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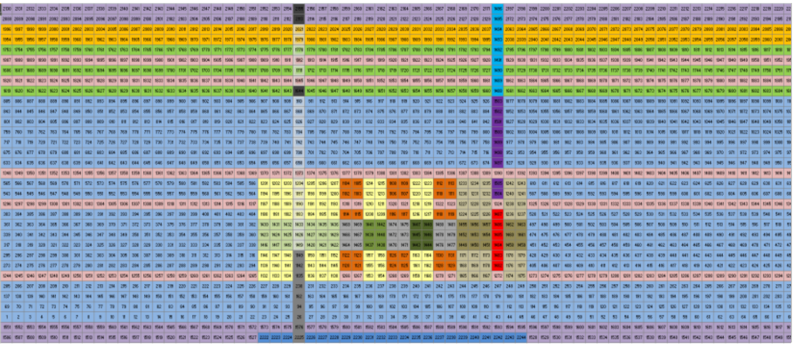

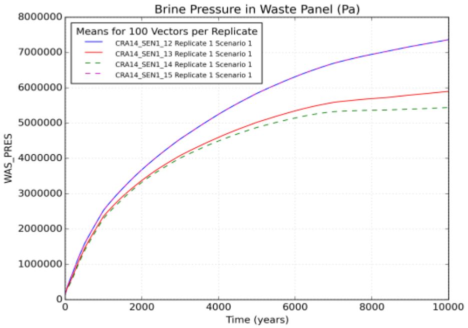

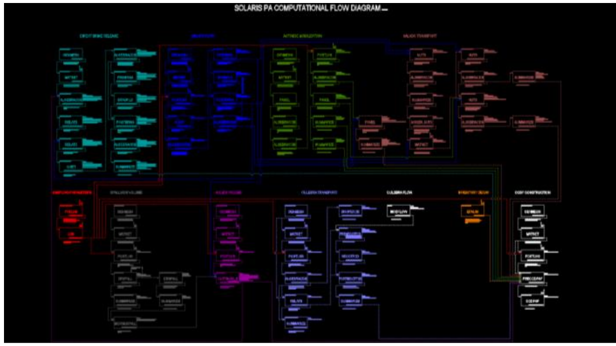

Non-Waste Area Sensitivity Study

DOE/EPA Technical Exchange Meeting

February 2, 2016

Presented by:
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Sandia Carlsbad
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Outline

- Background
- Overview of the Studies
- Review of Parameter Effects on Waste Areas
- Review of Parameter Effects on Releases
- Conclusions

Background

- Current PA implementation of Operations (OPS) and Experimental (EXP) cavities uses a constant porosity of 0.18, corresponding to a hydrostatic pressure of 7.8 MPa at 10,000 years based on work by Arguello (1994)
  - Past sensitivity analyses used a porosity surface developed for empty rooms to include effects of gas in the void as a restorative force to resist closure
  - FEP DR-3 supported the use of a constant, rather than time-varying, porosity because calculations had shown Performance Assessment (PA) was insensitive to the description of void closure utilized
- EPA requested a sensitivity study to evaluate a time-varying and much lower final porosity (~0.01) of OPS/EXP cavities based on work by Morgan (1987)
  - Morgan's closure calculations are based on an "all salt" stratigraphy and an "early" WIPP reference creep model with scaled elastic properties to provide agreement with SPDV test panel measured closure rates
  - Model did not include effects of gas in void as a restorative force to resist closure

Arguello, J.G. (1994), Memorandum to B.M. Butcher, Backfill Sensitivity Study – Creep Closure Behaviors of an "Equivalent" Empty Room at the North End of WIPP Subjected to Gas Generation", Sandia National Laboratories
Morgan, H.S. (1987), Memorandum to D.E. Munson, Estimate of the Time Needed for TRU Storage Rooms to Close

Background (cont.)

- EPA also requested for the sensitivity study to consider transition to two-phase flow properties in the cavity after the time in which the “closed” rooms behave as a porous media
- Although agreement was not achieved regarding the appropriate use of the Morgan (1987) closure data or the need to model the OPS/EXP cavities using two-phase flow properties, an agreement to proceed with performing a “Sensitivity Analysis” to determine the impact of various OPS/EXP closure parameters was reached
- Study results were preliminarily presented to the EPA on January 14, 2016
  - Results consisted of five 1-Replicate and one 3-Replicate full PA calculations
  - Consensus was not reached regarding the importance of modeling the OPS/EXP cavities with two-phase flow properties
  - Additional analyses were requested on January 15, 2016 to modify the residual brine and gas saturations in the OPS/EXP cavity, requesting that residuals be reset to actuals at the time of transition to two-phase flow properties if saturations were less than the initially specified residual

Background (cont.)

- CRA14 – OPS/EXP Cavity and DRZ Parameters:
  - CAVITY

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	1	-10	0	0.7	1	0	0	11	0	0	0
0 - 10000	0.18	-11	0	0.7	1	0	0	11	NA	0	0

  - DRZ

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	S_HALITE + 0.0029	-17	7.41E-10	0.7	1	0	0	4	1	0	0
0 - 10000	S_HALITE + 0.0029	sampled	7.41E-10	0.7	1	0	0	4	NA	0	0

Overview of the Studies

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Presented on 1/14/16

- Initial – focused on attempts to implement requested parameter settings in the OPS and EXP areas; diverged (nonphysical result) and unconverged (incomplete) solutions required reassessment of approach
- Second – focused on comparing the effects of modeling the OPS and EXP areas with tight (low permeability) vs loose (high permeability) parameters over the entire simulation duration (SEN1_12, SEN1_13, SEN1_14)
- Third – focused on comparing the effects of using a linear vs nonlinear relative permeability model and activation of capillary effects on relative permeability (SEN1_12, SEN1_15, SEN1_16)
- Fourth – recommended as final sensitivity analysis that implemented insight obtained from prior studies to capture relevant physics in a computationally stable and efficient manner (SEN1_17)
  - Equivalent to CRA14 but with step-down of porosity and permeability parameters only (no capillary pressure effects active in cavities)
- Fifth – focused on evaluating the effects of increasing residual saturations (SEN1_19)
  - Equivalent to SEN1_17 with nonzero residual brine and gas saturations

Overview of the Studies (cont.)

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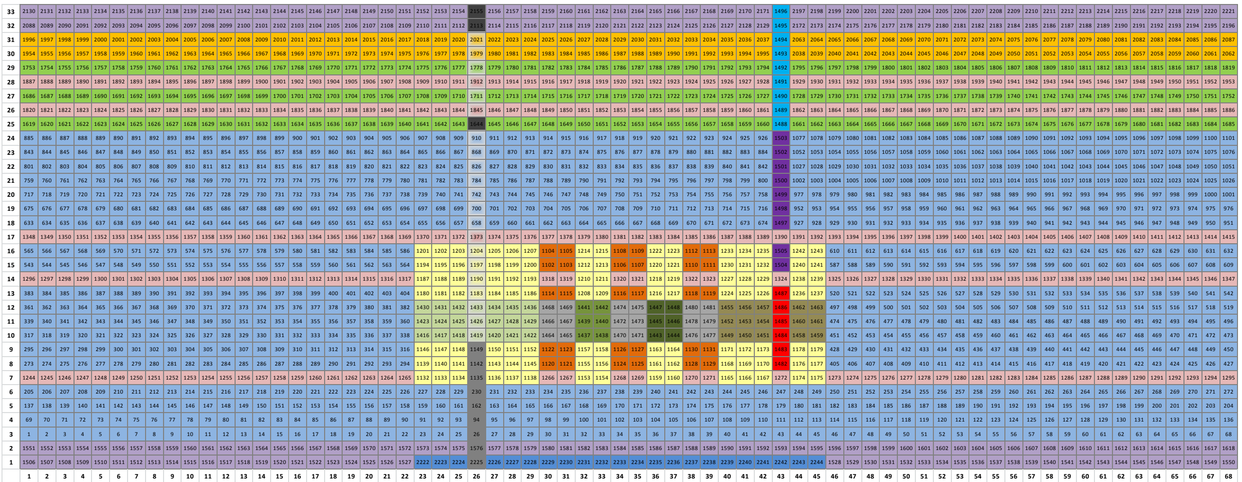
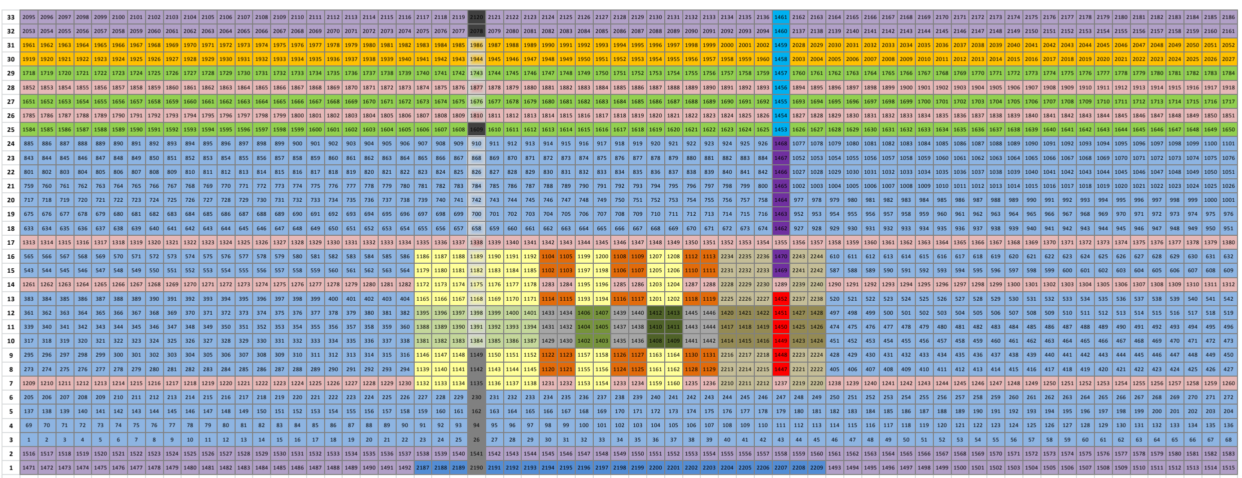
- BRAGFLO Grids



CRA14



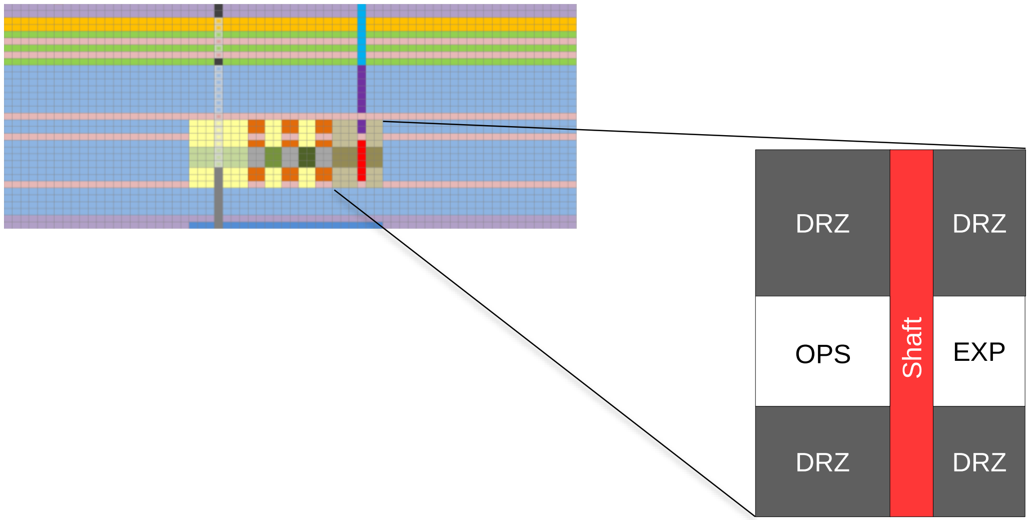
SEN1

Legend:

- DRZ
- Waste Panel
- South Rest of Repository
- North Rest of Respository
- Operations and Experimental Areas
- Operations and Experimental Areas DRZ

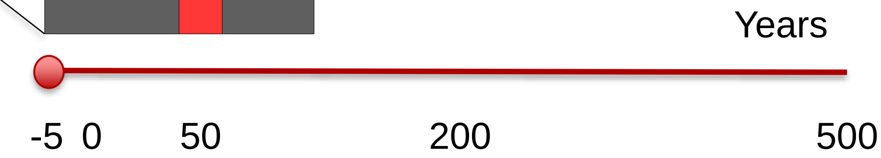
Overview of the Studies (cont.)

