DISCLAIMER

This contractor document was prepared for the U.S. Department of Energy (DOE), but has not undergone programmatic, policy, or publication review, and is provided for information only. The document provides preliminary information that may change based on new information to be used specifically for Total System Performance Assessment analyses. The document is a preliminary lower-level contractor document and is not intended for publication or wide distribution.

Although this document has undergone technical reviews at the contractor organization, it has not undergone a DOE policy review. Therefore, the views and options of authors expressed may not state or reflect those of the DOE. However, in the interest of the rapid transfer of information, we are providing this document for your information per your request.

4/13/00

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

1. QA: ~~QA~~ L
Page: 1 of: 19

2. ☒ Analysis ☐ Engineering ☒ Performance Assessment ☐ Scientific	3. ☐ Model ☐ Conceptual Model Documentation ☐ Model Documentation ☐ Model Validation Documentation

4. Title:
Probability Distribution for Flowing Interval Spacing

5. Document Identifier (including Rev. No. and Change No., if applicable):
ANL-NBS-MD-000003 REV00

6. Total Attachments:	7. Attachment Numbers - No. of Pages in Each:
3	I-9, II-3, III-2

	Printed Name	Signature	Date
8. Originator	Stephanie Kuzio	Stephanie Kuzio	9/28/99
9. Checker	Hubao Zhang	Hubao Zhang	9/29/99
10. Lead/Supervisor	Bill Arnold	Bill W. Arnold	9/29/99
11. Responsible Manager	Clifford K. Ho	Clifford K. Ho	9/29/99

12. Remarks:

~~Final Check Copy~~ SK 11/9/99

Editorial Corrections made 2/14/00 for the following:

- correction to Analysis/Model Cover Sheet
- corrections to Analysis/Model Revision Record
- corrections to page numbers in Table of Contents
- corrections to Figure List, page numbers and title corrections
- correction to QA designator, in keeping with the old procedure used.

Bill W. Arnold 2/14/00

RWA for B.W.A. 4/13/00

The editorial changes indicated on the cover sheet and revision record of the approved document were incorporated into the electronic file on 04/14/00, 88KB, 8:45am. The approved document (pages 3 – 19 only) was reprinted for clarity on 4/14/2000. The original hand-edited pages will be kept as part of the records package.

Stephanie Kuzio 4/21/00
Stephanie Kuzio, Originator

Clifford K. Ho 4/21/00
Clifford Ho, Responsible Manager

INFORMATION COPY

LAS VEGAS DOCUMENT CONTROL

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD
Complete Only Applicable Items

2. Analysis or Model Title:

Probability Distribution for Flowing Interval Spacing

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

ANL-NBS-MD-000003 Rev00

4. Revision/Change No.	5. Description of Revision/Change
~~Rev 00A~~	~~Check copy~~ spk 2/14/00
~~Rev 00B~~	~~Check copy~~ spk 2/14/00
~~Rev 00C~~	~~PCG Check & Review Copy~~ spk 2/14/00
~~Rev 00D~~	~~PCG Check & Review Copy~~ spk 2/14/00
~~Rev 00E~~	~~PCG Check & Review Copy~~ spk 2/14/00
Rev 00	~~Final Copy 9/28/99~~ Initial Issue spk 2/14/00

ACRONYMS

CDF	Cumulative Distribution Function
CFIS	Corrected Flowing Interval Spacing
CFS	Corrected Fracture Spacing in the Saturated Zone
D	Dips
DM	Degree of Welding
E	Existing Data
FIS	Flowing Interval Spacing
FMS	Flow Meter Survey Data
FSZ	Fracture Spacing in the Saturated Zone
LHS	Latin Hypercubed Sampling
OFR	Open File Report
Q	Qualified Data
SZ	Saturated Zone
WRIR	Water Resources Investigative Report
USGS	United States Geologic Society

CONTENTS

PAGE

FIGURES

TABLES

Page

1.0 Purpose

The purpose of this analysis is to develop a probability distribution for flowing interval spacing. A flowing interval is defined as a fractured zone that transmits flow in the Saturated Zone (SZ), as identified through borehole flow meter surveys (Figure 1). This analysis uses the term "flowing interval spacing" as opposed to fractured spacing, which is typically used in the literature. The term fracture spacing was not used in this analysis because the data used identify 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. Fracture spacing within the SZ is defined as the spacing between fractures, with no regard to which fractures are carrying flow. The Work direction Document associated with this analysis is entitled, *Abstraction of SZ Flow and Transport Model, Parameter Uncertainty Analysis*, (CRWMS M& O 1999a). The parameter from this analysis may be used in the TSPA SR/LA Saturated Zone Flow and Transport Work Direction and Planning Documents: 1) *Abstraction of Matrix Diffusion for SZ Flow and Transport Analyses* (CRWMS M& O 1999b) and 2) *Incorporation of Heterogeneity in SZ Flow and Transport Analyses*, (CRWMS M& O 1999c).

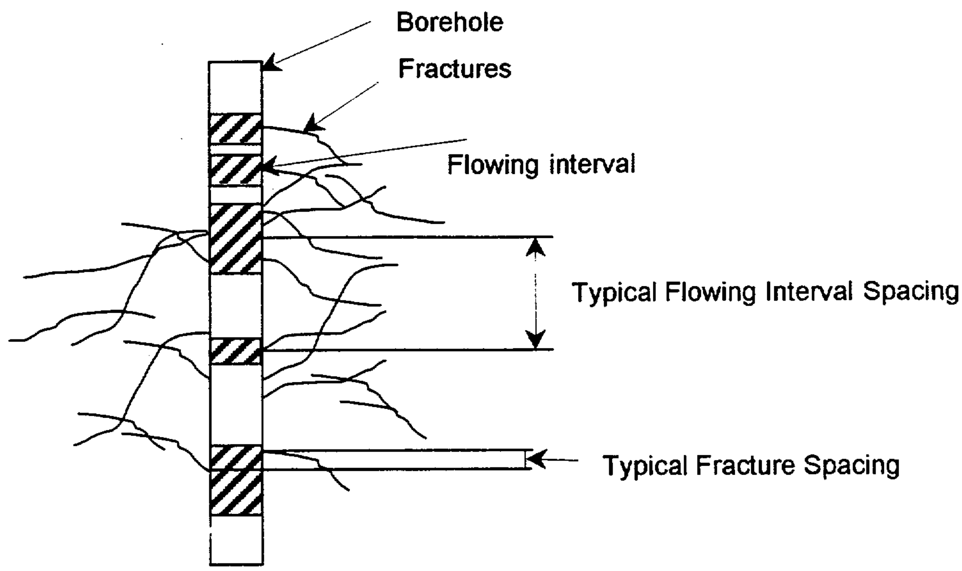


Figure 1. Example of Flowing Interval Spacing and Fracture Spacing as Identified from Borehole Flow Meter Survey Data.

A limitation of this analysis is that the probability distribution of flowing interval spacing may underestimate the effect of incorporating matrix diffusion processes in the SZ transport model because of the possible overestimation of the flowing interval spacing. Larger flowing interval spacing results in a decrease in the matrix diffusion processes. This analysis may overestimate the flowing interval spacing because the number of

fractures that contribute to a flowing interval can not be determined from the data. Because each flowing interval probably has more than one fracture contributing to a flowing interval, the true flowing interval spacing could be less than the spacing determined in this analysis. Therefore, in terms of repository performance the results of this analysis may underestimate the effect of matrix diffusion processes in SZ transport models. In summary, performance analysis will be conservative if the flowing interval spacing determined by this study is used in the simulation of mass transport in the saturated zone instead of the fracture spacing.

2.0 Quality Assurance

This document follows the activity evaluation for QAP-2-0, Conduct of Activities, as completed by Dan Wilkins on 3/17/99, that determined this work activity applicable to the QA program. The applicable implementing procedures are defined in the *Parameter Uncertainty Work Direction Document Rev. 1* (CRWMS M& O 1999a).

3.0 Computer Software and Model Usage

See Figure 2 for a flow chart of the software used for this analysis. The software cited below is appropriate for use in this application. The computer used for this analysis was a DELL OptiPlex GX1, Sandia serial number is R429068. The range of validation for the LHS portion of RIP, Excel, Statistica, and PV Wave is the set of real numbers.

Repository Integrated Program (RIP) Version 5.19.01

CSCI: 30055 V.5.19.01

DI: 30047-2003, REV2

The RIP 5.19.01 code was obtained from CM and installed by means of DI 30047-2003, Rev 2 and MI 30047-MO4-001, Rev. 2.

Only the Latin Hypercube Sampling (LHS) module of Rip was used to run the 1000 realizations of fracture spacing dip, flowing interval spacing dip, flowing interval spacing and fracture spacing.

Industry standard software:

Statistica REV 5 1997

Used for the statistical analysis and graphing of flowing interval spacing, fracture spacing and dip data.

Excel 97-SR-1

Used for spreadsheet calculations for flowing interval spacing, fracture spacing and dip data.

PV-Wave 6.21

Used to create Figure 15, comparison of the flow meter survey borehole information used in this analysis.

