DOCKET NO: A-93-02
V-B-13

TECHNICAL SUPPORT DOCUMENT FOR

SECTION 194.23: SENSITIVITY ANALYSIS REPORT

U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation and Indoor Air
Center for the Waste Isolation Pilot Plant
401 M. Street, S. W.
Washington, DC 20460

MAY 1998

Technical Support for this document was provided by TechLaw, Inc. and its subcontractors under EPA Contract 68D50174.

EXECUTIVE SUMMARY

This analysis was performed to evaluate the sensitivity of performance assessment (PA) modeling results to changes in the values of key input parameters used in the U.S. Department of Energy (DOE) Waste Isolation Pilot Project (WIPP) Compliance Certification Application (CCA) of October 1996. The input parameters selected for this analysis were based on: 1) the results of a comprehensive review by the Agency of over 1,500 parameters used in the WIPP PA; 2) concerns for specific parameters and processes expressed during EPA public hearings; 3) written public comments; and 4) results obtained in the initial EPA sensitivity studies. PA model output parameters that are most closely related to radionuclide releases and the repository conditions that most closely influence those releases were used as performance measures in this analysis. Approximately 80 parameters were varied in this analysis in 40 different sensitivity studies, many of which included variations of multiple parameters. The parameters varied in this analysis are used as inputs to five PA codes: BRAGFLO, BRAGFLO-DBR, CUTTINGS_S, SOURCE TERM, and CCDFGF.

The Agency's approach was to evaluate parameter sensitivity at the submodel level, such as review the results of BRAGFLO. The models used in the sensitivity analysis are identified in Table 2.1-1. Each is a submodel within the family of models used to perform the CCA PA calculations and most were used to provide intermediate results that would be more sensitive measures of model reactions to changes in input parameters than could be obtained by evaluating only the final resultant complementary cumulative distribution functions (CCDFs). The Agency believes that this approach provides a more sensitive method to evaluate individual parameter changes.

Through an iterative screening process, the Agency identified the most important and sensitive outputs of the five codes as performance measures and used the average absolute percent change as a measure for ranking their relative sensitivities. Examples of performance measures include gas pressure in the waste panels, cumulative brine release into the Culebra, direct brine releases to the ground surface, and cavings and spallings releases to the ground surface. The percent difference is calculated as the difference in performance measure values corresponding to the high and low values of the parameters used in the analysis, divided by the lower of the performance measure values, and multiplied by 100%. The average absolute percent change is the average of the absolute values of the percent changes for the key performance measures for each model.

The results of the analysis indicate a wide range of sensitivities to variations in the input parameters. These results are ranked by analysis in Table ES-1. Of the 40 sensitivity analyses performed, 27 had average absolute changes of less than 25%, and were not considered significant by the Agency. Of the remaining, 11 had changes greater than 100%, six had changes greater than 1,000%, and four had changes greater than 10,000%. The greatest absolute change was 103,611% for changes in the mass of waste in the WIPP inventory.

Table ES-1. Ranked Summary of Sensitivity Analysis Results

PA Model	Sensitivity Analysis	Average Change	Type of Impact
PARAMETERS WITH GREATER THAN 100,000% CHANGE			
BRAGFO	Waste Material Combined Inventory	103,611%	DBR, SPALL, LWB
PARAMETERS WITH 10,000% TO 100,000% CHANGE			
BRAGFLO	Waste Plastic Inventory	86,337%	DBR, SPALL, LWB
BRAGFLO	Waste Cellulosics Inventory	86,336%	DBR, SPALL, LWB
BRAGFLO	Waste Rubber Inventory	70,329%	DBR, SPALL, LWB
PARAMETERS WITH 1,000% TO 10,000% CHANGE			
BRAGFLO	Anhydrite Permeability	2,347%	DBR, SPALL, CUL, LWB
CUTTINGS_S	Waste Shear Resistance	1,413%	CAV
PARAMETERS WITH 100% TO 1,000% CHANGE			
BRAGFLO	Long Term Borehole Permeability	330%	DBR, SPALL
BRAGFLO	DRZ Permeability	325%	DBR
BRAGFLO-DBR	Maximum Period of Uncontrolled Borehole Flow	197%	DBR
CUTTINGS_S	Particle Cementation Strength	149%	SPALL
BRAGFLO	Borehole Plug Permeability	101%	DBR, SPALL
PARAMETERS WITH 25% TO 100% CHANGE			
CUTTINGS_S	Drill String Angular Velocity	60%	CAV
SOURCE TERM	Actinide Solubility Parameters	51%	DBR, CUL, LWB
PARAMETERS WITH LESS THAN 25% CHANGE			
BRAGFLO-DBR	Panel Seal Permeability	15%	NOT SIGNIFICANT
BRAGFLO	Anhydrite Initial Pressure	10%	NOT SIGNIFICANT
CCDFGF	Passive Institutional Control Drilling Reduction Factor	9%	NOT SIGNIFICANT
CCDFGF	Probability of Encountering Castile Brine Pocket	7%	NOT SIGNIFICANT
BRAGFLO	Steel Corrosion Rate	7%	NOT SIGNIFICANT
CUTTINGS_S	Gravity Scaling Factor	6%	NOT SIGNIFICANT
BRAGFLO	Microbial Degradation Effects	6%	NOT SIGNIFICANT
BRAGFLO	Waste Iron Inventory	5%	NOT SIGNIFICANT
SOURCE TERM	Microbial Colloid Proportionality Constant	3%	NOT SIGNIFICANT
SOURCE TERM	Humic Colloid Proportionality Constant	3%	NOT SIGNIFICANT
BRAGFLO	Castile Brine Pocket Rock Compressibility	2%	NOT SIGNIFICANT
BRAGFLO	Castile Brine Pocket Volume - EPA Range	1%	NOT SIGNIFICANT
BRAGFLO	Borehole Plug Porosity	1%	NOT SIGNIFICANT
BRAGFLO	Gas Generation Rate due to Microbial Action Under Inundated Conditions	1%	NOT SIGNIFICANT
BRAGFLO	Gas Generation Rate due to Microbial Action Under Humid Conditions	0%	NONE
BRAGFLO	Open Borehole Permeability	0%	NONE
BRAGFLO	Experimental and Operations Area Permeability	0%	NONE
BRAGFLO	Castile Brine Pocket Initial Pressure	0%	NONE
BRAGFLO	Panel Seal Permeability	0%	NONE
BRAGFLO	Anhydrite Porosity	0%	NONE
BRAGFLO	Waste Area Rock Compressibility	0%	NONE
BRAGFLO-DBR	Castile Brine Pocket Volume	0%	NONE
BRAGFLO-DBR	Minimum Period of Uncontrolled Borehole Flow	0%	NONE
BRAGFLO-DBR	DBR Cutoff Gas Flow Rate	0%	NONE

Table ES-1. Ranked Summary of Sensitivity Analysis Results (Continued)

PA Model	Sensitivity Analysis	Average Change	Type of Impact
BRAGFLO	Castile Brine Pocket Volume - CCA Range	**	NONE
CUTTINGS_S	Waste Permeability	*	NONE
CUTTINGS_S	Waste Area Absolute Roughness	*	NONE

* = Parameter not used in PA
** = Analysis superseded by Castile Brine Pocket Volume - EPA Range
DBR = Potential impact on direct brine releases
SPALL = Potential impact on spallings releases
LWB = Potential impact on subsurface releases at land withdrawal boundary through anhydrite interbed
CUL = Potential impact on subsurface releases at land withdrawal boundary through Culebra dolomite
CAV = Potential impact on cavings releases

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF FILES

LIST OF ACRONYMS

CCA	Compliance Certification Application
CCDF	Complementary Cumulative Distribution Function
CMS	Configuration Management System
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
JR	Parameter Justification Report
PA	Performance Assessment
PAVT	Performance Assessment Verification Test
PR	Parameter Report
QA	Quality Assurance
SA	Sensitivity Analysis
SNL	Sandia National Laboratories
WIPP	Waste Isolation Pilot Project

1.0 INTRODUCTION

This report describes the purpose, methodology, and results of a sensitivity analysis conducted by EPA of the performance assessment (PA) calculations presented by the U.S. Department of Energy (DOE) in the October 1996 Compliance Certification Application (CCA) for the Waste Isolation Pilot Plant (WIPP). This analysis evaluates the effects of changes in selected input parameters on the PA model output parameters used as performance measures. Performance measures that exhibit significant changes are considered sensitive to the values of the selected input parameters.