- OPS/EXP Closure



↓ Porosity - ϕ

↓ Permeability - k



Initial Study Overview

- Objective: To determine the effect of “tightening” the Operations (OPS) and Experimental (EXP) Cavity and Disturbed Rock Zone (DRZ) over the first 500 years after closure to approach intact halite properties
- Methodology: Introduce step-changes in porosity, permeability, and associated parameters at 50 and 200 years in the OPS/EXP Cavity and at 500 years in the OPS/EXP DRZ
  - Transition from a linear (RELP_MOD = 11) to a nonlinear (RELP_MOD = 4) relative permeability model and turn on capillary pressure effects (PCT_A & PCT_EXP $\neq$ 0) in the OPS/EXP Cavity at 200 years and in the OPS/EXP DRZ at 500 years

Initial Study Overview (cont.)

- First EPA Requested OPS/EXP Cavity and DRZ Parameters:
  - CAVITY

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	1	-10	0	0.7	1	0	0	11	0.05[A]	0	0
0 - 50	0.5	-12.4	0	0.7	1	0	0	11	NA	0	0
50 - 200	0.18	-14.43	0	0.7	1	0	0	11	NA	0	0
200 - 10000	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	NA	0.3	0.2

  - DRZ

Change from CRA14

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	S_HALITE + 0.0029	-17	7.41E-10	0.7	1	0	0	4	0.95*	0	0
0 - 500	S_HALITE + 0.0029	sampled	7.41E-10	0.7	1	0	0	4	NA	0	0
500 - 10000	S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	NA	0.3	0.2

[A] Not explicitly requested by EPA, but utilized

Initial Study Overview (cont.)

- Second EPA Requested OPS/EXP Cavity and DRZ Parameters:
  - CAVITY

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	0.98	-10	8E-11	3	2	0.56	-0.346	4	0.015	0.01	0.005
0 - 50	0.5	-12.4	8E-11	2.5	2	0.56	-0.346	4	NA	0.01	0.005
50 - 200	0.18	-14.43	8E-11	1.5	2	0.56	-0.346	4	NA	0.1	0.05
200 - 10000	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	NA	0.15	0.1

  - DRZ

Change from 1st EPA

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	S_HALITE + 0.0029	-17	7.41E-10	1	2	0.56	-0.346	4	0.15	0.1	0.05
0 - 500	S_HALITE + 0.0029	sampled	7.41E-10	1	2	0.56	-0.346	4	NA	0.15	0.1
500 - 10000	S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	NA	0.3	0.2

Initial Study Overview (cont.)

- Result: BRAGFLO runs failed when step changes to porosity/permeability were implemented and the second modified Brooks-Corey relative permeability model (RELP_MOD = 4, PCT_A & PCT_EXP $\neq$ 0) was active
  - Two analyses involved the use of EPA-initiated parameters; more than ten others were modified from those baselines
  - Many runs failed to complete due to excessive time steps (unconverged) with all completed runs demonstrated solution divergence (nonphysical result) as evidenced by large magnitude negative (-E8) brine pressures in the OPS/EXP Cavity and/or OPS/EXP DRZ
    - Tight residual tolerance settings resulted in failures to complete
    - Looser residual tolerance settings resulted in diverged solutions
- Conclusion: Implementation of step changes to porosity or permeability material parameters requires either the linear model (RELP_MOD = 11) or disabling of capillary pressure with the nonlinear model (RELP_MOD=4, PCT_A & PCT_EXP = 0)
  - Additional sensitivity studies designed to understand the effects of OPS/EXP porosity/permeability reductions and capillary pressure effects on relative permeability needed to be developed to evaluate the effects, separately

Second Study Overview

- Objective: To evaluate the sensitivity of Waste Area brine volumes, saturations, and pressures to a range of OPS/EXP Cavity and OPS/EXP DRZ porosity and permeability material parameters that remain fixed over the 10,000 yr simulation with the nonlinear relative permeability model active (RELP_MOD = 4 & PCT_A/PCT_EXP $\neq$ 0)
- Methodology: Use the second set of EPA "investigative" parameters to establish three primary cases for evaluation
  - SEN1_12 – "Tight"
    - OPS/EXP Cavity uses 200 to 10,000 yr values for entire simulation
    - OPS/EXP DRZ uses 500 to 10,000 yr values for entire simulation
  - SEN1_13 – "Looser"
    - OPS/EXP Cavity uses 0 to 50 yr values for entire simulation
    - OPS/EXP DRZ uses 0 to 500 yr values for entire simulation
  - SEN1_14 – "Loosest"
    - OPS/EXP Cavity uses -5 to 0 yr values for entire simulation
    - OPS/EXP DRZ uses -5 to 0 yr values for entire simulation
  - Brine saturation initial conditions adjusted to have equivalent OPS/EXP Cavity brine volumes at the start of the simulations

Second Study Overview (cont.)

- SEN1_12, SEN1_13, SEN1_14 – OPS/EXP Parameter Summary:
  - CAVITY – over all time

Model	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
SEN1 _12	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	0.95	0.3	0.2
SEN1 _13	0.5	-12.4	8E-11	2.5	2	0.56	-0.346	4	0.035	0.018	0.010
SEN1 _14	0.98	-10	8E-11	3	2	0.56	-0.346	4	0.018	0.009	0.005

  - DRZ – over all time

Change from SEN1_12

Model	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
SEN1 _12	S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	0.95	0.3	0.2
SEN1 _13	S_HALITE + 0.0029	-17	7.41E-10	1	2	0.56	-0.346	4	0.95	0.3	0.2
SEN1 _14	S_HALITE + 0.0029	-17	7.41E-10	1	2	0.56	-0.346	4	0.95	0.3	0.2

Third Study Overview

- Objective: To evaluate the sensitivity of Waste Area brine volumes, saturations, and pressures to the OPS/EXP Cavity and DRZ porosity and permeability material parameters subject to alternative capillary pressure and relative permeability models
- Methodology: Use SEN1_12 parameters with capillary pressure and relative permeability model changes only to establish three comparative cases for evaluation
  - SEN1_12 – “tight” unchanged
  - SEN1_15
    - Same as SEN1_12 with exception of PCT_A and PCT_EXP set to 0 and CAP_MOD set to 1
  - SEN1_16
    - Same as SEN1_15 with exception of RELP_MOD set to 11

Third Study Overview (cont.)

- SEN1_12, SEN1_15, SEN1_16 – OPS/EXP Parameter Summary:
  - CAVITY

Model	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
SEN1_12	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	0.95	0.3	0.2
SEN1_15	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	4	0.95	0.3	0.2
SEN1_16	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	11	0.95	0.3	0.2

  - DRZ

Change from SEN1_12

Model	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
SEN1_12	S_HALITE	S_HALITE + 1	S_HALITE	0.7	2	0.56	-0.346	4	0.95	0.3	0.2
SEN1_15	S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	4	0.95	0.3	0.2
SEN1_16	S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	11	0.95	0.3	0.2

Fourth Study Overview

- Objective: To determine the effect of "tightening" the OPS and EXP Cavity and DRZ over the first 500 years after closure to approach intact halite properties while utilizing computationally efficient and stable capillary pressure and relative permeability model settings
- Methodology: Select model parameters for capillary pressure and relative permeability understood as appropriate from the previous studies (SEN1_17)

Fourth Study Overview (cont.)

- SEN1_17 – OPS/EXP Parameter Summary:
  - CAVITY

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	1	-10	8E-11	0.7	1	0	0	11	0	0	0
0 - 50	0.5	-12.4	8E-11	0.7	1	0	0	11	NA	0	0
50 - 200	0.18	-14.43	8E-11	0.7	1	0	0	11	NA	0	0
200 - 10000	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	4	NA	0	0

  - DRZ

Change from CRA14

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	S_HALITE + 0.0029	-17	7.41E-10	0.7	1	0	0	4	1	0	0
0 - 500	S_HALITE + 0.0029	sampled	7.41E-10	0.7	1	0	0	4	NA	0	0
500 - 10000	S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	4	NA	0	0

Fifth Study Overview

- Objective: To determine the effect of increasing the OPS and EXP Cavity and DRZ residual brine and gas saturations
- Methodology: Use SEN1_17 parameters with residual brine and gas saturation parameter changes only to establish two comparative cases for evaluation
  - SEN1_17 – unchanged
  - SEN1_19
    - Same as SEN1_17 with exception of SAT_IBRN in DRZ reduced from 1 to 0.8 and SAT_RBRN / SAT_RGAS set to requested values greater than 0 at the requested times
    - Unable to address request to reset residual saturations based on actual saturation at the requested times without code modifications

Fifth Study Overview (cont.)