4.00 Inputs

Table 1. Borehole Input Data Table

Borehole	Report # and Reference	Q-status	TBVs	Input Parameters	Accession #	Output parameter
H-3	* USGS OFR-84-149 (Thordarson et al. 1984, pp. 11, 14, 19)	E	681	FMS Fig. 3 Dip Table 4 DM Fig. 2	NNA.19870406.0056	CFIS
H-1	* USGS OFR-83-141 (Rush et al. 1983, pp.7, 13, 17, 18)	E	681	FMS Fig. 4 and 5 Dip Table 6 DM Fig. 3	HQS.19880517 1835	CFIS
H-4	* USGS WRIR 85-4066 (Erickson and Waddell 1985, p. 7)	E	681	FMS Fig. 3 Dip Fig. 3 FSZ Fig. 3	NNA.19890713.0211	CFIS CFS
UE-25c#3	* BAA000000-01717-5000-002 Rev 00 (CRWMS M&O 1997, p B-2))	E	681	FMS Table B-3	MOL.19971031.0053	CFIS
	* USGS WRIR 94-4177 (Geldon 1996, pp. 108-119)	E	681	Dips Table 12 FSZ Table 12	MOL.19980724.0389 DTN: GS931008312313.016 (Tables 10-12 of WRIR 94-4177)	CFS
UE-25c#2	* USGS WRIR 94-4177 (Geldon 1996, pp. 15, 83-107))	E	681	FMS Table 5 Dip Table 11 FSZ Table 11	MOL.19980724.0389 DTN: GS931008312313.016 (Tables 10-12 of WRIR 94-4177)	CFIS CFS
UE-25c#1	* USGS WRIR 94-4177 (Geldon 1996, pp. 16, 17, 74-88))	E	681	FMS Table 4 Dip Table 10 FSZ Table 10	MOL.19980724.0389 DTN: GS931008312313.016 (Tables 10-12 of WRIR 94-4177)	CFIS CFS
G-4	* USGS OFR 84-063 (Bentley 1984, p. 32)	E	681	FMS Figure 8	NNA.19870519.0100	CFIS
G-4	* USGS OFR-84-789 (Spengler and Chornack 1984, pp. 36, and Plate 1)	E	681	FSZ Plate 1	NNA.19890804.0012	CFS

Borehole	Report # and Reference	Q-status	TBVs	Input Parameters	Accession #	Output parameter
G4 (continued)		E	681	Dips Figure 13	MOL.19980512.0376	
		E	681	DM Plate 1	NNA.19890804.0012	
UE-25P#-1	* USGS WRIR 84-4248 (Craig and Robison 1984, p. 11)	E	681	FMS Figure 5	NNA.19890905.0209	CFIS
	* USGS OFR-86-175 (Carr et al. 1986, Plate 1)	E	681	Dip Plate1	HQS.19880517.2633	
		E	681	FSZ Plate 1	HQS.19880517.2633	CFS
		E	681	DM Plate 1	HQS.19880517.2633	

Notes: * Data used for this analysis was acquired directly from the reports indicated.
E = Existing Data
Q = Qualified Data
Inputs:
FMS = Flow meter survey data
FSZ = Fracture Spacing data in the Saturated Zone (SZ) (includes flowing and non-flowing fractures)
D = Dips
DM = Degree of Welding, rock type
Outputs:
CFIS = Corrected flowing interval spacing
CFS = Corrected fracture spacing in the SZ

4.1 Criteria

Although no specific criteria have been identified in project requirements documents (i.e., System Description Documents) as applicable to this analysis activity, this probability distribution flow analysis supports the Yucca Mountain site with respect to site characterization (10CFR63, Subpart B, Section 15), and performance assessment hydrology data requirements (10CFR63, Subpart E, Section 114(a)), (CRWMS M&O, 1999).

4.2 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.

5.0 Assumptions

Assumptions utilized throughout this analysis include the following:

1) Boreholes are 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. This is inherent in the equation used to make the correction by Terzaghi, 1965.

2) Not all fractured zones in the SZ transmit water.

It has been well documented in various reports referenced in this analysis, (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 will be justified through three analyses that will be explained further in Section 6.0

4) There is no correlation between the flowing interval spacing and the dips.

This 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 dips.

6.0 Analysis

6.1 Methodology justification

This analysis develops a probability distribution for flowing interval spacing using borehole flow meter survey data. Fracture spacing has been shown to be a key hydrologic parameter in matrix diffusion, which could serve as an important retardation mechanism at Yucca Mountain. Previous studies in the UZ assumed that fracture spacing is correlated with hydrogeologic units. It would not be appropriate to use the UZ fracture spacing approach in the SZ for the primary reason that only portions of the fractures in the SZ contribute to the total flow

in a particular flowing interval. It is well documented in the borehole flow meter survey reports cited in this analysis (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 a portion of the fractures in the SZ contribute to the total flow in a borehole. 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.

6.2 Approach

The approach for this analysis consists of determining the spacing between flowing intervals using graphical and tabular data from USGS reports cited in Table 1. The boreholes used for this analysis and associated reports are shown in spreadsheet 6.1 (Attachment III, DTN: SN9907T0571599.001). The boreholes selected for this study had orientation data as well as flow meter survey data. Fracture orientation data were required to make a correction to the flowing interval spacing measured normal to the borehole, which will be explained further below. The flowing intervals were determined from the flow meter survey graphs that indicate the percentage of flow within an interval. Flowing intervals were identified at the location where the slope of the flow meter survey graph changed. The spacing between the midpoint of each identified flowing interval was then considered the spacing between the flowing intervals as shown in spreadsheet 6.1 (Attachment III, DTN: SN9907T0571599.001). Histograms of flowing interval spacing raw data and associated dips can be seen in Figures 3 and 4 respectively.

A cumulative distribution function (CDF) was generated from the flowing interval spacing data (Figure 5). To input the CDF in the LHS module of RIP, ten data points from the raw data were selected to generate 1000 realizations of flowing interval spacing. In Figure 5 the curve labeled "data input to LHS", is the data that was input to the LHS module of RIP. The input data to the LHS module in Rip is shown in Table 2. Dip data were recorded for flowing intervals from USGS reports as shown on spreadsheet 6.2 (Attachment III, DTN: SN9907T0571599.001) and a CDF generated (Figure 6). G-4 was the only borehole dip data not used as part of the data set. The dip data for G-4 did not distinguish between the entire saturated zone and the dips that were within the flowing intervals, therefore these data were not used. Similar to the procedure described for the flowing interval spacing, ten data points from the CDF were used as input to the LHS module of RIP for 1000 realizations, see spreadsheet 6.3 (Attachment III, DTN: SN9907T0571599.001) and Table 3. The resulting 1000 output data points for dip and flowing interval spacing were then used to correct for flowing intervals measured normal to the borehole using an equation after Terzaghi, (1965, pp. 295):

$$F_{smc} = F_{sm} \cos (D_f) \qquad \text{Equation 1}$$

where F_{smc} is the corrected flowing interval spacing, F_{sm} is the uncorrected flowing interval spacing from the LHS realizations, and D_f is the flowing interval spacing dip from the LHS realizations. The results of this calculation are shown in the file, resul_fis2.xls (Attachment III, DTN: SN9907T0571599.001). A probability distribution of the corrected flowing interval spacing data, was then developed using the industry standard software STATISTCA. A normal distribution of the log transformed corrected flowing interval spacing data was developed as shown in Figure 7. The mean of the log transformed data was found to be 1.29 m compared to the uncorrected flowing interval spacing mean of 1.68 m. The standard deviation of the log-transformed data was determined as 0.43 m.

For comparison purposes a second probability distribution was developed for the fracture spacing within the SZ. This includes all fracture spacing in the SZ, not just the flowing intervals. The same procedure was followed for this second distribution as outlined above for dips and flowing interval spacing including the correction using equation 1. Fracture spacing data and fracture dip data are shown on spreadsheet 6.4 and 6.5, respectively (Attachment III, DTN: SN9907T0571599.001). The data used to identify fracture spacing and dip data consisted of graphical data and tabular data. An explanation of how the data was extracted for each borehole are discussed below:

C-wells (C#-1, C#-2 and C#-3) Tables 10, 11 and 12 in USGS WRIR 94-4177 (Geldon, 1996), were used to determine spacing between fractures and the dip angle. The spacing was determined as an average for a 10-foot interval. When the spacing exceeded 10', the spacing greater than 10' was used. The spacing was averaged over ten foot intervals because many of the fractures were very close together. Spacing that exceeded ten feet was used directly because it was felt that a measurement greater than ten feet would be an accurate measurement.

G-4 Figure 13 in USGS OFR 84-789 (Spengler et al., 1984,), was used to determine the dips and fracture spacing. Figure 13 gives the percentage of fractures for each 10-degree dip interval. There was a total number of 300 fractures and associated dip angles recorded for the saturated zone interval. The number of dips for a 10 degree average dip were calculated as shown on spreadsheet "fracture_dips2.xls", worksheet "dipsz&cdf". The fracture spacing for the saturated zone was determined from Plate 1 (Spengler et al., 1984). Fracture frequency was given for 10-foot intervals. Fracture spacing was determined from the reciprocal of the fracture frequency given for 10-foot intervals.

H-4 Figure 3 in USGS WRIR 85-4066 (Erickson and Waddell, 1985), was used to determine the dips and the fracture spacing. Data points for dip angles were extracted from Figure 3 directly. Fracture spacing was measured between the data points when possible. When the data points were clustered together an average spacing was calculated based on the length of the cluster divided by the number of data points.

UE25P#-1 Plate 1 in USGS OFR-86-175 (Carr, et al., 1986), was used to determine fracture spacing and dip angles. Data points for dip angles were extracted from Plate 1 directly. Fracture spacing was measured between the data points.

