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NM3307

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

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4/25/2
SPK

2. ☒ Analysis	Check all that apply	3. ☐ Model	Check all that apply
Type of Analysis	☐ Engineering ☒ Performance Assessment ☐ Scientific	Type of Model	☐ Conceptual Model ☐ Abstraction Model ☐ Mathematical Model ☐ System Model ☐ Process Model
Intended Use of Analysis	☐ Input to Calculation ☒ Input to another Analysis or Model ☐ Input to Technical Document ☒ Input to other Technical Products	Intended Use of Model	☐ Input to Calculation ☐ Input to another Model or Analysis ☐ Input to Technical Document ☐ Input to other Technical Products
Describe use: Development of saturated zone stochastic and constant parameters that are input to the SZ site-scale model for TSPA-SR.		Describe use:	

4. Title:
Uncertainty Distribution for Stochastic Parameters

5. Document Identifier (including Rev. No. and Change No., if applicable):
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		Printed Name	Signature	Date
8.	Originator	Stephanie Kuzio	Stephanie Kuzio	4/24/2000
9.	Checker	Michael Kelley	Michael Kelley	4/24/00
10.	Lead/Supervisor	Bill Arnold	Bill W. Arnold	4/24/00
11.	Responsible Manager	Cliff Ho	Clifford K. Ho	4/24/00

12. Remarks: The following contributed significantly to this report: Bill Arnold, Mike Wallace, Theresa Brown and Jack Gauthier

Per Section 5.5.6 of AP-3.10Q, the responsible manager has determined that the subject AMR is not subject to AP-2.14Q review because the analysis does not affect a discipline or area other that the originating organization (Performance Assessment). Some of the upstream suppliers for this AMR included Andy Wolfsberg (Los Alamos), June Fabryka-Martin (Los Alamos), Paul Reimus (Los Alamos) and Steve Alcorn (Alcorn Environmental) and they worked closely with the originator in the development of this AMR to ensure that the inputs were used properly. The downstream user of the information resulting from this AMR is Performance Assessment (PA), which is also the originating organization of this work. PA leads, such as Bill Arnold, have worked closely with the originator during the development of this AMR.

Editorial correction changed total page count on cover page. RWA 5/17/00

ENCLOSURE 1

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD

Complete Only Applicable Items

2. Analysis or Model Title:

Uncertainty Distribution for Stochastic Parameters

3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-NBS-MD-000011 REV 00

4. Revision/Change No.	5. Description of Revision/Change
00	Initial Issue

CONTENTS

FIGURES

TABLES

ACRONYMS

AMR	analysis and model report
CDF	cumulative distribution function
DOE	Department of Energy
DIRS	Data Input Reference System
DTN	data tracking number
E	mean
FEHM	Finite Element Heat and Mass-Transfer Code
ISM	Integrated Site Model
IRSR	Issue Resolution Status Report
LANL	Los Alamos National Laboratory
LB	lower bound
LHS	Latin Hypercubed Sampling
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
PAO	Performance Assessment Operations
PFBA	pertafluorobenzoic acid
PMR	Process Model Report
Q	Qualified Data
QA	Quality Assurance
RIP	Repository Integrated Program
SD	standard deviation
SZ	saturated zone
TBV	to be verified

Uncertainty Distribution for Stochastic Parameters

TSPA-SR	Total System Performance Assessment for the Site Recommendation
UTM	Universal Transverse Mercator
YM	Yucca Mountain
UB	upper bound
USGS	United States Geological Survey
UZ	unsaturated zone

1. PURPOSE

The purpose of this analysis is to classify the parameters that will be included as uncertain and determine the constant parameters for the saturated zone (SZ) site-scale Total System Performance Assessment for the Site Recommendation (TSPA-SR) analyses. The stochastic distributions and constant parameter values are assessed in this analysis. The stochastic parameters are sampled for 100 realizations and the result of the simulation is included in this analysis and model report (AMR). The Work Direction and Planning Document associated with this analysis is entitled, Parameter Uncertainty Analysis (CRWMS M&O 1999a). The constant and stochastic parameters described herein, are inputs required for the SZ site-scale flow and transport model that will be included in the TSPA-SR.

2. QUALITY ASSURANCE

The Quality Assurance (QA) program applies to the development of this AMR. The Performance Assessment Operations (PAO) responsible manager has evaluated this activity in accordance with QAP-2-0, *Conduct of Activities*. The QAP-2-0 activity evaluation (CRWMS M&O 1999d) determined that the development of this AMR is subject to the Quality Assurance Requirements and Description (DOE 2000) requirements. The following procedures have been followed in the process of completing this report: AP-3.10Q, *Analysis and Models*; AP-3.15Q, *Managing Technical Product Inputs*; AP-SI.1Q, *Software Management*; and AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System.*

3. COMPUTER SOFTWARE AND MODEL USAGE

No models were used or developed in this AMR. The software cited below is appropriate for use in this application. This analysis used four computers as described: DELL OptiPlex GX1s, Sandia National Laboratories serial numbers are R429068, R429067, R430528 and an HP Kayak XU; S817845. The range of validation for Excel, Grapher, Surfer, and GoldSim is the set of real numbers.

3.1 COMMERCIALLY AVAILABLE SOFTWARE USED IN ANALYSIS

- Excel 97-SR-1 - This software was used to perform averages of data and other simple arithmetic operations. These calculations could have been performed by hand but a spreadsheet was used for ease in calculation. No marcos were included in the excel spreadsheets. The calculations were checked according to AP-3.10Q. This software was also used to visually display data. Figures developed with the software are indicated in Attachment I.

Per AP-SI.1Q, Section 5.1, the following information is required to document software routines:

- Identification, including version of the software routine:
  Kc_am.xls Version 0.0
  Newbulkd.xls Version 0.0
  Geo_names.xls Version 0.0
  De_Tortuosity.xls Version 0.0
  Alluv_colloid_aw.xls Version 0.0

- Name and version of commercial software that the routine was developed: All routines cited above were developed using Excel 97-SR-1.

- Documentation that the software routine provides correct results.

  Kc_am.xls Version 0.0: Calculates a cumulative distribution function (CDF) for the K_c parameter. The calculation is the rank of the data value/the total number of data values. This is checked in spreadsheet Kc_am.xls, in worksheet "check SR". The worksheet "check SR" documents the test case and verifies the routine provides correct results for the input parameters

  Newbulkd.xls Version 0.0: Calculates averages of bulk density and matrix porosity values and Equation 15 as discussed in Section 6.9.1. The averages are checked with a simple example in spreadsheet Newbulkd.xls, worksheet "check SR". The worksheet "check SR" documents the test case and verifies the routine provides correct results for the input parameters. The Excel function AVERAGE was used to average the bulk densities and matrix porosity values and therefore does not need to be verified.

  Geo_names.xls Version 0.0: Calculates a probability distribution function using the excel function "normdist". This does not have to be validated because this is a standard built-in function of Excel (see spreadsheet Geo_names.xls).

  De_Tortuosity.xls Version 0.0: Calculates the tortuosity as described in Section 6.8.3 using Equation 14 (see spreadsheet De_Tortuosity.xls). Spreadsheet kc_am.xls, worksheet "check SR" documents a test case of division and verifies the routine in the spreadsheet De_Tortuosity.xls provides the correct results for the input parameters.

  Alluv_colloid_aw.xls Version 0.0: Calculates a CDF for the K_c parameter. The calculation is explained in the spreadsheet Alluv_colloid_aw.xls, in worksheet "check SR". The worksheet "check SR" documents the test case and verifies the routine provides correct results for the input parameters.

- Grapher 2.00 - This software should be considered exempt per AP-SI.1Q Section 2.1 because the software is only used to visually display data. Figures developed with the software are indicated in Attachment I.

- Surfer 6.03 - This software should be considered exempt per AP-SI.1Q Section 2.1 because the software is only used to visually display data. Figures developed with the software are indicated in Attachment I.

3.2 SOFTWARE UNDER CONFIGURATION MANAGEMNET CONTROL (CM)

GoldSim 6.03 - The Latin Hypercube Module of Goldsim was used to perform the 100 realizations of the stochastic parameters developed in this AMR. All input parameters for the TSPA-SR calculation are simulated together to ensure consistency for the TSPA-SR calculations. GoldSim is valid for the range of the stochastic parameters defined in this AMR. GoldSim is in the process of being qualified (Sandia National Laboratory 2000. GoldSim V6.03), therefore AP-SI.1Q Section 5.11, *Interim Use of Unqualified Software to Support SR Products*, was followed.

4. INPUTS

The primary data used in this report is indicated below in Table 1, or for a more detailed listing of references and data information see the attached Document Input Reference System (DIRS) form. The definitions of the hydrogeologic units are described in Table 2.

The input data used for this AMR is considered appropriate to develop the SZ input parameters for the TSPA-SR calculation and the SZ flow and transport model. The best data that is currently available was used as input to this AMR and is described in Table 1. When ever possible, data was used from the Technical Data Management System. Other sources of input data included technical output from other AMRs and reports that are considered appropriate for the application of the input.

4.1 DATA AND PARAMETERS

Table 1. Parameters and Inputs

Parameter	Parameter (GOLDSIM) Input Name	Input Status	Unit	Source/Data Tacking Number (DTN)
Groundwater specific discharge (stochastic)	GWSPD	Q	All	DTN: MO0003SZFWTEEP.000 Expert elicitation aggregate CDF (p. 3-43).
Effective porosity alluvium (stochastic)	NVF19 and NVF7. NVF7 and NVF19 have been sampled separately.	Unconfirmed unqualified and uncontrolled (TBV) for Bedinger et al. 1989 p. A18.	Unit 19 and 7	Bedinger et al. 1989, p. A18.
Effective Porosity (constant)	-	Unqualified and unconfirmed (TBV) (for unit 6,5 and 3 only) Unconfirmed, unqualified and uncontrolled (TBV) for Bedinger et al. 1989 p. A18 Unconfirmed, unqualified and uncontrolled (TBV) DOE 1997 for Units 4 and 2. Unconfirmed, unqualified and uncontrolled (TBV) for Burbey and Wheatcraft 1986.	Unit 18-16, 6-1	Unit 18: Bedinger et al. 1989, Table 1, p. A18 (fine grain valley fill) Unit 17: Bedinger et al. 1989, Table 1, p. A18, (relatively dense carbonate rock) Unit 16: Bedinger et al. 1989, Table 1, p. A18 (Lava flows, average of mean fract. and dense) Unit 6,5 and 3: DTN: SNT05082597001.003 Unit 4 and 2: DOE 1997 report, Table 8-1, p. 8-5 Unit 1: Bedinger et al. 1989, Table 1, p. A18 (mean from felsic intrusive rocks, deep) Total Porosity: Burbey and Wheatcraft 1986, p. 26 and DOE 1997, Table 8-1 and 8-2

Table 1. Parameters and Inputs (Continued)

Parameter	Parameter (GOLDSIM) Input Name	Input Status	Unit	Source/Data Tacking Number (DTN)
Matrix Porosity Volcanic Units (constant) (Matrix diffusion model approach)	-	Unqualified, and unconfirmed (TBV) for SNT05082597001 .003, (Units 12, 11 and 9.) Units 15-13, 10, 9 and 8 Technical Product Output	Unit 15-8	Unit 15-13, 10, 8: MDL-NBS-GS-000004 REV 00, CRWMS M&O 1999b Unit 12, 11: DTN: SNT05082597001.003 Unit 9: DTN: SNT05082597001.003 and MDL-NBS-GS-000004, CRWMS M&O 1999b ISM 3.0 values applied within model domain in AMR CRWMS M&O 2000f
Flowing Interval Spacing (stochastic)	FISVO	Technical Product Output	Units 15-8 Volcanic Unit	DTN: SN9907T0571599.001
Bulk Density (constant)	-	Unqualified, and unconfirmed (TBV) for units 6-2, 17, 12 11 Qualified, unconfirmed Units 19, 18, and 7 Units 15-13 and 10-8 technical product output	Unit 19-1	Unit 19, 18, 7: DTN: LA 0002JC831341.001 Units 17, 12, 11, 6-2: DTN: SNT05082597001.003 Unit 15-13: MDL-NBS-GS-000004, CRWMS M&O 1999b, [a], p. 66 Unit 10, 8: MDL-NBS-GS-000004, CRWMS M&O 1999b, [a], p. 66 as used for unit 14. Unit 9: Average of Unit 11-13 and 15, MDL-NBS-GS-000004, CRWMS M&O 1999b, [a], p. 66 and SNT05082597001.003. ISM 3.0 values applied within model domain in CRWMS M&0 2000f
Sorption Coefficient (K_d) (stochastic)Np	KDNPVO	Technical Product Output	Unit 15-8 Volcanic Units	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic)Np	KDNPAL	Technical Product Output	Alluvium Units 19,7	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) I	KDIAL	Technical Product Output	Alluvium Units 19,7	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) U	KDUVO	Technical Product Output	Unit 15-8 Volcanic Units	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) U	KDUAL	Technical Product Output	Alluvium Units 19,7	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) Tc	KDTCAL	Technical Product Output	Alluvium Units 19,7	DTN: LA0003AM831341.001
Actinide matrix/alluvium K_ds for the Kc model	KDRN10	Technical Product Output	All units	DTN: LA0003AM831341.001

Table 1. Parameters and Inputs (Continued)

Parameter	Parameter (GOLDSIM) Input Name	Input Status	Unit	Source/Data Tacking Number (DTN)
Fission Products matrix/alluvium K_ds for the Kc model	KDRN9	Technical Product Output	All units	DTN: LA0003AM831341.001
Longitudinal Dispersivity	LDISP	Q	Units 19-1	DTN: MO0003SZFWTEEP.000 Expert Elicitation. Horizontal transverse dispersivity correlated with longitudinal dispersivity.
Horizontal Anisotropy (stochastic)	HAVO	Unconfirmed, unqualified and uncontrolled (TBV)	Unit 15-8 Volcanic Units	Winterle and La Femina 1999
Colloid Retardation Factor Volcanic Units	CORVO	Q Unconfirmed	Unit 15-8 Volcanic Units	DTN: LA0002PR831231.003 This parameter is perfectly correlated with CORAL (Correlation of 1)
Colloid Retardation Factor Alluvium Units	CORAL	Technical Product Output	Alluvium Units 19,7	DTN: LA0004AW12213S.001
K_c Am Parameter for reversible colloids All units	Kc_pu_gw_colloid	Technical Product Output	All units	DTN: MO0003SPAHLO12.004 and MO0004SPAKDS42.005

NOTE: a. Figure 24b and Equation 2.

Table 2. Hydrogeologic Unit Definition

Hydrogeologic Unit	Hydrogeologic Unit Identification Number
Valley fill	19
Valley fill confining unit	18
Cenozoic limestones	17
Lava Flows	16
Upper Volcanic Aquifer	15
Upper Volcanic Confining Unit	14
Lower Volcanic Aquifer Prow Pass	13
Lower Volcanic Aquifer Bullfrog	12
Lower Volcanic Aquifer Tram	11
Lower Volcanic Confining Unit	10
Older Volcanic Aquifer	9
Older Volcanic Confining Unit	8
Undifferentiated Valley Fill	7
Upper Carbonate Aquifer	6
Lower Carbonate Aquifer Thrust	5
Upper Clastic Confining Unit	4
Lower Carbonate Aquifer	3
Lower Clastic Confining Unit	2
Granites	1

NOTE: Hydrogeologic Units defined as CRWMS M&O 2000d

4.2 CRITERIA

This AMR complies with the Department of Energy (DOE) interim guidance (Dyer 1999). Subparts of the interim guidance that apply to this analysis or modeling activity are those pertaining to the characterization of the Yucca Mountain site (Subpart B, Section 15), the compilation of information regarding hydrology of the site in support of the License Application (Subpart B, Section 21(c)(1)(ii)), and the definition of hydrologic parameters and conceptual models used in performance assessment (Subpart E, Section 114(a)). A discussion of the Nuclear Regulatory Commission (NRC) Issue Resolution Status Report (IRSR) Criteria as it pertains to the SZ is discussed in the SZ Process Model Report (PMR).

4.3 CODES AND STANDARDS

This section is not applicable to this analysis. At this time, there are no known standards or codes for this type of analysis.

5. ASSUMPTIONS

In general, parameters to which the model results are sensitive, due to the combination of the numerical importance of the parameter in the model and the uncertainty in the parameter value, are represented stochastically. Conversely, it is assumed that parameters to which the model results are not sensitive, are sufficiently represented by constant values. This is a reasonable simplifying assumption because the results are not significantly altered by constant parameters due to the fact that they are certain, of little numerical importance in the model or used as placeholders in the parameter input file (i.e., parameter values that are not utilized in the simulations). The assumptions for each parameter and the justification for those assumptions are listed below. Each of the assumption sub-sections corresponds to the same section in Section 6.0.

5.1 GROUNDWATER SPECIFIC DISCHARGE (STOCHASTIC)

See Section 6.1 for the corresponding analysis section of groundwater specific discharge.

1. It is assumed that the uncertainty in groundwater flow velocities in the saturated zone is adequately represented by uniformly scaling the groundwater flux in the SZ site-scale flow model. This assumption is supported by the results of the SZ expert elicitation (CRWMS M&O 1998), in which the uncertainty distribution of specific discharge in the volcanic aquifer near Yucca Mountain is quantified. Uniform scaling of the groundwater flux in the SZ site-scale model domain causes a proportional change in the modeled specific discharge along the flowpath from the repository to the biosphere discharge location.

5.2 UNCERTAINTY OF ALLUVIUM BOUNDARY (STOCHASTIC)

See Section 6.2 for the corresponding analysis section of alluvium boundary.

1. The assumption is made that the Hydrologic Framework Model is the basis for determining the uncertainty in the location of the alluvium at the watertable along the modeled flowpath (CRWMS M&O 2000d). To maintain consistency with the Hydrologic Framework Model, the area representing the uncertainty zone is bounded on the south by boreholes indicating alluvium at the water table and on the north by boreholes with volcanic units at the water table. Where volcanic units outcrop at the land surface (as occurs west of the alluvium uncertainty zone), younger alluvium cannot be present at or below the water table.

2. The uncertainty in the location of the contact between volcanic units and alluvium at the water table is uniformly distributed between the bounds placed on the possible location of the boundaries. Given the lack of drilling data on the contact location within the bounds placed on that location, the most appropriate description of uncertainty is the uniform distribution.

5.3 EFFECTIVE POROSITY OF ALLUVIUM (STOCHASTIC) AND TOTAL POROSITY EQUIVALENT

See Section 6.3 for the corresponding analysis section of effective porosity of alluvium and total porosity equivalent.

1. The uncertainty in effective porosity of alluvium can be represented with a truncated normal distribution (the sampled values will be within the physical limits of porosity). This assumption is supported by the Bedinger et al. (1989) report on page A16, generalization 2. The assumption is also supported by the SZ expert elicitation project (CRWMS M&O 1998). The experts provided effective porosity parameters assuming a normal distribution. Also, Davis (1969) reports that, in general, porosity of a geologic medium has a normal distribution (pp. 76 and 77).

2. Bedinger et al. (1989, p. A10) values of porosity are relevant to SZ model for valley fill (unit 19) and undifferentiated alluvium (unit 7). The SZ model domain lies within the Basin and Range physiographic province of the Southwestern United States. The materials of unit 19 are comprised of alluvial fan, alluvium, fanglomerate, lacustrine, eolian, and mudflow deposits (CRWMS M&O 2000d). Therefore, the stochastic values taken from Bedinger et al. (1989, Table 1) are relevant. This is also true for the material of unit 7. CRWMS M&O (2000d, Table 1) describes unit 7's undifferentiated valley fill as having an indurated lithology. However, that only applies to areas of unit 7 which are not likely to be in the path of radionuclide transport. The area of unit 7 that might be in such a path is the southern portion, which consists of unconsolidated sediments basically similar to those of unit 19 (CRWMS M&O 2000e).

5.4 EFFECTIVE POROSITY FOR ALL NON-VOLCANIC UNITS WHICH ARE ASSIGNED A CONSTANT VALUE OF EFFECTIVE POROSITY

See Section 6.4 for the corresponding analysis section of effective porosity for all non-volcanic units which are assigned a constant value of effective porosity.

1. Effective porosities are specified constants for the units that will not be in the transport pathway. This simplifying assumption is supported based on the knowledge that the simulated radionuclide transport pathway will not include any of these units and the understanding that it will not impact the simulated flow and transport (CRWMS M&O 2000e). The transport model requires values of effective porosity, ϕ_e, for all units, whether or not the parameter is used. In effect, these values are simply placeholders, to allow the model to run.

2. Given a referenced effective porosity value for one unit, other units of the same basic rock type can be assigned the same value. The same reasoning that supports the above assumption applies here as well.

5.5 MATRIX POROSITY (CONSTANT)

See Section 6.5 for the corresponding analysis section of matrix porosity.

1. Matrix porosities are constant within hydrogeological units. Matrix porosity is only one of several parameters involved in the dual-porosity simulations employed for these units. In this formulation, advection does not occur in the matrix. As a result, the dual porosity transport simulations are far more sensitive to other parameters, including "flowing interval spacing" and "effective diffusion coefficient" than they are to matrix porosity, ϕ_m. As noted previously the sensitive parameters are treated stochastically.

2. Given a referenced matrix porosity value for one unit or group of units, other units of the same basic rock type can be assigned the same value (or average value). This assumption is supported based on the understanding that radionuclide transport will not occur in the units with borrowed porosity values (CRWMS M&O 2000e). The transport model requires values of porosity, ϕ, for all units, whether or not the parameter is used. In effect, these values are placeholders, that allow the model to run. By assigning values from similar rocks nearby (i.e. borrowing), the placeholder values are as representative as possible.

5.6 FLOWING INTERVAL SPACING (STOCHASTIC)

See Section 6.6 for the corresponding analysis section of flowing interval spacing. The assumptions stated below are from CRWMS M&O 1999c, and are presented here for information purposes.

1. Boreholes were assumed to be vertical. This assumption was necessary to apply the correction that was used to ensure that the distance measured between flowing intervals was normal to the borehole. That is, this assumption is implicit in the equation used to make the correction by Terzaghi (1966). All of the boreholes used in the analysis were drilled vertically and deviate from vertical within normal drilling practice.

2. Not all fractured zones in the SZ transmit water. It has been well documented in borehole flow meter survey reports (Erickson, and Waddell 1985, p. 1; Rush et al. 1983, p. 12; Craig and Robison 1984, p. 6; and Thordarson et al. 1984, p. 13) that only some of the fractures within the saturated zone contribute to the flow.

3. There is no correlation between flowing intervals and hydrogeological units. This was assumed primarily because of the lack of enough correlative data points for each hydrogeologic unit. There were only 32 data-points for flowing interval spacing within five hydrogeologic units and some of these spanned adjoining hydrogeologic units. This assumption is justified by the analyses presented in Section 6.0 of CRWMS M&O 1999c.

4. There is no correlation between the flowing interval spacing and the dip angle of fractures. This lack of correlation was assumed because the dip data were not associated with a particular flowing interval, therefore it was not possible to examine the correlation between the flowing interval spacing and the dip angles. If the assumption was made that there was a correlation between the dip angle and the flowing interval spacing, the most likely correlation would be between the steeply dipping features and the flowing intervals. This assumption would lead to a smaller flowing interval spacing (Terzaghi 1966), which would result in greater matrix diffusion.

5.7 FLOWING INTERVAL POROSITY (STOCHASTIC)

See Section 6.7 for the corresponding analysis section of flowing interval porosity. There are no direct measurements of the flowing interval porosity, however it is possible to estimate and bound the uncertainty in the model parameter value based on existing data using different models and data interpretations. The following assumptions are made in the models and data interpretations used to bound the uncertainty in the flowing interval porosity.

Theoretical estimates (models) of the interconnected pore volume of the fractures are based on the following assumptions about the nature of the fractured system:

1. The fracture system can be represented as a series of parallel plates or intersecting parallel plates with characteristics equivalent to the mean fracture aperture, dip and frequency observed in core samples.

2. Cores provide representative samples of the fracture system.

3. Fractures associated with the flowing intervals are sampled and measured.

These assumptions are inherent to the models that were applied. The uncertainty in the parameter value is bounded using these models. These assumptions do not bias the model results, they merely provide a mechanism for estimating the pore volume based on fracture data. The parallel plate model of fracture porosity provides estimates of the lower bound on the flowing interval porosity.

The upper bound on the uncertainty in the flowing interval porosity is based on interpretations of pumping test and tracer data. Flowing interval porosity estimates from pumping test and tracer data are based on the following assumptions about the nature of water flow and solute transport:

1. Specific yield represents the effective porosity.
2. No flow occurred in the matrix porosity (i.e., it is not part of the effective porosity).
3. Flowing interval thickness is known or conservatively estimated.

5.8 DIFFUSION COEFFICIENTS (STOCHASTIC)

See Section 6.8 for the corresponding analysis section of diffusion coefficients.

1. Uncertainty in geochemical conditions leads to uncertainty in aqueous speciation and charge of the contaminants. It is assumed that the size and charge of the ions considered here could fall within relatively wide ranges. Even with the wide ranges, which inflate their contributions, these characteristics have a small effect on diffusion when compared with the effect of tortuosity. Therefore, the assumption of wide ranges was appropriate.

2. Laboratory scale diffusion experiments are assumed to provide values of tortuosity representative of field scale diffusion and bound the range of tortuosity values due to matrix heterogeneity. This assumption is necessary given the long times that would be required to evaluate the process over a larger scale. The results of the experiments are used to bound the uncertainty in the diffusion coefficient. Actual tortuosity could be greater that the bounds from the laboratory experiments and the diffusion coefficient bounds developed are arbitrarily widened to account for this possibility.