- SEN1_19 – OPS/EXP Parameter Summary:
  - CAVITY

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	1	-10	8E-11	0.7	1	0	0	11	0	0	0
0 - 50	0.5	-12.4	8E-11	0.7	1	0	0	11	NA	0	0
50 - 200	0.18	-14.43	8E-11	0.7	1	0	0	11	NA	0	0
200 - 10000	(1+½σ) * S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	4	NA	0.3	0.2

  - DRZ

Change from SEN1_17

Time	POROSITY	PRMX_LOG	COMP_RCK	PORE_DIS	CAP_MOD	PCT_A	PCT_EXP	RELP_MOD	SAT_IBRN	SAT_RBRN	SAT_RGAS
-5 to 0	S_HALITE + 0.0029	-17	7.41E-10	0.7	1	0	0	4	0.8	0	0
0 - 500	S_HALITE + 0.0029	sampled	7.41E-10	0.7	1	0	0	4	NA	0.15	0.1
500 - 10000	S_HALITE	S_HALITE + 1	S_HALITE	0.7	1	0	0	4	NA	0.3	0.2

Sensitivity Results

- CRA14
- CRA14_SEN1_12 – “Tight” ϕ, k constant, k_r nonlinear, C_p nonzero, s_r high
- CRA14_SEN1_13 – “Looser” ϕ, k constant, k_r nonlinear, C_p nonzero, s_r low
- CRA14_SEN1_14 – “Loosest” ϕ, k constant, k_r nonlinear, C_p nonzero, s_r low
- CRA14_SEN1_15 – “Tight” ϕ, k constant, k_r nonlinear, C_p zero, s_r high
- CRA14_SEN1_16 – “Tight” ϕ, k constant, k_r linear, C_p zero, s_r high
- CRA14_SEN1_17 – “Stepped” ϕ, k function time, k_r linear/nonlinear, C_p zero, s_r zero
- CRA14_SEN1_19 – “Stepped” ϕ, k function time, k_r linear/nonlinear, C_p zero, s_r high

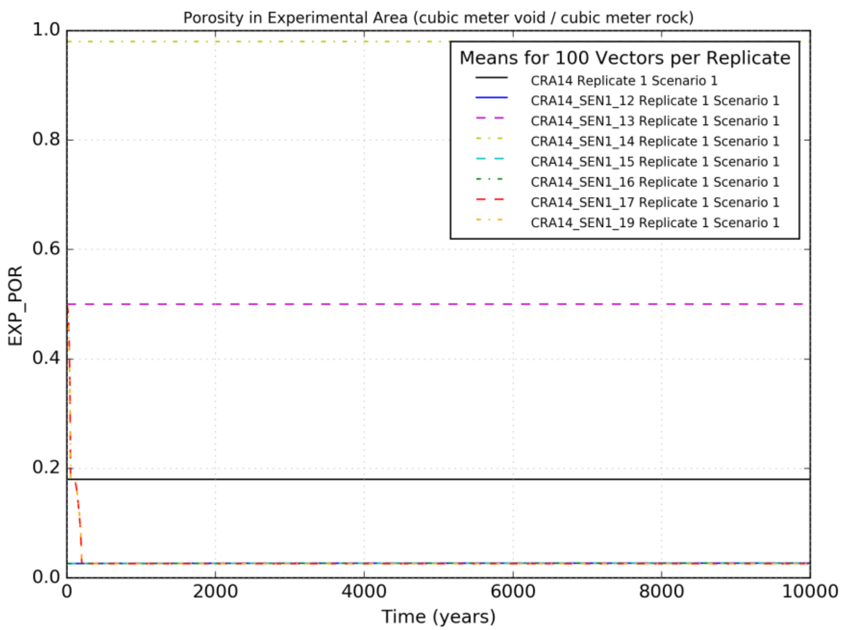
ϕ = porosity

k = permeability

k_r= relative permeability

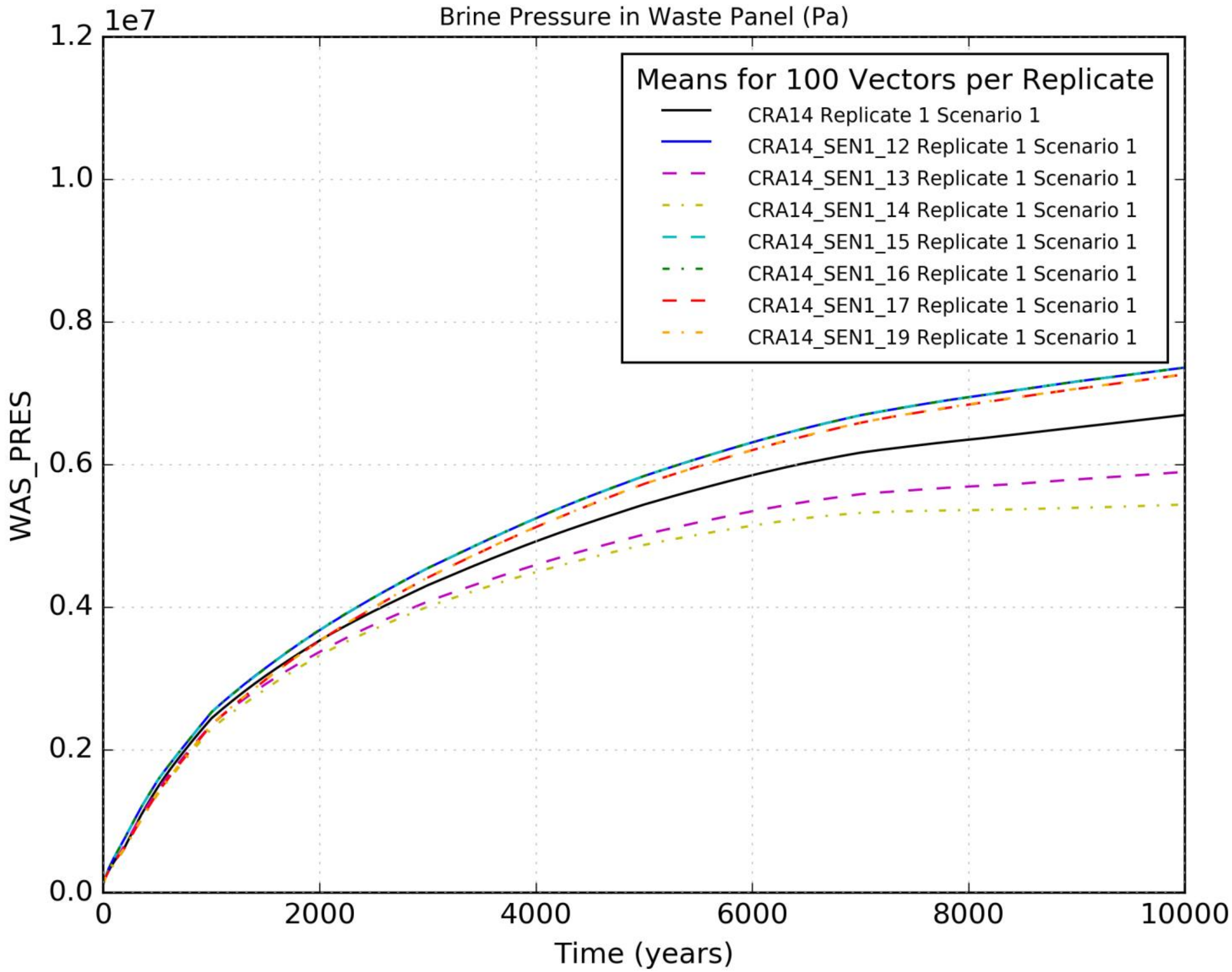
C_p= capillary pressure

s_r = residual saturation



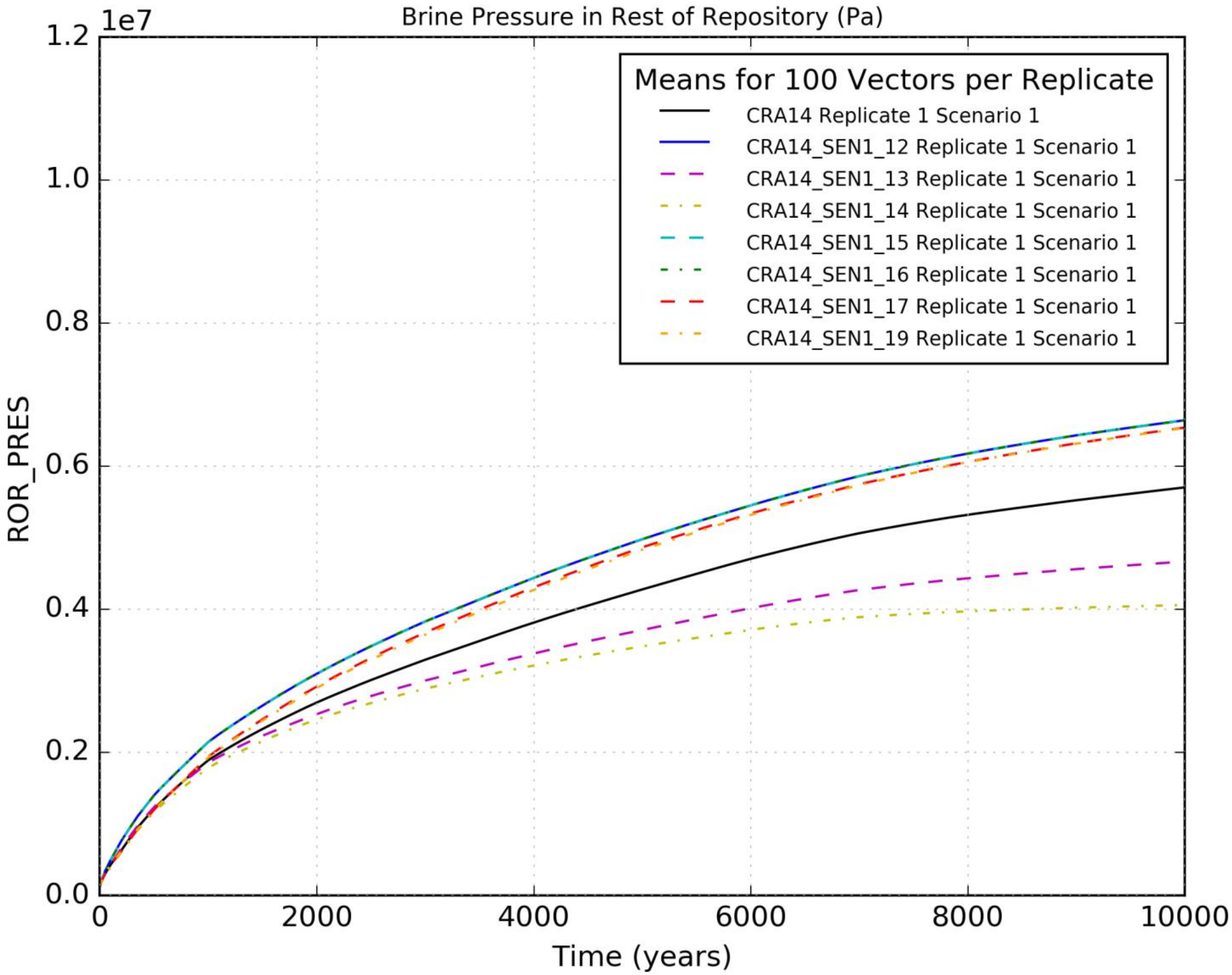
Waste Panel Pressure Sensitivity to OPS/EXP – Scenario 1

- SEN1_12/13/14
  - Decrease in porosity and permeability increases brine pressure
  - CRA14 pressure bounded by analyzed extremes
- SEN1_12/15/16
  - Relative permeability model type (linear/nonlinear) and status of capillary pressure activation has no discernible effect on brine pressure
- SEN1_17/19
  - Decrease in porosity and permeability increases brine pressure similar to SEN1_12 (tight over all times)
  - Change in residual saturations has no discernible effect on brine pressure