1.1 Background and Scope

This report is one in a series of three reports that provide detailed documentation of EPA's technical review of the CCA and of the methodology used by the Agency to evaluate DOE compliance with the requirements of 40 CFR 194.23(c)(4). These three reports are briefly described in the following paragraphs.

The first report, *Technical Support Document for Section 194.23 - Parameter Report* (PR) [Docket A-93-02, Item V-B-12], describes EPA's detailed review of DOE's supporting documentation and technical rationale for the supporting parameters used in the PA model. The report also describes the screening process used to identify those parameters that were poorly documented, that have a weak technical basis, and that may be important in determining compliance. This screening occurred in several steps and culminated in the Agency's March 19, 1997 letter informing DOE of those parameters that were inadequately supported and warranted further investigation (Trovato 1997A Enclosures 2, 3, and 4).

The second report, *Technical Support Document for Section 194.23 - Sensitivity Analysis Report* (SA) [Docket A-93-02, Item V-B-13] evaluates the sensitivity of key PA model outputs to changes in selected input parameters. The input parameters selected for this analysis were based primarily on the results of the PR and most of the parameters identified to DOE in the Agency's letter of 19 March 1997 were included in the SA (Trovato 1997A, Enclosures 2, 3, and 4); however, additional parameters or groups of parameters were added to the sensitivity analysis based on the results obtained in the initial sensitivity studies and on the concerns for specific parameters and processes expressed during EPA public hearings and in public written comments.

The third report, *Technical Support Document for Section 194.23 - Parameter Justification Report*, is referred to as the Justification Report (JR) [Docket A-93-02, Item V-B-14]. It summarizes EPA's findings from the PR and SA as well as other information used in developing a revised data base of parameters of major concern to the Agency that may be used in the EPA-mandated Performance Assessment Verification Test (PAVT). The PAVT is designed to provide a comprehensive test of the effects of changes in significant, uncertain parameters and changes in the CCA PA computer codes on the PA compliance calculations presented by DOE in the CCA.

1.2 Report Structure

This report is divided into four sections plus appendices. Following this introduction, the sensitivity analysis process is described in Section 2. These descriptions include parameter selection, model and performance measure selection, the sensitivity evaluation process, and the methods used to evaluate results. Section 3 describes the results obtained from the various PA models used in the analysis, and Section 4 presents a summary of results. The appendices present detailed information on the parameter values used in the analysis, the performance measures selected, and the models used. In addition, a separate appendix has been prepared for all cited references.

2.0 SENSITIVITY ANALYSIS PROCESS

2.1 Parameter Selection

2.1.1 Parameter Review

Most of the parameters used in this analysis were identified as the result of a screening process described in the PR. In overview, this process began with a detailed EPA review of the Sandia National Laboratories (SNL) parameter data base in Albuquerque, New Mexico. Individual Records Packages were obtained from SNL's Nuclear Waste Management Program Information Service Center and were used to identify the source and rationale for the principal parameters used in the CCA PA model. Deficiencies in documentation and lack of adequate rationale were identified and used along with information from the CCA and past SNL/DOE reports to begin an evaluation of parameter importance. This effort proceeded as a process of iterative sifting of the original CCA PA parameter database to identify those parameters deemed important to the performance of the WIPP.

The initial EPA review involved nearly 1,600 parameters. Of these, about 465 parameters were found to be worthy of a more detailed evaluation. These 465 parameters were given additional screening for importance and uncertainty, and about 150 were considered to have potential impact on performance. These 150 parameters were further reviewed and about 60 parameters were retained for detailed sensitivity analysis. About 20 more parameters were later added, making a total of about 80 input parameters to be evaluated in this sensitivity analysis.

2.1.2 Parameters Selected

Forty sensitivity analyses were performed by EPA as part of this study. A list of these analyses, the PA models used, and the principal parameters or analysis objectives are presented in Table 2.1-1. Many of the analyses required changing the values of multiple parameters to achieve the objectives. Detailed descriptions of the analyses, the parameters varied, the high and low parameter values used, and the basis for the parameter values are presented in Appendix PD. In most analyses, the parameters for which sensitivity was being analyzed were assigned low, high, and baseline values. The low and high values were selected by EPA to determine the changes in the performance measures resulting from large and sometimes extreme changes, both up and down, in the input parameter values. The baseline values were generally the values used by DOE in the CCA PA model or, in the case of sampled parameters, the median of the sampled range. The baseline values may be used as a basis for comparison when analyzing the results. Exceptions to this approach did occur and are identified in Appendix PD.

2.2 Model and Performance Measure Selection

2.2.1 Model Selection

The models used in the sensitivity analysis are identified in Table 2.1-1. Each is a submodel within the family of models used to perform the CCA PA calculations and most were used to provide intermediate results that would be more sensitive measures of model reactions to changes in input parameters than could be obtained by evaluating only the resultant complementary cumulative distribution functions (CCDFs). Further, most of these sensitivity analysis were performed by fixing all sampled parameters at their median values and running the model three times for the low, baseline (i.e., median or constant), and high values of the parameter or group of parameters for which sensitivity was being evaluated. These three model runs cannot be used to develop mean CCDFs, and the use of submodel outputs as performance measures was not only desirable but also necessary. The two analyses run using the CCDFGF submodel are exceptions. The two parameters being studied (the probability of encountering a Castile brine pocket and the passive institutional control drilling reduction factor) are both used only in this submodel to determine the final CCDF, thus the selected performance measure was necessarily the CCDF itself. These two analyses were run by fixing the values of the parameters in question and using Replicate 1 of the CCA PA modeling to provide the balance of the parameters. The resulting 100 model runs (vectors) for each high and low parameter value are sufficient to produce meaningful high and low mean CCDFs for comparison.

The role of each submodel within the overall PA model is illustrated by the flowchart presented in Figure 2.2-1. The model selected for each sensitivity analysis is the one that uses the input parameters being studied and provides outputs directly related to repository performance which can be used as performance measures for analysis. Five models were selected for performing the SA: BRAGFLO, BRAGFLO-DBR, CUTTINGS_S, SOURCE TERM, AND CCDFGF. BRAGFLO is the principal model for predicting repository conditions. BRAGFLO-DBR and CUTTINGS_S take inputs from BRAGFLO and compute releases during exploratory drilling from brine flow, cuttings, cavings, and spallings. The SOURCE TERM model computes actinide solubilities within the repository. SOURCE TERM calculations are performed with utility codes that are not specifically shown on the figure. The CCDFGF model combines the outputs from the other models and adds a few new inputs of its own (as noted above) to produce the final CCDFs. Several key PA models were not used in the SA including NUTS (for calculating long-term actinide transport from the repository) and the two SECO codes (for calculating flow and transport in the Culebra). These models were not needed to compute the performance measures used in this analysis.

2.2.2 Performance Measure Selection

Sensitivity was determined as a measure of the extent to which selected model outputs changed as a result of changes in input parameter values. Those selected model outputs constitute the performance measures for the sensitivity analysis. A detailed discussion of the selection of performance measures is presented by model in Appendix PM.