5.9 BULK DENSITY (CONSTANT)

See Section 6.9 for the corresponding analysis section of bulk density.

1. Bulk densities are constant for the geologic units of concern. Bulk density, ρ_b, is only one of several parameters involved in the dual-porosity simulations employed for these units. The dual porosity transport simulations are far more sensitive to two parameters, flowing interval spacing and effective diffusion coefficient, than they are to bulk density. Those two parameters are treated stochastically.

2. Given a referenced bulk density value for one unit or group of units, other units of the same basic rock type can be assigned the same value (or average value). This assumption is supported based on the understanding that radionuclide transport will not occur in the units which adopt the ρ_b values from other units (CRWMS M&O 2000e). The transport model requires values of ρ_b for all units, whether such a parameter is used or not. In effect, these values are simply placeholders, to allow the model to run. By assigning values from similar rocks nearby, the placeholder values are made as representative as possible.

3. The bulk density values used in the alluvium are assumed to be applicable to the SZ site-scale model. These values were determined in the laboratory from Yucca Mountain field samples (CRWMS M&O 2000a, p. 78). This assumption is consistent with the laboratory derived K_d values in the alluvium. These K_d values were calculated using the same bulk density values (CRWMS M&O, 2000a).

4. It was assumed that effective porosity values could be used for total porosity in Equation 16. This equation was used to calculate bulk density in the Lava Flow and

Granite units (units 1 and 16). This assumption is reasonable given that these units are not in the flow path (CRWMS M&O 2000e).

5.10 SORPTION COEFFICIENTS (STOCHASTIC)

See Section 6.10 for the corresponding analysis section of sorption coefficients. The assumptions below are taken from CRWMS M&O 2000a, and are presented here for information purposes.

1. The sorption model used in the AMR mentioned above assumes a linear relationship between the aqueous phase and sorbed phase. The actual mechanism involved in sorption is a function of the mineralogy and geochemistry, both of which are highly uncertain and vary spatially. The assumption of linearity results in the simplest model that still explains sorption behavior. Additionally, the sorption model assumes instantaneous equilibrium between the aqueous phase and the immobile solid phase. This assumption is justified because the sorption and de-sorption rates are much shorter than the time of interest in SZ transport.

2. It was assumed that sorption coefficients, K_d, can be grouped in terms three rock types and a grouping for iron oxides to represent the waste container. This assumption results in four sorption-coefficient distributions per radionuclide: iron oxides, vitric tuff, devitrified tuff, and zeolitic tuff (Wilson et al. 1994, p. 9-11). The K_d values chosen for the SZ TSPA SR analysis corresponds to the rock type with the most conservative K_d (lowest value K_d).

3. The waters from Wells J-13 and UE-25p#1 bound the chemistry of the groundwaters at Yucca Mountain. (CRWMS M&O 2000a, p. 31). The concentration of the major anions and cations in unsaturated-zone groundwaters at Yucca Mountains appears to be between the saturated-zone tuffaceous waters (such as Well J-13) and water from Paleozoic carbonate aquifer (such as Well UE-25 p#1) (CRWMS M&O 2000a , p. 31).

5.11 LONGITUDINAL DISPERSIVITY (STOCHASTIC)

See Section 6.11 for the corresponding analysis section of longitudinal dispersivity.

1. It was assumed that the distributions from the SZ expert elicitation for longitudinal dispersivity at 30 km would be applicable for the 20 km boundary used for SZ TSPA-SR (CRWMS M&O 1998). Within the SZ expert elicitation, Gelhar (CRWMS M&O 1998) provides two log-normal dispersivity distributions; one for a 5 km scale and the second for a 30 km scale, based in part on his knowledge of relevant sites. It is well-known that apparent dispersivity increases as a function of scale. For 5 km, the range is given as 5 m to 500 m. For 30 km, the range is larger, from 3.2 m to 3200 m. This range encompasses the range for the smaller scale. The 30 km range for dispersivity will also address the uncertainty for a 20 km scale. Given the lack of site-specific information, uncertainty for this parameter is high. There would be no justification for narrowing the expert-given range for 30 km to somehow capture uncertainty

'more accurately' for a 20 km scale. Therefore, the range given for the 30 km scale, (3.2 m to 3200 m) within a log-normal distribution, is considered appropriate to use in this analysis.

2. The SZ expert elicitation did not distinguish between dispersivities in the volcanic and the alluvial units (CRWMS M&O 1998). Gelhar (1993, p. 203) states that there does not seem to indicate a distinct difference between the dispersion characteristics of porous and fractured media.

3. Results of the SZ expert elicitation also suggest that one should assume a correlation between longitudinal and transverse dispersivity as described in the SZ expert elicitation (CRWMS M&O 1998, p. 3-21). Dr. Lynn Gelhar relates transverse horizontal dispersivity and transverse vertical dispersivity to longitudinal dispersivity as described in (CRWMS M&O 1998, p. 3-21) and further explained in Section 6.11.

5.12 HORIZONTAL ANISOTROPY (STOCHASTIC)

See Section 6.12 for the corresponding analysis section of horizontal anisotropy.

1. It is assumed that the potential anisotropy of permeability in the horizontal direction is adequately represented by a permeability tensor that is oriented in the north-south and east-west directions. The numerical grid in the SZ site-scale flow and transport model is aligned in the north-south and east-west directions and values of permeability may only be specified in directions parallel to the grid. Analysis of the probable direction of horizontal anisotropy shows that the direction of maximum transmissivity is N 33° E (Winterle and La Femina 1999, p. iii), indicating that the anisotropy applied on the SZ site-scale model grid is within approximately 30° of the inferred anisotropy.

2. The assumption is made that the horizontal anisotropy in permeability applies to the fractured and faulted volcanic units of the SZ system along the groundwater flowpath from the repository to the south and east of Yucca Mountain. The inferred flowpath from beneath the repository extends to the south and east. This is the area in which potential anisotropy could have significant impact on radionuclide transport in the SZ and is the area in which pumping tests were conducted. Given the conceptual basis for the anisotropy model, it is appropriate to only apply anisotropy to those hydrogeologic units that are dominated by groundwater flow in fractures.

3. It is assumed that potential anisotropy in permeability represents an alternative conceptual model of groundwater flow at the Yucca Mountain site. Sufficient uncertainty in the analysis of horizontal anisotropy exists to warrant consideration of two possible conceptual models; one with anisotropy and one without anisotropy (i.e., isotropic permeability). Given the lack of information on the relative validity of these alternative conceptual models, they are assigned equal probability for the purposes of TSPA calculations.

5.13 RETARDATION OF RADIONUCLIDES IRREVERSIBLY SORBED ON COLLOIDS (STOCHASTIC)

See Section 6.13 for the corresponding analysis section of retardation of radionuclides irreversibly sorbed on colloids.

1. Radionuclides that are irreversibly sorbed onto colloids (here called irreversible colloids for brevity) are assumed to be embedded in the colloids and are part of the colloidal structure. Thus, these radionuclides are unavailable for dissolution and their transport characteristics are assumed to be the same as the transport characteristics of the colloids. This situation can occur if, for instance, these colloids form during wasteform degradation and are essentially altered pieces of the wasteform. The most significant radionuclides assumed to be transported by this mechanism are americium and plutonium (this assumption is consistent with CRWMS M&O 2000c). Supporting this assumption is the discovery of plutonium associated with colloids on the Nevada Test Site (Kersting et al. 1999, pp. 56-59).

2. Matrix exclusion in the volcanic units is assumed because of the large size and small diffusivities of the colloids compared to the solute, plus the possibility of similar electrostatic charge of the colloids and the tuff matrix. Matrix exclusion is implemented by reducing the values of the effective diffusion coefficients for solutes (see Section 6.8 for a discussion of the solute diffusion coefficient) by ten orders of magnitude, thus preventing most (if not all) matrix diffusion.

5.14 REVERSIBLE COLLOIDS: K_C PARAMETER (STOCHASTIC)

See Section 6.14 for the corresponding analysis section of reversible colloid, K_c parameter. Several assumptions have been made to simplify the large number of possible cases (combinations of different K_cs and K_ds) that can occur when the different radionuclides are combined with the different colloid types.

1. It was assumed that the colloids with the highest affinity for radionuclide sorption, wasteform colloids (CRWMS M&O 2000c), are representative of all the colloids in the groundwater. This assumption is justified because transport travel times for radionuclides are shorter than if colloid types with lower sorption affinities are added to the mix. The reason is that the higher affinities lead to more radionuclides spending more time on colloids and thus are more mobile. Therefore, this assumption is conservative with respect to radionuclide travel time.

2. It was assumed that the radionuclide with the highest K_d value for sorption onto colloids, americium (CRWMS M&O 2000c), was representative of all the radionuclides that were considered to be transported by this mechanism. This assumption is justified because shorter transport travel times will occur compared to a more realistic representation that involves the sorption coefficients of all the radionuclides transported by this mechanism. Therefore, this assumption is conservative with respect to radionuclide travel time.

3. It was assumed that the maximum colloid concentration, as given in (CRWMS M&O 2000c) is sufficient in determining the K_c parameter for TSPA-SR. The greater the colloid concentration, the higher the K_c value, the greater the affinity for colloids, and thus the more mobile the radionuclides, according to this model. This assumption leads to transport travel times for radionuclides that are shorter than would occur if lower colloid concentrations were used in the calculation. Therefore, this assumption is conservative with respect to radionuclide travel time.

4. It was assumed that the K_d values in the volcanic matrix and the alluvium for all the actinides considered to transport by this mechanism would be described by a uniform distribution with a minimum of 0 and a maximum of 100. It is further assumed that the two fission products, cesium and strontium, have matrix K_d values that are described by a uniform distribution with a minimum of 0 and a maximum of 50 (CRWMS M&O 2000a). The values in these distributions are equal to or less than the sorption values given in Section 6.10 for solutes, and thus should lead to faster travel times for the radionuclides transported by the reversible colloid mechanism. The same distributions are assumed to apply to the alluvium, for lack of knowledge about the actual K_d values for the alluvium for these radionuclides. It is possible, however, that the values for the alluvium could be similar or possibly greater than those for the vitric tuffs.

5. It was assumed that physical and chemical filtration have no retardation effect on transport by the reversible colloids. Thus there is no additional retardation added to the K_c model. This assumption should lead to faster travel times for the radionuclides than if a retardation were added to the K_c model. Note that if a reversible colloid were physically or chemically filtered, the radionuclide could desorb and thus be available for further transport, and therefore this assumption is conservatively reasonable.

5.15 SOURCE REGION DEFINITION (STOCHASTIC)

See Section 6.15 for the corresponding analysis section of source region definition.

1. The assumption is made that four source regions for radionuclide transport in the SZ are sufficient to represent the variability in transport pathways and characteristics of the SZ system. Within the largest of the four source regions defined for the TSPA calculations, the northing location of the source can vary by approximately 1500 m from realization to realization. This variability represents less than 10% of the 20 km travel distance to the hypothetical interface with the biosphere.

6. ANALYSIS

6.1 GROUNDWATER SPECIFIC DISCHARGE (STOCHASTIC)

Considerable uncertainty exists in the groundwater flux in the saturated zone along the flowpath to the hypothetical point of release to the biosphere. This uncertainty was quantified as a distribution of specific discharge in the volcanic aquifer near Yucca Mountain by the SZ expert elicitation project (CRWMS M&O 1998). The results of the SZ expert elicitation are used as a quantitative basis for assigning probabilities to three discrete cases of groundwater flux in the saturated zone (low, mean, and high flux).

To approximate the empirical cumulative distribution function (CDF) of uncertainty in specific discharge from the SZ expert elicitation the probabilities for the three discrete cases are assigned such that the first and second statistical moments of the discrete cases match the moments of the CDF. The first and second moments are defined as:

$$m_1 = \int_{-\infty}^{\infty} x \cdot f(x)dx \qquad \text{(Eq. 1)}$$

$$m_2 = \int_{-\infty}^{\infty} (x - m_1)^2 \cdot f(x)dx \qquad \text{(Eq. 2)}$$

where m_1 is the first moment, m_2 is the second moment, x is the variable of interest ($\log_{10}$ transformed specific discharge in this case) [L/T], and $f(x)$ is the probability density function of x. The CDF from the SZ expert elicitation (CRWMS M&O 1998) is shown in Figure 1. Analysis of the CDF using Equations 1 and 2 result in a value of m_1 = -0.306 ($\log_{10}$ transformed m/year) and m_2 = 0.478 ($\log_{10}$ transformed m/year).

For the uncertainty distribution of the discrete cases the first and second statistical moments are calculated using:

$$m_1 = p_1 x_1 + p_2 x_2 + p_3 x_3 \qquad \text{(Eq. 3)}$$

$$m_2 = p_1(x_1 - m_1)^2 + p_2(x_2 - m_1)^2 + p_3(x_3 - m_1)^2 \qquad \text{(Eq. 4)}$$

where p_1 is the probability of case 1, p_2 is the probability of case 2, p_3 is the probability of case 3, x_1 is the $\log_{10}$ transformed specific discharge for case 1, x_2 is the $\log_{10}$ transformed specific discharge for case 2, and x_3 is the $\log_{10}$ transformed specific discharge for case 3. In addition, the probabilities for the three cases must sum to 1.0. Using this relationship and Equations 3 and 4, the probabilities of the discrete cases can be calculated for given values of specific discharge for the cases. For cases in which the mean value of flux is divided and multiplied by 10 to obtain the low and high cases, the probability of the low-flux case is 0.24, the probability of the mean-flux case is 0.52, and the probability of the high-flux case is 0.24. These results are illustrated graphically and compared to the SZ expert elicitation CDF in Figure 1.

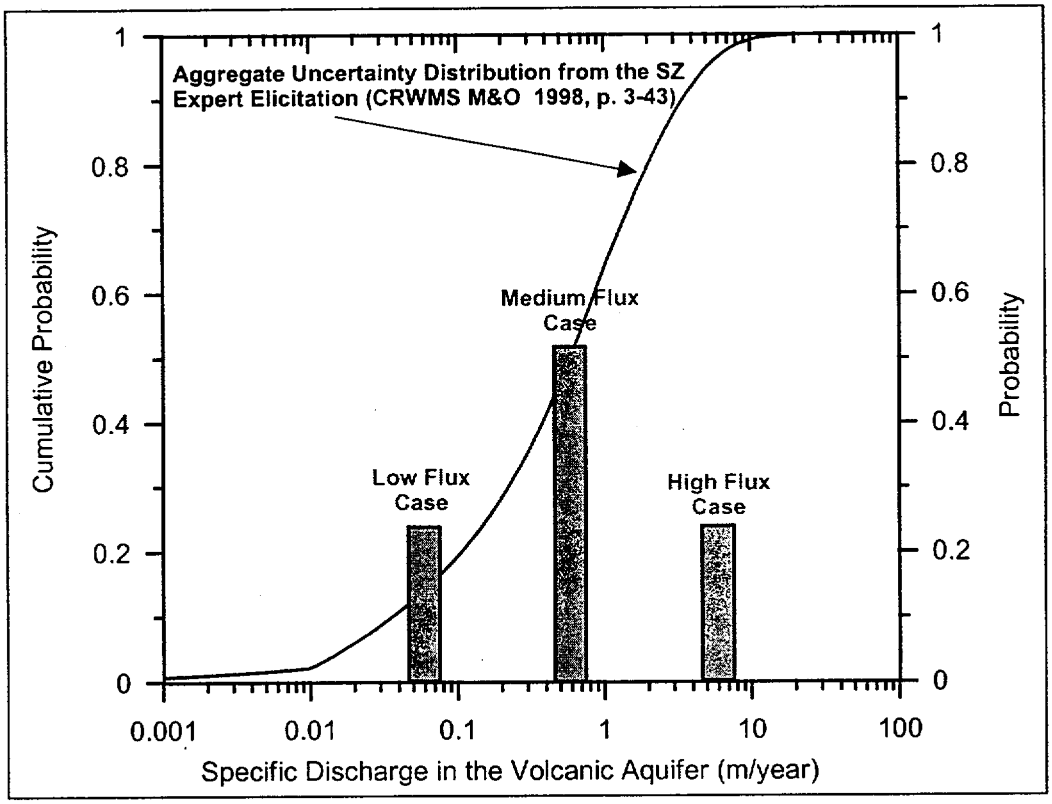

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Figure 1. Cumulative Distribution Function of Uncertainty in Specific Discharge in the Saturated Zone and Probabilities of Discrete Flux Cases Used in TSPA Calculations.

For TSPA calculations the uncertainty in groundwater flux is incorporated into the analyses by considering three discrete cases of low, mean, and high flux. The calibrated SZ site-scale flow model corresponds to the mean flux case. The low flux case is constructed by scaling the values of permeability and the boundary fluxes in the SZ site-scale flow model by a constant factor of 10. The high flux case is constructed in a similar manner by scaling the values of permeability and boundary fluxes upward by a factor of 10. Proportional scaling of permeability values and boundary fluxes in the SZ site-scale flow model preserves the calibration of the model to head measurements in wells among the three flux cases.

The stochastic parameter GWSPD is used to determine which groundwater flux case applies to each realization. The GWSPD parameter is uniformly distributed from 0.0 to 1.0. Those realizations with a value of 0.0 to 0.24 are assigned to the low flux case, those realizations with values of 0.24 to 0.76 are assigned to the mean flux case, and those with values of 0.76 to 1.0 are assigned to the high flux case.

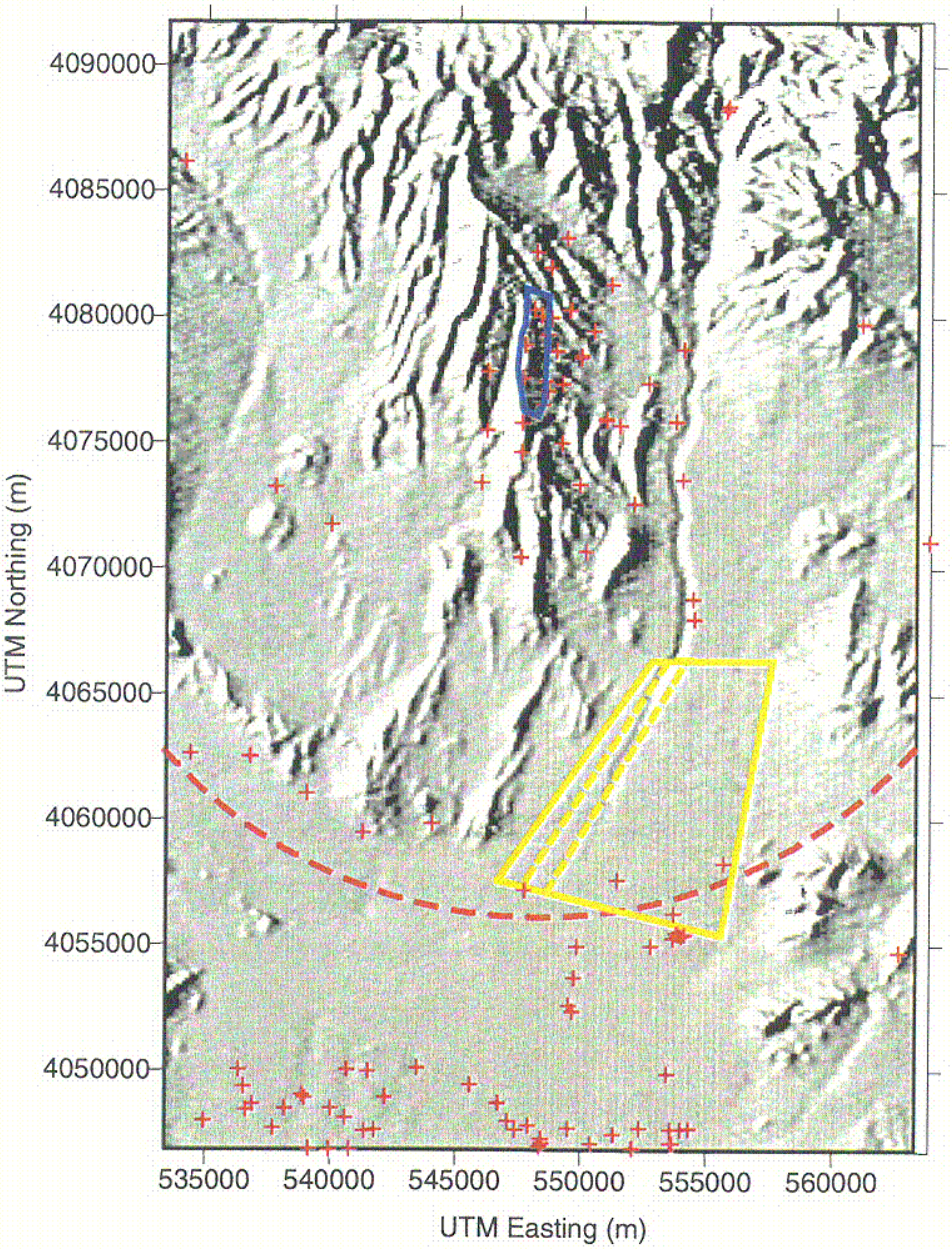
6.2 UNCERTAINTY OF ALLUVIUM BOUNDARY (STOCHASTIC)

Significant uncertainty in the geology below the water table exists along the inferred flowpath from the potential repository at distances of approximately 10 km to 20 km down gradient of the repository. The location at which groundwater flow moves from fractured volcanic rocks to alluvium is of particular significance from the perspective of repository performance assessment. This is because of contrasts between the fractured volcanic units and the alluvium in terms of groundwater flow (fracture dominated flow vs. porous medium flow) and in terms of sorptive properties of the media for some radionuclides.

The uncertainty in the northerly extent of the alluvium in the SZ of the site-scale flow and transport model is abstracted as a polygonal region that is assigned radionuclide transport properties representative of the valley-fill aquifer hydrogeologic unit (Figure 2). The dimensions of the polygonal region are stochastically varied in the SZ flow and transport simulations for TSPA calculations. The northern boundary of the uncertainty zone is varied from the most northerly yellow line shown in Figure 2 to the southernmost yellow line. The western boundary of the uncertainty zone is varied from the most westerly yellow line shown in Figure 2 to the easternmost dashed yellow line. The coordinates of the vertices defining the uncertainty zone are summarized in Table 3.

Table 3. Coordinates of the Alluvium Uncertainty Zone.

Point	UTM Easting (m)	UTM Northing (m)
Northwest (maximum westerly)	552791	4066370
Northwest (minimum westerly)	554152	4066320
Southwest (maximum westerly)	546653	4057620
Southwest (minimum westerly)	548588	4057090
Northeast	557577	4066320
Southeast	555550	4055400



NOTE: The yellow outline indicates the largest extent of the alluvial uncertainty zone. The outline of the repository is shown with the bold blue line and the 20 km limit from the repository is shown with the dashed red line. The figure is superimposed on a satellite image of the region. The red crosses indicate drill hole locations.

Figure 2. Alluvial Uncertainty Zone (outlined in yellow lines) in the SZ Site-Scale Model Area.

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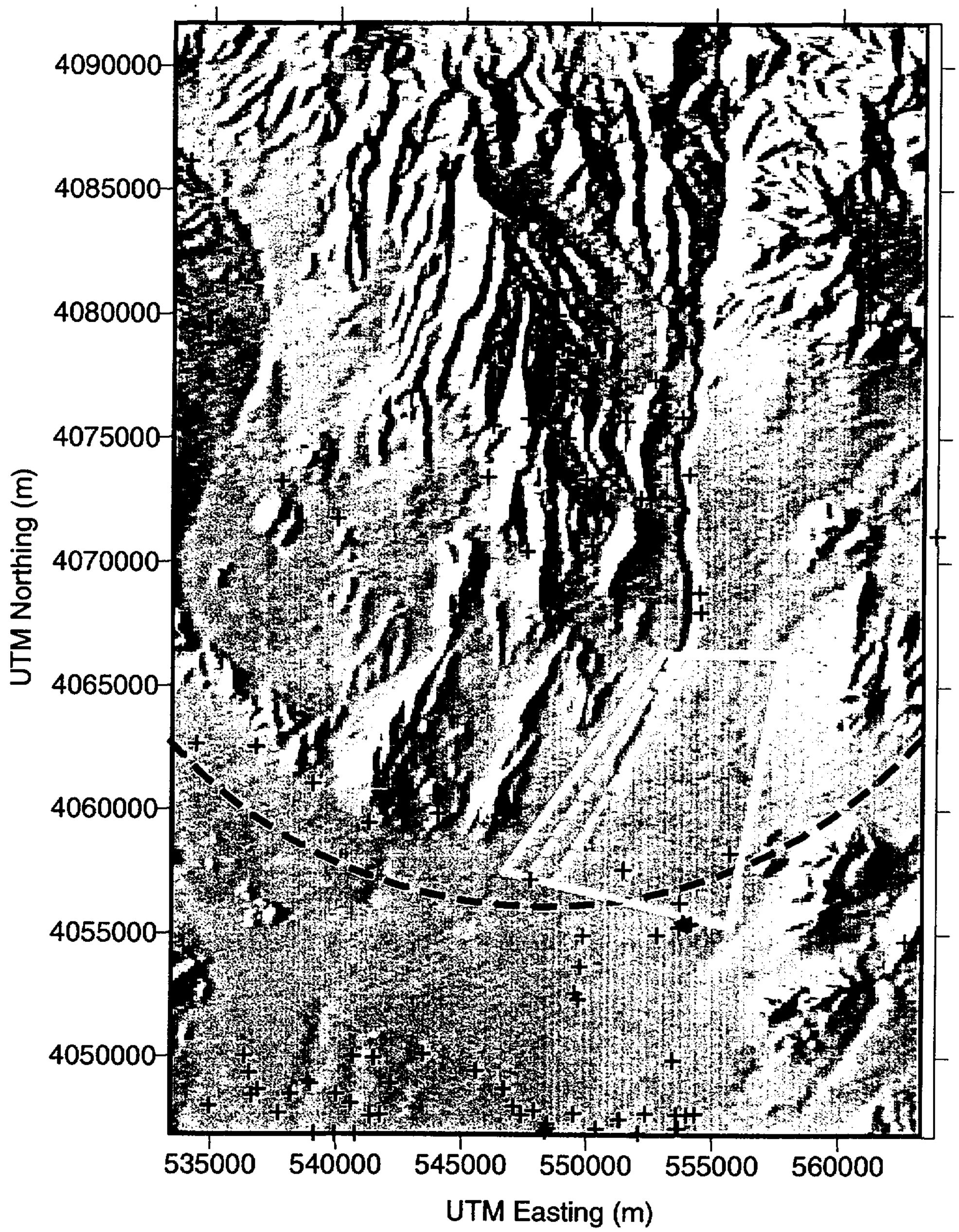


NOTE: The yellow outline indicates the largest extent of the alluvial uncertainty zone. The outline of the repository is shown with the bold blue line and the 20 km limit from the repository is shown with the dashed red line. The figure is superimposed on a satellite image of the region. The red crosses indicate drill hole locations.

