they are assumed to close "naturally" following closure of the WIPP. Although the closure of the OPS/EXP areas is expected to occur gradually over time, in PA calculations, constant porosity and permeability over 10,000 years have been assumed (SNL, 1996). In the APCS analysis, material properties for abandoned panel closure areas (i.e., panel closures for Panels 3-6 in the DBR grid and the southernmost panel closure in the BRAGFLO grid) will be changed to be those used for the OPS/EXP areas and given a new material name, PCS_NO. This change is justified in that it will be conservative with respect to releases, and that the properties used for the OPS/EXP areas are the only analogues for open areas used in WIPP PA.[3] For the ROMPCS panel closure areas, the same properties used in the CRA14_SEN4 analysis are applied.

Table 1: Open Panel Closure Properties

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

[3] An SNL computational study of the change in porosity with time for a room subject to creep closure was performed, which resulted in a set of porosity surfaces. However, permeability for such a system was not determined and the porosity surfaces have not been used in PA calculations (Butcher, 1997).

2.2.3 Use of DBR Scenarios in CCDFGF

The CCDFGF code calculates releases for hypothetical futures that are populated with drilling intrusion events. A typical PA analysis consists of 300 vectors, each of which has 10,000 hypothetical futures. In these futures, drilling intrusions may intersect any waste panel at any time and multiple times. CCDFGF calculates DBR releases from each intrusion event by translating and interpolating DBR volumes calculated at a few points in time for a much smaller set of scenarios (Table 3). For instance, while CCDFGF models intrusions into any of the ten panels, BRAGFLO_DBR simulations model intrusion events in only three of the ten panels (Panels 3, 5, or 10), and furthermore the BRAGFLO_DBR simulations select their initial conditions from a set of BRAGFLO scenarios (Table 2) in which only a single panel (Panel 5, the WP in the BRAGFLO grid)[4] is intruded (or is undisturbed). Thus, panel lumping and abstraction also enter the CCDFGF calculations, but in terms of the combinatorial problem of what panel was intruded and to which panel(s) is it adjacent.

Each BRAGFLO_DBR scenario described in Table 3 consists of three pieces of information about the BRAGFLO_DBR simulation: (1) the initial conditions of the BRAGFLO_DBR simulation, (2) which panel is intruded during the simulation, and (3) the time of the intrusion. The initial conditions are taken from BRAGFLO simulation output from different BRAGFLO scenarios – S1-DBR selects its initial conditions from the BRAGFLO S1-BF (E0 undisturbed) scenario, while scenarios S2-DBR through S5-DBR select their initial conditions from BRAGFLO scenarios S2-BF through S5-BF (in which the WP has been previously intruded – this is the "initial" intrusion that is referred to in Table 3). The panel intruded in the BRAGFLO_DBR simulation is labeled as lower, middle, and upper, or same, adjacent, and nonadjacent, and in both cases corresponds to Panels 5, 3, and 10, respectively. The terms same, adjacent, and nonadjacent refer to the position of the intruded panel with respect to Panel 5, the WP.[5] Lastly, the time of the intrusion specifies the time at with the initial conditions are selected from the corresponding BRAGLO scenario simulation. Thus, for BRAGFLO_DBR scenarios S2-DBR through S5-DBR (Table 3), three cases are run at each of the five intrusion times: Lower (L), Middle (M), and Upper (U). The L case corresponds to a first intrusion in Panel 5 followed by a subsequent intrusion in Panel 5. The M case corresponds to a first intrusion in Panel 5 followed by a subsequent intrusion in Panel 3. The U case corresponds to a first intrusion in Panel 5 followed by a subsequent intrusion in Panel 10.

---

[4] Panel 5 is chosen as the intruded panel because the down dip of the repository presumably will lead to the highest brine concentrations there, which would lead to greater gas generation and potentially maximize releases.

[5] Same, adjacent, and nonadjacent are primarily terminologies utilized in CCDFGF, but introduced in the DBR discussion to illustrate the correlation between lower, middle, and upper panel references.