The selected performance measures were those model outputs most closely linked with radionuclide releases and the ability of the WIPP to meet EPA's regulatory criteria. Examples of model outputs used as performance measures in this analysis include gas pressure and saturation in the waste panels, cumulative brine release into the Culebra, brine flow into the anhydrite interbeds away from the repository, and the length of the fracturing zone in the anhydrites.

The first step in focusing the sensitivity analysis on the most important performance measures was a preliminary evaluation of the drilling intrusion scenarios using the BRAGFLO model. BRAGFLO is configured to evaluate six different drilling intrusion scenarios identified as S1 through S6. One scenario (S1) represents an undisturbed case, two (S2 and S3) represent E1 intrusions of the repository and a Castile brine pocket, two (S4 and S5) represent E2 intrusions of only the repository, and one (S6) represents an E2 intrusion followed by an E1 intrusion. EPA's evaluation identified the S3 scenario as the best for use in this analysis. It represents an E1 intrusion at 1,000 years and was selected because it provided the most significant overall releases and would be expected to provide the most robust responses to changes in input parameters. A detailed description of the rationale for selecting this scenario is presented in Appendix PM.

Upon identifying the drilling scenario that would be used, the next step was to identify the specific performance measures. The 253 measures used by SNL/DOE for evaluating BRAGFLO results for the CCA PA were reviewed and 76 of those measures were selected by the Agency as primary review parameters for the BRAGFLO SA runs. Upon reviewing the SA results, 11 measures were selected as key release parameters for the final sensitivity evaluation of the BRAGFLO runs. Similarly, of the 60 measures used by SNL/DOE for evaluating BRAGFLO-DBR results, 15 were selected by the Agency as primary review parameters and one (cumulative direct brine release to the ground surface) was selected as a key release parameter for the final sensitivity evaluation. Only two measures were needed for the cuttings/cavings/spallings runs (the cumulative cavings release and the cumulative spallings release to the ground surface), two for the source term analyses (the calculated solubilities of americium and plutonium), and two for the CCDFGF analyses (the normalized release at the regulatory reference probabilities of 0.1 and 0.001). Additional information on the selection of performance measures is presented in Appendix PM.

2.3 Sensitivity Evaluation Process

2.3.1 Computational Approach

This section presents an overview of the computational approach developed by EPA to perform the sensitivity analysis and also serves as a guide to reproducing the individual analyses from the original files stored in the SNL/DOE WIPP-PA Configuration Management System (CMS). The EPA sensitivity analyses were performed using the same family of DEC ALPHA VAX computers that was used to perform the original CCA PA. Specific instructions on the Agency's use of these computers to run SNL/DOE's PA codes for sensitivity analyses and other purposes are presented in EPA's CCA PA Computer Code Users Manual (EPA 1997).

The PA calculations are executed using a series of utility codes that support the principal computational codes such as BRAGFLO and CUTTINGS_S by performing such functions as mesh generation (GENMESH), assignment of material names and property values (MATSET), Latin-hypercube sampling of variable parameters (LHS), setting user-specified initial conditions (ICSET), changing parameter units, specifying alternative parameter values, or calculating output performance measures (ALGEBRA), plotting output performance measures (SPLAT), tabulating output performance measures (GROPE), interpolating data from one coordinate grid to another (RELATE), and combining the outputs of individual runs into a single file (SUMMARIZE). Additional information on these and other utility codes is presented in the code-specific appendices of this report (Appendices BF, DBR, CUSP, ST, and CCDFGF), as well as in the EPA Users Manual (EPA 1997) and in the SNL/DOE QA documentation for each computer code.

The utility codes are linked with the principal computational codes in a specific sequence for performing PA calculations, such that the output from one code becomes the input for the next code. Flow charts showing this linkage are presented in the aforementioned code-specific appendices of this report. For example, Figures FSCA.BF 1 and FSCA.BF 2 in Appendix BF show flow charts for computations using the BRAGFLO code from mesh generation (using GENMESH) through postprocessing of output (using POSTBRAG). This sequence of codes is run three times to compute BRAGFLO outputs for the low, baseline, and high parameter values for the sensitivity analyses. Figure FCSA.BF-Rev in Appendix BF shows a flow chart for combining the three POSTBRAG output files into a single file for plotting comparisons of sensitivity analysis results. While the code linkages on Figures FSCA.BF 1 and 2 are essentially the same as used by SNL/DOE in the CCA, the linkages on Figure FSCA.BF-Rev are specific to these sensitivity analyses. Similar flow charts are presented in each of the other code-specific appendices in this report and in the EPA Users Manual (EPA 1997).

Selected input and output files from each code sequence used by SNL/DOE in the CCA have been saved in the WIPP-PA CCA CMS, and the modified input files used by the Agency in this sensitivity analysis have been saved in the WIPP-PA EPA CMS. The PA codes are structured to allow a user to enter the code sequence at several points, using files taken from the CMS to initiate the computations. However, in the Agency's sensitivity analysis all parameters that were sampled in the CCA were replaced with median values and the SA baseline run was performed using all codes in the sequence. Following the baseline run, an initiation point for the SA revisions to the baseline parameters was selected depending on the type of change that needed to be made. For example, in the BRAGFLO runs, changes were required for specific parameter values rather than, for example, the computational grid. Changes to GENMESH were therefore not needed and ALGEBRA was determined to be the most convenient code for making these changes. Referring again to Figures FCSA.BF 1 and 2 in Appendix BF, ALGEBRA was used to modify the baseline output file from ICSET by replacing the baseline parameter values in the ICSET output file with the low and high parameter values used in the sensitivity analysis. The ICSET output, as modified by ALGEBRA, was then used as input to the PREBRAG, BRAGFLO, and POSTBRAG computational sequence to calculate the low and high performance measures used in the sensitivity analysis. A similar pattern was followed when using the other principal computational codes, although different points for introducing the revised parameter values were used. Detailed descriptions of this process are presented in the code-specific appendices to this report.

The names of the VAX input files used by the Agency in this sensitivity analysis and archived in the EPA CMS are presented in Appendix PD following the discussion of each sensitivity analysis run. These file names allow a user to access the SA-specific files stored in the EPA CMS and reproduce the sensitivity analysis. The first of these analyses discussed in Appendix PD evaluated the sensitivity to changes in anhydrite interbed permeability using the BRAGFLO code (Section PD-1.1) and will be used as an example. The information presented in this example consists of the unique identification term, evaluation script files, ALGEBRA input files, and the baseline ICSET output file needed to run the evaluation script files.

The unique identification term is a unique alphanumeric sequence incorporated into the names of each of the input files prepared by the Agency to run the high and low values of the specific sensitivity analysis. Incorporation of this term allows all necessary input files to be identified using search routines. The unique identification term is abbreviated “Unique Id” or “UNIQUEID” in this report and is identified by the symbol “UNIQUE_ID” in the evaluation script files. The Unique Id for anhydrite interbed permeability in this example is listed in Section PD-1.1 as “anh_perm.” As will be seen, this term is contained in the name of each input file needed to run the high and low anhydrite permeability sensitivity analyses.

The evaluation script is a file that directs execution of the WIPP PA codes. It identifies the PA codes and utility codes that are to be run and names the input files that are to be used. Evaluation script files were used by the Agency to instruct the computer to use the altered input data files needed to perform each sensitivity analysis. The identification of a file residence includes the disk name, root- and sub-directory names, file name, and extension. The anhydrite permeability example in Section PD-1.1 instructs the user to look for the evaluation script files within the EPA CMS in the library “libepa_eval.” This is the EPA CMS library containing a list of all “eval” files. From within that library the desired “eval” file is retrieved using the command “CFE,” which is a WIPP PA-specific command symbol (CMS Fetch Element) for retrieving a file from the CMS and copying it into the current working directory. This command is followed in Section PD-1.1 by the complete "eval" file name for either the high or low value of the parameter. In the subject example, the "eval" input file names are "EVAL_BF_ANH_PERM_HI.INP" for the high parameter value and "EVAL_BF_ANH_PERM_LO.INP" for the low parameter value. It may be noted that the file nomenclature convention allows the Unique Id term to be extended by appending "_HI" or "_LO" to the more general Unique Id term. Thus the Unique Id for the input files for the high anhydrite permeability value is "ANH_PERM_HI," and the Unique Id for the low value is "ANH_PERM_LO."