Figure 2. Alluvial Uncertainty Zone (outlined in yellow lines) in the SZ Site-Scale Model Area.

The lower boundary of the alluvium uncertainty zone is assigned a constant elevation value of 400 m above sea level. This corresponds to a thickness of approximately 300 m below the water table in this area of the SZ site-scale flow and transport model.

The boundaries of the alluvium uncertainty zone are determined for a particular realization by the parameters FPLAW and FPLAN. These parameters have uniform distributions from 0.0 to 1.0, where a value of 0.0 corresponds to the minimum extent of the uncertainty zone in the westerly direction and 1.0 corresponds to the maximum extent of the uncertainty zone in the northerly direction.

6.3 EFFECTIVE POROSITY OF ALLUVIUM (STOCHASTIC) AND TOTAL POROSITY EQUIVALENT

Average linear ground water velocities are used in the simulation of radionuclide transport in the SZ site-scale model. They are customarily calculated by dividing the volumetric flux rate of water through a model grid cell by the porosity, ϕ. That value is rendered more accurate when dead end pores are eliminated from consideration (since they do not transmit water). The effective porosity, ϕ_e, results from that elimination. As a result ϕ_e will always be less than or equal to total porosity, ϕ_T. Effective porosity is generally estimated using tracer tests.

Effective porosity is treated as a stochastic parameter for the two alluvium members (19 and 7) of the nineteen SZ model hydrogeologic units. Stochastic, in this sense, means that ϕ_e will be constant spatially for each unit for any particular model realization, but that value will vary from one realization to the next. In comparison, constant parameters are constant spatially and also do not change from realization to realization. The parameter values and input source(s) are described in Section 4 and discussed in section 6.3.1 below. The underlying assumptions are discussed in Section 5.3 and Section 6.3.2 contains a discussion of the analyses used to develop the values.

The retardation coefficient, R_f, is also a function of porosity. Reducing total porosity to ϕ_e can inadvertently raise the magnitude of this value within the model. The correction for this is detailed in the analysis section (6.3.2).

6.3.1 Inputs

The following discussion covers data sources used in effective porosity inputs for the affected units. Those units are 19; Valley Fill and 7; Undifferentiated Valley Fill. Currently there are no site-specific data available for ϕ_e in the alluvium units. However, a range of data from different sources has applicability and relevance. Some of these sources comprise areas close to Fortymile Wash. The most useful data comes from a study of hydraulic characteristics of alluvium within the Southwest's Basin and Range Province (Bedinger et al. 1989). This study appears relevant to the local basin fill conditions and provides values for ϕ_e as a stochastic parameter. Other sources include porosity data from the Cambric study (Burbey and Wheatcraft 1986) within the Nevada Test Site (NTS) but several kilometers to the east, in Frenchman Flat. However, this is total porosity data, and not effective porosity. Total porosity is also featured in Tables 8-1 and 8-2 of the DOE (1997) report, pp. 8-5 and 8-6. Without additional information, such as tracer test data, it is not possible to determine ϕ_e. One can only infer that ϕ_e should be generally less than these values. Therefore, in the analysis section (Section 6.3.3), these values are included for this limited comparison only.

Finally, an expert elicitation on SZ flow and transport was performed by the Yucca Mountain Site Characterization Project (CRWMS M&O 1998). The experts were queried on many parameters, including, indirectly, effective porosity of alluvium (by way of 'average velocity'). Not all experts responded specifically with regard to this parameter. However, Table 3-2 of that report contains distribution parameters for this variable given by two experts, Dr. Shlomo Neuman and Dr. Lynn Gelhar. These values were incorporated into the SZ abstraction performed in TSPA-VA, but do not appear to have been based on any specific tests or site specific information. The current analysis uses the values tabulated in Bedinger et al. (1989). The ϕ_e ranges proposed by Neuman and Gelhar are included in Section 6.3.2 for comparison purposes.

6.3.2 Analysis

Development of Bedinger et al. (1989) and other distribution curves- Bedinger et al. (1989, p. A18, Table 1) contains the following distribution parameters for coarse-grained basin fill unconsolidated sediments as shown in Table 4:

Table 4. Effective Porosity Parameters from Bedinger et al. (1989)

Parameter	16.5 Percentile	Mean	83.5 Percentile
effective porosity	0.12	0.18	0.23

The percentiles given above do not exactly compare to the percentile for one standard deviation (σ) above and below the mean. Standard deviation values are necessary (in addition to the mean) inputs to conduct stochastic sampling when the distribution is normal. Therefore, some straightforward calculations were required to develop the value for the standard deviation, σ.

The standard deviation, σ, can be computed by use of the standard normal variable (Guttman et al. 1982, p. 141):

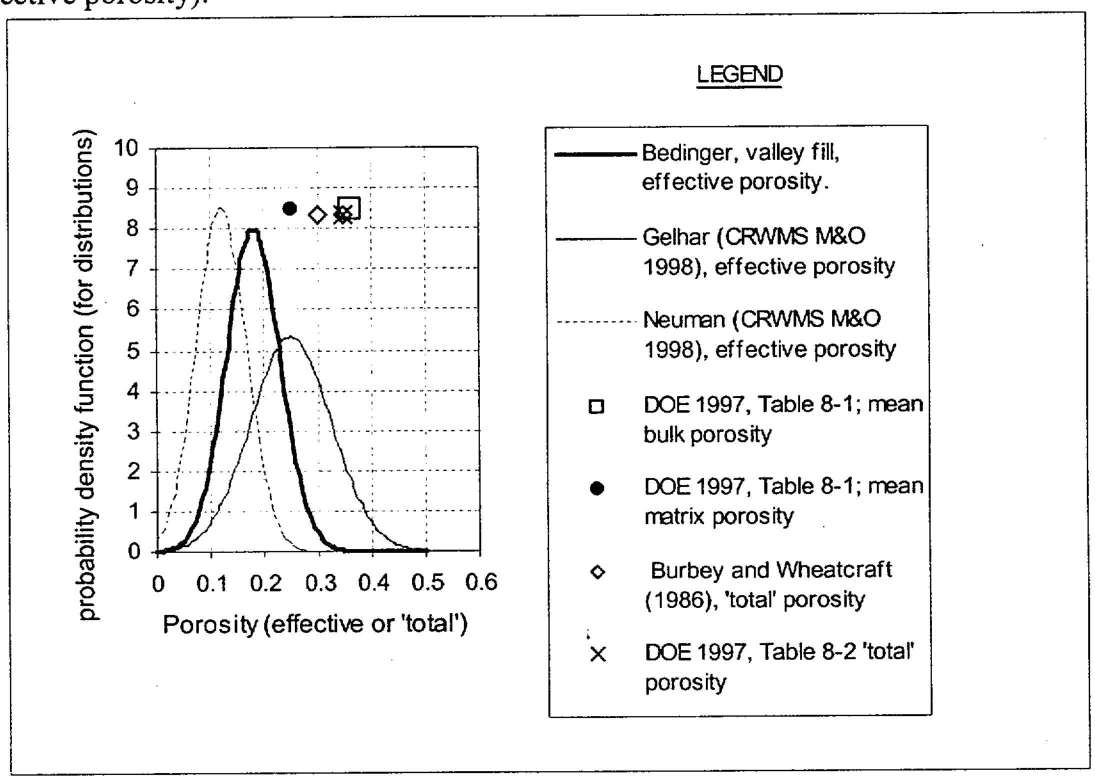
$$z = \frac{x - \mu}{\sigma} \quad \text{(Eq. 5)}$$

where x is the effective porosity value [-], μ [-] is the mean, and σ [-] is the standard deviation.

Engineering statistics textbooks contain tables of the percentiles ($\Phi(z)$) as a function of z. Given these tables and the mean and x, one can simply calculate σ. For example, using such a table (Guttman et al. 1982, Appendix VII, Table II), the value of z associated with the 83.5 percentile is approximately 0.975. Then, by Equation 5, σ is equal to approximately 0.05 (see spreadsheet geo-names.xls for this calculation).

Comparison to other distributions and ranges – Figure 3 compares the distribution of Bedinger et al. (1989) to distributions, ranges, and values from the other sources that were considered. The Bedinger distribution is depicted by the bold-line bell curve set approximately midway between two alternate Gaussian curves, those of Neuman (on the left) and Gelhar (on the right) (CRWMS M&O 1998).

The plot was generated in Microsoft Excel, see spreadsheet geo-names.xls for the calculations. The actual bell curves were generated in the following manner: First, the mean and standard deviation were acquired. Second, a range of effective porosity values were created in a data column. The values ranged in increasing magnitude from 0.0001 to 0.5. Next, a Microsoft Excel function was invoked for another column. The function is called NORMDIST, and calculates the probability density function (pdf) for any x, given the mean and the standard deviation. This function was applied to all values of effective porosity, leading to a companion column of 'y' values. Then the chart wizard was invoked to plot y (pdf) versus x (effective porosity).



DTN: MO0003SZFWTEEP.000 (Gelhar and Neuman, CRWMS M&O 1998)

NOTE: The single value data points do not have a y scale value, but do correspond to the x-axis. These points are shown for comparison purposes only.

Figure 3. Effective Porosity Distributions Compared

The distributions from Neuman and Gelhar are also plotted on this figure, using the same approach. Gelhar provided a mean value for effective porosity of 0.25 and a standard deviation of 0.075. Neuman, however provided the values in Table 5:

Table 5. Effective Porosity Parameters from Neuman (CRWMS M&O 1998, p. 3-20)

Parameter	10.0 Percentile	Mean	90.0 Percentile
effective porosity	0.06	0.12	0.18

These values were analyzed using Equation 5 (Guttman et al. 1982, Appendix VII, Table II), in the same manner as the Bedinger parameters, to develop a final value for the standard deviation equal to 0.0468.

A range of porosity values is provided from the Cambric study (Burbey and Wheatcraft 1986, Table 1, p. 23 and Table 3, p. 26). However, that report does not clarify if the values are for effective porosity or porosity. Effective porosity may be implied, by its' use in the study, but the measurements were apparently of total porosity. The values vary from 0.3 to 0.4, depending upon the measurement technique. The average porosity from Table 3 of that study is equal to approximately 0.34, and the so-called 'recommended' porosities range from 0.32 to 0.36. The remaining point values come from various tables of the DOE (1997) report, as summarized below:

Table 6. Porosity Parameters from DOE Report (DOE 1997, pp. 8-5 and 8-6)

DOE 1997 Table	Description	Value (rounded to 2nd dec.)
8-1	Mean matrix porosity	0.25
8-1	Mean bulk porosity	0.36
8-2	total porosity	0.35

As Figure 3 shows, the Bedinger (1989) distribution falls squarely between the two expert elicitation distributions. This is an encouraging result that supports the use of the Bedinger 1989 distribution. Here, a distribution based on actual data falls midway between the opinions of two experts on what form this distribution might take. Furthermore, as discussed earlier, the effective porosity should be less than the total porosity. All of the total porosities for alluvium found relevant to this site have been posted on this figure, and they all represent values that are greater than the mean of 0.18 from Bedinger et al. (1989). The values from the Cambric site report fall in the same general narrow range as the other 'total' porosities.

Correction of Retardation - The retardation factor for linear sorption of radionuclides is defined as follows (Freeze and Cherry 1979, p. 404):

$$R_f = 1 + \frac{\rho_b}{\phi} \cdot K_d \qquad \text{(Eq. 6)}$$

where: R_f is the retardation factor [-], ρ_b is the bulk density [M/L^3], ϕ is the porosity (total) [-], and K_d is the distribution coefficient [L^3/M]. The computer code, FEHM (Zyvoloski et al. 1997) to be used in the SZ site-scale flow and transport model automatically calculates R_f based on input values of ρ_b, ϕ, and K_d. For the hydrogeologic units of concern, the input value of ϕ is actually ϕ_e. Effective porosity is a macroscopic parameter that helps account for discrete flow paths and channelized flow. It was not intended to be used to estimate surface areas in this adsorption equation. Therefore, it is necessary to adjust another parameter in the equation to compensate for the lower effective porosity that is entered. If this were not done, then the calculated values of R_f would be non-conservative. For this series of runs, the K_d values will be adjusted according to the following relationship:

$$K_d^{new} = K_d^{orig} \cdot \frac{\phi_e}{\phi_T} \qquad \text{(Eq. 7)}$$

where: K_d^{new} is the adjusted distribution coefficient [L^3/M], K_d^{orig} is the original distribution coefficient [L^3/M], and ϕ_T is the total porosity.

The values of total porosity obtained from this study, and a calculated average are presented in Table 7. These values include the range from the Cambric study (Burbey and Wheatcraft 1986). The average total porosity is equal to 0.35.

Table 7. Summary of Values of Total Porosity (ϕ_T)

Reference	Total Porosity	Comments
DOE 1997 Table 8-1, p. 8-5	0.36	Mean bulk porosity
DOE 1997 Table 8-2, p. 8-6	0.35	Total porosity
Burbey and Wheatcraft, 1986, pp. 23-24	0.34	Average of porosity values from Table 3 of that study
average of above	0.35	N/A

Adjusting the distribution coefficient as shown will ensure that retardation retains the value it would have if calculated for a total porosity input. Changing the distribution coefficient values in this manner does not impact any other aspects of the transport simulation.

The effective porosity parameter for unit 7 and 19 are determined for a particular realization by the parameters NVF19 and NVF7 (these parameters are sampled independently). A truncated normal distribution (mean of 0.18 and SD of 0.051) is used for the uncertainty associated with this parameter for units 7 and 19. The value 0.35 is used for the total porosity value when adjusting distribution coefficients for the affected hydrogeologic units.

6.4 EFFECTIVE POROSITY FOR ALL NON-VOLCANIC UNITS WHICH ARE ASSIGNED A CONSTANT VALUE OF EFFECTIVE POROSITY

Effective Porosity, ϕ_e, is defined in Section 6.3. It is treated as a constant parameter for nine members of the nineteen SZ model hydrogeologic units. Constant, in this sense means that ϕ_e will vary from one unit to another, but, given a particular unit, the porosity will stay the same for all realizations. The porosity will also remain spatially constant for each unit. The parameter values and input source(s) are described in Section 4 and discussed in Section 6.4.1. The underlying assumptions are discussed in Section 5.4. Section 6.4.2 contains a discussion of the analyses used to develop the values.

6.4.1 Inputs

The following discussion covers data sources used in constant effective porosity inputs for the affected units. Those units are described in Table 1 of Section 4.

Table 1 in Section 4 shows the inputs used for ϕ_e values for the deep carbonate units, 3, 5, and 6 (DTN: SNT05082597001.003). The DOE (1997) report covers the Nevada Test Site region, which encompasses Yucca Mountain and surrounding areas. Therefore it is relatively location-specific. This report was used as a source for ϕ_e for the two lower clastic confining units 2 and 4. The Bedinger et al. (1989) report covers hydrogeologic data for the Basin and Range Province of the Southwestern U.S. This covers an extensive region overlapping into eight states. Yucca Mountain is located in this domain. Bedinger et al. 1989 was a source for the Valley Fill Confining unit (18), the Cenozoic Limestone (17), Lava Flows (16) and the Granites unit (1).

6.4.2 Analysis

Table 8 lists the constant values used for each unit, for the SZ site-scale model for TSPA SR.

Table 8. Values of Effective Porosity (ϕ_e) for Several Units of the SZ Site-Scale Model

SZ Unit Name	SZ Unit Number	Effective Porosity (ϕ_e)
Valley Fill Confining Unit	18	0.32
Cenozoic Limestone	17	0.01
Lava Flows	16	0.08
Upper Carbonate Aquifer	6	0.04
Lower Carbonate Aquifer Thrust	5	0.04
Upper Clastic Confining Unit	4	0.09
Lower Carbonate Aquifer	3	0.04
Lower Clastic Confining Unit	2	0.03
Granites	1	0.0001

The effective porosity values for units 3, 5 and 6 were determined by calculating the average of several values (DTN: SNT05082597001.003). That reference contained multiple values of ϕ_e for the units of concern. These values were obtained from various elevations from a single borehole, UE-25p#1, that penetrated the "Lower Carbonate Aquifer". An average ϕ_e was calculated for this unit, using the Microsoft Excel AVERAGE command, see (spreadsheet geo-names.xls, sheet 2). The averaged values were entered into Table 8. All of the carbonate units were assigned the same value.

6.5 MATRIX POROSITY OF VOLCANIC UNITS (CONSTANT)

Matrix porosity, ϕ_m, is treated as a constant parameter for nine members of the nineteen SZ model hydrogeologic units. Constant, in this sense, means that ϕ_m will vary from one unit to another, but, given a particular unit, the porosity is constant for all realizations. The porosity also remains spatially constant for each unit. The parameter values and input source(s) are shown in Section 4, Table 1 and discussed below in Section 6.5.1. The underlying assumptions are discussed in Section 5.5. Section 6.5.2 contains a discussion of the analysis used to develop the values.

6.5.1 Inputs

The following discussion covers data sources used in constant porosity inputs for the affected units. Those units are described in Table 1 of Section 4. The volcanic units 11 through 15 do lie in the expected flow paths per CRWMS M&O 2000e. Site specific sources for those data have been identified in CRWMS M&O 1999b. All of the remaining units are expected to lie outside of any expected SZ model transport paths. However, the model requires values for ϕ_m for all units whether they play a role or not. Therefore values as representative as possible were used when available.

Units 10 and 8 are both volcanic confining units. The value of ϕ_m for these units was obtained from the value for unit 14, which is a volcanic confining unit for which there is site-specific data. The ϕ_m value for Unit 9 (volcanic unit) was obtained by averaging the values for the three overlying Crater Flat group units (11-13).

Also, for the case of units 15-13, the values of ϕ_m do, in fact, vary spatially in the limited region of the SZ model that corresponds to the Integrated Site Model (ISM) rock-properties model. The ISM model consists of a series of stochastic simulations in which ϕ_m varies spatially and from realization to realization. The "expected value" of the spatial distribution of matrix porosity was developed from the average of these realizations (this calculation is not in this AMR, but is in CRWMS M&O 2000f). This distribution of matrix porosity values is used in the SZ site-scale flow and transport model CRWMS M&O 2000f.

6.5.2 Analysis

Minimal analyses were required for this parameter group. The matrix porosity value for unit 12 was derived from matrix porosity data from the boreholes; USW G-4, USW H-1, SD7, UE-25a#1, UE-25b#1, and J-13 (DTN: SNT05082597001.003). The matrix porosity value for unit 11 was based on values of matrix porosity from the boreholes; USW G-3, USW G-4, USW H-1, SD7, UE-25b#1, and J-13 (DTN: SNT05082597001.003). Simple averages were calculated from the collections of values for units 12 and 11, as shown in spreadsheet geo-names.xls. Those averages were used as the matrix porosity inputs to the SZ site-scale model for their respective units as shown in Table 9.

Table 9. Values of Matrix Porosity (ϕ_m) for Several Units of the SZ Site-Scale Model

SZ Unit Name	SZ Unit Number	Matrix Porosity (ϕ_m)
Upper Volcanic Aquifer (Topopah)	15	0.15
Upper Volcanic Confining Unit (Calico Hills)	14	0.25
Lower Volcanic Aquifer, Prow Pass	13	0.23
Lower Volcanic Aquifer, Bullfrog	12	0.19
Lower Volcanic Aquifer, Tram	11	0.23
Lower Volcanic Confining Unit	10	0.25
Older Volcanic Aquifer	9	0.22
Older Volcanic Confining Unit	8	0.25

6.6 FLOWING INTERVAL SPACING (STOCHASTIC)

The flowing interval parameter is a key parameter in the dual porosity model that is included in the SZ flow and transport model. A flowing interval is defined as a fractured zone that transmits flow in the SZ, as identified through borehole flow meter surveys (see Figure 4). The analysis uses the term "flowing interval spacing" as opposed to fracture spacing, which is typically used in the literature. The term fracture spacing was not used because the data used identified a zone (or a flowing interval) that contains fluid-conducting fractures but does not distinguish how many or which fractures comprise the flowing interval. The flowing interval spacing is measured between the midpoints of each flowing interval.

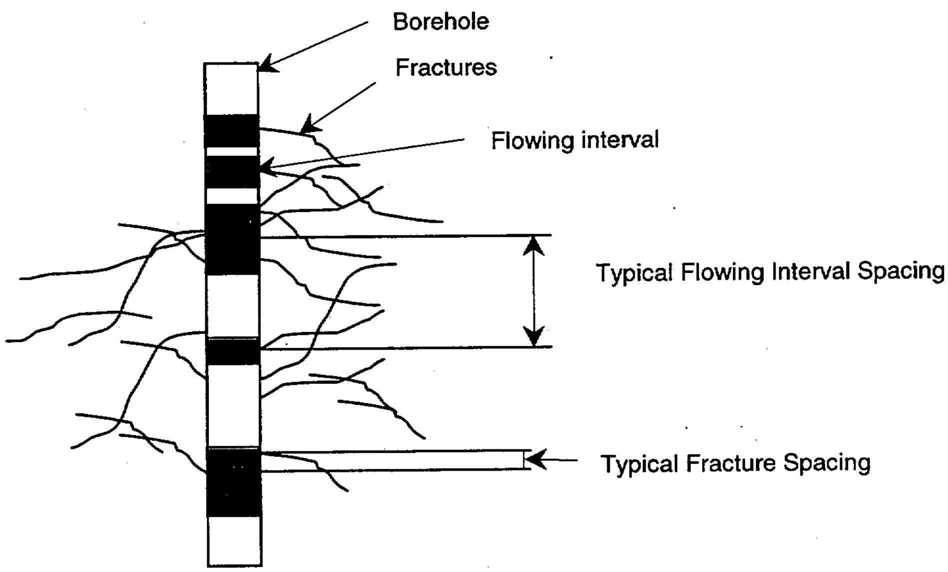


Figure 4. Example of Flowing Interval Spacing (CRWMS M&O 1999c) for a Typical Borehole

There is considerable uncertainty regarding the flowing interval spacing parameter due to the limited number of data points available. The data set used for the analysis consisted of borehole flow meter survey data. The boreholes selected for this study had orientation data as well as flow meter survey data. This type of data resembles the natural system in terms of flow through fractures in the SZ. It is well understood from the borehole flow meter survey tests that only some of the fractures contribute to the flow (Erickson and Waddell 1985, p. 1; Rush et al. 1983,

p. 12; Craig and Robison 1984, p. 6; and Thordarson et al. 1984, p. 13). UZ fracture spacing is significantly less than flowing interval spacing, and the use of UZ fracture spacing in the SZ would overestimate the effect of matrix diffusion. This analysis is described in detail in the CRWMS M&O 1999c, Probability Distributions for Flowing Interval Spacing. The following discussion will briefly summarize the flowing interval spacing analysis.

A cumulative distribution function (CDF) was generated from 32 flowing interval spacing data points as well as corresponding dip data (165 data points) from borehole flow meter survey reports (DTN: SN9907T0571599.001). As described in CRMS M&O 1999c, 1000 values were sampled from the CDFs, for the flowing interval spacing and dip data (CRWMS M&O 1999c).

The resulting 1000 output values for dip and flowing interval spacing were then used to correct for flowing intervals measured normal to the borehole as described in CRWMS M&0 1999c. A statistical analysis of the corrected flowing interval spacing data, determined that a lognormal fit the data best.

The flowing interval spacing parameter is determined for a particular realization by the parameter FISVO. The probability distribution proposed for the TSPA SR calculations, as stated in CRWMS M&O 1999c is a normal distribution with a $E[\log_{10}(F_{smc})]$: 1.29 m and $S.D.[\log_{10}(F_{smc})]$: 0.43.

6.7 FLOWING INTERVAL POROSITY (STOCHASTIC)

The flowing interval porosity is defined as the volume of pore space in the active flow field relative to the total saturated volume of rock in fractured media. There are no direct measurements of the flowing interval porosity. However, there are 2 general methods available for estimating the flowing interval porosity using existing data:

1. Theoretical estimates of the interconnected pore volume of the fractures given assumptions about the nature of the fractured system, and

2. Model estimates of the effective pore volume based on aquifer pumping and tracer tests given assumptions about the nature of water and solute flow.

