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Subject: Evaluation of Brine Flow Through Panel Closures using CRA-2014 BRAGFLO Results

The following analysis was performed to verify previous calculations conducted in support of WIPP's initial certification.

Background: Boreholes that intercept the operations and experimental areas of the repository have been screened out of PA calculations since the CCA (DOE 1996). Additionally, early screening efforts demonstrated that drilling into a non-repository area of the controlled area (within both the Salado and Culebra formations independently) resulted in low consequences to the performance of the repository (Wallace 1996 and Economy 1996). No known recent events or new information has become available that would weaken or render these determinations invalid.

The current BRAGFLO model does allow for brine and gas flow between the waste and non-waste regions, as has been the case since the CCA. A full discussion and analysis of boreholes intersecting non-waste regions is contained in the Supplemental Peer Review Report (Wilson et al. 1996), in which the Conceptual Models Peer Review Panel (CMPRP) evaluated the conceptual model for the exploration borehole and raised questions regarding the justification for excluding inadvertent intrusions into the experimental area of the repository from PA calculations. DOE's response to this issue was partially based on the fact that even though intrusions into these regions of the repository could occur, since waste will not be disposed in these areas, releases from cuttings, cavings, and spallings could (by their definitions) not occur. Nonetheless, radionuclides present in the repository could potentially be transported in brine into the experimental regions and contaminated brine could be brought to the surface during drilling. However, because the experimental area of the repository is separated from the waste regions by panel closures that will greatly reduce brine flow, insignificant quantities of brine flow across this boundary.

To respond to the CMPRP, the DOE provided intermediate BRAGFLO results that demonstrated that the panel closures effectively limited brine movement. In their Supplemental Peer Review Report (Wilson et al. 1996), the CMPRP stated:

> "...with very few exceptions, the maximum brine flow through a panel seal was found in modeling results to be about 12,000 m^3 following an E1 intrusion, and the expected flow would be about 3,000 m^3. Under undisturbed conditions, the cumulative brine inflow into the operations and experimental areas from all sources ranges from near zero to about 10,000 m^3 (see Figures 3-4 and 3-5). This flow would, on the average, be expected to result in approximately a twofold dilution of brine flowing in from the waste area following an E1 intrusion. Under disturbed conditions with intrusion boreholes penetrating the operations and experimental areas, the inflow of uncontaminated brine and the dilution of contaminated brine would be even greater.
>
> In the event that the operations and experimental areas are penetrated by intrusion boreholes, approximately 12,000 m^3 of brine could conceivably flow from these areas into the waste area. Performance assessment results indicate that total cumulative brine flow into the waste area is typically about 40,000 m^3 following an E1 intrusion at 1,000 years and about 30,000 m^3 following an E2 intrusion at 1,000 years. Given that about six borehole intrusions are expected to occur during the regulatory time frame, the total volume of brine potentially available to flow into the waste area could exceed 100,000 m^3. Although the actual volume of brine inflow will depend on the interrelationships among time of intrusion, repository creep closure, gas generation, repository pressure, and other factors, the modeling results indicate that sufficient brine is potentially available from other sources that an incremental supply of as much as 12,000 m^3 would have no consequential effect on performance assessment results. However, if subsequent model modifications result in significantly smaller fluid volumes in the repository, the significance of this issue should be reevaluated."

Thus, the CMPRP determined that the DOE had satisfactorily demonstrated that representing exploration boreholes and their effects in the experimental and operations areas of the repository was not necessary, and the representation of repository fluid flow and the exploration borehole was adequately incorporated into PA models.

New Analysis: To update the BRAGFLO results that were used by the CMPRP to make its decision, and verify that it remains appropriate to exclude boreholes in the operations and experimental areas from PA calculations, BRAGFLO results from replicate 1 of the CRA-2014 PA calculations are examined. Following the analysis of BRAGFLO results from the CRA-2014 (Camphouse 2013), some additional results from the completed BRAGFLO calculations were needed. The values of variables over the 10,000 year simulated time period were extracted from .CDB files (alg2_bf_cra14_R1_S*s*_V*vvv*.CDB kept in CMS Class CRA14-0 of CMS library LIBCRA14_BFR1S*s*, where *vvv*=1-100 and *s*=1,2,3,5) using SUMMARIZE version 3.01 (sample input file shown in Appendix A, same as used in another analysis of CRA14 output

(Zeitler 2015)) for 100 vectors of replicate 1/scenarios 1, 2, 3, and 5 of the CRA14-0 case. Variable values relevant to the discussion are plotted in Figures 1 and 2.

