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-156

Analysis Plan for the Impact Determination of SDI Heater Testing and Associated Excavation on Long-Term WIPP Performance

Task 1.4.1.2

Effective Date: 05/18/11

Authored by:	Chris Camphouse	*Original signed by Chris Camphouse*	*5/18/11*
	Print Name	Signature	Date
Authored by:	Kris Kuhlman	*Original signed by Kris Kuhlman*	*5/18/11*
	Print Name	Signature	Date
Reviewed by:	Kevin Barnhart	*Original signed by Kevin Barnhart*	*5/18/11*
	Print Name Technical Reviewer	Signature	Date
Reviewed by:	Mario Chavez	*Original signed by Mario Chavez*	*5/18/2011*
	Print Name Quality Assurance Reviewer	Signature	Date
Approved by:	Moo Lee	*Original signed by Moo Lee*	*5/18/11*
	Print Name Department Manager	Signature	Date

© 2011 Sandia Corporation

Table of Contents

1 Introduction and Objectives 3

2 Approach 3

2.1 Thermal Impacts 4
2.2 Excavation Impacts 4
2.3 FEPs Re-assessment 7
2.4 Reports and Documentation 7

3 Tasks 7

4 Software 8

5 Special Considerations 8

6 Applicable Procedures 9

7 References 9

1 *Introduction and Objectives*

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, has been developed by the U.S. Department of Energy (DOE) for the geologic (deep underground) disposal of transuranic (TRU) waste. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194 by means of performance assessment (PA) calculations performed by Sandia National Laboratories (SNL). WIPP PA calculations estimate the probability and consequence of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure. The models are maintained and updated with new information 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.

With the recertification of the WIPP in November of 2010 (U.S. EPA 2010), a new PA baseline was established by the PABC-2009. Following this most recent recertification decision, the DOE plans to submit a planned change notice (PCN) to the EPA that justifies additional excavation in the WIPP experimental area. This excavation will be done in order to support salt disposal investigations (SDI) that include field-scale heater tests at WIPP.

The proposed expansion of the WIPP experimental area in order to facilitate SDI work requires an assessment of associated impacts on long-term repository performance. The impacts of additional volume on brine/gas flow and brine/gas saturation in and around the waste regions of the repository must be determined. In addition, the impact of planned heater tests on the state of the repository at the time of closure must be evaluated and quantified. The DOE has requested that SNL undertake calculations and analyses to determine the impacts of the additional repository volume and planned heater tests on the long-term performance of the facility (U.S. DOE 2011a, 2011b). The impact of additional excavated volume on flow properties in and around the waste regions of the repository will be determined by a comparison to results obtained in the PABC-2009. Impacts of planned heater tests will be determined via an assessment of the evolution of heat dissipation from the beginning of SDI experimental work to the time of facility closure. This analysis plan outlines the approach SNL will use to determine the impacts of the planned additional excavation and heater tests in the WIPP experimental area on long-term repository performance.

2 Approach

The approach consists of two primary components to quantify the impacts of planned SDI work at the WIPP. First, the potential temperature rise at the time of closure resulting from previous heater testing must be determined. Second, the impact of a larger excavated volume in the experimental area on regulatory compliance must be assessed. The approaches taken for these two components are now discussed.

2.1 Thermal Impacts

Analytic heat conduction solutions will be used to conservatively estimate the rise in temperature at the WIPP waste disposal panels due to the proposed SDI heater tests. The calculation will use a well-known one-dimensional analytic solution and the method of superposition. These solutions and methods are found in heat conduction textbooks: for example Ozisik (1993), Lee (1999), and Carslaw and Jaeger (1959). The solution that will be used is analytic (there is no computational grid, time steps, or solver) and uses the simple mathematical concept of superposition to find the resulting expected rise in temperature. The advantages of an analytic solution include the lack of ancillary parameters related to numerical solution (e.g., grid spacing, time steps, convergence criteria). In this case an analytic solution will capture the conservative bounding nature of the proposed calculation without the complications introduced by a potentially more realistic gridded numerical model.

Superposition will be used to take a simple one-dimensional solution and build up a solution that considers both the timing and geometry of the proposed SDI heater tests. Superposition is possible due to the linearity of heat conduction in a solid. The analytic solution will ignore the effects that the excavations or any small-scale heterogeneity would have on the solution. The drifts may be circulated with relatively cool air, and would therefore serve as a sink for heat during the operational life of WIPP. This potential cooling effect will not be taken into account in the proposed superposition of analytic solutions.

The calculation begins with a solution for a point source with spherical symmetry, with a continuous heat flux as an intermediate step in developing the final solution. We will use superposition in time of a co-located source and sink to simulate a finite source (in this case 3 years). We will include the effect of anhydrite marker beds by treating Marker Beds 138 and 139 (above and below the repository, respectively) as perfectly insulating boundaries. In a purely homogeneous and isotropic medium with spherical symmetry, heat flow would be three-dimensional. Accounting for the marker beds will be quite conservative, forcing the heat to flow in a two-dimensional radial manner.

