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

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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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ACRONYMS

1D	One-dimensional, one-dimension
2D	Two-dimensional, two-dimensions
3D	Three-dimensional, three-dimensions
ACC	Accession Number
AMR	Analysis/Model Report
AP	Administrative Procedure
CRWMS	Civilian Radioactive Waste Management System
DFNM	Discrete Fracture Network Model
DIRS	Document Input Reference System
DOE	Department of Energy
DST	Drift Scale Test
DTN	Data Tracking Number
EBS	Engineered Barrier System
ESF	Exploratory Studies Facility
LBNL	Lawrence Berkeley National Laboratory
M&O	Management and Operating Contractor
OCRWM	Office of Civilian Radioactive Waste Management
PA	Performance Assessment
QAP	Quality Assurance Procedure
QARD	Quality Assurance Requirements and Description
QIP	Quality Implementing Procedure
R1, R2, R3	Three Realizations of 3D Heterogeneous Fracture Continuum Blocks
SHT	Single Heater Test
STN	Software Tracking Number
TBV	To Be Verified
Tptpmn	Topopah Spring middle nonlithophysal hydrogeologic unit
TSw	Topopah Spring welded hydrogeologic unit
TDMS	Technical Data Management System
UZ	Unsaturated Zone
YMP	Yucca Mountain Site Characterization Project

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1. PURPOSE

The purpose of this Analysis/Model Report (AMR) is to document the predictions and analysis performed using the Seepage Model for Performance Assessment (PA) and the Disturbed Drift Seepage Submodel. These results will be used by PA to develop the probability distribution of water seepage into waste emplacement drifts at Yucca Mountain, Nevada, as part of the evaluation of the long term performance of the potential repository. This is in accordance with the *AMR Development Plan for U0075 Seepage Models for Performance Assessment (PA) Including Drift Collapse* (CRWMS M&O 1999a). This purpose is accomplished by performing numerical simulations with stochastic representations of hydrological properties using the Seepage Model for PA and evaluating the effects of an alternative drift geometry representing a partially collapsed drift using the Disturbed Drift Seepage Submodel. This AMR supports:

- PA
- Abstraction of Drift-Scale Seepage
- Unsaturated Zone (UZ) Flow and Transport Process Model Report (PMR)

Seepage into drifts is evaluated by applying numerical models with stochastic representations of hydrological properties and performing multiple realizations of the permeability field around the drift. The Seepage Model for PA uses the distribution of permeabilities derived from seepage testing in niches to stochastically simulate the 3D flow of water in the fractured host rock in the vicinity of potential emplacement drifts under ambient conditions. The Disturbed Drift Seepage Submodel evaluates the impact of the partial collapse of a drift on seepage. Drainage in rock below the emplacement drift is also evaluated.

The work scope is to: (1) evaluate percolation flux predictions for UZ Site Scale Flow and Transport Model (UZ model) for use in establishing a range of flux rates to be applied at the upper boundary of the drift seepage model, (2) use the calibrated parameter sets developed using the Seepage Calibration Model, (3) design a set of simulations for evaluating drift seepage, (4) perform multiple realizations of heterogeneous rock properties and subsequent simulations of drift seepage using the Seepage Model for PA and provide input for the evaluation of the distribution probability of water dripping onto waste packages, (5) evaluate dependence of predictions on the effective local correlation length and the degree of heterogeneity of hydrologic parameters, (6) evaluate existing models of tunnel or drift collapse provided by the Engineered Barrier System (EBS) group for representation as an alternative drift geometry and develop a simplified representation of partial drift collapse, (7) perform simulations using this simplified representation, and (8) use Seepage Model for PA to evaluate drainage of rocks below a drift (CRWMS M&O 1999a, p. 4).

This AMR is classified as a scientific analysis because it documents predictions and analyses for seepage into drifts for use in the evaluation of the performance of natural barriers. The terms “model” and “analysis” are used interchangeably throughout this AMR and refer to predictions and evaluation of seepage and not necessarily to the classification of this AMR per AP-3.10Q, *Analyses and Models*.

The primary caveats and limitations in the scope of this AMR and the results from the Seepage Model for PA are that its basis is limited to the current repository design and available site data including the drift configuration defined by the current design, available hydrologic properties data from the site, limitations reported in the AMRs that directly support this AMR, and consideration of seepage under ambient conditions only. Thus thermal-hydrologic and thermal-hydrological-mechanical effects are not considered in this AMR. Also since the main available seepage-related data are for the Topopah Spring middle nonlithophysal geological unit (Tptpmn) at Yucca Mountain, evaluation in this AMR is mainly for this unit.

Note that the purpose of this AMR is to document the predictions from the Seepage Model for PA and not to draw conclusions on final PA predictions. Thus it forms a vital link between the field data and calibrated-model parameters and the PA effort. The AMR establishes trends of seepage over ranges of parameter values with a state-of-art understanding of the processes involved. PA, working under a separate AMR, will discuss probability weighting factors for parameter values and scenarios, that are appropriate to the potential repository horizon at Yucca Mountain. Thus for this AMR, the data that have been surveyed are not used directly but are used as corroborative information to establish the limits of the parameter ranges to be used. Similarly the scenarios (such as rockfalls) are taken to indicate trends and potential values of the results. In other words, this AMR does not utilize a particular parameter set, but considers ranges of possible values for these input parameters. Indeed, PA can select any of the combinations of input values for their analyses.

2. QUALITY ASSURANCE

The activities documented in this AMR were evaluated with other related activities in accordance with QAP-2-0, *Conduct of Activities*, and were determined to be subject to the requirements of the U.S. DOE Office of Civilian Radioactive Waste Management (OCRWM) *Quality Assurance Requirements and Description* (QARD) (DOE 1998). This evaluation is documented in *M&O Site Investigations* CRWMS M&O 1999b, c; and Wemheuer 1999 (*Activity Evaluation for Work Package WP 1401213UM1*).

The modeling activities documented in this AMR have been conducted in accordance with the CRWMS M&O quality assurance program, using OCRWM Administrative Procedures (APs) and YMP-LBNL Quality Implementing Procedures (QIPs) identified in the *AMR Development Plan for U0075, Seepage Models for PA Including Drift Collapse and Drainage, Rev.00* (CRWMS M&O 1999a). This AMR has been developed in accordance with procedure AP-3.10Q, Rev. 1, ICN 1, *Analyses and Models*.

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3. COMPUTER SOFTWARE AND MODEL USAGE

The software codes and routines used in this study are listed in Table 1 and were used in accordance with AP-SI.1Q, Rev. 2, ICN 1, *Software Management.* These are appropriate for the intended application and were used only within the range of software validation. The software codes were submitted to and obtained from software configuration management. The use of ITOUGH V3.2_drift (ITOUGH2 V3.2_drift, STN: 10055-3.2_DRIFT-00, Version 3.2) prior to obtaining it from configuration management and issuance of a user's request has been reviewed per AP-3.17, Rev. 0, ICN 0, *Impact Reviews*, and has been found to have no impact on this AMR and its products. The qualification status of this software is given in the Document Input Reference System (DIRS) included as Attachment I and in the DIRS database.

Table 1. Computer Software and Routines

Software Name	Version	Software Tracking Number (STN)	Computer Platform
ITOUGH2 V3.2_drift	3.2	10055-3.2_DRIFT-00	SUN and DEC w/Unix OS
GSLIB V 2.0 (SISIM module of GSLIB package)	2.0	10098-2.0MSISIMV2.0-00	SUN w/Unix OS and PC w/DOS
AMESH V 1.0	1.0	10045-1.0-00	SUN w/UNIX OS
Routines:		**Accession Number (ACC):**	
frac_calc	1.1	MOL.19990903.0032	PC w/DOS
Read_TDB	1.0	MOL.19990903.0031 MOL.20000104.0304	PC w/DOS
Meshbd.f	1.0	MOL.20000217.0297	SUN w/Unix OS
mininipresf.f	1.0	MOL20000217.0298	SUN w/Unix OS
mddf.f	1.0	MOL.20000217.0299	SUN w/Unix OS
mk_gener.f	1.0	MOL.20000217.0300	SUN w/Unix OS
mk_scale_k.f	1.0	MOL.20000217.0301	SUN w/Unix OS
mininipresf_ir.f	1.0	MOL.20000217.0302	SUN w/Unix OS
mddf_CC8.f	1.0	MOL.20000217.0303	SUN w/Unix OS
mddf_CS8.f	1.0	MOL.20000217.0304	SUN w/Unix OS
mddf_cc.f	1.0	MOL.20000217.0305	SUN w/Unix OS
minrefine3df.f	1.0	MOL.20000217.0306	SUN w/Unix OS

The codes ITOUGH2 V3.2_drift, SISIM module of the GSLIB package (GSLIB V2.0, STN: 10098-2.0MSISIMV2.0-00, Version 2.0) and AMESH (AMESH V1.0, STN: 10045-1.0-00, Version 1.0) were reverified as part of the YMP Configuration Management Software Revalidation effort under AP-SI.1Q, Rev. 1, ICN 0. The routines were qualified per Section 5.1 of AP-SI.1Q, Rev. 1, ICN 0 (the first two routines listed in Table 1) and AP-SI.1Q, Rev. 2, ICN 1 (all other routines). The source codes for the routines are provided in Attachment III. All other

related documentation per AP-SI.1Q, including test cases, has been submitted under the corresponding ACC number in Table 1 (see column 3).

The AMESH V1.0 code is used in the analysis to generate numerical grids for modeling simulations of the undisturbed and partially collapsed drifts. The SISIM module of GSLIB is used to generate stochastic representations of the permeability fields in the host rock surrounding the drifts using the air-k test data obtained from niche studies. ITOUGH2 V3.2_drift is used to perform forward simulations and calibration inversions during the analyses.

The first two routines (frac_calc and Read_TDB) in Table 1 were used for pre-processing of data from the TDMS and calculating fracture spacing for the discussion of alternative conceptual models in Section 6.7. The other macros listed in Table 1 were used for pre-processing and preparing input files for ITOUGH2 V3.2_drift.

The commercially-available visual-display graphics program TECPLOT (Version 7.0) was also used. It was used for plotting data and presentation purposes only and therefore is exempt from software quality assurance requirements per Section 2.0 of AP-SI.1Q, Rev. 2, ICN 1.

This AMR documents the analysis using the Seepage Model for PA. The input and output files for the model runs presented in this AMR are listed in Attachment II. It also utilizes results from the Seepage Calibration Model which is documented in CRWMS M&O (2000a).

4. INPUTS

The inputs to the models were obtained from the Technical Data Management System (TDMS) and their development is documented in other AMRs. The field and developed data used to characterize the seepage conditions in the models are discussed below.

4.1 DATA AND PARAMETERS

The input data used for the development of the Seepage Model for PA include the following:

- Proposed drift and waste package configuration (Table 2, Row 1)
- Calibrated drift-scale properties to establish parameter ranges (Table 2, Row 3)
- Fracture properties (frequency and calibrated van Genuchten α and n parameters) for the potential repository host rock to establish parameter ranges (Table 2, Row 2)
- Fracture permeabilities from air-k niche test results to corroborate the choice of permeability range (Table 2, Row 4)
- Pneumatic pressure data used for estimating air permeability from the Single Heater Test (SHT) (Table 2, Row 5; Tsang and Birkholzer 1999, p. 393) and Drift Scale Test (DST) (Table 2, Row 5; Birkholzer et al. 1999, p. 359) areas to corroborate the choice of parameter ranges
- Detailed line survey of fractures in the Topopah Spring middle nonlithophysal geological unit along the Exploratory Studies Facility (ESF) Main Drift (Stations 27 + 20 to 37 + 80) to corroborate the use of the fracture continuum approach (Table 2, Rows 6–8)
- General drift shape from the EBS AMR *Drift Degradation Analysis* (CRWMS M&O 2000b) (Table 2, Row 1)

Specific input data sets and the associated Data Tracking Numbers (DTNs) are listed in Table 2. The current Q-status of these data are provided in the DIRS which is included as Attachment I and in the DIRS database.

Table 2. Input Data Used

DTN	Data Description
SN9908T0872799.004	Drift geometry and waste package length and spacing
LB997141233129.001	Mountain-scale, calibrated parameter sets for base-case infiltration
LB990861233129.001	Drift-scale, calibrated parameter sets for base-case infiltration
LB980001233124.002	Pre- and post-excavation air permeability data from Niche 3650
LB960500834244.001 LB970600123142.001	Pneumatic pressure data from air injection tests in the SHT and DST areas used for air permeability estimates
GS971108314224.025	Fracture type (location, strike, dip, length) Sta. 26+00 to 30+00
GS960708314224.008	Fracture type (location, strike, dip, length) Sta. 30+00 to 35+00
GS960808314224.011	Fracture type (location, strike, dip, length) Sta. 35+00 to 40+00

In the data listed in Table 2, Rows 1, 4, and 5 are labeled to be verified (TBV) with TBV numbers 3471, 3094, 3247 and 3248, respectively. Their impact will be discussed in Section 7.

Reports documenting past numerical modeling related to drift seepage at Yucca Mountain as well as other pertinent documents are listed in Section 8.5, Supporting Bibliography. This bibliography is for information only, and this AMR does not directly rely on any of the listed documents.

4.2 CRITERIA

This AMR complies with the 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)).

4.3 CODES AND STANDARDS

No specific formally established standards have been identified as applying to this analysis and modeling activity.

5. ASSUMPTIONS

The Seepage Model for PA follows the approach and modeling framework described in Birkholzer et al. (1999, pp. 358–362) and CRWMS M&O (2000a, Sections 5 and 6). These documents provide the necessary scientific and technical background for the readers to understand this AMR.

The general model assumptions and justifications are similar to those of CRWMS M&O (2000a, pp. 19–20). The applicable assumptions are discussed below.

Assumption 1: It is assumed that the continuum approach is a valid concept to calculate percolation flux and drift seepage at Yucca Mountain. *Rationale:* The rationale for this assumption is presented in Section 5.3 of CRWMS M&O 2000a (also see Section 6.7 of this AMR).

Assumption 2: Adopting the continuum approach, water flow under unsaturated conditions is assumed to be governed by Richards' equation (Richards 1931, pp. 318–333). *Rationale:* This general concept is believed reasonable for unsaturated water flow through both porous matrix and fractures. Richards' equation simply states that water flows under the combined effect of gravitational and capillary forces, and that flow resistance is a function of saturation, thus neglecting resistance due to the presence of air.

Assumption 3: Permeabilities determined from air-injection tests are assumed to be representative of the hydraulic conductivity of the fracture medium at the site. *Rationale:* The injected air will seek out the most permeable paths in the medium that have the least capillary suction. These are in the fracture continuum part of the medium. The short duration of the air injection tests also implies that there is insignificant phase change during the tests so that the conventional single phase analysis method applies.

Assumption 4: Relative permeability and capillary pressure are assumed to be described as continuous functions of effective liquid saturation, following the expressions given by the van Genuchten-Mualem model (van Genuchten 1980, pp. 892–898; Luckner et al. 1989, pp. 2191–2192) as implemented in the ITOUGH2 code (Finsterle 1997, p. 224). *Rationale:* The van Genuchten-Mualem model is the standard model used in the suite of UZ flow and transport models; it was chosen here for consistency. Furthermore, the applicability of relative permeability and capillary pressure functions is consistent with the continuum assumption and seems appropriate also for fractures, which are likely to be rough and/or partially filled with porous material.

Assumption 5: Water removal from the formation and the capture system by vapor diffusion and evaporation is assumed to be small and hence the drift acts as having 100% relative humidity condition and as a capillary barrier to flow. *Rationale and discussion:* Under isothermal conditions, potential evaporation in the drift is small compared to the amount of water percolating through the medium. It is important to realize that prescribing a 100% relative humidity boundary condition in a seepage prediction model is a conservative assumption. While such a model underestimates vapor flow, it yields the maximum liquid-phase influx, which is defined here as drift seepage. The

underestimation of vapor flow is irrelevant, since the assumption of 100% relative humidity already implies that the moisture content in the drift environment is at its maximum.

Assumption 6: Imbibition and flow into the matrix continuum is not considered. *Rationale*: In the current AMR, except for the episodic percolation flux case (Sections 6.5 and 6.6.7), we are calculating steady-state flow conditions over long time frames. At steady-state, the flow exchange between fracture and matrix continua will settle to a small amount with the matrix close to full saturation. The flow partitions between the fracture and matrix continua according to their effective permeabilities and porosities, and it follows that the matrix with its five to six orders-of-magnitude lower permeability would not have significant effects on seepage into drift, which would be controlled by the flow in the fracture continuum. For the episodic percolation flux case (Sections 6.5 and 6.6.7), the matrix continuum provides a damping effect on seepage in the fracture continuum, and neglecting it represents a conservative case.

Note that assumption 5 in CRWMS M&O (2000a, Section 5) states that the van Genuchten parameter $1/\alpha$ is assumed to be correlated to the absolute permeability according to the Leverett scaling rule (Leverett 1941, p. 159). This scaling rule, which states that $1/\alpha$ is inversely proportional to the square root of the absolute permeability, was developed for porous media. For fractured media, a large permeability could possibly result from both larger fracture apertures and an increase in the intensity of fracturing. The former affects the α values and the latter does not. In our calculations, we have chosen to assume α to be constant over the heterogeneous domain for each case, which allows more efficient numerical computation. Then the impact of α-k correlation according to the Leverett relationship is calculated as a correction factor (see Section 6.6.4)

All of the above assumptions are used throughout this report. None of the above assumptions require further confirmation, either because we have addressed its uncertainty in this AMR, we have taken a more conservative alternative, or we have attached a range to the parameters used.

6. ANALYSIS/MODEL

6.1 OBJECTIVES AND OUTLINE

This AMR models drift seepage under long-term, steady-state and episodic conditions for a range of parameters and conditions (such as drift collapse scenarios). The model used follows that of Birkholzer et al. (1999, pp. 358-362). The objectives are to calculate seepage values for different values of percolation flux down to the drift, to discuss the effect on seepage resulting from various processes such as excavation-induced drift degradation (i.e. drift collapse), and to provide results as input to PA.

This section will first discuss the validity of this analysis for its intended purpose as required by AP-3.10Q *Analyses and Models*. Then, the geometry used, the ranges of parameters, and the choice of conditions will be presented and rationalized. Next, results will be given. Finally, the AMR will conclude with discussions of alternative models and conclusions.

Key scientific notebooks (with relevant page numbers) used for modeling activities described in this AMR are listed in Table 3.

Table 3. Scientific Notebooks

LBNL Scientific Notebook ID	M&O Scientific Notebook Register ID	Page Numbers	Accession Numbers (ACC)
YMP-LBNL-CFT-2	SN-LBNL-SCI-058-V1	91–108	MOL.19991103.0330
YMP-LBNL-CFT-GL-1	SN-LBNL-SCI-033-V1	71–72, 86–89, 125–156	MOL.19991103.0331
YMP-LBNL-DSM-MC-1	SN-LBNL-SCI-052-V1	1–42	MOL.19991025.0236
YMP-LBNL-GSB-1.9	SN-LBNL-SCI-053-V1	105	MOL.19990908.0227

6.2 MODEL VALIDATION

As required by AP-3.10Q, Rev. 1, ICN 1, a model should be valid for its intended purpose. This normally requires testing model results against relevant data which are not used in the original development of the model and which are appropriate to the intended use of the model. For the Seepage Model for PA, these data should include percolation flux at low flow rates over periods of years, even hundreds of years, in many locations in the repository block (for proper statistical representation). Those data are not available. Further, data for adequate validation would need to cover the wide range of conditions (such as drift degradation and collapse with time) studied in this AMR. Those are not available either. Hence we cannot use the approach of Section 5.3a of AP-3.10Q for model validation, and an alternative approach under Section 5.3b is used. First, the relevant physics of the problem as represented by Richards' equation (Richards, 1931, pp. 318-333), van Genuchten-Mualem model (Luckner et al. 1989, pp. 2191–2192), Philip's studies (Philip et al. 1989, pp. 16–28), and effects of flow channelization resulting from heterogeneity and ponding (Birkholzer and Tsang, 1997, pp. 2221–2224; Birkholzer et al. 1999, pp. 370–379) are used. These are all in the open literature and have gone through proper technical peer review and which have withstood scrutiny of the scientific community since their

dates of publication (AP-3.10Q, Section 5.3.b.2). Further, the model is consistent with results from niche seepage tests in the ESF (Wang et al. 1999, pp. 332–338). These data were used in the Seepage Calibration Model on which the seepage model is based (AP-3.10Q, Section 5.3.b.5), as described in CRWMS M&O (2000a, Section 6). Further, parameters used are reasonable and consistent with all relevant data (AP-3.10Q, Section 5.3.b.3). Thus, based on these external pieces of evidence, we conclude that the analysis and predictions using the Seepage Model for PA presented here, with proper uncertainty ranges assigned to these predictions, is an acceptable representation of the process system.

6.3 CALCULATION MODEL AND SELECTION OF CASES

The calculation model follows that of Birkholzer et al. (1999, pp. 358-362), which provides the scientific and technical background for the readers to understand this AMR. The conceptual model is a heterogeneous permeability field for the fracture continuum generated with parameters discussed below using the SISIM module of the GSLIB package (GSLIB V2.0, STN: 10098-2.0MSISIMV2.0-00,Version 2.0). The 3D field is 20 m vertical, 15 m wide normal to drift axis and 5.23 m along the drift axis. With the drift of 5.5 m diameter (see Section 6.3.1) and the distance to either side boundary of 4.75 m, we expect the vertical cross section to capture the flow features around the drift. The distance along the drift axis is defined by the waste package length being 5.13 m (see below) with 0.1 m between the waste packages. The side boundary conditions are no-flow, the lower boundary condition is gravity drainage, and the upper boundary surface is simulated by an extra grid cell with constant percolation flux connected to all the grid cells in the upper boundary, so that flow is free to move into these cells according to local property parameters. A comment may be added on the no-flow boundary condition on the two planes at the end of the waste package normal to the drift axis. For homogeneous, constant-property medium, these are symmetric planes between successive waste packages and a no-flow boundary condition is justified. For a heterogeneous system, the issue is the length of the flow domain versus the spatial correlation length λ. From Section 6.3.5 below, $\lambda = 0.5$ m so that the length of the domain is about 10 correlation lengths, and the effect of the no-flow boundary should not have a significant effect on the flow results.

The mesh is generated using the AMESH V1.0 code (AMESH V1.0, STN: 10045-1.0-00, Version 1.0) and the grid cell used is $0.5 \times 0.5 \times 0.5$ m, chosen as a compromise between being fine enough to include the main flow features and being coarse enough to allow the feasibility of about 1000 3D stochastic simulations. As discussed in Section 6.7 of this AMR, the choice of grid size is not related to Philip's boundary layer at the drift crown (Philip et al. 1989, p. 21, Figure 1), but to heterogeneity field characteristics. A numerical study (YMP-LBNL-CFT-GL-1, pp. 86–89) has shown that 0.5 m is an adequate grid size for our calculations.

Flow calculation was performed using ITOUGH2 V3.2_drift (ITOUGH V3.2_drift, STN: 10055-3.2_DRIFT-00, Version 3.2). A number of routines were also used for pre-processing of inputs for ITOUGH2 V3.2_drift and these are listed in Table 1 and documented in YMP-LBNL-CFT-GL-1, and provided in Attachment III.

The selection of parameter ranges and particular cases to be modeled is presented in this subsection together with rationale for the selection. We shall consider a drift emplaced in Topopah Springs middle nonlithophysal unit (UZ model layer tsw34 or the lithostratigraphic unit

Tptpmn). The discussion of parameter values below refers to this unit. Figure 1 is a sketch summarizing the modeling cases, which can be used as a guide as one follows the discussions below. The top part of Figure 1 shows a 3D grid, spanned by the three parameters, which are most sensitive in affecting drift seepage; namely, fracture continuum permeability k_{FC}, van Genuchten α value and the standard deviation σ in ln k_{FC}, which is a measure of heterogeneity of the permeability field. For each combination of these three parameters, i.e. at each grid point, seepage model calculations (Birkholzer et al. 1999, pp. 358–362) will be made for 3 realizations, using a range of values for percolation flux Q_p at the repository level. Two particular combinations of parameters, Set A and Set B, are selected for additional studies. Their selection and values are discussed in Section 6.3.5.

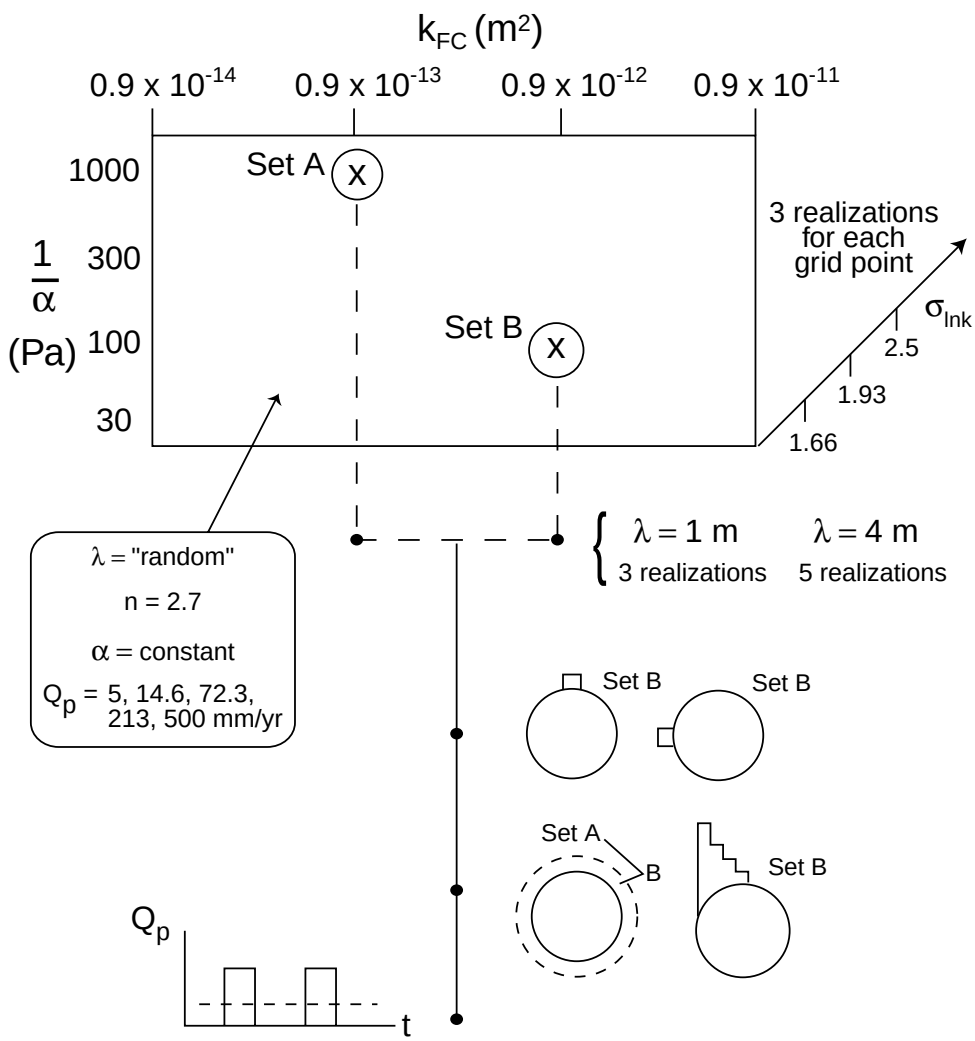


Figure 1. Cases Studied.

The middle part of Figure 1 indicates a study of drift seepage for three alternative permeability spatial correlation lengths λ. This allows an evaluation of the effect of this important parameter, which is difficult to determine in the field. The minimum set of parameters that describe a simple

heterogeneous field can be the two parameters σ and λ. Thus this AMR will investigate how seepage depends on the heterogeneous field.

The lower right part of Figure 1 shows the disturbed drift seepage submodel. Based on a review of current information, alternative drift degradation modes are evaluated (see below) and four scenarios are identified for seepage model studies as indicated. The lower left part of Figure 1 shows the case when the percolation flux above the drift is episodic rather than at a constant average value, so that all the flux comes within a short period of time, with no flux between such pulses. This case will also be evaluated.

All the cases are computed on 3D heterogeneous unsaturated systems. Since some cases involve more than one run, altogether more than 1000 runs were made. What follows below, after the specification of drift geometry, are the choices of parameter ranges on which seepage calculations are performed. These choices are based on a comprehensive review of available relevant data. However the data are not used directly to produce a single set of simulation results, but are used as references to establish parameter ranges.

6.3.1 Geometry

As provided in DTN: SN9908T0872799.004, the drift diameter is 5.5 m and the drift section under study has the same length as that of a waste package with half the spacing to the next waste packages on its two ends. Since the waste package length is 5.13 m and the spacing between the waste packages is 0.1 m, the drift section modeled is 5.23 m. This drift section is emplaced in a heterogeneous fracture continuum of dimension 15 m wide and 20 m high, following Birkholzer et al. (1999, p. 360).

6.3.2 Fracture Continuum Permeability k_{FC}

As shown in Figure 1, the range of permeability chosen for the fracture continuum k_{FC} is from 0.9×10^{-14} m^2 to 0.9×10^{-11} m^2. The choice is based on the air permeability tests at Niche 3650 in the ESF, which give a mean log permeability of -11.66 or 2.2×10^{-12} m^2 (CRWMS M&O 2000a, p.43, Table 5), which is within our range. Note that the parameter is based on field air-permeability data (see Table 2, Row 4 for DTN) around the niche that has been impacted by excavation effect. Air permeability represents mainly permeability of the fractures, whose permeability is much larger and whose water capillary effect is much smaller than those of the rock matrix. The excavation is a coupled hydromechanical process in which the fracture apertures may be made larger in the immediate neighborhood of the opening. The permeability change associated with these aperture changes can be as much as two orders of magnitude (Wang et al. 1999, p. 328, Figure 3).

The fracture permeability before excavation was also measured by Wang et al. (1999, p. 328) and the mean value is 6.6×10^{-14} m^2. This is based on their tests in boreholes at their niche experiment, with a packer interval of 0.3 m (Wang et al. 1999, p. 325). Air-permeability tests were also carried out in the SHT area in the ESF. There, the packer intervals are typically 3 to 7 m, and the mean permeability was found to be 5.8×10^{-14} m^2 (Tsang and Birkholzer, 1999, p. 393). Air-permeability measurements were also carried out in the DST block in the ESF, where they found the mean permeability to be 10^{-13} m^2 with a standard deviation in ln k_{FC} to be 2

(Birkholzer et al. 1999, p. 359). Here, the packer intervals are mainly between 10 and 20 m in length. The DTNs for these data are provided in Table 2, Rows 4 and 5.