The maximum brine flow through a panel seal is now about 8,000 m^3 following an E1 intrusion, which occurred for brine flow across the panel closure separating the waste panel and southern rest of repository (SRoR) (output parameter BNWPNPCS) for scenario 2 (Figure 1). (BRAGFLO scenarios S2 and S3 consider E1 intrusions.) The maximum expected northward flow across any panel closure is about 1,000 m^3 (for brine flow across the panel closure separating the waste panel and SRoR in scenario 2, output parameter BNWPNPCS). For undisturbed conditions (S1), the cumulative brine inflow into the operations and experimental areas from all sources ranges from 700 to 35,000 m^3 (sum of output parameters BRNOPSIC and BRNEXPIC) (Figure 2). This flow would, on average, result in about a seventeen-fold dilution of brine flowing in from the waste area following an E1 intrusion (comparing (35,000+700)m^3/2 = 17,850 m^3 to 1,000 m^3).

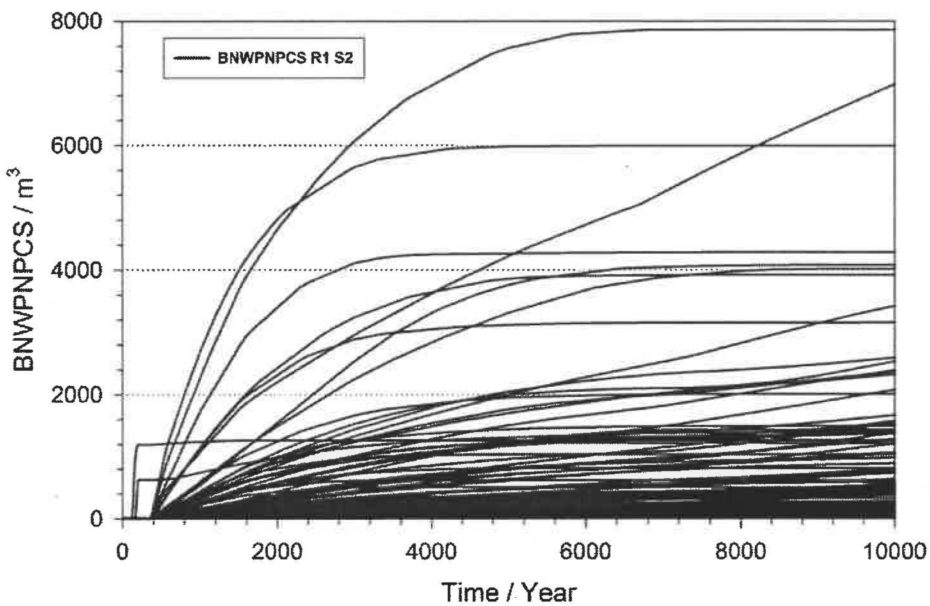

Figure 1. Cumulative brine volume passing northward from the waste panel to the SRoR through the panel closure for the 100 vectors of replicate 1, scenario 2 (E1 intrusion at 350 years)