Table 2 - BRAGFLO Scenarios

Fundamental Scenario	Specific Scenario	Time of Drilling Intrusion(s)
E0: no drilling intrusions	S1-BF	N/A
E1: single intrusion through an excavated area of the repository that penetrates pressurized brine in the Castile.	S2-BF	350 years
	S3-BF	1,000 years
E2: single intrusion through an excavated area of the repository that does not penetrate pressurized brine in the Castile.	S4-BF	350 years
	S5-BF	1,000 years
E1E2: two intrusions into the same waste panel, the first being an E2 intrusion and the second being an E1 intrusion.	S6-BF	1,000 years for E2 intrusion 2,000 years for E1 intrusion

Table 3 - BRAGFLO-DBR Scenarios

Scenario	Description
S1-DBR	*Initially undisturbed repository (i.e., E0 conditions).* Intrusion into lower, middle, or upper waste panel at 100; 350; 1,000; 3,000; 5,000; or 10,000 years: 18 combinations.
S2-DBR	Initial E1 intrusion at 350 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 550; 750; 2,000; 4,000; or 10,000 years: 15 combinations.
S3-DBR	Initial E1 intrusion at 1,000 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 1,200; 1,400; 3,000; 5,000; or 10,000 years: 15 combinations.
S4-DBR	Initial E2 intrusion at 350 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 550; 750; 2,000; 4,000; or 10,000 years: 15 combinations.
S5-DBR	Initial E2 intrusion at 1,000 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 1,200; 1,400; 3,000; 5,000; or 10,000 years: 15 combinations.

The BRAGFLO_DBR L case is then used by CCDFGF to represent a drilling intrusion event in a future in which the same panel has been previously intruded (the "Same" case in CCDFGF). For example, if an intrusion in Panel 10 followed a previous intrusion into Panel 10, then results from the L case (which were actually calculated for the more conservative case in which Panel 5 is intruded twice) would be used.

The BRAGFLO_DBR M case is used by CCDFGF to represent a drilling intrusion event in a future in which the most recently intruded panel was adjacent to the panel currently being intruded (the "Adjacent" case in CCDFGF). For example, if an intrusion in Panel 10 followed a previous intrusion into Panel 8 (which is adjacent to Panel 10; see Section 2.2.4 below), then the M case results (which were actually calculated for the more conservative case in which Panel 3 is intruded after Panel 5) would be used.

The BRAGFLO_DBR U case is used by CCDFGF to represent a drilling intrusion event in a future in which the most recently intruded panel was non-adjacent to the panel currently being intruded (the "Nonadjacent" case in CCDFGF). For example, if an intrusion in Panel 10 followed a previous intrusion into Panel 3 (which is not adjacent to Panel 10; see Section 2.2.4 below), then the U case results (which were actually calculated for the more conservative case in which Panel 10 is intruded after Panel 5) would be used.

2.2.4 Redefinition of Panel Adjacency in CCDFGF

Version 6.02 (and previous versions) of the CCDFGF code specified 144 model node locations for drilling intrusions, which corresponded to 14 locations per panel for Panels 1-8 and 16 locations each for Panels 9 and 10 (Figure PA-11 in Appendix PA, 2014). For a given intrusion into the repository, a node was chosen at random with equal probability. Node-to-Panel correlations and "panel adjacency" (the adjacent or non-adjacent relationship between panels) were specified explicitly in the CCDFGF code (i.e., were "hard-coded"). As explained above, panel adjacency is relevant to the calculation of DBRs. The CCDFGF code version 6.0 was used in CRA-2014 calculations.

Table 4: Listing of adjacent panel ("neighbor") relationships for CRA14_SEN4 and APCS

Panel	CRA14_SEN4	APCS
1	2, 10	10
2	1, 3, 10	10
3	2, 4, 9	4, 5, 6, 9, 10
4	3, 9	3, 5, 6, 9, 10
5	6, 9	3, 4, 6, 9, 10
6	5, 7, 9	3, 4, 5, 9, 10
7	6, 8, 10	10
8	7, 10	10
9	3, 4, 5, 6, 10	3, 4, 5, 6, 10
10	1, 2, 7, 8, 9	1, 2, 3, 4, 5, 6, 7, 8, 9

Beginning with CCDFGF v. 7.00, the use of node locations for intrusions was replaced with the use of panel locations, with panel probabilities specified at run-time via relative panel areas in the CCDFGF control file (WIPP PA, 2010).[6] Panel adjacency is handled by specifying immediate (i.e., adjacent) neighbors for each panel in the CCDFGF control file. The definition of panel adjacency used in CRA14_SEN4 (which used CCDFGF v. 7.02) is the same as that used in the CRA-2014 described in (Table 4).[7] For example, Panel 1 had Panels 2 and 10 as neighbors and Panel 5 has Panels 6 and 9 as neighbors.