The mean air permeability values without excavation effects, as mentioned in the last paragraph, are 0.7×10^{-13} m^2, 0.6×10^{-13} m^2 and 10^{-13} m^2 after being rounded to one significant figure. They are quite consistent to each other even though the packer intervals used in the tests ranged from 0.3 m to ~20 m. These values are somewhat more than one order of magnitude smaller than post-excavation values (mean $k = 2.2 \times 10^{-12}$ m^2). For seepage into drifts, the permeability of rock near the drift is the relevant value. Thus, the weighting of seepage results in this table should be at this larger permeability value. On the other hand, the excavation effect on permeability depends on local fracture orientation, distribution, and density as well as on excavation methods. This has sufficient uncertainty to require the computation of seepage percentages over the full range of fracture continuum permeability, 0.9×10^{-14} m^2 to 0.9×10^{-11} m^2, as shown in Figure 1.

It is interesting to note that Ahlers et al. (1999, p. 66), from their pneumatic data analysis in surface-based boreholes, give air permeability for the TSw units of 4×10^{-12} m^2, vertical, to 8×10^{-13} m^2 horizontal. Also, LeCain's air-injection tests in four surface-based deep boreholes, UE–25 UZ#16, USW SD–12, USW NRG–6 and USW NRG–7a (LeCain 1997, pp. 2, 11–14), give permeability for the Tptpmn unit as ranging from ~2.5×10^{-14} to ~1×10^{-11} m^2, based on measurements with packer intervals of 3.5–4.9 m. These results are all covered by the full range of values in Figure 1.

6.3.3 Standard Deviation in ln k_{FC}

Finsterle and Trautz in CRWMS M&O (2000a, p. 43, Table 5) give the standard deviation of fracture continuum permeability in log base 10 to be 0.72, which translates to the standard deviation σ (in ln k_{FC}) of 1.66. Birkholzer et al. (1999, p. 359) on the other hand used $\sigma = 2.1$.

According to Birkholzer et al. (1999, p. 371, Figure 14) drift seepage tracks the probability for finding local ponding in the heterogeneous field and, further, the ponding probability is smaller for smaller permeability standard deviations (Birkholzer et al. 1999, p. 375, Figure 17). Hence we expect less seepage for smaller σ values. Thus, in our simulations we decided to study the dependence on σ by going to larger values than 1.66. Three alternatives, $\sigma = 1.66$, 1.93, and 2.5, are selected for our study.

6.3.4 van Genuchten Parameters

The van Genuchten n parameter used by Birkholzer et al. (1999, p. 354, Table 1) has a value of 2.7 corresponding to m parameter equal to 0.63, based on a review of fracture properties in the ESF (YMP–LBNL–GSB–1.9, p. 105). Finsterle and Trautz (CRWMS M&O 2000a, p. 52, Table 8), on the other hand, use a value n = 2.551. In their calibration study, this parameter is not varied, since it is not as sensitive a parameter as the van Genuchten α parameter and the effective porosity, which were indeed varied in the calibration (CRWMS M&O 2000a, p. 51). On the other hand, n is varied in another calibration study (Bandurraga and Bodvarsson 1999, p. 33). Considering these studies, we decided to use one single value for n = 2.7, since it is based on

fracture information in the ESF, and then a sensitivity study is made by running several cases with n = 2.55. As will be seen below, (Section 6.6.3), the differences in seepage results are not significant.

For α value, CRWMS M&O (2000a, p. 57, Table 10) provides a value of 1.82 for log (1/α [Pa]) through their calibration exercise, for the case of the 3D heterogeneous model. This translates to 1/α = 66 Pa. For the four alternative models they used, the smallest value obtained through their calibration is 31.6 Pa. Birkholzer et al. (1999, p. 354, Table 1), on the other hand, used an α value of 9.73×10^{-4} Pa^{-1}, which translates to 1/α = 1028 Pa. We decided to use four 1/α values bracketed by values used in these two references, i.e., 1/α = 30, 100, 300, and 1000 Pa, as shown in Figure 1.

For the main part of this AMR, for each case corresponding to the grid point (k_{FC}, α) in Figure 1 (top), we consider α to be constant over the 3D heterogeneous field. Thus, the k_{FC} value is the mean fracture permeability over the heterogeneous field with its standard deviation given by σ, but α is constant at all points in the 3D space. This is the "uncorrelated α" case. We also study the impact of α being correlated with the square root of local k_{FC} values, according to the Leverett (1941, p. 159) scaling rule. In such cases the k_{FC} and α values specified will be considered as the reference, and the local α value at each point in the 3D heterogeneous field is calculated by Leverett's scaling rule from the reference values, according to the local k_{FC} value, i.e.

$$(\alpha)_{local} = \alpha \cdot \left[\frac{(k_{FC})_{local}}{k_{FC}} \right]^{1/2}$$

Simulations using this method will be referred to as the "correlated α" cases (Section 6.6.4).

6.3.5 Spatial Correlation Length λ of k_{FC}

The analysis of air-permeability tests in the AMR by Finsterle and Trautz (CRWMS M&O 2000a, Section 6.3.2) suggests that “the permeability is essentially random without a noticeable spatial correlation.” Thus, for the main set of calculations, we adopt this result and generate heterogeneous fields with λ equal to grid size, corresponding to no spatial correlation. Note that Finsterle and Trautz shows a result that λ=3.87 m (CRWMS M&O, 2000a, Section 6.3.2), but in this case, the nugget is 0.40 and the sill is 0.53. With the nugget value close to the sill value, the accuracy of determining λ is very poor, and in fact, if the nugget and sill values are equal, λ is undefined. To be consistent within this AMR, we have taken the nugget to be zero, then Finsterle and Trautz’s result is equivalent to the λ-0 case, based on which they made the statement referenced above.

For each combination of k_{FC}, 1/α and σ values (see top part of Figure 1), we shall conduct calculations for three realizations to obtain an estimate of the variation range as a result of geostatistics. These multiple-realization results give a preliminary indication on the probability distribution spread of seepage predictions due to the geostatistical uncertainty.

Since λ is not a well-determined parameter *in situ*, we decided to investigate its sensitivity by computing seepage for alternative λ values. For this, we shall select only two particular parameter sets out of the 3D table of (k_{FC}, $1/\alpha$, σ) values (see Figure 1). We designate the first Set A, close to the base case of Birkholzer et al. (1999, p. 354, Table 1), with

$$\left.\begin{aligned} k_{FC} &= 0.9\times10^{-13}\,\mathrm{m}^2 \\ 1/\alpha &= 1000\ \mathrm{Pa} \\ \sigma &= 1.93 \\ \lambda &= 0.5\,\mathrm{m} \end{aligned}\right\} \qquad \text{(Set A)}$$

and the second parameter set is chosen to be close to Finsterle and Trautz's (CRWMS M&O 2000a, Tables 5 and 10) calibrated model parameters, with

$$\left.\begin{aligned} k_{FC} &= 0.9\times10^{-12}\,\mathrm{m}^2 \\ 1/\alpha &= 100\ \mathrm{Pa} \\ \sigma &= 1.66 \\ \lambda &= 0.5\,\mathrm{m} \end{aligned}\right\} \qquad \text{(Set B)}$$

For these two cases, we study the alternatives of $\lambda = 1$ m and $\lambda = 4$ m. For the former, again three realizations will be considered, while for the latter, because of the large λ value as compared with the drift diameter, we expect large variations in results and five realizations will be evaluated. It should be remarked here that while the many calculations made in this AMR help us to understand the trends of seepage results, parameter Sets A and B are closest to the data we have so far from the field.

6.3.6 Percolation Flux, Q_p

Wu et al. (1999, p. 210) calculated the percolation flux expected at the repository level, based on a 3D UZ model of Yucca Mountain. They obtained an averaged fracture flow of 4 to 5 mm/yr at the repository level under present conditions. Ritcey and Wu (1999, p. 262) found that under a simulated 21-ka pluvial scenario, the percolation flux ranges from 0 to 120 mm/yr, with the peak of the probability distribution to be around 20 mm/yr. For our calculations, we decided to select 5 values for Q_p ranging from 5 to 500 mm/yr; more specifically at Q_p = 5, 14.6, 73.2, 213 and 500 mm/yr. The upper limit of 500 mm/yr is chosen to safely bracket an uncertainty range more than four times the high flux value of 120 mm/yr.

6.4 IMPACT OF DRIFT DEGRADATION ON SEEPAGE

Drift degradation may occur in three ways:

1. Loosening of rock blocks and hence wider fracture aperture (fracture dilation)
2. Rock fall from the ceiling of the drift
3. Extended rock failure in drift roof.

These are discussed below. Based on these discussions, a drift degradation submodel is designed to evaluate the impact of drift degradation on seepage, and it is shown in Figure 2 as four alternative scenarios.

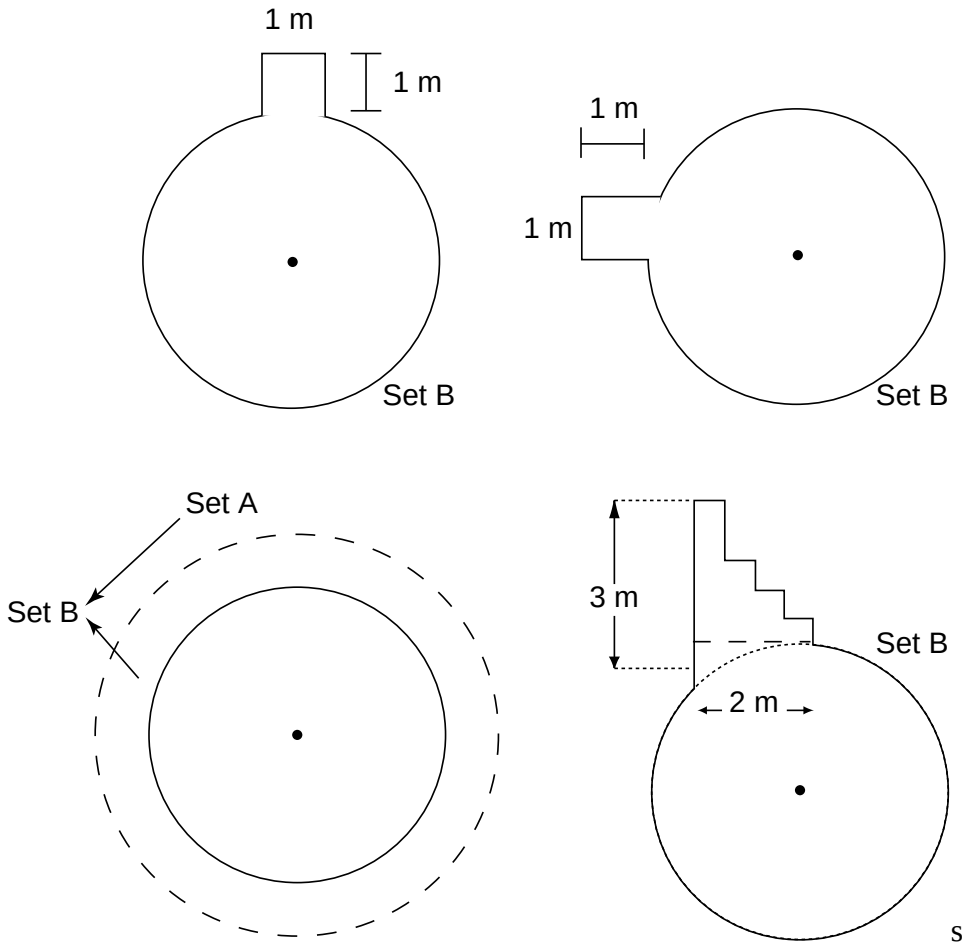


Figure 2. Drift Degradation Submodel Scenarios, with Associated Parameter Set Used in the Modeling

6.4.1 Fracture Dilation

Because of excavation, stress is relieved at the drift and fractures are expected to dilate at certain areas around the drift. Hart in Brekke et al. (1999, pp. E3-E29) shows that such fracture dilation depends on the orientation of the fracture set and generally occurs within one drift radius. An increase in fracture aperture generally causes an increase in fracture permeability and a decrease in $1/\alpha$ value. We believe that the increase in permeability from the pre-excavation to the post-excavation values (Wang et al. 1999, p. 328) is a result of this effect. In this sense, Set B, Section 6.3.5 (see also Figure 1), which is based on in-situ post-excavation results (CRWMS M&O 2000a, p. 42), already has taken this into account. This means that the fracture dilation neighboring the drift causes properties to change from parameter Set A to Set B in Figure 1, as the new rock properties to represent the total effect of the near-field distributed zone and the far

field as shown in Figure 2, lower-left. Results with parameter Set B are shown in Tables 4-8, and no further calculations are necessary.

There is a possibility that new fractures may be formed during fracture dilation. In this case, k_{FC} will be increased with a relatively smaller decrease in the $1/\alpha$ value. This is, however, not studied.

6.4.2 Rock Fall from Drift Ceiling

Kicker in CRWMS M&O (2000b, p. 53, Tables 23 and 24) used the key block theory to calculate the rock fall probability in the drifts based on fracture maps in the ESF. For the Topopah Spring middle nonlithophysal zone, he calculated 39 key blocks per km of the drift and 19 m^3 volume of total rock fall per km. This implies that rock fall occurs on the average with one block every 25 m and that the mean size of the block is about 0.5 m^3. Kicker also estimated that 90% of the blocks have size less than 1.18 m^3 (CRWMS M&O 2000b, p. 48, Table 17). Hart in Brekke et al. (1999, p. E-12) used a 2D discrete-element method and found rock fall to occur at the spring line of the drift and the size of the block to depend on the assumed fracture spacing. To study the effect of rock fall on seepage, we use parameter Set B and do two calculations, one in which a $(1.0\ m)^3$ block is taken out from the crown of the drift and the second in which the $(1.0\ m)^3$ block is taken out at the spring line (see Figure 2). The size used for the block is close to Kicker's 90 percentile value, to study a more significant event.

6.4.3 Extended Rock Failure at the Drift Roof

Over time, extended rock failure may also occur at the roof of the drift. Kaiser (Brekke et al. 1999, pp. D12-D14) estimated the failure at the roof to be 0.1–1 m in depth, and it would be 0.4–1.2 m in depth if one were to include seismic effects. Generally he expected that stress-induced failure at the drift crown to be over a distance of 1/2 drift radius, i.e., ~1.25 m. Kicker in CRWMS M&O (2000b, p. 56, Figure 28; p. 60, Figure 32) used a discrete-region key-block analysis, which shows a more extended failure region up to one drift diameter above the drift roof. In our seepage study, we designed a case in which an extended cavity is found in the drift roof with a step shape of 0.5 m at the crown, 1 m depth at 0.5 m to one side, and so on, reaching 3 m depth at 2 m laterally from the drift crown (see Figure 2, lower right). Further, the step-shaped failure is 1 m thick (into the page in Figure 2, lower right). Parameter Set B is used.

6.5 EPISODIC PERCOLATION FLUX

The cases discussed thus far use a steady-state percolation flux, ranging from 5 to 500 mm/yr. To study the sensitivity of seepage to episodic flux, we shall do a transient calculation for seepage percentage by assuming that, every year, the total flux over the year is concentrated in the first two months and no flux occurs in the other 10 months. The results will be compared with the cases using steady-state percolation.

6.6 RESULTS

Seepage percentage is defined as the liquid that seeped into the drift divided by the total liquid arriving on a cross-sectional area corresponding to the footprint of the drift. All results are

submitted to TDMS under DTN: LB991101233129.002, and the input/output files for the model computation are submitted under DTN: LB991101233129.001 and described as in Attachment II.

6.6.1 Seepage Over (k_{FC}, $1/\alpha$) Space

For values of $k_{FC} = 0.9 \times 10^{-14}$, 0.9×10^{-13}, 0.9×10^{-12} and 0.9×10^{-11} m^2, $1/\alpha$ = 30, 100, 300, 1000 Pa and λ = 0.5 m, Tables 4–8 give the seepage percentages in a matrix form of k_{FC} and $1/\alpha$ coordinates. Within each table are three subtables giving results of three realizations of the heterogeneous field R1, R2, and R3, indicating the spread of geostatistical uncertainty. Generally, to calculate the spread of geostatistical uncertainty, many realizations, much more than three, are needed. However, because of the need to keep computations within reasonable limits, three realizations are used to indicate the possible spread of this uncertainty. Also, the tables show a definite decrease of seepage percentage with increasing $1/\alpha$ or k_{FC}. Thus when the seepage percentage is zero for a given case, the cases with larger $1/\alpha$ and k_{FC} also have zero seepage. This reduces the amount of calculations needed significantly. In all these tables, results are presented to two significant figures.

Tables 4a, 4b, and 4c give results for the same Q_p = 5mm/yr and σ = 1.66, 1.93 and 2.5 respectively.

Table 4a. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.66 and Q_p = 5 mm/yr.

Realizations	1/α (Pa)	k_{FC} (m^2)			
		0.9×10^{-14}	0.9×10^{-13}	0.9×10^{-12}	0.9×10^{-11}
R1	1000	0	0.0	0	0
	300	0.0	0.0	0	0
	100	4.5	0.0	0	0
	30	37	0.0	0	0
R2	1000	0	0	0	0
	300	0.0	0	0	0
	100	4.5	0	0	0
	30	33	0.0	0	0
R3	1000	0	0	0	0
	300	0.0	0	0	0
	100	7.4	0	0	0
	30	34	0.0	0	0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 4b. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.93 and Q_p = 5 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	0.0	0.0	0	0
	300	0.0	0.0	0	0
	100	6.2	0.0	0	0
	30	38	0.0	0	0
R2	1000	0	0	0	0
	300	0.0	0	0	0
	100	5.1	0.0	0	0
	30	33	0.0	0	0
R3	1000	0	0	0	0
	300	0.0	0	0	0
	100	9.0	0	0	0
	30	34	0.0	0	0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 4c. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 2.5 and Q_p = 5 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	0.0	0	0	0
	300	0.0	0	0	0
	100	8.4	0.0	0	0
	30	41	0.02	0.0	0
R2	1000	0	0	0	0
	300	0.0	0	0	0
	100	6.0	0	0	0
	30	34	0.0	0	0
R3	1000	0.0	0	0	0
	300	2.6	0	0	0
	100	12	0	0	0
	30	35	0.0	0	0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Then, Tables 5a–c through Tables 8a–c give results for Q_p = 14.6, 73.2, 213 and 500 mm/yr, respectively.

Table 5a. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.66 and Qp = 14.6 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	0.0	0	0	0
	300	6.2	0	0	0
	100	38	0.0	0	0
	30	66	3.9	0.0	0
R2	1000	0.0	0	0	0
	300	5.7	0	0	0
	100	34	0.0	0	0
	30	59	5.8	0.0	0
R3	1000	0.0	0	0	0
	300	9.9	0	0	0
	100	36	0.0	0	0
	30	64	7.0	0.0	0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 5b. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.93 and Q_p = 14.6 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	0.0	0.0	0	0.0
	300	7.2	0.0	0	0.0
	100	41	0.0	0	0.0
	30	65	5.9	0.0	0.0
R2	1000	0.0	0	0	0
	300	6.1	0.0	0	0
	100	34	0.0	0	0
	30	58	6.5	0.0	0
R3	1000	0.0	0	0	0
	300	11	0	0	0
	100	36	0.0	0	0
	30	65	8.7	0.0	0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 5c. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 2.5 and Q_p = 14.6 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	0.0	0	0	0
	300	8.3	0	0	0
	100	42	0.0	0	0
	30	68	9.0	0.0	0
R2	1000	0.0	0	0	0
	300	6.8	0	0	0
	100	35	0.0	0	0
	30	60	7.8	0.0	0
R3	1000	2.1	0	0	0
	300	13	0.0	0	0
	100	35	0.12	0	0
	30	64	11	0.0	0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 6a. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.66 and Q_p = 73.2 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	24	0	0	0
	300	57	0.0	0	0
	100	75	15	0.0	0
	30	85	52	0.09	0.0
R2	1000	20	0	0	0
	300	51	0.0	0	0
	100	69	15	0.0	0
	30	81	46	0.02	0.0
R3	1000	27	0	0	0
	300	57	0.0	0	0
	100	75	17	0.0	0
	30	84	48	0.28	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 6b. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.93 and Q_p = 73.2 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	24	0.0	0	0.0
	300	57	0.0	0	0.0
	100	75	15	0.0	0.0
	30	85	52	0.83	0.0
R2	1000	19	0.0	0	0
	300	51	0.0	0	0
	100	68	15	0.0	0
	30	81	46	0.63	0.0
R3	1000	26	0.0	0	0
	300	56	1.5	0	0
	100	75	17	0.0	0
	30	84	44	0.66	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 6c. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 2.5 and Q_p = 73.2 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	23	0.0	0	0
	300	56	0.05	0	0
	100	75	16	0.0	0
	30	86	55	1.88	0.0
R2	1000	19	0.0	0	0
	300	52	0.0	0	0
	100	68	13	0.0	0
	30	80	47	0.23	0.0
R3	1000	24	0.0	0	0
	300	58	5.4	0	0
	100	*.**	20	0.0	0
	30	*.**	48	4.8	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: *.** Seepage large, solution not convergent
“0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 7a. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.66 and Q_p = 213 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	60	0.0	0	0
	300	78	17	0	0
	100	86	50	0.0	0
	30	91	73	13	0.0
R2	1000	53	0.0	0	0
	300	73	15	0	0
	100	82	44	0.0	0
	30	*.**	66	14	0.0
R3	1000	63	0.0	0	0
	300	79	19	0	0
	100	87	47	0.0	0
	30	*.**	71	15	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: *.** Seepage large, solution not convergent
"0.0" is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 7b. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.93 and Q_p = 213 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	59	0.0	0	0.0
	300	78	17	0	0.0
	100	86	50	0.0	0.0
	30	*.**	73	15	0.0
R2	1000	53	0.0	0	0
	300	73	14	0	0
	100	83	51	0.0	0.0
	30	*.**	64	14	0.0
R3	1000	63	1.6	0	0
	300	80	19	0	0
	100	*.**	47	0.0	0
	30	90	72	16	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: *.** Seepage large, solution not convergent
"0.0" is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 7c. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 2.5 and Q_p = 213 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	56	0.0	0	0
	300	76	16	0.0	0
	100	*.**	50*	0.48	0
	30	*.**	73	18	0.0
R2	1000	53	0.0	0	0
	300	73	14	0	0
	100	83	46	0.0	0
	30	90	66	15	0.0
R3	1000	*.**	5.1	0	0
	300	*.**	20	0.0	0
	100	*.**	46	3.7	0
	30	91	*.**	18	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: * Steady-state not quite reached (flow out/flow in ≥ 95%)
*.** Seepage large, solution not convergent
"0.0" is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 8a. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.66 and Q_p = 500 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	78	9.6	0	0
	300	*.**	46	0.0	0
	100	92	69	4.5	0
	30	*.**	82*	42	0.0
R2	1000	73	8.2	0	0
	300	85	41	0.0	0
	100	*.**	62	4.5	0
	30	91	77*	35	0.0
R3	1000	*.**	14	0	0
	300	*.**	45	0.0	0
	100	*.**	69	6.9	0
	30	92	82	36	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: * Steady-state not quite reached (flow out/flow in ≥ 95%)
*.** Seepage large, solution not convergent
"0.0" is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 8b. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 1.93 and Q_p = 500 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	*.**	9.5	0	0.0
	300	87	46	0.0	0.0
	100	*.**	69	6.2	0.0
	30	*.**	82	38	0.0
R2	1000	74	7.9	0	0
	300	86	42	0.0	0
	100	*.**	62	5.1	0.0
	30	*.**	76	38	0.0
R3	1000	*.**	14	0	0
	300	90	45	0.0	0
	100	*.**	68	9.0	0.0
	30	*.**	81	35	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: *.** Seepage large, solution not convergent
"0.0" is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

Table 8c. Seepage Percentage as a Function of k_{FC} and $1/\alpha$ for σ = 2.5 and Q_p = 500 mm/yr.

		k_{FC} (m^2)			
Realizations	**$1/\alpha$ (Pa)**	**0.9×10^{-14}**	**0.9×10^{-13}**	**0.9×10^{-12}**	**0.9×10^{-11}**
R1	1000	77	11	0	0
	300	*.**	46	0.0	0
	100	*.**	69	8.4	0.0
	30	*.**	*.**	44	0.02
R2	1000	72 *	8.2	0	0
	300	*.**	43	0.0	0
	100	*.**	62	6.9	0
	30	*.**	*.**	39	0.0
R3	1000	*.**	15	0.0	0
	300	*.**	45*	2.4	0
	100	*.**	*.**	12	0.0
	30	94 *	81	35	0.0

Based on data submitted with this AMR under DTN: LB991101233129.002
NOTE: * Steady-state not quite reached (flow out/flow in ≥ 95%)
*.** Seepage large, solution not convergent.
"0.0" is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases.

In these tables, results indicated by " 0 " without decimal point imply zero seepage as inferred from calculated zero-seepage cases with smaller $1/\alpha$ and smaller k_{FC}. Results indicated by " * " are the large seepage cases where steady-state is reached within 95% due to numerical

convergence problems. For these cases, we expect the calculated values to be within 5% of the steady-state results. For cases, indicated by " *.** ", the seepage percentages are large and the solutions are not convergent, but we can safely consider them to be larger than the neighboring values in the tables.

At Q_p = 5 mm/yr, seepage is essentially zero, except for cases with the very low permeability value of 0.9×10^{-14} m^2. Generally, seepage is larger for lower permeability and lower $1/\alpha$ values. Seepage is also larger for larger σ values as one would expect (Birkholzer et al. 1999, pp. 371, 375; Figures 14, 17). Though the extensive required computations prevent us from obtaining the full geostatistical distribution of seepage, results of three realizations are given for each case, giving an indication of the spread of the results. Note also that the results are all for λ = 0.5 m and, as shown in the next section, they are smaller than the corresponding results for larger λ values.

6.6.2 Seepage for Alternative λ Values

Table 9 gives results for Parameter Set A defined in Section 6.3.5 (see also Figure 1). For the four Q_p values from 14.6 to 500 mm/yr, seepage percentages are given for three realizations of the λ = 1 m case and for five realizations of the λ = 4 m case. Seepage was not calculated for Q_p = 5 mm/yr because, from Table 9, the results are expected to be zero. Appropriate results for λ = 0.5 m from Tables 5 through 8 are included for comparison. Table 10 gives the results for Set B. It is interesting to note that seepage increases with λ, with the geostatistical spread of predictions also increasing with λ. While the results in Tables 9 and 10 provide an understanding of the trends, the best data we have so far (CRWMS M&O 2000a, Section 6.3.2) indicate no spatial correlation, so that λ = 0.5 m, equal to grid size, may be the most appropriate value to use.

Table 9. Seepage Percentage as a Function of Q_p for Alternative λ Values for Set A
(k_{FC} =.0.9 $\times$ 10^{-13} m, $1/\alpha$ = 1000 Pa, σ = 1.93)

		Q_p (mm/yr)			
λ		**14.6**	**73.2**	**213**	**500**
Random (λ = 0.5 m)	R1	0.0	0.0	0.0	9.5
	R2	0	0.0	0.0	7.9
	R3	0	0.0	1.6	14
λ = 1 m	R1a	0.0	0.11	4.5	12
	R2a	0.0	0.0	0.0	7.1
	R3a	0.0	0.0	0.27	7.0
λ = 4 m	R1b	0.0	6.7	14	21
	R2b	0.0	8.3	19	27
	R3b	0.0	0.58	2.3	15
	R4b	0.0	0.0	0.0	7.1
	R5b	2.1	3.9	8.4	36

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases. Three realizations are calculated for each of the λ = 0.5 m and λ = 1 m cases and five realizations re calculated for the λ = 4 m case.

Table 10. Seepage Percentage as a Function of Q_p for Alternative λ Values for Set B
(k_{FC} =.0.9 $\times$ 10^{-12} m^2, $1/\alpha$ = 100 Pa, σ = 1.66)

		Q_p (mm/yr)			
λ		**14.6**	**73.2**	**213**	**500**
Random (λ = 0.5 m)	R1	0	0	0.0	4.5
	R2	0	0	0.0	4.5
	R3	0	0	0.0	6.9
λ = 1 m	R1c	0.0	0.0	1.8	7.4
	R2c	0.0	0.0	0.04	4.3
	R3c	0.0	0.0	0.12	3.6
λ = 4 m	R1d	0.0	0.0	0.0	2.2
	R2d	0.0	1.6	7.7	14
	R3d	0.0	0.0	0.0	1.3
	R4d	0.0	0.0	0.0	6.4
	R5d	0.0	0.01	3.3	10

Based on data submitted with this AMR under DTN: LB991101233129.002.
NOTE: “0.0” is a calculated value and "0" indicates seepage is inferred to be zero from results of neighboring cases. Three realizations are calculated for each of the λ = 0.5 m and λ = 1 m cases and five realizations are calculated for the λ = 4 m case.

6.6.3 Sensitivity to n value

As discussed in Section 6.3.4, we have used van Genuchten n = 2.7 in all the calculations. To study the impact of using n = 2.55, we calculate two cases with parameter Sets A and B, respectively, for Q_p = 500 mm/yr and realization R1. The results are shown in Table 11, which indicates that the impact can be neglected.

Table 11. Sensitivity to n Value. Seepage is given as percentage for Q_p = 500 mm/yr and realization R1

Parameter Set A (but varying $1/\alpha$)

$1/\alpha$ (Pa)	**1000**	**300**	**100**	**30**
n = 2.7	9.5	46	69	82
n = 2.55	10	47	69	82

Parameter Set B (but varying $1/\alpha$)

$1/\alpha$ (Pa)	**1000**	**300**	**100**	**30**
n = 2.7	0.0	0.0	4.5	42
n = 2.55	0.0	0.0	4.8	42

Based on data submitted with this AMR under DTN: LB991101233129.002.

6.6.4 Sensitivity to correlated α parameter.

The simulations presented thus far used a constant value for van Genuchten α parameter over the permeability heterogeneous field for each simulation. To study the alternative approach based on Leverett scaling law (Leverett 1941, p. 159), we performed calculations by setting α to be proportional to the square root of k_{FC}, with the reference values corresponding to parameter Sets A and B respectively (see Section 6.3.5). Figure 3 shows the seepage percentage versus the percolation rate for realizations R1 and R3, and parameter Set A (lower two curves in the figures). They also show results for additional cases where all parameters are the same except the reference α value is changed. Similarly Figure 4 shows the results for parameter Set B with variants as indicated in the figures.

It is interesting to note that the correlated α condition yields higher seepage by 0–10%. We propose that these figures can be used to provide adjustments to seepage predictions when one wants to use the correlated α condition.

6.6.5 Effects of Drift Degradation

Table 12 presents the seepage percentages for the three realizations (R1, R2 and R3) with drift degradation modes as defined in Section 6.4 (Figure 2) and compares them with the no-degradation case. Only the Q_p = 500 mm/yr cases are shown. Additional calculations were made for Q_p = 73.2 mm/yr and the results for all cases in the Table are zero.

Table 12. Seepage Percentage (%) for Alternative Drift Degradation Scenarios, for Q_p = 500 mm/yr and Parameter Set B.