Superposition in space and time will produce a field of predicted temperature rise due to one heater. The effects of all of the proposed heaters will be estimated by superimposing the required number of these point solutions at the proposed heater locations, (x, y, and z); this final superposition will determine the expected total rise in temperature due to all proposed heaters at any location in space or time after the heaters turn on.

The calculation will be documented in a report with the material properties, and temporal and geometrical arrangement used to allow the calculations to be checked and verified by other researchers.

2.2 Excavation Impacts

Additional excavation in the WIPP experimental area to support SDI work potentially alters brine and gas flow in and around the repository, as well as pressure profiles in the repository sub-regions. While the impact of these changes on potential releases is expected to be small due to the significant isolation of the repository waste region from the experimental area, they must be

quantified to determine their impact on compliance. For example, slight changes in pressure and brine saturation in a waste panel due to additional excavation, and consequently lower pressure, in the experimental area can result in a change to the number of vectors that meet the necessary criteria for a DBR at the time of intrusion. In addition, reductions in waste panel pressure due to gradual pressure release into the expanded experimental area would yield a corresponding reduction in spallings releases. Changes in spallings releases and DBRs are the primary items of interest in the SDI PA 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 PABC-2009. Results obtained will be compared to those calculated in the PABC-2009. For codes unaffected by the additional SDI excavation, results from the PABC-2009 will be used for the generation of CCDFs.

Specific codes executed for the SDI impact assessment are now discussed. Results generated from the PABC-2009 will be used for codes not discussed below. Finally, the same parameters and parameter values that were used for the PABC-2009 will be used in the SDI PA calculations.

2.2.1 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 additional excavated volume in the experimental area, BRAGFLO simulations will be performed using a modified version of the PABC-2009 BRAGFLO computational grid. Grid cells in the PABC-2009 grid corresponding to the repository experimental area will be adjusted to incorporate the additional excavated volume proposed for the SDI work. The SDI BRAGFLO calculations will use the same procedures that were used in the PABC-2009 BRAGFLO calculations (Nemer 2010), with the exception of a slightly modified numerical grid. A complete suite of BRAGFLO calculations will be executed using the parameters established for the PABC-2009. These calculations will consist of 3 replicates, 100 vectors per replicate, and 6 scenarios (see Table 1) per vector. Results obtained from the SDI BRAGFLO calculations will be compared to those calculated in the PABC-2009.

Table 1: WIPP PA BRAGFLO Scenarios

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

The same codes used for PABC-2009 will be used for the SDI BRAGFLO calculations, specifically PREBRAG version 8.0, BRAGFLO version 6.0 and POSTBRAG version 4.00A.

2.2.2 Spallings: DRSPALL and CUTTINGS_S

Repository pressures may be affected due to gradual release of pressure into the expanded experimental area. Changes in repository pressures have the potential to impact spallings results. Consequently, spallings releases for the SDI impact assessment may differ from those found in the PABC-2009 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 in the PABC-2009 will also be used in the SDI impact assessment. The SDI impact assessment will use the same procedure as was used for the PABC-2009 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. The code CUTTINGS_S version 6.02 will be used for the SDI impact assessment, which is the same code used for the PABC-2009.

2.2.3 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 expansion of the experimental area potentially impacts pressures and brine saturations in waste-containing repository regions, DBR calculations will be performed as part of the SDI impact assessment. These calculations will use the same procedures and DBR numerical grid as were used in the PABC-2009. Conditions required for the initiation of a DBR release will remain unchanged from the PABC-2009, and the DBR volumes will be calculated for the same scenarios and times (Table 2). The codes PREBRAG version 8.0, BRAGFLO version 6.0 and POSTBRAG version 4.00A will be used for the SDI impact assessment, which are the same codes used for the PABC-2009.

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

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

2.2.4 CCDF Construction: CCDFGF

Expansion of the repository experimental area will have minimal impact on potential releases from the Culebra. As a result, the SDI impact assessment will calculate CCDFs of individual vectors for total normalized releases using Culebra release results calculated in the PABC-2009. Mean CCDFs for spallings releases and DBRs 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. The SDI impact assessment CCDFGF calculations will use the same procedures that were used in the PABC-2009 CCDFGF calculations. The codes PRECCDFGF version 1.01 and CCDFGF version 5.02 will be used for the SDI impact assessment, which are the same codes used for the PABC-2009.

2.3 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 additional excavated volume and heater tests proposed for the SDI experimental work. 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.

2.4 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 summarize the results from the heater test thermal impact investigation. A third report will summarize results demonstrating the impact of the expanded experimental area on regulatory compliance.

3 Tasks

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

Table 3: Task list and estimated schedule for the SDI impact analysis.

