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Use of Replicated Latin Hypercube Sampling to Estimate Sampling Variance in Uncertainty and Sensitivity Analysis Results for the Geologic Disposal of Radioactive Waste

Clifford W. Hansen*, Jon C. Helton, Cedric J. Sallaberry

Sandia National Laboratories, Albuquerque, NM, 87185-1399, USA

Abstract

Sampling-based methods are commonly used to propagate uncertainty through models for complex systems (Helton and Davis (2003), Helton et al. (2006)). Replicated sampling involves repeating a sampling-based uncertainty propagation for several independent samples of the same size (Iman (1982)). Variance between replicates indicates the numerical uncertainty in analysis results that derives from the sampling-based method. Results from the replicates can be used to estimate confidence intervals for analysis results and to determine whether the sample size in use is sufficient to obtain statistically stable results. Replicated sampling can be used to assess the adequacy of the sample size in situations where more formal statistical procedures are not applicable (Iman (1982)).

Keywords: Replicated sampling, statistical stability, sensitivity analysis, top-down coefficient of concordance

1. Main text

This paper illustrates the use of replicated sampling to determine the stability of both uncertainty analysis results and sensitivity analysis results obtained in the 2008 performance assessment (PA) for the proposed Yucca Mountain (YM) repository for high level radioactive waste (SNL (2008)). Specifically, this very large analysis was repeated with three replicated Latin hypercube samples of size 300 from 392 epistemically uncertain analysis inputs.

At the simplest level, the stability of uncertainty analysis and sensitivity analysis results obtained in the 2008 YM PA was demonstrated by the comparison of the results for each replicate. At a more sophisticated level, the stability of expected values over aleatory uncertainty for radiation exposure to a reasonably maximally exposed individual was assessed by calculating time-dependent confidence intervals on the basis of results obtained with the replicated samples. Further, the stability of sensitivity analysis results was assessed by using top-down coefficients of concordance (TDCCs) on stepwise regression results (Iman and Conover (1987), Helton et al (2005)). Specifically, TDCCs were used to identify sets of important variables on the basis of the similarity in outcomes of sensitivity

* Corresponding author. Tel.: +1-702-295-5473; fax: +1-702-295-5223.
E-mail address: cwhanse@sandia.gov.

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analyses performed for the individual replicated samples. For example, Table 1 summarizes the first eight variables selected in a stepwise regression on the expected values (over aleatory uncertainty) for radiation exposure at 500,000 yr, performed for each of three replicated samples. Although the stepwise regressions select different variables at the fourth and subsequent addition, computing the TDCC for these results obtained a p-value of 7.6E-05, indicating that agreement in the ordering of variables in the stepwise regression across replicates is unlikely to have arisen by chance. Thus, the sensitivity analysis results can be regarded as stable.

The analyses with the three replicated samples showed that a Latin hypercube sample of size 300 was adequate for the propagation of epistemic uncertainty in the 2008 YM PA and for sensitivity analyses of the results of the PA. Specifically, any one of the three replicated samples would have led to the same overall assessment of the implications of epistemic uncertainty in the 2008 YM PA.

Table 1. Stepwise regression results for expected values (over aleatory uncertainty) for radiation exposure at 500,000 yr for three replicates of the 2008 YM PA. Variable definitions are provided in SNL (2008), Table K3-1.

	Replicate 1			Replicate 2			Replicate 3		
Step	**Variable**	**R^2**	**SRRC**	**Variable**	**R^2**	**SRRC**	**Variable**	**R^2**	**SRRC**
1	IGRATE	0.29	0.52	IGRATE	0.33	0.57	IGRATE	0.21	0.48
2	WDGCA22	0.41	-0.31	WDGCA22	0.40	-0.25	SZGWSPDM	0.32	0.27
3	SZGWSPDM	0.52	0.31	SZGWSPDM	0.47	0.24	WDGCA22	0.41	-0.30
4	EP1LOWNU	0.56	0.18	INFIL	0.50	0.14	INFIL	0.46	0.19
5	MICNP237	0.59	0.18	GOESITED	0.53	-0.16	SCCTHRP	0.51	-0.19
6	SCCTHRP	0.61	-0.15	EP1LOWPU	0.55	0.17	GOESITED	0.53	-0.21
7	SZCONCOL	0.63	0.13	MICU234	0.56	0.13	MICAM243	0.56	0.12
8	EP1LOWPU	0.64	0.14	SCCTHRP	0.58	-0.12	SZFISPVO	0.58	0.12

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