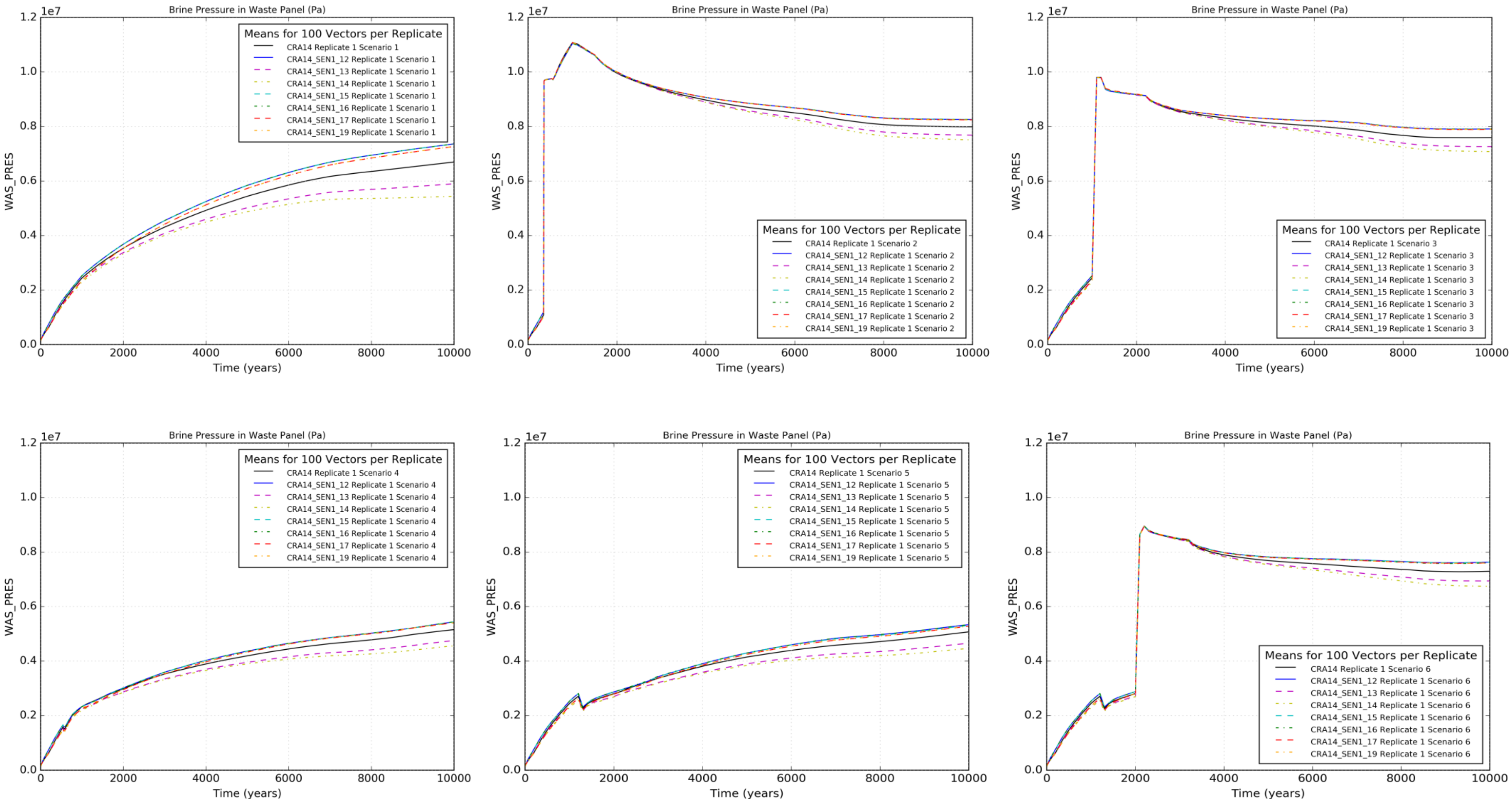
ROR Pressure Sensitivity to OPS/EXP – Scenario 1

- All general observations for the Rest of Repository (ROR) waste areas are the same as for the Waste Panel



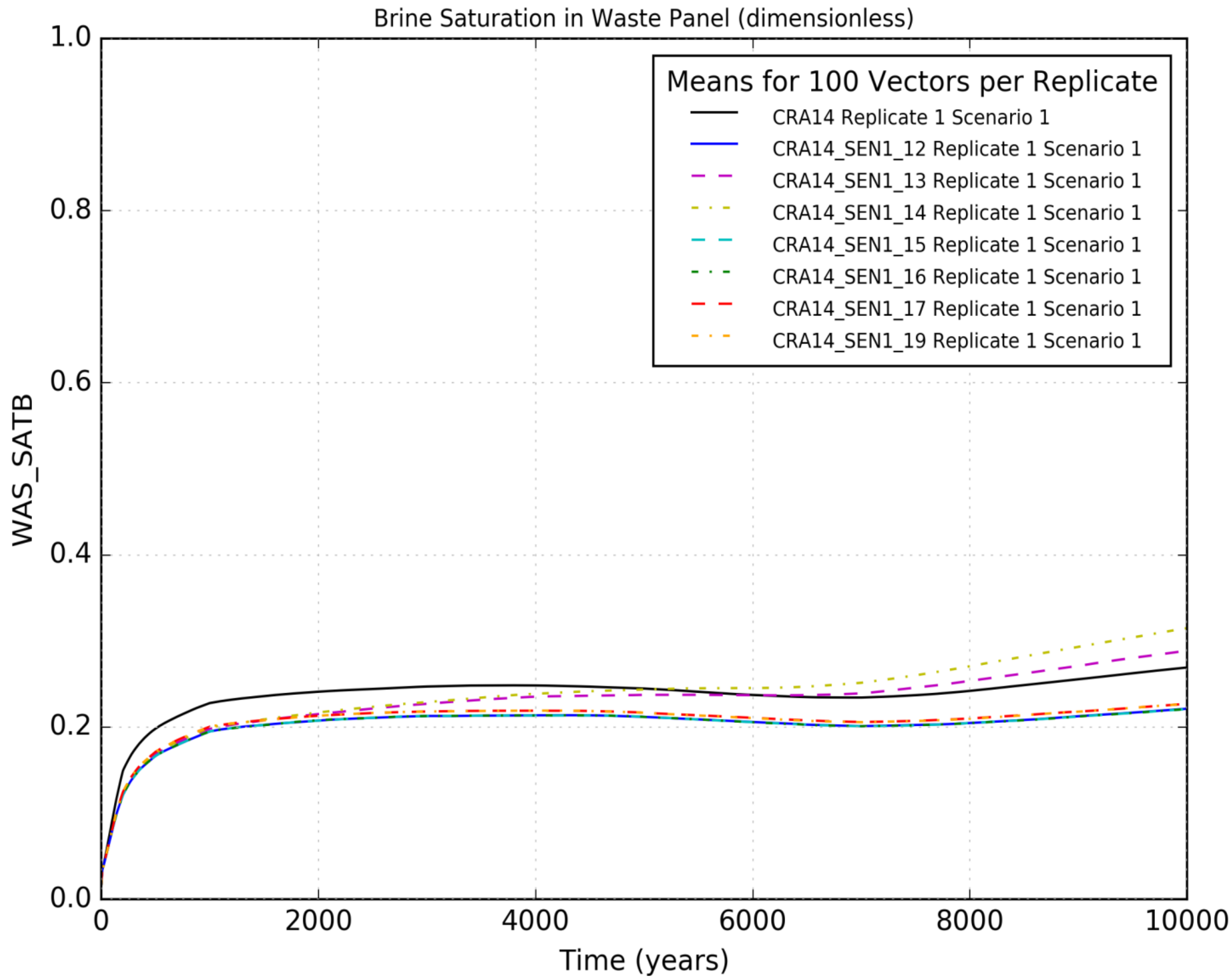
Waste Panel Pressure Sensitivity to OPS/EXP – Scenarios 2 thru 6

- All general observations for Scenario 1 apply to other scenarios



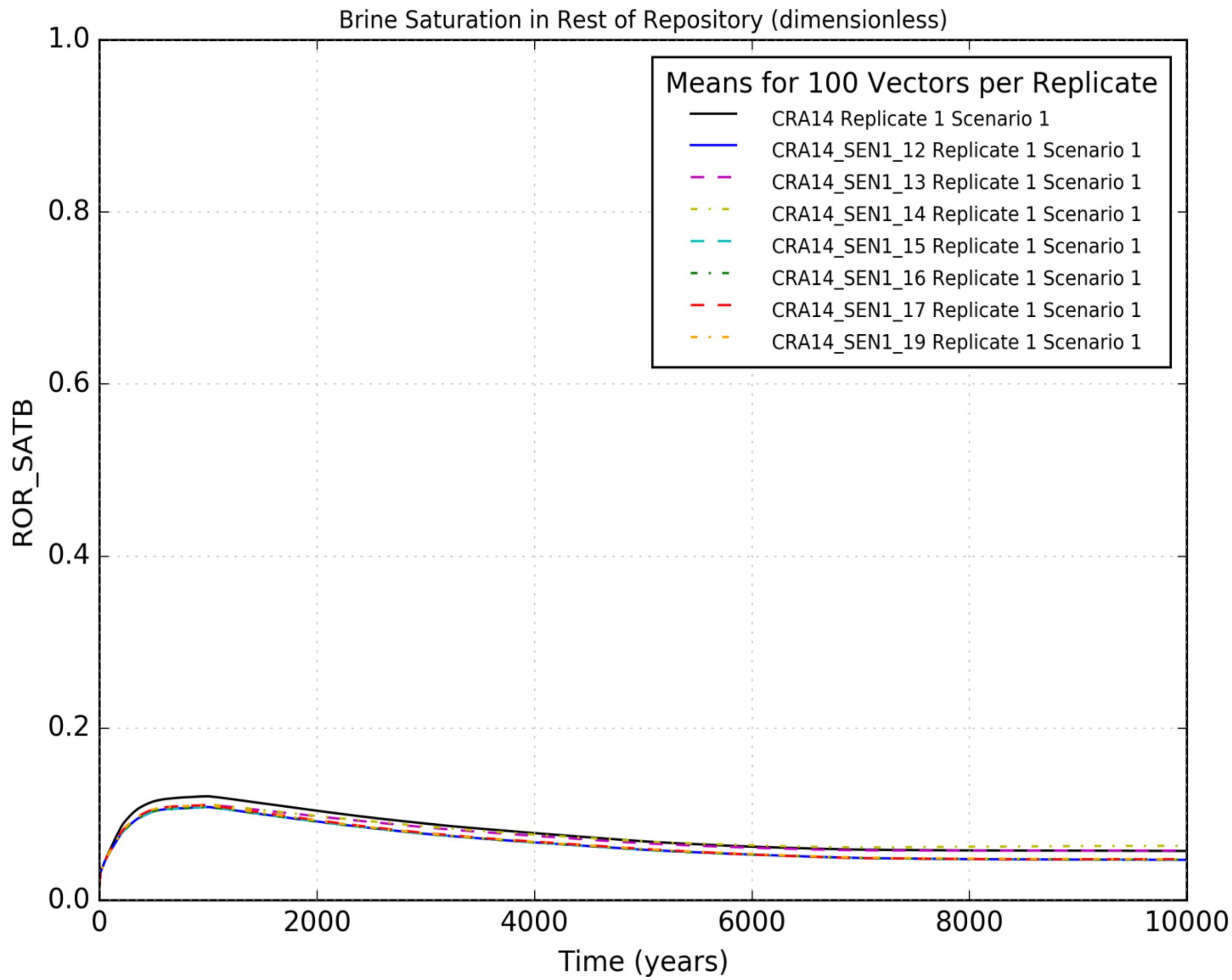
Waste Panel Brine Saturation Sensitivity to OPS/EXP – Scenario 1