Example copies of evaluation script files are presented in each of the code-specific appendices to this report. One such example is the evaluation script file in Appendix BF for the high value of the Castile brine pocket volume. This example, called File BF-EVAL in the appendix, lists the global symbols and logicals used in the analysis including the Unique Id, the scenario number, the first and last codes run, and the working directory used for the run. The codes used are appropriately identified as those used for the 1996 PA. The Unique Id in this case is CAS_VOL_HI, and the scenario number is 3 (an E1 drilling intrusion at 1,000 years; see Appendix PM, Section PM-1.1). The replicate number and vector number are not material because all sampled parameters have been replaced with median values for the baseline analysis. The first code is ALGEBRA and the last code is POSTBRAG, as discussed above. The ALGEBRA input files include the EPA ALGEBRA file ALG_BF@.INP and the ICSET baseline input file IC_BF_BL. The ampersand "@" in the ALGEBRA file name is a character that stands for the Unique Id defined earlier, thus the actual ALGEBRA file name for this example is ALG_BF_CAS_VOL_HI.INP. Other characters are also used as substitutions and are defined on the second page of the example script file. The remaining codes in the sequence (PREBRAG, BRAGFLO, and POSTBRAG) take inputs from these codes and from the baseline runs. In this example the star symbol "*" identifies a comment rather than a code command. In other examples the exclamation mark "!" is used for this purpose.

The ALGEBRA input files are identified in Section PD-1.1 as the next VAX files used by the Agency to evaluate anhydrite permeability. As discussed above, these files are used to make the actual parameter changes in the PA codes needed for the sensitivity analysis. The names of two ALGEBRA input files are listed in Section PD-1.1, one for the high parameter values (ALG_BF_ANH_PERM_HI.INP) and one for the low parameter values (ALG_BF_ANH_PERM_LO.INP). Note that the Unique Ids for this sensitivity analysis are properly embedded in these file names. In other sensitivity analyses the parameter changes may have been introduced using, for example, the MATSET rather than the ALGEBRA code. The codes used are identified for each sensitivity analysis in Appendix PD as well as in the corresponding code-specific appendix.

An example ALGEBRA input file (File BF_ALG) is presented in Appendix BF for analysis of sensitivity to the EPA's Castile brine pocket volume range. The Unique Id embedded in the file name "ALG_BF_CAS_VOL_HI.INP" indicates that the parameters are being altered to reflect the high end of the range. To assist in identification, the changes made to the file are indicated in bold script. The change is effected only for Limit Block 11 wherein the log rock compressibility is reset at COMP_RCK = -10.0 (1 x 10^{-10} Pa^{-1}) replacing the sampled value, the GRIDFLO parameter (see Appendix PD Section PD-1.10 for definition) is reset at 32 replacing the sampled value, and a new variable C_POROSITY is introduced and set equal to 0.924 to adjust for the the maximum Castile brine pocket volume of 1.7 x 10^7 m^3. This new porosity term is further explained in Section PD-1.10 and is defined for the code in Limit Block 11. No further changes to the PA ALGEBRA input file were required and the rest of the file was not included in the example.

Output routines that present the high, low, and baseline results on single plots were developed to display the sensitivity analysis results for the BRAGFLO and BRAGFLO-DBR runs and are initiated using a parallel approach to that for the input files. An evaluation script was prepared to direct the plotting for each run. The plotting was performed using an ALGEBRA file to provide the basic computational information, a SUMMARIZE file to combine the outputs of the separate runs, and a SPLAT file to plot the results. Examples of these files are presented in Files PLOT-EVAL, PLOT-ALG, PLOT-SUM, and PLOT-SPLAT in Appendix BF and are illustrated in Figure FSCA.BF-Rev in the same appendix. The evaluation script (File EVAL_SPL_PLT_BL_HI_LO_BF_CAS_VOL.INP in the example) names the working directory and the other three files and provides the computer with an overall description of the run. The ALGEBRA file (File POSTALG_BF_253.INP), SUMMARIZE file (File SUM_BF_BL_HI_LO.INP), and SPLAT file (File SPL_BF_BL_HI_LO_CAS_VOL.INP) is each run in turn to produce the necessary plot. The ALGEBRA file is the same as used by SNL/DOE to compare outputs for the 253 performance measures discussed above and in Appendix PM Section PM-1.2, and was not changed for this sensitivity analysis. The SUMMARIZE file was prepared specifically for this analysis and the same file was used for all BRAGFLO sensitivity analysis runs. The evaluation and SPLAT files both contain the Unique Id (CAS_VOL in the example files) and are specific to each sensitivity analysis.

Output from the CUTTINGS_S and SOURCE TERM sensitivity analyses was prepared in tabular form using the GROPE code, from which sensitivity was determined by directly comparing key performance measure values for the low, high, and baseline parameter values (see Appendices CUSP and ST). Cumulative release to the ground surface was tabulated as the performance measure for CUTTINGS_S and americium and plutonium solubility were tabulated as performance measures for SOURCE TERM.

Output from the CCDFGF analyses was plotted in the form of CCDFs for the low, high, and nominal CCA-PA parameter values, and also prepared in tabular form (see Appendix CCDFGF).

Sensitivity was evaluated through a visual comparison of the CCDFs and through a comparison of tabulated CCDF values at the Agency's 0.1 and 0.001 regulatory reference probabilities.

2.3.2 Execution and Documentation

This sensitivity analysis was designed and performed by the Agency with assistance from SNL personnel working under EPA direction. The analyses were performed between March and July 1997 using the SNL VAX computer facilities in Albuquerque, New Mexico. Initial SA results were available in April and were used to support the Agency's selection of parameters for the PAVT. Later results were used to confirm the earlier results and to gain further understanding of the interactions among parameters in the PA models. Analysis and interpretation of results were the sole responsibilities of the Agency. Final results were prepared in both graphical and tabular form and have been archived in the EPA CMS within the SNL/DOE computer system. The input files needed to reproduce the sensitivity analyses have also been similarly archived. Instructions for accessing the files and reproducing these analyses are presented in this report and in the cited reference documents.

2.4 Methodology for Analyzing Results

The sensitivity results were analyzed as detailed in Appendix PM. Most results were analyzed by calculating the percent change in the values of selected performance measures at 10,000 years. As previously noted, some parameters were changed individually and some were changed in groups. Because only one set of performance measures was calculated for the high and low values of those parameters changed in groups, all parameters within the group are necessarily associated with the same sensitivity analysis result. The selection of performance measures and drilling scenarios, and the calculation of percent changes are described in detail in Appendix PM.

BRAGFLO results were individually plotted as discussed in Section PM-1.3 to help identify the most sensitive parameters. The percent change was computed as the high minus the low performance measure values divided by the lower of these two values, times 100%. The high value is the value of the performance measure corresponding to the high value of the parameter for which sensitivity was being analyzed, and similarly for the low value. Occasionally the high value of the performance measure would be numerically smaller than the low value, resulting in a negative percent difference. In cases where only high or low values were of interest, the comparison was made with the baseline value.

