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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: disturbed conditions

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Abstract

Uncertainty and sensitivity analysis results obtained in the 1996 performance assessment (PA) for the Waste Isolation Pilot Plant (WIPP) are presented for two-phase flow in the vicinity of the repository under disturbed conditions resulting from drilling intrusions. 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 and brine flow from the repository to the Culebra Dolomite are potentially the most important in PA for the WIPP. Subsequent to a drilling intrusion, repository pressure was dominated by borehole permeability and generally below the level (i.e. 8 MPa) that could potentially produce spallings and direct brine releases. Brine flow from the repository to the Culebra Dolomite tended to be small or nonexistent, with its occurrence and size also dominated by borehole permeability. Published by Elsevier Science Ltd.

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

1. Introduction

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

The results under study were calculated with the BRAGFLO program [2] for the three replicated samples (i.e. R1, R2, R3) indicated in Eq. (7) of Ref. [3]. In particular, results for the following cases in Ref. [4, Table 6] will be presented: an E1 intrusion at 1000 yr, an E2 intrusion at 1000 yr, and an E2E1 intrusion with the E2 intrusion at 800 yr and the E1 intrusion at 2000 yr. In the preceding, the designation E1 refers to a single drilling intrusion through the repository that penetrates pressurized brine in the Castile Formation (Fm); the designation E2 refers to a single drilling intrusion through the repository that does not penetrate pressurized brine in the Castile Fm; and the designation E2E1 refers to two drilling intrusions through the repository, with the first and second intrusions not penetrating and penetrating pressurized brine in the Castile Fm, respectively. Calculations were also performed for E1 and E2 intrusions at 350 yr [4, Table 6]. However, as the results for fluid flow in the vicinity of the repository for intrusions at 350 yr are similar to those for intrusions at 1000 yr, the results for intrusions at 350 yr will not be presented.

The following topics related to conditions in the repository are considered: brine inflow (Section 2), gas generation (Section 3), pressure (Section 4), saturation (Section 5), brine and gas flow in an intruding borehole (Section 6), behavior of brine pocket (Section 7), and behavior of E2E1 intrusions (Section 8). As in the presentation for undisturbed conditions [1], a number of specific results calculated by BRAGFLO are examined with techniques

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Table 1
Results calculated by BRAGFLO considered in uncertainty and sensitivity analyses for fluid flow in the vicinity of the respository under disturbed (i.e. E1, E2, E2E1) conditions in addition to the results in Table 1 of Ref. [1]

B_P_PRES-Volume-averaged pressure (Pa) in brine pocket (i.e. in cells 1007–1023 in Fig. 3 of Ref. [2])

BNBHDNUZ-Cumulative brine flow (m^3) down borehole at MB 138 (i.e. from cell 223 to cell 575 in Fig. 3 of Ref. [2])

BNBHUDRZ-Cumulative brine flow (m^3) up borehole at bottom of lower disturbed rock zone (DRZ) (i.e. from cell 78 to cell 439 in Fig. 3 of Ref. [2])

BNBHUDRZ-Cumulative brine flow (m^3) up borehole at top of DRZ (i.e. from cell 513 to cell 575 in Fig. 3 of Ref. [2])

BRNVOL_B-Brine volume (m^3) in brine pocket (i.e. in cells 1007–1023 in Fig. 3 of Ref. [2])

GASBHUDZ-Cumulative gas flow (m^3 at standard temperature and pressure; $GASBHUDZ = 0.2463\ m^3/mol * GSMBUDZ$) up borehole at top of DRZ (i.e. from cell 513 to cell 575 in Fig. 3 of Ref. [2])

GSMBHUDZ-Cumulative gas flow (mol) up borehole at top of DRZ (i.e. from cell 513 to cell 575 in Fig. 3 of Ref. [2])

based on examination of scatterplots, partial correlation coefficients, and stepwise regression analysis [5, Section 3.5]). The analyses were performed with the STEPWISE [6,7] and PCCSRC [8,9] programs with rank-transformed data [10]. The specific BRAGFLO results considered are listed in Table 1 of this paper and Ref. [1, Table 1], which can be used to obtain exact definitions of the individual variables under consideration.