The assumptions for this section are discussed in Section 5.7. To estimate the lower bound of flowing interval porosity the parallel plate model is used. The upper bound of uncertainty in the flowing interval porosity is based on interpretations of pumping test and tracer data.

6.7.1 Parallel Plates

It is considered appropriate that the fracture system can be represented as a series of parallel plates or intersecting parallel plates for theoretical estimates of ϕ_f for tuff deposits in the Yucca Mountain region. Since the fractures are not uniform, parallel plates, the characteristics of an equivalent set of fractures are estimated using the mean fracture aperture, dip and frequency as observed in core samples.

Snow 1968 (p.80, Equation 7), provides the following relationship for the parallel plate model:

$$\phi_{\text{fractures}} = Nb \qquad \text{(Eq. 8)}$$

Where N is the number of fractures per unit distance (or unit depth)[1/L] and b [L] is the fracture aperture.

6.7.2 Intersecting Parallel Plates

If there are 3 or more planes, the system becomes isotropic even if spacing and apertures are not uniform (Cubic Set of Plates, Snow 1968, p. 80, Equation 11)

$$\phi_{\text{fractures}} = 3Nb \qquad \text{(Eq. 9)}$$

Anisotropic conditions with greatest permeability in plane of intersections yields permeabilities that are twice the maximum in the plane of isotropy (fractures with equal spacing) (Snow 1969). Since the parallel plate model results in smaller estimated porosities and the fracture models result in lower values of porosity than the tracer and pumping tests, the parallel plate model is used to estimate the lower bound on the uncertainty in this parameter value.

6.7.3 Estimates of $\phi_{\text{fractures}}$ from Yucca Mountain Core Data

The Nevada Environmental Restoration Project (DOE 1997) evaluated the fracture spacing and apertures in seven cores from wells at Pahute Mesa. The volcanic rocks in these cores include the Timber Mountain tuff, Tuff Cones, Belted Range Aquifer and undistinguished welded tuff deposits. The estimated open fracture porosities based on the assumption of parallel plates, range from 6.1×10^{-6} to 4.7×10^{-4} in the welded tuffs and 2.6×10^{-6} to 4.7×10^{-4} in the tuff cones (DOE 1997, p. 5-14).

Similarly, data compiled for TSPA-1993 indicate average fracture porosities of 8.0×10^{-5} to 1.0×10^{-3}, in core from USW G-1, USW GU-3, USW G-4 and UE25a#1e, when parallel plate fracture geometry is assumed (Wilson et al. 1994, Volume 1, Chapter 7, Table 7-19, p. 7-30).

Additional data could be analyzed to obtain a distribution of fracture porosities with depth, for a specific location and the data could be analyzed using different assumptions about the fracture geometry. However, this would be of limited value given the considerable uncertainty in conditions between boreholes and the appropriate method for scaling core data to site-scale processes. These estimates provide an order of magnitude estimate and are used to bound the uncertainty in the flowing interval porosity.

6.7.4 Estimates of $\phi_{\text{fractures}}$ from Yucca Mountain Pumping and Tracer Tests

Pumping tests of the tuff aquifer at the C-wells can be interpreted in several ways. If it is considered appropriate that the aquifer is a deep, unconfined saturated unit, the drawdown curves are used to estimate specific yield (S_y) and hydraulic conductivity. In this case it was considered appropriate that the S_y represents the drainable volume of voids or the effective porosity. The C-wells pumping tests and curve fitting analyses indicate a S_y of 0.01 to 0.20 (Geldon et al. 1998,

p. 29). Tracer tests at the same C-well complex as interpreted in CRWMS M&O (1997a, p. 29) indicates an effective porosity between 0.004 and 0.125. In their review of the interpretations of those same pumping and tracer tests, Winterle and La Femina (1999) observe that Geldon et al.'s (1998) interpretation of the data did not include a conservative assumption regarding the thickness of the flowing interval and neither the pumping or tracer analyses accounted for the effects of preferential vertical and non-radial flow. Winterle and La Femina (1999, p. 4-12) re-interpreted the results of the pumping test and estimate the S_y between 0.004 and 0.03. But they note that even with changing the assumptions about the thickness of the aquifer, the results only provide an upper bound on the estimated drainable porosity.

There is tremendous uncertainty in the flowing interval porosity. Given the estimates of this parameter value based on theoretical models, pumping test and tracer data the parameter uncertainty ranges over 4 orders of magnitude. The best representation of the uncertainty in the flowing interval porosity, ϕ_f, is a log-uniform distribution between 0.00001 and 0.10.

This range in uncertainty leads to an equivalent range in estimated water velocities if the flux of water into the system is held constant. The relationship to the estimated transport velocities is not clear. Smaller flowing interval porosities represent conditions with smaller fracture apertures and therefore greater fluid contact with the matrix. Greater contact with the matrix results in greater interaction between the matrix and contaminants by diffusive mass transfer and therefore greater retardation of the contaminant front.

The flowing interval porosity parameter is determined for a particular realization by the parameter FPVO. The probability distributions for flowing interval porosity is a log-uniform distribution with a lower bound, LB[$\log_{10}(\phi_f)$]: -5.0 and upper bound, UB[$\log_{10}(\phi_f)$]: -1.0.

6.8 EFFECTIVE DIFFUSION COEFFICIENTS (STOCHASTIC)

The effective diffusion coefficient, D_e, is both variable and uncertain. Variability in D_e is caused by differences in molecular diffusion for individual contaminants. The variability in molecular diffusion occurs primarily due to differences in the size (atom, ion, or molecule) and charge of individual contaminants. The effective diffusion coefficients also vary over time and space due to variability (spatial) and changes (temporal) in the temperature of pore fluids, geochemical conditions and length of the diffusion path through the porous medium relative to a straight line (tortuosity). There is uncertainty about how and when these factors will vary because of uncertainties in the existing and future thermal, hydrogeologic and geochemical conditions. Of these factors, differences in the size, charge, and chemical behavior of the transported contaminants cause differences between the effective diffusion coefficient for individual contaminants. Temperature and tortuosity should impact all contaminants equally.

The uncertainty in the effective diffusion coefficient is a function of the uncertainty and variability in the radionuclide size, temperature, heterogeneity of rock properties, and geochemical conditions along the transport pathway. The contribution of these uncertainties and variabilities to the uncertainty in the effective diffusion coefficient is evaluated in the following subsections. See Section 5.8 for the assumptions associated with this section.

6.8.1 Variability from Ionic Radius and Charge

The diffusion coefficient for ions in infinitely dilute solutions, D_m [L^2/T] can be described as follows (Vanýsek, 1999, p. 5-93):

$$D_m = \left(\frac{RT}{F^2} \times \frac{\lambda}{|z|} \right) \qquad \text{(Eq. 10)}$$

where R [J/mole(T)] is the molar gas constant, T [T] is temperature, F is the Faraday constant [C/mole], z [-] is the ion charge, and λ [L^2/mole(ohms)] (note: C is Coulombs and J is Joules) and is the limiting equivalent conductivity of the fluid for the ion. The limiting equivalent conductivity of a fluid is ion dependent. For solutions at the same ionic potential, λ tends to be higher for cations than anions (Vanýsek 1999, p. 5-93 – 5-94). However, they are of the same order of magnitude. Since the size of the ion also influences the rate of diffusion, it makes it difficult to generalize that cations diffuse faster than anions. This is particularly true when the geochemical conditions are uncertain.

For cations in water at 25°C λ can be estimated as a function of the size and charge of the ion (Nigrini 1970, pp. 76-77):

$$\lambda \approx \left(10.56 + 90.72 Log(z) + 42.95 \frac{r}{z} \right) \qquad \text{(Eq. 11)}$$

where r [Ångstroms] is the ionic radius.

Combining Equations 10 and 11 illustrates the relative effect of ionic radius (for cations) and charge:

$$D_m = \left(\frac{RT}{F^2} \times \frac{(10.56z + 90.72z\log(z) + 42.95r)}{z^2} \right) \qquad \text{(Eq. 12)}$$

By using Equation 12 and the ionic radii for U^{4+} (Uranium with a charge of + 4) (0.93 Ångstrom; Sharpe 1981, p. 657) and Cs^{+} (Cesium with a charge of +1) (2.65 Ångstrom; Sharpe 1981, p. 228), it can be shown that the molecular diffusion coefficient can vary by a factor of approximately 2.5 because of differences in ionic radii. And by comparing Cs^{+} (a charge of +1) and U^{4+} (a charge of +4), it can be shown that the molecular diffusion coefficient can vary by a factor of approximately 2.8 because of differences in ionic charge. U^{4+} is probably an overestimate of the charge on the actual species that would occur at Yucca Mountain, but was selected as a reasonable bounding case for small solutes with small radii. As discussed below, the variability and uncertainty due to tortuosity is much greater than these factors.

6.8.2 Variability from Temperature

The uncertainty and variability in diffusion due solely to temperature variations (over space and time) will affect all contaminants equally hence the uncertainty in temperature will not affect the decision to use a single diffusion coefficient. The Stokes-Einstein relationship can be used to approximate the molecular diffusion of ions in water with concentrations of ions as high as seawater and with temperatures ranging from 0-100°C (Li and Gregory 1974, p.704 and Simpson and Carr 1958, p. 1201). Using the Stokes-Einstein relationship, the molecular diffusion coefficient for a given temperature, D_m, can be estimated as a function of the diffusion coefficient at a reference absolute temperature (T_0) and the relative change in temperature and water viscosity, (η) [FL/A(LT)] (Li and Gregory 1974, p. 704):

$$D_m(T_1) = \frac{T_1}{T_0}\frac{\eta_0}{\eta_1} D_m(T_0) \tag{Eq. 13}$$

Given the maximum potential range in temperature for the Yucca Mountain groundwater of 20-60°C and the viscosity of water at those temperatures (Viswanath and Natarajan 1989, p. 714), Equation 13 can be rewritten and solved as follows:

$$\frac{D_m(T_1)}{D_m(T_0)} = \frac{T_1}{T_0}\frac{\eta_0}{\eta_1} = \frac{333.15K}{293.15K}\frac{1.007Ns/m^2}{0.466Ns/m^2} = 2.45$$

Thus the molecular diffusion coefficient can vary by a factor of about 2.5 to changes in water temperature.

6.8.3 Variability from Tortuosity

The tortuosity is defined here as the length of the transport path relative to the straight-line distance over which the contaminant travels and is treated as a property of the porous media.

This results in an effective diffusion coefficient, D_e [L^2/T], that is directly proportional to the molecular diffusion coefficient, D_m [L^2/T], and inversely proportional to the tortuosity, τ [-], of the porous medium.

$$D_e = \frac{D_m}{\tau} \qquad \text{(Eq.14)}$$

It is considered appropriate that the uncertainty in the molecular diffusion coefficient will depend on the uncertainty in the chemical form of the individual contaminants. The amount of uncertainty caused by tortuosity is quantified in the next section.

6.8.4 Effective Diffusion Coefficients for Yucca Mountain Volcanic Units

In general, the range in molecular diffusion coefficient values can be bounded based on the range of measured values for a wide variety of ions and molecules. A minimum value of 3.06×10^{-6} cm^2/s (for Am, americium) (Higgo et al. 1987, p.29 Table 2) and a maximum of 9.31×10^{-5} cm^2/s (for H^+, a hydrated proton) Vanýsek (1999, p. 5-93) bound the measured molecular diffusion coefficient values presented by. This range, a factor of 30, is relatively narrow considering the variation in the size, charge (anion and cation) and composition of the ions in the cited reference.

Effective diffusion coefficients for non-sorbing isotopes measured in devitrified tuffs from Yucca Mountain are on the order of 1.0×10^{-6} to 3.5×10^{-6} cm^2/s for tritium (diffusing as tritiated water, HTO) and 1.0×10^{-7} to 4.9×10^{-7} cm^2/s for ^{95m}Tc (technetium) (diffusing as the pertechnetate anion, TcO^-_4) (Triay et al. 1997, p. 192). The free-water molecular diffusion coefficient for H^+ is 9.3×10^{-5} cm^2/s (Vanýsek 1999, p. 5-93) and 2.3×10^{-5} cm^2/s for HTO (Sposito 1981, p. 6945). If tritium diffuses at a rate consistent with H^+ it indicates a range of tortuosity between 27 to 93 for the devitrified tuffs. If it diffuses as HTO the tortuosity is 6 to 23. The free-water molecular diffusion coefficient of TcO^-_4 is 3.9×10^{-5} cm^2/s (Albinsson and Engkvist 1991, p. 239), indicating a tortuosity of 80 to 390 if there is no sorption in the devitrified tuffs (all of the preceding tortuosity calculations use Equation 14 and spreadsheet De_Tortuosity.xls contains the calculations). The apparent tortuosity for pertechnetate may be greater than that of tritium due to exclusion from interconnected pores (anion exclusion) or other attenuation mechanisms such as sorption. However, pertechnetate is generally considered a conservative (non-sorbing) tracer. Given the larger ionic radius of TcO_4^- relative to tritium and tritiated water, there could be filtering effects, although anion exclusion is generally perceived to decrease the tortuosity of the diffusion pathway by keeping the ion in the center of the pores. The differences in the results for these two tracers indicate there are significant uncertainties in the effective diffusion coefficients due to uncertainties in the interaction between the porous medium and the contaminants and that this uncertainty dominates all the other uncertainties and variability in the effective diffusion coefficients for individual contaminants.

Additional diffusion studies with pertafluorobenzoic acid (PFBA) and bromide (CRWMS M&O 2000a p. 248) indicate an effective diffusion coefficient of 0.4×10^{-6} to 6×10^{-6} cm^2/s for bromide, depending on the sample (correlated to matrix permeability), and an effective diffusion coefficient for PFBA that was consistently 1/3 smaller than the bromide diffusion coefficient, possibly because of the difference in ionic radius. As a result, the estimated tortuosity of the diffusion pathway will be the same with either tracer. Bromide has a molecular diffusion coefficient of 2.08×10^{-5} cm^2/s (Vanýsek 1999, p. 5-94) yielding a range in tortuosity from 3.5 to 52 (Equation 14, see spreadsheet De_Tortuosity.xls for calculations).

If the uncertainty in the tortuosity is estimated using the bromide, tritium, and pertechnetate tracer studies (3.5 – 390) and the range of molecular diffusion coefficients, D_m, for the potential contaminants is assumed to be 0.306 to 2.0 x 10^{-5} cm^2/s (bounds based on molecular diffusion coefficient values for Am (Higgo et al. 1987) and Cs^+ in Vanýsek (1999, p. 5-93). Americium was selected as a lower bound because it has one of the lowest molecular diffusion coefficients that is representative of the waste contaminants. Cesium was selected as an upper bound because it has the highest D_m that is representative of the waste contaminants. Higher D_m values could have been used as an upper bound although this would add a non-conservative bias. Note that this estimate implicitly includes differences in ionic radius and charge, but it is dominated by differences in tortuosity.

Then based on the range of tortuosity cited above and the D_m values for Am and Cs^+, the uncertainty in the effective diffusion coefficient (calculated using Equation 14) can be represented as a distribution with a range of 8×10^{-9} cm^2/s to 6×10^{-6} cm^2/s. For the lower bound, $D_e = D_m/\tau = 3.06 \times 10^{-6}/390 = 8 \times 10^{-9}$ cm^2/s. For the upper bound, $D_e = D_m/\tau =$ $2.06 \times 10^{-5}/3.5 = 6 \times 10^{-6}$ cm^2/s. To ensure that the effective diffusion coefficient is not over estimated, the upper bound is set below the smallest observed molecular diffusion coefficient. This reduction is accomplished by setting the upper bound of the effective diffusion coefficient at a value of 1×10^{-6} cm^2/s. This is a conservative assumption because it biases the sample to lower values, minimizing matrix diffusion and thus causing shorter travel times.

There is additional uncertainty in the effective diffusion coefficient on a field scale due to the limitations of the laboratory measurements such as: limited number of measurements made under limited geochemical conditions, potential effects of fracture coatings on effective diffusion coefficient, and temperature uncertainty and variability along the transport pathway. Given these additional sources of uncertainty along with the uncertainty and potential variability in contaminant form, the overall uncertainty in the effective diffusion coefficient limits us to an estimate of the order of magnitude of the model parameter value, between 10^{-9} and 10^{-6} cm^2/s. Because of the choice in this analysis the fastest (Cs) and the slowest (Am) diffusing radionuclides from the radionuclides considered in TSPA-SR (plus the extension of upper bound of this range), this range of D_e encompasses the radionuclides of interest to performance.

The effective diffusion coefficient is determined for a particular realization by the parameter DCVO. For a discussion on how this is parameter is used in the SZ site-scale model for TSPA-SR see CRWMS M&O 2000f. The log-uniform distribution for DCVO is specified here to be between 1×10^{-9} cm^2/s and 1×10^{-6} cm^2/s. The log-uniform distribution is unbiased with respect to the order of magnitude of the sampled parameter value, but it is skewed toward lower values of effective diffusion coefficient because of reasons stated above.

6.9 BULK DENSITY (CONSTANT)

Bulk density (ρ_b) is defined in Freeze and Cherry (1979, p. 337) as the "oven dried-mass of the sample divided by its field volume". It is a factor in the equation used to determine retardation of a solute due to chemical adsorption Equation 6 in groundwater. That equation is employed in the SZ site-scale flow and transport model (as part of the FEHM code, Zyvoloski et al. 1997).

Bulk density is treated as a constant parameter for all members of the nineteen SZ model hydrogeologic units. Constant, in this sense, means that ρ_b will vary from one unit to another, but, given a particular unit, the bulk density will stay the same for all realizations. The bulk density will also remain spatially constant for each unit. The parameter values and input source(s) are described in Section 4, Table 1. The underlying assumptions are discussed in Section 5.9. Section 6.9.1 contains a discussion of the analyses used to develop the values.

The volcanic units 11 through 15 do lie in the expected flow paths. Site specific indirect sources for those data have been identified, as shown by the DTN numbers provided in Section 4, Table 1. The source for units 13 through 15 was a graph that related bulk density to matrix porosity (CRWMS M&O 1999b, p. 71, Figure 24b). The graph led to an equation that is discussed in Section 6.9.1. As shown in Section 4, Table 1, the source for units 11 and 12 was a spreadsheet of values of measured bulk density from various Yucca Mountain boreholes (DTN: SNT05082597001.003). An average was taken of a majority of the entries for the 'middle volcanic aquifer'. The two alluvium units 7 and 19 also lie within the expected flow paths. CRWMS M&O 2000a, has been cited for bulk density for those units, based on area-specific core tests.

All of the remaining units 1-6, 8-10 and 16-18, are expected to lie outside of any expected SZ model transport paths per CRWMS M&O 2000e. However, the model requires values for ρ_b for all units whether or not they play a role. Therefore, values as representative as possible were used when available.

Site specific ρ_b values were available for the Lower Carbonate Aquifer (unit 3) and the Upper Clastic Confining Unit (unit 4) as shown in Section 4, Table 1, (DTN: SNT05082597001.003). Units 5, 6, and 17 are also carbonate aquifer units, so the value of ρ_b assigned to unit 3 was also assigned to those units. The bulk density assigned to unit 4 was used as an analogous value for unit 2, since unit 2 is also a clastic confining unit.

Units 8 and 10 are both volcanic confining units. The value of ρ_b for these units was obtained from the value for unit 14, which is a volcanic confining unit for which we have site-specific data. Unit 9 is a 'volcanic aquifer'. Its value was obtained by averaging the values for the three overlying volcanic Crater Flat group units (11-13) and unit 15.

The value of ρ_b for the "Valley Fill Confining Unit", 18, was adapted from the ρ_b used for the other alluvial units 7 and 19. Bulk density was calculated for the remaining two units, 16 (Lava Flows) and 1 (Granite), by an equation from Hillel (1980, p. 12) that relates bulk density to particle density and matrix porosity. Those calculations are described below.

6.9.1 Analysis

Estimates for bulk density were either based on the use of an analogous unit, or a calculation was required, as discussed below. For some units, including part of the volcanic units, the alluvial units, and the carbonate units, the calculation involved averaging a group of referenced bulk density values. A separate set of volcanic units required the use of a referenced graph to calculate bulk density as a certain function of matrix porosity (for which values had already been determined). Finally, two units (granite and lava flows) required the use of a general equation that relates bulk density to porosity. Many of the calculations required referencing either the effective porosities or the matrix porosities that were tabulated in Tables 8 and 9, respectively.

The estimated bulk densities are summarized in Table 10 and the methods used to obtain these values are summarized in the discussion below.

Table 10. Values of Bulk Density (ρ_b) for All Units of the SZ Site-Scale Model

SZ Unit Name	SZ Unit Number	Bulk Density (ρ_b) (g/cm^3)
Valley Fill	19	1.27
Valley Fill Confining Unit	18	1.27
Cenozoic Limestone	17	2.76
Lava Flows	16	2.44
Upper Volcanic Aquifer (Topopah)	15	2.08
Upper Volcanic Confining Unit (Calico Hills)	14	1.77
Lower Volcanic Aquifer, Prow Pass	13	1.84
Lower Volcanic Aquifer, Bullfrog	12	1.94
Lower Volcanic Aquifer, Tram	11	1.94
Lower Volcanic Confining Unit	10	1.77
Older Volcanic Aquifer	9	1.95
Older Volcanic Confining Unit	8	1.77
Undifferentiated Valley Fill	7	1.27
Upper Carbonate Aquifer	6	2.76
Lower Carbonate Aquifer Thrust	5	2.76
Upper Clastic Confining Unit	4	2.52
Lower Carbonate Aquifer	3	2.76
Lower Clastic Confining Unit	2	2.52
Granites	1	2.65

Alluvium - CRWMS M&O (2000a, p. 78, Table 9) contains a series of 12 values of bulk density for the alluvium units (7 and 19). A simple average was calculated from those values. As stated earlier, unit 18 also borrowed this value.

Carbonates - Bulk density for unit 3 is determined from a series of 17 values from the borehole UE-25p#1 (DTN: SNT05082597001.003). A simple average was calculated from those values. As stated earlier, the units 5, 6, and 17 all use this calculated value as well. See spreadsheet newbulkd.xls .

Clastics - Bulk density for unit 4 is determined from a series of 21 values from the borehole UE-25a#3 (DTN: SNT05082597001.003). A simple average was calculated from those values (see spreadsheet newbulkd.xls). As stated earlier, unit 2 also uses this calculated value.

Volcanic Units 13, 14, and 15 - The Rock Properties Model (CRWMS M&O 1999b) contains a graph (Figure 24b, on page 71) that relates point values of ρ_b to ϕ_m. The graph demonstrates a strong linear correlation between the two parameters. The equation for the straight-line fit to the scatterplot is shown below:

$$\rho_b = 2.5019 - 2.8924 \cdot \phi_m \qquad \text{(Eq. 15)}$$

Table 9 lists the values of ϕ_m for the units (13-15) that were used to calculate ρ_b. Units 8 and 10 are volcanic confining units. They were simply assigned the same bulk density value as calculated for unit 14, as described earlier.

Volcanic Units 11 and 12 - Bulk density for units 11 and 12 are determined from a series of 560 values of the so-called 'middle volcanic aquifer' which is equivalent to the SZ units 11 and 12 (DTN: SNT05082597001.003). The bulk density values come from the boreholes SD7, USW H-1, UE-25b#1, J-13, UE-25a#1, USW GU-3, USW G-3, USW G-4, UE-25p#1, and USW G-1. A simple average was calculated from those values (see spreadsheet newbulkd.xls).

Volcanic Unit 9 - Bulk density for this unit was simply calculated as an average of the values from the other volcanic units 11 through 13 and 15.

Lava Flows (unit 16) and Granites (unit 1) - Rearrangement of the terms from an equation in Hillel (1980, p. 12, Equation 2.14) yields the following general relationship between bulk density and porosity:

$$\rho_b = (1 - \phi_T) \cdot \rho_s \qquad \text{(Eq. 16)}$$

where ρ_s equals particle density [M/L^3] and ϕ_T equals the total porosity. The same text reference considers it appropriate that ρ_s can be equal to 2.65g/cm^3 (Hillel 1980, p. 9). As both of these units are not in the transport model path, it was considered suitable to use the particle density value and effective porosity to calculate bulk density (Equation 16) (see spreadsheet newbulkd.xls). The effective porosity values were used for Equation 16 because it was assumed that the effective porosity is very similar to the total porosity for the lava flow and granite units. The porosity values were taken from Table 8 . The lava flow unit has an effective porosity of 0.08 and the granite unit has a porosity of 0.0001. Therefore the bulk densities assigned for those units are 2.44 and 2.65 g/cm^3.

For the case of units 13-15, the values of bulk density vary spatially in the limited region of the SZ model that corresponds to the ISM rock-properties model. The ISM model consists of a series of stochastic simulations in which bulk density varies spatially and from realization to realization. The "expected value" of the spatial distribution of bulk density was developed from the average of these realizations (this calculation is not in this AMR, but is in CRWMS M&0 2000f). This distribution of bulk density values is used in the SZ site-scale flow and transport model (CRWMS M&O 2000f).

6.10 SORPTION COEFFICIENTS (STOCHASTIC)

Sorption or adsorption is the process by which dissolved radionuclides temporarily adhere or bond to rock and alluvial substrate along a transport path. Sorption occurs because of the electro-chemical affinity between the dissolved species and the substrate. The significance of sorption to the SZ site-scale flow and transport model is that sorption results in a retardation of the radionuclide because part of the radionuclides travel time is spent on the immobile surface. A comprehensive listing of assumptions associated with this section can be found in Section 5.10.