Through a screening process, the eleven most important performance measures in BRAGFLO were selected as previously mentioned (see Appendices PM and BF) and the average absolute percentage change was computed to determine the overall sensitivity of those measures to changes in the input parameters. This value was calculated as the average of the absolute values of the percentage change for each of the eleven performance measures. The overall BRAGFLO results were considered sensitive to changes in an input parameter (or group of parameters) if the average absolute change was greater than 25%. In reviewing the results, this value was found by the Agency to be a reasonable cutoff because average changes far exceeding 25% were found to be associated with the more sensitive parameters. The results of the sensitivity analysis for BRAGFLO parameters are presented in Section 3.1 below.

BRAGFLO-DBR results were plotted and analyzed using an approach similar to that of BRAGFLO. Of the 15 performance measures initially selected by the Agency for review, the Agency determined that the cumulative direct brine release to the ground surface was the most critical parameter and the SA results were evaluated based only on the absolute percent change in that performance measure. Again, BRAGFLO-DBR results were considered sensitive to changes in an input parameter if the absolute change was greater than 25%. The results of the sensitivity analysis for BRAGFLO-DBR parameters are presented in Section 3.2 below.

CUTTINGS_S results were prepared in tabular form using the GROPE code, from which sensitivity was determined by directly comparing cumulative releases to the ground surface for the low, high, and baseline parameter values. Results were considered sensitive to changes in an input parameter if the absolute change was greater than 25%. The results of the sensitivity analysis for CUTTINGS_S parameters are presented in Section 3.3 below.

SOURCE TERM results were also prepared in tabular form using the GROPE code, from which sensitivity was determined by directly comparing solubilities of americium and plutonium for the low, high, and baseline parameter values. Results were considered sensitive to changes in an input parameter if the average absolute change in the two solubilities was greater than 25%. The results of the sensitivity analysis for SOURCE TERM parameters are presented in Section 3.4 below.

CCDFGF results were plotted and also prepared in tabular form. Sensitivity was evaluated through a visual comparison of the CCDFs and through a comparison of tabulated CCDF values at the Agency's 0.1 and 0.001 regulatory reference probabilities. Results were considered sensitive to changes in input parameters if the absolute change was greater than 25%. In the case of the passive institutional control credit, only high values of the parameter were of interest (corresponding to no reduction in drilling rates), and the results were compared to the baseline (CCA PA) CCDF. The results of the sensitivity analyses for CCDFGF parameters are presented in Section 3.5 below.

3.0 EVALUATION OF RESULTS

3.1 BRAGFLO Parameters

The results of the sensitivity analysis of BRAGFLO parameters are summarized in Table 3.1-1 for the 24 analyses performed using this code. Sixteen of the 24 analyses resulted in average absolute percent changes of less than 25% and are therefore considered by the Agency to have no significant impact. Parameters without significant impact included all of the Castile brine pocket physical properties; waste compressibility; permeability of the open borehole, panel seal, and experimental/operations areas; probability of microbial degradation; steel corrosion rate; anhydrite interbed initial porosity and pressure; density of iron; and the gas generation rates due to microbial action. The DRZ, borehole plug, and long term borehole permeabilities were associated with average changes on the order of several hundred percent and potentially impact the direct brine and spallings releases. The anhydrite interbed permeability and densities of organic wastes (rubber, plastic, and cellulosics) were associated with changes on the order of several thousand percent and are considered to potentially impact direct brine releases, spallings releases, and brine releases to the Culebra and at the land withdrawal boundary through the anhydrite interbeds. The waste densities were associated with changes of over 10,000% and may affect direct brine releases, spallings releases, and brine releases at the land withdrawal boundary.

3.2 BRAGFLO-DBR Parameters

The results of the sensitivity analysis of BRAGFLO-DBR parameters are summarized in Table 3.2-1 for the five sensitivity analyses performed using this code. Only one of these analyses, the maximum period of uncontrolled borehole flow, resulted in an average absolute percent change greater than 25%. The average change for this parameter was 197% and affects direct brine releases. The remaining BRAGFLO-DBR parameters had average percent changes of less than 25% and are not considered significant.

3.3 CUTTINGS/CAVINGS/SPALLINGS Parameters

The results of the sensitivity analysis of CUTTINGS/CAVINGS/SPALLINGS parameters are summarized in Table 3.3-1 for the six sensitivity analyses performed using the CUTTINGS_S code. One of these analyses, the gravity scaling factor, resulted in an average absolute percent change of less than 25% and is therefore not considered significant. Two of the varied parameters, waste permeability and waste area absolute roughness, were found to no longer be used in the PA calculations and therefore had no impact. Two parameters, the drill string angular velocity and particle cementation strength, were found to result in changes on the order of 100%, and the remaining parameter, waste shear resistance, was found to result in a change of about 1,400%. The three parameters with changes greater than 25% affect cavings and spallings releases.

3.4 SOURCE TERM Parameters

The results of the sensitivity analysis of SOURCE TERM parameters are summarized in Table 3.4-1 for the three sensitivity analyses performed using this code. The two analyses for the microbial action and humic colloid proportionality constants resulted in average absolute percent changes of less than 25% and are therefore not considered significant. The remaining analysis, wherein a number of solubility parameters were varied together, resulted in an average absolute change of 51%. The actual sign of this change was negative, indicating that the average of americium and plutonium solubility decreased as a result of the variations in the input parameters shown on the table. This change would affect releases accompanying brine flow to the Culebra and land withdrawal boundary, as well as direct brine releases.

3.5 CCDFGF Parameters

The results of the sensitivity analyses of CCDFGF parameters are summarized in Table 3.5-1 for the two sensitivity analyses performed using this code. Neither variations in the probability of encountering a brine pocket nor elimination of PICs credit changed the CCDF values used for analysis (see Section 2.4) by more than 25%, thus the PA results are not considered to be sensitive to either parameter.

4.0 SUMMARY OF RESULTS

The analyses conducted in this study are ranked by sensitivity in Table 4.0-1. The model results were found to be most sensitive to changes in the densities of waste materials which affect the assumed waste mass in the repository. The average absolute change in performance measures due to changes in waste density was over 100,000% when the densities of all waste materials were varied simultaneously. When the densities of the organic waste materials were varied separately by type of waste, the average change in performance measures varied from 70,000% to over 80,000%. However, when the density of the waste iron inventory was varied separately, the average change in performance measures was only 5%. The only other parameters to effect an average absolute percent change in performance measures exceeding 1,000% were the anhydrite interbed permeability and the waste shear resistance. Seven additional parameters were found to effect changes between 25% and 1,000%, and the remaining 27 parameters were found to effect changes of less than 25%, as shown in the table.

Table 2.1-1. Sensitivity Analyses Performed by EPA

Model and Analysis Number	Principal Parameter or Analysis Objective
BRAGFLO	
1	Anhydrite permeability
2	Anhydrite porosity
3	Anhydrite initial pressure
4	Open borehole permeability
5	Long term borehole permeability
6	Borehole plug permeability
7	Borehole plug porosity
8	Castile brine pocket rock compressibility
9	Castile brine pocket volume - CCA range
10	Castile brine pocket volume - EPA range
11	Castile brine pocket initial pressure
12	Disturbed rock zone permeability
13	Experimental and operations area permeability
14	Panel seal permeability
15	Waste area rock compressibility
16	Steel corrosion rate
17	Waste material combined inventory
18	Waste iron inventory
19	Waste cellulosics inventory
20	Waste rubber inventory
21	Waste plastic inventory
22	Gas generation rate due to microbial action under humid conditions
23	Gas generation rate due to microbial action under inundated conditions
24	Microbial degradation effects
BRAGFLO-DBR	
1	Castile brine pocket volume
2	DBR cutoff gas flow rate
3	Maximum period of uncontrolled borehole flow
4	Minimum period of uncontrolled borehole flow
5	Panel seal permeability

Table 2.1-1. Sensitivity Analyses Performed by EPA (Continued)