- SEN1_12/13/14
  - Decrease in porosity and permeability decreases brine saturation
  - CRA14 saturation bounded by analyzed extremes
- SEN1_12/15/16
  - Relative permeability model type (linear/nonlinear) and status of capillary pressure activation has no discernible effect on brine saturation
- SEN1_17/19
  - Decrease in porosity and permeability decreases brine saturation similar to SEN1_12 (tight over all times)
  - Change in residual saturations has no discernible effect on brine saturation



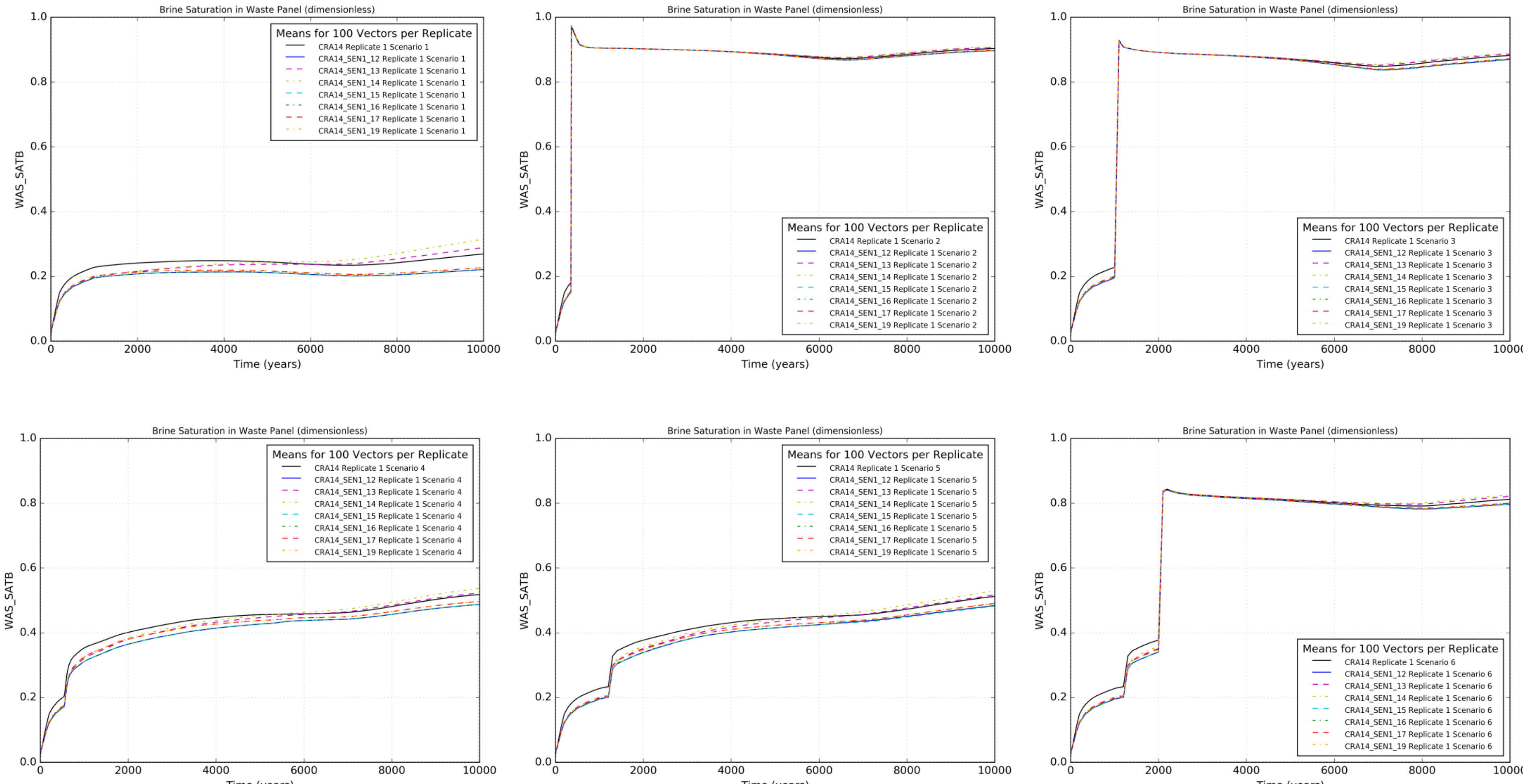
ROR Brine Saturation Sensitivity to OPS/EXP – Scenario 1

- All general observations for the Rest of Repository (ROR) waste areas are the same as for the Waste Panel



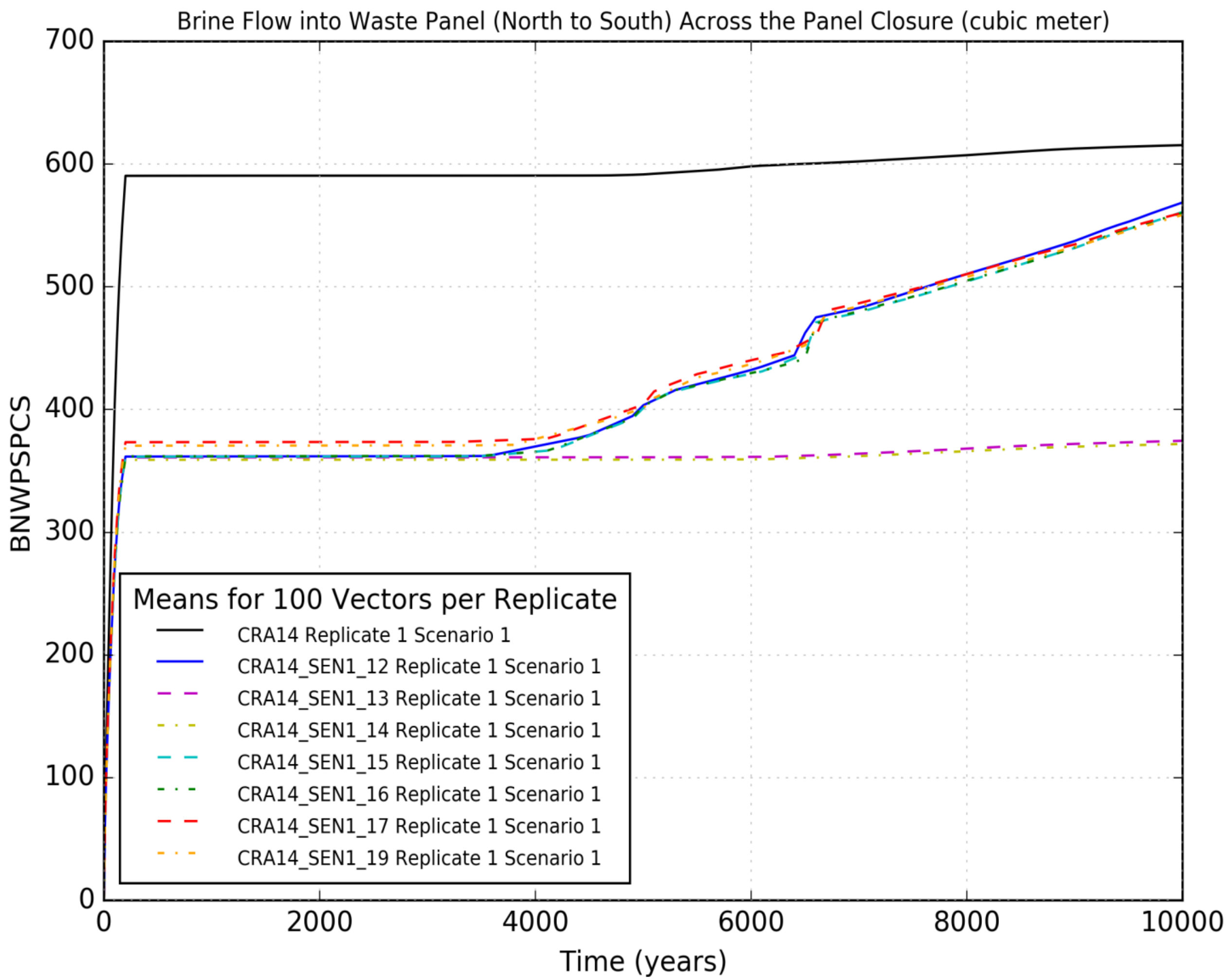
Waste Panel Brine Saturation Sensitivity to OPS/EXP – Scenarios 2 thru 6

- All general observations for Scenario 1 apply to other scenarios



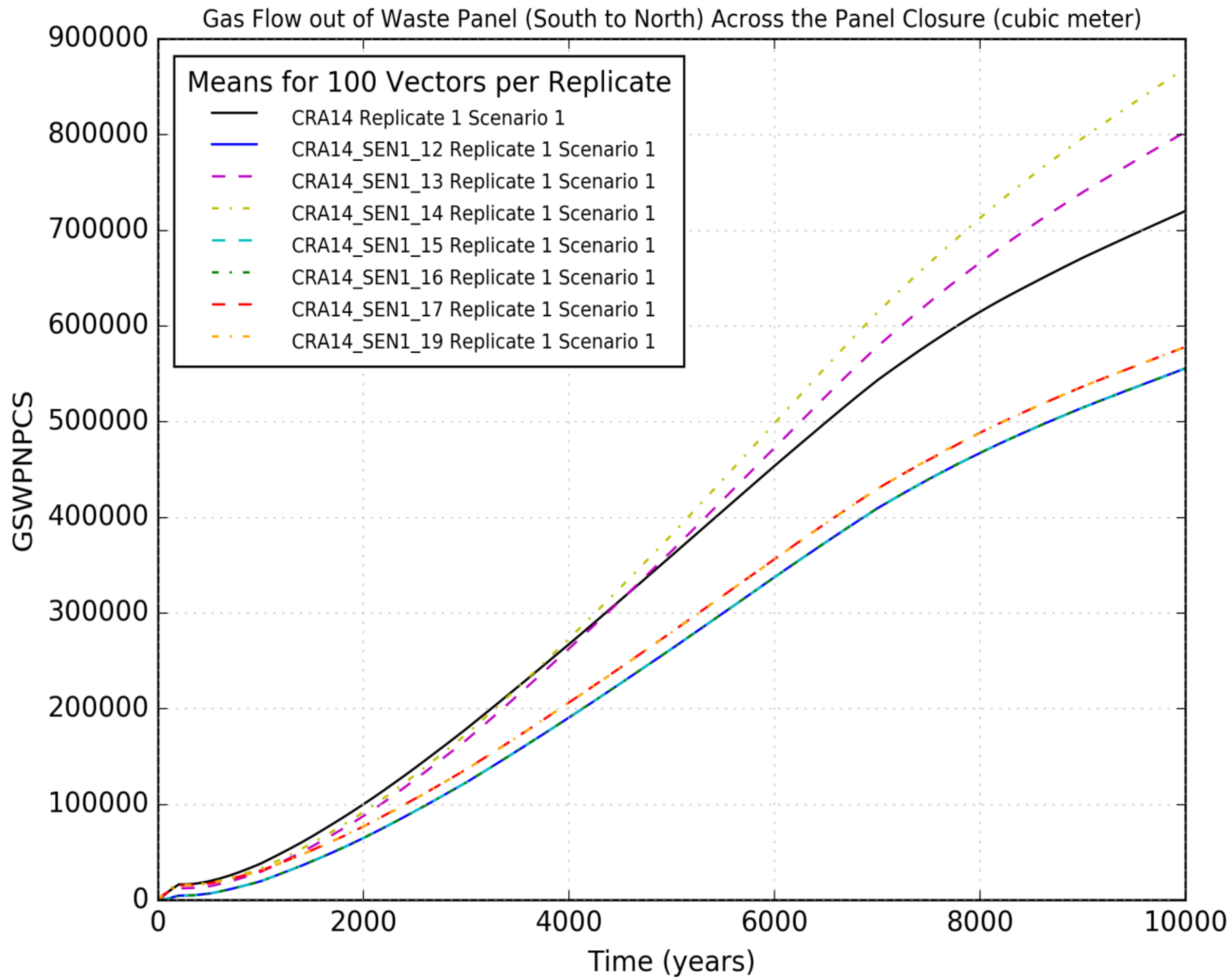
Into Waste Panel Brine Flow (N to S) Sensitivity to OPS/EXP – Scenario 1