A linear, equilibrium, sorption coefficient, K_d, is considered appropriate for the radionuclides that exhibit sorption during transport. The K_d model also assumes chemical equilibrium between the aqueous phase and sorbed phase of a given species.

The K_d relationship is defined as follows (Domenico and Schwartz 1990, p. 441):

$$S = K_d C \qquad \text{(Eq. 17)}$$

where S [moles/g] is the mass sorbed on the surface of the substrate, and C [moles/mL] is the concentration of the dissolved mass (K_d [mL/g]). The K_d model determines transport retardation as described earlier per Equation 5. The quantity of ρ_b / ϕ in Equation 5 is a measure of the amount of substrate available for sorption.

The Yucca Mountain project has conducted various measurements to define the K_d parameter in different substrates for different radionuclides. Laboratory experiments have been conducted including batch sorption tests and column tests involving pure minerals (e.g., geothite and hematite) and crushed tuff for radionuclides such as neptunium (Np) and plutonium (Pu). Additional sorption coefficient laboratory experiments were conducted including alluvial samples for the radionuclides Np, Tc, and iodine (I) (CRWMS M&O 2000a). Field tests were also performed and the sorption process was studied at the C-well complex using a reactive tracer Lithium Bromide. The sorption process for colloids was also studied at the C-wells complex using micropheres (CRWMS M&O 2000b).

Sorption is a function of water chemistry and the mineralogy of the rock matrix encountered along the transport pathway (Triay et al. 1997, p. 134), both of which vary areally and can not be defined for all points in space with certainty. Not only are these characteristics of the system variable, but the exact path that a radionuclide takes through the system is uncertain, and the exact chemistry and mineralogy that a particular radionuclide will come in contact with are uncertain. Therefore, the sorption coefficient parameter is considered highly uncertain and can vary by several orders of magnitude. The sorption coefficients are described using probability distributions that span several orders of magnitude.

6.10.1 Sorption Coefficients in the Volcanic Units

The report, CRWMS M&O 2000a, states the assumption that sorption coefficients can be grouped by rock type. This assumption resulted in four sorption-coefficient distributions per radionuclide: iron oxides, vitric tuff, devitrified tuff, and zeolitic tuff (Wilson et al. 1994). The sorption coefficient distributions selected to be used in the SZ site-scale flow and transport calculations correspond to the *Kd* value with the lowest mean (a conservative approach).

Sorption coefficients (K_ds), for the volcanic units were determined for the following radionuclides: neptunium and uranium. Iodine, technetium and carbon in the volcanic units, have been classified as constant parameters and given a K_d value of 0, indicating no retardation. Iodine does not sorb onto tuffs therefore the sorption coefficient for Iodine was given a constant value of 0 (DTN: LA0003AM831341.001). Additionally, technetium exists as pertechnetate under oxidizing conditions and does not sorb (DTN: LA0003AM831341.001). Carbon is also assumed to be 0 because the major retardation mechanism is an exchange of carbon-14 with carbon in the carbon dioxide dissolved in the groundwater; therefore, assuming no adsorption is considered to be conservative (CRWMS M&O, 2000a , p. 114). K_ds for radionuclides that undergo colloid facilitated transport are discussed in Section 6.14.

These radionuclides were chosen as a result of Inventory Abstraction CRWMS M&O 2000g. Using (DTN: LA0003AM831341.001) as a basis, the radionuclide with the most conservative K_d distribution from among the three types of tuff were assigned to the volcanic units (distribution with the lowest mean K_d value). The sorption coefficient probability distributions used in the SZ site-scale model for the volcanic units are shown in Table 11.

Table 11. Sorption Coefficient Inputs to the SZ Site-Scale Model for the Volcanic Units

Radionuclide/Unit	Parameter Name	Stochastic/Constant	Distribution Type	Distribution Statistics/constant Values
Tc/volcanic	KDTCVO	Constant	NA	Constant value of 0
U/volcanic	KDUVO	Stochastic	Uniform	LB: 0.0, UB: 4.0 (units ml/g)
I/volcanic	KDIVO	Constant	NA	Constant value of 0
Np/volcanic	KDNPVO	Stochastic	Beta	Mean: 0.5; SD: 0.5; LB: 0.0; UB: 2.0 (units ml/g)
Carbon/all units	KDCVA	Constant	NA	Constant value of 0

DTN: LA0003AM831341.001. Carbon is based on CRWMS M&O 2000a.

6.10.2 Sorption Coefficients in the Alluvium Units

Sorption coefficients for the alluvial units were determined for the same radionuclides as discussed above for the volcanic units. The most recent summary of alluvium sorption data for Np, Tc and I is contained in CRWMS M&O 2000a and the associated DTNs are shown in Section 4 Table 1. Laboratory batch-sorption tests for Np, Tc, and I were conducted using alluvium from three boreholes drilled by the Nye County Early Warning Drilling Program. Waters used in these laboratory experiments were in equilibrium with atmospheric oxygen which probably resulted in lower K_d values (CRWMS M&O 2000a, p. 127). There is some evidence that reducing conditions exist in the groundwater at Yucca Mountain which, could result in higher K_d values than found in the laboratory experiments cited. It was considered appropriate to use a value of 0 for the sorption coefficient for carbon because of the same reasons cited above for the volcanic units. The sorption coefficient probability distributions used in the SZ site-scale flow and transport model in the alluvial units are shown in Table 12.

Table 12. Sorption Coefficient Inputs to the SZ Site-Scale Model for the Alluvial Units

Radionuclide/Unit	Parameter Name	Stochastic/Constant	Distribution Type	Distribution Statistics/constant Values
Tc/alluvium	KDTCAL	Stochastic	Uniform	LB: 0.27, UB: 0.62 (units ml/g)
U/alluvium	KDUAL	Stochastic	Uniform	LB: 0.0, UB: 8.0 (units ml/g)
I/alluvium	KDIAL	Stochastic	Uniform	LB: 0.32, UB: 0.63 (units ml/g)
Np/alluvium	KDNPAL	Stochastic	Beta	Mean: 18.2, SD: 18.8, LB: 0, UB: 100 (units ml/g)
Carbon/all units	KDCVA	Constant	NA	Constant value of 0

DTN: LA0003AM831341.001 for all radionuclides except for carbon which is based on CRWMS M&O 2000a.

6.11 LONGITUDINAL DISPERSIVITY (STOCHASTIC)

Longitudinal dispersion is the mixing of a solute with clean water that occurs along the direction of flow. This mixing is a function of many factors including the relative concentrations of the solute, the velocity pattern within the flow field, and the host rock properties. An important component of this dispersion is the dispersivity, a coarse measure of solute (mechanical) spreading properties of the rock. The dispersion process causes spreading of the solute in directions transverse to the flow path as well as in the longitudinal flow direction (Freeze and Cherry 1979, p.394). Longitudinal dispersivity will be important only at the leading edge of the advancing plume, while transverse dispersivity (horizontal transverse and vertical transverse) is the strongest control on plume spreading and possible dilution for the proposed Yucca Mountain repository (CRWMS M&O 1998, p. LG-12). The assumptions for longitudinal dispersivity are described in Section 5.11.

These dispersivities (longitudinal, vertical transverse and horizontal transverse) are used in the advection-dispersion equation governing solute transport and are implemented into the SZ site-scale model as a stochastic parameter. Recommendations from the expert elicitation were used as the basis for determining the distribution for longitudinal and transverse dispersivity. As part of the expert elicitation, Dr. Lynn Gelhar provided statistical distributions for longitudinal dispersivity at 5 km and 30 km (CRWMS M&O 1998, p. 3-21). These distributions for longitudinal dispersivity are consistent with his previous work (Gelhar 1986, pp. 135s-145s). CRWMS M&O 2000h, provided estimates of the transverse and longitudinal dispersion that may occur at the sub gridblock scale within the SZ site-scale model. The results from this AMR are in general agreement with the estimates by the expert elicitation panel (CRWMS M&O 2000h, p. 53).

In the SZ site-scale flow and transport model, the longitudinal dispersivity parameter will be sampled in log space for 100 realizations and the transverse dispersivities are then calculated according to the following relationships:

$$\alpha_h = \frac{\alpha_l}{200} \quad \text{(Eq. 18)}$$

$$\alpha_v = \frac{\alpha_l}{20000} \quad \text{(Eq. 19)}$$

where α_l is the longitudinal dispersivity, α_h is the transverse horizontal dispersivity and α_v is transverse vertical dispersivity.

The longitudinal dispersivity is determined for a particular realization by the parameter LDISP. The recommended statistical distribution is a truncated log-normal distribution: $E[\log_{10}(\alpha)]$: 2.0 and $S.D.[\log_{10}(\alpha)]$: 0.75.

6.12 HORIZONTAL ANISOTROPY

Anisotropy occurs when the permeability is directionally dependant. A recent study by Winterle and La Femina (1999) concluded that a conceptual model of horizontal anisotropy in the tuff aquifer is reasonable and flow in the tuff aquifer is believed to occur in a fracture network that exhibits a preferential north-south strike azimuth. In addition, north to north-northeast striking structural features are optimally oriented perpendicular to the direction of least principal horizontal compressive stress, suggesting tendency toward dilation and potentially higher permeability (Ferrill et al. 1999, p. 5). They recommended that hydrogeologic conceptual models for site-scale flow should consider the potential effects of horizontally anisotropic transmissivity. Performance assessment could be impacted by the inclusion of horizontal anisotropy because the flow could be diverted to the south causing transported solutes to remain in the fractured volcanic tuff for longer distances before moving into the valley fill/alluvial aquifer. The importance of this is that a more southward flow path would increase travel distances in the tuff and reduce the amount of flow in the alluvium (Ferrill et al. 1999, p. 7). A reduction in the flow path length in the alluvium would decrease the amount of total radionuclide retardation that could occur for those radionuclides with greater sorption coefficients in alluvium than in fractured volcanic rock matrix. In addition, potentially limited matrix diffusion in the fractured volcanic units could lead to shorter travel times in the volcanic units relative to the alluvium.

There is significant uncertainty in the appropriate model parameter value for horizontal anisotropy due to lack of data on the variability in the horizontal anisotropy over the scale of the transport path length. Winterle and La Femina (1999) estimated values for anisotropic transmissivity using data from the pumping tests at the C-well complex. These estimates are poorly constrained and may not be representative of the anisotropy on the scale of the transport model. The uncertainties include differences in pumping test analysis methods, the fact that only a minimum number of observation wells were used, and the additional uncertainty regarding the validity of assuming a homogenous effective continuum over the scale of the test (Winterle and La Femina 1999, p. 4-29). Given this uncertainty in anisotropy, and to simplify the model, the potential effects of anisotropy are bounded by setting the anisotropy ratio to 1 (isotropic) or 5 (based on the C-well data).

The stochastic parameter HAVO determines whether horizontal anisotropy is applied to a given realization for the TSPA calculations. The HAVO parameter is uniformly distributed from 0.0 to 1.0. For a value of 0.0 to 0.5 the isotropic groundwater flow field is used in radionuclide transport simulations. For a value of 0.5 to 1.0 the anisotropic groundwater flow field is used. The horizontal anisotropy ratio of 5:1 is imposed in the SZ site-scale flow model by multiplying values of horizontal permeability in the north-south direction by 2.24 and dividing values of horizontal permeability in the east-west direction by 2.24. This modification of the permeability field of the SZ site-scale model is applied to the volcanic units in an area beneath and to the south and east of Yucca Mountain.

6.13 RETARDATION OF RADIONUCLIDES IRREVERSIBLY SORBED ON COLLOIDS (STOCHASTIC)

For TSPA-SR, two conceptual models of colloid-facilitated transport of radionuclides are implemented: The first conceptual model involves radionuclides that are irreversibly or permanently (in the time frame of groundwater transport) sorbed onto colloids; the second deals with radionuclides that are reversibly or temporarily attached to colloids. This section deals with the first case; Section 6.14 addresses the second.

Important radionuclides considered appropriate for transported by this mechanism are americium, plutonium and thorium. The daughter products of these radionuclides, which are generated by radionculide decay, can also be transported by this mechanism. Americium, plutonium, and thorium, as well as several other radionuclides, are considered to be transported as reversibly sorbed onto colloids (see Section 6.14). The fraction of irreversibly sorbed to reversibly sorbed radionuclides is determined in the waste-form component of TSPA-SR and is used as input to the SZ flow and transport model.

6.13.1 Transport of Radionuclides Irreversibly Sorbed onto Colloids in the Volcanic Units

The processes important to the transport of irreversible colloids in the volcanic units of the saturated zone are as follows: advection and dispersion of colloids in the fracture water, exclusion of the colloids from the matrix waters, and chemical filtration or adsorption (here called filtration for brevity) of the colloids onto the fracture surfaces.

Modeling of the advective/dispersive processes is handled as if the colloids were solute in the SZ site-scale transport model. Matrix exclusion in the volcanic units is considered to be appropriate because of the large size and small diffusivities of the colloids compared to the solute, plus the possibility of similar electrostatic charge of the colloids and the tuff matrix. Matrix exclusion is implemented by reducing the values of the effective diffusion coefficients for solute (see Section 6.8 for a discussion of the solute diffusion coefficient) by ten orders of magnitude, thus preventing most (if not all) matrix diffusion. Filtration is modeled by applying a retardation factor to the transport. The retardation factor is discussed below and its use in the SZ site-scale model is described in CRWMS M&O 2000f.

The AMR, CRWMS M&O 2000b, derived colloid transport parameters from tracer tests conducted in fractured tuffs at the C-wells complex. The colloid tracers used at the C-wells complex consisted of fluorescent carboxylate-modified latex polystyrene microspheres. Based on CRWMS M&O 2000b, the discrete cumulative probability density function for microsphere retardation factors in the fractured tuff will be the statistical distribution used for colloid filtration in the volcanic units for input to the SZ site-scale model for TSPA-SR (see Figure 5 and Table 13). Colloid filtration in the volcanic units is determined for a particular realization by the parameter CORVO. Note that CRWMS M&O 2000b, refers to colloid filtration as retardation.

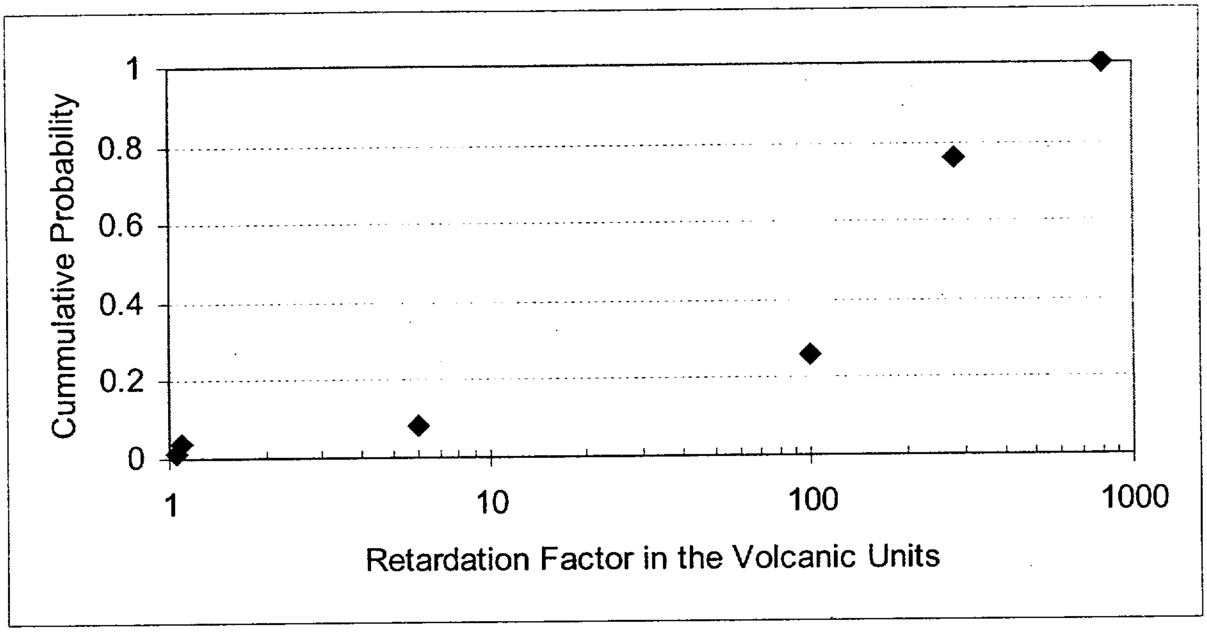


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Figure 5. Discrete Cumulative Probability Density Function for the Colloid Retardation Parameter in the Volcanic Units

Table 13. Values for Cumulative Probability Density Function Shown in Figure 5

Retardation Factor	Probability
1.06	0.0105
1.1	0.039
6	0.08125
100	0.2605
280	0.7605
800	1.0

6.13.2 Transport of Radionuclides Irreversibly Sorbed onto Colloids in the Alluvium

The processes modeled in the case of irreversible colloids in the alluvium are the same as those modeled for irreversible colloids in the volcanic units, with the exception of matrix exclusion, because the alluvium is a modeled as a single porous medium and is, therefore, in some sense, all matrix. The diffusion coefficient used for the irreversible colloids in the alluvium is the same as that for a solute in the alluvium. (Note that although there is no matrix diffusion in the alluvium, there is still a diffusion coefficient in the dispersion term of the advective-dispersive equation.) The diffusion coefficient is negligibly small part of the dispersion term, however.

Filtration of colloids, and the subsequent transport retardation, is conceptually the same in the volcanic units and the alluvium, except that the adsorption is not on the fracture surfaces, but rather on the alluvial grains. CRWMS M&O 2000b, uses two techniques to define a distribution of possible retardations: filtration theory, involving colloid/grain collisions and subsequent sorption, and evaluation of field-test data. As with irreversible colloids in the volcanic units, filtration in the alluvium is modeled by applying a retardation factor to the transport. Figure 6 and Table 14 are based on CRWMS M&O 2000b, and show the distribution of retardation in the alluvium that is input into the SZ site-scale model for TSPA-SR (see spreadsheet alluv_colloid_aw.xls). This CDF for retardation is based on a fine grain sand distribution. It should be noted that horizons with grains much larger than a coarse sand are likely to have their interstitial spaces filled by finer material, and horizons with grain sizes much smaller (e.g., clays) are unlikely to transmit much water (CRWMS M&O 2000b, p. 13). Colloid filtration in the alluvium units is determined for a particular realization by the parameter CORAL. The implementation of the retardation factor in the SZ site-scale model is described in CRWMS M&O 2000f.

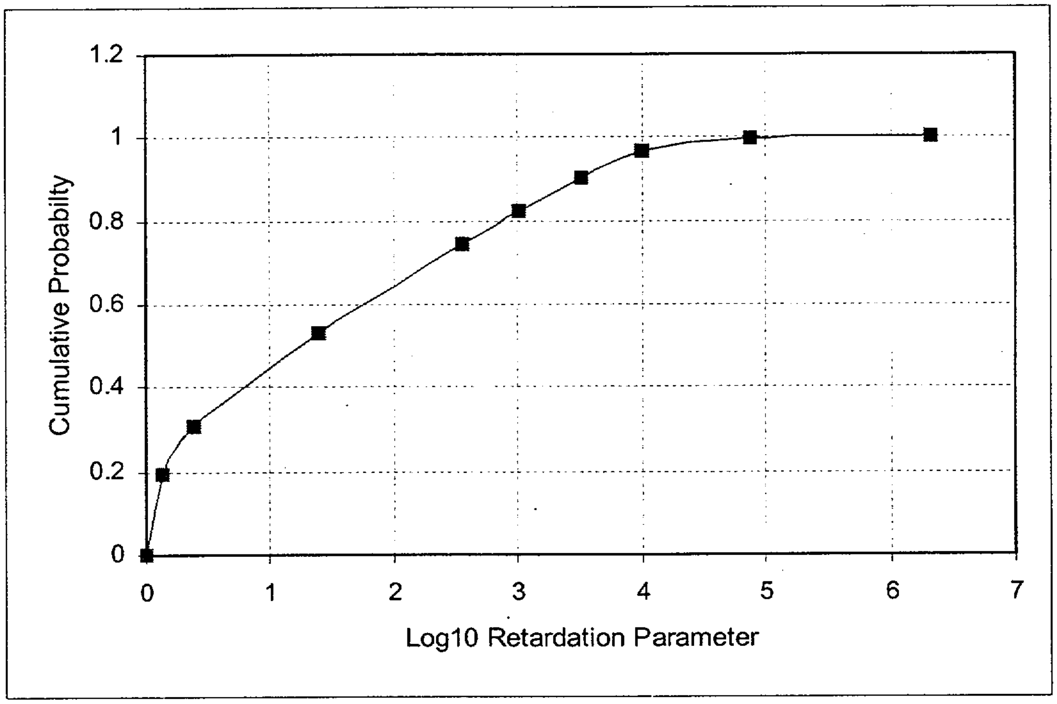

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Figure 6. Cumulative Probability Density Function for the Colloid Retardation Parameter in the Alluvium

Table 14. Values of the Cumulative Probability Density Function for the Retardation Parameter in the Alluvium

Log10 Retardation Factor	Probability
0.0011	0
0.13	0.19
0.38	0.31
1.40	0.53
2.56	0.74
3.01	0.82
3.51	0.90
3.99	0.97
4.88	0.99
6.32	1.0

6.14 RETARDATION OF RADIONUCLIDES REVERSIBLY SORBED ON COLLOIDS: THE K_C PARAMETER (STOCHASTIC)

Radionuclides that are reversibly sorbed onto colloids (here called reversible colloids for brevity) are assumed to be temporarily attached to the surface of colloids. Thus, these radionuclides are available for dissolution and their transport characteristics are a combination of the transport characteristics of solute and colloids. The colloids that form the substrate for the reversible sorption can be of any type, e.g., natural colloids (typically clay or silica), wasteform colloids resulting from degradation of spent fuel or glass, and iron oxihydroxide colloids resulting from degradation of the waste container.

Important radionuclides for the TSPA-SR nominal scenario that are transported as reversibly sorbed onto colloids are americium, plutonium, protactinium and thorium. Americium, plutonium and thorium are the highly sorbing radionuclides identified as significant in CRWMS M&O 2000g, and can only effectively transport with colloids. Americium and plutonium can also be transported as irreversibly sorbed onto colloids, see Section 6.13. Protactinium is included here because it is necessary to accurately compute the transport of the actinium radionuclide chain (protactinium is identified in CRWMS M&O 2000g only as being significant in the million-year time frame). Actinium, a highly sorbing radionuclide that is identified in CRWMS M&O 2000g as being significant, is not included here because, with its short half-life, secular equilibrium with protactinium is assumed for transport purposes. The radionuclides that will be transported by this mechanism in the human-intrusion calculation also includes cesium and strontium. These two radionuclides are included in CRWMS M&O 2000g as significant and are relatively highly sorbing, therefore, it is assumed that if they are going to transport at all they will transport via a colloidal mechanism.

For TSPA-SR, reversible colloids are modeled using the distribution coefficient, K_c, concept. The K_c parameter is a distribution coefficient that represents the equilibrium partitioning of radionuclides between the aqueous phase and the colloidal phase (CRWMS M&O 1997b, p. 8-35):

$$K_c = K_{dcol} C_{col} \qquad \text{(Eq. 20)}$$

where K_{dcol} [mL/g] is the sorption coefficient on colloids and C_{col} [mg/L] is the mass concentration of colloids in the groundwater. The K_c is a function of only radionuclide sorption properties, colloid substrate properties, and colloid mass concentration, and not any properties of the immobile media through which transport occurs; thus the same K_c applies to transport of a radionuclide in both the volcanic units and the alluvium.

For TSPA-SR, the K_{dcol} parameter is the based on the K_d for americium onto wasteform colloids from CRWMS M&O 2000c. The statistical distribution is a log-normal distribution with a geometric mean of 10^5 mL/g and a geometric standard deviation of 10. It is considered appropriate that the radionuclide with the highest K_d value for sorption onto colloids, americium (CRWMS M&O 2000c), is representative of all the radionuclides that are considered to be transported by this mechanism. This should lead to shorter transport travel times than if a more realistic representation is used that involves the sorption coefficients of all the radionuclides transported by this mechanism

The C_{col} parameter was taken directly from, CRWMS M&O 2000c and is considered the maximum colloid concentration. It is considered appropriate that the maximum colloid concentration as given in, CRWMS M&O 2000c is sufficient to determine the K_c parameter for TSPA-SR. This leads to transport travel times for radionuclides that are shorter than would occur if lower colloid concentrations were used in the calculation. The colloid concentration used to determine K_c was $C_{col} = 3 \times 10^{-2}$ mg/L (DTN: MO0003SPAHLO12.004). This value corresponds well with the value of $\sim 2.7 \times 10^{-2}$ mg/l reported by Ogard (1987, p. 115) for J-13 water. J-13 water, a dilute water in terms of major ion concentrations, results in a higher possible colloid concentration and a more conservative K_c value.