Condition	Seepage Percentage		
	R1	R2	R3
No-degradation case (Set B)	4.5	4.5	6.9
1-m rock fall from crown of drift	4.5	4.7	7.0
1-m rock fall from springline of drift	4.5	4.5	7.4
3-m rock failure in drift roof	5.8	8.6	10
3–m rock failure case: calc. from Set B non-degraded case	5.8	5.9	9.0

Based on data submitted with this AMR under DTN: LB991101233129.002.

The results show that the effect of a single rock fall is not significant for seepage. A deeper rock failure in the drift roof increases seepage. Now we propose an approach to calculate drift degradation effects from no-degradation results from Tables 4–8. The approach is based on the fact that λ (0.5 m) is much smaller than the drift diameter and that seepage is due to flow channeling and local ponding from medium heterogeneity, and not due to Philip's model of homogeneous flow exclusion by the drift (Philip et al. 1989, pp. 17–20). The latter model would

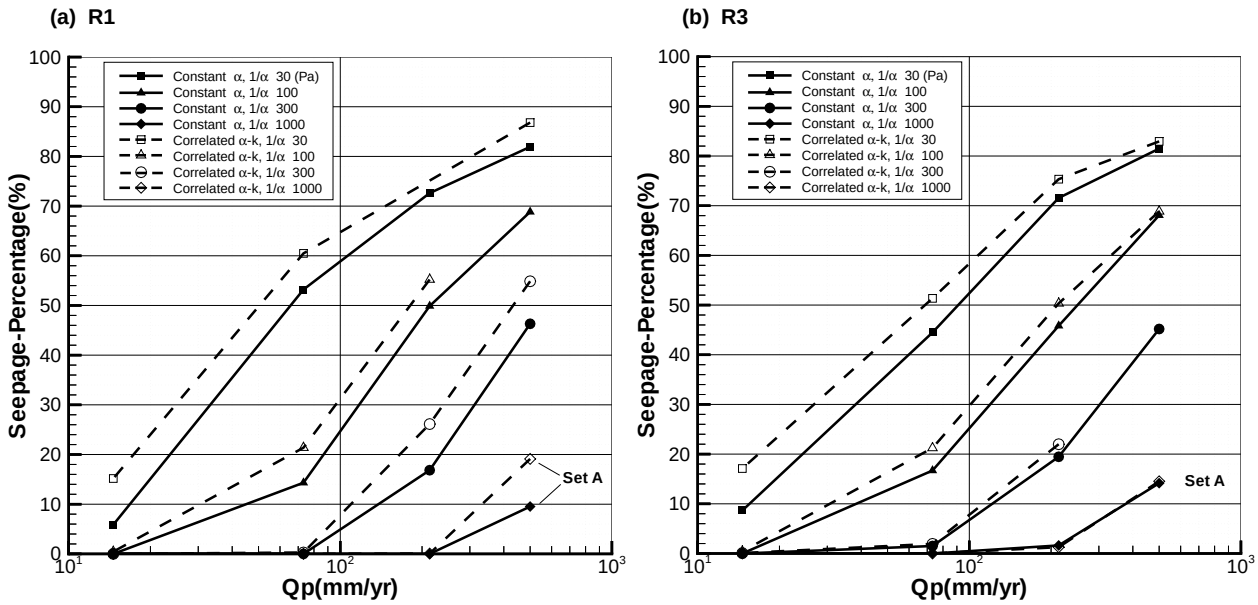


Figure 3. Seepage Percentage as a Function of Percolation Flux for Uncorrelated and Correlated α-k_{FC} Cases. Parameter Set A is used (lower two curves). Variant cases were obtained by varying the mean or reference $1/\alpha$ values while keeping all other parameters the same. Realizations R1 and R3 are used in (a) and (b), respectively.

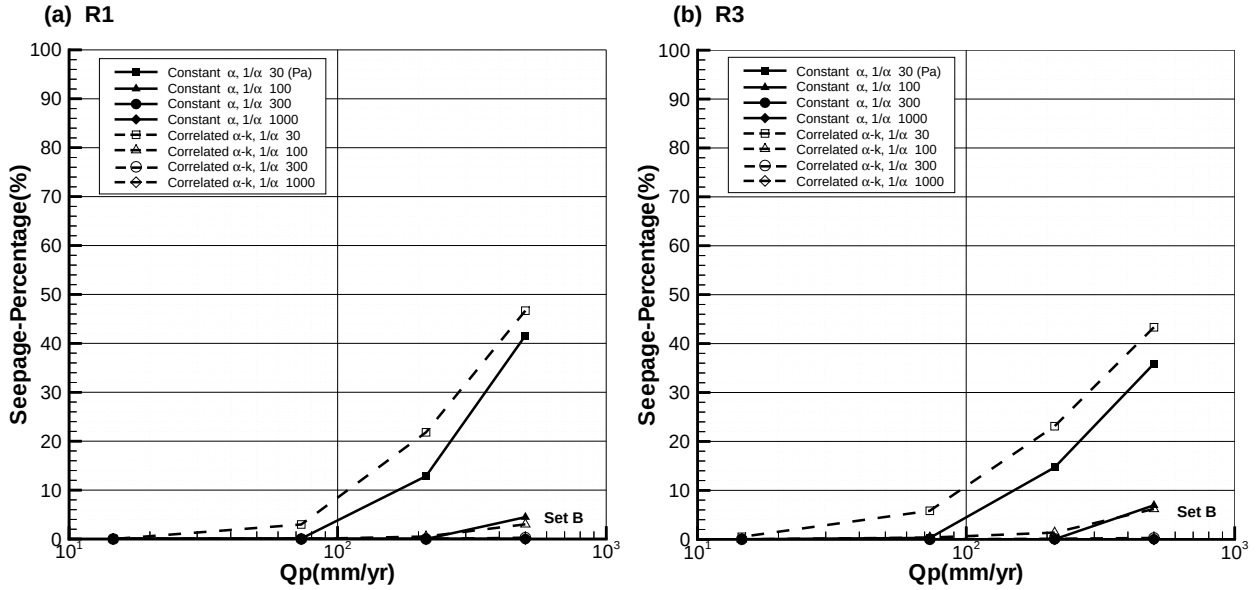


Figure 4. Seepage Percentage as a Function of Percolation Flux for Uncorrelated and Correlated α-k_{FC} Cases. Parameter Set B is used (lower two curves). Variant cases were obtained by varying the mean or reference $1/\alpha$ values while keeping all other parameters the same. Realizations R1 and R3 are used in (a) and (b), respectively

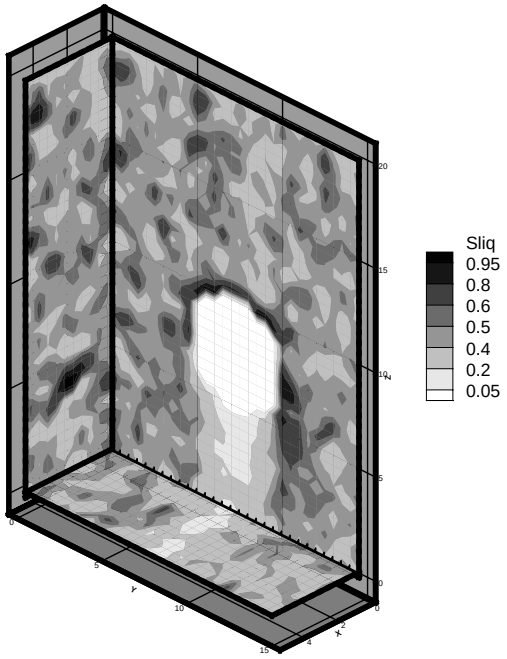
imply that a drift shape like the deep failure case (Figure 2, lower right) with a sharper ceiling will allow an easier flow around the drift and hence less seepage (Philip 1989, pp. 1531–1533), contrary to the results in Table 12. Heterogeneity causes flow channeling and local ponding, and the ponding probability is shown to be correlated to seepage by Birkholzer et al. (1999, p. 371, Figure 14). For a given realization the ponding probability for the medium is the same and seepage is proportional to the up-stream area of drift wall which may encounter these channels and local ponding locations.

For the case of 3–m rock failure, the area of the original non-degraded drift wall is $\pi(5.5)\cdot(5.23)/2\ m^2 = 45.2\ m^2$, where 5.5 and 5.23 are the drift diameter and drift length in meters, respectively, and the division by 2 indicates that we only take the upper half surface of the drift wall. Now with the 3–m rock failure, the added rock surface area is estimated to be $(3.5)\times1+(9\times0.5)\times1+(11\times0.25)\times2\ m^2 = 13.5\ m^2$, where the thickness (along drift axis) of the rock failure is 1 m. The estimation can be understood by examining the bottom right part of Figure 2 (YMP-LBNL-CFT-2, pp. 107–108). The additional surface area on the left side of the cavity formed by rock failure in the drift ceiling is 3.5 m high and 1 m thick along the axis of the drift. The second term $9 \times 0.5 \times 1\ m^2$ represents the extra area due to the step structure on the right side of the cavity. The third term represents the areas of the cavity in the two planes normal to the drift axis (see Figure 2: the area of the step-structure cavity above the broken line), except for the part closest to the original curved surface of the drift. The latter would compensate for the curved drift area no longer present because of the cavity.

Now if we scale the seepage value for the no-degradation case (B) by the factor (1+13.5/45.2), we obtain 5.85, 5.85 and 8.97 for the three realizations. These are indicated in Table 12 and compare with the numerical results very well for the first and third realizations. This approach may provide an easy way to estimate the impact of drift degradation, once the degraded shape is found from mechanical modeling. It deserves further consideration.

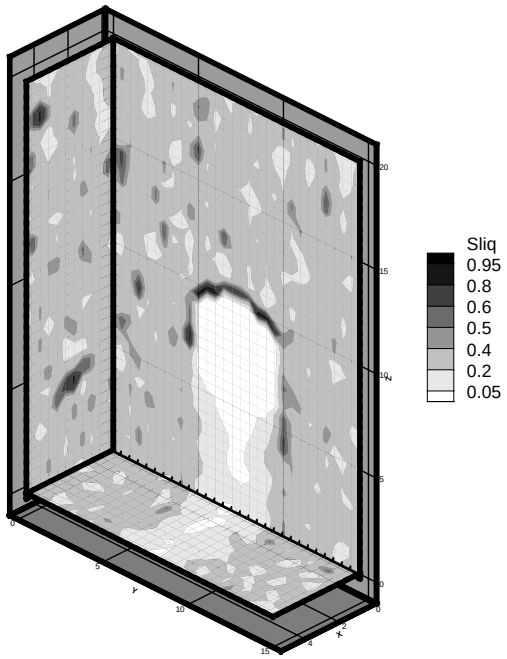
6.6.6 Drainage Below the Drift

The drift provides a barrier to downward percolation flux. Water moves around the drift or seeps into it. For the case that the water seeped into the drift is gone, then directly below the drift is a shadow of dryer zone. This dryer zone will decrease in width with depth below the drift. The vertical extent of the shadow zone depends on both k_{FC} and $1/\alpha$ values (Philip et al. 1989, pp. 16-28). Figures 5 and 6 illustrate the saturation profiles one drift diameter below the drift for parameter Sets A and B, with Q_p=500 mm/yr. The figures clearly show the shadow effect. Philip et al. (1989, pp. 21–23) also provide an approximate analytic solution to define the shadow zone that may be useful for practical applications.



Based on data submitted with this AMR under DTN: LB991101233129.001.

Figure 5. Saturation Profiles Around a Drift with Parameter Set A.



Based on data submitted with this AMR under DTN: LB991101233129.001

Figure 6. Saturation Profiles Around a Drift with Parameter Set B.

6.6.7 Effects of Episodic Percolation

Episodic percolation is simulated for a drift without degradation. Table 13 shows the seepage results if, every year, the percolation flux over the year is concentrated in the first 2 months representing a wet period and then zero flux occurs for the remaining 10 months. These results are compared with the case where the flux is constant over the whole year. In both alternatives, the average flux over the year is 73.2 mm/yr. The seepage percentage at the end of the wet period (after the first 2 months) for the episodic scenario stabilizes very quickly after the first year. Calculations were performed for Parameter Sets A and B and also for an additional parameter set with Set A properties, except that $1/\alpha$ is reduced to 100 Pa to ensure some seepage even in the constant flux case. In all cases, the seepage percentages for episodic scenarios are higher than those of the constant seepage scenario. Note that the percolation flux in the two wet months is 6×73.2 mm/yr, or 439.2 mm/yr. In Tables 7 and 8, calculated seepage percentages for Q_p = 213 and 500 mm/yr can be found, and, if we interpolate between these cases to obtain the seepage percentages for 439.2 mm/yr, they are found to be approximately equal to the seepage percentage for the episodic scenario. It appears that for our sets of parameters, the memory effect between percolation pulses separated by 10 months is small and each pulse can be treated independently at the high percolation rate of the wet period. The seepage rate over this period increases with time and its peak value at the end of the two wet months may be roughly estimated by interpolation from Tables 4–8 or calculated directly.

Table 13. Effects of Episodic Percolation. Q_p = 73.2 mm/yr

Parameters	Seepage % at end of wet period*	Seepage % if flux is constant over the year
Parameter Set A	6.3	0
Parameter Set B	2.5	0
Parameter Set A, but with $1/\alpha$ = 100 Pa	67	14

Based on data submitted with this AMR under DTN: LB991101233129.002.

NOTE: *This value is the seepage rate at the end of the wet period divided by the percolation flux of the wet period, which is 6 times the average flux rate. For each year, the total percolation is all in the first 2 months and no flux in the remaining 10 months. Results are the same every year after the first year. Heterogeneous field used is Realization R1.

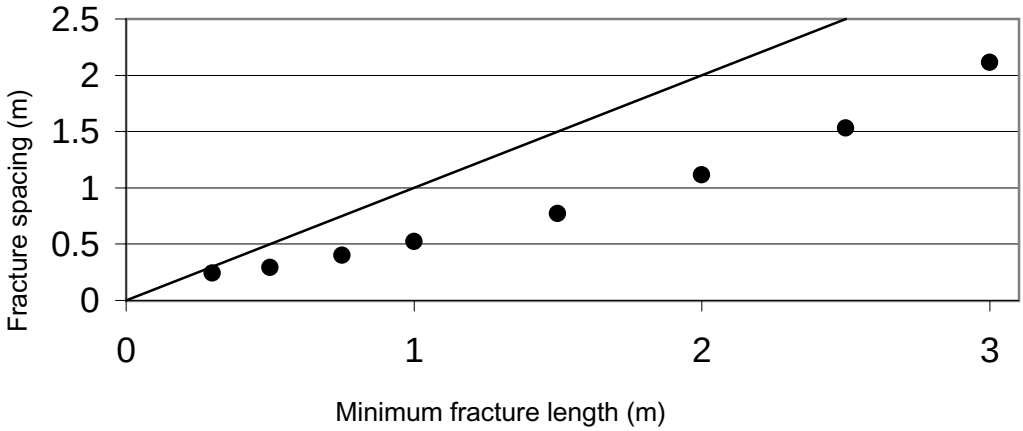
The results show the importance of the appropriate episodic percolation flux profile at the repository level, with all the possible flow dissipation and diversion in the lithostratigraphic units above.

6.7 ALTERNATIVE CONCEPTUAL MODELS AND SENSITIVITY ANALYSIS

Sensitivity analyses are part of the scope of this AMR and are presented in the above subsections (6.6.2 through 6.6.7). The main alternative conceptual model is the discrete fracture-network model (DFNM). This is thoroughly discussed by Finsterle and Trautz (CRWMS M&O 2000a, p. 68) and will not be repeated here. Note further that the rock in the ESF is highly fractured and the fractures are well connected, so that the fracture continuum model is a reasonable one. This is

shown in Figure 7, in which fracture data from the ESF main drift from Station 27+20 to 37+80 (see Table 2 for DTNs) were plotted as the average fracture spacing (calculated using the software routine frac_calc V1.1) against the minimum fracture length for groups of fractures that contain all fractures longer or equal to the minimum length selected (YMP-LBNL-DSM-MC-1, pp. 40–42). The figure shows that the spacing is consistently less than fracture lengths for all classes of fracture grouping. Further, Kicker in CRWMS M&O (2000b, p. 26, Fig. 5) shows that the major fracture sets in Tptpmn unit are in three almost orthogonal planes with strike/dip angles given by 131/84, 209/83, and 329/09. The result is thus a well-connected fracture network that can be represented by a fracture continuum. Note, however, that the fracture continuum is very heterogeneous (see Section 6.3.3), so that flow through the fracture continuum is highly channelized (Birkholzer and Tsang 1997, pp. 2229–2231).

As explained in Birkholzer et al. (1999, pp. 358–384), seepage into drift under conditions discussed in the AMR is controlled by heterogeneity-induced channeling and local ponding. It occurs much earlier than results of the conceptual model of a drift in homogeneous constant-property medium (Philip et al. 1989, pp. 17–21). In other words, Philip et al. would predict seepage to occur at a threshold that is orders of magnitude larger. In this sense, Philip's approach is not relevant. Thus, Philip's boundary layer flow regime near the drift crown (Philip et al. 1989, p. 21, Figure 1) should not be used to define the required grid size. Rather the grid size should be chosen based on the heterogeneity spatial correlation scale λ, which controls the flow channel width and the scale of local ponding. The use of grid size of 0.5 m equal to λ is probably sufficient to study the relevant physics in our problem. The sensitivity of seepage results on grid size was calculated for grid sizes 0.5 m and 0.25 m (YMP-LBNL-CFT-GL-1, pp. 86–89). The change due to the grid size is of the same order as changes due to the different realizations, with an increase of 0-3% for the finer mesh for the case calculated.



Based on data from DTN: GS971108314224.025, GS960708314224.008 and GS960808314224.011

NOTE: Straight line indicates a 1:1 correspondence

Figure 7. Average Fracture Spacing for Topopah Spring Middle Nonlithophysal Hydrogeologic Unit in the ESF from Stations 27+20 to 37+80.

The drift seepage problem involves the accumulation of unsaturated flow at the location near the drift wall, until the local saturation is large, and capillary suction is small. Then seepage into drift occurs. This problem is intrinsically a 3D problem, because flow accumulation at a location in 2D could easily disappear if it is allowed to flow away in the third dimension. Hence 2D models would overestimate seepage.

The present AMR considers alternative spatial correlation lengths, using a spherical correlation structure and a gaussian field. There have been suggestions to use alternative geostatistical methods, such as nonparametric representation of the heterogeneity field and multiple-scale correlation structure. However for a specific problem with a particular scale of a drift, such complications are not needed so long as the parameters used are appropriate to this scale. The reason is that structures much smaller than the drift diameter can be approximated by an average property parameter, except near the drift wall (see below for the "surface needle" effect). Structures with correlation lengths much larger than the drift diameter should be handled deterministically for each case of occurrence, and can probably not be handled statistically.

What is of more interest and importance is the question of the appropriate parameter values to be used in the seepage-prediction model. This depends on an interplay between seepage-model grid-element scale, calibration-model grid-element scale, and field data support scale. We have shown in this AMR that the air (fracture) permeability without excavation effects seems to have quite consistent values when the data support scale ranges from 0.3 to ~20 m. However we have no similar information on $1/\alpha$ and other parameters. Further study of the interplay among the three scales for the purpose of deriving appropriate parameter values for predictive modeling would be very useful to enhance confidence in these values. However, one would expect they will still be in the ranges shown in Figure 1.

One issue of great concern that may have significant negative impact on seepage is the “surface needle” effect. This refers to the possibility that there are 1D pathways from within the rock above the drift to the drift ceiling, from which there are no effective lateral intersecting fractures to divert water away. Then these 1D pathways or needles will act as special conduits through which seepage can occur. The increase in seepage due to their presence could be very significant and needs to be carefully evaluated. One example of such “needles” is the rock bolts used to stabilize the drift roof. Whether rock bolts would form such special seepage pathways depends on the leakage around the bolts and how it develops as the bolt cement degrades and the bolt corrodes with time. This is an important issue. A very preliminary estimate has been made on the needles effect (YMP-LBNL-CFT-GL-1, pp. 71-72). For parameter Set A, but with λ=2m, seepage increases are calculated as a function of needle length and the number of needles in the section. With the needle length, the seepage increase stabilizes to a constant value after the length exceeds 0.15-0.25 m. For a 16.5-m section of the drift (approximately three waste package lengths), the seepage increase is found to be about 3% when there are three needles present in the drift ceiling; about 40% when there are 33 needles, and 70% when there are 330 needles.

7. CONCLUSIONS

The present AMR is based on the Seepage Calibration Model AMR (CRWMS M&O 2000a) and Birkholzer et al. (1999). By reviewing available information (Section 6.3 and 6.4), we selected a range of parameters and possible scenarios (Figure 1) on which seepage calculations were conducted. Results are tabulated (Tables 4–13) that show the impact of various factors on seepage and provide data for PA to develop probability distributions (DTN: LB991101233129.002). Generally, seepage is calculated to be larger for smaller k_{FC}, smaller $1/\alpha$ and larger Q_p values (Tables 4–8). It is insensitive to n parameter (Table 11). To allow local α values to be correlated with local k_{FC} (proportional to the square root of k_{FC}) increases seepage by 0–10% as compared with a constant α case. Results in this AMR are based on a review of available in-situ field results appropriate to the Tptpmn geological unit. As more data from this unit and from neighboring units (where the potential repository resides) are obtained in field measurements, parameter values with their uncertainties and probability weightings should be developed and then seepage predictions from tables in this AMR can be used in PA to obtain the best estimates (with uncertainty ranges) for Yucca Mountain.

Uncertainty associated with geostatistics is evaluated with calculations of three realizations for each case (five for a case of large spatial correlation length) and results are in Tables 4 through 8 and Table 10. In general, to establish geostatistical probability requires many more realizations than three, but the extensive amount of simulations in this AMR prevents us from doing more realizations. Nevertheless the spread of results from the three should give an indication of geostatistical distribution. In general, the spread is expected to be larger for large λ and more limited if λ is much smaller than drift diameter. Use of the multi-realization results requires care based on this discussion.

The present effort demonstrated that the impact of mechanical effects can be evaluated (Sections 6.4 and 6.6.5). This is based on the recent AMR by Kicker (CRWMS M&O 2000b) and the Brekke et al.'s Panel Report (Brekke et al. 1999), which includes Hart and Kaiser's scoping analyses. These reports also considered thermal and seismic effects on drift degradation in a schematic way. As further mechanical studies are made on drift degradation, seepage calculations should follow to update the assessment of their impact. A possible approach is proposed in this AMR to calculate seepage for degraded drift case from that of no-degradation case. The preliminary results show promise so that the approach deserves further development.

As mentioned in Section 1, no analysis on the impact of coupled thermal-hydrological-chemical effects on seepage has yet been made, since such modeling results are not formally available at the time of this AMR and hence not citable.

In summary, the present AMR identifies the following significant issues:

1. Drift degradation – disturbed zone scenario and extended failure scenario (Section 6.6.5)

2. Episodic percolation flux (Section 6.6.7).

3. "Surface Needles" effect; in particular, impact of rock bolts in the long time frame (Section 6.7)

4. Effects of property change on seepage due to coupled thermal-hydrological-chemical processes.

These issues need to be addressed in performance assessment.

This AMR may be affected by technical product input 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 DIRS database.

Among the input data relied upon, the only essential data value used is the drift diameter of 5.5 m. The results of this AMR should not change if the verification of this value results in a change in diameter of less than 10%. In general, smaller diameter cases would result in less seepage or less conservative results. The only other relied upon data are the permeability data that are used to establish a range of values for the simulations. These permeability data could change by an order of magnitude and still be in the selected range and not affect the results of this AMR. In general, the verification and confirmation of these permeability data should not affect the results of this AMR.

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9. ATTACHMENTS

Attachment I - Document Input Reference System

Attachment II - Model Input and Output Files

Attachment III – Software Routine Code Listing

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ATTACHMENT I—DOCUMENT INPUT REFERENCE SYSTEM

DIRS as of the issue date of this AMR. Refer to the DIRS database for the current status of these inputs.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SYSTEM

JCH 4/21/00

1. Document Identifier No./Rev.: MDL-NBS-HS-000002/Rev. 00	Change: N/A	Title: Seepage Models for PA Including Drift Collapse

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
1	DTN: GS960708314224.008. Provisional Results: Geotechnical Data for Station 30+00 to Station 35+00, Main Drift of the ESF. Submittal date: 08/05/1996.	Fracture Type, Location, Strike, Dip, Length above, and length below for each fracture	N/A-Not critical	4.1 6.7	Fracture type (location, strike, dip, length) Sta. 30+00 to 35+00. Corrabative use only.	N/A	N/A	N/A	N/A
2	DTN: GS960808314224.011. Provisional Results: Geotechnical Data for Station 35+00 to Station 40+00, Main Drift of the ESF. Submittal date: 08/29/1996.	Fracture Type, Location, Strike, Dip, Length above, and length below for each fracture	N/A-Not Critical	4.1 6.7	Fracture type (location, strike, dip, length) Sta. 35+00 to 40+00. Corrabative use only.	N/A	N/A	N/A	N/A
3	DTN: GS971108314224.025. Revision 1 of Detailed Line Survey Data, Station 26+00 to Station 30+00, North Ramp and Main Drift, Exploratory Studies Facility. Submittal date: 12/03/1997.	Fracture Type, Location, Strike, Dip, Length above, and length below for each fracture	N/A-Not critical	4.1 6.7	Fracture type (location, strike, dip, length) Sta. 26+00 to 30+00. Corrabative use only.	N/A	N/A	N/A	N/A

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1. Document Identifier No./Rev.:	Change:	Title:
MDL-NBS-HS-000002/Rev. 00	N/A	Seepage Models for PA Including Drift Collapse

Input Document							8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-confirmed
2a									
4	DTN: LB960500834244.001. Hydrological Characterization of the Single Heater Test Area in ESF. Submittal date: 08/23/1996.	Entire	TBV-3247	4.1 6	Air injection and permeability data-SHT area	1	N/A	N/A	✓
5	DTN: LB970600123142.001. Ambient Characterization of The ESF Drift Scale Test Area by Field Air Permeability Measurements. Submittal date: 06/13/1997.	Entire	TBV-3248	4.1 6	Air injection and permeability data-DST area	1	N/A	N/A	✓
6	DTN: LB980001233124.002. Air Permeability Testing in Niches 3566 and 3650. Submittal date: 04/23/1998.	S98131_002	TBV-3094	4.1 6	Post-excavation air permeability data from niche 3650	1	N/A	N/A	✓
7	DTN: LB990861233129.001. Drift Scale Calibrated 1-D Property Set, FY99. Submittal date: 08/06/1999.	1d_driftscale_basecase.xls	N/A-Not Critical	4.1 6	Drift-Scale Calibrated Fracture and Matrix Property sets. (Used for comparison purposes only).	N/A	N/A	N/A	N/A
8	DTN: LB997141233129.001. Calibrated Basecase Infiltration 1-D Parameter Set for the UZ Flow and Transport Model, FY99. Submittal date: 07/21/1999.	1dbasecaseR1wodis.xls	N/A-Not Critical	4.1 6	Mountain-scale, calibrated parameter sets for base-case infiltration. (Used for comparison purposes only).	N/A	N/A	N/A	N/A

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Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
9	DTN: SN9908T0872799.004. Tabulated In-Drift Geometric and Thermal Properties Used in Drift-Scale Models for TSPA-SR (Total System Performance Assessment-Site Recommendation). Submittal date: 08/30/1999. Initial use.	indriftgeom_rev01.doc	TBV-3471	4.1 6.3.1	Drift diameter, waste package length and spacing	1	✓	N/A	N/A
10	Ahlers, C.F.; Finsterle, S. and Bodvarsson, G.S. 1999. "Characterization and Prediction of Subsurface Pneumatic Response at Yucca Mountain, Nevada." *Journal of Contaminant Hydrology, 38* (1–3), 47–68. Amsterdam, The Netherlands: Elsevier Science Publishers. TIC: 244160.	p. 66	N/A-Reference only	6.3.2	Air permeabilities from pneumatic data analysis.	N/A	N/A	N/A	N/A

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Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
11.	Bandurraga, T.M. and Bodvarsson, G.S. 1999. "Calibrating Hydrogeologic Parameters for the 3-D Site-Scale Unsaturated Zone Model of Yucca Mountain, Nevada." *Journal of Contaminant Hydrology, 38* (1–3), 25–46. Amsterdam, The Netherlands: Elsevier Science Publishers. TIC: 244160.	p. 33	N/A-Reference only	6.3.4	Study varying van Genuchten *n*.	N/A	N/A	N/A	N/A
12	Birkholzer, J.; Li, G.; Tsang, C.F.; and Tsang, Y. 1999. "Modeling Studies and Analysis of Seepage into Drifts at Yucca Mountain." *Journal of Contaminant Hydrology, 38* (1–3), 349–384. Amsterdam, The Netherlands: Elsevier Science Publishers. TIC: 244160.	Entire	N/A-Reference only	4.1 5 6.1 6.2 6.3 6.3.1 6.3.2, 6.3.3 6.3.4 6.3.5 6.6.1 6.6.5 6.7 7	Modeling approach	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SYSTEM

JEH 4/21/00

1. Document Identifier No./Rev.: MDL-NBS-HS-000002/Rev. 00	Change: N/A	Title: Seepage Models for PA Including Drift Collapse

Input Document							8. TBV Due To		
2a	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-confirmed
B	Birkholzer, J. and Tsang, C.F. 1997. "Solute Channeling in Unsaturated Heterogeneous Porous Media." *Water Resources Research, 33* (10), 2221–2238. Washington, D.C.: American Geophysical Union. TIC: 235675.	pp. 2221–2224 2229–2231	N/A-Reference only	6.2 6.7	Unsaturated zone flow channeling effect.	N/A	N/A	N/A	N/A
14	Brekke, T.L.; Cording, E.J.; Daemen, J.; Hart, R.D.; Hudson, J.A.; Kaiser, P.K.; and Pelizza, S. 1999. "Panel Report on the Drift Stability Workshop." *Drift Stability Workshop, Las Vegas, Nevada, December 9–11, 1998.* Las Vegas, Nevada: YMSCP. ACC: MOL.19990331.0102.	pp. E3–E29 D12–D14	N/A - Reference only	6.4.1 6.4.2, 6.4.3 7	Drift degradation scenario	N/A	N/A	N/A	N/A

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DOCUMENT INPUT REFERENCE SYSTEM

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Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
15	CRWMS M&O (Civilian Radioactive Waste Management System, Management & Operating Contractor) 1999a. Analysis and Modeling Report Development Plan (DP) for U0075 "*Seepage Models for PA including Drift Collapse & Drainage, Rev. 00.*" TDP-NBS-HS-000009. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990830.0384.	Entire	N/A - Reference only	1 2	Plan	N/A	N/A	N/A	N/A
16	CRWMS M&O 1999b. *M&O Site Investigations.* Activity Evaluation. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990317.0330.	Entire	N/A - Reference only	2	Activity Evaluation	N/A	N/A	N/A	N/A
17	CRWMS M&O 1999c. *M&O Site Investigations.* Activity Evaluation. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0224.	Entire	N/A - Reference only	2	Activity Evaluation	N/A	N/A	N/A	N/A