- SEN1_12/13/14
  - Decrease in porosity and permeability increases brine flow into panel
  - CRA14 inflow slightly greater than analyzed extremes
- SEN1_12/15/16
  - Relative permeability model type (linear/nonlinear) and status of capillary pressure activation has no discernible effect on brine flow into panel
- SEN1_17/19
  - Decrease in porosity and permeability increases brine inflow similar to SEN1_12 (tight over all times)
  - Increase in residual saturations slightly reduces brine flow into panel



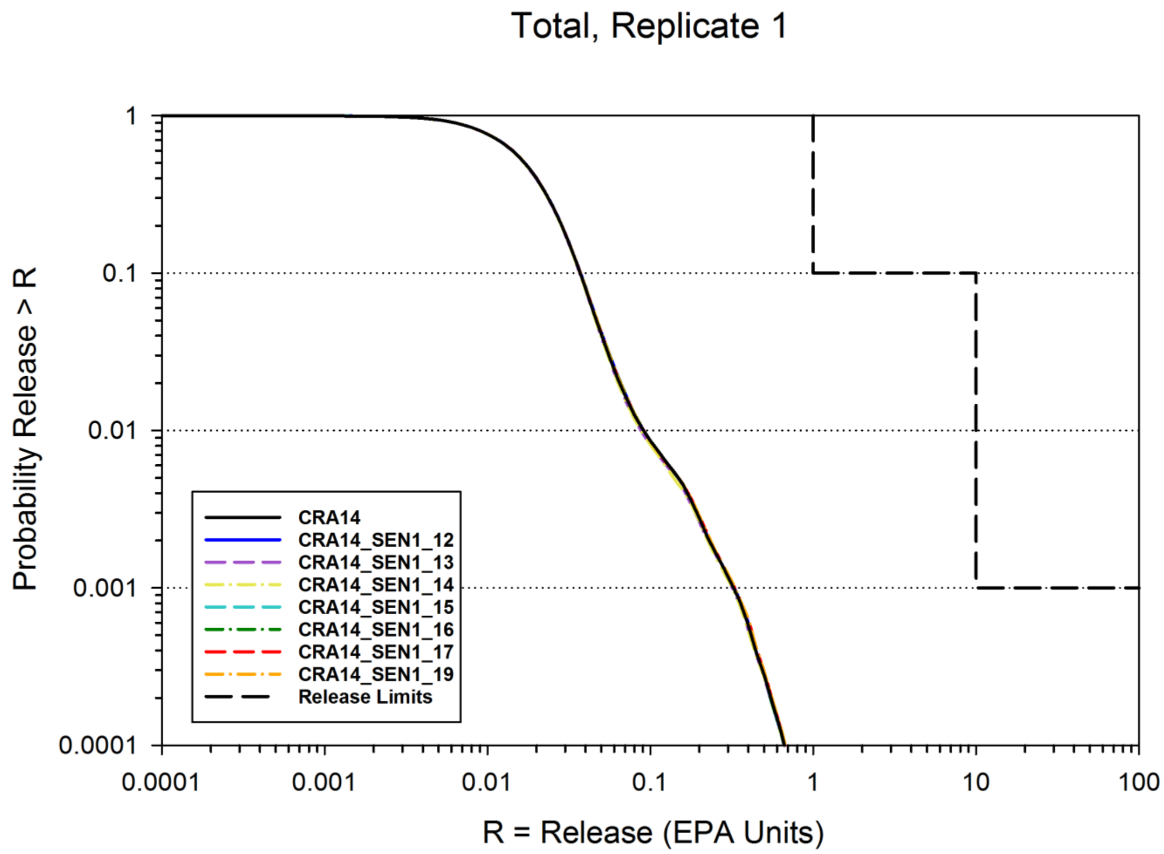
Out of Waste Panel Gas Flow (S to N) Sensitivity to OPS/EXP – Scenario 1

- SEN1_12/13/14
  - Decrease in porosity and permeability decreases gas flow out of panel
  - CRA14 outflow bounded by analyzed extremes
- SEN1_12/15/16
  - Relative permeability model type (linear/nonlinear) and status of capillary pressure activation has no discernible effect on gas flow out of panel
- SEN1_17/19
  - Decrease in porosity and permeability decreases gas outflow similar to SEN1_12 (tight over all times)
  - Change in residual saturations has no discernible effect on gas flow out of panel



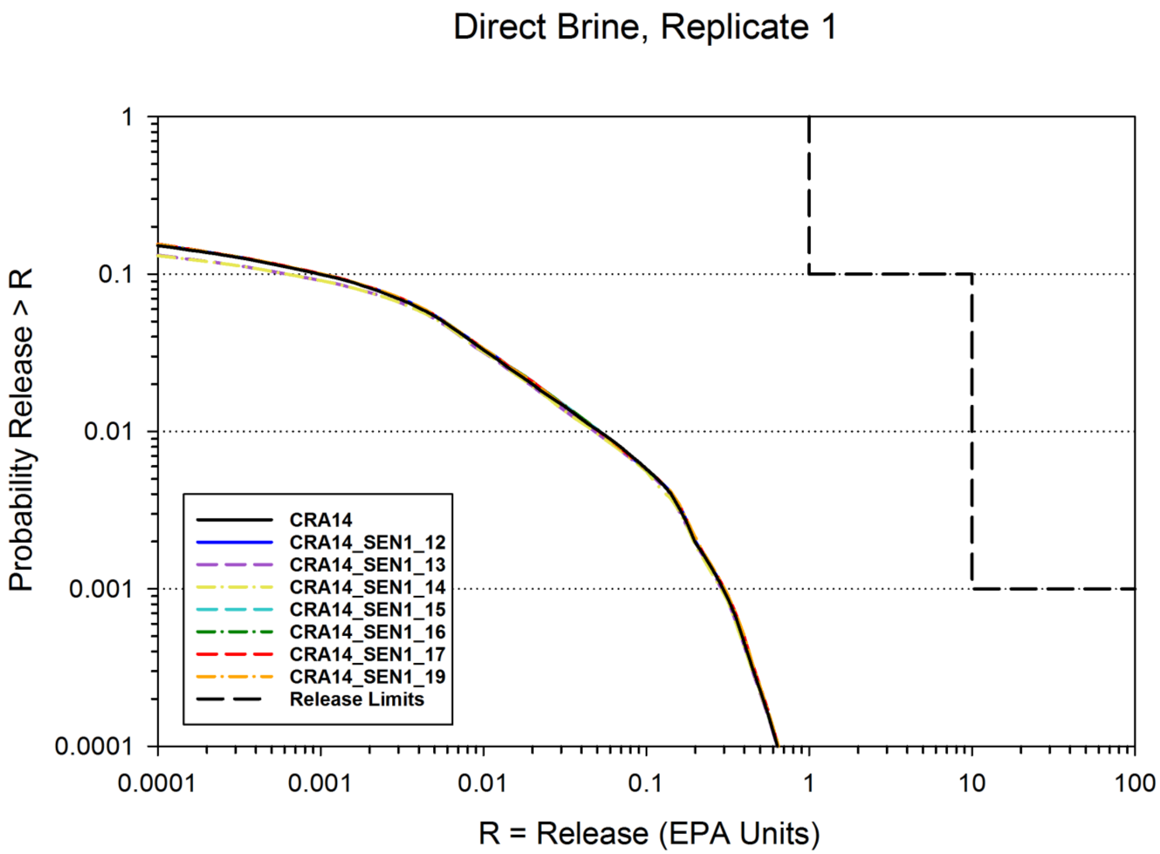
Single Replicate Release Results

- SEN1_12/13/14
  - No discernible differences with CRA14
- SEN1_12/15/16
  - No discernible differences with CRA14
- SEN1_17/19
  - No discernible differences with CRA14



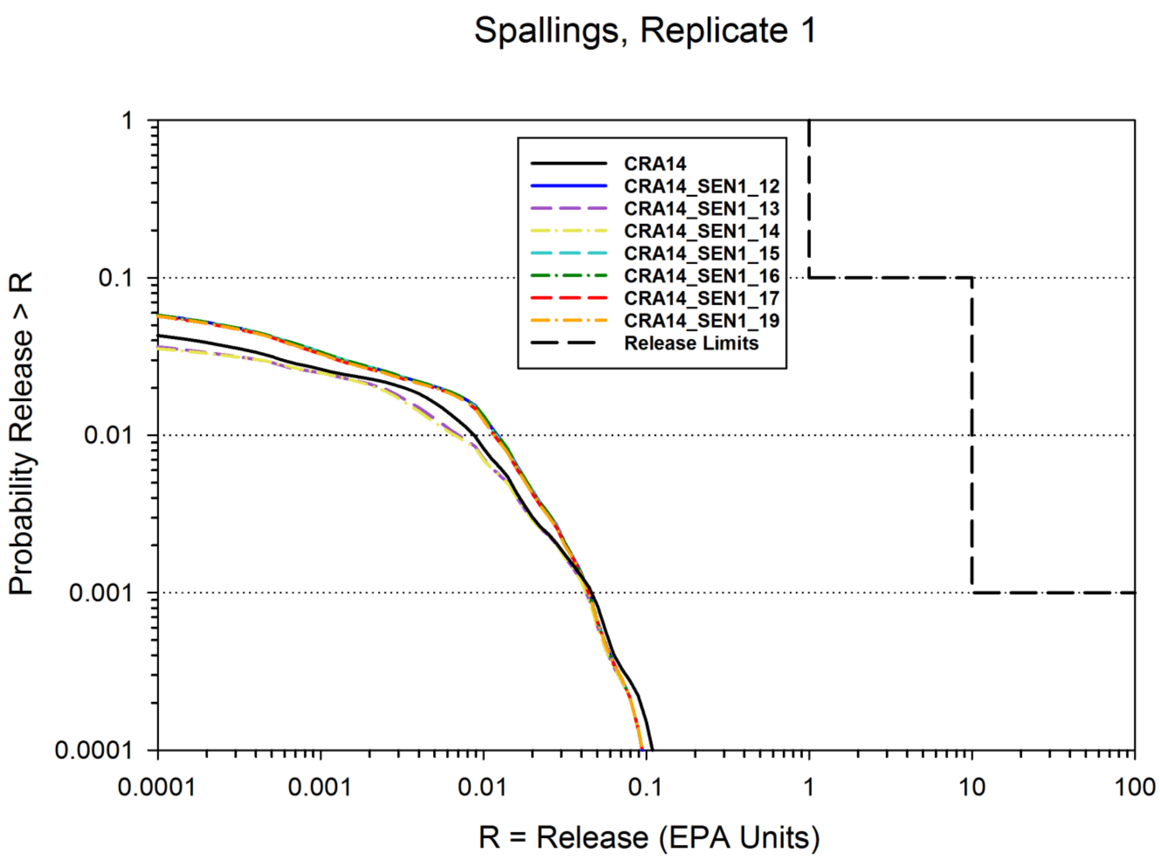
Single Replicate Release Results (cont.)