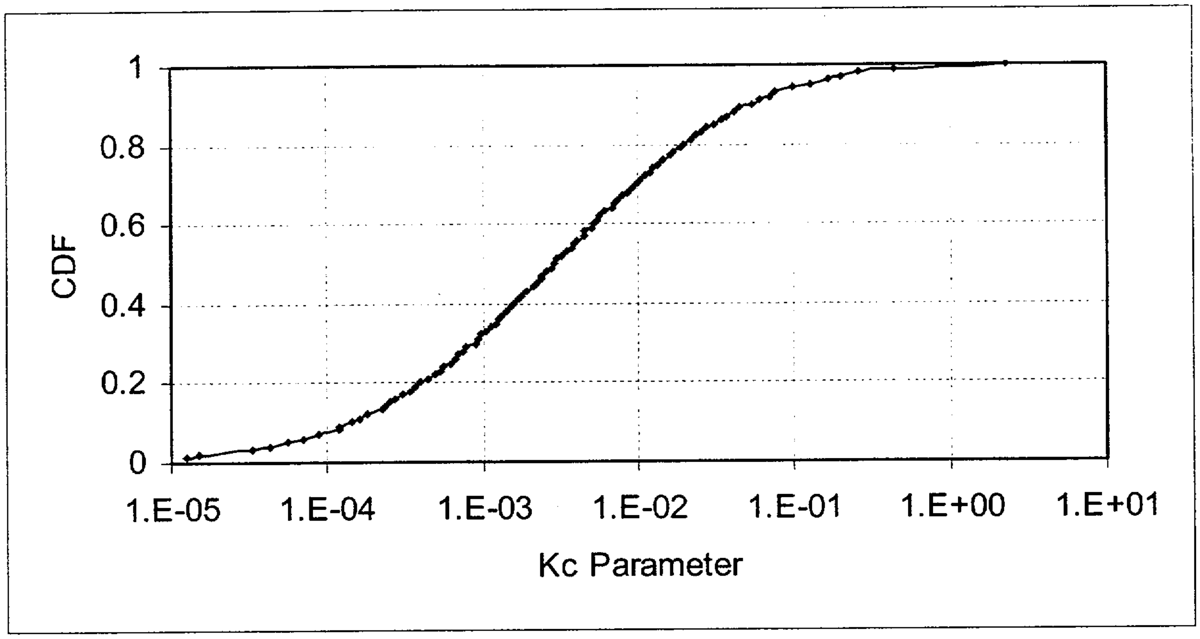
The product of K_{dcol} and C_{col} is a simple linear transformation (see Equation 20) of the K_{dcol} distribution from CRWMS M&O 2000c. This calculation is as follows: (note that a unit conversion factor has been added)

$$\text{Geo. Mean } (K_c) = \text{Geo.Mean}(K_{dcol}) \times C_{col} \text{ (after Equation 20)}$$

$$= \left(10^5 \frac{\text{mL}}{\text{g}}\right)(3 \times 10^{-2} \frac{\text{mg}}{\text{L}})(10^{-6} \frac{\text{g}-\text{L}}{\text{mL}-\text{mg}})$$

$$= \quad 3 \times 10^{-3} [\mathit{unitless}]$$

The resulting K_c log-normal distribution has a geometric mean (calculated above) of 3×10^{-3} and a geometric standard deviation 10 as shown in Figure 7. The K_c parameter, retardation of radionuclides reversibly sorbed on colloids, is determined for a particular realization by the parameter Kc_Am_gw_colloid.



DTN: MO0003SPAHLO12.004 and MO0004SPAKDS42.005.

Figure 7. The Statistical Distribution for the K_c Parameter

Accompanying the K_c model is the partitioning of radionuclides between the aqueous phase and the sorbed phase onto the tuff matrix and the alluvium, as described by the K_d for the radionuclide. The K_ds for americium, plutonium, protactinium, and thorium are described by a uniform distribution with a minimum of 0 and a maximum of 100 (based on DTN: LA0003AM831341.001). The K_ds for cesium and strontium are described by a uniform distribution with a minimum of 0 and a maximum of 50 (based on DTN: LA0003AM831341.001). The values in these distributions are equal to or less than the sorption values given in Section 6.10 for solute, and thus should lead to faster travel times for the radionuclides transported by the reversible-colloid mechanism. The same distributions are assumed to apply to the alluvium, for lack of knowledge about the actual K_d values for the alluvium for these radionuclides. It is possible, however, that the values for the alluvium could be similar or possibly greater than the vitric tuffs. Implementation of the K_c model in the SZ site-scale model is discussed in CRWMS M&O 2000f.

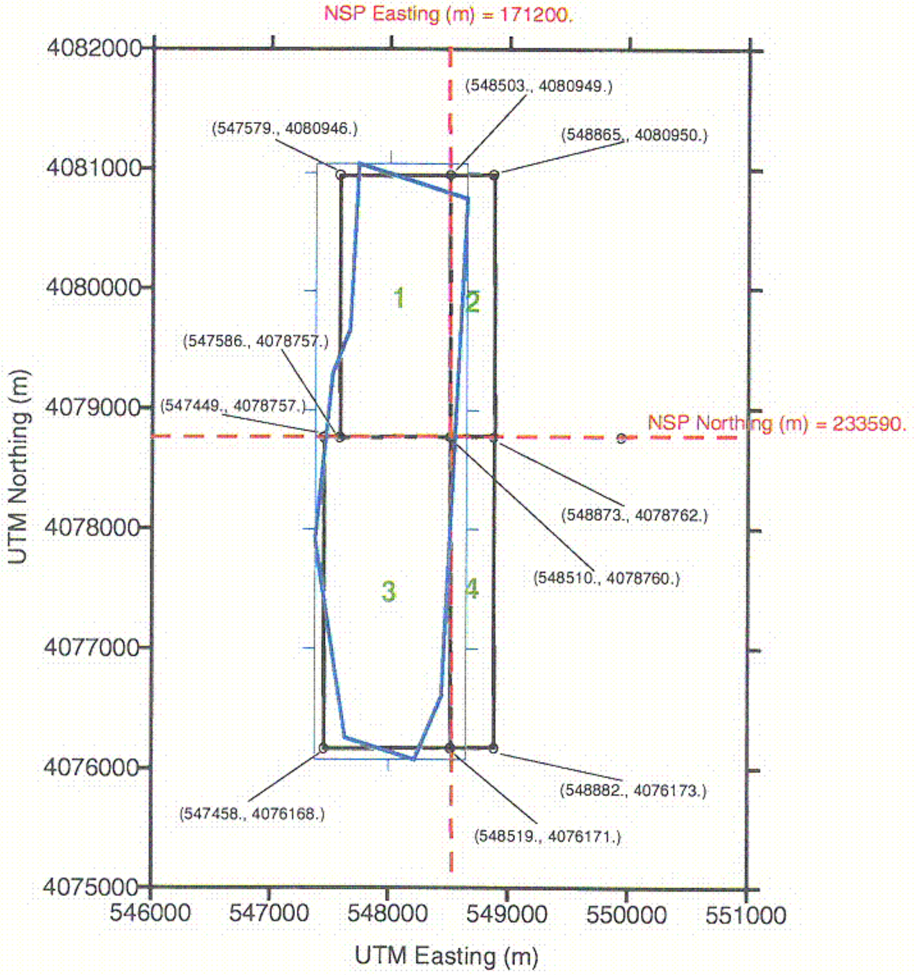
6.15 SOURCE REGION DEFINITION

Variations in radionuclide transport pathways and travel times in the saturated zone from various locations beneath the repository are considered by defining four radionuclide source regions at the water table. For any particular TSPA realization a point source of radionuclides is defined within each of the four regions for simulation of radionuclide transport in the SZ site-scale flow and transport model. A point source of radionuclides in the saturated zone is appropriate for a single leaking waste package or for highly focused groundwater flow along a fault or single fracture in the unsaturated zone. Whereas a more diffuse source of radionuclides at the water table may be more physically realistic for later times when numerous leaking waste packages occur, use of a point source in the SZ is a conservative approach that can be applied for all situations.

The SZ source region locations are based on the general pattern of groundwater flow in the unsaturated zone as simulated by the UZ site-scale flow and transport model. Variations in the pattern of groundwater flow from the repository to the water table exist among infiltration models, alternative conceptual models, and climate states for the UZ site-scale model (CRWMS M&O 2000i). The UZ flow and transport simulations indicate varying degrees of lateral diversion of groundwater to the east of the repository and downward redirection by interception of flow at major faults. The SZ source region locations are defined to accommodate the general range in UZ transport pathways simulated by the suite of UZ site-scale flow model simulations.

The four SZ radionuclide source regions are shown in Figure 8. Source regions 1 and 3 are located in the area directly below the repository to capture radionuclide transport that occurs vertically downward in the UZ site-scale flow and transport model. In addition, regions 1 and 3 are appropriate source locations for radionuclides arriving at the water table in the human intrusion scenario, in which a hypothetical borehole penetrates the repository and extends to the saturated zone. Source regions 2 and 4 are located to the east of the repository to capture radionuclide transport that is subject to lateral diversion of groundwater to the east along dipping volcanic strata in the saturated zone.

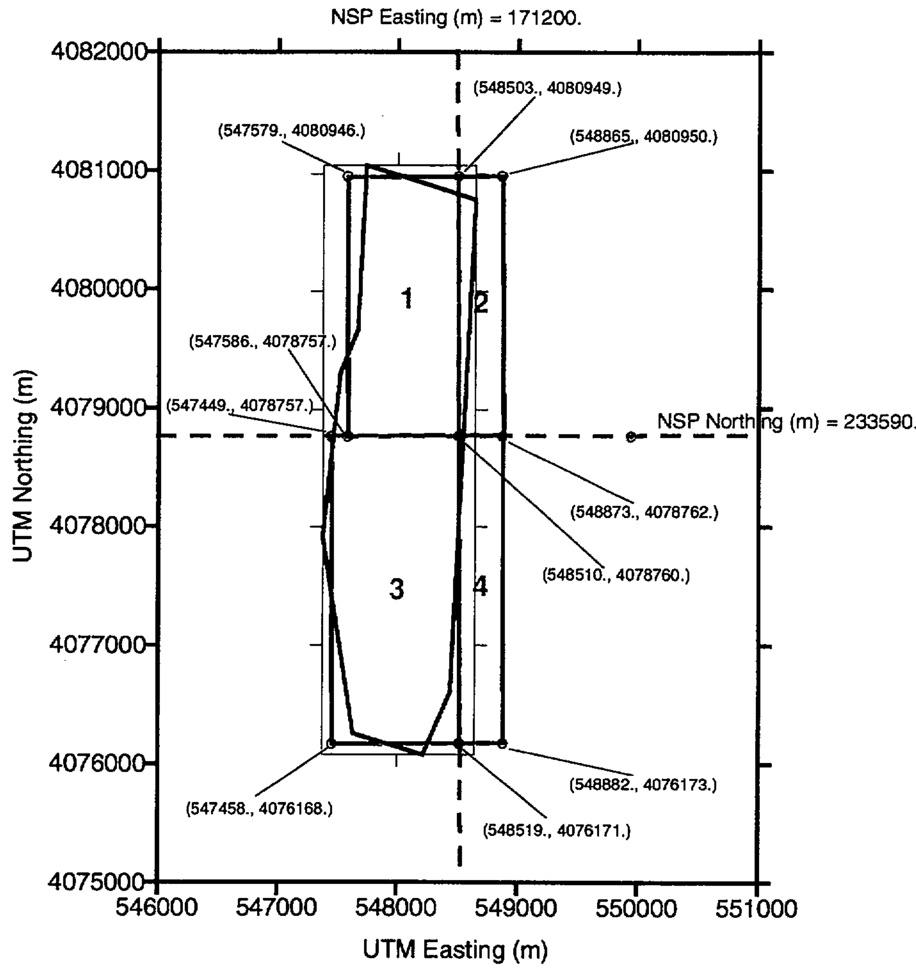
The random locations of the radionuclide source term for each realization are defined by eight stochastic parameters. The parameters SRC1X, SRC1Y, SRC2X, SRC2Y, SRC3X, SRC3Y, SRC4X, SRC4Y determine the x coordinate and y coordinate for the source location within regions 1 to 4, respectively. These parameter values are drawn from independent, uniform distributions from 0.0 to 1.0. The result is a randomly located point source within each of the four source regions for each realization of the SZ site-scale transport model.



NOTE: Source regions are outlined with the solid black rectangles and numbered from 1 to 4. The coordinates of the vertices of the source region rectangles are given in UTM coordinates (m). The outline of the repository is shown by the blue line. The dashed red lines indicate the quadrants from which radionuclide arrivals from the unsaturated zone model are applied to the SZ source regions. Coordinates of the dashed red lines are given in Nevada State Plane (NSP) coordinates (m)

Figure 8. Diagram Of Source Regions for the SZ Radionuclide Transport Simulations

C-2



NOTE: Source regions are outlined with the solid black rectangles and numbered from 1 to 4. The coordinates of the vertices of the source region rectangles are given in UTM coordinates (m). The outline of the repository is shown by the blue line. The dashed red lines indicate the quadrants from which radionuclide arrivals from the unsaturated zone model are applied to the SZ source regions. Coordinates of the dashed red lines are given in Nevada State Plane (NSP) coordinates (m)

Figure 8. Diagram Of Source Regions for the SZ Radionuclide Transport Simulations

7. CONCLUSIONS

Table 15 is a summary of all parameters (stochastic and constant values) developed in this AMR. Table 15 also includes the classification of the parameter as stochastic or constant, the constant values, and the statistical distributions that will be used in the SZ site scale model for TSPA-SR. The stochastic parameters were input into GoldSim and the parameters were sampled (for 100 realizations). The output file for Goldsim is located in the "results" area of the GoldSim file UZ_SZ_parameters_Sampling_03_30_00.gsm and in the text file sz_parameters_03_30_00.txt and is shown in Attachment II. Note that there are some parameters in this output file that are not used as input to the SZ site-scale model for the TSPA-SR calculations. The only parameters that are used as input to the SZ flow and transport model are shown in Table 15. It should be noted that these parameters should be limited to use as input to SZ flow and transport model for TSPA-SR calculations. Use of these parameters in other models should be evaluated for appropriateness. An additional limitation is that all outputs from this AMR are considered unqualified due to the use of the unqualified software GoldSim.

The developed data and the associated TBV numbers for the parameters developed in this analysis must be verified (see DIRS). It is important that the input TBVs are verified as expedient as possible because the parameters described in this AMR are inputs to the SZ site-scale calculations for TSPA-SR. This document may be affected by the technical product information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System Database.

Table 15. Summary Table of SZ Flow and Transport Stochastic and Constant Parameters

Parameter/Process	Parameter Goldsim Input Name	Flow Model Unit	Distribution Type	Distribution Statistics/Constant Values	Comments
Groundwater specific discharge (stochastic)	GWSPD	All	Uniform	LB: 0.0; UB: 1.0	Three discrete cases considered (low: 0.06, medium: 0.6, high: 6.0 m/yr). Expert elicitation aggregate CDF (CRWMS M&O 1998).
Northern Boundary of Alluvium (stochastic)	FPLAN	Valley Fill	Uniform	LB: 0.0; UB: 1.0	Northern boundary of the alluvium uncertainty zone defined by this parameter.
Western Boundary of Alluvium (stochastic)	FPLAW	Valley Fill	Uniform	LB: 0.0; UB: 1.0	Western boundary of the alluvium uncertainty zone defined by this parameter.
Effective porosity alluvium (stochastic)	NVF19 And NVF7	Unit 19 and 7, have been sampled separately	Truncated normal	Unit 19 and 7: Mean: 0.18, SD: 0.051	Bedinger et al. 1989, mean from (coarse grain valley fill) Table 1.
Effective Porosity (constant)	-	Units 18-16, 6-1	Constant	Mean Values: Unit 18: 0.32 Unit 17: 0.01 Unit 16: 0.08 Unit 6: 0.041 Unit 5: 0.041 Unit 4: 0.09 Unit 3: 0.041 Unit 2: 0.03 Unit 1: 0.0001 Total Porosity = 0.35	Unit 18: mean from (fine grain valley fill) Bedinger et al. 1989, Table 1 Unit 17: mean from (relatively dense carbonate rock) Bedinger et al. 1989, Table 1 Unit 16: mean from (Lava flow, average of mean fract. and dense) Bedinger et al. (1989, Table 1) Unit 6: same as unit 3 Unit 5: same as unit 3 Unit 4: DOE 1997 report, Table 8-1 Unit 3: DTN: SNT05082597001.003 Unit 2: DOE 1997 report, Table 8-1 Unit 1: mean from (felsic intrusive rocks, deep) Bedinger et al. 1989, Table 1 Total Porosity: Burbey and Wheatcraft 1986, p. 26 and DOE 1997, Table 8-1 and 8-2
Matrix Porosity Volcanic Units (constant) (Matrix diffusion model approach)	-	Units 15-8	Constant	Mean Values: Unit 15: 0.15 Unit 14: 0.25 Unit 13: 0.23 Unit 12: 0.19 Unit 11: 0.23 Unit 10: 0.25 Unit 9: 0.22 Unit 8: 0.25	Unit 15 - 13: MDL-NBS-GS-000004 REV 00, CRWMS M&O 1999b, p. 56, Table 13. Unit 12, 11: Mean values from DTN: SNT05082597001.003 Unit 10: same as unit 14 for matrix porosity Unit 9: average of unit 11-13 matrix porosity Unit 8: same as unit 14 for matrix porosity ISM 3.0 values applied within model domain, (Implemented in ANL-NBS-HS-000030, CRWMS M&O 2000f).

Table 15. Summary Table of SZ Flow and Transport Stochastic and Constant Parameters (Continued)

Parameter/Process	Parameter Goldsim Input Name	Flow Model Unit	Distribution Type	Distribution Statistics/Constant Values	Comments
Flowing interval spacing (stochastic)	FISVO	Units 15-8 Volcanic units	Log-normal	Mean: $E[\log_{10}(F_{smc})]$: 1.29 m and $S.D.[\log_{10}(F_{smc})]$: 0.43. (units: m)	DTN: SN9907T0571599.001
Flowing interval porosity (stochastic)	FPVO	Units 15-8 Volcanic units	Log-Uniform	Log_{10}(LB): -5.0; Log_{10}(UB): -1.0	Corroborative Data: DOE 1997, p. 5-14; Winterle and La Femina 1999, p. 4-12; CRWMS M&O, 1997a, p. 28; Geldon et al. 1998, p. 29; Wilson et al. 1994, p. 7-30.
Diffusion Coefficient (stochastic)	DCVO	Units 15-8 Volcanic units	Log-Uniform	Log_{10}(LB): -13.0; Log_{10}(UB): -10 (units: m^2/s)	Corroborative Data: Sharpe 1981, pp. 228, 657; Li and Gregory 1974, p. 704; Viswanath and Natarajan 1989, pp. 714, 715; Sposito 1981, p. 6945 Triay et .al. 1997, p. 192
Bulk Density (constant)	-	All units	Constant	Mean Values(units: g/cm^3): Unit 19: 1.27 Unit 18: 1.27 Unit 17: 2.76 Unit 16: 2.44 Unit 15: 2.08 Unit 14: 1.77 Unit 13: 1.84 Unit 12: 1.94 Unit 11: 1.94 Unit 10: 1.77 Unit 9: 1.95 Unit 8: 1.77 Unit 7: 1.27 Unit 6: 2.76 Unit 5: 2.76 Unit 4: 2.52 Unit 3: 2.76 Unit 2: 2.52 Unit 1: 2.65	Unit 19, 18 and 7: DTN: LA 0002JC831341.001 Unit 17: Same as unit 3 Unit 16 and Unit 1: Hillel 1980, p. 12. Equation 2.17 Unit 13, 14 and 15: (MDL-NBS-GS-000004, REV 00 CRWMS M&O 1999b, p.72, Figures 25d, 25c, and 25b) Unit 12: DTN: SNT05082597001.003 Unit 11: DTN: SNT05082597001.003 Unit 10: same as unit 14 Unit 9: average of unit 15, 13, 12, and 11 Unit 8: same as unit 14 Unit 6: same as unit 3 Unit 5: same as unit 3 Unit 4: DTN: SNT05082597001.003 Unit 3: DTN: SNT05082597001.003 Unit 2: Same as unit 4 ISM 3.0 values applied within model domain, (Implemented in ANL-NBS-HS-000030, CRWMS M&O 2000f)
Sorption Coefficient (K_d) (stochastic) Np	KDNPVO	Units 15-8 Volcanic units	Beta (exp)	Mean: 0.5; SD: 0.5; LB: 0.0; UB: 2.0 (units ml/g)	DTN: LA0003AM831341.001

Table 15. Summary Table of SZ Flow and Transport Stochastic and Constant Parameters (Continued)

Parameter/Process	Parameter Goldsim Input Name	Flow Model Unit	Distribution Type	Distribution Statistics/Constant Values	Comments
Sorption Coefficient (K_d) (stochastic) Np	KDNPAL	Alluvium Units 19,7	Beta	Mean: 18.2; SD: 18.8 LB: 0 ; UB: 100 (units ml/g)	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) I	KDIAL	Alluvium Units 19,7	Uniform	LB: 0.32; UB: 0.63 (units ml/g)	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (constant) I	KDIVO	Unit 15-8 Volcanic units	Constant	Constant value of 0 (units ml/g)	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) U	KDUVO	Unit 15-8 Volcanic units	Uniform	LB: 0.0; UB: 4.0 (units ml/g)	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) U	KDUAL	Alluvium Units 19,7	Uniform	LB: 0.0; UB: 8.0 (units ml/g)	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (stochastic) Tc	KDTCAL	Alluvium Units 19,7	Uniform	LB: 0.27, UB: 0.62 (units ml/g)	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (constant in volcanic units) Tc	KDTCVO	Unit 8-15 Volcanic units	Constant	Constant value of 0 (units ml/g)	DTN: LA0003AM831341.001
Sorption Coefficient (K_d) (constant) C	KDCVA	All units	Constant	Constant value of 0 (units ml/g)	Based on CRWMS M&0 2000a
Actinide (Am, Pu, Pa, Th)[a] matrix/alluvium K_ds for the Kc model	KDRN10	All units	Uniform	LB: 0, UB: 100	Based on DTN: LA0003AM831341.001
Fission Products (Cs and Sr)[b] matrix/alluvium K_ds for the Kc model	KDRN9	All units	Uniform	LB: 0, UB: 50	Based on DTN: LA0003AM831341.001
Longitudinal Dispersivity	LDISP	All	Truncated Log-normal	$E[\log_{10}(\alpha)]$: 2.0 $S.D.[\log_{10}(\alpha)]$: 0.75 Units: (m)	DTN: MO0003SZFWTEEP.000. (CRWMS M&O 1998, LG-14) Expert Elicitation. Horizontal transverse dispersivity and vertical transverse dispersivity correlated with longitudinal dispersivity. Horizontal transverse dispersivity $E[\log_{10}(\alpha_h)]$: -0.30; $SD[\log_{10}(\alpha_h)]$: 0.75. Vertical transverse dispersivity $E[\log_{10}(\alpha_v)]$: -2.30; $SD[\log_{10}(\alpha_h)]$: 0.75.
Horizontal Anisotropy (stochastic)	HAVO	All volcanic Units 15-8	Uniform	LB: 0, UB: 1.0	Winterle and La Femina 1999 and Ferrill et al. 1999 (Corroborative) 0.0 to 0.5 isotropic flow, 0.5 to 1.0 anisotropic flow

Table 15. Summary Table of SZ Flow and Transport Stochastic and Constant Parameters (Continued)

Parameter/Process	Parameter Goldsim Input Name	Flow Model Unit	Distribution Type	Distribution Statistics/Constant Values	Comments
Source region definition (stochastic) Zone 1 x dimension	SRC1X	SRC1X	Uniform	UB: 0; LB: 1.0	N/A
Source region definition (stochastic) Zone 1 y dimension	SRC1Y	SRC1Y	Uniform	UB: 0; LB: 1.0	N/A
Source region definition (stochastic) Zone 2 x dimension	SRC2X	SRC2X	Uniform	UB: 0; LB: 1.0	N/A
Source region definition (stochastic) Zone 2 y dimension	SRC2Y	SRC2Y	Uniform	UB: 0; LB: 1.0	N/A
Source region definition (stochastic) Zone 3 x dimension	SRC3X	SRC3X	Uniform	UB: 0; LB: 1.0	N/A
Source region definition (stochastic) Zone 3 y dimension	SRC3Y	SRC3Y	Uniform	UB: 0; LB: 1.0	N/A
Source region definition (stochastic) Zone 4 x dimension	SRC4X	SRC4X	Uniform	UB: 0; LB: 1.0	N/A
Source region definition (stochastic) Zone 4 y dimension	SRC4Y	SRC4Y	Uniform	UB: 0; LB: 1.0	N/A
Colloid Retardation Factor Volcanic Units (irreversible)	CORVO	All Volcanic Units 15-8	Piece-wise CDF	See Figure 5 and Table 13	DTN: LA0002PR831231.003 This parameter is perfectly correlated with CORAL (Correlation of 1).
Colloid Retardation Factor Alluvium Units (irreversible)	CORAL	Alluvium Units 19,7	CDF	See Figure 6 and Table 14	DTN: LA0004AW12213S.001
Kc Am Parameter for reversible colloids	Kc_Am_gw_colloid	All units	Log-normal	Geometric mean: 3 x 10^{-3}, Geometric SD: 10.0	DTN: MO0003SPAHLO12.004 and DTN: MO0004SPAKDS42.005

[a] Am (Americium), Pu (Plutonium), Pa (Protactinium), and Th (Thorium).
[b] Cs (Cesium) and Sr (Strontium)

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LA0004AW12213S.001. Input and Output Modeling Data for Goldsim Calculations Associated with AMR: ANL-NBS-HS-000031. Submittal date: 04/11/2000. URN-0270

MO0003SPAHLO12.004. Highest and Lowest Observed or Expected Groundwater Colloid Masses Per Unit Volume or Mass of Water; Values of Ionic Strength Above Which Groundwater Colloid Dispersions Are Unstable Concentration and Stability of Groundwater Colloids as Defined by Ionic Strength of Groundwater. Submittal date: 03/16/2000.