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JEH 4/21/00

1. Document Identifier No./Rev.:	Change:	Title:
MDL-NBS-HS-000002/Rev. 00	N/A	Seepage Models for PA Including Drift Collapse

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
18	CRWMS M&O 2000a. *Seepage Calibration Model and Seepage Testing Data.* MDL-NBS-HS-000004. Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0521.	Entire	N/A-Reference only	3 5 6.2 6.3.2 6.3.3 6.3.4 6.3.5 6.6.2 6.7 7	Parameters	N/A	N/A	N/A	N/A
19	CRWMS M&O 2000b. *Drift Degradation Analysis.* ANL-EBS-MD-000027. Rev. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000107.0328.	Entire pp. 48, 53 56, 60 26 Entire	N/A - Reference only	4.1 6.4.2 6.4.3 6.7 7	Drift degradation scenario	N/A	N/A	N/A	N/A

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JEH 4/24/00

1. Document Identifier No./Rev.: MDL-NBS-HS-000002/Rev. 00	Change: N/A	Title: Seepage Models for PA Including Drift Collapse

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
20	Dyer, J.R. 1999. "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." Letter from J.R. Dyer (DOE) to D.R. Wilkins (CRWMS M&O), September 9, 1999, OL&RC:SB-1714, with enclosure, "Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01)." ACC: MOL.19990910.0079.	Subpart B, Section 15 Subpart B, Section 21(c) (l) (ii) Subpart E, Section 114 (a)	N/A Reference only	4.2	Interim Guidance	N/A	N/A	N/A	N/A
21.	Finsterle, S. 1997. *ITOUGH2 Command Reference, Version 3.1*. LBNL-40041. Berkeley, California: Lawrence Berkeley National Laboratory. ACC: MOL.19981008.0015.	p. 244`	N/A-Reference only	5	Genuchten-Mualem model	N/A	N/A	N/A	N/A

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Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
22	LeCain, G.D. 1997. *Air-Injection Testing in Vertical Boreholes in Welded and Nonwelded Tuff, Yucca Mountain, Nevada.* Water-Resources Investigations Report 96-4262. Denver, Colorado: U.S. Geological Survey. TIC: 233455.	pp. 2, 11–14	N/A-Reference only	6.3.2	Air permeability	N/A	N/A	N/A	N/A
23	Leverett, M.C. 1941. "Capillary Behavior in Porous Solids." *AIME Transactions, Tulsa Meeting, October 1940, 142*, 152–169. New York, New York: American Institute of Mining, Metallurgical, and Petroleum Engineers. TIC: 240680.	p. 159	N/A-Reference only	5 6.3.4	Permeability-α correlation	N/A	N/A	N/A	N/A
24	Luckner, L.; van Genuchten, M.T.; and Nielsen, D.R. 1989. "A Consistent Set of Parametric Models for the Two-Phase Flow of Immiscible Fluids in the Subsurface." *Water Resources Research*, 25 (10), 2187–2193. Washington, D.C.: American Geophysical Union. TIC: 224845.	pp. 2191-2192	N/A-Reference only	5 6.2	Genuchten-Mualem Model	N/A	N/A	N/A	N/A

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1. Document Identifier No./Rev.:	Change:	Title:
MDL-NBS-HS-000002/Rev. 00	N/A	Seepage Models for PA Including Drift Collapse

Input Document							8. TBV Due To		
2a	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-confirmed
25.	Philip, J.R. 1989. "Asymptotic Solutions for the Seepage Exclusion Problem for Elliptic-Cylindrical, Spheroidal, and Strip-and Disc-Shaped Cavities." *Water Resources Research, 25* (7), 1531–540. Washington, D.C.: American Geophysical Union. TIC: 239858.	pp. 1531–1533	N/A-Reference only	6.6.5	Seepage exclusion for elliptical drift	N/A	N/A	N/A	N/A
26.	Philip, J.R.; Knight, J.H. and Waechter, R.T. 1989. "Unsaturated Seepage and Subterranean Holes: Conspectus, and Exclusion Problem for Cylindrical Cavities." *Water Resources Research, 25* (1), 16–28. Washington, D.C.: American Geophysical Union. TIC: 239117.	Entire	N/A-Reference only	6.2 6.3 6.6.4 6.6.5 6.6.6 6.7	Flow around subsurface opening	N/A	N/A	N/A	N/A
27.	Richards, L.H. 1931. "Capillary Conduction of Liquids through Porous Mediums." *Physics, 1*, 318–333. Washington, D.C.: American Physical Society. TIC: 225383.	Entire	N/A-Reference only	5 6.2	Richard's Equation	N/A	N/A	N/A	N/A

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1. Document Identifier No./Rev.: MDL-NBS-HS-000002/Rev. 00	Change: N/A	Title: Seepage Models for PA Including Drift Collapse

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
28.	Ritcey, A.C. and Wu, Y.S. 1999. "Evaluation of the Effect of Future Climate Change on the Distribution and Movement of Moisture." *Journal of Contaminant Hydrology, 38* (1–3), 257–280. Amsterdam, The Netherlands: Elsevier Science Publishers. TIC: 244160.	p. 262	N/A-Reference only	6.3.6	Percolation fluxes at repository level	N/A	N/A	N/A	N/A
29.	Tsang, Y.W. and Birkholzer, J.T. 1999. "Predictions and Observations of the Thermal-Hydrological Conditions in the Single Heater Test." *Journal of Contaminant Hydrology, 38* (1–3), 385–425. Amsterdam, The Netherlands: Elsevier Science Publishers. TIC: 244160.	p. 393	N/A-Reference only	4.1 6.3.2	Air permeability	N/A	N/A	N/A	N/A
30	van Genuchten, M. 1980. "A Closed-Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils." *Soil Science Society of America Journal, 44* (5), 892–898. Madison, Wisconsin: Soil Science Society of America. TIC: 217327.	Entire	N/A-Reference only	5	van Genuchten model	N/A	N/A	N/A	N/A

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2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
31.	Wang, J.S.Y.; Trautz, R.C.; Cook, P.J.; Finsterle, S.; James, A.L.; and Birkholzer, J. 1999. "Field Tests and Model Analysis of Seepage into Drift." *Journal of Contaminant Hydrology, 38* (1–3), 323–348. Amsterdam, The Netherlands: Elsevier Science Publishers. TIC: 244160.	332-338 328 325	N/A-Reference only	6.2 6.3.2 6.4.1	Air permeability	N/A	N/A	N/A	N/A
32	Wemheuer, R.F. 1999. "First Issue of FY00 NEPO QAP-2-0 Activity Evaluations." Interoffice correspondence from R.F. Wemheuer (CRWMS M&O) to R.A. Morgan (CRWMS M&O), October 1, 1999, LV.NEPO.RTPS.TAG.10/99-155, with attachments. Activity Evaluation for Work Package #1401213UM1. ACC: MOL.19991028.0162.	WP1401213 UM1	N/A-Reference only	2	Activity Evaluation	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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1. Document Identifier No./Rev.: MDL-NBS-HS-000002/Rev. 00	Change: N/A	Title: Seepage Models for PA Including Drift Collapse

Input Document							8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-confirmed
2a									
33.	Wu, Y.S.; Haukwa, C.; and Bodvarsson, G.S. 1999. "A Site-Scale Model for Fluid and Heat Flow in the Unsaturated Zone of Yucca Mountain, Nevada." *Journal of Contaminant Hydrology, 38* (1–3), 185–216. Amsterdam, Netherlands: Elsevier Science Publishers. TIC: 244160.	p. 210	N/A-Reference only	6.3.6	Parameters	N/A	N/A	N/A	N/A
34.	Software Code: AMESH V1.0. CSCI: 10045-1.0-00.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6.3	General software use	N/A	N/A	N/A	N/A
35.	Software Code: GSLIB V2.0, Module SISIM V2.0. STN: 10098-2.0MSISIMV2.0-00.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6.3	General software use	N/A	N/A	N/A	N/A
36.	Software Code: ITOUGH2 V3.2_drift. STN: 10055-3.2_DRIFT-00.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6.3	General software use	N/A	N/A	N/A	N/A
37.	Macro/Routine: Frac_calc V1.1. ACC: MOL.19990903.0032.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6.3	General software use	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SYSTEM

JH 4/21/00

1. Document Identifier No./Rev.: MDL-NBS-HS-000002/Rev. 00	Change: N/A	Title: Seepage Models for PA Including Drift Collapse

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2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
38.	Macro/Routine: Read_TDB V1.0. ACC: MOL.19990903.0031.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6.7	General software use	N/A	N/A	N/A	N/A
39.	Macro/Routine: Meshbd.f V1.0. ACC: MOL.20000217.0297.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
40.	Macro/Routine: mininipresf.f V1.0. ACC: MOL20000217.0298.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
41.	Macro/Routine: mddf.f V1.0. ACC: MOL.20000217.0299.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
42.	Macro/Routine: mk_gener.f V1.0. ACC: MOL.20000217.0300.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
43.	Macro/Routine: mk_scale_k.f V1.0. ACC: MOL.20000217.0301.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SYSTEM

JCA 4/21/00

1. Document Identifier No./Rev.:	Change:	Title:
MDL-NBS-HS-000002/Rev. 00	N/A	Seepage Models for PA Including Drift Collapse

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a									
44.	Macro/Routine: mininipresf_ir.f V1.0. ACC: MOL.20000217.0302.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
45.	Macro/Routine: mddf_CC8.f V1.0. ACC: MOL.20000217.0303.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
46.	Macro/Routine: mddf_CS8.f V1.0. ACC: MOL.20000217.0304.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
47.	Macro/Routine: mddf_cc.f V1.0. ACC: MOL.20000217.0305.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A
48.	Macro/Routine: minrefine3df.f V1.0. ACC: MOL.20000217.0306.	Entire	N/A-Qualified/ Verfied/ Confirmed	3 6	General software use	N/A	N/A	N/A	N/A

AP-3.15Q. Rev. 06/30/1999

ATTACHMENT II–MODEL INPUT AND OUTPUT FILES

Below are the descriptions of the directory paths and the input and output files submitted under DTN: LB991101233129.001 for this AMR.

Tables 4-8

Directories
/ad5k**#@**_r**&**/ (includes subpaths and data files)

- 'ad5' indicates that the correlation length is 0.5 meter.
- **#** 11,12,13 and 14 corresponding to the mean permeability at 0.9×10^{-11}, 0.9×10^{-12}, 0.9×10^{-13} m^2, and 0.9×10^{-14} m^2.
- **@** standard deviation: 's' means the value of standard deviation is 1.66; 'l' means the value is 2.50; otherwise the value is 1.93.
- **&** realization number.

For example, /ad5k13s_r1/ identifies the root directory for simulations where the correlation length is 0.5 meter and the mean permeability of realization 1 is 0.9×10-13 m2 with a standard deviation of 1.66.

Mesh filename
MESHSF input file of mesh generation for a 5.5 m diameter drift.

Initial Condition Filenames
INCON**@&_%**

- **@** standard deviation: 's' means the value of standard deviation is 1.66; 'l' means the value is 2.50; 'o' means the value is 1.93.
- **&** realization number. If the realization number is missing the file is generated for the realization number of the directory given above.
- **%** value of $1/\alpha$.

For example, INCONs1_100 identifies the initial condition file for realization 1 with standard deviation of 1.66 and $1/\alpha$ of 100 Pa. /ad5k13s_r1/INCONo_100 is generated for realization 1.

Subdirectories
/*****_a**%**/

- ***** is the percolation flux (mm/yr).
- **%** is the value of $1/\alpha$.

For example, /500_a100/ is a subdirectory containing the files for a simulation with a percolation flux of 500 mm/yr and $1/\alpha$ of 100 Pa.

ITOUGH2 Input files

*****_a^

* is the percolation flux.

^ value of 1/α: 1k = 1000, 3h = 300 and 1h = 100, or 30.

For example, 500_a1h is a input file for a flux of 500 mm/yr and 1/α of 100 Pa.

Output files

*_a^.out	output file for ITOUGH2.
*_a^.sav	ITOUGH2 .sav file with output conditions
outq	file containing seepage results
t2.msg	ITOUGH2 message file providing simulation status

Steps to rerun an example case corresponding to Tables 4 through 8

In table 4C, realization 3 and 1/α 30Pa with the mean permeability of 0.9×10^{-14} m^2 (the seepage percentage is 35).

Step 1: go to directory ad5k14l_r3, where the correlation length is 0.5 meter ('ad5'), $\sigma = 2.5$, the realization is 3 and the mean permeability is 0.9×10^{-14} m^2;

Step 2: go to directory 5_a30, where the percolation flux is 5 mm/yr and the 1/α is 30 Pa;

Step 3: Type "rund" and enter to run ITOUGH2v3.2_drift with the input file 5_a30;

Step 4: Calculate the seepage percentage from the output file outq.

<u>Tables 9-10</u>

Root directory

/a**!**_**?**/ includes subdirectories and data files.

! 1 or 4 is the value of the correlation length.

? 'stefan' means Parameter Set B and 'old' means Set A.

For example, /a1_stefan/ indicates that the correlation length is 1 meter with Parameter Set B.

Mesh filename

MESHSF input file of mesh for a 5.5 m diameter drift.

Initial Condition Filenames

INCON**@a!_&_%**

@ standard deviation: 's' means the value of standard deviation is 1.66; 'l' means the value is 2.50; 'o' means the value is 1.93.

! 1 or 4 is the value of the correlation length.
& realization number.
% value of 1/α.

For example, INCONsa1_1_100 indicates that it is for realization 1 with a standard deviation of 1.66, correlation length of 1 meter and 1/α of 100 Pa.

Subdirectories
/*****_a**%**_a**!**_**&**/
subpaths under /a**!**_**?** /.
***** is the percolation flux (mm/yr).
% is the value of 1/α.
! 1 or 4 is the value of the correlation length.
& realization number (1 through 5 for correlation length 4).

For example, /500_a100_a1_1/ indicates that the correlation length of realization 1 is 1 meter, 1/α is 100 Pa and the percolation flux is 500 mm/yr.

ITOUGH2 Input files
*****_a^
* is the percolation flux.
^ value of 1/α: 1k = 1000, 3h = 300 and 1h = 100, or 30.

For example, 213_a30 is a input file for a flux of 213 mm/yr and 1/α of 30 Pa.

Output files

*_a^.out	output file for ITOUGH2.
*_a^.sav	ITOUGH2 .sav file with output conditions
outq	file containing seepage results
t2.msg	ITOUGH2 message file providing simulation status

Steps to rerun an example case corresponding to the tables 9-10

In table 10, use Parameter Set B, alternative λ value of 4, realization 2, flux 213 mm/yr (the seepage percentage is 7.7).

Step 1: go to directory a4_stefan, where the correlation length is 4 meter ('a4');

Step 2: go to directory 213_a100_a4_2, where the percolation flux is 213 mm/yr, 1/α is 100 Pa, correlation length 4, realization 2;

Step 3: type "rund" and enter to run ITOUGH2v3.2_drift with the input file 213_a1h;

Step 4: calculate the seepage percentage from the output file outq.

Table 11

Root directory
/ad5k**#@**_r1_**nn**/ includes subdirectories and data files.

- 'ad5' indicates that the correlation length is 0.5 meter.
- **#** 12,13 corresponding to the mean permeability at 0.9×10^{-12}or 0.9×10^{-13} m^2
- **@** standard deviation: 's' means the value of standard deviation is 1.66; 'l' means the value is 2.50; otherwise the value is 1.93.
- '**nn**' means the van Genuchten parameter n is 2.55

For example, /ad5k13s_r1_nn/ indicates that the correlation length is 0.5 meter, van Genuchten n is 2.55 and the mean permeability of realization 1 is 0.9×10^{-13} m^2 with the standard deviation of 1.66.

Mesh filename
MESHSF input file of mesh generation for a 5.5 m diameter drift.

Initial Condition Filenames
INCON**@&_%**

- **@** standard deviation: 's' means the value of standard deviation is 1.66; 'l' means the value is 2.50; 'o' means the value is 1.93.
- **&** realization number.
- **%** value of $1/\alpha$.

For example, INCONl1_1000 identifies the initial condition file for realization 1 with standard deviation of 2.50 and $1/\alpha$ of 1000 Pa.

Subdirectories
/*****_a**%**/ subpaths under /ad5k#@_r&_nn/

- ***** is the percolation flux (mm/yr).
- **%** is the value of $1/\alpha$.

For example, /500_a100/ a subdirectory containing the files for a simulation with a percolation flux of 500 mm/yr and $1/\alpha$ of 100 Pa.

ITOUGH2 Input files
*****_a^

- * is the percolation flux.
- ^ value of $1/\alpha$: 1k = 1000, 3h = 300 and 1h = 100, or 30.

For example, 500_a1h is a input file for a flux of 500 mm/yr and $1/\alpha$ of 100 Pa.

Output files

*_a^.out	output file for ITOUGH2.
*_a^.sav	ITOUGH2 .sav file with output conditions
outq	file containing seepage results
t2.msg	ITOUGH2 message file providing simulation status

Steps to rerun an example case corresponding to the table 11

In Table 11, use the file with a van Genuchten n of 2.55, and 1/α 300 Pa, and Parameter Set A (the seepage percentage is 47).

Step 1: go to directory ad5k13_r1_nn, where the correlation length is 0.5 meter ('ad5'), σ = 1.93, realization 1 and the mean permeability is 0.9×10^{-13} m^2;

Step 2: go to directory 500_a300, where the percolation flux is 500 mm/yr and the 1/α is 300 Pa;

Step 3: type "rund" and enter to run ITOUGH2v3.2_drift with the input file 500_a3h;

Step 4: calculate the seepage percentage from the output file outq.

<u>Figures 3 and 4 with correlated α-k simulations</u>

Root directory
/ad5k#@_r&_k+/ includes subpaths and data files.

'ad5'	indicates that the correlation length is 0.5 meter.
#	12 or 13 corresponding to the mean k of 0.9×10^{-12}or 0.9×10^{-13} m^2
@	standard deviation: 's' means the value of standard deviation is 1.66; 'l' means the value is 2.50; 'o' means the value is 1.93.
&	the realization number.
'+'	'o' for Parameter Set A; 's' for Set B.

For example, /ad5k13s_r1_ko/ indicates that it is for parameter Set A with correlated α-k.

Mesh filename
MESHSF input file of mesh generation for a 5.5 m diameter drift.

Initial Condition Filenames
INCON**o_%**

%	value of 1/α.

For example, INCONo_100 indicates that it is for 1/α of 100 Pa.

Subdirectories

/*****_a**%**/ subpaths under /ad5k#@_r&_k+/

***** is the percolation flux (mm/yr).

% is the value of 1/α.

For example, /500_a100/ a subdirectory containing the files for a simulation with a percolation flux of 500 mm/yr and 1/α of 100 Pa.

ITOUGH2 Input files

*****_a^

* is the percolation flux.

^ value of 1/α: 1k = 1000, 3h = 300 and 1h = 100, or 30.

For example, 500_a1h is a input file for a flux of 500 mm/yr and 1/α of 100 Pa.

Output files

*_a^.out	output file for ITOUGH2.
*_a^.sav	ITOUGH2 .sav file with output conditions
outq	file containing seepage results
t2.msg	ITOUGH2 message file providing simulation status

Steps to rerun a case corresponding to Figures 3 and 4

In Figure 3(a), 1/α is 30Pa with the correlated α-k (the seepage percentage is about15).

Step 1: go to directory ad5k13_r1_ko, where the correlation length is 0.5 meter ('ad5'), σ = 1.93, the realization is 1 and the mean permeability is 0.9×10^{-13} m^2 (Parameter Set A).

Step 2: go to directory 500_a30, where the percolation flux is 500 mm/yr and the 1/α is 30 Pa;

Step 3: type "rund" and enter to run ITOUGH2v3.2_drift with the input file 500_a30;

Step 4: calculate the seepage percentage from the output file outq.

<u>Table 12</u>

Root directory

/drift_geo/ includes subpaths and files for drift collapse models

Subdirectories

/drift_cc/drift_cc_r&/ files for the model cut out 3m depth and 2m width at the drift roof.
/drift_cc8/drift_cc8_r&/ files for the model cut out 1 m^3 rock-fall from the drift crown.
/drift_cs8/drift_cs8_r&/ files for the model cut out 1 m^3 rock-fall from the drift springline

/drift_kzone/drift_kz_r&/ files for the model with disturbed zone around the drift

Mesh names MESHSF_cc; MESHSF_cc8; MESHSF_cs8; MESHSF

Initial Condition Filenames
INCONcc_a1h_r&
INCONcc8_a1h_r&
INCONcs8_a1h_r&
INCONkz_r&
& is the realization number.

Subdirectories
/*****_a**%**/
***** is the percolation flux (mm/yr).
% is the value of 1/α.

For example, /500_a100/ a subdirectory containing the files for a simulation with a percolation flux of 500 mm/yr and 1/α of 100 Pa.

ITOUGH2 Input files
*****_a^
* is the percolation flux.
^ value of 1/α: 1k = 1000, 3h = 300 and 1h = 100, or 30.

For example, 500_a1h is a input file for a flux of 500 mm/yr and 1/α of 100 Pa.

Output files

*_a^.out	output file for ITOUGH2.
*_a^.sav	ITOUGH2 .sav file with output conditions
outq	file containing seepage results
t2.msg	ITOUGH2 message file providing simulation status

Steps to rerun a example case corresponding to table 12

In Table 12, 3_m rock failure in drift roof and realization 2 with Parameter Set B (the seepage percentage is 8.6).

Step 1: go to directory drift_geo/drift_cc/drift_cc_r2/, where the correlation length is 0.5 meter, $\sigma = 1.66$, the realization is 2 and the mean permeability is 0.9×10^{-12} m^2;

Step 2: go to directory 500_a100, where the percolation flux is 500 mm/yr and the 1/α is 100 Pa;

Step 3: type “rund” and enter to run ITOUGH2v3.2_drift with the input file 500_a100;

Step 4: calculate the seepage percentage from the output file outq.

Table 13

Root Directory
/multi_p/ includes subpaths and data files for episodic percolation simulations

Mesh Filename
MESHSF input file mesh for a 5.5 m diameter drift.

Subdirectory
/multi_73+_2-10/

+ ‘s’ means Set A, ‘a1k’ means Set B. If + is missing this indicates Set A but with $1/\alpha$ = 100 Pa.

For example, file multi_73_2-10 indicates a flux of 73 mm/yr, Parameter Set A but with $1/\alpha$ =100 Pa, with flux occurring in the first two months of each year.

Initial Conditions Filename INCON

Input files
*_^m+?y

* is the percolation flux during the first two months of the year in mm/yr.
^ shows the number of months for the run.
? is the year number of the run. The sequence starts with 0 .

For example, 439_2m+1y is a input file for a simulation over the two wet months with the percolation flux of 439 mm/yr in the second year. 439_10m+1y is the file for the simulation of the following 10 months.

Output files

*_^m+?y.out	ITOUGH2 output
*_^m+?y.sav	ITOUGH2 .sav file with final simulation conditions
*_^m+?y.tec	ITTOUGH2 .tec file for plotting
outq_^m+?y	output file from ITOUGH2 for seepage rates.

For example, outq_2m+1y is a output file for the percolation flux of 439 mm/yr over the second wet period (second year).

Steps to rerun an example case corresponding to table 13

In Table 13, use Parameter Set B at the end of wet period (the seepage percentage is 2.5).

Step 1: go to directory /multi_p/multi_73s_2-10/;

Step 2: copy 0_10m+2y.sav to INCON as initial condition of the forth wet period. After three years episodic percolation the seepage is near steady state;

Step 3: type “rund” and enter to run ITOUGH2v3.2_drift with the input file 439_2m+3y;

Step 4: calculate the seepage percentage from the output file outq_2m+3y.

ATTACHMENT III–SOFTWARE ROUTINE CODE LISTING

(Documentation per AP-SI.1Q is included in the records packages submitted for each routine as listed in Table 1 in Section 3.)

Source code for Software Routine frac_calc, Version 1.1

```
      program Frac_Calc

c     Version 1.1
c     All changes for Version 1.1 are indicated by MAC V1.1
c     See Scientific Notebook YMP-LBNL-GSB-MC-1.2 pages 14-16

c     Discussion for Version 1.0
c
c     The purpose of this program is to calculate means and variances
c     for fracture properties for UZ model layers     based on detailed
c     line survey (DLS) data for the Exploratory Studies Facility (ESF)
c     that has been downloaded from the Technical Database (TDB).

c     This program was originally written by Eric Sonnenthal with
c     revisions and additions by Mark Cushey (4/98 to 7/98) which are
c     labeled MAC and dated.  Major additions include using data
c     statements and coding to combine subunits for model   layers
c     internally in the program; calculating additional parameters;
c     program     recalculates all numbers for each model layer each time
c     it is executed; calculate apertures; calculate alpha & log alpha
c     and its statistics; calculates spacing, frequencies   and intensity
c     for selected interval lengths; new input format for direct reading
c     of data from TDB after processing through read_tdb.f; and new
c     output formats.

c       MAC V1.1 - updated pages below for references for Version 1.0
c     See Scientific Notebook YMP-LBNL-GSB-MC-1 pages 60-69, 124-125, 137
c     See Scientific Notebook YMP-LBNL-GSB-MC-1.1 pages 98, 101-108, 114-115
c     See Reference Binder YMP-LBNL-GSB-MC-1.1A pages 88-97, 98-106

c     - Mark Cushey 7/98
c-----------------------------------------------------------------------
c     Below comments by E.Sonnenthal
c...  Program to read USGS ESF data and calculate fracture geometries
c...  and densities for plotting (11/4/96: E. Sonnenthal)
c...  Components of hydraulic conductivity tensor (de Marsily, 1986)
c...  11/11/96 E. Sonnenthal
c...  revised 2/6/97 for a fracture size range
c     nf     = Number of fractures
c     blksiz = Block size (m)
c     kfrc   = Hydraulic conductivity of each fracture (m/s)
c     aper   = Aperture of each fracture (m)
c     strike = Strike of each fracture (azimuth in radians)
c     dip    = Dip of each fracture (dip in radians)
c     ktens  = Conductivity tensor (9 component)
c      k(9) = (kxx,kxy,kxz,kyx,kyy,kyz,kzx,kzy,kzz)
c          | kxx  kxy  kxz |
c          | kyx  kyy  kyz |
c          | kzx  kzy  kzz |
```