H-1 Table 6 in USGS OFR-83-141 (Rush et al., 1983), was used to determine dip angles directly. Only three data points were available for dip angle. Fracture spacing in the saturated zone was not available for this borehole.

H-3 Table 4 in USGS OFR-84-149 (Thordarson, et al., 1984), was used to determine dip angles directly. Fracture spacing in the saturated zone was not available for this borehole.

The procedure outlined for flowing interval spacing regarding the data input to the LHS module of RIP, was also followed for the fracture spacing and dip data. The corresponding histograms of fracture spacing and associated dips raw data can be seen in Figures 8 and 9. The CDF's of the fracture spacing and the dips are shown in Figures 10 and 11 respectively. Tables 4 and 5 list the data input to the LHS module of RIP.

A normal distribution of the log transformed data of the corrected fracture spacing was developed resulting in a mean of –0.59 m compared to the uncorrected fracture spacing mean of -0.25 m and the standard deviation was calculated to be 0.63 m. The lognormal probability distribution for the corrected flowing interval spacing and fracture spacing are compared and shown in Figure 12. Table 6 shows a comparison of the descriptive statistics (based on the logs) for the flowing interval spacing and the fracture spacing distributions.

6.3 Independent repetition of the analysis

See Attachment III and DTN: SN9907T0571599.001, for a listing of the input files required to reproduce the analysis cited herein. Also see Figure 2 for a flow chart of the software used in this analysis.

6.4 Justification of Assumption Three

To justify the assumption that the flowing interval spacing is not correlated with the hydrogeologic units, three analyses were completed. The first analysis included a statistical test for significant differences between the hydrogeologic units based on the percentage of flow within each flowing interval. This analysis was done using a nonparametric rank test called the Kruskal-Wallis test which assesses the hypothesis that different samples in the comparison were drawn from the same distribution (StatSoft, Inc. 1995, pg. non-1601). The software STATISTICA was used to run this test. The Kruskal-Wallis test results show the difference in flow as not significant. Thus, based on the percentage of flow in each hydrogeologic unit, the hydrogeologic units were not significantly different from each other, see Table 7, Attachment 2. If the results from this test had been significant this would indicate that the units were significantly different from one another based on the percentage of flow in each hydrogeologic unit. In other words, based on this data set the statistical test does not show a significant difference between the percentages of flow among hydrogeologic units.

The second analysis examined the possibility of correlation between rock type and frequency of flowing intervals. The four rock types considered were Partially Welded, Welded, Non-Welded and Bedded. The data for the rock types for each flowing interval are identified in spreadsheet "Fracture_dips2.xls" , worksheet "FIS" (Attachment III and DTN: SN9907T0571599.001). The source data used to determine the rock types are identified in Table 1 except for the C-hole data, which was found in the Site Characterization Plan (DOE, 1988, p. 8.3.1.2-388). The percentage

of rock type for each of the identified rock types was calculated as shown in spreadsheet "Fracture_dips2.xls", worksheet "rocktype" Attachment III and DTN: SN9907T0571599.001. The frequency of flowing intervals was calculated by dividing the number of flowing intervals that were within the rock type by the total length of rock type, see Table 8. Partially Welded and Non-Welded rock types have similar frequencies of 0.0099 and 0.0094 respectively although Partially Welded comprises 77% of the total rock type. Welded and Bedded only have 1 data point, which limits the use of this datum for comparison. This limited data set shows no correlation between rock type and frequency of flowing intervals.

The third analysis included calculating the total length of each hydrologic unit as a function of the number of flowing intervals within a particular hydrogeologic unit. The five hydrogeologic units examined were the Calico Hills, Prow-Pass, Bullfrog, Tram and the Lithic. This calculation results in a spacing of flowing intervals within each hydrogeologic unit. The data are shown in worksheet "FIS", and the calculation is shown on worksheet "rocktype", in spreadsheet "Fracture_dips2.xls". Table 9 compares the spacing of flowing intervals within each hydrogeologic unit. The spacing calculated within Prow-Pass, Bullfrog and Tram is, 19.5, 21.4, and 21.0 m respectively. Since the flowing interval spacing is essentially the same for the three hydrogeologic units, we can conclude that there is no correlation between spacing of the flowing intervals and the hydrogeologic units. Note the flowing interval spacing calculated for this analysis has not been corrected for dip. The Lithic and Calico Hills only have a frequency of occurrence of 2 and 1, respectively. Therefore these units were not compared with the other results.

Figure 13 demonstrates the percentage of flow within a flowing interval per hydrogeological unit. This figure does not show a correlation between the percentage of flow and hydrogeologic unit. Figure 14 is a box and whisker plot that shows the flowing interval spacing for each hydrogeologic unit and the number of data points located within each unit. Note that many of the flowing interval data points span two units.

Figure 15 shows all of the boreholes and the flowing intervals used in this analysis. The shaded area indicates the flowing intervals, including the percentage of flow within the indicated interval. This figure also shows the limited number of data points within each interval and how the flowing interval spacings span adjoining hydrogeological units.

7.0 Conclusions

Probability distributions for flowing interval spacing and fracture spacing in the SZ were determined through this analysis. The flowing interval spacing distribution was derived from flow meter survey data. This analysis did not correlate flowing interval spacing with the hydrogeologic units as was previously done in studies of the UZ. This assumption was justified through various analyses, which included testing for statistical differences between the hydrogeological units based on the percentage of flow in each interval. A second analysis examined the flowing interval frequencies within the four rock types identified in this analysis. The third analysis investigated the number of flowing intervals within each hydrogeologic unit versus the total length of an identified hydrogeologic unit. The three analyses confirm the following: 1) there is no correlation between percentage of flow within an interval and hydrogeological unit, 2) rock type and the frequency of flowing intervals show no correlation, and 3) flowing interval spacing within each hydrogeologic unit displays no correlation.

The corrected flowing interval spacing and fracture spacing in SZ resulted in a lognormal probability distribution function for both variables and is shown in Figure 12. The mean of the log transformed corrected flowing interval and fracture spacing data is 1.29 m and –0.59 m, respectively. For a complete statistical summary of the developed variables, flowing interval spacing and fracture spacing, See Table 6. As mentioned earlier, this analysis may be considered conservative in terms of the effect of matrix diffusion, since the flowing interval spacing calculated from the raw data is probably greater than the true spacing between the flowing interval. The result of this analysis is a probability distribution for flowing interval spacing that may be used in the TSPA SR/LA, SZ Work Direction and Planning Documents entitled Abstractions of Matrix Diffusion and Incorporation of Heterogeneity in the SZ Flow and Transport.

It should be noted that a limitation to the borehole data (TBV 681) used for this analysis is the number of possible missed vertical fractures using a vertical borehole. It is difficult to discern with the available data if the intersection of more vertical fractures would result in a significant change in the flowing interval spacing. Additionally, the data is limited because of the inability to determine the packer spacing used for each borehole. Different packer spacing may create inconsistencies in comparing flowing interval spacing data from different boreholes.

Another limitation of the use of borehole flow meter survey data (TBV 681) is the differences in the types of flow meter tests. The data used in this analysis include flow meter survey tests such as radioactive-tracer tests (while water is pumped into or out of the borehole), spinner tests, and heat pulse flowmeter tests. The various tests may introduce biases that may add additional uncertainties to the results.

The input data, TBV 681, is not entirely in the TDMS at this time. These data were acquired from the actual USGS reports that are cited in Table 1. It is expected that this data will ultimately be in the TDMS as well as be qualified for use in TSPA SR and LA through implementation of AP 3-15. The output data, TBV 1214, will become qualified when TBV 681 is verified. It is important that TBV 681 is verified because the parameter from this analysis, flowing interval spacing, is an input for a matrix diffusion model in the 3-D Saturated Zone Model for TSPA SR/LA.

8.0 References

See Table 1, which identifies the borehole and the associated, report and the specific information used from the reports.

Bentley, C.B. 1984. *Geohydrologic Data for Test Well USW G-4, Yucca Mountain Area, Nye County, Nevada.* United States Department of the Interior Geological Survey. Open File Report 84-063. Denver, Colorado. ACC: NNA.19870519.0100.

Carr, M.D.; Waddell, S.J.; Vick, G. S.; Stock, J.M.; Monsen, S.A.; Harris, A.G.; Cork, B.W.; and Byers, F.M., Jr. 1986. *Geology of Drill Hole UE25P#1: A Test Hole into Pre-Tertiary Rocks Near Yucca Mountain, Southern, Nevada.* United States Department of the Interior Geological Survey. Open File Report 86-175. Menlo Park, California ACC: HQS.19880517.2633.

Craig, R.W. and Robison, J.H. 1984. *Geohydrology of Rocks Penetrated by Test Well UE-25p#1, Yucca Mountain Area, Nye County, Nevada.* Water-Resources Investigations Report 84-4248. U.S. Geological Survey. Denver, Colorado. ACC: NNA.19890905.0209.

CRWMS M&O 1997. *Analysis of Flow Rate Logs from Borehole UE25c#3 in Support of Characterization of the Site Saturated-Zone Groundwater Flow System at Yucca Mountain, Nevada.* BAA000000-01717-5000-002 REV 00. Las Vegas, Nevada. ACC: MOL.19971031.0053.

CRWMS M&O 1999a. *Work Direction and Planning Document, Abstraction of SZ Flow and Transport Model. Parameter Uncertainty Analysis Rev. 1.* Las Vegas, Nevada ACC: MOL. 19990707.0106.