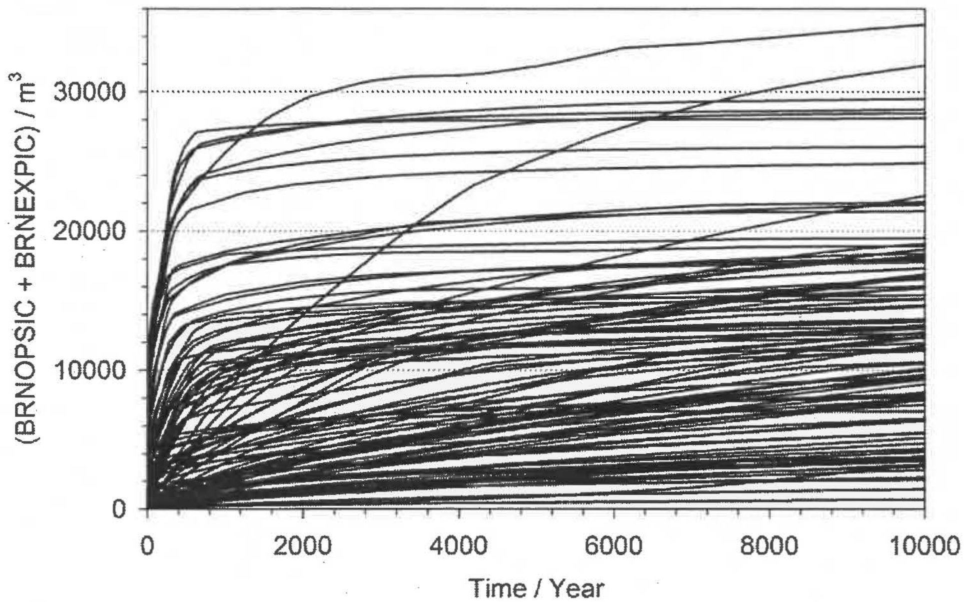

Figure 2. Cumulative brine flow into the experimental and operations areas for the 100 vectors of replicate 1, scenario 1 (undisturbed repository)

The CRA-2014 PA results indicate that a total cumulative brine flow into the waste area (including the waste panel, northern rest of repository, and SRoR) is on average about 36,000 m^3 following an E1 intrusion at 1,000 years (S3) and about 20,500 m^3 following an E2 intrusion at 1,000 years (S5) (sum of output parameters BRNWASIC, BRNSRRIC, and BRNNRRIC). Given that about 7.4 borehole intrusions are expected to occur during the regulatory period,[1] the total volume of brine potentially available to flow into the waste area could exceed 200,000 m^3 (7.4*(36,000+20,500)m^3/2 = 209,050 m^3). Thus, with an incremental supply of only 8,000 m^3, the same conclusion as the CMPRP can reached: [the additional brine volume] "would have no consequential effect on performance assessment results." Compared to the previous analysis, the maximum brine flow across a panel seal has decreased (12,000 to 8,000 m^3) and the total volume of brine potentially available to flow into the waste area has stayed the same (210,000 to 209,500 m^3)[2]. Thus, the relative amount of "incremental supply" of brine has decreased from 12,000/210,000=0.0571 to 8,000/209,500=0.0382, indicating approximately a 33 percent decrease in the relative amount of brine available in the non-waste regions of the repository. Therefore,

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[1] We observed an average of 7.4 drilling intrusions per future in the CRA-2014 simulations. This value is stored in an output file from the CCDFGF code, but for verification the expected value can be computed as 7.4 = 0.00673 intrusions-km^{-2}-yr^{-1} * 0.1115 km^2 * 9900 yr, where the drilling rate is 0.00673 intrusions-km^{-2}-yr^{-1}, the area of 0.1115 km^2 is the footprint of the repository, and 9900 is the number of years simulated after the period of institutional controls.

[2] The original analysis concludes that "the total volume of brine potentially available to flow into the waste area could exceed 100,000 m^3." We assume that this lower limit was based on a calculation using the numbers included in the same paragraph. Multiplying the average of the total cumulative brine flows given there ((40,000+30,000)/2 = 35,000) by the number of borehole intrusions (6) gives 210,000 m^3.

boreholes that intersect the non-waste regions of the repository still do not need to be accounted for in PA calculations.

References:

Camphouse, R. 2013. *Analysis Package for Salado Flow Modeling Done in the 2014 Compliance Recertification Application Performance Assessment (CRA-2014 PA).* ERMS 559980. Carlsbad, NM: Sandia National Laboratories.

Economy, K. 1996. "Drilling Into a Salado Zone of Contamination Within the Controlled Area; Drilling Into a Non-Salado Zone of Contamination Within the Controlled Area." Summary Memo of Record for S-9 and NS-6 FEPs Screening. August 21, 1996. Sandia National Laboratories. Albuquerque, NM. ERMS 416368.

