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Uncertainty and sensitivity analysis for two-phase flow in the vicinity of the repository in the 1996 performance assessment for the Waste Isolation Pilot Plant: undisturbed conditions

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Abstract

Uncertainty and sensitivity analysis results obtained in the 1996 performance assessment for the Waste Isolation Pilot Plant are presented for two-phase flow in the vicinity of the repository under undisturbed conditions. Techniques based on Latin hypercube sampling, examination of scatterplots, stepwise regression analysis, partial correlation analysis and rank transformations are used to investigate brine inflow, gas generation, repository pressure, brine saturation, and brine and gas outflow. Of the variables under study, repository pressure is potentially the most important due to its influence on spallings and direct brine releases, with the uncertainty in its value being dominated by the extent to which the microbial degradation of cellulose takes place, the rate at which the corrosion of steel takes place, and the amount of brine that drains from the surrounding disturbed rock zone into the repository. Published by Elsevier Science Ltd.

Keywords: BRAGFLO; Compliance certification application; Epistemic uncertainty; Latin hypercube sampling; Performance assessment; Radioactive waste; Sensitivity analysis; Subjective uncertainty; Transuranic waste; Two-phase flow; Uncertainty analysis; Undisturbed conditions; Waste Isolation Pilot Plant

1. Introduction

Uncertainty and sensitivity analysis results for fluid flow in the vicinity of the repository under undisturbed conditions obtained as part of the 1996 performance assessment (PA) for the Waste Isolation Pilot Plant (WIPP) are presented. A following paper will present results for disturbed conditions [1].

The results under study were calculated with the BRAGFLO program [2] for the three replicated Latin hypercube samples (LHSs) (i.e. R1, R2, R3) described in Ref. [3, Eq. (7)]. In particular, the results under consideration are the outcomes of the 300 E0 BRAGFLO calculations indicated in Ref. [4, Table 6]. The topics considered are brine inflow (Section 2), gas generation (Section 3), pressure (Section 4), brine saturation (Section 5), and brine and gas outflow (Section 6). In each section, a number of results calculated by BRAGFLO are examined with sensitivity analysis techniques based on examination of scatterplots, partial correlation coefficients, and stepwise regression analysis [5, Section 3.5]. The sensitivity analyses make extensive use of rank-transformed data [6], the STEPWISE program [7,8] for stepwise regression analysis, and the PCCSRC program [9,10] for the calculation of partial correlation coefficients. The specific BRAGFLO results considered are listed in Table 1, which can be used to obtain exact definitions of the individual variables under consideration; further, the uncertain analysis inputs are described in Ref. [3, Table 1].

The sensitivity analysis results will be based on all 300 observations (i.e. replicates R1, R2 and R3 will be pooled for the performance of sensitivity analyses with scatterplots, partial correlation coefficients and stepwise regression analyses), which permits the analysis results to be based on all available information. Similarly, summaries of uncertainty based on box plots will also use all 300 observations. In contrast, distributions of time-dependent results will

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Table 1 Results calculated by BRAGFLO considered in uncertainty and sensitivity analyses for fluid flow in the vicinity of the repository under undisturbed (i.e. E0) conditions