---

[6] As part of the process for migrating WIPP PA codes from the Alpha/VMS system to the Solaris system, the use of CCDFGF v. 7.02 was regression tested against CRA-2014 calculations with panel probabilities given as 14/144=0.09722222 for Panels 1-8 and 16/144=0.11111111 for each of Panels 9 and 10. Panel adjacency was specified in input control files to correspond exactly to that which had been "hard-coded" in v. 6.02 (and previous versions) of CCDFGF.

[7] For CRA14_SEN4, actual panel areas (rather than fraction of node locations) were used to calculate panel probabilities (Schreiber, 1991).

In the current analysis, panel neighbor relationships will be modified to correspond to degree of separation by panel closures (Table 4) instead of merely spatial proximity. The modification is consistent with the definition that panels having one or fewer panel closures between them are considered neighbors. The approach is consistent with the use of panel closures in both the BRAGFLO and BRAGFLO_DBR grids and the definitions of SROR and NROR (see Section 2.2 above).

The neighbor relationship updates (Table 4) manifest themselves in two ways: (1) decreased number of neighbors for Panels 1-8 due to no longer counting adjacencies across pure halite; and (2) increased number of neighbors for panels in WP and SROR due to the reduced use of panel closures (and thus increased transmissivity between panels). Panels that are separated from each other by a single set of panel closures are considered neighbors ("Adjacent"). As an example of the first type of update, Panel 1 now only has one neighbor, Panel 10 (but not Panel 2). As an example of the second type of update, Panel 5 is now neighbors with Panels 3, 4, 6, 9, and 10. There is only a single set of panel closures between any of the WP or SROR panels and Panel 10; as a result, all other panels are neighbors of Panel 10.

As a logical extension of the updated panel neighbor relationships, the question may arise as to whether the WP and SROR areas should be modeled as a single, combined panel. That would entail, for CCDFGF calculations, treating successive intrusion into any two of Panels 3, 4, 5, 6 and 9 as the "Same" instead of "Adjacent." For this analysis, panels will not be combined in order to preserve flexibility in the model because there exists uncertainty in the evolution of the "open areas" where panel closures were previously planned to be inserted. On one hand, if the open areas close relatively quickly and compact tightly (such that they behave as run-of-mine salt panel closures), then the true neighbor adjacency of those panels will have properly been preserved.[8] If, on the other hand, the open areas close slowly and compact loosely (such that they provide little barrier to brine and gas flow), then results from the "Same" and "Adjacent" BRAGFLO_DBR cases will be similar because, in the BRAGFLO_DBR simulations, Panels 3, 4, 5, 6 and 9 will behave as a single, large panel. Thus, in the CCDFGF calculations, any selected "Adjacent" case will use DBR results that include the effects of a lack of panel closures. Furthermore, regardless of whether there is zero or one set of panel closures between neighboring panels, CCDFGF will use the same DBR results that include the effects of a lack of panel closures. Therefore, CCDFGF will calculate DBR releases that are conservative with respect to the proposed change in panel closure configurations.

2.3 Removal of Waste from Panel 9

Removal of waste from Panel 9 and relocation of waste to a new panel somewhere north of Panel 8 in the repository is expected to increase overall DBR releases by an amount equal to DBR releases from similar panels in the NROR. The expected increase is anticipated due to an increase in the probability of intersecting a panel (i.e., on the order of a 10% increase). This estimation assumes that radioactively contaminated brine could migrate to and accumulate in panels without

[8] In this case, some of the neighbor designations (e.g., Panels 5 and 9) would no longer be consistent with the updated definition of panel adjacency. However, the result can be considered conservative with respect to releases, since "Adjacent" DBR results would be used in place of "Non-Adjacent" DBR results.

waste. Cuttings and cavings releases are expected to be unaffected by removal of waste from Panel 9 and relocation to the north as both are directly related to the presence of solid waste material within the area in question. Due to a reduction in brine saturation and associated gas generation-driven pressures in the NROR as compared to the SROR and WP, spallings are expected to be reduced by relocation of waste from Panel 9 to the north.