Wallace, M. 1996. "Leakage from Abandoned Boreholes." Summary Memorandum of Record for NS-7b, SWCF-A 1.1.6.3:PA:QA:TSK:NS-7b. ERMS 240819. Albuquerque, NM: Sandia National Laboratories.

Wilson, C., D. Porter, J. Gibbons, E. Oswald, G. Sjoblom, and F. Caporuscio. 1996. Conceptual Models Supplementary Peer Review Report (December). ERMS 243153. Carlsbad, NM: Carlsbad Area Office.

U.S. Department of Energy (DOE). 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant (October). 21 vols. DOE/CAO-1996-2184. Carlsbad, NM: Carlsbad Field Office.

Zeitler, T. R. 2015. Summarized BRAGFLO Results for R1S2 of CRA14-0 Analysis. ERMS 563788. Carlsbad, NM: Sandia National Laboratories.

Appendix A:

Contents of SUMMARIZE input file:

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*input files
    template= [shared.rccamph.cra2014.cra14.bragflo.algebra2.alg2cdb]alg2_bf_cra14_R1_S2_V###
    type=   CDB

*vector
    id=   #
    vector= 1 to 100

*times
    read=   seconds
    input=  years
    output= years
    times=  0 to 500 by 10,500 to 1000 by 20, 1000 to 10000 by 100

*items
 type= GLOBAL
 name = &
WAS_PRES,&
SRR_PRES,&
NRR_PRES,&
ROR_PRES,&
OPS_PRES,&
EXP_PRES,&
BRNVOL_W,&
BRNVOL_S,&
```

BRNVOL_N,&

BRNVOL_R,&

BRNVOL_O,&

BRNVOL_E,&

BV_PCS_S,&

BV_PCS_M,&

BV_PCS_N,&

WAS_SATG,&

SRR_SATG,&

NRR_SATG,&

ROR_SATG,&

OPS_SATG,&

EXP_SATG,&

GS_PCS_S,&

GS_PCS_M,&

GS_PCS_N,&

WAS_SATB,&

SRR_SATB,&

NRR_SATB,&

ROR_SATB,&

OPS_SATB,&

EXP_SATB,&

BS_PCS_S,&

BS_PCS_M,&

BS_PCS_N,&

WAS_POR,&

SRR_POR,&

NRR_POR,&

ROR_POR,&

OPS_POR,&

EXP_POR,&

BRNREPIC,&

BRNWASIC,&

BRNSRRIC,&

BRNNRRIC,&

BRNRORIC,&

BRNOPSIC,&

BRNEXPIC,&

BRNREPOC,&

BRNWASOC,&

BRNSRROC,&

BRNNRROC,&

BRNROROC,&

BRNOPSOC,&

BRNEXPOC,&

BNBHUDRZ,&

BNSHUDRZ,&

BNWPNPCS,&

BNWPSPCS,&

BNSRNPCS,&

BNSRSPCS,&

BNNRNPCS,&

BNNRSPCS,&

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GSWPNPCS,&

GSWPSPCS,&

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GSNRNPCS,&

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FEKG_W,&

FEKG_R,&

FEKG_T,&

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CELLKG_R,&

CELLKG_T,&

MGOKG_W,&

MGOKG_R,&

MGOKG_T,&

FEREM_W,&

FEREM_R,&

FEREM_T,&

CELREM_W,&

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CELREM_T,&

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MGOREM_R,&

MGOREM_T,&

GASMOL_W,&

GASVOL_W,&

GASMOL_R,&

GASVOL_R,&

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GASVOL_T,&

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BRAABNOC,&

BRM39NOC,&

BRM38SOC,&

BRAABSOC,&

BRM39SOC,&

BRTOMBOC,&

GSM38NOC,&

GSAABNOC,&

GSM39NOC,&

GSM38SOC,&

GSAABSOC,&

GSM39SOC,&

GSTOMBOC,&

BRM38NLW,&

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BRM39NLW,&

BRM38SLW,&

BRAABSLW,&

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BRTOLWBC,&

FRACX38N,&

FRACXABN,&

FRACX39N,&

FRACX38S,&

FRACXABS,&

FRACX39S,&

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FEMOL_R,&
FEMOL_T,&
CELMOL_W,&
CELMOL_R,&
CELMOL_T

*output
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      write=  time vs item
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*end
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