BRAABNIC—Cumulative brine flow (m^3) out of north anhydrites A and B into disturbed rock zone (DRZ) (i.e. from Cell 556 to Cell 527 in Fig. 3, Ref. [2])
BRAABNLW—Cumulative brine flow (m^3) in north anhydrites A and B across land withdrawal boundary (i.e. from Cell 561 to Cell 562 in Fig. 3, Ref. [2])
BRAABNOC—Cumulative brine flow (m^3) out of DRZ into north anhydrites A and B (i.e. from Cell 527 to Cell 556 in Fig. 3, Ref. [2])
BRAABSLW—Cumulative brine flow (m^3) in south anhydrites A and B across land withdrawal boundary (i.e. from Cell 550 to Cell 549 in Fig. 3, Ref. [2])
BRAABSOC—Cumulative brine flow (m^3) out of DRZ into south anhydrites A and B (i.e. from Cell 482 to Cell 555 in Fig. 3, Ref. [2])
BRAALLW—Cumulative brine flow (m^3) in all MBs across land withdrawal boundary (i.e. *BRM38NLW* + *BRAABNLW* + *BRM39NLW* + *BRM38SNLW* + *BRAABNLW* + *BRM39SLW*)
BRAALOC—Cumulative brine flow (m^3) out of DRZ into all MBs (i.e. *BRM38NOC* + *BRAABNOC* + *BRM39NOC* + *BRM38SNOC* + *BRAABNOC* + *BRM39SOC*)
BRM38NLW—Cumulative brine flow (m^3) in north MB138 across land withdrawal boundary (i.e. from Cell 593 to Cell 594 in Fig. 3, Ref. [2])
BRM38NOC—Cumulative brine flow (m^3) out of DRZ into north MB138 (i.e. from Cell 587 to Cell 588 in Fig. 3, Ref. [2])
BRM38SIC—Cumulative brine flow (m^3) out of south MB138 into DRZ (i.e. from Cell 571 to Cell 572 in Fig. 3, Ref. [2])
BRM38SLW—Cumulative brine flow (m^3) in south MB138 across land withdrawal boundary (i.e. from Cell 566 to Cell 565 in Fig. 3, Ref. [2])
BRM38SOC—Cumulative brine flow (m^3) out of DRZ into south MB138 (i.e. from Cell 572 to Cell 571 in Fig. 3, Ref. [2])
BRM39NIC—Cumulative brine flow (m^3) out of north MB139 into DRZ (i.e. from Cell 540 to Cell 465 in Fig. 3, Ref. [2])
BRM39NLW—Cumulative brine flow (m^3) in north MB139 across land withdrawal boundary (i.e. from Cell 545 to Cell 546 in Fig. 3, Ref. [2])
BRM39NOC—Cumulative brine flow (m^3) out of DRZ into north MB139 (i.e. from Cell 465 to Cell 540 in Fig. 3, Ref. [2])
BRM39SIC—Cumulative brine flow (m^3) out of south MB139 into DRZ (i.e. from Cell 539 to Cell 436 in Fig. 3, Ref. [2])
BRM39SLW—Cumulative brine flow (m^3) in south MB139 across land withdrawal boundary (i.e. from Cell 534 to Cell 533 in Fig. 3, Ref. [2])
BRM39SOC—Cumulative brine flow (m^3) out of DRZ into south MB139 (i.e. from Cell 436 to Cell 539 in Fig. 3, Ref. [2])
BRN_DNSH—Cumulative brine flow (m^3) down shaft at upper boundary of DRZ (i.e. from Cell 654 to Cell 653 in Fig. 3, Ref. [2])
BRN_RMV—Cumulative brine (m^3) consumed in repository by corrosion (i.e. in Cells 596–625 in Fig. 3, Ref. [2])
BRNVOL_R—Brine volume (m^3) in upper waste panels (i.e. in Cells 617–625 in Fig. 3, Ref. [2])
BRNVOL_W—Brine volume (m^3) in lower waste panels (i.e. in Cells 596–616 in Fig. 3, Ref. [2])
BRNREPTC—Cumulative brine flow (m^3) into repository (i.e. into region corresponding to Cells 596–625, 638–640 in Fig. 3, Ref. [2])
BRNSHUC—Cumulative brine flow (m^3) up shaft at boundary between Salado and Rustler Formations (i.e. from Cell 660 to Cell 661 in Fig. 3, Ref. [2])
BSCL8AOC—Cumulative brine flow (m^3) up shaft at boundary of DRZ and intact halite (i.e. from Cell 653 to Cell 654)
CELL_KG—Mass of cellulose (kg) in repository (i.e. in Cells 596–625 in Fig. 3, Ref. [2])
CELL_M_H—Cumulative gas generation (mol) in repository due to microbial degradation of cellulose under inundated conditions (i.e. in Cells 596–625 in Fig. 3, Ref. [2])
CELL_M_I—Cumulative gas generation (mol) in repository due to microbial degradation of cellulose under inundated conditions (i.e. in Cells 596–625 in Fig. 3, Ref. [2])