MO0003SZFWTEEP.000. Data Resulting from the Saturated Zone Flow and Transport Expert Elicitation Project. Submittal date: 03/06/2000.

MO0004SPAKDS42.005. Kds for Pu and Am on Waste Form, Iron (hydr)Oxide, and Groundwater Colloids. Submittal date: 04/10/2000.

SN9907T0571599.001. Probability Distribution of Flowing Interval Spacing. Submittal date: 07/15/1999.

SNT05082597001.003. TSPA-VA (Total System Performance Assessment-Viability Assessment) Saturated Zone (SZ) Base Case Modeling Analysis Results. Submittal date: 02/03/1998.

8.4 SOFTWARE

Sandia National Laboratory. 2000. *Software Code: GoldSim V6.03.* V6.03. 10296-6.03-00.

9. ATTACHMENTS

I Electronic listing of files used to develop the subject AMR

II Stochastic Parameters

ATTACHMENT I

The following listing identifies the electronic files for this AMR which have been submitted to the Technical Data Management System (TDMS) under SN0004T0571599.004.

The following files are the output of this AMR:

UZ_SZ_parameters_Sampling_03_30_00.gsm	GoldSim input file (results included in this file also)
Sz_parameters_03_30_00.txt	Result file from GoldSim in a text file format.

The following files are the supporting files that provide calculations, figures, and documentation to verify that the routines used in this AMR provide the correct results.

Excel:

Kc_am.xls	graph for Kc distribution
Newbulkd.xls	bulk density information
Geo_names.xls	effective porosity and matrix porosity
De_Tortuosity.xls	effective diffusion coefficients calculations
Alluv_colloid_aw.xls	volcanic and alluvial colloidal distribution graphs

Grapher: specific discharge figure.

Surfer: alluvial boundary figure.

ATTACHMENT II

FPLAW	FPLAN	NVF19	NVF7	FISVO	FPVO	DCVO	KDNPVO	KDNPAL	KDIAL	KDUVO	KDUAL	KCPU	GWSPD	KDRN10	KDRN9	KDRN8	KDRN7	KDRN6	KDRN5
0.36069	0.98069	0.20253	0.13542	0.59155	-2.1972	-10.388	0.78027	28.627	0.35742	3.1628	2.0056	-0.72999	0.91425	0.50425	0.62425	0.84425	0.61425	0.13425	0.14425
0.98312	0.67312	0.13587	0.097752	1.5198	-1.5075	-10.771	0.83848	0.94526	0.56587	1.0125	7.4649	-2.3516	0.71046	0.91046	0.50046	0.62046	0.84046	0.61046	0.13046
0.67125	0.19125	0.096864	0.20692	1.7773	-2.035	-10.716	0.018233	31.656	0.39789	3.725	1.77	-3.3701	0.44643	0.71643	0.91643	0.50643	0.62643	0.84643	0.61643
0.1913	0.0513	0.20693	0.23777	1.5688	-1.9548	-12.636	0.91696	3.2667	0.6087	0.8852	3.8504	0.74359	0.2755	0.4455	0.7155	0.9155	0.5055	0.6255	0.8455
0.051887	0.70189	0.23792	0.21311	1.5967	-4.5125	-10.624	0.078308	53.16	0.38878	1.9275	2.0951	0.57933	0.95395	0.27395	0.44395	0.71395	0.91395	0.50395	0.62395
0.70805	0.87805	0.21408	0.21735	0.80445	-1.8078	-12.226	1.4761	2.7529	0.4713	1.0722	5.5044	-1.0184	0.92214	0.95214	0.27214	0.44214	0.71214	0.91214	0.50214
0.87245	0.74245	0.21642	0.12077	1.6408	-3.9902	-10.203	0.060918	10.819	0.40136	2.7298	0.73961	-4.3312	0.66006	0.92006	0.95006	0.27006	0.44006	0.71006	0.91006
0.74465	0.76465	0.12132	0.22196	1.0079	-1.2614	-12.326	0.30383	3.5825	0.53224	0.37862	6.0372	0.020328	0.11565	0.66565	0.92565	0.95565	0.27565	0.44565	0.71565
0.7657	0.1257	0.22215	0.14657	1.9439	-4.0972	-11.543	0.087559	22.394	0.34967	3.0228	3.9656	-1.8756	0.83954	0.11954	0.66954	0.92954	0.95954	0.27954	0.44954
0.12125	0.79125	0.14586	0.25577	0.96165	-3.075	-12.216	0.64148	0.56635	0.55289	1.965	5.85	-1.0887	0.52976	0.83976	0.11976	0.66976	0.92976	0.95976	0.27976
0.79331	0.25331	0.25657	0.14124	1.2729	-3.9468	-10.95	0.010797	27.945	0.47293	2.9332	7.5465	-2.4072	0.65082	0.52082	0.83082	0.11082	0.66082	0.92082	0.95082
0.25894	0.93894	0.1422	0.17861	1.0268	-2.2443	-12.703	0.82736	11.556	0.54907	3.7957	2.7915	-4.3591	0.43597	0.65597	0.52597	0.83597	0.11597	0.66597	0.92597
0.93325	0.22325	0.17789	0.14776	1.4955	-4.627	-10.74	0.31534	26.172	0.61241	1.373	4.346	-3.6837	0.10441	0.43441	0.65441	0.52441	0.83441	0.11441	0.66441
0.22411	0.48411	0.14789	0.20443	0.72774	-1.9836	-11.518	0.76381	56.307	0.42667	2.1764	2.6729	-0.10655	0.21303	0.10303	0.43303	0.65303	0.52303	0.83303	0.11303
0.4818	0.2618	0.2041	0.11227	1.5829	-3.0328	-10.805	1.4962	5.6716	0.48796	1.3272	3.3744	-2.6714	0.81687	0.21687	0.10687	0.43687	0.65687	0.52687	0.83687
0.26006	0.68006	0.11173	0.21441	1.2802	-2.0797	-10.18	0.14499	13.518	0.42232	1.6803	2.4805	-4.7307	0.38929	0.81929	0.21929	0.10929	0.43929	0.65929	0.52929
0.68314	0.093137	0.2149	0.17915	1.558	-1.2275	-11.971	0.38781	5.4152	0.45117	1.2525	5.7851	-2.1729	0.045317	0.38532	0.81532	0.21532	0.10532	0.43532	0.65532
0.096651	0.75665	0.1796	0.21228	1.9842	-3.6134	-11.36	0.14196	8.5571	0.41816	2.9066	6.9332	-3.8963	0.47838	0.048382	0.38838	0.81838	0.21838	0.10838	0.43838
0.75269	0.49269	0.21167	0.26049	1.1172	-2.8292	-12.002	0.22771	4.8208	0.54404	3.4508	1.1416	-1.7888	0.18406	0.47406	0.04406	0.38406	0.81406	0.21406	0.10406
0.49047	0.73047	0.25952	0.15908	1.3344	-3.6781	-11.739	0.12014	25.102	0.58675	0.56187	1.0437	-0.06353	0.53465	0.18465	0.47465	0.044651	0.38465	0.81465	0.21465
0.73655	0.94655	0.15993	0.18597	1.11	-3.2938	-12.05	0.74525	40.994	0.36543	0.54619	4.9324	-3.5113	0.82233	0.53233	0.18233	0.47233	0.042331	0.38233	0.81233
0.94328	0.34328	0.18555	0.15808	1.2079	-3.7469	-10.83	1.151	1.2519	0.36132	2.4531	6.7463	-4.8593	0.2402	0.8202	0.5302	0.1802	0.4702	0.040198	0.3802
0.34516	0.54516	0.15834	0.17042	1.0845	-2.0994	-10.405	0.026739	1.1244	0.5107	3.3806	5.0013	-4.0201	0.022989	0.24299	0.82299	0.53299	0.18299	0.47299	0.042989
0.54108	0.33108	0.16989	0.15492	1.5424	-1.5557	-12.577	0.021518	17.423	0.58074	2.4843	4.0087	-1.909	0.16501	0.025006	0.24501	0.82501	0.53501	0.18501	0.47501
0.33946	0.42946	0.15612	0.21117	1.7737	-4.4022	-12.582	0.51741	38.574	0.51513	2.0378	7.3556	-4.9349	0.51203	0.16203	0.022034	0.24203	0.82203	0.53203	0.18203
0.42629	0.31629	0.21068	0.23657	0.83995	-4.4548	-11.151	1.0906	18.356	0.47695	3.6652	5.7303	-1.1427	0.013264	0.51326	0.16326	0.023264	0.24326	0.82326	0.53326
0.31891	0.72891	0.2372	0.12697	0.82596	-2.5244	-10.453	0.53518	12.013	0.60486	2.8756	3.5912	-4.6058	0.64229	0.01229	0.51229	0.16229	0.02229	0.24229	0.82229
0.72148	0.86148	0.12531	0.12298	1.4123	-1.6341	-11.136	0.32672	48.694	0.54056	1.7659	2.1718	-1.5682	0.063041	0.64304	0.013041	0.51304	0.16304	0.023041	0.24304
0.86459	0.14459	0.12372	0.19485	1.7262	-2.5016	-11.486	1.3608	24.622	0.45782	1.0984	7.6367	-3.741	0.57903	0.069028	0.64903	0.019028	0.51903	0.16903	0.029028
0.14688	0.13688	0.19516	0.23219	1.4296	-2.9725	-10.249	0.7221	9.3439	0.40583	3.8275	7.415	0.78266	0.20534	0.57534	0.065341	0.64534	0.015341	0.51534	0.16534
0.13528	0.61528	0.23185	0.19628	1.2965	-1.3389	-10.854	0.25392	3.834	0.61614	3.7011	5.3223	-2.5498	0.96371	0.20371	0.57371	0.063714	0.64371	0.013714	0.51371
0.61118	0.84118	0.19573	0.18017	1.8701	-2.1553	-11.676	0.091262	58.35	0.60557	2.6447	0.88947	-4.5235	0.40039	0.96039	0.20039	0.57039	0.060388	0.64039	0.010388
0.84978	0.62978	0.18127	0.25161	1.5408	-3.2009	-12.161	1.6012	52.66	0.52763	0.47913	6.7183	0.86554	0.070612	0.40061	0.96061	0.20061	0.57061	0.060612	0.64061
0.62343	0.50343	0.24949	0.20873	1.2299	-3.9063	-10.14	1.4024	20.802	0.35516	3.3337	4.1875	-3.1498	0.97584	0.075844	0.40584	0.96584	0.20584	0.57584	0.065844
0.50546	0.91546	0.20904	0.17305	1.0352	-1.1782	-10.224	0.60791	0.84698	0.57899	2.1018	5.2437	-3.2229	0.30585	0.97585	0.075848	0.40585	0.96585	0.20585	0.57585
0.9152	0.7152	0.17301	0.1496	2.0204	-1.2992	-11.004	0.016459	36.71	0.48281	2.6208	3.4816	-4.4825	0.29947	0.30947	0.97947	0.079473	0.40947	0.96947	0.20947
0.71289	0.44289	0.14925	0.26538	1.9031	-2.3484	-12.661	1.0454	12.672	0.5224	1.7316	0.82314	-3.5648	0.082942	0.29294	0.30294	0.97294	0.072942	0.40294	0.96294
0.44989	0.27989	0.26925	0.25525	1.4795	-4.5205	-10.48	0.36768	20.555	0.45636	0.43954	1.7591	-1.4036	0.23158	0.081577	0.29158	0.30158	0.97158	0.071577	0.40158
0.27852	0.95852	0.25473	0.20222	0.78453	-1.6459	-11.414	0.59363	9.0113	0.35364	0.87409	6.5482	-3.0502	0.5904	0.2304	0.080405	0.2904	0.3004	0.9704	0.070405
0.95659	0.92659	0.20195	0.11927	1.7121	-2.8936	-11.03	0.24369	0.73874	0.38714	3.2664	3.0927	-1.4606	0.32321	0.59321	0.23321	0.08321	0.29321	0.30321	0.97321
0.92546	0.66546	0.11898	0.22978	1.3182	-2.3782	-11.694	0.013793	2.4994	0.57279	1.5418	0.36366	-1.1815	0.58725	0.32725	0.59725	0.23725	0.087247	0.29725	0.30725
0.66618	0.11618	0.22993	0.18336	1.4633	-3.2553	-12.681	0.057542	34.404	0.43972	0.18474	3.8095	-1.3763	0.63815	0.58815	0.32815	0.59815	0.23815	0.088149	0.29815
0.11433	0.83433	0.18312	0.20024	1.22	-4.5827	-12.357	0.98604	7.035	0.33374	1.8973	1.4746	-0.81168	0.60432	0.63432	0.58432	0.32432	0.59432	0.23432	0.084316
0.8354	0.5254	0.20039	0.17175	0.75516	-4.1384	-10.554	0.18783	0.17158	0.46737	0.7416	4.2832	-0.34133	0.69396	0.60396	0.63396	0.58396	0.32396	0.59396	0.23396
0.52747	0.65747	0.17201	0.11683	0.95616	-1.7301	-11.838	0.002794	10.608	0.37811	2.1499	6.6197	-1.642	0.77241	0.69241	0.60241	0.63241	0.58241	0.32241	0.59241
0.65801	0.43801	0.11698	0.14033	1.6808	-3.448	-12.856	0.29497	1.9542	0.48678	3.312	1.9841	-4.7915	0.55816	0.77816	0.69816	0.60816	0.63816	0.58816	0.32816
0.4395	0.1095	0.14059	0.22659	1.1706	-4.802	-11.562	0.044369	13.49	0.57714	0.99799	0.23599	0.34631	0.038456	0.55846	0.77846	0.69846	0.60846	0.63846	0.58846
0.10843	0.21843	0.22639	0.1656	0.58226	-3.0863	-12.435	0.38059	35.867	0.39701	0.1137	1.3474	0.32275	0.89655	0.036549	0.55655	0.77655	0.69655	0.60655	0.63655
0.21819	0.81819	0.16556	0.095352	1.2674	-4.2472	-11.385	1.0301	3.1931	0.32874	0.67276	4.1455	-4.0798	0.88266	0.89266	0.03266	0.55266	0.77266	0.69266	0.60266
0.81792	0.38792	0.095217	0.17721	0.9113	-2.8483	-10.516	0.075967	0.074713	0.37206	2.0717	0.14339	-2.7207	0.15078	0.88078	0.89078	0.030784	0.55078	0.77078	0.69078
0.3882	0.048204	0.17724	0.13495	1.3319	-1.6872	-12.255	0.000987	1.6432	0.48064	0.072816	5.1856	-2.8655	0.37826	0.15826	0.88826	0.89826	0.038258	0.55826	0.77826
0.042678	0.47268	0.13389	0.18419	1.6884	-4.0293	-12.932	0.033236	12.191	0.32393	2.5707	0.50142	-3.3079	0.35425	0.37425	0.15425	0.88425	0.89425	0.034255	0.55425

FPLAW	FPLAN	NVF19	NVF7	FISVO	FPVO	DCVO	KDNPVO	KDNPAL	KDIAL	KDUVO	KDUAL	KCPU	GWSPD	KDRN10	KDRN9	KDRN8	KDRN7	KDRN6	KDRN5
0.47776	0.18776	0.18484	0.22822	0.99868	-4.8889	-12.497	0.34982	0.034467	0.52081	0.27106	4.6221	-3.924	0.28045	0.35045	0.37045	0.15045	0.88045	0.89045	0.030451
0.18398	0.53398	0.22747	0.14469	0.45085	-4.3441	-11.458	0.000242	19.489	0.33983	2.2959	1.6319	-2.1832	0.17858	0.28858	0.35858	0.37858	0.15858	0.88858	0.89858
0.53628	0.82628	0.14506	0.081392	0.87563	-2.9349	-12.951	0.56891	0.32774	0.49865	0.82512	7.7302	-1.5936	0.46514	0.17514	0.28514	0.35514	0.37514	0.15514	0.88514
0.82583	0.24583	0.081017	0.13055	1.3078	-4.9367	-11.063	0.005375	15.397	0.38381	3.8633	3.2466	-2.5122	0.56341	0.46341	0.17341	0.28341	0.35341	0.37341	0.15341
0.24544	0.025439	0.13047	0.18199	0.37811	-2.4182	-12.804	0.43975	2.2977	0.61929	1.6218	0.60351	-0.16668	0.41354	0.56354	0.46354	0.17354	0.28354	0.35354	0.37354
0.021747	0.16175	0.18152	0.065005	1.4466	-4.753	-11.285	0.050415	61.812	0.44454	0.28699	7.774	0.12337	0.80099	0.41099	0.56099	0.46099	0.17099	0.28099	0.35099
0.16398	0.51398	0.068362	0.19882	0.64034	-2.7041	-12.388	1.6282	7.7199	0.34293	3.8959	2.4318	-2.2535	0.85278	0.80278	0.41278	0.56278	0.46278	0.17278	0.28278
0.51597	0.015972	0.19909	0.10328	1.373	-4.1761	-10.102	0.20929	0.41393	0.62255	1.2239	2.3678	-4.9507	0.45399	0.85399	0.80399	0.41399	0.56399	0.46399	0.17399
0.018071	0.64807	0.1041	0.19005	0.94231	-1.1277	-11.776	0.007559	68.757	0.4155	1.1923	0.70457	-2.6541	0.006403	0.4564	0.8564	0.8064	0.4164	0.5664	0.4664
0.65	0.069998	0.1903	0.13893	2.0992	-3.36	-12.76	1.7454	4.7487	0.413	0.35999	1.92	-0.28089	0.39701	0.00701	0.45701	0.85701	0.80701	0.41701	0.56701
0.064468	0.57447	0.13794	0.27209	1.1872	-4.7021	-10.077	0.11545	4.3333	0.34619	0.93787	4.7557	0.4137	0.78646	0.39646	0.00646	0.45646	0.85646	0.80646	0.41646
0.57716	0.20716	0.2739	0.16807	0.68167	-1.0914	-12.079	0.10996	0.52353	0.39352	2.3886	2.6172	0.9455	0.90213	0.78213	0.39213	0.002132	0.45213	0.85213	0.80213
0.20932	0.96932	0.16835	0.1082	2.1676	-3.7627	-12.102	0.009894	2.9832	0.50579	1.3173	4.7145	-2.7838	0.99568	0.90568	0.78568	0.39568	0.005681	0.45568	0.85568
0.96853	0.40853	0.10793	0.28327	1.0765	-3.8059	-12.734	0.070419	16.676	0.42185	2.3541	5.1083	0.90691	0.36649	0.99649	0.90649	0.78649	0.39649	0.006486	0.45649
0.40115	0.071151	0.27683	0.15348	1.0551	-4.6754	-12.307	0.4665	5.0605	0.50016	2.5246	4.8092	-0.94458	0.98675	0.36675	0.99675	0.90675	0.78675	0.39675	0.006749
0.076752	0.97675	0.1543	0.15283	0.70856	-4.053	-11.21	0.13351	16.005	0.51739	2.427	5.574	-3.8486	0.67803	0.98803	0.36803	0.99803	0.90803	0.78803	0.39803
0.97757	0.30757	0.15295	0.11094	0.98471	-2.6097	-12.017	0.46032	19.074	0.50835	2.7903	6.2205	-4.6978	0.19896	0.67896	0.98896	0.36896	0.99896	0.90896	0.78896
0.30481	0.29481	0.11005	0.14318	1.3937	-3.7008	-11.246	0.54647	17.049	0.53539	3.0992	4.4385	-0.75896	0.053983	0.19398	0.67398	0.98398	0.36398	0.99398	0.90398
0.29577	0.085773	0.14334	0.19236	1.0973	-2.6569	-11.093	0.49233	23.151	0.56049	2.2231	0.28619	0.25899	0.70239	0.052391	0.19239	0.67239	0.98239	0.36239	0.99239
0.080968	0.23097	0.19173	0.15634	1.3784	-2.4761	-11.197	0.66274	29.608	0.4908	0.12387	7.1277	-0.5325	0.8791	0.7091	0.059102	0.1991	0.6791	0.9891	0.3691
0.23193	0.59193	0.15648	0.19055	1.4354	-2.5923	-10.924	0.86232	14.124	0.3299	3.5677	7.0554	-0.41966	0.74881	0.87881	0.70881	0.058807	0.19881	0.67881	0.98881
0.59245	0.32245	0.19062	0.19725	1.4022	-2.2302	-10.683	0.40238	0.096601	0.59666	3.5298	1.2196	-4.2789	0.76634	0.74634	0.87634	0.70634	0.056343	0.19634	0.67634
0.32036	0.58036	0.19697	0.19297	1.5041	-1.9186	-11.349	0.001143	44.789	0.59291	0.60144	2.9629	-0.23391	0.12616	0.76616	0.74616	0.87616	0.70616	0.056157	0.19616
0.58055	0.63055	0.19299	0.20536	1.6089	-2.7978	-12.908	1.2566	43.156	0.36667	1.4822	2.8044	-3.483	0.7967	0.1267	0.7667	0.7467	0.8767	0.7067	0.056705
0.63604	0.60604	0.20616	0.2187	1.3512	-4.8558	-10.312	1.2383	1.4523	0.43657	1.4242	2.2883	0.58823	0.25503	0.79503	0.12503	0.76503	0.74503	0.87503	0.70503
0.60032	0.69032	0.21774	0.18646	0.49251	-1.4387	-10.359	0.028654	6.5715	0.4286	1.1213	1.3626	-3.6347	0.93575	0.25575	0.79575	0.12575	0.76575	0.74575	0.87575
0.69543	0.77543	0.18711	0.088069	1.8305	-1.4583	-12.534	0.17776	6.0907	0.40848	0.70171	3.7234	-2.1105	0.2267	0.9367	0.2567	0.7967	0.1267	0.7667	0.7467
0.77617	0.55617	0.088545	0.24428	1.8092	-4.3753	-11.871	0.15942	4.1113	0.37461	1.8647	4.5293	-3.3996	0.48264	0.22264	0.93264	0.25264	0.79264	0.12264	0.76264
0.55568	0.035678	0.24414	0.24141	0.85708	-3.4973	-11.933	0.10134	1.7605	0.46436	2.2627	3.3254	-0.89339	0.262	0.482	0.222	0.932	0.252	0.792	0.122
0.034941	0.89494	0.24122	0.12827	1.1542	-3.5802	-12.145	0.037784	10.078	0.49513	1.6598	6.4395	-4.4544	0.68599	0.26599	0.48599	0.22599	0.93599	0.25599	0.79599
0.89833	0.88833	0.12899	0.16425	1.1353	-3.8467	-12.465	0.28253	14.989	0.44968	3.2333	6.8666	-0.46463	0.09409	0.68409	0.26409	0.48409	0.22409	0.93409	0.25409
0.88339	0.15339	0.16358	0.16087	1.0453	-4.3065	-11.61	0.41989	8.0615	0.56905	3.4135	3.6271	-2.0197	0.75687	0.096867	0.68687	0.26687	0.48687	0.22687	0.93687
0.15276	0.37276	0.16078	0.15075	0.88661	-3.1489	-11.312	0.21656	32.892	0.58436	1.8111	0.022107	-0.6101	0.49905	0.75905	0.099055	0.68905	0.26905	0.48905	0.22905
0.37438	0.35438	0.15099	0.13227	1.2526	-2.7425	-11.757	0.95561	39.246	0.46086	0.017511	3.155	0.6439	0.73071	0.49071	0.75071	0.090712	0.68071	0.26071	0.48071
0.35291	0.28291	0.13198	0.17529	1.3587	-3.3484	-10.591	1.1137	9.5842	0.3209	1.5716	6.2633	-2.9133	0.94842	0.73842	0.49842	0.75842	0.098422	0.68842	0.26842
0.28753	0.17753	0.17588	0.18868	1.2016	-1.7699	-10.427	0.26894	0.007948	0.44324	3.1501	7.2603	-1.7293	0.34449	0.94449	0.73449	0.49449	0.75449	0.09449	0.68449
0.17253	0.46253	0.18803	0.16877	1.6562	-1.5899	-11.642	7.95E-06	7.321	0.56259	3.6101	7.9403	-2.9812	0.54262	0.34262	0.94262	0.73262	0.49262	0.75262	0.092616
0.46469	0.56469	0.16906	0.22379	1.7449	-3.1812	-12.986	0.19725	30.978	0.60046	3.9788	2.9176	-2.4215	0.33216	0.54216	0.34216	0.94216	0.73216	0.49216	0.75216
0.56321	0.41321	0.22351	0.23358	1.2405	-4.9872	-11.82	0.8938	47.088	0.62789	1.4528	7.8657	-3.1398	0.42481	0.33481	0.54481	0.34481	0.94481	0.73481	0.49481
0.41461	0.80461	0.23389	0.17422	0.21402	-3.4216	-10.646	1.316	81.345	0.43303	3.9384	5.3968	-0.6782	0.31937	0.42937	0.33937	0.54937	0.34937	0.94937	0.73937
0.80038	0.85038	0.17368	0.017518	1.1716	-1.8785	-10.299	1.842	6.2505	0.62392	2.6815	1.523	0.1818	0.72509	0.31509	0.42509	0.33509	0.54509	0.34509	0.94509
0.85476	0.45476	0.048979	0.16644	1.6294	-1.3809	-10.016	0.16758	72.641	0.52918	0.77905	0.4381	-4.1416	0.86201	0.72201	0.31201	0.42201	0.33201	0.54201	0.34201
0.45429	0.004289	0.16637	0.22013	1.8522	-1.0228	-11.907	1.7823	21.563	0.38023	0.21716	5.6343	-4.1988	0.1408	0.8608	0.7208	0.3108	0.4208	0.3308	0.5408
0.003431	0.39343	0.21998	0.24639	2.3568	-3.5463	-10.05	0.62469	2.056	0.33656	2.8137	6.9874	-1.3203	0.1384	0.1484	0.8684	0.7284	0.3184	0.4284	0.3384
0.39625	0.78625	0.24724	0.31639	1.1444	-1.055	-10.971	0.047702	0.24754	0.53894	3.505	5.97	0.060254	0.61672	0.13672	0.14672	0.86672	0.72672	0.31672	0.42672
0.78395	0.90395	0.30801	0.16231	2.2121	-2.3042	-12.418	0.00361	23.78	0.59093	2.9758	6.1116	-1.2531	0.84295	0.61295	0.13295	0.14295	0.86295	0.72295	0.31295
0.90658	0.99658	0.16267	0.29294	1.4874	-4.2137	-12.83	0.69807	42.528	0.55144	3.0663	1.0127	-1.9761	0.62522	0.84522	0.61522	0.13522	0.14522	0.86522	0.72522
0.99861	0.36861	0.29616	0.20365	0.92798	-4.7656	-10.874	1.2089	27.515	0.55827	0.51443	6.3889	0.50648	0.5013	0.6213	0.8413	0.6113	0.1313	0.1413	0.8613