The current conceptual model and PA code base is incapable of handling the complexity introduced by removing waste from Panel 9 and relocating the waste to a new panel in the north. Firstly, CCDFGF does not allow individual release mechanisms to separately be turned on/off within a panel. Additionally, the BRAGFLO grid and CCDFGF codes are currently limited to conceptually representing all waste panels as a grouping of lower, middle, and upper panels. With radially concentric flow being a central tenet of the Salado Flow conceptual model, inclusion of a fourth grouping of panels to represent a new panel that is not symmetrically configured with respect to the existing panels is not possible.

Even with the above discussed conceptual model and code limitations, it is appropriately conservative with respect to releases to continue to model waste within the existing Panel 9 in lieu of adding new waste panel(s) to the north. The conservatism is attributed to the 1 degree (south) dip in the Salado formation, which results in increased brine accumulation due to gravity drainage, increased hydrostatic pressure, and increased gas generation due to corrosion (enabled by the increased availability of brine) at the deeper/south portion of the repository. Previous PA analyses consistently show increasing brine saturations and pressures in the repository when moving from the north to the south. Thus, continuing to model the same mass of waste as if it is located in Panel 9 will result in somewhat larger DBR and spallings releases compared to if the same mass is relocated to an arbitrary location further north.

In the APCS analysis, this conservatism will be greatly enhanced due to the abandonment of panel closures between Panels 3, 4, 5, 6, and 9, which effectively equilibrates the brine pressures and saturations in Panels 3, 4, 5, 6, and 9. This result is appropriate when modeling DBR releases from panels in the south due to the lack of separating panel closures. However, it represents a major source of conservatism when modeling DBR releases from panels in the north that have intact panel closures. This is because BRAGFLO_DBR simulates DBR releases for sequential intrusions of adjacent panels only in the south of the repository, but CCDFGF uses those same BRAGFLO_DBR results regardless of whether the adjacent panels are in the south (with no panel closures) or north (with panel closures) section of the repository. For example, a CCDFGF future that encounters an initial brine intrusion into Panel 10 followed by a subsequent intrusion in Panel 1, 2, 7, 8, or 9 would use DBR releases from an adjacent release case due to the modification of Panel 10 neighbor relationships. This treatment under APCS will be exceedingly conservative because the panel closure between Panels 10 and 9 and the panel closures between Panel 10 and Panels 1, 2, 7, and 8 would not allow brine pressures and saturations in the initially intruded panel to readily equilibrate with that of the subsequently intruded panel.

An important product of the analyses discussed within this AP is that the conservatism associated with representing adjacent intrusions in the north will be shown to more than compensate for the non-conservatism associated with not addressing the probability of DBR release from a new Panel 9 replacement in the north rest-of-repository.

2.4 Impact Assessment via PA Calculations

Changing the properties for the southernmost panel closure area in the BRAGFLO grid and in Panels 3, 4, 5, and 6 in the BRAGFLO_DBR grid potentially alters brine and gas flow in and around the repository, as well as pressure profiles in the repository sub-regions. Changes in pressure and brine saturation in a waste panel area can result in a change to the number of vectors that meet the necessary criteria for a DBR at the time of intrusion, DBR volumes, and releases to the Culebra. In addition, changes in waste panel pressure can potentially impact spallings releases. Changes to panel adjacencies in CCDFGF can impact DBRs. Changes in spallings releases and DBRs are expected to be greater than those of other release mechanisms for the current impact assessment. To determine the impacts of these potential changes on regulatory compliance, a focused set of PA calculations will be performed. These calculations will use the same waste inventory as was used in the CRA-2014 and the CRA14_SEN4 analysis. Results obtained will be primarily compared to those calculated in the CRA14_SEN4.

Specific codes executed for the impact assessment are now discussed. Results from the SECOTP2D and DRSPALL codes that were used for CRA14_SEN4 will be used here. Although the results from the LHS, EPAUNI, and PANEL (actinide mobilization mode) codes are unaffected by the changes made for APCS, for simplicity in the run control process, they will be rerun for APCS using the same input as for CRA14_SEN4.

2.4.1 Salado Flow: BRAGFLO

The two-phase flow code BRAGFLO simulates brine and gas flow in and around the WIPP repository, incorporating the effects of gas pressure on disposal room closure, gas generation, brine consumption, and inter-bed fracturing. To assess the impacts resulting from changing properties of the southernmost panel closure area, BRAGFLO simulations will be performed using the CRA14_SEN4 BRAGFLO computational grid. A complete suite of BRAGFLO calculations will be executed. These calculations will consist of 3 replicates, 100 vectors per replicate, and 6 scenarios per vector. Results obtained from the APCS calculations will be compared to those calculated in CRA14_SEN4.