- SEN1_12/13/14
  - "Loose/Looser" cases 13 and 14 have slight reduction in high-probability direct brine releases in comparison to CRA14
  - "Tight" case 12 has no discernible difference with CRA14
- SEN1_12/15/16
  - No discernible differences with CRA14
- SEN1_17/19
  - No discernible differences with CRA14



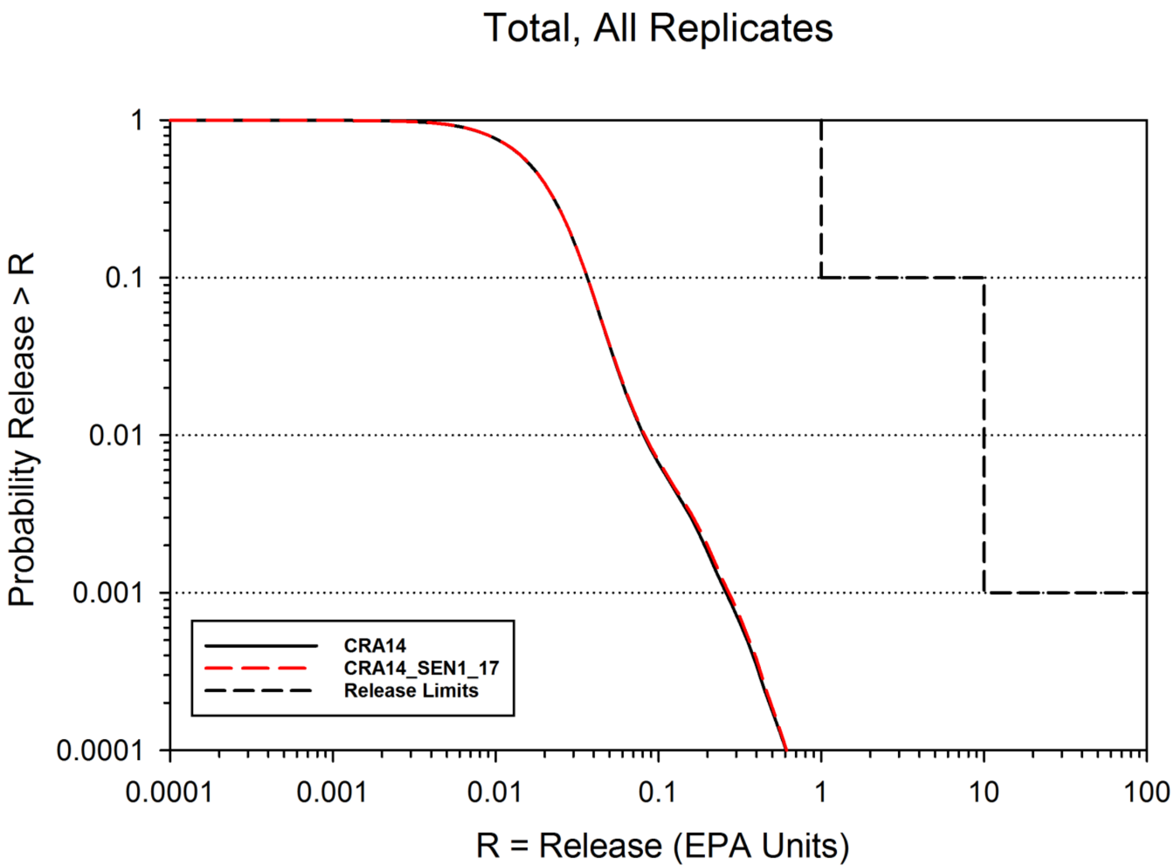
Single Replicate Release Results (cont.)

- SEN1_12/13/14
  - "Loose/Looser" cases 13 and 14 have slight reduction in high-probability spallings releases in comparison to CRA14
  - "Tight" case 12 has slight increase in high-probability spallings releases in comparison to CRA14
- SEN1_12/15/16
  - Equivalent
- SEN1_17/19
  - Equivalent to case 12



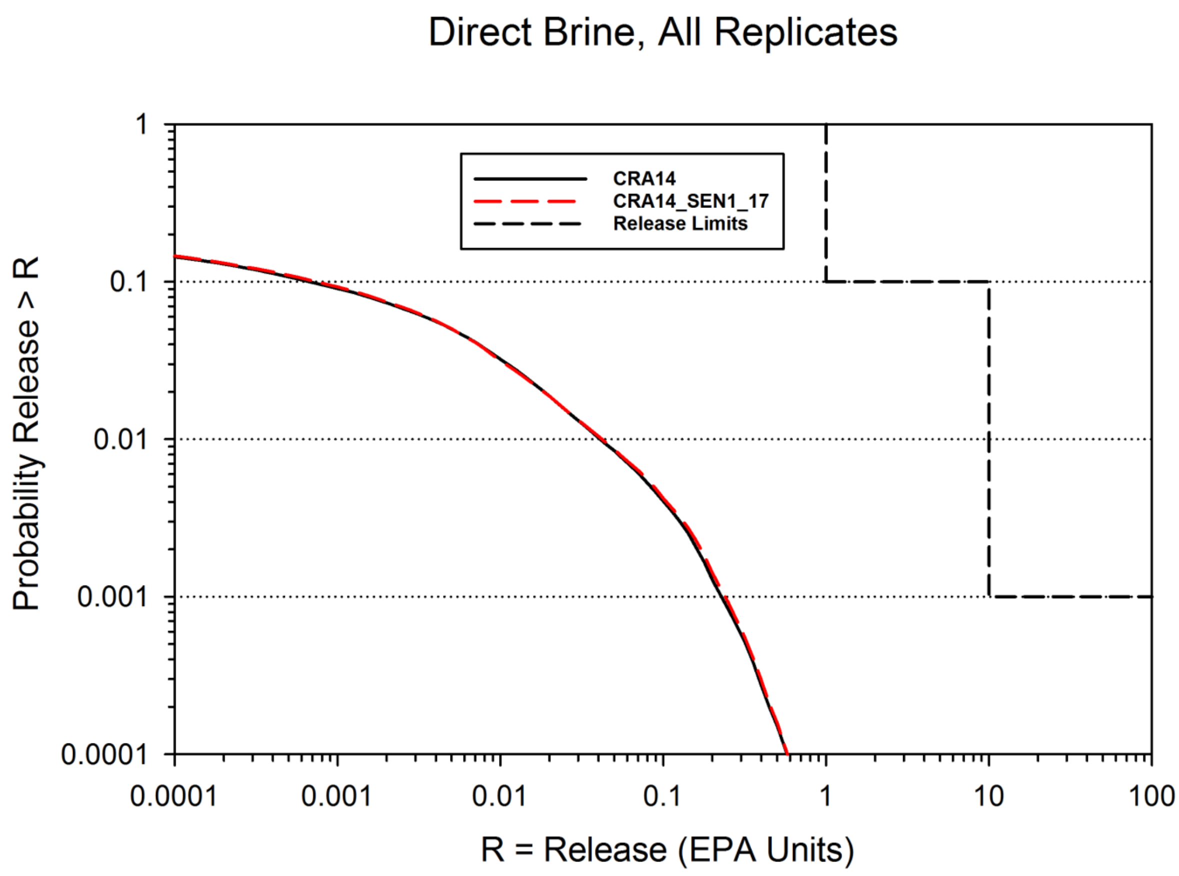
Three Replicate Release Results

- SEN1_17
  - Computationally efficient representative of all “Tight” cases
  - Very small increase in low-probability Total releases in comparison to CRA14



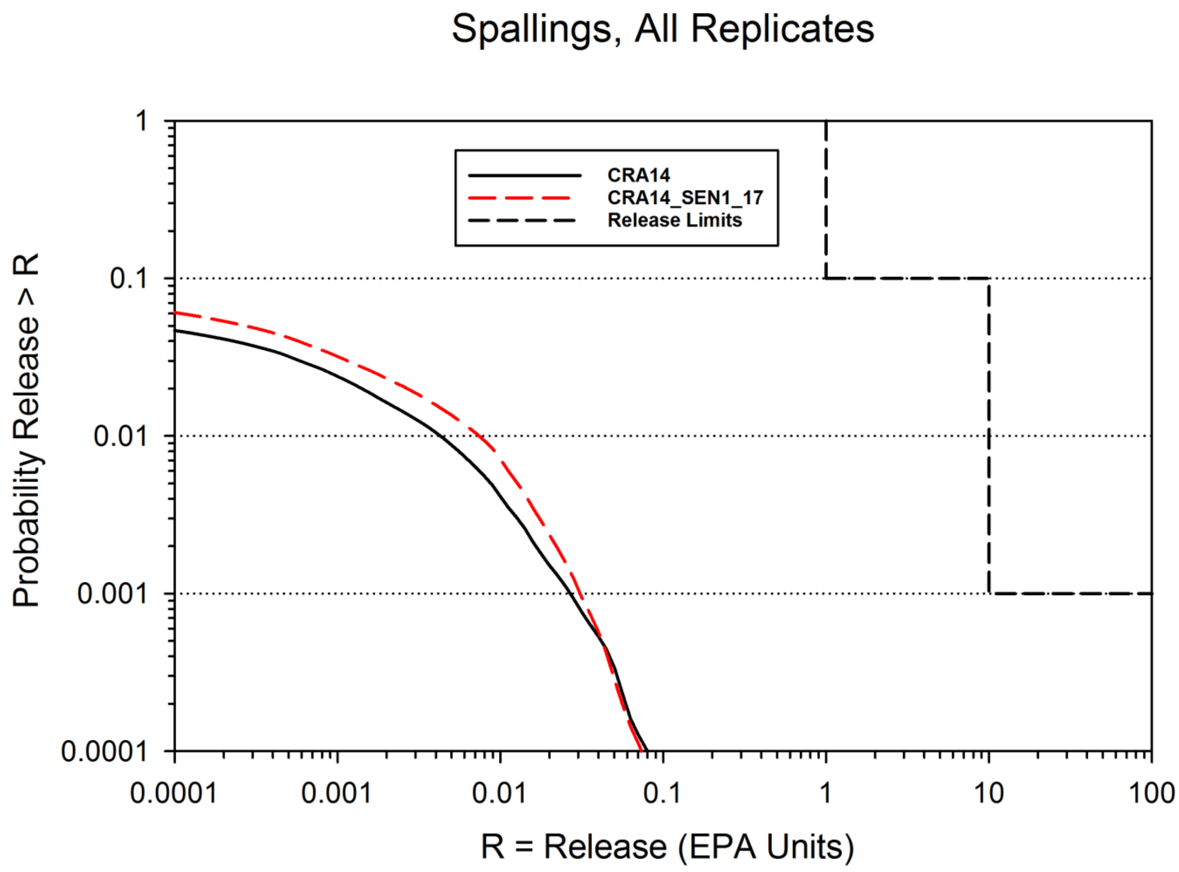
Three Replicate Release Results (cont.)