KDRN4	KDRN3	KDRN2	KDRN1	CORAL	CORVO	SRC4Y	SRC4X	SRC3X	SRC2Y	SRC2X	SRC3Y	SRC1Y	SRC1X	HAVO	LDISP	KDTCAL	Kc_Pu_gw_Colloid	Kc_Am_gw_Colloid
0.86425	0.72425	0.31425	0.42425	0.49705	2.066	0.34425	0.94425	0.73425	0.49425	0.75425	0.094248	0.68425	0.26425	0.48425	1.4395	0.59699	0.000217	0.000746
0.14046	0.86046	0.72046	0.31046	0.89067	2.1431	0.54046	0.34046	0.94046	0.73046	0.49046	0.75046	0.090463	0.68046	0.26046	1.9673	0.34716	7.74E-05	0.16403
0.13643	0.14643	0.86643	0.72643	0.41569	2.05	0.33643	0.54643	0.34643	0.94643	0.73643	0.49643	0.75643	0.096429	0.68643	1.5392	0.44025	0.016832	0.076408
0.6155	0.1355	0.1455	0.8655	2.4592	2.4159	0.4255	0.3355	0.5455	0.3455	0.9455	0.7355	0.4955	0.7555	0.095502	2.3647	0.36293	0.008751	0.007855
0.84395	0.61395	0.13395	0.14395	3.2581	2.6441	0.31395	0.42395	0.33395	0.54395	0.34395	0.94395	0.73395	0.49395	0.75395	1.0284	0.50938	0.000825	0.000181
0.62214	0.84214	0.61214	0.13214	0.096253	1.1932	0.72214	0.31214	0.42214	0.33214	0.54214	0.34214	0.94214	0.73214	0.49214	2.5131	0.30225	1.85E-05	0.027341
0.50006	0.62006	0.84006	0.61006	0.088924	1.1109	0.86006	0.72006	0.31006	0.42006	0.33006	0.54006	0.34006	0.94006	0.73006	1.9852	0.53252	0.002927	0.003508
0.91565	0.50565	0.62565	0.84565	1.8583	2.3176	0.14565	0.86565	0.72565	0.31565	0.42565	0.33565	0.54565	0.34565	0.94565	2.4747	0.44348	0.000348	0.007504
0.71954	0.91954	0.50954	0.62954	3.1688	2.6167	0.13954	0.14954	0.86954	0.72954	0.31954	0.42954	0.33954	0.54954	0.34954	3.2321	0.52884	0.000762	0.002118
0.44976	0.71976	0.91976	0.50976	1.9355	2.3303	0.61976	0.13976	0.14976	0.86976	0.72976	0.31976	0.42976	0.33976	0.54976	1.7162	0.60242	0.000209	0.00016
0.27082	0.44082	0.71082	0.91082	1.2575	2.2149	0.84082	0.61082	0.13082	0.14082	0.86082	0.72082	0.31082	0.42082	0.33082	2.0802	0.38929	1.57E-05	0.000503
0.95597	0.27597	0.44597	0.71597	3.601	2.7431	0.62597	0.84597	0.61597	0.13597	0.14597	0.86597	0.72597	0.31597	0.42597	1.6882	0.46109	4.83E-05	0.02347
0.92441	0.95441	0.27441	0.44441	2.3985	2.406	0.50441	0.62441	0.84441	0.61441	0.13441	0.14441	0.86441	0.72441	0.31441	1.8617	0.38704	0.002444	0.001523
0.66303	0.92303	0.95303	0.27303	0.99372	2.1633	0.91303	0.50303	0.62303	0.84303	0.61303	0.13303	0.14303	0.86303	0.72303	1.6407	0.41806	0.000156	5.72E-05
0.11687	0.66687	0.92687	0.95687	0.31076	2.0146	0.71687	0.91687	0.50687	0.62687	0.84687	0.61687	0.13687	0.14687	0.86687	2.4547	0.3809	5.34E-06	0.002605
0.83929	0.11929	0.66929	0.92929	3.949	2.8256	0.44929	0.71929	0.91929	0.50929	0.62929	0.84929	0.61929	0.13929	0.14929	2.8442	0.52525	0.000264	0.000373
0.52532	0.83532	0.11532	0.66532	3.6761	2.7609	0.27532	0.44532	0.71532	0.91532	0.50532	0.62532	0.84532	0.61532	0.13532	1.2187	0.57286	3.94E-05	0.003714
0.65838	0.52838	0.83838	0.11838	2.1467	2.3648	0.95838	0.27838	0.44838	0.71838	0.91838	0.50838	0.62838	0.84838	0.61838	1.196	0.32193	0.000365	0.025951
0.43406	0.65406	0.52406	0.83406	0.079215	1.0018	0.92406	0.95406	0.27406	0.44406	0.71406	0.91406	0.50406	0.62406	0.84406	2.2202	0.31692	0.00256	0.000623
0.10465	0.43465	0.65465	0.52465	3.0765	2.5884	0.66465	0.92465	0.95465	0.27465	0.44465	0.71465	0.91465	0.50465	0.62465	2.7623	0.48513	5.90E-05	3.35E-05
0.21233	0.10233	0.43233	0.65233	1.3558	2.2342	0.11233	0.66233	0.92233	0.95233	0.27233	0.44233	0.71233	0.91233	0.50233	2.2364	0.56482	3.64E-06	0.000305
0.8102	0.2102	0.1002	0.4302	2.0473	2.3485	0.8302	0.1102	0.6602	0.9202	0.9502	0.2702	0.4402	0.7102	0.9102	2.0041	0.48707	3.20E-05	0.003262
0.38299	0.81299	0.21299	0.10299	0.94786	2.1543	0.52299	0.83299	0.11299	0.66299	0.92299	0.95299	0.27299	0.44299	0.71299	3.0214	0.44605	0.000321	1.52E-05
0.045006	0.38501	0.81501	0.21501	0.07372	0.94008	0.65501	0.52501	0.83501	0.11501	0.66501	0.92501	0.95501	0.27501	0.44501	2.4283	0.59025	2.35E-06	0.007111
0.47203	0.042034	0.38203	0.81203	0.16843	1.6696	0.43203	0.65203	0.52203	0.83203	0.11203	0.66203	0.92203	0.95203	0.27203	1.8951	0.51921	0.000717	8.69E-05
0.18326	0.47326	0.043264	0.38326	2.9503	2.5476	0.10326	0.43326	0.65326	0.52326	0.83326	0.11326	0.66326	0.92326	0.95326	1.5546	0.42514	8.42E-06	0.004564
0.53229	0.18229	0.47229	0.04229	0.71639	2.1089	0.21229	0.10229	0.43229	0.65229	0.52229	0.83229	0.11229	0.66229	0.92229	3.2523	0.3653	0.000456	0.000438
0.82304	0.53304	0.18304	0.47304	0.036119	0.11186	0.81304	0.21304	0.10304	0.43304	0.65304	0.52304	0.83304	0.11304	0.66304	3.0712	0.60356	4.39E-05	0.19843
0.24903	0.82903	0.53903	0.18903	1.1581	2.1955	0.38903	0.81903	0.21903	0.10903	0.43903	0.65903	0.52903	0.83903	0.11903	2.3304	0.59516	0.020579	0.001715
0.025341	0.24534	0.82534	0.53534	0.12247	1.4877	0.045341	0.38534	0.81534	0.21534	0.10534	0.43534	0.65534	0.52534	0.83534	1.1146	0.50287	0.000171	0.000118
0.16371	0.023714	0.24371	0.82371	1.4101	2.2444	0.47371	0.043714	0.38371	0.81371	0.21371	0.10371	0.43371	0.65371	0.52371	2.7287	0.3098	1.02E-05	0.2666
0.51039	0.16039	0.020388	0.24039	2.9904	2.5612	0.18039	0.47039	0.040388	0.38039	0.81039	0.21039	0.10039	0.43039	0.65039	2.0419	0.56064	0.023992	0.000951
0.010612	0.51061	0.16061	0.020612	0.23116	1.8644	0.53061	0.18061	0.47061	0.040612	0.38061	0.81061	0.21061	0.10061	0.43061	2.2927	0.45221	9.50E-05	0.000895
0.64584	0.015844	0.51584	0.16584	0.025683	0.035965	0.82584	0.53584	0.18584	0.47584	0.045844	0.38584	0.81584	0.21584	0.10584	1.8834	0.49955	8.90E-05	0.000121
0.065848	0.64585	0.015848	0.51585	0.11064	1.3548	0.24585	0.82585	0.53585	0.18585	0.47585	0.045848	0.38585	0.81585	0.21585	1.0778	0.42255	1.21E-05	0.000557
0.57947	0.069473	0.64947	0.019473	1.3427	2.2316	0.029473	0.24947	0.82947	0.53947	0.18947	0.47947	0.049473	0.38947	0.81947	1.4276	0.30832	5.83E-05	0.005268
0.20294	0.57294	0.062942	0.64294	0.017853	0.030645	0.16294	0.022942	0.24294	0.82294	0.53294	0.18294	0.47294	0.042942	0.38294	2.6686	0.34453	0.000534	0.001035
0.96158	0.20158	0.57158	0.061577	2.0001	2.3408	0.51158	0.16158	0.021577	0.24158	0.82158	0.53158	0.18158	0.47158	0.041577	1.7792	0.55405	0.000109	0.005029
0.4004	0.9604	0.2004	0.5704	0.046655	0.41465	0.010405	0.5104	0.1604	0.020405	0.2404	0.8204	0.5304	0.1804	0.4704	0.72235	0.40314	0.000489	0.006756
0.07321	0.40321	0.96321	0.20321	1.6261	2.2797	0.64321	0.01321	0.51321	0.16321	0.02321	0.24321	0.82321	0.53321	0.18321	1.9537	0.28512	0.000665	0.005495
0.97725	0.077247	0.40725	0.96725	0.15792	1.637	0.067247	0.64725	0.017247	0.51725	0.16725	0.027247	0.24725	0.82725	0.53725	1.3431	0.43704	0.000554	0.00998
0.30815	0.97815	0.078149	0.40815	4.0711	2.8425	0.57815	0.068149	0.64815	0.018149	0.51815	0.16815	0.028149	0.24815	0.82815	2.0752	0.33585	0.000966	0.017142
0.29432	0.30432	0.97432	0.074316	0.81695	2.1286	0.20432	0.57432	0.064316	0.64432	0.014316	0.51432	0.16432	0.024316	0.24432	2.7009	0.45701	0.001752	0.004071
0.083959	0.29396	0.30396	0.97396	0.054881	0.65101	0.96396	0.20396	0.57396	0.063959	0.64396	0.013959	0.51396	0.16396	0.023959	1.4873	0.55839	0.000409	4.35E-05
0.23241	0.082405	0.29241	0.30241	4.1872	2.8506	0.40241	0.96241	0.20241	0.57241	0.062405	0.64241	0.012405	0.51241	0.16241	0.54655	0.35484	4.58E-06	0.054841
0.59816	0.23816	0.088163	0.29816	0.37946	2.0426	0.078163	0.40816	0.96816	0.20816	0.57816	0.068163	0.64816	0.018163	0.51816	1.2889	0.27986	0.005112	0.045025
0.32846	0.59846	0.23846	0.088456	0.35815	2.0339	0.97846	0.078456	0.40846	0.96846	0.20846	0.57846	0.068456	0.64846	0.018456	2.0383	0.32896	0.004623	0.000277
0.58655	0.32655	0.59655	0.23655	0.06252	0.81427	0.30655	0.97655	0.076549	0.40655	0.96655	0.20655	0.57655	0.066549	0.64655	0.46717	0.45079	2.81E-05	0.001418
0.63266	0.58266	0.32266	0.59266	0.21371	1.8102	0.29266	0.30266	0.97266	0.07266	0.40266	0.96266	0.20266	0.57266	0.06266	2.2767	0.27443	0.000143	0.00127
0.60078	0.63078	0.58078	0.32078	1.7223	2.2954	0.080784	0.29078	0.30078	0.97078	0.070784	0.40078	0.96078	0.20078	0.57078	0.86162	0.49427	0.000131	0.000787
0.69826	0.60826	0.63826	0.58826	0.4697	2.0606	0.23826	0.088258	0.29826	0.30826	0.97826	0.078258	0.40826	0.96826	0.20826	2.1511	0.29389	8.20E-05	0.000345

KDRN4	KDRN3	KDRN2	KDRN1	CORAL	CORVO	SRC4Y	SRC4X	SRC3X	SRC2Y	SRC2X	SRC3Y	SRC1Y	SRC1X	HAVO	LDISP	KDTCAL	Kc_Pu_gw_Colloid	Kc_Am_gw_Colloid
0.77425	0.69425	0.60425	0.63425	1.6866	2.2896	0.59425	0.23425	0.084255	0.29425	0.30425	0.97425	0.074255	0.40425	0.96425	1.3887	0.47099	3.61E-05	0.002443
0.55045	0.77045	0.69045	0.60045	1.9393	2.3309	0.32045	0.59045	0.23045	0.080451	0.29045	0.30045	0.97045	0.070451	0.40045	3.3187	0.34016	0.00024	0.004463
0.038579	0.55858	0.77858	0.69858	1.8196	2.3113	0.58858	0.32858	0.59858	0.23858	0.088579	0.29858	0.30858	0.97858	0.078579	1.8315	0.609	0.000447	0.00178
0.89514	0.035142	0.55514	0.77514	2.2931	2.3887	0.63514	0.58514	0.32514	0.59514	0.23514	0.085142	0.29514	0.30514	0.97514	0.94025	0.4118	0.000187	0.022189
0.88341	0.89341	0.033411	0.55341	2.726	2.4718	0.60341	0.63341	0.58341	0.32341	0.59341	0.23341	0.083411	0.29341	0.30341	3.4517	0.29569	0.002243	0.034893
0.15354	0.88354	0.89354	0.033539	1.5185	2.2621	0.69354	0.60354	0.63354	0.58354	0.32354	0.59354	0.23354	0.083539	0.29354	1.6206	0.61074	0.003475	0.002366
0.37099	0.15099	0.88099	0.89099	0.028808	0.038089	0.77099	0.69099	0.60099	0.63099	0.58099	0.32099	0.59099	0.23099	0.080994	1.5937	0.37535	0.000234	1.24E-05
0.35278	0.37278	0.15278	0.88278	3.4367	2.699	0.55278	0.77278	0.69278	0.60278	0.63278	0.58278	0.32278	0.59278	0.23278	0.97774	0.37247	1.08E-06	0.001579
0.28399	0.35399	0.37399	0.15399	3.3822	2.6823	0.033988	0.55399	0.77399	0.69399	0.60399	0.63399	0.58399	0.32399	0.59399	1.4634	0.2994	0.000167	0.018968
0.1764	0.2864	0.3564	0.3764	0.10491	1.2904	0.8964	0.036403	0.5564	0.7764	0.6964	0.6064	0.6364	0.5864	0.3264	2.1859	0.35274	0.001811	0.060738
0.46701	0.17701	0.28701	0.35701	0.69228	2.1042	0.88701	0.89701	0.03701	0.55701	0.77701	0.69701	0.60701	0.63701	0.58701	1.6698	0.47895	0.006178	2.3425
0.56646	0.46646	0.17646	0.28646	0.59846	2.0858	0.15646	0.88646	0.89646	0.03646	0.55646	0.77646	0.69646	0.60646	0.63646	2.1667	0.38426	0.19713	0.001316
0.41213	0.56213	0.46213	0.17213	0.32231	2.0193	0.37213	0.15213	0.88213	0.89213	0.032132	0.55213	0.77213	0.69213	0.60213	2.2557	0.47375	0.000139	0.44001
0.80568	0.41568	0.56568	0.46568	0.11661	1.4218	0.35568	0.37568	0.15568	0.88568	0.89568	0.035681	0.55568	0.77568	0.69568	2.2038	0.49249	0.035386	0.00848
0.85649	0.80649	0.41649	0.56649	1.1008	2.1842	0.28649	0.35649	0.37649	0.15649	0.88649	0.89649	0.036486	0.55649	0.77649	2.3881	0.48227	0.000869	0.000397
0.45675	0.85675	0.80675	0.41675	1.5908	2.2739	0.17675	0.28675	0.35675	0.37675	0.15675	0.88675	0.89675	0.036749	0.55675	2.573	0.51386	4.16E-05	7.10E-05
0.008031	0.45803	0.85803	0.80803	0.87957	2.1409	0.46803	0.17803	0.28803	0.35803	0.37803	0.15803	0.88803	0.89803	0.038031	2.1126	0.54231	7.72E-06	0.010251
0.39896	0.008955	0.45896	0.85896	2.9261	2.5394	0.56896	0.46896	0.17896	0.28896	0.35896	0.37896	0.15896	0.88896	0.89896	0.71061	0.46563	0.001021	0.041701
0.78398	0.39398	0.003983	0.45398	3.1963	2.6252	0.41398	0.56398	0.46398	0.17398	0.28398	0.35398	0.37398	0.15398	0.88398	2.9379	0.28189	0.004424	0.013322
0.90239	0.78239	0.39239	0.002391	1.0364	2.1716	0.80239	0.41239	0.56239	0.46239	0.17239	0.28239	0.35239	0.37239	0.15239	2.8922	0.58234	0.001398	0.016242
0.9991	0.9091	0.7891	0.3991	0.015524	0.029061	0.8591	0.8091	0.4191	0.5691	0.4691	0.1791	0.2891	0.3591	0.3791	1.2618	0.58119	0.001634	0.000223
0.36881	0.99881	0.90881	0.78881	0.7918	2.1237	0.45881	0.85881	0.80881	0.41881	0.56881	0.46881	0.17881	0.28881	0.35881	1.7738	0.32558	2.21E-05	0.019445
0.98634	0.36634	0.99634	0.90634	2.7988	2.4964	0.006344	0.45634	0.85634	0.80634	0.41634	0.56634	0.46634	0.17634	0.28634	1.7294	0.40172	0.002032	0.000662
0.67616	0.98616	0.36616	0.99616	3.5222	2.7245	0.39616	0.006157	0.45616	0.85616	0.80616	0.41616	0.56616	0.46616	0.17616	1.5831	0.39465	6.45E-05	0.099809
0.1967	0.6767	0.9867	0.3667	4.8496	2.8968	0.7867	0.3967	0.006705	0.4567	0.8567	0.8067	0.4167	0.5667	0.4667	1.3136	0.37035	0.010652	0.000543
0.055026	0.19503	0.67503	0.98503	0.63757	2.0935	0.90503	0.78503	0.39503	0.005026	0.45503	0.85503	0.80503	0.41503	0.56503	1.9384	0.33126	5.12E-05	0.00277
0.70575	0.055753	0.19575	0.67575	4.5511	2.876	0.99575	0.90575	0.78575	0.39575	0.005753	0.45575	0.85575	0.80575	0.41575	2.1273	0.43301	0.00028	0.000693
0.8767	0.7067	0.056702	0.1967	2.1923	2.3723	0.3667	0.9967	0.9067	0.7867	0.3967	0.006702	0.4567	0.8567	0.8067	1.847	0.46835	7.00E-05	0.009283
0.74264	0.87264	0.70264	0.052641	0.1269	1.5374	0.98264	0.36264	0.99264	0.90264	0.78264	0.39264	0.002641	0.45264	0.85264	2.6404	0.41442	0.000907	0.000145
0.762	0.742	0.872	0.702	0.041558	0.26816	0.672	0.982	0.362	0.992	0.902	0.782	0.392	0.002004	0.452	2.7857	0.5507	1.42E-05	0.01437
0.12599	0.76599	0.74599	0.87599	2.3525	2.3984	0.19599	0.67599	0.98599	0.36599	0.99599	0.90599	0.78599	0.39599	0.005989	1.9214	0.5696	0.001485	0.002895
0.79409	0.12409	0.76409	0.74409	3.3209	2.6634	0.05409	0.19409	0.67409	0.98409	0.36409	0.99409	0.90409	0.78409	0.39409	0.19643	0.42893	0.000289	0.012373
0.25687	0.79687	0.12687	0.76687	2.5766	2.435	0.70687	0.056867	0.19687	0.67687	0.98687	0.36687	0.99687	0.90687	0.78687	1.8089	0.2724	0.001253	0.12973
0.93905	0.25905	0.79905	0.12905	2.7015	2.4635	0.87905	0.70905	0.059055	0.19905	0.67905	0.98905	0.36905	0.99905	0.90905	2.6044	0.40967	0.013092	0.001236
0.22071	0.93071	0.25071	0.79071	0.083251	1.0471	0.74071	0.87071	0.70071	0.050712	0.19071	0.67071	0.98071	0.36071	0.99071	2.9661	0.54325	0.000117	0.003977
0.48842	0.22842	0.93842	0.25842	2.8668	2.5194	0.76842	0.74842	0.87842	0.70842	0.058422	0.19842	0.67842	0.98842	0.36842	4.2152	0.58795	0.00038	0.00115
0.26449	0.48449	0.22449	0.93449	0.26163	1.959	0.12449	0.76449	0.74449	0.87449	0.70449	0.05449	0.19449	0.67449	0.98449	1.7456	0.61807	0.000116	0.001934
0.68262	0.26262	0.48262	0.22262	3.7347	2.7748	0.79262	0.12262	0.76262	0.74262	0.87262	0.70262	0.052616	0.19262	0.67262	3.5848	0.39692	0.000193	0.000976
0.092163	0.68216	0.26216	0.48216	0.19066	1.7387	0.25216	0.79216	0.12216	0.76216	0.74216	0.87216	0.70216	0.052163	0.19216	2.3368	0.61376	9.87E-05	0.011987
0.75481	0.094813	0.68481	0.26481	1.1845	2.2006	0.93481	0.25481	0.79481	0.12481	0.76481	0.74481	0.87481	0.70481	0.054813	1.3637	0.50618	0.001187	0.036748
0.49937	0.75937	0.099371	0.68937	0.2943	2.0079	0.22937	0.93937	0.25937	0.79937	0.12937	0.76937	0.74937	0.87937	0.70937	0.85318	0.33978	0.003811	0.000251
0.73509	0.49509	0.75509	0.09509	2.2381	2.3798	0.48509	0.22509	0.93509	0.25509	0.79509	0.12509	0.76509	0.74509	0.87509	2.4066	0.28928	2.54E-05	0.000232
0.94201	0.73201	0.49201	0.75201	0.065836	0.85152	0.26201	0.48201	0.22201	0.93201	0.25201	0.79201	0.12201	0.76201	0.74201	2.8539	0.5157	2.28E-05	0.005721
0.3408	0.9408	0.7308	0.4908	2.5988	2.4385	0.6808	0.2608	0.4808	0.2208	0.9308	0.2508	0.7908	0.1208	0.7608	2.4865	0.57478	0.000586	0.030588
0.5484	0.3484	0.9484	0.7384	1.2465	2.2128	0.0984	0.6884	0.2684	0.4884	0.2284	0.9384	0.2584	0.7984	0.1284	2.5523	0.53194	0.003039	0.006166
0.33672	0.54672	0.34672	0.94672	2.5205	2.4259	0.75672	0.096716	0.68672	0.26672	0.48672	0.22672	0.93672	0.25672	0.79672	1.156	0.53835	0.000636	0.003042
0.42295	0.33295	0.54295	0.34295	3.8178	2.7945	0.49295	0.75295	0.092951	0.68295	0.26295	0.48295	0.22295	0.93295	0.25295	2.6146	0.31303	0.000314	0.071407
0.31522	0.42522	0.33522	0.54522	0.54713	2.0758	0.73522	0.49522	0.75522	0.095218	0.68522	0.26522	0.48522	0.22522	0.93522	1.5136	0.54833	0.006745	0.011256
0.7213	0.3113	0.4213	0.3313	1.4516	2.2512	0.9413	0.7313	0.4913	0.7513	0.091304	0.6813	0.2613	0.4813	0.2213	3.116	0.35796	0.001106	0.002203