CRWMS M&O 1999b. *Work Direction and Planning Document, Abstraction of SZ Flow and Transport Model. Abstraction of Matrix Diffusion for SZ Flow and Transport Analyses, Rev. 1.* Las Vegas, Nevada. ACC: MOL. 19990707.0107.

CRWMS M&O 1999c. *Work Direction and Planning Document, Abstraction of SZ Flow and Transport Model. Incorporation of Heterogeneity in SZ Flow and Transport Analyses, Rev 1.* Las Vegas, Nevada. ACC: MOL. 19990707.0109.

CRWMS M&O 1999. *Interim Guidance Pending Issuance Of New U. S. Nuclear Regulatory Commission (NRC) Regulations For Yucca Mountain, Nevada.* Las Vegas, Nevada. ACC: MOL.19990623.0026, MOL.19990623.0027.

DOE (U.S. Department of Energy) 1988. *Site Characterization Plan: Yucca Mountain Site, Nevada Research and Development Area.* DOE/RW-0199. Washington, D.C.: U.S. Department of Energy Office of Civilian Radioactive Waste Management. ACC: HQO.19881201.0002.

Erickson, J.R. and Waddell, R.K. 1985. *Identification and Characterization of Hydrologic Properties of Fractured Tuff Using Hydraulic and Tracer Tests — Test Well USW H-4, Yucca Mountain, Nye County, Nevada.* Water-Resources Investigations Report 85-4066. U.S. Geological Survey. Denver, Colorado. ACC: NNA.19890713.0211.

Geldon, A.L. 1996. *Results and Interpretation of Preliminary Aquifer Tests in Boreholes UE25c#1, UE25c#2, and UE25c#3, Yucca Mountain, Nye County, Nevada*. Water-Resources Investigations Report 94-4177. U.S. Geological Survey. Denver, Colorado. ACC: MOL.19980724.0389.

Rush, F.E.; Thordarson, W.; and Bruckheimer, L. 1983. *Geologic and Drill-Hole Data for Test Well USW H-1, Adjacent to Nevada Test Site, Nye County, Nevada*. United States Department of the Interior Geological Survey. Open File Report 83-141. Denver, Colorado. ACC: HQS.19880517.1835.

Spengler, R.W. and Chornack, M.P. with a section on geophysical logs by Muller, D.C. and Kibler, J.E. 1984. *Stratigraphic and Structural Characteristics of Volcanic Rocks in Core Hole USW G-4, Yucca Mountain, Nye County, Nevada*. United States Department of the Interior Geological Survey. Open File Report 84-789. Denver, Colorado. ACC: NNA.19890804.0012 and MOL.19980512.0376.

StatSoft, Inc. 1995. STATISTICA (Volume I). Tulsa, Oklahoma: STATISTICA. TIC: 239795.

Terzaghi, R.D. 1965. "Sources of Error in Joint Surveys." *Geotechnique, 15,* 287-304. London, United Kingdom: Institution of Civil Engineers. TIC: 239078.

Thordarson, W.; Rush, F.E.; Spengler, R.W.; and Waddell, S.J. 1984. *Geohydrologic and Drill-Hole Data for Test Well H-3, Yucca Mountain, Nye County, Nevada*. United States Department of the Interior Geological Survey. Open File Report 84-149. Denver, Colorado. ACC: NNA.19870406.0056

9.0 Attachments

Attachment I	Figures	9 pages
Attachment II	Tables	3 pages
Attachment III	List of directories for reference and reproducibility 2 pages	

Attachment I

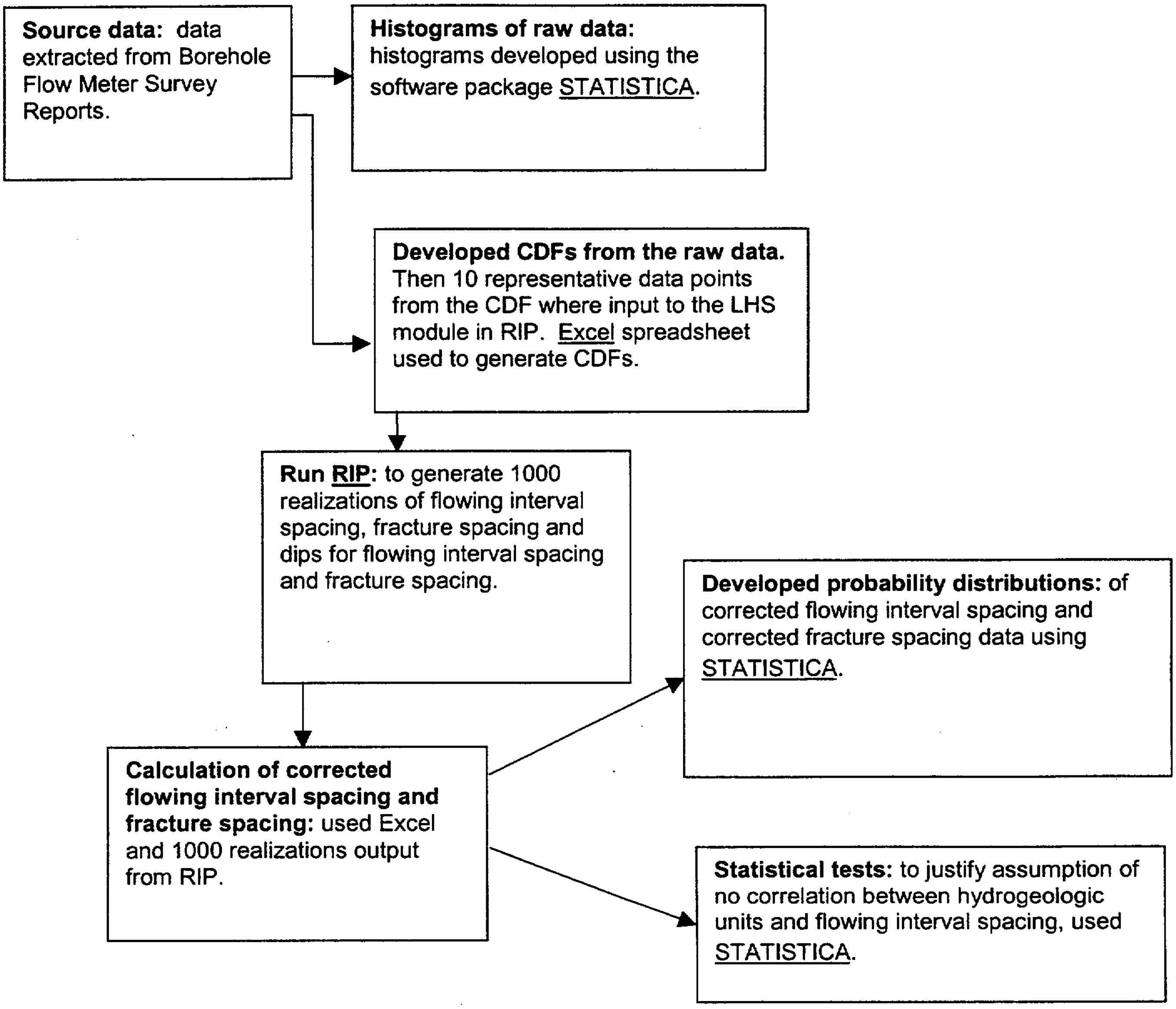


Figure 2. Flow Chart of Software Used in This Analysis.

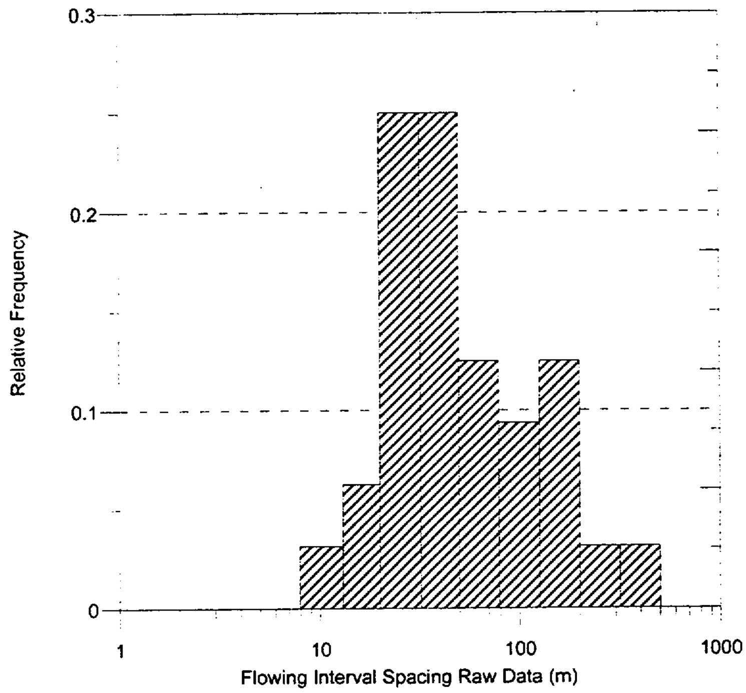


Figure 3. Histogram of the Flowing Interval Spacing Raw Data. DTN: SN9907T0571599.001