Model and Analysis Number	Principal Parameter or Analysis Objective
CUTTINGS_S	
1	Drill string angular velocity
2	Waste shear resistance
3	Waste area absolute roughness
4	Waste permeability
5	Gravity scaling factor
6	Particle cementation strength
SOURCE TERM	
1	Actinide solubility parameters
2	Microbial colloid proportionality constant
3	Humic colloid proportionality constant
CCDFGF	
1	Probability of encountering Castile brine pocket
2	Passive institutional control drilling reduction factor

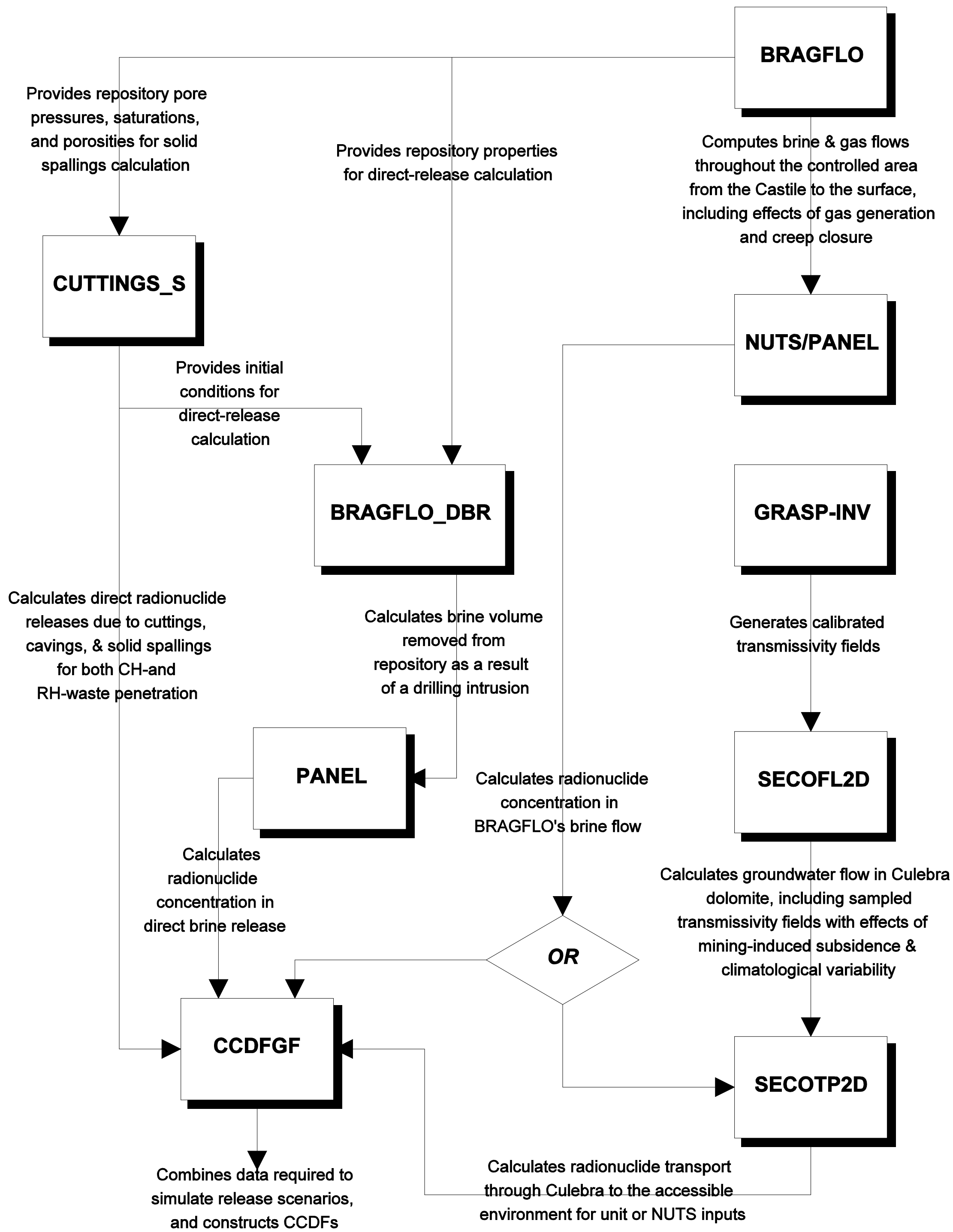

Figure 2.2-1 Generalized Performance Assessment Flowchart

Table 3.1-1. BRAGFLO Sensitivity Analysis Summary Table

ID No.	Material ID	Parameter ID	Minimum	Median	Maximum	Average Change	Type of Impact
	1. Anhydrite Permeability						
591	S_MB139	PRMX_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
592		PRMY_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
593		PRMZ_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
570	S_MB138	PRMX_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
571		PRMY_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
572		PRMZ_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
531	S_ANH_AB	PRMX_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
532		PRMY_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
533		PRMZ_LOG*	-21.0	-18.89	-17.1	2347%	DBR,SPALL,CUL,LWB
	2. Anhydrite Porosity						
528	S_ANH_AB	POROSITY*	6.0E-3	1.1E-2	1.7E-2	0%	NONE
567	S_MB138	POROSITY*	6.0E-3	1.1E-2	1.7E-2	0%	NONE
588	S_MB139	POROSITY*	6.0E-3	1.1E-2	1.7E-2	0%	NONE
	3. Anhydrite Initial Pressure						
546	S_HALITE	PRESSURE	1.10E+07	1.24E+07	1.38E+07	10%	NOT SIGNIFICANT
	4. Open Borehole Permeability						
3134	BH_OPEN	PRMX_LOG*	-9.0	-9.0	-6.0	0%	NONE
3186		PRMY_LOG*	-9.0	-9.0	-6.0	0%	NONE
3187		PRMZ_LOG*	-9.0	-9.0	-6.0	0%	NONE
	5. Long Term Borehole Permeability						
3184	BH_SAND	PRMX_LOG*	-17.0	-12.5	-11.0	330%	DBR, SPALL
3190		PRMY_LOG*	-17.0	-12.5	-11.0	330%	DBR, SPALL
3191		PRMZ_LOG*	-17.0	-12.5	-11.0	330%	DBR, SPALL
	6. Borehole Plug Permeability						
3185	CONC_PLUG	PRMX_LOG*	-18	-16.3	-11	101%	DBR, SPALL
3192		PRMY_LOG*	-18	-16.3	-11	101%	DBR, SPALL
3193		PRMZ_LOG*	-18	-16.3	-11	101%	DBR, SPALL
	7. Borehole Plug Porosity						
3147	CONC_PLUG	POROSITY	0.24	0.32	0.4	1%	NOT SIGNIFICANT
	8. Castile Brine Pocket Rock Compressibility						
61	CASTILER	COMP_RCK	-11.3	-10.0	-8.0	2%	NOT SIGNIFICANT
	9. Castile Brine Pocket Volume- CCA Range						
	Assumed Volume Range (m^3)		3.2E+04	1.28E+05	1.6E+05	**	- -
2918	CASTILER	GRIDFLO*	1	16	32	**	- -
	10. Castile Brine Pocket Volume- EPA Range						
	Assumed Volume Range (m^3)		3.4E+06	1.28E+05	1.7E+07	1%	NOT SIGNIFICANT
61	CASTILER	COMP_RCK*	2.0E-11	1.0E-10	1.0E-10	1%	NOT SIGNIFICANT
2918		GRIDFLO*	1	16	32	1%	NOT SIGNIFICANT
		C_POROSITY*	0.1848	0.00696	0.924	1%	NOT SIGNIFICANT
	11. Castile Brine Pocket Initial Pressure						
66	CASTILER	PRESSURE	1.11E+7	1.27E+7	1.70E+7	0%	NONE
	12. DRZ Permeability						
198	DRZ_1	PRMX_LOG*	-21.0	-15.0	-12.5	325%	DBR
199		PRMY_LOG*	-21.0	-15.0	-12.5	325%	DBR
200		PRMZ_LOG*	-21.0	-15.0	-12.5	325%	DBR