CELL_MOL—Cumulative gas generation (mol) in repository due to microbial degradation of cellulose (i.e. *CELL_M_H* + *CELL_M_I*)
FE_KG—Mass of steel (kg) in repository (i.e. in Cells 596–625 in Fig. 3, Ref. [2])
FE_MOLE—Cumulative gas generation (mol) in repository due to corrosion (i.e. in Cells 596–625 in Fig. 3, Ref. [2])
FEREM_R—Fraction of steel remaining in upper waste panels (i.e. in Cells 617–625 in Fig. 3, Ref. [2])
FEREM_W—Fraction of steel remaining in lower waste panel (i.e. in Cells 596–616 in Fig. 3, Ref. [2])
FRACXABN—Length (m) of fractured zone in north anhydrites A and B (i.e. in Cells 556–563 in Fig. 3, Ref. [2])
FRACXABS—Length (m) of fractured zone in south anhydrites A and B (i.e. in Cells 548–555 in Fig. 3, Ref. [2])
FRACX38N—Length (m) of fractured zone in north MB 138 (i.e. in Cells 588–595 in Fig. 3, Ref. [2])
FRACX38S—Length (m) of fractured zone in south MB 138 (i.e. in Cells 564–571 in Fig. 3, Ref. [2])
FRACX39N—Length (m) of fractured zone in north MB 139 (i.e. in Cells 540–547 in Fig. 3, Ref. [2])
FRACX395—Length (m) of fractured zone in south MB 139 (i.e. in Cells 532–539 in Fig. 3, Ref. [2])
GAS_MOLE—Total cumulative gas generation in repository (i.e. *FE_MOLE* + *CELL_MOL*)
GASMOL_R—Cumulative gas generation (mol) in upper waste panels due to corrosion and microbial degradation (i.e. in Cells 617–625 in Fig. 3, Ref. [2])
GASMOL_W—Cumulative gas generation (mol) in lower waste panel due to corrosion and microbial degradation (i.e. in Cells 596–616 in Fig. 3, Ref. [2])
GSAABNIM—Cumulative gas flow (mol) out of north anhydrites A and B into DRZ (i.e. from Cell 556 to Cell 527 in Fig. 3, Ref. [2])
GSAABNOC—Cumulative gas flow (mol) out of DRZ into north anhydrites A and B (i.e. from Cell 527 to Cell 556 in Fig. 3, Ref. [2])
GSAABSIM—Cumulative gas flow (mol) out of south anhydrites A and B into DRZ (i.e. from Cell 555 to Cell 482 in Fig. 3, Ref. [2])
GSAABSOC—Cumulative gas flow (mol) out of DRZ into south anhydrites A and B (i.e. from Cell 482 to Cell 555 in Fig. 3, Ref. [2])
GSAALIM—Cumulative gas flow (mol) out of all MBs into DRZ (i.e. *GSM38NIM* + *GSAABNIM* + *GSM39NIM* + *GSM38SNIM* + *GSAABNIM* + *GSM39SIM*)
GSAALOM—Cumulative gas flow (mol) out of DRZ into all MBs (i.e. *GSM38NOC* + *GSAABNOC* + *GSM39NOC* + *GSM38SNOC* + *GSAABNOC* + *GSM39SOC*)
GSM38NIM—Cumulative gas flow (mol) out of north MB138 into DRZ (i.e. from Cell 588 to Cell 587 in Fig. 3, Ref. [2])
GSM38NOC—Cumulative gas flow (mol) out of DRZ into north MB138 (i.e. from Cell 587 to Cell 588 in Fig. 3, Ref. [2])
GSM38SIM—Cumulative gas flow (mol) out of south MB138 into DRZ (i.e. from Cell 571 to Cell 572 in Fig. 3, Ref. [2])
GSM38SOC—Cumulative gas flow (mol) out of DRZ into south MB138 (i.e. from Cell 572 to Cell 571 in Fig. 3, Ref. [2])
GSM39NIM—Cumulative gas flow (mol) out of north MB139 into DRZ (i.e. from Cell 540 to Cell 465 in Fig. 3, Ref. [2])
GSM39NOC—Cumulative gas flow (mol) out of DRZ into north MB139 (i.e. from Cell 465 to Cell 540 in Fig. 3, Ref. [2])
GSM39SIM—Cumulative gas flow (mol) out of south MB139 into DRZ (i.e. from Cell 539 to Cell 436 in Fig. 3, Ref. [2])
GSM39SOC—Cumulative gas flow (mol) out of DRZ into south MB139 (i.e. from Cell 436 to Cell 539 in Fig. 3, Ref. [2])
GSMSHUPC—Cumulative gas flow (mol) up shaft at boundary between Salado and Rustler Formations (i.e. from Cell 660 to Cell 661 in Fig. 3, Ref. [2])
PORVOL_R—Pore volume (m^3) in upper waste panels (i.e. in Cells 617–625 in Fig. 3, Ref. [2])