- SEN1_17
  - Very small increase in low-probability direct brine releases in comparison to CRA14
  - Increased pressures and lower brine saturations effectively cancel each other to produce equivalent results



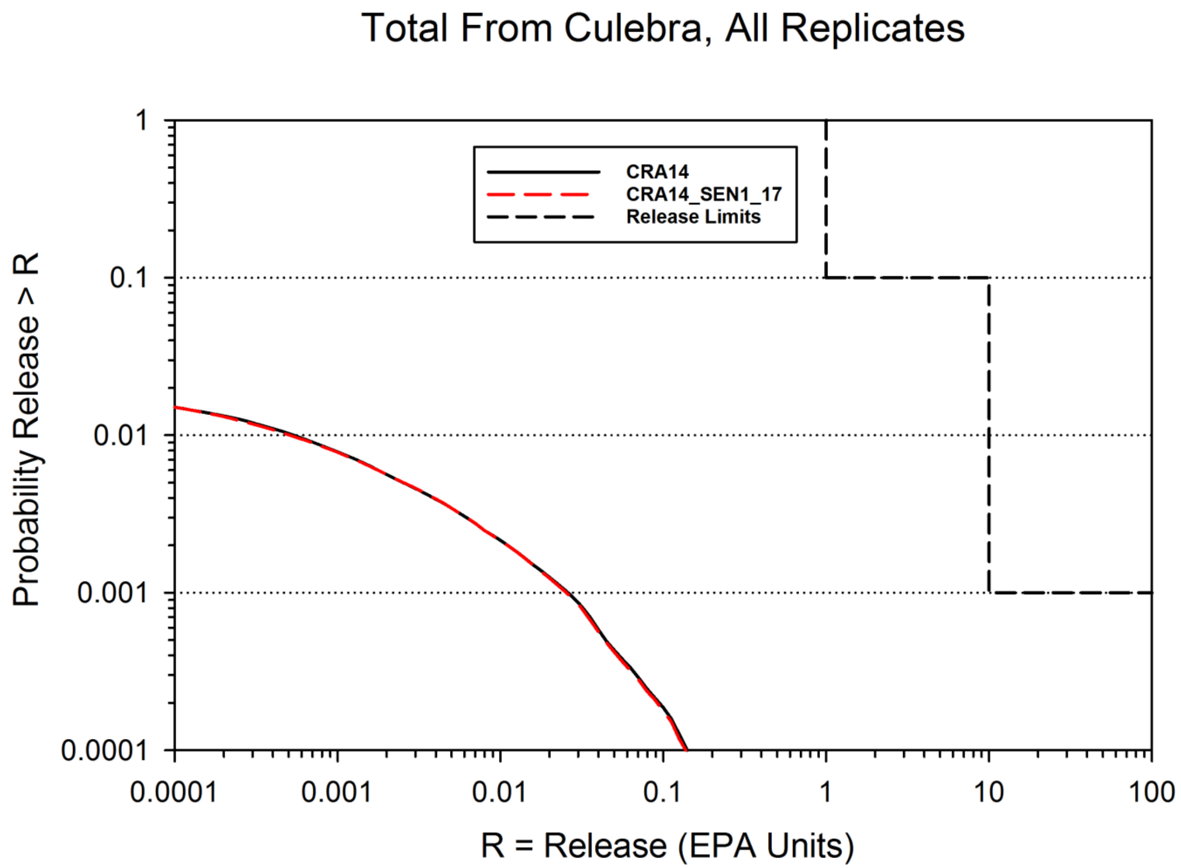
Three Replicate Release Results (cont.)

- SEN1_17
  - Marginal increase in spallings releases in comparison to CRA14 due to higher waste area pressures



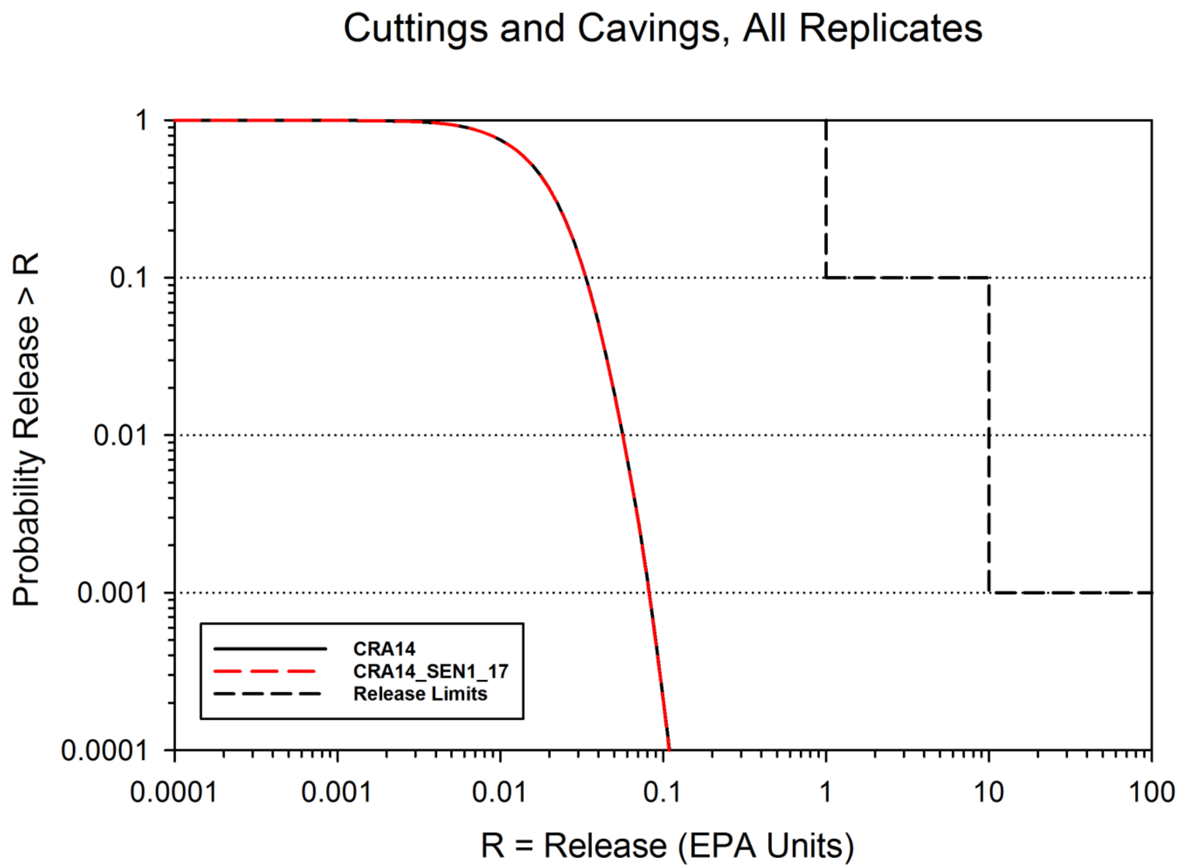
Three Replicate Release Results (cont.)

- SEN1_17
  - No discernible difference with CRA14



Three Replicate Release Results (cont.)

- SEN1_17
  - No discernible difference with CRA14



Conclusions by Study

- Initial
  - Model OPS/EXP using EPA Requested Parameters
    - Expected numerical difficulties introduced when step-changing of material properties (porosity/permeability) when capillary pressure effects on relative permeability are active
- Second (SEN1_12, SEN1_13, SEN1_14)
  - Model OPS/EXP with fixed porosity/permeability over all times with capillary pressure effects on relative permeability active
    - Simulating the early-state closure process is unnecessary and has computational benefits if not undertaken; CRA14 fixed value of 0.18 is appropriate
- Third (SEN1_12, SEN1_15, SEN1_16)
  - Model OPS/EXP with low porosity and permeability over all times with various relative permeability models
    - Implementing capillary pressure effects on relative permeability is unnecessary and has computational benefits if not undertaken; CRA14 use of RELP_MOD=11 is appropriate
- Fourth/Fifth (SEN1_17, SEN1_19)
  - Model OPS/EXP with step-down in porosity and permeability as a function in time with capillary pressure effects on relative permeability inactive and residual saturations varied
    - Residual saturations have negligible effect on waste area pressures and saturations; CRA14 use of SAT_RBRN and SAT_RGAS = 0 is appropriate

General Conclusions

- OPS/EXP Parameters
  - Reduced porosity/permeability
    - Marginally increased brine pressures in waste areas due to reduced gas flow from S to N
    - Marginally decreased brine saturations in waste areas due to reduced brine flow from N to S
    - Only parameters (k, ϕ) produce a discernible impact and result in a minor increase in high-probability Spallings releases
    - Insignificant impact on other release components such that Total releases are negligibly affected
  - Relative permeability model with capillary pressure effects
    - No discernible effect on pressures and saturations in areas that contribute to release (i.e., waste), so no discernible effect on releases
  - Residual brine and gas saturations
    - No discernible effect on pressures and saturations in areas that contribute to release (i.e., waste), so no discernible effect on releases

Overall Conclusions

- Total releases for all cases (SEN1_12 thru SEN1_17 and SEN1_19) are essentially identical to CRA14
  - No significant effect on Total releases due to modeling the OPS/EXP Cavity and DRZ as tight or loose over all times vs tightening over the first 500 years, using a linear vs nonlinear relative permeability model, having an active vs inactive capillary pressure model, or having zero vs nonzero brine and gas residual saturations
  - Currently utilized relative permeability models are appropriately conservative by minimizing gas flow out of and maximizing brine flow into the waste areas
- Overall
  - OPS/EXP region degree of and rates of closure do not significantly impact the prediction of Total releases established in CRA14
  - BRAGFLO capillary pressure and relative permeability models and conceptual model material parameters in CRA14 sufficiently capture the relevant physics in areas that contribute to releases