Table 3.1-1. BRAGFLO Sensitivity Analysis Summary Table (Continued)

ID No.	Material ID	Parameter ID	Minimum	Median	Maximum	Average Change	Type of Impact
	13. Experimental and Operations Area Permeability						
214	EXP_AREA	PRMX_LOG*	-17.0	-11.0	-11.0	0%	NONE
215		PRMY_LOG*	-17.0	-11.0	-11.0	0%	NONE
216		PRMZ_LOG*	-17.0	-11.0	-11.0	0%	NONE
14	OPS_AREA	PRMX_LOG*	-17.0	-11.0	-11.0	0%	NONE
15		PRMY_LOG*	-17.0	-11.0	-11.0	0%	NONE
16		PRMZ_LOG*	-17.0	-11.0	-11.0	0%	NONE
	14. Panel Seal Permeability						
259	PAN_SEAL	PRMX_LOG*	-21.0	-15.0	-13.0	0%	NONE
260		PRMY_LOG*	-21.0	-15.0	-13.0	0%	NONE
261		PRMZ_LOG*	-21.0	-15.0	-13.0	0%	NONE
	15. Waste Area Rock Compressibility						
653	WAS_AREA	COMP_RCK	4.06E-8	1.53E-7	1.16E-6	0%	NONE
	16. Steel Corrosion Rate						
2907	STEEL	CORRMCO2	1.0E-30	7.94E-15	1.59E-14	7%	NOT SIGNIFICANT
	17. Waste Material Combined Inventory						
2046	WAS_AREA	DRUBBRHW*	0	3.3E+00	4.4E+02	103611%	DBR,SPALL,LWB
2042		DRUBBCHW*	0	1.0E+01	6.3E+02	103611%	DBR,SPALL,LWB
2275		DPLASRHW*	0	1.5E+01	6.2E+00	103611%	DBR,SPALL,LWB
2043		DPLASCHW*	0	3.4E+01	8.9E+02	103611%	DBR,SPALL,LWB
2044		DIRONRHW*	0	1.0E+02	1.7E+03	103611%	DBR,SPALL,LWB
2040		DIRONCHW*	0	1.7E+02	2.6E+03	103611%	DBR,SPALL,LWB
2274		DCELLRHW*	0	1.7E+02	5.7E+02	103611%	DBR,SPALL,LWB
2041		DCELLCHW*	0	5.4E+01	9.6E+02	103611%	DBR,SPALL,LWB
	18. Waste Iron Inventory						
2044	WAS_AREA	DIRONRHW*	0	1.0E+02	1.7E+03	5%	NOT SIGNIFICANT
2040		DIRONCHW*	0	1.7E+02	2.6E+03	5%	NOT SIGNIFICANT
	19. Waste Cellulosics Inventory						
2274	WAS_AREA	DCELLRHW*	0	1.7E+02	5.7E+02	86336%	DBR,SPALL,LWB
2041		DCELLCHW*	0	5.4E+01	9.6E+02	86336%	DBR,SPALL,LWB
	20. Waste Rubber Inventory						
2046	WAS_AREA	DRUBBRHW*	0	3.3E+00	4.4E+02	70329%	DBR,SPALL,LWB
2042		DRUBBCHW*	0	1.0E+01	6.3E+02	70329%	DBR,SPALL,LWB
	21.Waste Plastic Inventory						
2275	WAS_AREA	DPLASRHW*	0	1.5E+01	6.2E+00	86337%	DBR,SPALL,LWB
2043		DPLASCHW*	0	3.4E+01	8.9E+02	86337%	DBR,SPALL,LWB
	22. Gas Generation Rate due to Microbial Action under Humid Conditions						
656	WAS_AREA	GRATMICH	0.0	6.342E-10	1.268E-9	0%	NONE
	23. Gas Generation Rate due to Microbial Action under Inundated Conditions						
657	WAS_AREA	GRATMICI	3.171E-10	4.915E-9	9.512E-9	1%	NOT SIGNIFICANT
	24. Microbial Degradation Effects						
2823	WAS_AREA	PROBDEG*	0.0	2.0	2.0	6%	NOT SIGNIFICANT
2824	REPOSIT	PROBDEG*	0.0	2.0	2.0	6%	NOT SIGNIFICANT

DBR = Increase direct brine releases
SPALL = Increase spall release
CUL = Increase releases to the Culebra
LWB = Increase releases to the Land Withdrawal Boundary through the marker beds.
* = Parameters varied together
** = Results not analyzed (see Appendix PD Section PD-1.9)

Table 3.2-1. BRAGFLO-DBR Sensitivity Analysis Summary Table

ID No.	Material ID	Parameter ID	Minimum	Median	Maximum	Average Change	Type of Impact
	1. Castile Brine Pocket Volume						
3473	BLOWOUT	THCK_CAS*	24	12.34	7	0%	NONE
3456		RE_CAST*	30	114	230	0%	NONE
	2. DBR Cutoff Gas Flow Rate						
3470	BLOWOUT	GAS_MIN	50	100	200	0%	NONE
	3. Maximum Period of Uncontrolled Borehole Flow						
3471	BLOWOUT	MAXFLOW	5	11	20	197%	DBR
	4. Minimum Period of Uncontrolled Borehole Flow						
3472	BLOWOUT	MINFLOW	1	3	5	0%	NONE
	5. Panel Seal Permeability						
259	PAN_SEAL	PRMX_LOG*	-21.0	-15.0	-13.0	15%	NOT SIGNIFICANT
260		PRMY_LOG*	-21.0	-15.0	-13.0	15%	NOT SIGNIFICANT
261		PRMZ_LOG*	-21.0	-15.0	-13.0	15%	NOT SIGNIFICANT

Time intrusions calculated at 1200, 1400, 3000, 5000, and 10000 years for the upper and lower waste panels.
* = Parameters varied together.

Table 3.3-1. CUTTINGS/CAVINGS/SPALLINGS Sensitivity Analysis Summary Table

ID No.	Material ID	Parameter ID	Minimum	Median	Maximum	Average Change	Type of Impact	
	1. Drill String Angular Velocity							
27	BOREHOLE	DOMEGA	4.200	7.800	23.000	60%	CAV	
	2. Waste Shear Resistance							
2254	BOREHOLE	TAUFAIL		0.010	0.100	10.000	1413%	CAV
	3. Waste Area Absolute Roughness							
651	WAS_AREA	ABSROUGH	0.01	0.025	0.04	*	- -	
	4. Waste Permeability							
3259	BLOWOUT	APORO	8.0E-15	1.7E-13	1.1E-12	*	- -	
	5. Gravity Scaling Factor							
3256	BLOWOUT	FGE	1.000	9.300	18.100	6%	NOT SIGNIFICANT	
	6. Particle Cementation Strength							
3245	BLOWOUT	CEMENT	**	1 PSI	700 PSI	149%	SPALL	

* = Parameter not used in CUTTINGS_S
** = This value was not evaluated.
SPALL = Increase spallings release
CAV = Increase in cavings release