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
1	Thermal Impact Analysis	AP-156	5/20/11	Kuhlman
2	BRAGFLO Calculations	AP-156	5/25/11	Long
3	CUTTINGS_S Calculations	AP-156	6/1/11	Long
4	BRAGFLO DBR Calculations	AP-156	6/6/11	Long
5	CCDFGF Calculations	AP-156	6/10/11	Long
6	Salado Flow Analysis	AP-156	6/25/11	Camphouse
7	Spallings Analysis	AP-156	6/29/11	Kicker
8	DBR Analysis	AP-156	7/1/11	Pasch
9	CCDFGF Analysis	AP-156	7/1/11	Kirchner
10	FEPS Re-assessment	SP 9-4	5/27/11	Kirkes
11	Thermal Impact Summary Report	AP-156	5/27/11	Kuhlman
12	Excavation Impact Summary Report	AP-156	7/22/11	Camphouse Kicker Kirchner Pasch

4 Software

The major WIPP PA codes to be used for this analysis are listed in Table 4. These codes will be executed on the WIPP PA Alpha Cluster, which is described in Table 5. 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 4: Codes to be used for the SDI Impact Assessment

Code	Version	Build Date	Executable
ALGEBRACDB	2.35	31-JAN-1996	ALGEBRACDB_PA96.EXE
BRAGFLO	6.0	12-FEB-2007	BRAGFLO_QB0600.EXE
CCDFGF	5.02	13-DEC-2004	CCDFGF_QB0502.EXE
CUTTINGS_S	6.02	9-JUN-2005	CUTTINGS_S_QA0602.EXE
GENMESH	6.08	31-JAN-1996	GM_PA96.EXE
ICSET	2.22	1-FEB-1996	ICSET_PA96.EXE
MATSET	9.10	29-NOV-2001	MATSET_QA0910.EXE
POSTBRAG	4.00A	28-MAR-2007	POSTBRAG_QA0400A.EXE
POSTLHS	4.07A	25-APR-2005	POSTLHS_QA0407A.EXE
PREBRAG	8.0	8-MAR-2007	PREBRAG_QA0800.EXE
PRECCDFGF	1.01	7-JUL-2005	PRECCDFGF_QA0101.EXE
RELATE	1.43	6-MAR-1996	RELATE_PA96.EXE
SUMMARIZE	3.01	21-DEC-2005	SUMMARIZE_QB0301.EXE

Table 5: WIPP PA Alpha Cluster

Node	Hardware Type	CPU	Operating System
CCR	HP AlphaServer ES45	Alpha EV68	Open VMS 8.2
TDN	HP AlphaServer ES45	Alpha EV68	Open VMS 8.2
BTO	HP AlphaServer ES45	Alpha EV68	Open VMS 8.2
CSN	HP AlphaServer ES45	Alpha EV68	Open VMS 8.2
GNR	HP AlphaServer ES47	Alpha EV7	Open VMS 8.2
MC5	HP AlphaServer ES47	Alpha EV7	Open VMS 8.2
TRS	HP AlphaServer ES47	Alpha EV7	Open VMS 8.2
TBB	HP AlphaServer ES47	Alpha EV7	Open VMS 8.2

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

Carslaw, H.S., and J.C. Jaeger, 1959. Conduction of Heat in Solids, second edition, Oxford Science, Oxford.

Lee, T.-C., 1999. Applied Mathematics in Hydrogeology, CRC Press, Boca Raton.

Nemer, M.B. 2010. Analysis Package for Salado Flow Modeling: CRA-2009 Performance Assessment Baseline Calculation. Sandia National Laboratories. Carlsbad, NM. ERMS 552956.

Oziski, N.M., 1993. Heat Conduction, second edition, Wiley-Interscience, New York.

U.S. Department of Energy (DOE) 2011a. Direction Letter for SDI Field Testing Planned Change Notice. U.S. Department of Energy Waste Isolation Pilot Plant, Carlsbad Area Office, Carlsbad, NM. ERMS 555494.

U.S. Department of Energy (DOE) 2011b. Inputs and Information for the SDI Thermal Test Planned Change Notice. U.S. Department of Energy Waste Isolation Pilot Plant, Carlsbad Area Office, Carlsbad, NM. ERMS 555495.

U.S. Environmental Protection Agency (EPA). 2010. 40 CFR Part 194 Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance With the Disposal Regulations: Recertification Decision, Federal Register No. 222, Vol. 75, pp. 70584-70595, November 18, 2010.

This work of authorship was prepared as an account of work sponsored by an agency of the United States Government. Accordingly, the United States Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so for United States Government purposes. Neither Sandia Corporation, the United States Government, nor any agency thereof, nor any of their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately-owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by Sandia Corporation, the United States Government, or any agency thereof. The views and opinions expressed herein do not necessarily state or reflect those of Sandia Corporation, the United States Government or any agency thereof.

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Parties are allowed to download copies at no cost for internal use within your organization only provided that any copies made are true and accurate. Copies must include a statement acknowledging Sandia Corporation's authorship of the subject matter.