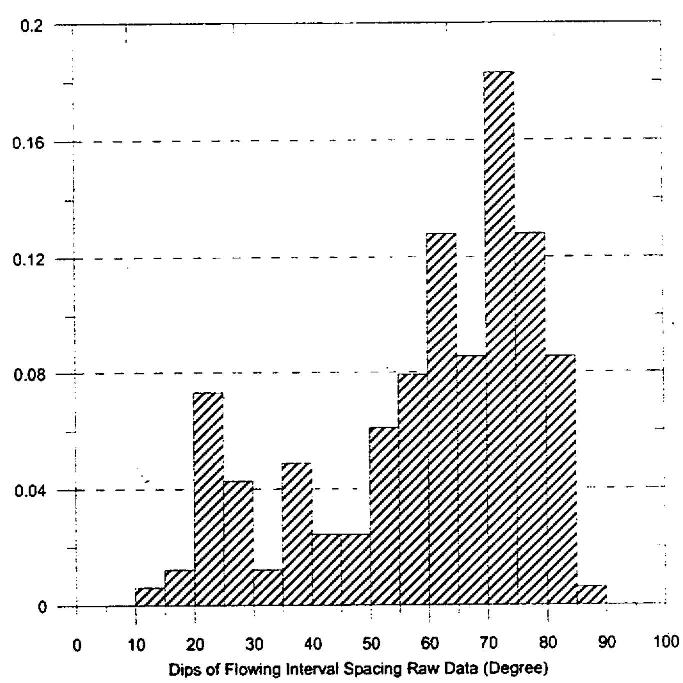


Figure 4. Histogram of the Flowing Interval Spacing Dip Raw Data. DTN: SN9907T0571599.001

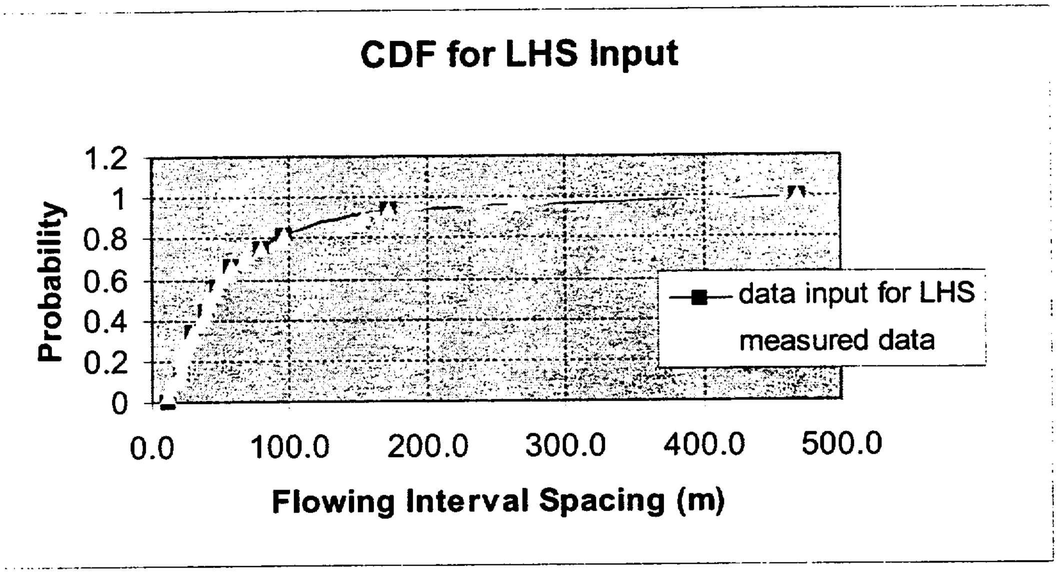


Figure 5. CDF for Flowing Interval Spacing Used as Input to LHS Module in RIP. DTN: SN9907T0571599.001

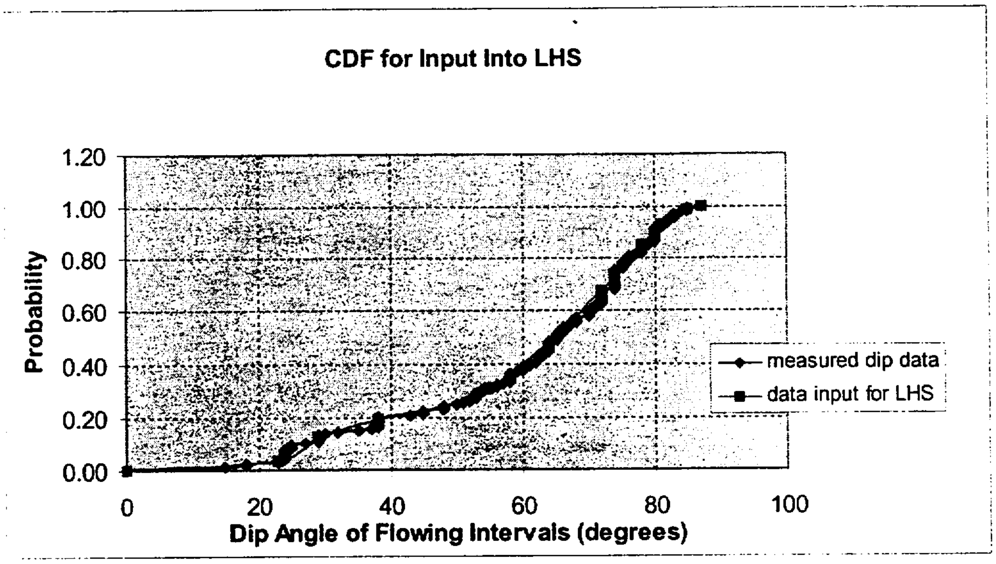


Figure 6. CDF for Flowing Interval Spacing Dip Used as Input to LHS Module in RIP for. DTN: SN9907T0571599.001

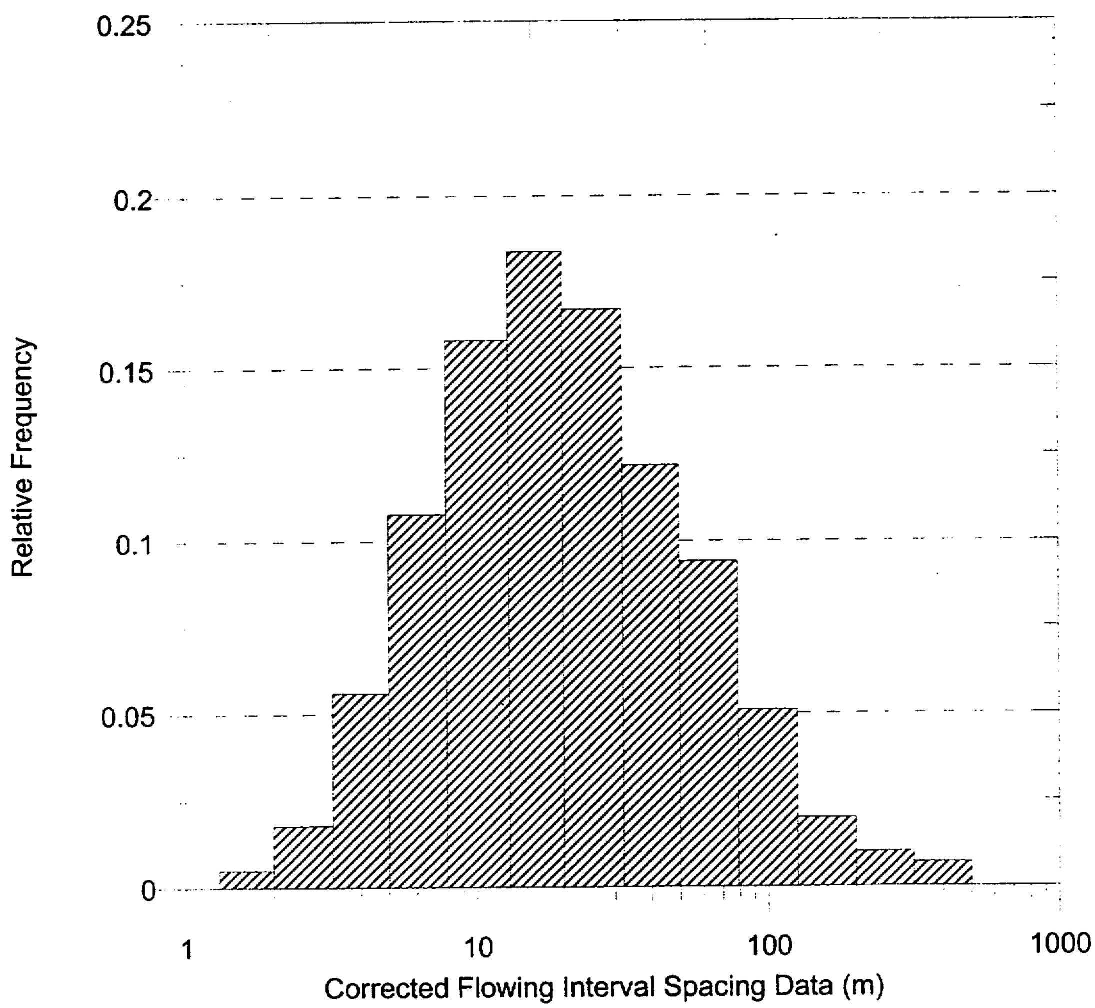


Figure 7. Probability Distribution of Corrected Flowing Interval Spacing. DTN: SN9907T0571599.001