As in the analyses for undisturbed conditions [1], the sensitivity analysis results presented in this article are based on all 300 observations (i.e. replicates R1, R2 and R3 are pooled for the performance of sensitivity analyses with scatterplots, correlation coefficients and stepwise regression analysis; see, Ref. [3, Section 8]. Similarly, summaries of uncertainty based on box plots also use all 300 observations. In contrast, distributions of time-dependent results are typically shown for only replicate R1 to avoid the presentation of plots with so many individual curves that they are unreadable. However, mean and percentile curves are obtained from all 300 observations. Descriptions of the individual independent (i.e. sampled) variables in the sensitivity analyses are given in Ref. [3, Table 1]. As in the sensitivity analyses for undisturbed conditions, the variables *ANHCOMP* and *HALCOMP* are not used in the calculation of partial correlation coefficients and regression models due to the −0.99 rank correlations imposed on the variable pairs (*ANHCOMP*, *ANHPRM*) and (*HALCOMP*, *HALPRM*) [11, Section 7.2].

The results contained in this presentation were obtained in support of the US Department of Energy's (DOE) compliance certification application (CCA) for the WIPP [12] and are based on material contained in Ref. [11, Chap. 8].

2. Disturbed conditions: brine inflow for E1 and E2 intrusions

For undisturbed (i.e. E0) conditions, the two main pathways by which brine enters the repository are flow from the Salado Fm through the anhydrite marker beds and drainage from the disturbed rock zone (DRZ) [1, Section 2]. For E2 intrusions, an additional pathway is provided by brine flow down the intruding borehole from overlying formations; for E1 intrusions, two additional pathways are provided by brine flow down the intruding borehole from overlying formations and brine flow up the borehole from a pressurized brine pocket in the Castile Fm.

For brine inflow from the marker beds, E0, E1 and E2 conditions produce similar results ([1, Fig. 1]; Fig. 1), with the inflows for E1 and E2 intrusions tending to be somewhat

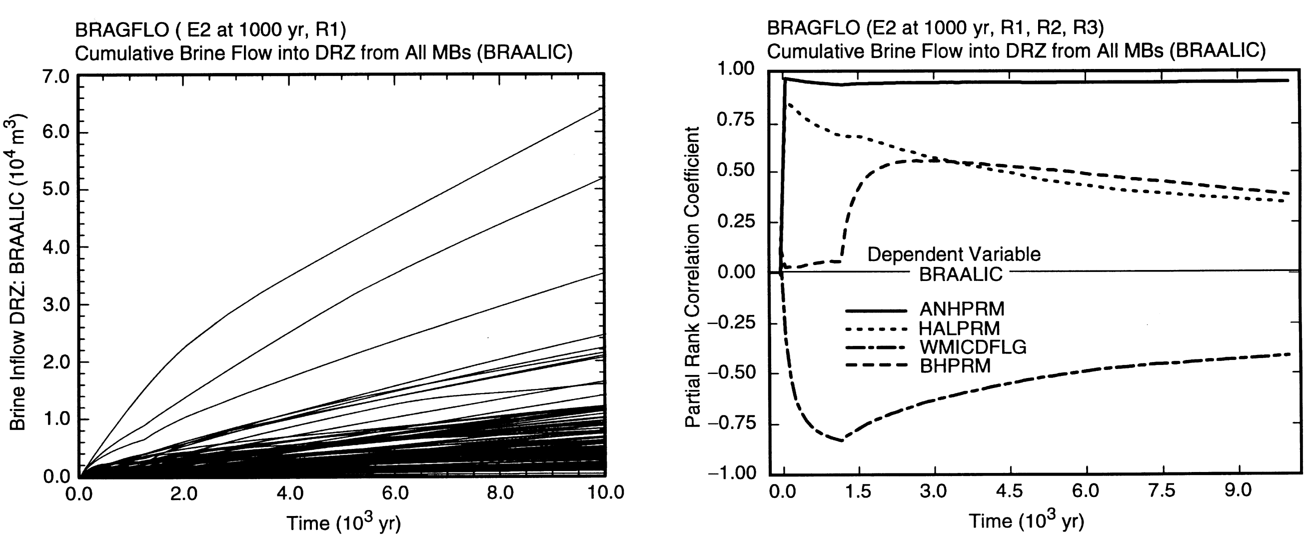

Fig. 1. Uncertainty and sensitivity analysis results for cumulative brine flow from anhydrite marker beds (*BRAALIC*) for an intrusion at 1000 yr into lower waste panel; similar results are obtained for an E1 intrusion ([11, Fig. 8.2.1]).