2.4.2 Spallings: DRSPALL and CUTTINGS_S

Repository pressures may be affected due to changes in panel closure area properties. Changes in repository pressures have the potential to impact spallings results. Consequently, spallings releases for the current impact assessment may differ from those found in CRA14_SEN4 due to differences in repository pressures calculated by BRAGFLO. Spallings volumes from a single borehole intrusion are calculated by code DRSPALL at initial repository pressures of 10, 12, 14, and 14.8 MPa. DRSPALL calculations that were utilized to generate spallings volumes at these pressures for CRA14_SEN4 will also be used in the current assessment. The current assessment will use the same procedure as was used for CRA14_SEN4 to interpolate between these DRSPALL volumes to calculate spallings volumes corresponding to a particular drilling intrusion. The initial repository pressure for a given scenario, time, location, and vector will be retrieved from the BRAGFLO results, and CUTTINGS_S will use this initial pressure to calculate a spallings volume for each scenario, time, location, and vector combination by interpolating between DRSPALL results.

2.4.3 Direct Brine Releases: BRAGFLO

In addition to its role as a tool used to simulate brine and gas flow in and around the WIPP repository, BRAGFLO is also used in PA to calculate DBR volumes. As the panel closure area properties for Panels 3, 4, 5, and 6 potentially impact pressures and brine saturations in waste-containing repository regions, DBR calculations will be performed as part of the current assessment. These calculations will use the same procedures and DBR numerical grid as were used in CRA14_SEN4. Properties for panel closures for Panels 3, 4, 5, and 6 will be equivalent to those used in the OPS/EXP areas in CRA14_SEN4. Conditions required for the initiation of a DBR release will remain unchanged from CRA14_SEN4, and the DBR volumes will be calculated for the same scenarios and times.

2.4.4 Salado Transport: NUTS and PANEL

Changes in repository conditions found with BRAGFLO can potentially impact radionuclide transport. The WIPP radioisotope transport code NUTS is used to simulate the transport of radionuclides through the Salado Formation for scenarios S1-BF through S5-BF. Three replicates of NUTS runs (all scenarios and times) will be performed for APCS.

Based on drilling event characteristics, intrusions are classified as no change (not significantly changing repository behavior), an E1 type (where a region of pressurized brine is encountered) or an E2 type (where pressurized brine pocket is not encountered). Radionuclide transport to the Culebra for the E2E1 intrusion combination (BRAGFLO scenario S6-BF) is calculated by running the PANEL code in "intrusion mode" (PANEL_INT). Three replicates of PANEL_INT calculations will be performed for APCS using the same procedure that was used in the CRA14_SEN4 PANEL_INT calculations.

2.4.5 CCDF Construction: CCDFGF

Modification of definition of panel adjacency will have an impact on releases. Mean CCDFs for all release mechanisms will be calculated by replicate and across all replicates. The 95% confidence limit on the mean across all replicates will also be calculated for total normalized releases.

2.4.6 Sensitivity Analysis: STEPWISE

The APCS PA will implement sensitivity analyses for results from the major codes. Sensitivity analyses will be conducted in a manner consistent with those employed for CRA14_SEN4. Specifically, global sensitivity analyses will be conducted on the results from CCDFGF using the linear regression code STEPWISE.

2.5 FEPs Re-assessment

An assessment of the Features, Events, and Processes (FEPs) baseline will be conducted to determine if the FEPs basis remains valid in consideration of the changes to panel closure area properties and reconsideration of waste for Panel 9. The re-assessment will be performed according to SP 9-4, Performing FEPs Impact Assessment for Planned or Unplanned Changes. A discussion of the way FEPs are affected and the effect on the screening determination for those FEPs will be documented in a report separate from the summary report.

2.6 Reports and Documentation

Three reports will be generated as a result of this analysis plan. FEPs impact assessment results will be documented in the first report. A second report will cover the results of an analysis of the sensitivity of releases to sampled parameter values. A third report will summarize results demonstrating the impact of the changes described above on regulatory compliance.

3 Tasks

The tasks, responsible personnel and estimated task schedule are summarized below in Table 5.

Table 5: Task list and estimated schedule for the impact analysis.