The obliterated or illegible information does not impact the technical meaning or content of the record.

```
c-----------------------------------------------------------------------

c Commented out variables no longer used MAC 7/98
c     integer ni1,ni2
      integer i,k,ni,n,nn,nm1,nfr,nf,ns1,ns2
      parameter (nf = 50000)
      parameter (pi=3.1415926536d0)
      parameter (ni = 199)

c Added MAC 4/13/98
      character*32 fname

c Commented out variables no longer used MAC 7/98
c      character*8 outfile, header2, fstat
c      character*200 header
c      integer dist1
c      double precision height(nf),dist2

      integer nfrint(ni),ns
      double precision blksiz,kf,sdsq,stkrad,diprad,proptf
      double precision fmin,fmax
      double precision kfrc(nf),aper(nf)
      double precision ktens(9)
      double precision kxx,kxy,kxz,kyx,kyy,kyz,kzx,kzy,kzz
      double precision endp1,endp2,totaltr,totalht,adip,bdip
      double precision dist(nf),nfrc(nf)
      double precision strike(nf),dip(nf),alen(nf),blen(nf)
      double precision atrace(nf),btrace(nf),trace(nf)
      double precision trlen,fmesf,frint,fgrp1,fgrp2,fsiz
      double precision trcmax,dipmin,dipmax,aperture
      double precision avgsp,frcint,varsp,sdspac
      double precision freq,sdfreq,frcvol,frcrad,frcpor,blkht,blkdp
      double precision sdlen,varlen,avglen,frarea,frcp2d
      character*1 ans1,ans2

c     MAC V1.1
      double precision intarea, gmlen

c
c-------------------------------------------------------------------------
c     Below added by MAC 4/98 - 5/98
c     Data statements added to identify subunits and later combine
c     subunits for each model layer.
c     Moved to include MAC 6/98 so that various combinations could be
c     used by simply using a different file for include
c     Note that alcove stations are entered with Alcove # in the
c     ten thousandth location.
c     Assignment for model layers based on CRWSM M&O, 1998.
c     For most recent assignment see
c     Scientific Notebook YMP-LBNL-GSB-MC-1.1 pages 36-39.
c
c     Include file 'datablk.f' includes data statements for
c     unitname, modlayer, unitsta, unitend, and logairk

c     MAC V1.1
      include 'datablk11.f'
c
```

```
c     For testing, instead of 'datablk.f', include file 'uzmodel97.f'
c     for comparison with calculations performed for the July 97
c     milestone (Chapter 7, Sonnethal et. al, 1997) or include
c     'sweetkind.f' for comparison with calculations in
c     Sweetkind et. al (1997). Use the data files ericdls.dat and
c     sweetdls.dat, respectively.
c     include 'uzmodel97.f'
c     include 'sweetkind.f'
c     MAC 7/98 For the more detailed PTn model layers use
c     include 'ptnblk.f'


c-----------------------------------------------------------------------------
c Below added MAC 4/98 - 6/98
c     ntotal is the total number of UZ model layers
c     nlayers is the total number of segments along the ESF
c     Both are used for the data statements and are defined in the
c           file 'datablk.f'
c     npar is the number of parameters saved for calculating properties
c     for entire model layer
c     variables with 'int' are for calculating fracture properties for
c           intervals
c     variables for data statements [integer modlayer(ntotal);
c           double precision logairk(nlayers),unitsta(nlayers),
c           unitend(nlayers)] are in file 'datablk.f'

      integer     layer,first,last,npar
c     MAC V1.1 changed npar from 16 to 18
      parameter(npar=18)
      double precision spac,frcp1d,trcmin, combine,kzzkxx,kyykxx,kzzkyy,
      +     alpha,loga,logf,sdalpha
      dimension combine(nlayers,npar)
      character*5 outfile

      integer intn,intmax,intnfr,intlayer
      parameter(intmax=10000)
      double precision intfreq,intspace, intlength, inttrace
      dimension intfreq(intmax),intspace(intmax),intnfr(intmax),
      +     inttrace(intmax)

c...Input file name
2     print *, 'Enter fracture data filename: '
      read (*,*) fname
      open(unit=12,file=fname,status='old',err=5)
      go to 7
5     write(*,*)'File not found'
      go to 2
7     continue

c Removed call to station file -- all in one file MAC 4/13/98

c revised MAC 4/13/98 - starting and end points for model layers
c           now determined internally

c revised MAC 4/17/98   - changed input process
      dipmin = 0.d0
      dipmax = 90.d0
```

```
      ans1 = 'n'
      ans2 = 'y'
      write(*,*)'Enter minimum and maximum fracture length to use'
      read(*,*)fmin,fmax

c Added MAC 7/8/98 - query user for interval length
      write(*,*)'Enter interval length (in meters)'
      read(*,*)intlength
c--------------------
c... Read station file - Removed MAC 4/13/98

c     MAC 4/98 open output files
      open(13,file='all1.par',status='unknown')
      open(14,file='all2.par',status='unknown')
      write(13,441)
      write(14,442)
      open(18,file='interval.par',status='unknown')
      write(18,1999)
      open(20,file='tmp.par')

c
c... Read fracture data file
c Rev MAC 4/13/98
      read (12,*)
      i = 0
10    i = i + 1
c     rev MAC 6/29/98 - Don't read in height
c     read(12,*,end=99)dist(i),strike(i),dip(i),atrace(i),
c     &     btrace(i),height(i)
      read(12,*,end=99)dist(i),strike(i),dip(i),atrace(i),
      &     btrace(i)
      go to 10
99    ns = i - 1
      dist(ns+1)=99999.9
      close(12)
c
c Added MAC 6/25/98
c     initialize combine
      do j=1,npar
            do i=1,nlayers
                  combine(i,j) = 0d0
            end do
      end do

c----------------
c Added MAC 4/17/98
c     Loop through model layers, assiging station ranges
c     Define endp1, endp2, ns1, ns2
c
      DO layer = 1,nlayers
            endp1 = unitsta(layer)
            endp2 = unitend(layer)
            write(*,*)unitname(layer),endp1,endp2
            ns1 = 0
            ns2 = 0
            do i = 1,ns+1
                  if (((dist(i).ge.endp1).and.(dist(i-1).lt.endp1))
```

```
      &           .or.((dist(i).ge.endp1).and.(i.eq.1)))
      &                 ns1 = i
                  if ((dist(i).gt.endp2).and.(dist(i-1).le.endp2))
      &                 ns2 = i     - 1
            end do
c           MAC V1.1 - changed 0.0 to 0
            if ((ns2-ns1).le.0) go to 999
            write(*,*)'     ',dist(ns1),dist(ns2)

c           outfile = unitname(layer)
            outfile = 'dummy'
c           if ((layer.eq.48).or.(layer.eq.27)) then
c                 outfile = unitname(layer)
c                 write(*,*)'Tecplot file for',unitname(layer),
c     +                 unitsta(layer),unitend(layer)
c           end if
c... Find size distribution for all fractures
      if(ans2.eq.'y')then
          fmesf = 0.3d0
          frint = 0.2d0
      do i = ns1,ns2
          trlen = atrace(i) + btrace(i)
        do k = 1, ni
          fgrp1 = fmesf + dble(k-1)*frint
          fgrp2 = fmesf + dble(k)*frint
          if(trlen.ge.fgrp1.and.trlen.lt.fgrp2)
      &           nfrint(k)=nfrint(k)+1
        enddo
      enddo
      endif
c

c Added MAC 4/98 find minimum trace length before excluding
      trcmin = fmax
      do i = ns1,ns2
        trcmin = min((atrace(i)+btrace(i)),trcmin)
      enddo

c... Find fractures that are within range if given
      n = 0
      nfr = 0
      do i = ns1,ns2
        if(dip(i).ge.dipmin.and.dip(i).le.dipmax.and.atrace(i)+
     +    btrace(i).ge.fmin.and.atrace(i)+btrace(i).le.fmax)
     +      then
            n = n + 1
            nfrc(n) = i
            nfr = n
        endif
      enddo
      if (nfr.le.1) go to 999

c
c... Calculate proportion of total fractures
      proptf = dble(nfr)/(dble(ns2-ns1+1))

c
```

```
c... Find total trace length
        do n = 1, nfr
          nn = nfrc(n)
          trace(n) = atrace(nn) + btrace(nn)
        enddo
c
c... Find maximum trace length
      trcmax = -1.d5
      do n = 1, nfr
        trcmax = max(trace(n),trcmax)
      enddo

c
c... Length of fracture segment for plotting is 0.15 inch/meter
      do n = 1, nfr
        nn = nfrc(n)
        alen(n) = atrace(nn)*0.15d0
        blen(n) = btrace(nn)*0.15d0
      enddo
c
c... Calculate blocksize (interval length)
      blksiz = endp2 - endp1
      blkht = 6.d0
      blkdp = 6.d0
c
c Rev MAC 4/17/98 - moved perm, frac volume, porisity to after
c parameters

c Rev MAC 4/98 - zero sum parameters
      totalht = 0d0
      totaltr = 0d0
      ssqht = 0d0
      ssqtr = 0d0
      sspac = 0d0
      ssqsp = 0d0
      ssqlsp =0d0
      slgsp = 0d0
c     MAC V1.1
      gmlen = 0d0
      intarea = 0d0

c Added MAC 5/98
      do n = 1, intmax
            intspace(n) = 0d0
            intfreq(n) = 0d0
            intnfr(n) = 0
            inttrace(n) = 0d0
      end do
      intn = 0
      intlayer = 0
c
c... Calculate fracture parameters - loop through fractures
        do n = 1, nfr
          nn = nfrc(n)
          totaltr = trace(n) + totaltr
          ssqtr = trace(n)**2 + ssqtr
```

```
c           MAC V1.1
            gmlen = gmlen + dlog10(trace(n))

          if(n.gt.1)then
            nm1 = nfrc(n-1)
c rev MAC 4/13/98 - put in if
            spac = dabs(dist(nn)-dist(nm1))
              if (spac.eq.0.0) then
                  write(*,*)'station overlap',dist(nn),nn,nm1
              end if
2099  format(1x,a5,3(1x,f9.2))


            sspac = spac + sspac
c correction MAC 4/13/98
c                 put in '+ slgsp' in place of '+ sspac'
c                 put in dlog10 and if-then
            if (spac.ne.0.0) then
                   slgsp = dlog10(spac) + slgsp
c correction MAC 4/98
c                 put in '+ ssqlsp' in place of '+ ssqsp'
c                 put in dlog10
               ssqlsp = (dlog10(spac))**2 + ssqlsp
            else
c rev MAC 4/98 for zero spacing use 0.005 m which is 1/2
c                 of the measurement precision
               slgsp = dlog10(5d-3) + slgsp
                   ssqlsp = (dlog10(5d-3))**2 + ssqlsp
              end if

            ssqsp = spac**2 + ssqsp


c added MAC 5/98 - for determining frequency and intensity over interval
c                 added MAC 7/98 - if-then statment to prevent from
c                 overextending interval boundary
                  intn = INT((dist(nn)-endp1)/intlength)+1
                  if ( (endp1+(intn*intlength)).le.endp2 ) then
                        if (intn.gt.intmax) then
                              write(*,*)'Max number of intervals exceeded -',
      +                                     ' program stopped'
                              write(*,*)'Resize intmax -
intmax,intn',intmax,intn
                              stop
                        end if
                        intspace(intn) = intspace(intn) + spac
                        intnfr(intn) = intnfr(intn) + 1
                        inttrace(intn) = inttrace(intn) + trace(n)
                        intlayer = intn
                  end if
          endif
300         continue
        enddo

            avgsp = sspac/dble(nfr-1)
            freq = 1.d0/avgsp
```

```
c added MAC 5/98 - for determining frequency and intensity over interval
            do intn = 1,intlayer
                  if (intnfr(intn).gt.1) then
                        intspace(intn) = intspace(intn)/dble(intnfr(intn)-1)
                        intfreq(intn) = 1d0/intspace(intn)
                  else
                        intfreq(intn) = 1d0/intlength
                  end if
                  inttrace(intn) = inttrace(intn)/intlength/blkht
            end do

c           MAC 5/98 added if-then for small # of fractures
            if (nfr.gt.2) then
c                 nfr-1 is the number of pairs used to calculate spacing
                  varsp = (ssqsp - ((sspac**2)/dble(nfr-1)))/(dble(nfr-2))
                  if (varsp.gt.0.0) then
                        sdspac = sqrt(varsp)
c added comment and put in varsp rather than sdspac**2 by MAC 5/98
c V[f]= V[s]*(-E[s]**-2)**2
                        sdfreq = sqrt((((-avgsp)**(-2))**2)*varsp)
                  else
                        sdspac = 0d0
                        sdfreq = 0d0
                  end if
            else
                  varsp = 0d0
                  sdspac = 0d0
                  sdfreq = 0d0
            end if

           frcint = totaltr/blksiz/blkht
           avglen = totaltr/dble(nfr)
             varlen = (ssqtr - ((totaltr**2)/dble(nfr)))/dble(nfr-1)
           if (varlen.gt.0.0) then
                  sdlen = sqrt(varlen)
             else
                  sdlen = 0d0
             end if

c Rev MAC 4/17/98 - calculate b (in um) from airk
             aperture = 1d6*(12d0*(10**logairk(layer))/freq)**(1.0/3.0)

c... Calculate permeability of each fracture and pass to ktensor
      do n = 1, nfr
        aper(n) = aperture*1.d-6
        kfrc(n) = (aper(n)**3)/12.d0
      enddo

c Rev MAC 4/98 - zero sum parameters
      frcvol = 0d0
      frarea = 0d0
      do i = 1,9
            ktens(i) = 0d0
      end do

c... Calculate fracture volume based on penny-shaped fractures
      do n = 1, nfr
```

```
        frcrad = trace(n)*0.5d0
        frcvol = pi*aper(n)*frcrad**2 + frcvol
        frarea = aper(n)*frcrad*2.d0 + frarea
c           MAC V1.1 - will divide by block volume after combining
        intarea = pi*frcrad**2 + intarea

      enddo
c... Calculate fracture porosity
      frcpor = frcvol/(blksiz*blkht*blkdp)
      frcp2d = frarea/(blksiz*blkht)

c Added MAC 4/22/98 - include 1-D porosity
      frcp1d = freq*aperture*1d-6
c
c... Calculate components associated with each fracture, then sum
        radian = pi/180.d0
      do n = 1, nfr
        nn = nfrc(n)
        if(strike(nn).le.90.d0)then
          stkrad = strike(nn)*radian
          diprad = dip(nn)*radian
        elseif(strike(nn).gt.90.d0.and.strike(nn).le.180.d0)then
          stkrad = strike(nn)*radian
          diprad = (180.d0-dip(nn))*radian
        elseif(strike(nn).gt.180.d0.and.strike(nn).le.270.d0)then
          stkrad = strike(nn)*radian
          diprad = (180.d0-dip(nn))*radian
        else
          stkrad = strike(nn)*radian
          diprad = dip(nn)*radian
        endif
        sdsq = (dsin(diprad))**2
        kxx = 1.d0 - ((dcos(stkrad))**2)*sdsq
        kxy = 0.5d0*dsin(2.d0*stkrad)*sdsq
        kxz = -0.5d0*dsin(2.d0*diprad)*dcos(stkrad)
        kyx = kxy
        kyy = 1.d0 - ((dsin(stkrad))**2)*sdsq
        kyz = 0.5d0*dsin(2.d0*diprad)*dsin(stkrad)
        kzx = kxz
        kzy = kyz
        kzz = sdsq
        kf = kfrc(n)*freq
        ktens(1) = kxx*kf + ktens(1)
        ktens(2) = kxy*kf + ktens(2)
        ktens(3) = kxz*kf + ktens(3)
        ktens(4) = kyx*kf + ktens(4)
        ktens(5) = kyy*kf + ktens(5)
        ktens(6) = kyz*kf + ktens(6)
        ktens(7) = kzx*kf + ktens(7)
        ktens(8) = kzy*kf + ktens(8)
        ktens(9) = kzz*kf + ktens(9)
      enddo

c Added MAC 4/21/98
      kzzkxx = ktens(9)/ktens(1)
      kyykxx = ktens(5)/ktens(1)
      kzzkyy = ktens(9)/ktens(5)
```

```
c Added MAC 4/21/98
c     Calculate alpha (see equation 7)
      alpha = aperture*1d-6/2d0/72d-3
c
c Commented out MAC 7/98
c... Open and write permeability components of fracture networks
c      open(11,file=outfile//'.prm',status='unknown')
c        write(11,*)'Permeability Tensor for: ',outfile
c        write(11,450)'kxx','kxy','kxz','kyx','kyy','kyz','kzx',
c     +   'kzy','kzz'
c        write(11,460)ktens(1),ktens(2),ktens(3),ktens(4),
c     +    ktens(5),ktens(6),ktens(7),ktens(8),ktens(9)
c        write(11,*)'kzz/kxx= ',ktens(9)/ktens(1)
c        write(11,*)'kyy/kxx= ',ktens(5)/ktens(1)
c      close(11)

c... Calculate orientations and open and write GMT plot file
            open(11,file=outfile//'.plt',status='unknown')
      do n = 1, nfr
          nn = nfrc(n)
          if(strike(nn).le.90.d0)then
            adip = dip(nn)
            bdip = dip(nn) + 180.d0
          elseif(strike(nn).gt.90.d0.and.strike(nn).le.270.d0)then
            adip = 180.d0 - dip(nn)
            bdip = 360.d0 - dip(nn)
          else
            adip = dip(nn)
            bdip = dip(nn) + 180.d0
          endif
          write(11,404)dist(nn),adip,alen(n),unitname(layer)
          write(11,404)dist(nn),bdip,blen(n),unitname(layer)
        enddo
      close(11)
c-----------------------------------------------------------------
c     Below by MAC 4/98
c     Completely changed output file formatting
c     now 'all1.par' and 'all2.par' which list data for each subunit
c     Deleted E.S. output file writing

      if (endp2.lt.9999.0) then
            write(13,443)unitname(layer),endp1,endp2,trcmin,fmin,
      +     trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
            write(14,444)unitname(layer),fmin,nfr,freq,
     +      aperture,frcpor,frcp2d,frcp1d,alpha,kzzkxx,kyykxx,kzzkyy
            write(13,443)'     ',dist(ns1),dist(ns2)
      else
c           alcove data & ECRB data
c           ECRB is read in as if it is alcove 9 MAC 3-23-99
            if (endp1.lt.90000.0) then
             write(13,2443)unitname(layer),INT(endp1/10000.0),trcmin,fmin,
      +      trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
            else
             write(13,2445)unitname(layer),trcmin,fmin,
      +      trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
            end if
```

```
            write(14,444)unitname(layer),fmin,nfr,freq,
     +      aperture,frcpor,frcp2d,frcp1d,alpha,kzzkxx,kyykxx,kzzkyy
            write(13,2444)(dist(ns2)-dist(ns1))

      end if
441   format(1x,' Unit',1x,'<---Station--->',1x,
      +     ' Min-m',1x,'MinUse',1x,' Max-m',1x,' #Frac',1x,
      +     'Spac-m',1x,'SDSpac',1x,'Fq-1/m',
      +     1x,'SDFreq',1x,'Leng-m',1x,'SDLeng',1x,'Intens')
442   format(1x,' Unit',1x,
      +     'MinUse',1x,' #Frac',1x,'Fq-1/m'
     +      ,1x,'Apr-um',1x,'   Por-3D',1x,'   Por-2D',1x,'   Por-1D'
     +      ,1x,'    alpha',1x,'kzz/kxx',1x,'kyy/kxx',1x,'kzz/kyy')
443   format(1x,a5,2(1x,f7.2),3(1x,f6.2),1x,i6,7(1x,f6.2))
444   format(1x,a5,1x,f6.2,1x,i6,1x,f6.2,1x,f6.0,4(1x,es9.2),
      +           3(1x,f7.2))
2443  format(1x,a5,4x,'Alcove',i2,4x,3(1x,f6.2),1x,i6,7(1x,f6.2))
2444  format(7x,f7.2,1x,'meters')
2445  format(1x,a5,4x,'ECRB  ',2x,4x,3(1x,f6.2),1x,i6,7(1x,f6.2))

c     Save results for combined output
c     added MAC 4/98
      combine(layer,1)=endp1
      combine(layer,2)=endp2
      combine(layer,3)=trcmin
      combine(layer,4)=trcmax
      combine(layer,5)=dble(nfr)
      combine(layer,6)=avgsp*dble(nfr-1)
      combine(layer,7)=ssqsp
      combine(layer,8)=avglen*dble(nfr)
      combine(layer,9)=ssqtr
      combine(layer,10)=frcpor*blksiz/(aperture*1d-6)
      combine(layer,11)=frcp2d*blksiz/(aperture*1d-6)
      combine(layer,12)=ktens(1)/freq
      combine(layer,13)=ktens(5)/freq
      combine(layer,14)=ktens(9)/freq
      combine(layer,15)=slgsp
      combine(layer,16)=ssqlsp
c     MAC V1.1
      combine(layer,17)=intarea
      combine(layer,18)=gmlen

c Added MAC 5/98 - Output interval results to 'interval.par'
      do intn=1,intlayer
                  write(18,2000)unitname(layer),
      +           (endp1+(intn-1)*intlength),
     +            (endp1+(intn)*intlength),
     +            intnfr(intn),intspace(intn),intfreq(intn),
     +            (dble(intnfr(intn))/intlength),inttrace(intn)
      end do
1999  format(1x,' Unit',2(1x,'  Station'),1x,'   #Frac',4x,
      +     'Spacing',2x,'Frequency',3x,'#/Length',2x,'Intensity')
2000  format(1x,a5,2(1x,f9.1),1x,i8,4(1x,f10.2))
c-----------------------------------------------------------------------

c... Write fracture size distributions
      if(ans2.eq.'y')then
```

```
      open(12,file=outfile//'.szd',status='unknown')
      do k = 1, ni
          fgrp1 = fmesf + dble(k-1)*frint
          fsiz = fgrp1 + frint*0.5d0
c rev MAC 5/12/97  write(12,470)fsiz,dble(nfrint(k))/dble(ns)
        write(12,475)fsiz,nfrint(k)
      enddo
      close(12)
        fsum = 0.d0
c           write cumulative size distributions
      open(12,file=outfile//'.csd',status='unknown')
        ftot = 1.d0
        write(12,470)fmesf,ftot
      do k = 1, ni
        fgrp1 = fmesf + dble(k)*frint
        fsum = dble(nfrint(k))/dble(ns) + fsum
        write(12,470)fgrp1,1.d0 - fsum
      enddo
      close(12)
      endif
c

c Added MAC 4/17/98
999   continue
      END DO
      close(13)
      close(14)

c-----------------------------------------------------------------------------
----------
c     Below is all new code added by MAC 4/98

c     Combine results for single values for each model layer
c
c     Output to files 'comb1.par' & 'comb2.par' - combined results of
c     all1.par & all2.par
c     Output to file 'calibrate.par' - data to be used for inversion
c
      open(13,file='comb1.par',status='unknown')
      open(14,file='comb2.par',status='unknown')
      open(15,file='calibrate.par',status='unknown')
      write(13,1441)
      write(14,442)
      write(15,2501)
      DO i = 1,ntotal
            trcmin = 1d6
            trcmax = 0d0
            nfr = 0
            avgsp = 0d0
            sspac = 0d0
            sdspace = 0d0
            ssqsp = 0d0
            avglen = 0d0
            sdlen = 0d0
            ssqtr = 0d0
            frcpor = 0d0
            frcp2d = 0d0
```

```
            blksiz = 0d0
            kxx = 0d0
            kyy = 0d0
            kzz = 0d0
            slgsp = 0d0
            sslgsp = 0d0
c           MAC V1.1
            intarea = 0d0
            gmlen = 0d0

            first = modlayer(i)
            if (i.ne.ntotal) then
                  last = modlayer(i+1) - 1
            else
                  last = nlayers
            end if
            n = last - first + 1
      DO layer = first,last
            trcmin = min(trcmin,combine(layer,3))
            trcmax = max(trcmax,combine(layer,4))
            nfr = nfr + NINT(combine(layer,5))
            sspac = sspac + combine(layer,6)
            ssqsp = ssqsp + combine(layer,7)
            avglen = avglen + combine(layer,8)
            ssqtr = ssqtr + combine(layer,9)
            frcpor = frcpor + combine(layer,10)
            frcp2d = frcp2d + combine(layer,11)
            blksiz = blksiz + combine(layer,2) - combine(layer,1)
            kxx = kxx + combine(layer,12)
            kyy = kyy + combine(layer,13)
            kzz = kzz + combine(layer,14)
c
            slgsp = slgsp + combine(layer,15)
            ssqlsp = ssqlsp + combine(layer,16)

c           MAC V1.1
            intarea = intarea + combine(layer,17)
            gmlen = gmlen + combine(layer,18)
            if ((layer.eq.last).and.(nfr.gt.(n+1))) then
                  avgsp = sspac/dble(nfr-n)
                  freq = 1.d0/avgsp
c                 nfr-n is the number of pairs used to calculate spacing
                  varsp = (ssqsp - ((sspac**2)/dble(nfr-n)))/(dble(nfr-n-1))
                  if (varsp.gt.0.0) then
                        sdspac = dsqrt(varsp)
                  else
                        sdspac = 0d0
                  end if
                  varlen = (ssqtr - ((avglen**2)/dble(nfr-n))) /
     >                              (dble(nfr-n-1))
                  avglen = avglen/dble(nfr)
                  if (varlen.gt.0.0) then
                        sdlen = dsqrt(varlen)
                  else
                        sdlen = 0d0
                  end if
                  if (sdspac .gt. 0.0) then
```

```
                        sdfreq = dsqrt(varsp/(avgsp**4))
                    else
                        sdfreq = 0d0
                    end if
                    aperture = 1d6*(12d0*(10**logairk(layer))/freq)
      &                                **(1.0/3.0)
                    alpha = aperture*1d-6/2d0/72d-3
                    frcpor = frcpor*(aperture*1d-6)/blksiz
                    frcp2d = frcp2d*(aperture*1d-6)/blksiz
                    frcp1d = freq*aperture*1d-6
c                   calculate k ratios (note freq cancels)
                    kzzkxx = kzz/kxx
                    kyykxx = kyy/kxx
                    kzzkyy = kzz/kyy
c                   calulate fracture intensity
                    frcint = avglen*dble(nfr)/blksiz/6e0
c                   MAC V1.1
                    gmlen = 10**(gmlen/dble(nfr))
                    intarea = intarea/blksiz/(gmlen**2)

                    write(13,1443)unitname(layer),trcmin,fmin,
      +              trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
                    write(14,444)unitname(layer),fmin,nfr,freq,
     +              aperture,frcpor,frcp2d,frcp1d,alpha,kzzkxx,kyykxx,kzzkyy

c
                    ssqlsp = (ssqlsp - slgsp**2/dble(nfr-n) )/ dble(nfr-n-1)
                    slgsp = slgsp / dble(nfr-n)
                    logf = - slgsp
                    loga = (1d0/3d0)*(dlog10(12d0)+logairk(layer)-logf)
      >                        - dlog10(2d0*72d-3)
                    sdalpha = sdfreq*dsqrt(1d0/72d-3) *
      >             ( (10**logairk(layer)) /18d0/(freq**4) )**(1.0/3.0)
                    if (ssqlsp.le.0.0) then
                        write(*,2500)unitname(layer),slgsp,ssqlsp
                        ssqlsp = 0.0
                    end if

c           MAC V1.1 add new parameters gmlen (gemetric mean length) and
c           intarea (fracture area/block volume where block volume is
c           block length * gmlen^2).  Also changed output for calibrate.par
      write(15,2500)unitname(layer),fmin,frcp2d,(aperture*1d-6),freq,
      +     intarea,gmlen,alpha,sdalpha,loga,dsqrt(ssqlsp/9d0)
2500  format(1x,a5,5x,f9.2,2(3x,es9.2),3x,f9.2,2(3x,f9.3),
      +     2(3x,es9.2),2(3x,f9.2))
2501  format(1x,' Unit',1x,'Min-Fr-Length',1x,'Fr-Porosity',4x,
      +     'Aperture',3x,'Frequency',2x,'Inter-Area',3x,'Gm-length',
     +      4x,'Fr-Alpha',4x,'SD-Alpha',4x,'LogAlpha',1x,'SD-LogAlpha')
c2500 format(1x,a5,2(1x,f7.2),2(1x,es9.2),3(1x,f7.2),1x,f7.3,1x,f7.2,
c     +     1x,i5,2(1x,f7.2))
c2501 format(1x,' Unit',4x,'Freq',2x,'SDFreq',5x,'alpha',3x,'sdalpha',
c     +     4x,'loga',2x,'logsda',2x,'<loga>',
c     +     1x,'s<loga>',2x,'gmFreq',1x,'#Frac',3x,'Block',3x,'#Freq')


c     added else statement - MAC 6/25/98
            else
```

```
                  if (layer.eq.last) then
                        write(13,2500)unitname(layer)
                        write(14,2500)unitname(layer)
                        write(15,2500)unitname(layer)
                  end if

            end if
      END DO
      END DO
1441  format(1x,' Unit',1x,
      +     ' Min-m',1x,'MinUse',1x,' Max-m',1x,' #Frac',1x,
      +     'Spac-m',1x,'SDSpac',1x,'Fq-1/m',
      +     1x,'SDFreq',1x,'Leng-m',1x,'SDLeng',1x,'Intense')
1443  format(1x,a5,3(1x,f6.2),1x,i6,7(1x,f6.2))
      close(13)
      close(14)


      stop


  400 format(a200)
  404 format(f13.2,1x,f8.4,1x,f9.5,1x,a5)
  408 format(a10)
  410 format(i2,1x,f5.2)
  415 format(a21,2(1x,f7.2))
  420 format(a48,2(1x,f7.3),1x,i5,1x,f5.3)
  425 format(a78)
  430 format(f8.4,5(2x,f8.4),2(2x,e10.4))
  440 format(a40)
  450 format(9(4x,a4,3x))
  460 format(9(1x,e10.3))
  470 format(f10.3,1x,f8.4)
  475 format(f10.3,1x,i8)
c
      stop
      end
```

Source code for Software Routine Read_TDB, Version 1.0

```
      program Read_TDB

c     This program reads the data files from the
c     Technical Database.  Output are written
c     unformatted to selected output file.  All messages are
c     recorded to the screen and file 'index.txt'
c     Mark Cushey 4/98

c     Output is limited to 10 numerical datatypes
c     It is assumed that the maximum line length is less than 250

      real anum,bnum,value(10),limvalue(10,2),loctype
      character*4 first
      character*25 filename
      character*250 all
      character*250 datastring
      character*8 astat,bstat,avalue,limtext(10)
      character*1 onestring(250),onedata(8),plus(8),ans
      character*8 dataname(10),limitname(10)
      integer row,iname,istring,idata,icolumn(10),i,loc,rowused,
      +     im,limnum,limtxt

c     ----------------------------------------

c     open output files
      write(*,*)'Enter name of output file:'
      read(*,1000)filename
      open(unit=20,file=filename)
      open(unit=21,file='index.txt')
      write(*,*)'Details on data retrieval are in index.txt'

c     ----------------------------------------
c     query for different data types to be stored
c
      write(*,*)'List names of data types to be retrieved - up to 10'
      write(*,*)'   Enter only the first 8 letters for each'
      write(*,*)'   Enter the word end for last entry'
      i = 0
40    i = i + 1
      read(*,1010)dataname(i)
      if ((dataname(i).ne.'end').and.
      &     (dataname(i).ne.'END')) go to 40
      iname = i - 1
      write(*,1040)iname
      write(21,1040)iname
      write(20,1041)(dataname(i),i=1,iname)
      write(*,*)'Should header be printed in output file - Y or N'
      read(*,1011)ans
      if ((ans.eq.'Y').or.(ans.eq.'y'))
      &     write(21,1041)(dataname(i),i=1,iname)
1010  format(a8)
1011  format(a1)
1040  format(1x,i7,' datatypes selected')
1041  format(10(2x,a8))
c     ----------------------------------------
```

```
c     query for limits on outputting data
      limnum = iname
      limtxt = iname
      write(*,*)'Are there limits for the output - Y or N ?'
      read(*,1011)ans
      if ((ans.eq.'Y').or.(ans.eq.'y')) then
            i = iname
c           write(*,*)'Enter the parameter names for numerical limits'
c           write(*,*)'   Enter only the first 8 letters for each'
c           write(*,*)'   Enter the word end for last entry'
c45         i = i + 1
c           read(*,1010)dataname(i)
c           if ((dataname(i).eq.'end').or.
c     &     (dataname(i).eq.'END')) go to 46
c           write(*,*)'Enter upper and lower value for limit'
c           read(*,*)limvalue(i,1),limvalue(i,2)
c           write(*,*)'Enter next limit or end'
c           go to 45
c46         i = i - 1
c           limnum = i
            write(*,*)'Enter the parameter names for text-defined limits'
            write(*,*)'   Enter only the first 8 letters for each'
            write(*,*)'   Enter the word end for last entry'
47          i = i + 1
            read(*,1010)dataname(i)
            if ((dataname(i).eq.'end').or.
      &     (dataname(i).eq.'END')) go to 49
            write(*,*)'Enter text to exclude - up to 8 characters'
            read(*,1010)limtext(i)
            write(*,*)'Enter next limit or end'
            go to 47
49          limtxt = i - 1
            do i=(iname+1),limtxt
                  if (i.le.limnum) then
                        write(*,1045)dataname(i),limvalue(i,1),limvalue(i,2)
                        write(21,1045)dataname(i),limvalue(i,1),limvalue(i,2)
                  else
                        write(*,1046)dataname(i),limtext(i)
                        write(21,1046)dataname(i),limtext(i)
                  end if
            end do
      end if
1045  format(1x,'Limits on',a8,1x,f9.3,1x,f9.3)
1046  format(1x,'Limits on',a8,1x,'exclude',1x,a8)

c     ------------------------------------------
c     query for input filename and open

50    write(*,*)'Enter next data filename (use MS-DOS filename) or quit'
      read(*,1000)filename
      if ((filename.eq.'quit').or.(filename.eq.'QUIT'))go to 990
      open(unit=10,file=filename,action='READ',
      &     form='FORMATTED',status='old',err=75)
      write(*,*)filename
      write(21,*)'------------------'
      write(21,*)filename
```

```
      write(21,*)'------------------'
1000  format(a25)
      go to 80
75    write(*,*)'File does not exist'
      go to 50

c     ----------------------------------------
c     If one of the parameters is LOCATION, determine type.
c     If LOCATION is station number along DLS, loctype =0
C     If LOCATION is along alcove, loctype = alcove # (can be #.1, #.2)
c     If other, then loctype = -1.
80    loctype = -1.0
      Do i = 1,iname
            if (dataname(i).eq.'LOCATION') then
                  write(*,*)'Is LOCATION a station number along the',
      +' DLS, alcove, or other - d, a, or o'
                  read(*,*)ans
                  if ((ans.eq.'d').or.(ans.eq.'D')) then
                        loctype = 0.0
                  else
                        if ((ans.eq.'a').or.(ans.eq.'A')) then
                              write(*,*)'Which alcove #'
                              read(*,*)loctype
                        else
                              loctype = -1.0
                        end if
                  end if
            end if
      End Do
c     ----------------------------------------

c     find header line (between rows of asteriks)
82    read(10,1001)first
      if (first.ne.'****') go to 82
1001  format(a4)

c     ----------------------------------------

c     find location where different data starts (use header)

      do i=1,limtxt
            icolumn(i)=0
      end do

      read(10,1020)datastring
      read(datastring,1021)(onestring(istring),istring=1,250)
      do i = 1,limtxt
            read(dataname(i),1022)(onedata(idata),idata=1,8)
            do istring = 1,250
             do idata = 1,8
              if( (onestring(istring+idata-1).ne.onedata(idata)) )
      &           go to 98
             end do
98           if (idata.eq.9) go to 99
            end do
99          if (istring.ne.251) then
                  icolumn(i)=istring
```

```
            else
                  write(*,1023)dataname(i)
                  pause
                  stop
            end if
      end do

      write(*,1003)(icolumn(i),i=1,iname)
      write(21,1003)(icolumn(i),i=1,iname)
1003  format(1x,'Column headers at',10(1x,i5))
1020  format(a250)
1021  format(250(a1))
1022  format(8(a1))
1023  format(1x,a8,' not found in file -- stopped')


c     ---------------------------------------
c     move forward to first data row

105   read(10,1001)first
      if (first.ne.'****') go to 105
c     skip blank line
      read(10,1002)all
1002  format(a72)

c     ----------------------------------------

c     read data lines from file and get values
      rowused = 0
      row = 0
200   read(10,2001,err=900,end=900)datastring
      if (datastring.eq.'End of Report') go to 900
      if (datastring.eq.'             ') go to 200
      row = row + 1
      write(*,*)row

c     first see if data is within text-defined limits
      do ii=(limnum+1),limtxt
            loc = icolumn(ii)
            read(datastring,1999)all
            if (all.eq.limtext(ii)) then
                  write(*,2025)row,dataname(ii),limtext(ii)
                  write(*,2026)datastring
                  write(21,2025)row,dataname(ii),limtext(ii)
                  write(21,2026)datastring
                  go to 200
            end if
      end do

      do i=1,iname
            loc = icolumn(i)
            read(datastring,1999)avalue

c           first check to see if any are not recorded (NR) or
c           special (*) -- exclude NR and use *
            read(avalue,2002)(onedata(idata),idata=1,8)
            do idata=1,8
```

```
                  if ((onedata(idata)).eq.'N') then
c                 the entire line is excluded
                   write(*,2020)row,onedata(idata),onedata(idata+1),
      &                 dataname(i)
                   write(21,2020)row,onedata(idata),onedata(idata+1),
      &                 dataname(i)
                   go to 200
                  end if
            if (onedata(idata).eq.'*') then
                  write(*,2021)row
                  write(21,2021)row
                  read(avalue,2024)avalue
            end if
            end do

c           check if entry is a station number -- if loctype = 0
c           LOCATION is station number along DLS, if loctype = +#
c           LOCATION is along alcove (number loctype)

            If ((loctype.ge.0.0).and.(dataname(i).eq.'LOCATION')) then
c                 get station number
                  read(avalue,2005)(plus(ip),ip=1,8)
                  do ip=1,8
                        if (plus(ip).eq.'+') go to 215
                  end do
215               read(avalue,2010)astat,all,bstat
                  read(astat,*)anum
                  read(bstat,2005)(plus(im),im=1,(8-ip))
                  do im = 1, (8-ip)
                        if (plus(im).eq.'-') go to 216
                  end do
216               read(bstat,2011)astat
                  read(astat,*)bnum

                  if (loctype.eq.0.0) then
                        value(i) = anum*100 + bnum
                  else
                        value(i) = loctype*10000 + anum*100 + bnum
                  end if
            else
                  read(avalue,*)value(i)
            end if

      end do

2001  format(a250)
c     change a8 to larger value if number is more than 8 digits
1999  format(<loc-1>x,a8)
2002  format(8(a1))
2005  format(8(a1))
2010  format(a<ip-1>,a1,a8)
2011  format(a<im-1>)
2020  format(1x,'Row',i5,' has a ',a1,a1,' for ',a8,
      &           ' - this data row is not used')
2021  format(1x,'Row',i5,' has a * - printed value will be used')
2024  format(a<idata-1>)
```

```
2025  format(1x,'Row',i5,' excluded ',a8,' is ',a8)
2026  format(5x,a40)


c     write data to output file and read next line

      write(20,3000)(value(i),i=1,iname)

3000  format(10(f10.3))
      rowused = rowused + 1
      go to 200

900   close(10)
      write(*,*)row,' rows read and',rowused,' used'
      write(21,*)row,' rows read and',rowused,' used'
c     ask for next file
      go to 50

990   close(20)
      close(21)
      pause
      stop
999   write(*,*)'Error in file formatting -- stopped'
      write(*,*)'Error in file formatting -- stopped'
      close(20)
      close(21)
      close(10)
      pause
      stop
      end
```