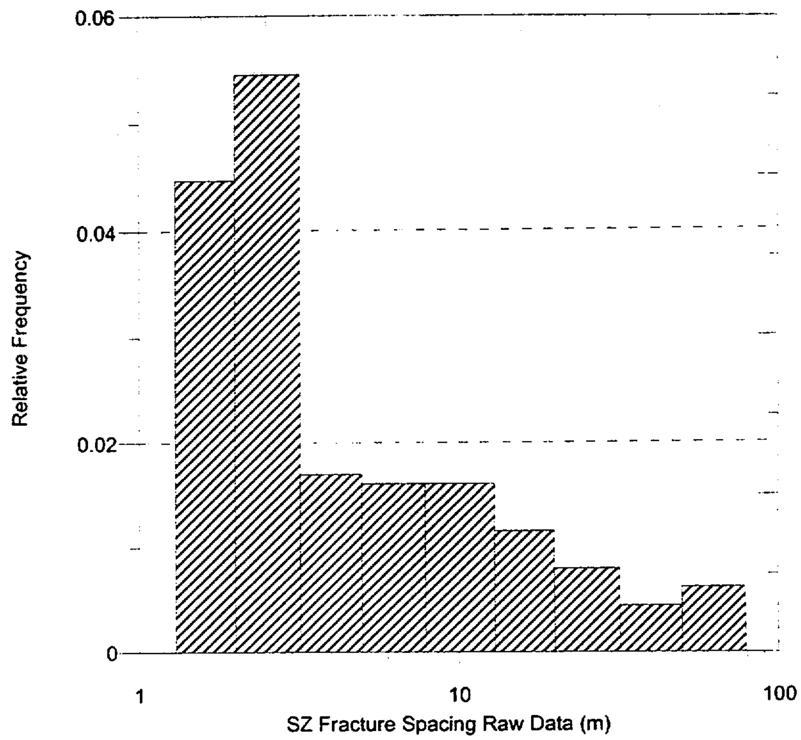


Figure 8. Histogram of the Raw Fracture Spacing Data. DTN: SN9907T0571599.001

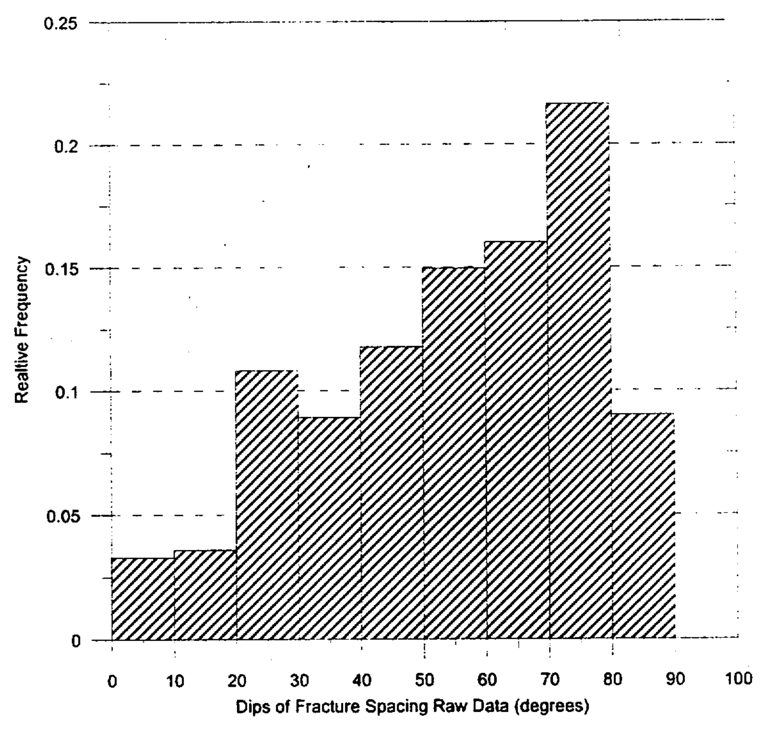


Figure 9. Histogram of the Raw Fracture Spacing Dip Data DTN: SN9907T0571599.001

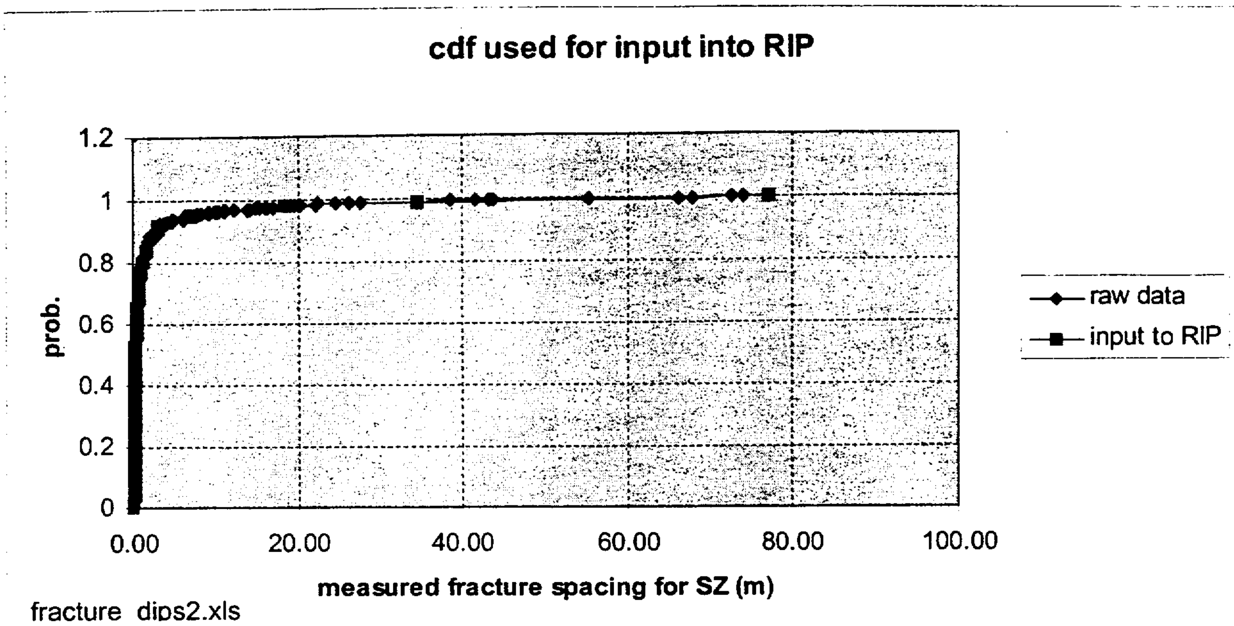


Figure 10. CDF for Fracture Spacing Used as Input to RIP for LHS. DTN: SN9907T0571599.001

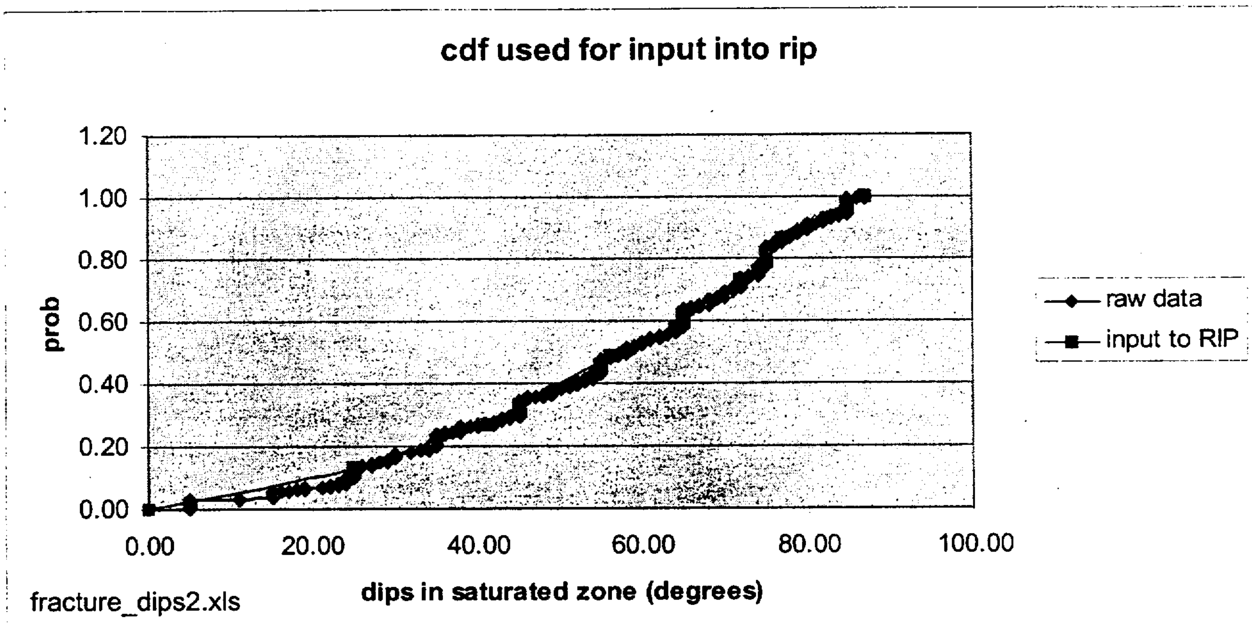


Figure 11. CDF for Fracture Spacing Dips Used as Input to RIP for LHS. DTN: SN9907T0571599.001