Table 3.4-1. SOURCE TERM Sensitivity Analysis Summary Table

ID No.	Material ID	Parameter ID	Minimum	Median	Maximum	Average Change	Type of Impact		
	1. Actinide Solubility Parameters								
3433	PHUMOX3	PHUMSIM*	0.008	0.19	0.19	51%[$]	DBR, CUL, LWB		
3429		PHUMCIM*	0.065	1.37	1.6	51%[$]	DBR, CUL, LWB		
3434	PHUMOX4	PHUMSIM*	6.3	6.3	6.3	51%[$]	DBR, CUL, LWB		
3430		PHUMCIM*	6.3	6.3	6.3	51%[$]	DBR, CUL, LWB		
3435	PHUMOX5	PHUMSIM*	0.000053	0.0048	0.00091	51%[$]	DBR, CUL, LWB		
3431		PHUMCIM*	0.00043	0.0039	0.0074	51%[$]	DBR, CUL, LWB		
3436	PHUMOX6	PHUMSIM*	0.008	0.056	0.12	51%[$]	DBR, CUL, LWB		
3432		PHUMCIM*	0.062	0.28	0.51	51%[$]	DBR, CUL, LWB		
3317	PU	PROPMIC*	7.00E-4	0.300	2.000	51%[$]	DBR, CUL, LWB		
3311	AM	PROPMIC*	1.900	3.600	5.400	51%[$]	DBR, CUL, LWB		
3292	SOLU6	SOLCIM*		-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB	
3291		SOLSIM*	-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB		
3264	SOLPU3	SOLCIM*		-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB	
3265		SOLSIM*	-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB		
3389	SOLPU4	SOLCIM*		-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB	
3266		SOLSIM*	-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB		
3263	SOLAM3	SOLCIM*			-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB
3262		SOLSIM*	-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB		
3393	SOLTH4	SOLSIM*	-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB		
3390	SOLU4	SOLSIM*	-2.0	-9.0E-2	1.4	51%[$]	DBR, CUL, LWB		
	2. Microbial Colloid Proportionality Constant								
3317	PU	PROPMIC*	7.00E-4	0.300	2.000	4%	NOT SIGNIFICANT		
3311	AM	PROPMIC*	1.900	3.600	5.400	4%	NOT SIGNIFICANT		
	3. Humic Colloid Proportionality Constant								
3433	PHUMOX3	PHUMSIM*	0.008	0.19	0.19	3%	NOT SIGNIFICANT		
3429		PHUMCIM*	0.065	1.37	1.6	3 %	NOT SIGNIFICANT		
3434	PHUMOX4	PHUMSIM*	6.3	6.3	6.3	3 %	NOT SIGNIFICANT		
3430		PHUMCIM*	6.3	6.3	6.3	3 %	NOT SIGNIFICANT		
3435	PHUMOX5	PHUMSIM*	0.000053	0.0048	0.00091	3 %	NOT SIGNIFICANT		
3431		PHUMCIM*	0.00043	0.0039	0.0074	3 %	NOT SIGNIFICANT		
3436	PHUMOX6	PHUMSIM*	0.008	0.056	0.12	3 %	NOT SIGNIFICANT		
3432		PHUMCIM*	0.062	0.28	0.51	3 %	NOT SIGNIFICANT		

* = Parameters varied together
[$] = Percent change is the average of AM and PU solubility
DBR = Increase in direct brine releases
LWB = Increase in releases to the Land Withdrawal Boundary through the marker beds
CUL = Increase in releases to the Culebra

Table 3.5-1. CCDFGF Sensitivity Analysis Summary Table

ID No.	Material ID	Parameter ID	Minimum	Median	Maximum	Average Change	Type of Impact
	1. Probability of Encountering Castile Brine Pocket						
3493	GLOBAL	PBRINE	1%	8%	60%	7%	NOT SIGNIFICANT
	2.Passive Institutional Control Drilling Reduction Factor						
3500	GLOBAL	FPICM	**	0.01	1.0	9%	NOT SIGNIFICANT
3501	GLOBAL	FPICD	**	0.01	1.0	9%	NOT SIGNIFICANT

** = This value was not evaluated.

Table 4.0-1. Ranked Summary of Sensitivity Analysis Results

PA Model	Sensitivity Analysis	Average Change	Type of Impact
PARAMETERS WITH GREATER THAN 100,000% CHANGE			
BRAGFO	Waste Material Combined Inventory	103,611%	DBR, SPALL, LWB
PARAMETERS WITH 10,000% TO 100,000% CHANGE			
BRAGFLO	Waste Plastic Inventory	86,337%	DBR, SPALL, LWB
BRAGFLO	Waste Cellulosics Inventory	86,336%	DBR, SPALL, LWB
BRAGFLO	Waste Rubber Inventory	70,329%	DBR, SPALL, LWB
PARAMETERS WITH 1,000% TO 10,000% CHANGE			
BRAGFLO	Anhydrite Permeability	2,347%	DBR, SPALL, CUL, LWB
CUTTINGS_S	Waste Shear Resistance	1,413%	CAV
PARAMETERS WITH 100% TO 1,000% CHANGE			
BRAGFLO	Long Term Borehole Permeability	330%	DBR, SPALL
BRAGFLO	DRZ Permeability	325%	DBR
BRAGFLO-DBR	Maximum Period of Uncontrolled Borehole Flow	197%	DBR
CUTTINGS_S	Particle Cementation Strength	149%	SPALL
BRAGFLO	Borehole Plug Permeability	101%	DBR, SPALL
PARAMETERS WITH 25% TO 100% CHANGE			
CUTTINGS_S	Drill String Angular Velocity	60%	CAV
SOURCE TERM	Actinide Solubility Parameters	51%	DBR, CUL, LWB
PARAMETERS WITH LESS THAN 25% CHANGE			
BRAGFLO-DBR	Panel Seal Permeability	15%	NOT SIGNIFICANT
BRAGFLO	Anhydrite Initial Pressure	10%	NOT SIGNIFICANT
CCDFGF	Passive Institutional Control Drilling Reduction Factor	9%	NOT SIGNIFICANT
CCDFGF	Probability of Encountering Castile Brine Pocket	7%	NOT SIGNIFICANT
BRAGFLO	Steel Corrosion Rate	7%	NOT SIGNIFICANT
CUTTINGS_S	Gravity Scaling Factor	6%	NOT SIGNIFICANT
BRAGFLO	Microbial Degradation Effects	6%	NOT SIGNIFICANT
BRAGFLO	Wasste Iron Inventory		5% NOT SIGNIFICANT
SOURCE TERM	Microbial Colloid Proportionality Constant	4%	NOT SIGNIFICANT
SOURCE TERM	Humic Colloid Proportionality Constant	3%	NOT SIGNIFICANT
BRAGFLO	Castile Brine Pocket Rock Compressibility	2%	NOT SIGNIFICANT
BRAGFLO	Castile Brine Pocket Volume - EPA Range	1%	NOT SIGNIFICANT
BRAGFLO	Borehole Plug Porosity	1%	NOT SIGNIFICANT
BRAGFLO	Gas Generation Rate due to Microbial Action Under Inundated Conditions	1%	NOT SIGNIFICANT
BRAGFLO	Gas Generation Rate due to Microbial Action Under Humid Conditions	0%	NONE
BRAGFLO	Open Borehole Permeability	0%	NONE
BRAGFLO	Experimental and Operations Area Permeability	0%	NONE
BRAGFLO	Castile Brine Pocket Initial Pressure	0%	NONE
BRAGFLO	Panel Seal Permeability	0%	NONE
BRAGFLO	Anhydrite Porosity	0%	NONE
BRAGFLO	Waste Area Rock Compressibility	0%	NONE
BRAGFLO-DBR	Castile Brine Pocket Volume	0%	NONE
BRAGFLO-DBR	Minimum Period of Uncontrolled Borehole Flow	0%	NONE
BRAGFLO-DBR	DBR Cutoff Gas Flow Rate	0%	NONE

Table 4.0-1. Ranked Summary of Sensitivity Analysis Results (Continued)

PA Model	Sensitivity Analysis	Average Change	Type of Impact
BRAGFLO	Castile Brine Pocket Volume - CCA Range	**	NONE
CUTTINGS_S	Waste Permeability	*	NONE
CUTTINGS_S	Waste Area Absolute Roughness	*	NONE

* = Parameter not used in PA
** = Analysis superseded by Castile Brine Pocket Volume - EPA Range