Source code for Software Routine Meshbd.f, Version 1.0

```
      program Meshbd
c
c change mesh order
c change z direction from "-" to "+"
c change interface at top boundary
c
      implicit double precision (a-h,o-z)
      integer nc,ne
      integer me,mc,nh
      parameter (me  = 88500)
      parameter (mc  =310000)
      parameter (nh  = 1000)
      double precision voll(mc),aa(mc)
      character*5 dddd,ccc,cccc
      character*5 texte
      character*1 text
      character*5 wrd,wrd2
      nx=12
      ny=30
      nz=42
c
      open(unit=2,file='MESH',status='unknown')
      rewind(2)
      texte='ELEME'
      write(2,'(a)')texte
c
      open(unit=1,file='meshm.mes',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
c
      ne = 0
      nesum = 0
      locat = 1
      do i=1,nx
        do j=1,ny
         do k=1,nz
           ne=ne+1
           read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     dddd,texte,voll(ne),v1,x1,y1,z1
         nesum = nesum + 1
           if(k.eq.nz)then
             texte='BUNOF'
           elseif(k.eq.1)then
             texte='DRAIN'
           voll(ne)=1.0e+50
           else
             texte='SOILF'
           endif
           write(2,'(a,10x,a,2e10.4,10x,3e10.4)')
     &     dddd,texte,voll(ne),v1,x1,y1,-z1

          enddo
```

```
        enddo
      enddo

c
      read(1,*)
      read(1,'(a)')cccc
      write(2,*)
      cccc='CONNE'
      write(2,'(a)')cccc

      nc=0
      locat =1
30    read(1,'(2a,19x,a,4e10.4)',end=40)wrd,wrd2,text,v1,v2,aa(nc+1),v3
      if(wrd.ne. '     ' .and.wrd.ne.'+++  ')then
       if(wrd(1:2).eq.'B7'.and.wrd2(1:2).eq.'B7')aa(nc+1)=100.0
      write(2,'(2a,19x,a,4e10.4)')wrd,wrd2,text,v1,v2,aa(nc+1),v3
         nc=nc+1
         goto 30
      endif

c
      texte='     '
      write(2,'(a)')texte
      close(1)
      close(2)
      stop
   40 stop'Premature End of File'
      end
```

Source code for Software Routine mininipresf.f, Version 1.0

```
      program mininipresf
c for 12x30x42 mesh (5.23x15x20 m)
c make incon block from
c MESH
c
      implicit double precision(a-h,o-z)
      character name*5,head*80
      dimension xfield(100,100,100,20),class(100)
c read mod.in
      nz=42
      ny=30
      nx=12
      ndual=1
      do i=1,nx
      do j=1,ny
         do k=1,nz
        do kk=1,ndual
          xfield(i,j,k,kk)=4.e-18
        enddo
       enddo
       enddo
      enddo

c read kfield
      open(unit=1,file='permcut.dat',status='old')
      rewind(1)
      read(1,*)
      do k=1,nz
      do j=1,ny
      do i=1,nx
      read(1,*)xfield(i,j,k,1)
      enddo
      enddo
      enddo
      close(1)
c check input field
      do k=1,100
      class(k)=0.0d0
      enddo
      write(*,*)'   number of classes'
      read(*,*)inums
      xmins=1.0e+30
      xmaxs=-1.0e+30
         do k=2,nz-1
         do j=1,ny
         do i=1,nx
         if(xfield(i,j,k,1).lt.xmins)xmins=xfield(i,j,k,1)
         if(xfield(i,j,k,1).gt.xmaxs)xmaxs=xfield(i,j,k,1)
         enddo
         enddo
         enddo
         write(*,*)'min= ',xmins
         write(*,*)'max= ',xmaxs
      xmeans=0.0d0
      sss=0.0d0
```

```
      dxs=(xmaxs-xmins)/dble(inums)
      iouts=0
      do kk=2,nz-1
      do j=1,ny
      do i=1,nx
         do k=1,inums
         x1=xmins+(k-1)*dxs
         x2=xmins+k*dxs
         if(xfield(i,j,kk,1).ge.x1.and.xfield(i,j,kk,1).le.x2)then
         class(k)=class(k)+1.0d0
         goto 12
         endif
         enddo
         enddo
      iouts=iouts+1
   12 enddo
      enddo

      do k=2,nz-1
      do j=1,ny
      do i=1,nx
      xmeans=xmeans + xfield(i,j,k,1)
      enddo
      enddo
      enddo

      xmeans=xmeans/dble(12*30*40)

      do k=2,nz-1
      do j=1,ny
      do i=1,nx
      sss=sss+(xfield(i,j,k,1)-xmeans)*(xfield(i,j,k,1)-xmeans)
      enddo
      enddo
      enddo

      sss=sss/dble(12*30*40)
      sssd=sqrt(sss)

      do i=1,inums
      class(i)=class(i)/dble(12*30*40)
      enddo
      open(unit=3,file='perm.tec',status='unknown')
      rewind(3)
      write(3,*)'MEAN IN Log10 ',xmeans
      write(3,*)'STANTARD DIVIATION IN Log10 and Ln ',sssd,2.3026*sssd
      write(3,*)'TITLE="FREQUENCY OF PERMEABILITY"'
      write(3,*)'VARIABLES = "LOG10 PERM", "FREQUENCY"'
      write(3,*)'ZONE, I = ',2*inums
         do k=1,inums
         write(3,'(2e15.6)')xmins+(k-1)*dxs,class(k)/dxs
         write(3,'(2e15.6)')xmins+k*dxs,class(k)/dxs
         enddo
         close(3)

c read and write incon
      open(unit=1,file='MESH',status='old')
```

```
      rewind(1)
      open(unit=2,file='inconsf.out',status='unknown')
      rewind(2)
c
      read(1,'(a)')dddd
      write(2,*)'INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY '
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      read(1,'(a,14x,a,2e10.4,10x,3e12.6)')name
c      sat=sini

      if(k.eq.1)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,2,kk))
      porm=0.000124
      sat=0.011
      alfa0=0.
      else
      xkf=xfield(i,j,1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif
      goto 99
      endif

      if(k.eq.nz)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,nz-1,kk))
      porm=0.000124
      sat=0.011
      alfa0=0.
      else
      xkf=xfield(i,j,nz,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500
      endif
      goto 99
      endif


      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,k,kk))
      porm=0.000124
      sat=0.011
      alfa0=0.
      else
      xkf=xfield(i,j,k-1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif
```

```
   99 continue
c
      por=porm
      write(2,'(a5,2i5,e15.9,5e10.4)')name,idum,idum,porm,xkf,alfa0
      write(2,'(2e20.14)')sat
      enddo
      enddo
      enddo
      enddo
      texte='     '
      write(2,'(a)')texte
      write(2,*)
      close(1)
      close(2)
      stop
      end
```

Source code for Software Routine mddf.f, Version 1.0

```
      program mddf
c cut round tunnel with radius R in 3D FD mesh
c truncate elements and connections within R
c cut for refined mesh
c write connectivity list for tunnel bound elements to tunnel element
c file: 'drift3d.con'
c write list with coordinates of tunnel bound elements in
c file: 'drift3d.coor'
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      parameter (me  =160000)
      parameter (mc  =700000)
      parameter (nh  = 128)
      character*5 ,id(me)
      double precision x(3,me)
      double precision a(mc),rdrift,dx,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc
      integer ne1
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      write(*,*)'radius tunnel'
      read(*,*)rdrift
      call rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      stop
      end
c
      subroutine rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      character*5 id(me)
      character*5 irock
      character*1 text
      double precision x(3,me)
      double precision a(mc),rdrift,rr,v1,v2,v3,dy,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
```

```
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc,neall,nz
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      open(unit=1,file='MESH',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
      open(unit=10,file='MESHsf.new',status='unknown')
      rewind(10)
      write(10,'(a)') wrd
      open(unit=3,file='driftff.con',status='unknown')
      rewind(3)
      open(unit=9,file='driftff.coor',status='unknown')
      rewind(9)
      open(unit=7,file='driftff.tec',status='unknown')
      rewind(7)
      write(3,*)'CONNE'
      write(9,*)'COOR'
      ne = 0
      neall=0
      nz=42
      locat = 1
 10   read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),irock,vol,v1,x1,y1,z1

      neall=neall+1
      x(1,ne+1) = x1
      x(2,ne+1) = y1
      x(3,ne+1) = z1
      if(id(ne+1) .ne. '     ') then
         if(vol .eq. 0.) goto 10
c
      dy=dabs(y1-7.5)
c      dy=idint(dy/0.5)*0.5+0.25
      dz=dabs(z1- 7.75)
c      dz=idint(dz/0.5)*0.5+0.25
c
c check radius
         rr=sqrt(dy*dy+dz*dz)
         if(rr.lt.rdrift) goto 10
         write(10,'(a,10x,a,2e10.4,10x,3e10.4)')
     &         id(ne + 1),irock,vol,v1,x1,y1,z1
         ne = ne + 1
         ind(ne) = ne
```

```
         if(x1 .ne. 0.0 .or. y1 .ne. 0.0 .or. z1 .ne. 0.0) locat = 0
         goto 10
      endif
      call hash(id,ind,hsh,ne,nh,ec)
      if(locat .ne. 0) then
         do i = 1, ne
            x(2,i) = -999.d0
            x(3,i) = -999.d0
         enddo
         open(unit=2,file='locat',status='old')
         read(2,'(a)',end=50) wrd
         if(wrd .ne. 'locat' .and. wrd .ne. 'LOCAT') then
            stop 'no locat in locat'
         endif
 20      read(2,'(a5,5x,2f20.0)',end=50) wrd, y1, z1
         if(wrd .ne. '     ') then
            nu1 = ihash(wrd, id,ind,hsh,ne,nh)
            if(nu1 .eq. 0) then
               goto 20
            endif
            x(2,nu1) = y1
            x(3,nu1) = z1
            goto 20
         endif
         write(10,*)
      endif
      if(ne .ge. me) then
         stop 'Exceeded maximum number of elements'
      endif
      ixyz=3
      ne1 = 0
      ne2 = ne
      do while(ne1 .lt. ne2)
         x1 = x(1,ne1+1)
         y1 = x(2,ne1+1)
         z1 = x(3,ne1+1)
         if(y1 .ne. -999.d0 .or. z1 .ne. -999.d0) then
            if(ne1 .eq. 0) then
              xhi = x1
              xlo = x1
              yhi = y1
              ylo = y1
              zhi = z1
              zlo = z1
          else
              xhi = max(xhi,x1)
              xlo = min(xlo,x1)
              yhi = max(yhi,y1)
              ylo = min(ylo,y1)
              zhi = max(zhi,z1)
              zlo = min(zlo,z1)
          endif
            ne1 = ne1 + 1
         else if(x(2,ne2) .eq. -999.d0 .and. x(3,ne2) .eq. -999.d0) then
            ne2 = ne2 - 1
         else
            wrd = id(ne1+1)
```

```
            x(1,ne1+1) = x(1,ne2)
            x(2,ne1+1) = x(2,ne2)
            x(3,ne1+1) = x(3,ne2)
            id(ne1+1) = id(ne2)
            x(1,ne2) = x1
            x(2,ne2) = y1
            x(3,ne2) = z1
            id(ne2) = wrd
         endif
      enddo
      if(ixyz .eq. 0) then
         xhi = xhi - xlo
         yhi = yhi - ylo
         zhi = zhi - zlo
         if(zhi .le. min(xhi,yhi)) then
            ixyz = 3
         else if (yhi .le. min(xhi,zhi)) then
            ixyz = 2
         else
            ixyz = 1
         endif
      endif
      if(ixyz .eq. 2) then
         do i = 1, ne1
            x(2,i) = x(3,i)
         enddo
      elseif(ixyz .eq. 1) then
         do i = 1, ne1
            x(1,i) = x(2,i)
            x(2,i) = x(3,i)
         enddo
      endif
      call hash(id,ind,hsh,ne,nh,ec)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'conne' .and. wrd .ne. 'CONNE') then
         stop 'no conne in MESH'
      endif
      write(10,*)
      write(10,'(a)')wrd
      nc = 0
      do i = 1, ne
         ec(i) = 0
      enddo
 30   read(1,'(2a,19x,a,4e10.4)',end=40) wrd,wrd2,text,v1,v2,a(nc+1),v3
      if(wrd .ne. '     ' .and. wrd .ne. '+++  ') then
         nu1 = ihash(wrd, id,ind,hsh,ne,nh)
         nu2 = ihash(wrd2,id,ind,hsh,ne,nh)
         if(nu1 .eq. 0) then
c            write(6,60) wrd,nc+1
            if(nu2 .ne. 0)then
            wrd='DRI 1'
            text='3'
c  no gravity
           write(3,'(2a,19x,a,4e10.4)')
     &      wrd2,wrd,text,v2,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd2,x(1,nu2),x(2,nu2),
     &      x(3,nu2),v3
```

```
            endif
            goto 30
         else if(nu2 .eq. 0) then
c            write(6,60) wrd2,nc+1
            if(nu1 .ne. 0)then
            wrd2='DRI 1'
            text='3'
            write(3,'(2a,19x,a,4e10.4)')
     &      wrd,wrd2,text,v1,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd,x(1,nu1),x(2,nu1),
     &      x(3,nu1),v3
            endif
            goto 30
         endif
      write(10,'(2a,19x,a,4e10.4)') wrd,wrd2,text,v1,v2,a(nc+1),v3
      nc=nc+1
         e(1,nc) = nu1
         e(2,nc) = nu2
         if(nu1 .gt. ne1 .or. nu2 .gt. ne1) goto 30
         cc(1,nc) = ec(nu1)
         cc(2,nc) = ec(nu2)
         ec(nu1) = nc
         ec(nu2) = nc
         goto 30
      endif
      if(nc .ge. mc) then
         stop 'Exceeded maximum number of connections'
      endif
      close(unit=1)
      close(unit=10)
      close(unit=3)
      close(unit=9)
      ne = ne1
      return
 40   stop 'Premature EOF on MESH'
 50   stop 'Premature EOF on locat'
 60   format(' Unknown element "',a,'" at connection',i8)
      end
      subroutine hash(id,ind,hsh,ne,nh,h)
      implicit none
      integer ne, nh
      character*5 id(ne)
      integer ind(ne)
      integer h(ne)
      integer hsh(nh)
      character*5 w1
      integer i,i1,i2,j,k,n
      do j = 1, ne
         w1 = id(j)
         if(w1(4:4) .eq. '0') w1(4:4) = ' '
         n = 0
         do i = 1, 5
            n = n + i * ichar(w1(i:i))
         enddo
         h(j) = mod(n,nh) + 1
      enddo
      i1 = 1
```

```
do i = 1, nh
   i2 = i1
   do j = i2, ne
      k = ind(j)
      if(h(k) .eq. i) then
         h(k) = 0
         ind(j) = ind(i1)
         ind(i1) = k
         i1 = i1 + 1
      endif
   enddo
   hsh(i) = i1
enddo
return
end
integer function ihash(wrd,id,ind,hsh,ne,nh)
implicit none
integer ne, nh
character*5 id(ne)
integer ind(ne)
integer hsh(nh)
character*5 wrd, w1, w2
integer i,i1,i2,n
w1 = wrd
if(w1(4:4) .eq. '0') w1(4:4) = ' '
n = 0
do i = 1, 5
   n = n + i * ichar(w1(i:i))
enddo
n = mod(n,nh) + 1
i1 = 1
if(n .gt. 1) i1 = hsh(n - 1)
i2 = hsh(n) - 1
do i = i1, i2
   ihash = ind(i)
   w2 = id(ihash)
   if(w2(4:4) .eq. '0') w2(4:4) = ' '
   if(w1 .eq. w2) then
      if(ihash .gt. ne) ihash = 0
      return
   endif
enddo
ihash = 0
return
end
```

Source code for Software Routine mk_gener.f, Version 1.0

```
      program mk_gener
c makes gener block for heater in drift and wing heaters
      implicit double precision (a-h,o-z)
      integer ne,ixyz
      integer me,mc,nh
      parameter (me  =160000)
      parameter (mc  =700000)
      parameter (nh  = 2500)
      character*5 id(me)
      character*5 tfeld(me)
      double precision x(3,me)
      double precision a(mc),voll(me)
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      call rmesh
     &(rdrift,ne,id,tfeld,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz,voll)
      stop
      end
c
      subroutine rmesh
     &(rdrift,ne,id,tfeld,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz,voll)
      implicit double precision (a-h,o-z)
      character*5 id(me)
      character*5 texte
      character*5 tfeld(me)
      double precision x(3,me)
      double precision a(mc)
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      double precision voll(me)
      character*5 wrd
c
      write(*,*)'Infiltration Rate in mm/a'
      read(*,*)rinf
c
      open(unit=2,file='GENERsf',status='unknown')
      rewind(2)
      texte='GENER'
      write(2,'(a)')texte
      iw1=0
      iw2=0
c
      open(unit=1,file='MESHSF',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
c
```

```
      ne = 0
      nesum = 0
      locat = 1
 10   read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),texte,voll(ne+1),v1,x1,y1,z1
      nesum = nesum + 1
      if(id(ne+1) .ne. '     ') then
c        if(vol .eq. 0.) goto 10
         if(texte.eq.'BUNOF')ne = ne + 1
       goto 10
      endif
c
      volsum=0.0
      do i=1,ne
      volsum=volsum+voll(i)
      enddo
c
      do i=1,ne
      fakt=voll(i)/volsum
      write(2,'(2a,i4,25x,a,e10.4)')
     &id(i),'I',i,'WATE ',fakt*rinf*78.45*3.171e-08
      enddo
c
      close(1)
      close(2)
      stop
   40 stop'Premature End of File'
      end
```

Source code for Software Routine mk_scale_k.f, Version 1.0

```
      program mk_scale_k
c for 12x30x42 mesh (5.23x15x20 m)
c
      implicit double precision(a-h,o-z)
      character name*5,head*80
      dimension xfield(100,100,100,20),class(100)
c read mod.in
      nz=42
      ny=30
      nx=12
      ndual=1

c read kfield
      open(unit=1,file='permd5_r3.dat',status='old')
      rewind(1)
      read(1,*)
      do k=1,nz
      do j=1,ny
      do i=1,nx
      read(1,*)xfield(i,j,k,1)
      enddo
      enddo
      enddo
      close(1)

      do k=1,nz
      do j=1,ny
      do i=1,nx
      xmeans=xmeans + xfield(i,j,k,1)
      enddo
      enddo
      enddo

      xmeans=xmeans/dble(12*30*42)

      do k=1,nz
      do j=1,ny
      do i=1,nx
      sss=sss+(xfield(i,j,k,1)-xmeans)*(xfield(i,j,k,1)-xmeans)
      enddo
      enddo
      enddo

      sss=sss/dble(12*30*42)
      sssd=sqrt(sss)

      open(unit=3,file='perm.new',status='unknown')
      rewind(3)
      write(3,*)'MEAN IN Log10 ',xmeans

      do k=1,nz
      do j=1,ny
      do i=1,nx
      scalek=(xfield(i,j,k,1)-xmeans)*0.860+xmeans
      write(3,*)scalek
```

```
      enddo
      enddo
      enddo

      close(1)
      close(3)
      stop
      end
```

Source code for Software Routine mininipresf_ir.f, Version 1.0

```
      program mininipresf_ir
c for 12x30x42 mesh (5.23x15x20 m, with rock fall)
c make incon block from
c MESH
c
      implicit double precision(a-h,o-z)
      character name*5,head*80
      dimension xfield(100,100,100,20),class(100)
c read mod.in
      nz=42
      ny=30
      nx=12
      ndual=1
      do i=1,nx
      do j=1,ny
         do k=1,nz
        do kk=1,ndual
          xfield(i,j,k,kk)=4.e-18
        enddo
       enddo
       enddo
      enddo

c read kfield
      open(unit=1,file='permcut.dat',status='old')
      rewind(1)
      read(1,*)
      do k=1,nz
      do j=1,ny
      do i=1,nx
      read(1,*)xfield(i,j,k,1)
      enddo
      enddo
      enddo
      close(1)
c check input field
      do k=1,100
      class(k)=0.0d0
      enddo
      write(*,*)'   number of classes'
      read(*,*)inums
      xmins=1.0e+30
      xmaxs=-1.0e+30
         do k=2,nz-1
         do j=1,ny
         do i=1,nx
         if(xfield(i,j,k,1).lt.xmins)xmins=xfield(i,j,k,1)
         if(xfield(i,j,k,1).gt.xmaxs)xmaxs=xfield(i,j,k,1)
         enddo
         enddo
         enddo
         write(*,*)'min= ',xmins
         write(*,*)'max= ',xmaxs
      xmeans=0.0d0
      sss=0.0d0
```

```
      dxs=(xmaxs-xmins)/dble(inums)
      iouts=0
      do kk=2,nz-1
      do j=1,ny
      do i=1,nx
         do k=1,inums
         x1=xmins+(k-1)*dxs
         x2=xmins+k*dxs
         if(xfield(i,j,kk,1).ge.x1.and.xfield(i,j,kk,1).le.x2)then
         class(k)=class(k)+1.0d0
         goto 12
         endif
         enddo
         enddo
      iouts=iouts+1
   12 enddo
      enddo

      do k=2,nz-1
      do j=1,ny
      do i=1,nx
      xmeans=xmeans + xfield(i,j,k,1)
      enddo
      enddo
      enddo

      xmeans=xmeans/dble(12*30*40)

      do k=2,nz-1
      do j=1,ny
      do i=1,nx
      sss=sss+(xfield(i,j,k,1)-xmeans)*(xfield(i,j,k,1)-xmeans)
      enddo
      enddo
      enddo

      sss=sss/dble(12*30*40)
      sssd=sqrt(sss)

      do i=1,inums
      class(i)=class(i)/dble(12*30*40)
      enddo
      open(unit=3,file='perm.tec',status='unknown')
      rewind(3)
      write(3,*)'MEAN IN Log10 ',xmeans
      write(3,*)'STANTARD DIVIATION IN Log10 and Ln ',sssd,2.3026*sssd
      write(3,*)'TITLE="FREQUENCY OF PERMEABILITY"'
      write(3,*)'VARIABLES = "LOG10 PERM", "FREQUENCY"'
      write(3,*)'ZONE, I = ',2*inums
         do k=1,inums
         write(3,'(2e15.6)')xmins+(k-1)*dxs,class(k)/dxs
         write(3,'(2e15.6)')xmins+k*dxs,class(k)/dxs
         enddo
         close(3)

c read and write incon
      open(unit=1,file='MESH',status='old')
```

```
      rewind(1)
      open(unit=2,file='inconsf.out',status='unknown')
      rewind(2)
c
      read(1,'(a)')dddd
      write(2,*)'INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY '
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      read(1,'(a,14x,a,2e10.4,10x,3e12.6)')name
c      sat=sini

      if(k.eq.1)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,2,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif
      goto 99
      endif

      if(k.eq.nz)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,nz-1,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,nz,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500
      endif
      goto 99
      endif

      yyy=(j-1)*0.5+0.25
      zzz=(k-2)*0.5+0.25

      if(kk.eq.1)then
      if((yyy.gt.3.0.and.yyy.lt.11.5).and.
     j   (zzz.gt.3.5.and.zzz.lt.12.0))then
      xkf=10.0*(10.0**((xfield(i,j,k,kk)+13.05)*0.860-13.05))
        alfa0=100.
      else
      xkf=(10.0**xfield(i,j,k,kk))
        alfa0=1000.
      end if
```

```
      porm=0.000124
      sat=0.011
      else
      xkf=xfield(i,j,k-1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif

   99 continue
c
      por=porm
      write(2,'(a5,2i5,e15.9,5e10.4)')name,idum,idum,porm,xkf,alfa0
      write(2,'(2e20.14)')sat
      enddo
      enddo
      enddo
      enddo
      texte='     '
      write(2,'(a)')texte
      write(2,*)
      close(1)
      close(2)
      stop
      end
```