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
1	FEPS Re-assessment	SP 9-4	8/7/17	Kirkes
2	PA Calculations	AP-177	7/21/17	Long
3	Sensitivity Analysis: STEPWISE	AP-177	8/15/17	Sarathi
4	Summary Report	AP-177	8/31/17	Day and Zeitler

4 Software

The major WIPP PA codes to be used for this analysis are listed in Table 6. These codes will be executed on the WIPP PA Solaris Cluster, which is described in Table 7. Additionally, we may utilize COTS (Commercial off-the-shelf) software such as MATHEMATICA®, MATLAB®, MATHCAD®, Excel®, Access®, Grapher®, Python, or Kaleidagraph®, running on workstations. The use of any COTS application will be verified per NP 9-1 Appendix C as appropriate.

Table 6: Codes to be used for the current calculations

Code	Version	Build Date
ALGEBRACDB	2.36	09/11/12
BRAGFLO	6.03	02/01/13
CCDFGF	7.03	05/03/17
CUTTINGS_S	6.03	01/15/13
EPAUNI	1.19	09/12/16
GENMESH	6.10	01/12/15
ICSET	2.23	09/11/12
LHS	2.44	06/02/15
MATSET	9.24	10/11/16
NUTS	2.06	03/27/13
PANEL	4.04	09/26/12
POSTBRAG	4.02	01/10/13
POSTLHS	4.11	06/02/16
PREBRAG	8.03	01/23/13
PRECCDFGF	2.01	09/09/13
PRELHS	2.44	10/11/16
RELATE	1.45	09/11/12
STEPWISE	2.22	07/02/13
SUMMARIZE	3.02	10/31/12

Table 7: WIPP PA Solaris Cluster

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
HP	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
JA	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
ML	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
RE	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
UH	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
ZZ	Oracle/SUN X4-2B	x86 (GenuineIntel 306E4 family 6 model 62 step 4 clock 2693 MHz)	Oracle Solaris 11	48
SAN	Dell PowerEdge R820	x86 (GenuineIntel 206D7 family 6 model 45 step 7 clock 2400 MHz)	Oracle Solaris 11	64

5 Special Considerations

None

6 Applicable Procedures

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

- Training of personnel will be conducted in accordance with the requirements of NP 2-1, *Qualification and Training*.
- FEPs assessment will be conducted according to SP 9-4, *Performing FEPs Baseline Impact Assessments 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*.

7 References

U.S. Department of Energy, Carlsbad Field Office. 2016. *WIPP UPDATE: October 14, 2016, Plans Call for Controlled Withdrawal from South End of Underground.* http://www.wipp.energy.gov/Special/WIPP%20Update%2010_14_16.pdf

U.S. Department of Energy, Carlsbad Field Office. 2017. *Sandia Recommendation for Completion of Fully-Qualified RPC2 Calculations*. Email from R. Patterson to P. Shoemaker dated February 7, 2017.

U.S. Department of Energy. 2014. *Transmittal of the Electronic 2014 Compliance Recertification Application*. Letter from J. Franco to C. Gelles dated March 21, 2014.

Zeitler, T.R and Day, B. 2016. *CRA14_SEN4 Sensitivity Study, Rev. 1.* Sandia National Laboratories. Carlsbad, NM. ERMS 567505.

Camphouse, R.C. 2012. *Analysis Package for Salado Flow Modeling Done in the AP-161 (PCS-2012) Performance Assessment*. Sandia National Laboratories. Carlsbad, NM. ERMS 558204.

U.S. Environmental Protection Agency. 2014. *Final rule: Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance With the Disposal Regulations; Panel Closure Redesign*. October 8, 2014. Document Number: 2014-24025.

WIPP PA. 2010. *Design Document and User's Manual for CCDFGF (Version 7.00)*. ERMS 554046. Sandia National Laboratories, Carlsbad, NM.

Schreiber, J. 1991. *Updated Waste Storage Volumes*. Sandia National Laboratories, Carlsbad, NM. ERMS 237713.

Sandia National Laboratories. 1996. *Summary Memo of Record, DR-3: Dynamic Closure of the North-End and Hallways*, Memorandum from P. Vaughn, M. Lord, and R. MacKinnon to D.R. Anderson, Subject: FEP Screening Issue DR-3. Sandia National Laboratories, Carlsbad, NM. ERMS 230798.

Butcher, B.M., 1997. *Waste Isolation Pilot Plant Disposal Room Model*. Sandia Technical Report SAND97-0794, August 1997.