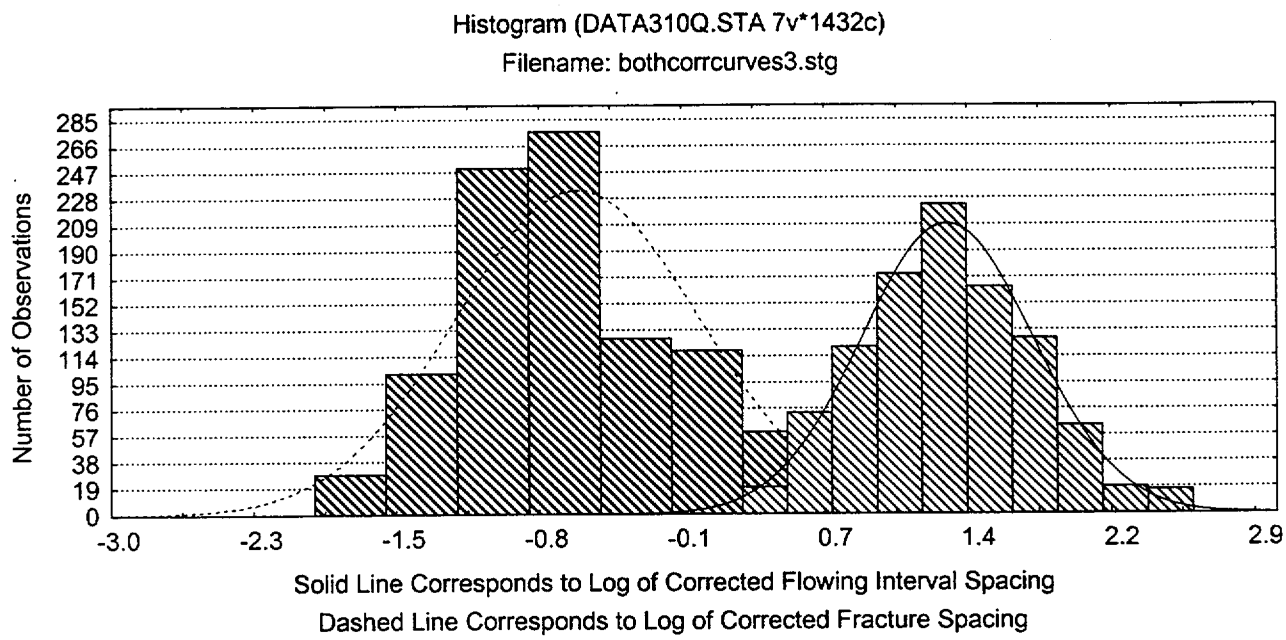


Figure 12. Comparison of the Probability Distributions of the Log of Corrected Flowing Interval Spacing and Corrected Fracture Spacing. DTN: SN9907T0571599.001

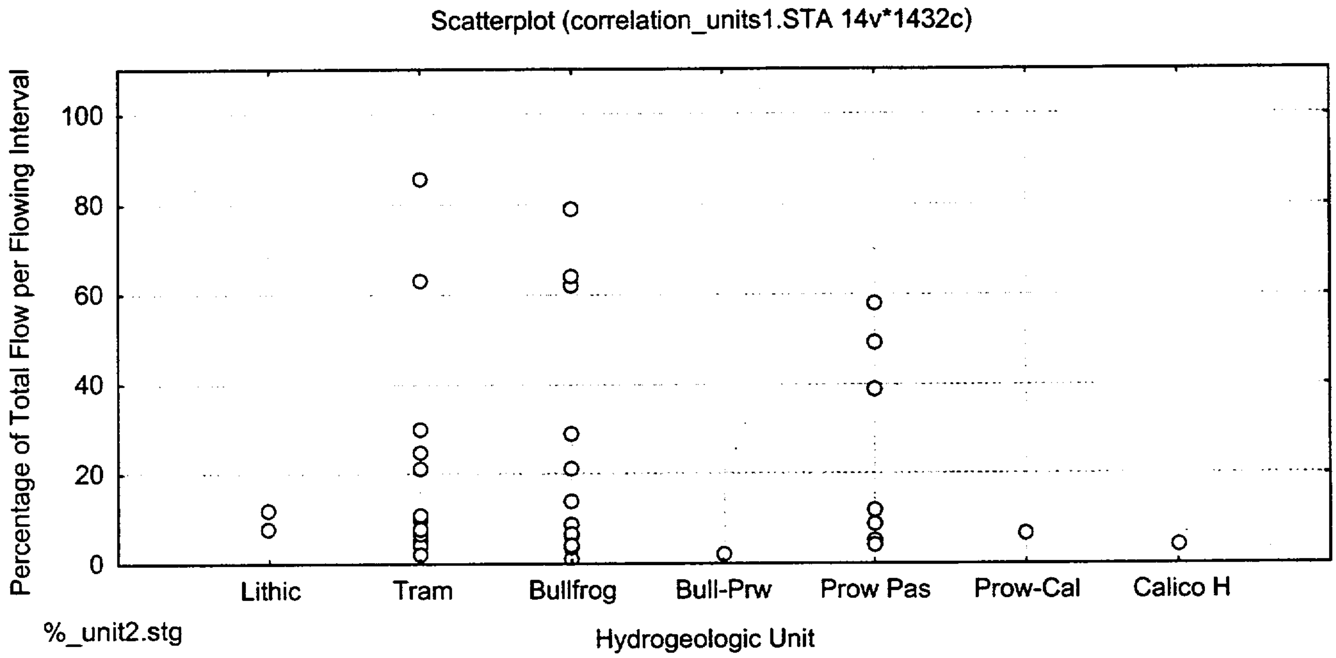


Figure 13. Percentage of flow in each flowing interval per hydrogoelogic unit. DTN: SN9907T0571599.001

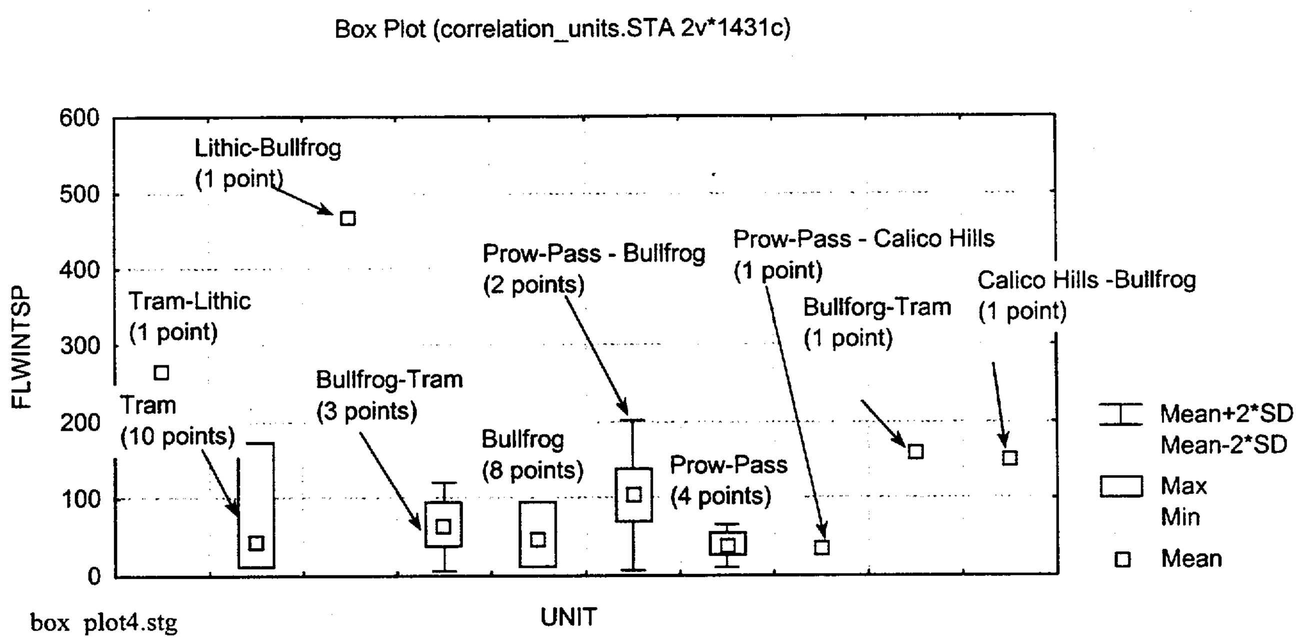
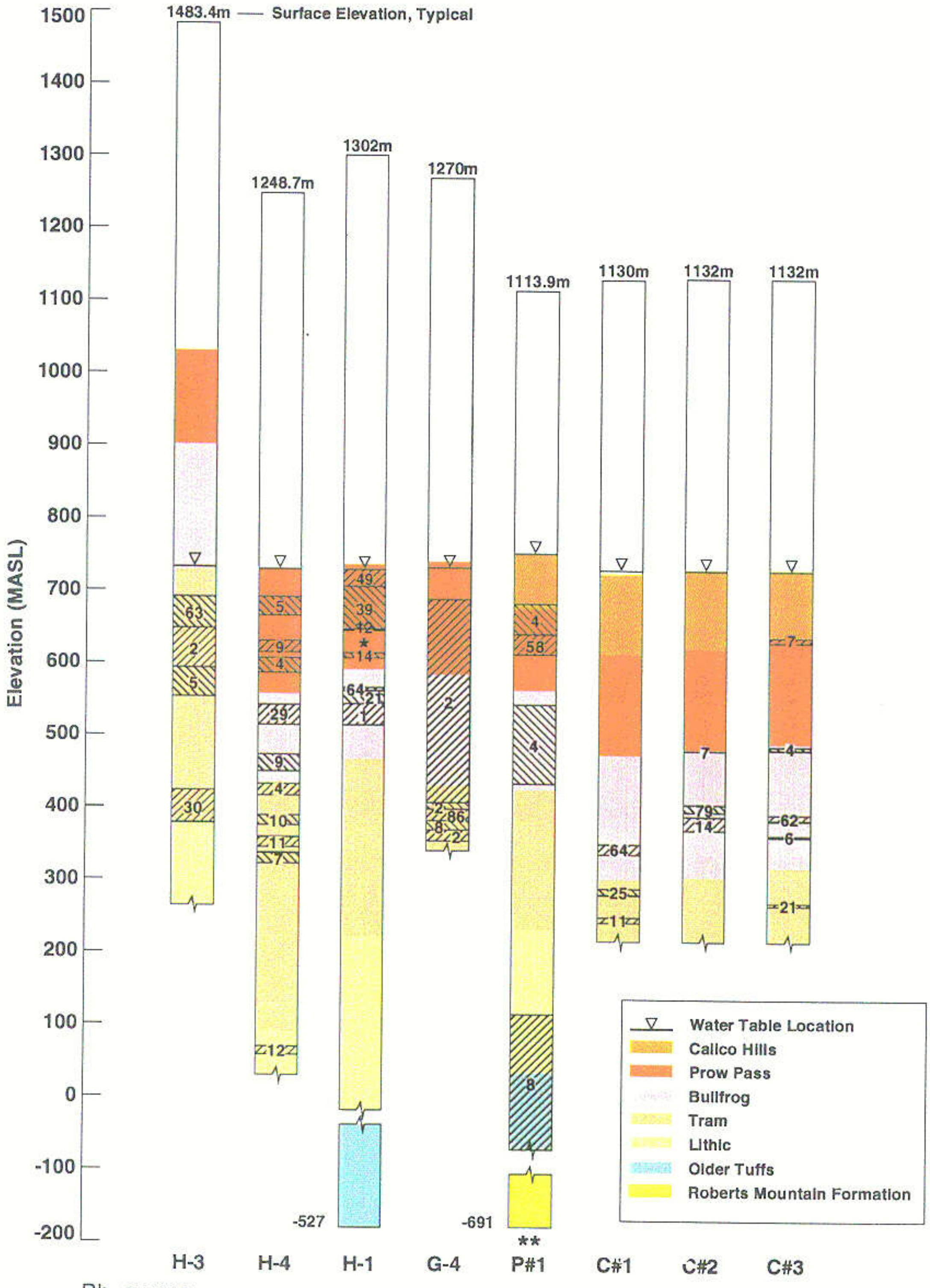