Source code for Software Routine mddf_CC8.f, Version 1.0

```
      program mddf_cc8
c cut round tunnel with radius R in 3D FD mesh and rock fall from the crown
c truncate elements and connections within R
c cut for refined mesh
c write connectivity list for tunnel bound elements to tunnel element
c file: 'drift3d.con'
c write list with coordinates of tunnel bound elements in
c file: 'drift3d.coor'
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      parameter (me  =160000)
      parameter (mc  =700000)
      parameter (nh  = 128)
      character*5 ,id(me)
      double precision x(3,me)
      double precision a(mc),rdrift,dx,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc
      integer ne1
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      write(*,*)'radius tunnel'
      read(*,*)rdrift
      call rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      stop
      end
c
      subroutine rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      character*5 id(me)
      character*5 irock
      character*1 text
      double precision x(3,me)
      double precision a(mc),rdrift,rr,v1,v2,v3,dy,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
```

```
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc,neall,nz
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      open(unit=1,file='MESH',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
      open(unit=10,file='MESHsf.new',status='unknown')
      rewind(10)
      write(10,'(a)') wrd
      open(unit=3,file='driftff.con',status='unknown')
      rewind(3)
      open(unit=9,file='driftff.coor',status='unknown')
      rewind(9)
      open(unit=7,file='driftff.tec',status='unknown')
      rewind(7)
      write(3,*)'CONNE'
      write(9,*)'COOR'
      ne = 0
      neall=0
      nz=42
      locat = 1
 10   read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),irock,vol,v1,x1,y1,z1

      neall=neall+1
      x(1,ne+1) = x1
      x(2,ne+1) = y1
      x(3,ne+1) = z1
      if(id(ne+1) .ne. '     ') then
         if(vol .eq. 0.) goto 10
c
      dy=dabs(y1-7.5)
c      dy=idint(dy/0.5)*0.5+0.25
      dz=dabs(z1- 7.75)
c      dz=idint(dz/0.5)*0.5+0.25
c
c check radius
         rr=sqrt(dy*dy+dz*dz)
         if(rr.lt.rdrift) goto 10

      if(x1.gt.2.2.and.x1.lt.3.0)then
      if(y1.gt.7.1.and.y1.lt.7.9)then
      if(z1.gt.10.20.and.z1.lt.11.30)then
```

```
         go to 10

      end if
      end if
      end if


         write(10,'(a,10x,a,2e10.4,10x,3e10.4)')
     &         id(ne + 1),irock,vol,v1,x1,y1,z1
         ne = ne + 1
         ind(ne) = ne
         if(x1 .ne. 0.0 .or. y1 .ne. 0.0 .or. z1 .ne. 0.0) locat = 0
         goto 10
      endif
      call hash(id,ind,hsh,ne,nh,ec)
      if(locat .ne. 0) then
         do i = 1, ne
            x(2,i) = -999.d0
            x(3,i) = -999.d0
         enddo
         open(unit=2,file='locat',status='old')
         read(2,'(a)',end=50) wrd
         if(wrd .ne. 'locat' .and. wrd .ne. 'LOCAT') then
            stop 'no locat in locat'
         endif
 20      read(2,'(a5,5x,2f20.0)',end=50) wrd, y1, z1
         if(wrd .ne. '     ') then
            nu1 = ihash(wrd, id,ind,hsh,ne,nh)
            if(nu1 .eq. 0) then
               goto 20
            endif
            x(2,nu1) = y1
            x(3,nu1) = z1
            goto 20
         endif
         write(10,*)
      endif
      if(ne .ge. me) then
         stop 'Exceeded maximum number of elements'
      endif
      ixyz=3
      ne1 = 0
      ne2 = ne
      do while(ne1 .lt. ne2)
         x1 = x(1,ne1+1)
         y1 = x(2,ne1+1)
         z1 = x(3,ne1+1)
         if(y1 .ne. -999.d0 .or. z1 .ne. -999.d0) then
            if(ne1 .eq. 0) then
              xhi = x1
              xlo = x1
              yhi = y1
              ylo = y1
              zhi = z1
              zlo = z1
       else
```

```
            xhi = max(xhi,x1)
            xlo = min(xlo,x1)
            yhi = max(yhi,y1)
            ylo = min(ylo,y1)
            zhi = max(zhi,z1)
            zlo = min(zlo,z1)
         endif
           ne1 = ne1 + 1
        else if(x(2,ne2) .eq. -999.d0 .and. x(3,ne2) .eq. -999.d0) then
           ne2 = ne2 - 1
        else
           wrd = id(ne1+1)
           x(1,ne1+1) = x(1,ne2)
           x(2,ne1+1) = x(2,ne2)
           x(3,ne1+1) = x(3,ne2)
           id(ne1+1) = id(ne2)
           x(1,ne2) = x1
           x(2,ne2) = y1
           x(3,ne2) = z1
           id(ne2) = wrd
        endif
     enddo
     if(ixyz .eq. 0) then
        xhi = xhi - xlo
        yhi = yhi - ylo
        zhi = zhi - zlo
        if(zhi .le. min(xhi,yhi)) then
           ixyz = 3
        else if (yhi .le. min(xhi,zhi)) then
           ixyz = 2
        else
           ixyz = 1
        endif
     endif
     if(ixyz .eq. 2) then
        do i = 1, ne1
           x(2,i) = x(3,i)
        enddo
     elseif(ixyz .eq. 1) then
        do i = 1, ne1
           x(1,i) = x(2,i)
           x(2,i) = x(3,i)
        enddo
     endif
     call hash(id,ind,hsh,ne,nh,ec)
     read(1,'(a)',end=40) wrd
     if(wrd .ne. 'conne' .and. wrd .ne. 'CONNE') then
        stop 'no conne in MESH'
     endif
     write(10,*)
     write(10,'(a)')wrd
     nc = 0
     do i = 1, ne
        ec(i) = 0
     enddo
 30  read(1,'(2a,19x,a,4e10.4)',end=40) wrd,wrd2,text,v1,v2,a(nc+1),v3
     if(wrd .ne. '     ' .and. wrd .ne. '+++  ') then
```

```
         nu1 = ihash(wrd, id,ind,hsh,ne,nh)
         nu2 = ihash(wrd2,id,ind,hsh,ne,nh)
         if(nu1 .eq. 0) then
c            write(6,60) wrd,nc+1
            if(nu2 .ne. 0)then
            wrd='DRI 1'
            text='3'
c  no gravity
           write(3,'(2a,19x,a,4e10.4)')
     &      wrd2,wrd,text,v2,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd2,x(1,nu2),x(2,nu2),
     &      x(3,nu2),v3
            endif
            goto 30
         else if(nu2 .eq. 0) then
c            write(6,60) wrd2,nc+1
            if(nu1 .ne. 0)then
            wrd2='DRI 1'
            text='3'
            write(3,'(2a,19x,a,4e10.4)')
     &      wrd,wrd2,text,v1,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd,x(1,nu1),x(2,nu1),
     &      x(3,nu1),v3
            endif
            goto 30
         endif
      write(10,'(2a,19x,a,4e10.4)') wrd,wrd2,text,v1,v2,a(nc+1),v3
      nc=nc+1
         e(1,nc) = nu1
         e(2,nc) = nu2
         if(nu1 .gt. ne1 .or. nu2 .gt. ne1) goto 30
         cc(1,nc) = ec(nu1)
         cc(2,nc) = ec(nu2)
         ec(nu1) = nc
         ec(nu2) = nc
         goto 30
      endif
      if(nc .ge. mc) then
         stop 'Exceeded maximum number of connections'
      endif
      close(unit=1)
      close(unit=10)
      close(unit=3)
      close(unit=9)
      ne = ne1
      return
 40   stop 'Premature EOF on MESH'
 50   stop 'Premature EOF on locat'
 60   format(' Unknown element "',a,'" at connection',i8)
      end
      subroutine hash(id,ind,hsh,ne,nh,h)
      implicit none
      integer ne, nh
      character*5 id(ne)
      integer ind(ne)
      integer h(ne)
      integer hsh(nh)
```

```
      character*5 w1
      integer i,i1,i2,j,k,n
      do j = 1, ne
         w1 = id(j)
         if(w1(4:4) .eq. '0') w1(4:4) = ' '
         n = 0
         do i = 1, 5
            n = n + i * ichar(w1(i:i))
         enddo
         h(j) = mod(n,nh) + 1
      enddo
      i1 = 1
      do i = 1, nh
         i2 = i1
         do j = i2, ne
            k = ind(j)
            if(h(k) .eq. i) then
               h(k) = 0
               ind(j) = ind(i1)
               ind(i1) = k
               i1 = i1 + 1
            endif
         enddo
         hsh(i) = i1
      enddo
      return
      end
      integer function ihash(wrd,id,ind,hsh,ne,nh)
      implicit none
      integer ne, nh
      character*5 id(ne)
      integer ind(ne)
      integer hsh(nh)
      character*5 wrd, w1, w2
      integer i,i1,i2,n
      w1 = wrd
      if(w1(4:4) .eq. '0') w1(4:4) = ' '
      n = 0
      do i = 1, 5
         n = n + i * ichar(w1(i:i))
      enddo
      n = mod(n,nh) + 1
      i1 = 1
      if(n .gt. 1) i1 = hsh(n - 1)
      i2 = hsh(n) - 1
      do i = i1, i2
         ihash = ind(i)
         w2 = id(ihash)
         if(w2(4:4) .eq. '0') w2(4:4) = ' '
         if(w1 .eq. w2) then
            if(ihash .gt. ne) ihash = 0
            return
         endif
      enddo
      ihash = 0
      return
      end
```

Source code for Software Routine mddf_CS8.f, Version 1.0

```
      program mddf_cs8
c cut round tunnel with radius R in 3D FD mesh with rock fall around the spring
line
c truncate elements and connections within R
c cut for refined mesh
c write connectivity list for tunnel bound elements to tunnel element
c file: 'drift3d.con'
c write list with coordinates of tunnel bound elements in
c file: 'drift3d.coor'
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      parameter (me  =160000)
      parameter (mc  =700000)
      parameter (nh  = 128)
      character*5 ,id(me)
      double precision x(3,me)
      double precision a(mc),rdrift,dx,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc
      integer ne1
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      write(*,*)'radius tunnel'
      read(*,*)rdrift
      call rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      stop
      end
c
      subroutine rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      character*5 id(me)
      character*5 irock
      character*1 text
      double precision x(3,me)
      double precision a(mc),rdrift,rr,v1,v2,v3,dy,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
```

```
      integer hsh(nh)
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc,neall,nz
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      open(unit=1,file='MESH',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
      open(unit=10,file='MESHsf.new',status='unknown')
      rewind(10)
      write(10,'(a)') wrd
      open(unit=3,file='driftff.con',status='unknown')
      rewind(3)
      open(unit=9,file='driftff.coor',status='unknown')
      rewind(9)
      open(unit=7,file='driftff.tec',status='unknown')
      rewind(7)
      write(3,*)'CONNE'
      write(9,*)'COOR'
      ne = 0
      neall=0
      nz=42
      locat = 1
 10   read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),irock,vol,v1,x1,y1,z1

      neall=neall+1
      x(1,ne+1) = x1
      x(2,ne+1) = y1
      x(3,ne+1) = z1
      if(id(ne+1) .ne. '     ') then
         if(vol .eq. 0.) goto 10
c
      dy=dabs(y1-7.5)
c      dy=idint(dy/0.5)*0.5+0.25
      dz=dabs(z1- 7.75)
c      dz=idint(dz/0.5)*0.5+0.25
c
c check radius
         rr=sqrt(dy*dy+dz*dz)
         if(rr.lt.rdrift) goto 10

      if(x1.gt.2.2.and.x1.lt.3.0)then
      if(y1.gt.3.9.and.y1.lt.4.9)then
```

```
      if(z1.gt.7.5.and.z1.lt.8.5)then

         go to 10

      end if
      end if
      end if


         write(10,'(a,10x,a,2e10.4,10x,3e10.4)')
     &         id(ne + 1),irock,vol,v1,x1,y1,z1
         ne = ne + 1
         ind(ne) = ne
         if(x1 .ne. 0.0 .or. y1 .ne. 0.0 .or. z1 .ne. 0.0) locat = 0
         goto 10
      endif
      call hash(id,ind,hsh,ne,nh,ec)
      if(locat .ne. 0) then
         do i = 1, ne
            x(2,i) = -999.d0
            x(3,i) = -999.d0
         enddo
         open(unit=2,file='locat',status='old')
         read(2,'(a)',end=50) wrd
         if(wrd .ne. 'locat' .and. wrd .ne. 'LOCAT') then
            stop 'no locat in locat'
         endif
 20      read(2,'(a5,5x,2f20.0)',end=50) wrd, y1, z1
         if(wrd .ne. '     ') then
            nu1 = ihash(wrd, id,ind,hsh,ne,nh)
            if(nu1 .eq. 0) then
               goto 20
            endif
            x(2,nu1) = y1
            x(3,nu1) = z1
            goto 20
         endif
         write(10,*)
      endif
      if(ne .ge. me) then
         stop 'Exceeded maximum number of elements'
      endif
      ixyz=3
      ne1 = 0
      ne2 = ne
      do while(ne1 .lt. ne2)
         x1 = x(1,ne1+1)
         y1 = x(2,ne1+1)
         z1 = x(3,ne1+1)
         if(y1 .ne. -999.d0 .or. z1 .ne. -999.d0) then
            if(ne1 .eq. 0) then
              xhi = x1
              xlo = x1
              yhi = y1
              ylo = y1
              zhi = z1
              zlo = z1
```

```
          else
              xhi = max(xhi,x1)
              xlo = min(xlo,x1)
              yhi = max(yhi,y1)
              ylo = min(ylo,y1)
              zhi = max(zhi,z1)
              zlo = min(zlo,z1)
          endif
            ne1 = ne1 + 1
         else if(x(2,ne2) .eq. -999.d0 .and. x(3,ne2) .eq. -999.d0) then
            ne2 = ne2 - 1
         else
            wrd = id(ne1+1)
            x(1,ne1+1) = x(1,ne2)
            x(2,ne1+1) = x(2,ne2)
            x(3,ne1+1) = x(3,ne2)
            id(ne1+1) = id(ne2)
            x(1,ne2) = x1
            x(2,ne2) = y1
            x(3,ne2) = z1
            id(ne2) = wrd
         endif
      enddo
      if(ixyz .eq. 0) then
         xhi = xhi - xlo
         yhi = yhi - ylo
         zhi = zhi - zlo
         if(zhi .le. min(xhi,yhi)) then
            ixyz = 3
         else if (yhi .le. min(xhi,zhi)) then
            ixyz = 2
         else
            ixyz = 1
         endif
      endif
      if(ixyz .eq. 2) then
         do i = 1, ne1
            x(2,i) = x(3,i)
         enddo
      elseif(ixyz .eq. 1) then
         do i = 1, ne1
            x(1,i) = x(2,i)
            x(2,i) = x(3,i)
         enddo
      endif
      call hash(id,ind,hsh,ne,nh,ec)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'conne' .and. wrd .ne. 'CONNE') then
         stop 'no conne in MESH'
      endif
      write(10,*)
      write(10,'(a)')wrd
      nc = 0
      do i = 1, ne
         ec(i) = 0
      enddo
 30   read(1,'(2a,19x,a,4e10.4)',end=40) wrd,wrd2,text,v1,v2,a(nc+1),v3
```

```
      if(wrd .ne. '     ' .and. wrd .ne. '+++  ') then
         nu1 = ihash(wrd, id,ind,hsh,ne,nh)
         nu2 = ihash(wrd2,id,ind,hsh,ne,nh)
         if(nu1 .eq. 0) then
c            write(6,60) wrd,nc+1
            if(nu2 .ne. 0)then
            wrd='DRI 1'
            text='3'
c  no gravity
          write(3,'(2a,19x,a,4e10.4)')
     &      wrd2,wrd,text,v2,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd2,x(1,nu2),x(2,nu2),
     &      x(3,nu2),v3
            endif
            goto 30
         else if(nu2 .eq. 0) then
c            write(6,60) wrd2,nc+1
            if(nu1 .ne. 0)then
            wrd2='DRI 1'
            text='3'
            write(3,'(2a,19x,a,4e10.4)')
     &      wrd,wrd2,text,v1,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd,x(1,nu1),x(2,nu1),
     &      x(3,nu1),v3
            endif
            goto 30
         endif
      write(10,'(2a,19x,a,4e10.4)') wrd,wrd2,text,v1,v2,a(nc+1),v3
      nc=nc+1
         e(1,nc) = nu1
         e(2,nc) = nu2
         if(nu1 .gt. ne1 .or. nu2 .gt. ne1) goto 30
         cc(1,nc) = ec(nu1)
         cc(2,nc) = ec(nu2)
         ec(nu1) = nc
         ec(nu2) = nc
         goto 30
      endif
      if(nc .ge. mc) then
         stop 'Exceeded maximum number of connections'
      endif
      close(unit=1)
      close(unit=10)
      close(unit=3)
      close(unit=9)
      ne = ne1
      return
 40   stop 'Premature EOF on MESH'
 50   stop 'Premature EOF on locat'
 60   format(' Unknown element "',a,'" at connection',i8)
      end
      subroutine hash(id,ind,hsh,ne,nh,h)
      implicit none
      integer ne, nh
      character*5 id(ne)
      integer ind(ne)
      integer h(ne)
```

```
      integer hsh(nh)
      character*5 w1
      integer i,i1,i2,j,k,n
      do j = 1, ne
         w1 = id(j)
         if(w1(4:4) .eq. '0') w1(4:4) = ' '
         n = 0
         do i = 1, 5
            n = n + i * ichar(w1(i:i))
         enddo
         h(j) = mod(n,nh) + 1
      enddo
      i1 = 1
      do i = 1, nh
         i2 = i1
         do j = i2, ne
            k = ind(j)
            if(h(k) .eq. i) then
               h(k) = 0
               ind(j) = ind(i1)
               ind(i1) = k
               i1 = i1 + 1
            endif
         enddo
         hsh(i) = i1
      enddo
      return
      end
      integer function ihash(wrd,id,ind,hsh,ne,nh)
      implicit none
      integer ne, nh
      character*5 id(ne)
      integer ind(ne)
      integer hsh(nh)
      character*5 wrd, w1, w2
      integer i,i1,i2,n
      w1 = wrd
      if(w1(4:4) .eq. '0') w1(4:4) = ' '
      n = 0
      do i = 1, 5
         n = n + i * ichar(w1(i:i))
      enddo
      n = mod(n,nh) + 1
      i1 = 1
      if(n .gt. 1) i1 = hsh(n - 1)
      i2 = hsh(n) - 1
      do i = i1, i2
         ihash = ind(i)
         w2 = id(ihash)
         if(w2(4:4) .eq. '0') w2(4:4) = ' '
         if(w1 .eq. w2) then
            if(ihash .gt. ne) ihash = 0
            return
         endif
      enddo
      ihash = 0
      return
```

```
end
```

Source code for Software Routine mddf_cc.f, Version 1.0

```
      program mddf_cc
c cut round tunnel with radius R in 3D FD mesh with 3-m rock failure in the roof
c truncate elements and connections within R
c cut for refined mesh
c write connectivity list for tunnel bound elements to tunnel element
c file: 'drift3d.con'
c write list with coordinates of tunnel bound elements in
c file: 'drift3d.coor'
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      parameter (me  =160000)
      parameter (mc  =700000)
      parameter (nh  = 128)
      character*5 ,id(me)
      double precision x(3,me)
      double precision a(mc),rdrift,dx,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc
      integer ne1
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      write(*,*)'radius tunnel'
      read(*,*)rdrift
      call rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      stop
      end
c
      subroutine rmesh(rdrift,ne,id,x,ec,e,a,cc,hsh,ind,me,mc,nh,ixyz)
      implicit none
      integer ne,ixyz
      integer me,mc,nh
      character*5 id(me)
      character*5 irock
      character*1 text
      double precision x(3,me)
      double precision a(mc),rdrift,rr,v1,v2,v3,dy,dz
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
```

```
      integer ind(me)
      double precision vol
      double precision x1, y1, z1
      double precision xhi, yhi, zhi
      double precision xlo, ylo, zlo
      character*5 wrd, wrd2
      integer i
      integer ihash
      integer locat
      integer nc,neall,nz
      integer ne1
      integer ne2
      integer nu1
      integer nu2
      open(unit=1,file='MESH',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
      open(unit=10,file='MESHsf.new',status='unknown')
      rewind(10)
      write(10,'(a)') wrd
      open(unit=3,file='driftff.con',status='unknown')
      rewind(3)
      open(unit=9,file='driftff.coor',status='unknown')
      rewind(9)
      open(unit=7,file='driftff.tec',status='unknown')
      rewind(7)
      write(3,*)'CONNE'
      write(9,*)'COOR'
      ne = 0
      neall=0
      nz=42
      locat = 1
 10   read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),irock,vol,v1,x1,y1,z1

      neall=neall+1
      x(1,ne+1) = x1
      x(2,ne+1) = y1
      x(3,ne+1) = z1
      if(id(ne+1) .ne. '     ') then
         if(vol .eq. 0.) goto 10
c
      dy=dabs(y1-7.5)
c      dy=idint(dy/0.5)*0.5+0.25
      dz=dabs(z1- 7.75)
c      dz=idint(dz/0.5)*0.5+0.25
c
c check radius
         rr=sqrt(dy*dy+dz*dz)
         if(rr.lt.rdrift) goto 10

      if(x1.gt.2.2.and.x1.lt.3.0)then

      if((y1.gt.7.0.and.y1.lt.7.5).and.(z1.gt.8.0.and.z1.lt.11.0))then
```

```
         go to 10
      elseif((y1.gt.6.5.and.y1.lt.7.0).and.(z1.gt.8.0.and.z1.lt.11.5))then
         go to 10
      elseif((y1.gt.6.0.and.y1.lt.6.5).and.(z1.gt.8.0.and.z1.lt.12.0))then
         go to 10
      elseif((y1.gt.5.5.and.y1.lt.6.0).and.(z1.gt.8.0.and.z1.lt.13.0))then
         go to 10
      end if

      end if


         write(10,'(a,10x,a,2e10.4,10x,3e10.4)')
     &         id(ne + 1),irock,vol,v1,x1,y1,z1
         ne = ne + 1
         ind(ne) = ne
         if(x1 .ne. 0.0 .or. y1 .ne. 0.0 .or. z1 .ne. 0.0) locat = 0
         goto 10
      endif
      call hash(id,ind,hsh,ne,nh,ec)
      if(locat .ne. 0) then
         do i = 1, ne
            x(2,i) = -999.d0
            x(3,i) = -999.d0
         enddo
         open(unit=2,file='locat',status='old')
         read(2,'(a)',end=50) wrd
         if(wrd .ne. 'locat' .and. wrd .ne. 'LOCAT') then
            stop 'no locat in locat'
         endif
 20      read(2,'(a5,5x,2f20.0)',end=50) wrd, y1, z1
         if(wrd .ne. '     ') then
            nu1 = ihash(wrd, id,ind,hsh,ne,nh)
            if(nu1 .eq. 0) then
               goto 20
            endif
            x(2,nu1) = y1
            x(3,nu1) = z1
            goto 20
         endif
         write(10,*)
      endif
      if(ne .ge. me) then
         stop 'Exceeded maximum number of elements'
      endif
      ixyz=3
      ne1 = 0
      ne2 = ne
      do while(ne1 .lt. ne2)
         x1 = x(1,ne1+1)
         y1 = x(2,ne1+1)
         z1 = x(3,ne1+1)
         if(y1 .ne. -999.d0 .or. z1 .ne. -999.d0) then
            if(ne1 .eq. 0) then
              xhi = x1
              xlo = x1
              yhi = y1
```

```
            ylo = y1
            zhi = z1
            zlo = z1
        else
            xhi = max(xhi,x1)
            xlo = min(xlo,x1)
            yhi = max(yhi,y1)
            ylo = min(ylo,y1)
            zhi = max(zhi,z1)
            zlo = min(zlo,z1)
        endif
          ne1 = ne1 + 1
      else if(x(2,ne2) .eq. -999.d0 .and. x(3,ne2) .eq. -999.d0) then
          ne2 = ne2 - 1
      else
          wrd = id(ne1+1)
          x(1,ne1+1) = x(1,ne2)
          x(2,ne1+1) = x(2,ne2)
          x(3,ne1+1) = x(3,ne2)
          id(ne1+1) = id(ne2)
          x(1,ne2) = x1
          x(2,ne2) = y1
          x(3,ne2) = z1
          id(ne2) = wrd
      endif
   enddo
   if(ixyz .eq. 0) then
      xhi = xhi - xlo
      yhi = yhi - ylo
      zhi = zhi - zlo
      if(zhi .le. min(xhi,yhi)) then
          ixyz = 3
      else if (yhi .le. min(xhi,zhi)) then
          ixyz = 2
      else
          ixyz = 1
      endif
   endif
   if(ixyz .eq. 2) then
      do i = 1, ne1
          x(2,i) = x(3,i)
      enddo
   elseif(ixyz .eq. 1) then
      do i = 1, ne1
          x(1,i) = x(2,i)
          x(2,i) = x(3,i)
      enddo
   endif
   call hash(id,ind,hsh,ne,nh,ec)
   read(1,'(a)',end=40) wrd
   if(wrd .ne. 'conne' .and. wrd .ne. 'CONNE') then
      stop 'no conne in MESH'
   endif
   write(10,*)
   write(10,'(a)')wrd
   nc = 0
   do i = 1, ne
```

```
         ec(i) = 0
      enddo
 30   read(1,'(2a,19x,a,4e10.4)',end=40) wrd,wrd2,text,v1,v2,a(nc+1),v3
      if(wrd .ne. '     ' .and. wrd .ne. '+++  ') then
         nu1 = ihash(wrd, id,ind,hsh,ne,nh)
         nu2 = ihash(wrd2,id,ind,hsh,ne,nh)
         if(nu1 .eq. 0) then
c            write(6,60) wrd,nc+1
            if(nu2 .ne. 0)then
            wrd='DRI 1'
            text='3'
c  no gravity
          write(3,'(2a,19x,a,4e10.4)')
     &      wrd2,wrd,text,v2,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd2,x(1,nu2),x(2,nu2),
     &      x(3,nu2),v3
            endif
            goto 30
         else if(nu2 .eq. 0) then
c            write(6,60) wrd2,nc+1
            if(nu1 .ne. 0)then
            wrd2='DRI 1'
            text='3'
            write(3,'(2a,19x,a,4e10.4)')
     &      wrd,wrd2,text,v1,1.0e-08,a(nc+1),0.0!v3
            write(9,'(a,5x,4e12.6)')wrd,x(1,nu1),x(2,nu1),
     &      x(3,nu1),v3
            endif
            goto 30
         endif
      write(10,'(2a,19x,a,4e10.4)') wrd,wrd2,text,v1,v2,a(nc+1),v3
      nc=nc+1
         e(1,nc) = nu1
         e(2,nc) = nu2
         if(nu1 .gt. ne1 .or. nu2 .gt. ne1) goto 30
         cc(1,nc) = ec(nu1)
         cc(2,nc) = ec(nu2)
         ec(nu1) = nc
         ec(nu2) = nc
         goto 30
      endif
      if(nc .ge. mc) then
         stop 'Exceeded maximum number of connections'
      endif
      close(unit=1)
      close(unit=10)
      close(unit=3)
      close(unit=9)
      ne = ne1
      return
 40   stop 'Premature EOF on MESH'
 50   stop 'Premature EOF on locat'
 60   format(' Unknown element "',a,'" at connection',i8)
      end
      subroutine hash(id,ind,hsh,ne,nh,h)
      implicit none
      integer ne, nh
```

```
      character*5 id(ne)
      integer ind(ne)
      integer h(ne)
      integer hsh(nh)
      character*5 w1
      integer i,i1,i2,j,k,n
      do j = 1, ne
         w1 = id(j)
         if(w1(4:4) .eq. '0') w1(4:4) = ' '
         n = 0
         do i = 1, 5
            n = n + i * ichar(w1(i:i))
         enddo
         h(j) = mod(n,nh) + 1
      enddo
      i1 = 1
      do i = 1, nh
         i2 = i1
         do j = i2, ne
            k = ind(j)
            if(h(k) .eq. i) then
               h(k) = 0
               ind(j) = ind(i1)
               ind(i1) = k
               i1 = i1 + 1
            endif
         enddo
         hsh(i) = i1
      enddo
      return
      end
      integer function ihash(wrd,id,ind,hsh,ne,nh)
      implicit none
      integer ne, nh
      character*5 id(ne)
      integer ind(ne)
      integer hsh(nh)
      character*5 wrd, w1, w2
      integer i,i1,i2,n
      w1 = wrd
      if(w1(4:4) .eq. '0') w1(4:4) = ' '
      n = 0
      do i = 1, 5
         n = n + i * ichar(w1(i:i))
      enddo
      n = mod(n,nh) + 1
      i1 = 1
      if(n .gt. 1) i1 = hsh(n - 1)
      i2 = hsh(n) - 1
      do i = i1, i2
         ihash = ind(i)
         w2 = id(ihash)
         if(w2(4:4) .eq. '0') w2(4:4) = ' '
         if(w1 .eq. w2) then
            if(ihash .gt. ne) ihash = 0
            return
         endif
```

```
      enddo
      ihash = 0
      return
      end
```

Source code for Software Routine minrefine3df.f, Version 1.0

```
      program minrefine3df
c make incon block from inconsf.out
c and MESH (refined new mesh)
c
c
      implicit double precision(a-h,o-z)
      character*5 name,wrd
      character head*60
      character*1 text
      character*5 irock
      dimension x(160000),y(160000),z(160000)
      dimension por(70,45,55,5),xperm(70,45,55,5),
     j     xalfa(70,45,55,5)
      dimension xsat(70,45,55,5)
      character*5 id(160000)
      character*5 iinc(70,45,55,5)
c
c read refined mesh

      ndual=1

      open(unit=1,file='MESHsf.new',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
      ne = 0
   10 read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),irock,vol,v1,x1,y1,z1
      if(id(ne+1) .eq. '     ') goto 100
      ne = ne + 1
      x(ne) = x1
      y(ne) = y1
      z(ne) = z1
      goto 10
  100 close(1)
c
c read incon    (not refined)
      nx=12
      ny=30
      nz=42
c
      open(unit=1,file='inconsf.out',status='old')
      rewind(1)
      read(1,'(a60)')head
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      read(1,'(a5,2i5,e15.9,2e10.4)')
     &iinc(i,j,k,kk),idum,idum,por(i,j,k,kk),xperm(i,j,k,kk),
     j   xalfa(i,j,k,kk)
      read(1,'(e20.14)')xsat(i,j,k,kk)
      enddo
```

```
      enddo
      enddo
      enddo

c
      open(unit=2,file='INCONsf',status='unknown')
      rewind(2)
      write(2,'(a60)')head
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      do nn=1,ne
      if(id(nn).eq.iinc(i,j,k,kk))then
          write(2,'(a5,2i5,e15.9,2e10.4)')
     &     id(nn),idum,idum,por(i,j,k,kk),10.0*xperm(i,j,k,kk),
     &     xalfa(i,j,k,kk)
          write(2,'(e20.14)')xsat(i,j,k,kk)
        endif
      enddo
      enddo
      enddo
      enddo
      enddo


c
      write(2,*)
      close(1)
      close(2)
      stop
 40   stop 'Premature EOF on MESH'
      end
```

frac_calc V1.1
Routine/Macro Documentation Form*

Note: All relevant scientific notebook (SN) pages are included in this records package. In some instances, the included SN pages cross-reference other pages that are not included here because these were not essential to the documentation of this routine.

1. Name of routine/macro with version/OS/hardware environment:
   frac_calc / Version 1.1 / DOS (or Windows with DOS) / PC

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77 / FORTRAN Powerstation 4.0 (see SN YMP-LBNL-GSB-MC-1.1, p. 105)

3. Description and Test Plan.

   - Explain whether this is a routine or macro and describe what it does: (frac_calc is a routine)

The software routine frac_calc is a FORTRAN code which performs simple calculations using Detailed Line Survey (DLS) data including fracture location, strike, dip, and trace lengths above and below the traceline to compute fracture hydrologic properties. The user can select a minimum and maximum fracture length to include in the calculations. Version 1.1 is a minor revision of Version 1.0 and calculates additional fracture properties from the same data. The fracture properties calculated include fracture frequency, aperture and other properties. These properties are listed and the computation methods are described on pages 60-65 in YMP-LBNL-GSB-MC-1, pp. 102-104 in YMP-LBNL-GSB-MC-1.1, and p. 14 in YMP-LBNL-GSB-MC-1.2. To install the software, copy frac_calc11.f and datablk11.f from a disk onto the hard drive of a PC. Then, compile frac_calc using a FORTRAN 77 compiler and run executable.

Changes between Version 1.1 and 1.0 are discussed on p. 14 in YMP-LBNL-GSB-MC-1.2 for the source code (filename: frac_calc11.f) and on pp. 12-13 in YMP-LBNL-GSB-MC-1.2 for the parameter dimensions file (filename: datablk11.f).