Figure 14. Box and whisker plot of flowing interval spacing data points and the number of data points within each unit. .Note some data points span adjoining hydrogeologic units. DTN: SN9907T0571599.001



Bh_gv.eps

* Top of second survey. Two surveys were conducted in this borehole

** Note 28% of flow moved past lowest measurable station

Figure 15 Comparison of the flow meter survey borehole information used in this analysis. The shaded areas indicate flowing intervals and the number within the flowing interval represents the percentage of total flow within that interval. DTN: SN9907T0571599.001

Attachment II

Table 2. Input to LHS in RIP for Flowing Interval Spacing

Probability (Number of raw data points = 32)	Flowing Interval Spacing (m)
0	11.5
0.13	21.34
0.34	30.48
0.44	39.01
0.56	47.5
0.66	58.67
0.75	79.1
0.81	96.32
0.94	172.5
1	468.5

Table 3. Input to LHS in RIP for Flowing Interval Spacing Dips

Probability (Number of raw data points = 165)	Flowing Interval Spacing Dips (Degree)
0	0
0.036	23
0.127	29
0.19	38
0.31	55
0.678	72
0.848	78
0.93	81
0.99	85
1	87

Table 4. Input to LHS in RIP for Fracture Spacing in SZ

Probability (Number of raw data points = 1119)	Fracture Spacing in SZ (m)
0	0.1
0.0598	0.16
0.227	0.19
0.3955	0.28
0.659	0.52
0.9205	3.08
0.95	7.09
0.979	18.5
0.99	34.5
1.0	77.1

Table 5. Input to LHS in RIP for Fracture Spacing Dips

Probability (Number of raw data points = 943)	Fracture Spacing Dips (Degree)
0	0.001
0.13	25
0.27	41
0.33	45
0.49	56
0.58	64
0.73	72
0.79	75
0.87	77
1	87

Table 6. Comparison of Statistics of the Logs of the Corrected Flowing Interval Spacing and the Logs of the Corrected Fracture Spacing
(Output form STATISTICA)

Variable	Valid N	Mean (m)	Min. (m)	Max. (m)	Std.Dev. (m)
Log of corrected flowing interval spacing	1000	1.29385	0.25428	2.571806	0.433811
Log of corrected fracture spacing in the SZ	1000	-0.59449	-1.94979	1.728895	0.628003

Table 7. Statistical Test Results From Kruskal-Wallis Rank Test

Statistical Nonparametric Statistics	**Kruskal-Wallis Anova by Ranks**	**Kruskal-Wallis test: H (4, N=41) = 3.23 p=0.5185**	
Dependant:newvar17	Code	Valid N	Sum of Ranks
Lithic	100	3	69.5
Tram	101	14	268.0
Bullfrog	102	14	330.5
Bull-Prow-Pass	103	1	3.5
Prow-Pass	104	9	189.5

Table 8. Comparison of Frequency of Flowing Intervals with Rock Type

Rock Type	% of Rock Type	Total Length (m)	Number of Flowing Intervals	Frequency of Flowing Intervals(1/m)
Paritally Welded	77.0	2525.6	25	0.0099
Welded	7.9	259.1	1	0.0039
Non-welded	9.7	318.7	3	0.0094
Beddded	5.4	176.6	1	0.0057

Table 9. Comparison of Flowing Interval Spacing with Hydrogeologic Units

Unit	Total Length of Unit (m)	Number of Flowing Intervals per Unit	Flowing Interval Spacing (m)
Calico Hills	6.7	1	6.7
Prow-Pass	175.9	9	19.5
Bullfrog	278.4	13	21.4
Tram	314.6	15	21.0
Lithic	197.7	2	98.8

Attachment3.doc

Attachment III

<u>List of Directories</u>

AP3.10Q/FIS/EXCEL/

Fracture_dips2.xls

Sheet: *FIS*	data from USGS reports used to calculate raw flowing interval spacing data. **spreadsheet 6.1 (Figure 3).**
Sheet:*FIS_CDF*	flowing interval data used to generate CDF for input to RIP, **spreadsheet 6.2 (Figure 5).**
Sheet: *FIS_dip*	flowing interval dip data from USGS reports and data used to generate CDF for input to RIP, **spreadsheet 6.3 (Figures 4 and 6).**
Sheet: *fspsz&cdf*	raw fracture spacing data from USGS reports and CDF for input to RIP, **spreadsheet 6.4 (Figures 8 and 10).**
Sheet: *dipsz&cdf*	raw fracture spacing dip data from USGS reports and CDF for input to RIP, **spreadsheet 6.5 (Figures 9 and 11).**

resul_fis2.xls	calculation of corrected flowing interval spacing from 1000 LHS realizations (excel spreadsheet).
resul_fpsz2.xls	calculation of corrected fracture spacing from 1000 LHS realizations (excel spreadsheet).

<u>AP3.10Q/FIS/RIP/</u>

FIS1.dat	Input file for RIP LHS runs for flowing interval spacing and flowing interval spacing dips
Res_fis2.txt	Rip output file for flowing interval spacing and flowing interval spacing dips
Fracture.dat	Input file for RIP LHS runs for fracture spacing in the SZ and fracture spacing dips
Re_419.txt	Rip output file for fracture spacing and fracture spacing dips
Rip.exe	Rip executable

AP3.10Q/FIS/GRAPHER

Workheet2.dat	Data file for Figures 3,4, 7-9
Plot4b.grf	Graph file for Figure 3
Plot5b.grf	Graph file for Figure 4
Corr_fis.grf	Graph file for Figure 7
Plot6.grf	Graph file for Figure 8
Plot7.grf	Graph file for Figure 9

AP3.10Q/FIS/STATISTICA

Data 3.10Q.sta	Data file for Figure 12
Bothcorrcurves3.stg	Graph file for Figure 12
Correlation_units1.sta	Data input file for Figure 12 (columns "unit" and "%flow"). (Data for this spreadsheet is located in stat_unit.xls)
%_unit2.stg	Graph file for Figure 13
Correlation_units.sta	Data input file for Figure 14. (Data for this spreadsheet comes from Fractures_dips2.xls)
Box_plot4.stg	Graph file for Figure 14

AP3.10Q/FIS/WORD/

FIS_doc7_rev0e.doc	Text write-up for AP3.10Q document
Figures4.doc	Attachment I, Figures
Attachment2.doc	Attachment II, Tables
Attachment3.doc	Attachment III, List of Directories

AP3.10Q/FIS/PVwave/

Bh_gv.eps	Graph file for Figure 15
borehole_flow.pro	PV-Wave code to generate Figure 15
fracsp_eleva3.xls	Excel spreadsheet to calculate the elevations used to produce Figure 15