This software routine is documented in the following scientific notebook pages (the order below provides a chronology of the documentation from Version 1.1 back to Version 1.0):

YMP-LBNL-GSB-MC-1.2	**pp. 14-16, 12-13**
Reference Binder YMP-LBNL-GSB-MC-1.2A	**pp. 67-87, 63-66**
YMP-LBNL-GSB-MC-1.1	**pp. 114-115, 105-109, 101-104**
YMP-LBNL-GSB-MC-1	**pp. 60-65**

Inputs:

The code is designed to use an ASCII input file. The first row is a header and is not read. Each row represents a single fracture. It must have five columns of data for each fracture – location (in meters), strike (in degrees), dip (in degrees), length above (in meters), and length below (in meters) – in that order. The fractures must be in increasing order of location (distance along the ESF, an alcove, or the ECRB). All values must be numbers (no text, except the first row). All values must be positive. The limit on size of the input values is that the strike must be less than 360 degrees and the dip must be less than 90 degrees. For other values, there are no limits except those for double precision parameters and computations.

- Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
  pp. 72-87, in Reference Binder YMP-LBNL-GSB-MC-1.2A for frac_calc.f, the source code.
  pp. 63-66, in Reference Binder YMP-LBNL-GSB-MC-1.2A for datablk11.f, the include file that sets parameter dimensions and values.

- Description of test(s) to be performed (be specific):
  A sample case using site data will be used to test the routine. The test case for Version 1.0 is rerun for Version 1.1 to test the new features as well as confirm that the previous computations

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are still performed correctly. The Version 1.0 test case included selecting a minimum fracture length of 1 meter to confirm that fractures smaller than 1 meter in the sample case will be excluded from the computations (the Version 1.0 test case is on pp. 105 – 108 in YMP-LBNL-GSB-MC-1.1). All new output from the output files all1.par and all2.par will be compared with computations performed using a calculator (previous output will be compared to Version 1.0). The acceptance criterion is that the values computed by hand and from the routine are the same within the round-off difference between the code and the calculator.

- Specify the range of input values to be used and why the range is valid:
  The input values are a direct sample from the TDMS (see p. 105 in YMP-LBNL-GSB-MC-1) after pre-processing using the routine Read_TDB. The sample input includes small and large fracture lengths and a range of strikes and dips that are representative of the fracture parameters found at Yucca Mtn.

4. **Test Results.**

- Output from test :
  Test results are shown on p. 15 in YMP-LBNL-GSB-MC-1.2 and in Reference Binder YMP-LBNL-GSB-MC-1.2A, pp. 67-71.

- Description of how the testing shows that the results are correct for the specified input:
  Values from Version 1.1 matched exactly with those from Version 1.0 (regression testing), see p. 15 in YMP-LBNL-MC-1.2. Calculated values for new fracture calculations (gmlen and intarea) matched with rounding to 3 decimal places (the output format of frac_calc).

- List limitations or assumptions to this test case and code in general:
  As noted above the fractures must be listed in order of their locations with increasing distances along a survey line.

- Electronic files identified by name and location (include disc if necessary):
  See pp. 15-16 in YMP-LBNL-GSB-MC-1.2. No electronic files submitted.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation. Pages from YMP-LBNL-GSB-MC-1.1 and YMP-LBN-GSB-MC-1 are for Version 1.0 and provide the necessary background information for Version 1.1. The original qualification and references for Version 1.0 are provided on pp. 114-115 of YMP-LBNL-GSB-MC-1.1.

MAINTAIN PAGES IN THIS ORDER:

This 2 page "Routine Documentation" summarization form	
YMP-LBNL-GSB-MC-1.2	**pp. 14-16, 12-13**
Reference Binder YMP-LBNL-GSB-MC-1.2A	**pp. 67-87, 63-66**
YMP-LBNL-GSB-MC-1.1	**pp. 114-115, 105-109, 101-104**
YMP-LBNL-GSB-MC-1	**pp. 60-65**

***Note that this supplement includes:**
-Addition of this 2-page "Routine Documentation" summarization form
-Addition of pp. 63-66, Reference Binder YMP-LBNL-GSB-MC-1.2A
-Addition of pp. 12-13, S/N YMP-LBNL-GSB-MC-1.2

3/1/2000

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PROJECT NAME MC-1.2 NOTEBOOK NO.

Computing Fracture Frequencies - Preliminary 7/21/99

The multi-user macro frac_calc Version 1.0 ~~was~~ MC 7/21/99 (YMP-LBNL-GSB-MC-1.1 p.114) was updated to reflect the new layering for the UZ model for FY99. Essentially

GSB MC 7/21/99

FY98	FY99
ptn 24 } ptn 25	ptn 24
ptn 26	→ ptn 25
ptn 27	→ ptn 26

The model layers for FY97, FY98 & FY99 are summarized in Reference Binder YMP-LBNL-~~MC~~GSB-MC-1.2A on pp. 52-54. MC 7/21/99

The assignment of ESF stations to model layers was also re-evaluated. An error was found in the assignment of layers for the South Ramp. The contacts given for the South Ramp are "exit" points whereas those for the North Ramp & Main Drift are "entrance" points. The South Ramp assignments were therefore shifted. In particular tsw35 was misassigned:

previous 57+29.2 – 63+08
correct 57+29.2 – 58+78.3

The original assignments are in YMP-LBNL-GSB-MC-1.1 pp. 36-39.

The new assignments are in Reference Binder YMP-LBNL-GSB-MC-1.2A pp. 55-58
These were reviewed by Jennifer Hinds on 3/24/99

Intervals that were less than 5 meters were considered too small & these data were excluded.

Reference Binder YMP-LBNL-GSB-MC-1.2A p.59 gives a summary of these assignments.

SIGNATURE DATE 19
READ AND UNDERSTOOD DATE 19

Fracture permeabilities in frac_calc were revised to reflect the new layer MC 7/21/99

	log k (k in m^2)
ptn 24	-11.53
ptn 25	-12.78
ptn 26	-12.66

old old previous values assigned to ptn 24 were for ptn 25 & considered analogous ∴ only old ptn 25 used for new ptn 24

The original fracture permeabilities are given in YMP-LBNL-GSB-MC-1.1 p. 61.

Page 65 in YMP-LBNL-GSB-MC-1.1 provides a summary of ~~where~~ the files and data used to determine fracture permeabilities. MC 7/21/99

Pages 53 - 54 in Reference Binder YMP-LBNL-GSB-1.2A show how the model layers have changed from FY98 to FY99.

2A

The file 'datablk.f' (see pp. 62-63 in YMP-LBNL-GSB-MC-1.1) which is part of 'frac_calc' was updated to reflect these changes and a new file was created 'datablk11.f' which is for Version 1.1 of frac_calc. ~~This file is included in Reference Binder YMP-LBNL-GSB-MC-1.2A pp.~~ MC 7/21/99

The assignment of ECRB stations to model layers was completed using the locations of lithostratigraphic contacts from MOL.19981229.0038. This is in Reference Binder YMP-LBNL-GSB-MC-1.2A pp. 60-62. The corresponding model layers are recorded on that page also. These were also put in 'datablk11.f' with a header of "9" (see p. 10)

The file "datablk11.f" is given in YMP-LBNL-GSB-MC-1.2A pp. 63-66. & stored on "nwt-cushey" in d:\code\~~frac_calc~~\frac_calc1.1 calc_frac MC 7/21/99

SIGNATURE [signature] DATE 7/21 19 99

READ AND UNDERSTOOD [signature] DATE 19

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Mc-1.2A

File 'datablk11.f'
File with data blocks for
frac_calc Version 1.1

Referenced on p. 13

```
c-----------------------------------------------------------------------
c     Includes data statements for assigning model layers for use in
c     the program frac_calc.f
c     Created by Mark Cushey

c     Made into a separate file 6/98
c     Original data statements created by MAC 4/98 - 5/98

c     Data statements added to identify subunits and later combine
c     subunits for each model layer.
c
c     MAC 6/16/98
c     The following assignment of stations for PTN (new UZ model layers)
c     is based my analysis of data in Table 2, CRWSM M&O, 1998.
c     See Scientific Notebook YMP-LBNL-GSB-MC-1.1 pages 8-9

c     MAC 6/25/98
c     Stations reassigned for TCw and TSw (new UZ model layers)
c     based on my analysis of data in Table 2, CRWSM M&O, 1998.
c     Also reassigned alcoves.
c     See Scientific Notebook YMP-LBNL-GSB-MC-1.1 pages 38-39, 47

c     MAC 7/98
c     Most recent fracture permeabilities are in d:\permeability\
c     properties\airk.xls which is linked to other data spreadsheets
c     See Scientific Notebook YMP-LBNL-GSB-MC-1.1 pages 34, 61

c     MAC V 1.1
c     Version 1.1 - reevaluated station assignments, assigned values
c     to 1999 Model layers, and added ECRB

c     Alcove stations are entered with Alcove # in the
c     ten thousandth location.  ECRB has a '9' in the ten
c     thousandth location.

c     First, set up arrays
c         ntotal is the total number of UZ model layers and
c         nlayers is the total number of segments along the ESF
c         for the data statements

      integer nlayers,ntotal
      parameter(nlayers=57,ntotal=16)
      integer modlayer(ntotal)
      double precision logairk(nlayers),unitsta(nlayers),
     +        unitend(nlayers)
      character*5 unitname(nlayers)

      data unitname /'tcw11'
     +    ,'tcw12','tcw12','tcw12','tcw12','tcw12'
     +    ,'tcw12'                                    !Alcove 3
     +    ,'tcw13','tcw13','tcw13','tcw13'
     +    ,'ptn21','ptn21','ptn21'
     +    ,'ptn22'                    ! no fracture data
     +    ,'ptn23'                    ! no fracture data
     +    ,'ptn24','ptn24','ptn24'
     +    ,'ptn25','ptn25'
     +    ,'ptn26','ptn26','ptn26','ptn26'
```


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```
     +    ,'ptn26','ptn26'                          ! Alcove 4
     +    ,'tsw31','tsw31','tsw31','tsw31'
     +    ,'tsw32','tsw32','tsw32','tsw32','tsw32'
     +    ,'tsw33','tsw33','tsw33','tsw33','tsw33','tsw33
     +    ,'tsw33'                                  !ECRB
     +    ,'tsw34','tsw34','tsw34','tsw34'
     +    ,'tsw34','tsw34','tsw34','tsw34','tsw34'    !Alcove 5 & 6
     +    ,'tsw34'                                  !ECRB
     +    ,'tsw35'
     +    ,'tsw35'                                  !ECRB
     +    ,'tsw36'                                  !ECRB
     +    ,'tsw37'                                  !ECRB
c    +    ,'burst'
     +    /
      data modlayer / 1,2,8
     +                ,12,15,16,17,20,22
     +                ,28,32,37,44,54,56,57
c     +   ,58
     +    /
c     station for start and end of unit in meters & log airk (m2)
      data unitsta /348.8                          !tcw11
     +    ,61.7,441.9,6725.5,6769.4,7514.2              !tcw12
     +    ,30003.00                                     !tcw12 alcove 3
     +    ,776.5,6718.5,6761.4,7507.8                   !tcw13
     +    ,793.6,6697.5,7495.4                          !ptn21
     +    ,0.0                          !ptn22
     +    ,0.0                                          !ptn23 - no data
     +    ,875.8,6680.7,7481.3                                  !ptn24
     +    ,894.6,7476.3                                 !ptn25
     +    ,1021.0,6637.5,6996.5,7451.9             !ptn26
     +    ,40000.0,40029.55                             !ptn26 alcove 4
     +    ,1075.7,6632.8,6990.3,7440.0                  !tsw31
     +    ,1191.0,6507.7,6527.4,6885.0,7341.5               !tsw32
     +    ,1716.0,6308.0,6327.5,6791.8,7167.5,7290.0  !tsw33
     +    ,90000.0                          !tsw33 ECRB
     +    ,2720.0,5878.3,7057.4,7143.0                  !tsw34
     +    ,50000.0,51000.0,52000.0,60000.0,61000.0      !tsw34 alc 5 & 6
     +    ,91015.0                                      !tsw34 ECRB
     +    ,5729.2                                       !tsw35
     +    ,91444.0                              !tsw35 ECRB
     +    ,92326.0                              !tsw36/37 ECRB
     +    ,92326.0                              !tsw36/37 ECRB
c     +   ,4000.0
     +    /
      data unitend /435.2                          !tcw11
     +    ,198.6,776.5,6761.4,6787.5,7875.0             !tcw12
     +    ,30035.0                                      !tcw12 alcove 3
     +    ,793.6, 6725.5,6769.4,7514.2                      !tcw13
     +    ,869.3,6718.5,7507.8                          !ptn21
     +    ,0.0                                          !ptn22
     +    ,0.0                                          !ptn23 - no data
     +    ,894.6,6694.0,7494.0                                  !ptn24
     +    ,1021.0,7481.3                                !ptn25
     +    ,1075.7,6680.7,7057.4,7476.3             !ptn26
     +    ,40022.2,40051.0                              !ptn26 alcove 4
     +    ,1191.0,6637.5,6996.5,7451.9             !tsw31
     +    ,1716.0,6525.2,6632.8,6990.3,7440.0           !tsw32
```


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```
     +    ,2720.0,6324.2,6507.7,6885.0,7255.0,7341.5  !tsw33
     +    ,91015.0                                !tsw33 ECRB
     +    ,5729.2,6308.0,7100.0,7167.5                !tsw34
     +    ,50012.0,51015.0,52140.0,60024.0,61175.0    !tsw34 alc 5 & 6
     +    ,91444.0                        !tsw34 ECRB
     +    ,5878.3                                     !tsw35
     +    ,92326.0                        !tsw35 ECRB
     +    ,92583.0                        !tsw36 ECRB
     +    ,92583.0                        !tsw37 ECRB
c    +    ,5200.0
     +    /
      data logairk /-10.52                       !tcw11
     +    ,-11.28,-11.28,-11.28,-11.28,-11.28         !tcw12
     +    ,-11.28                                     !tcw12 alcove 3
     +    ,-11.34,-11.34,-11.34,-11.34                !tcw13
     +    ,-11.49,-11.49,-11.49                       !ptn21
     +    ,-12.52                                     !ptn22
     +    ,-12.52                                     !ptn23
     +    ,-11.53,-11.53,-11.53                               !ptn24
     +    ,-12.78,-12.78                              !ptn25
     +    ,-12.66,-12.66,-12.66,-12.66            !ptn26
     +    ,-12.66,-12.66                              !ptn26 alcove 4
     +    ,-12.20,-12.20,-12.20,-12.20                !tsw31
     +    ,-12.15,-12.15,-12.15,-12.15,-12.15         !tsw32
     +    ,-12.11,-12.11,-12.11,-12.11,-12.11,-12.11      !tsw33
     +    ,-12.11                         !tsw33 ECRB
     +    ,-12.80,-12.80,-12.80,-12.80                !tsw34
     +    ,-12.80,-12.80,-12.80,-12.80,-12.80         !tsw34 alc 5 & 6
     +    ,-12.80                         !tsw34 ECRB
     +    ,-12.04                                     !tsw35
     +    ,-12.04                         !tsw35 ECRB
     +    ,-11.87                         !tsw36 ECRB
     +    ,-11.87                         !tsw37 ECRB
c    +    ,-12.80
     +    /
```


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Version 1.1 of frac-calc 7/21/99

The following changes were made to Version 1.0
(see p. 114 in YMP-LBNL-GSB-MC-1.1
pp. 88-97 in YMP-LBNL-GSB-MC-1.1A)

- kf = kfrc(n) * freq
  was replaced with
  kf = kfrc(n) * aper
  see discussion on p. 103 in YMP-LBNL-GSB-MC-1.1 a1

- The parameters intarea & gmlen were added.

  gmlen - geometric mean of the fracture length
  mc 7/21/99 ~~While fracture lengths are being~~
  mc 7/21/99 ~~summed added~~
  mc 7/21/99 ~~gmlen = gmlen + log (trace length)~~ a11

$$\log[gmlen] = \frac{\sum_{i=1}^{n} \log(t_i)}{n}$$

  t_i = trace length for fracture i
  n = number of fractures

  intarea - fracture interface area

$$intarea = \frac{\sum_{i=1}^{n} \pi r_i^2}{(\text{~~block length~~})(gmlen)^2}$$

  mc 7/21/99 along wall

  essentially the fracture area divided by the block volume
  gmlen is used vertical length & depth into wall since these are unknown.
  r_i = radius of fracture i

- The output file "calibrate.par" was revised to include "gmlen" & "intarea" and was reformatted

* - All of these changes are marked with MAC V1.1 in the comments.

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Reran ~~V~~ MC 7/21/99 test case used for Version 1.0
(pages 101-108 YMP-LBNL-GSB-MC-1.1)
[using setting that limits calculations to 1m or larger]

		Version 1.1	Version 1.0
all1.par	min-m	0.43	0.43
	Min Use	1.00	1.00
	Max-m	8.00	8.00
	# Frac	5	5
	Spac-m	3.61	3.61
	SD Spac	2.78	2.78
	Fq-1/m	0.28	0.28
	SD Freq	0.21	0.21
	Leng-m	3.68	3.68
	SD Leng	2.91	2.91
	Intens	0.16	0.16
all2.par	Apr-um	504.	504.0
	Por-3D	5.93×10^{-5}	5.93×10^{-5}
	Por-2D	8.21×10^{-5}	8.21×10^{-5}
	Por-1D	1.40×10^{-4}	1.40×10^{-4}
	alpha	3.50×10^{-3}	3.50×10^{-3}
	kzz/kxx	1.69	1.69
	kyy/kxx	1.81	1.81
	kzz/kyy	0.93	0.93

~~MC 7/21/99 alpha~~
~~MC 7/21/99 Salpha~~

				Version 1.0 headers
Fr-porosity	8.21×10^{-5}		8.21×10^{-5}	Por-3D MC 7/21/99
Aperture	5.04×10^{-4} m	checks	504.0 μm	Apr-um
Frequency	0.28		0.28	Fq-1/m
Intr-Area	0.547		NA	
Gm-length	2.784		NA	
Fr-Alpha	3.50×10^{-3}		3.50×10^{-3}	alpha
SD-Alpha	2.41×10^{-4}		2.41×10^{-4}	sdalpha
Log Alpha	-2.54		MC 7/21/99 ~~-2.46~~ -2.54	loga
SD-Log Alpha	0.34		MC 7/21/99 ~~-3.62~~ 0.344	logsda

The output files & input files for this test case are in Reference Binder YMP-LBNL-GSB-MC-1.2A pp. 67-71. These are in d:/~~dlis~~ MC 7/21/99 /code/calc_frac/frac-calc11/Test Case

The above indicates that the calculations for Version 1.1

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check for those included in Version 1.0.
The two new computations are checked below.

(formulas on p 14)

fractures less than 1 m excluded

$$\log[\text{gmlen}] = [\log(8) + \log(5.17) + \log(1.11) + \cancel{\log(0.45)} + \log(1.3) + \log(2.8)] / \cancel{6}\ 5$$

MC 7/21/99

$$\text{gmlen} = 2.7836 \text{ m}$$

$$\text{intarea} = \pi\left[(4)^2 + (2.585)^2 + (0.555)^2 + \cancel{(0.215)^2} + (0.65)^2 + (1.4)^2\right] / (18.8)(2.7836)^2$$

$$= 0.5472 \text{ m}^2/\text{m}^3$$

frac_calc Version 1.1 gives

gmlen = 2.784 m

intarea = 0.547 m^2/m^3

frac_calc Version 1.1 checks

MC 7/21

The code frac_calc Version 1.1 is included in Reference Binder YMP-LBNL-GSB-MC-1.2A pp. 72-87

The file is on "nwd-cushey" in d:\code\~~frac-calc~~ calc_frac MC 7/21/99
frac_calc11

The filenames are frac_calc11.f & frac_calc11.exe

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filenames are
frac_calc11.f and
frac_calc11.exe
MC
9/23/99

Input and Output files for test case for frac_calc Version 1.1

Input: test.dat

Output: all1.par, all2.par, & calibrate.par

(S/N YMP LBNL GSB-MC-1.2A)

LOCATION	STRIKE	DIP	LENGTH A	LENGTH B
879.700	20.000	8.000	2.000	6.000
882.370	184.000	78.000	3.500	1.670
887.300	299.000	78.000	.000	1.110
893.860	20.000	49.000	.100	.330
893.920	22.000	80.000	.680	.620
894.130	20.000	67.000	1.200	1.600

For test case run, program excludes this because minimum fracture length cutoff is set to 1 m (see next page)

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selected cutoff length

Unit	<---Station--->		Min-m	MinUse	Max-m	#Frac	Spac-m	SDSpac	Fq-1/m	SDFreq	Leng-m	SDLeng	Intens
ptn24	875.80	894.60	.43	1.00	8.00	5	3.61	2.78	.28	.21	3.68	2.91	.16
	879.70	894.13		(m)				(m)		(1/m)		(m)	

3111.par

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Unit	MinUse	#Frac	Fg-1/m	Apr-um	Por-3D	Por-2D	Por-1D	alpha	kzz/kxx	kyy/kxx	kzz/kyy
ptn24	1.00	5	.28	504.	5.93E-05	8.21E-05	1.40E-04	3.50E-03	1.69	1.81	.93

all 2.par

70 74
MO 7/22/4

01/12/11 HJ 34 - 111

Unit	Min-Fr-Length	Fr-Porosity	Aperture	Frequency	Inter-Area	Gm-length	Pr-Alpha	SD-Alpha	LogAlpha	SD-LogAlpha
tcw11										
tcw12										
tcw13										
ptn21										
ptn22										
ptn23										
ptn24	1.00	8.21E-05	5.04E-04	.28	.547	2.784	3.50E-03	2.41E-04	-2.54	.34
ptn25										
ptn26										
tsw31										
tsw32										
tsw33										
tsw34										
tsw35										
tsw36										
tsw37										

Calibrate.par

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Code for
Frac_calc
Version 1.1

```
      program Frac_Calc

c     Version 1.1
c     All changes for Version 1.1 are indicated by MAC V1.1
c     See Scientific Notebook YMP-LBNL-GSB-MC-1.2 pages 14-16

c     Discussion for Version 1.0
c
c     The purpose of this program is to calculate means and variances
c     for fracture properties for UZ model layers based on detailed
c     line survey (DLS) data for the Exploratory Studies Facility (ESF)
c     that has been downloaded from the Technical Database (TDB).

c     This program was originally written by Eric Sonnenthal with
c     revisions and additions by Mark Cushey (4/98 to 7/98) which are
c     labeled MAC and dated.  Major additions include using data
c     statements and coding to combine subunits for model layers
c     internally in the program; calculating additional parameters;
c     program recalculates all numbers for each model layer each time
c     it is executed; calculate apertures; calculate alpha & log alpha
c     and its statistics; calculates spacing, frequencies and intensity
c     for selected interval lengths; new input format for direct reading
c     of data from TDB after processing through read_tdb.f; and new
c     output formats.

c       MAC V1.1 - updated pages below for references for Version 1.0
c     See Scientific Notebook YMP-LBNL-GSB-MC-1 pages 60-69, 124-125, 137
c     See Scientific Notebook YMP-LBNL-GSB-MC-1.1 pages 98, 101-108, 114-115
c     See Reference Binder YMP-LBNL-GSB-MC-1.1A pages 88-97, 98-106

c    - Mark Cushey 7/98
c-----------------------------------------------------------------------
c     Below comments by E.Sonnenthal
c...  Program to read USGS ESF data and calculate fracture geometries
c...  and densities for plotting (11/4/96: E. Sonnenthal)
c...  Components of hydraulic conductivity tensor (de Marsily, 1986)
c...  11/11/96 E. Sonnenthal
c...  revised 2/6/97 for a fracture size range
c     nf     = Number of fractures
c     blksiz = Block size (m)
c     kfrc   = Hydraulic conductivity of each fracture (m/s)
c     aper   = Aperture of each fracture (m)
c     strike = Strike of each fracture (azimuth in radians)
c     dip    = Dip of each fracture (dip in radians)
c     ktens  = Conductivity tensor (9 component)
c      k(9) = (kxx,kxy,kxz,kyx,kyy,kyz,kzx,kzy,kzz)
c         | kxx  kxy  kxz |
c         | kyx  kyy  kyz |
c         | kzx  kzy  kzz |
c-----------------------------------------------------------------------

c Commented out variables no longer used MAC 7/98
c     integer ni1,ni2
      integer i,k,ni,n,nn,nm1,nfr,nf,ns1,ns2
      parameter (nf = 50000)
      parameter (pi=3.1415926536d0)
      parameter (ni = 199)
```


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```
c Added MAC 4/13/98
      character*32 fname

c Commented out variables no longer used MAC 7/98
c       character*8 outfile, header2, fstat
c       character*200 header
c       integer dist1
c       double precision height(nf),dist2

      integer nfrint(ni),ns
      double precision blksiz,kf,sdsq,stkrad,diprad,proptf
      double precision fmin,fmax
      double precision kfrc(nf),aper(nf)
      double precision ktens(9)
      double precision kxx,kxy,kxz,kyx,kyy,kyz,kzx,kzy,kzz
      double precision endp1,endp2,totaltr,totalht,adip,bdip
      double precision dist(nf),nfrc(nf)
      double precision strike(nf),dip(nf),alen(nf),blen(nf)
      double precision atrace(nf),btrace(nf),trace(nf)
      double precision trlen,fmesf,frint,fgrp1,fgrp2,fsiz
      double precision trcmax,dipmin,dipmax,aperture
      double precision avgsp,frcint,varsp,sdspac
      double precision freq,sdfreq,frcvol,frcrad,frcpor,blkht,blkdp
      double precision sdlen,varlen,avglen,frarea,frcp2d
      character*1 ans1,ans2

c     MAC V1.1
      double precision intarea, gmlen

c
c-----------------------------------------------------------------------
c     Below added by MAC 4/98 - 5/98
c     Data statements added to identify subunits and later combine
c     subunits for each model layer.
c     Moved to include MAC 6/98 so that various combinations could be
c     used by simply using a different file for include
c     Note that alcove stations are entered with Alcove # in the
c     ten thousandth location.
c     Assignment for model layers based on CRWSM M&O, 1998
c     For most recent assignment see
c     Scientific Notebook YMP-LBNL-GSB-MC-1.1 pages 36-39.
c
c     Include file 'datablk.f' includes data statements for
c     unitname, modlayer, unitsta, unitend, and logairk

c     MAC V1.1
      include 'datablk11.f'
c
c     For testing, instead of 'datablk.f', include file 'uzmodel97.f'
c     for comparison with calculations performed for the July 97
c     milestone (Chapter 7, Sonnethal et. al, 1997) or include
c    'sweetkind.f' for comparison with calculations in
c     Sweetkind et. al (1997). Use the data files ericdls.dat and
c     sweetdls.dat, respectively.
c     include 'uzmodel97.f'
c     include 'sweetkind.f'
```


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```
c     MAC 7/98 For the more detailed PTn model layers use
c     include 'ptnblk.f'

c-----------------------------------------------------------------------
c Below added MAC 4/98 - 6/98
c     ntotal is the total number of UZ model layers
c     nlayers is the total number of segments along the ESF
c     Both are used for the data statements and are defined in the
c         file 'datablk.f'
c     npar is the number of parameters saved for calculating properties
c     for entire model layer
c     variables with 'int' are for calculating fracture properties for
c         intervals
c     variables for data statements [integer modlayer(ntotal);
c         double precision logairk(nlayers),unitsta(nlayers),
c         unitend(nlayers)] are in file 'datablk.f'

      integer layer,first,last,npar
c     MAC V1.1 changed npar from 16 to 18
      parameter(npar=18)
      double precision spac,frcpld,trcmin, combine,kzzkxx,kyykxx,kzzkyy,
     +    alpha,loga,logf,sdalpha
      dimension combine(nlayers,npar)
      character*5 outfile

      integer intn,intmax,intnfr,intlayer
      parameter(intmax=10000)
      double precision intfreq,intspace, intlength, inttrace
      dimension intfreq(intmax),intspace(intmax),intnfr(intmax),
     +    inttrace(intmax)

c...Input file name
2     print *, 'Enter fracture data filename: '
      read (*,*) fname
      open(unit=12,file=fname,status='old',err=5)
      go to 7
5     write(*,*)'File not found'
      go to 2
7     continue

c Removed call to station file -- all in one file MAC 4/13/98

c revised MAC 4/13/98 - starting and end points for model layers
c         now determined internally

c revised MAC 4/17/98 - changed input process
      dipmin = 0.d0
      dipmax = 90.d0
      ans1 = 'n'
      ans2 = 'y'
      write(*,*)'Enter minimum and maximum fracture length to use'
      read(*,*)fmin,fmax

c Added MAC 7/8/98 - query user for interval length
      write(*,*)'Enter interval length (in meters)'
      read(*,*)intlength
```


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```
c--------------------
c... Read station file - Removed MAC 4/13/98

c     MAC 4/98 open output files
      open(13,file='all1.par',status='unknown')
      open(14,file='all2.par',status='unknown')
      write(13,441)
      write(14,442)
      open(18,file='interval.par',status='unknown')
      write(18,1999)
      open(20,file='tmp.par')

c
c... Read fracture data file
c Rev MAC 4/13/98
      read (12,*)
      i = 0
10    i = i + 1
c     rev MAC 6/29/98 - Don't read in height
c     read(12,*,end=99)dist(i),strike(i),dip(i),atrace(i),
c    &    btrace(i),height(i)
      read(12,*,end=99)dist(i),strike(i),dip(i),atrace(i),
     &    btrace(i)
      go to 10
99    ns = i - 1
      dist(ns+1)=99999.9
      close(12)
c
c Added MAC 6/25/98
c     initialize combine
      do j=1,npar
          do i=1,nlayers
              combine(i,j) = 0d0
          end do
      end do

c----------------
c Added MAC 4/17/98
c     Loop through model layers, assiging station ranges
c     Define endp1, endp2, ns1, ns2
c
      DO layer = 1,nlayers
          endp1 = unitsta(layer)
          endp2 = unitend(layer)
          write(*,*)unitname(layer),endp1,endp2
          ns1 = 0
          ns2 = 0
          do i = 1,ns+1
              if (((dist(i).ge.endp1).and.(dist(i-1).lt.endp1))
     &        .or.((dist(i).ge.endp1).and.(i.eq.1)))
     &            ns1 = i
              if ((dist(i).gt.endp2).and.(dist(i-1).le.endp2))
     &            ns2 = i - 1
          end do
c         MAC V1.1 - changed 0.0 to 0
          if ((ns2-ns1).le.0) go to 999
          write(*,*)'     ',dist(ns1),dist(ns2)
```


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```
c         outfile = unitname(layer)
          outfile = 'dummy'
c         if ((layer.eq.48).or.(layer.eq.27)) then
c             outfile = unitname(layer)
c             write(*,*)'Tecplot file for',unitname(layer),
c    +            unitsta(layer),unitend(layer)
c         end if
c... Find size distribution for all fractures
      if(ans2.eq.'y')then
          fmesf = 0.3d0
          frint = 0.2d0
      do i = ns1,ns2
          trlen = atrace(i) + btrace(i)
        do k = 1, ni
          fgrp1 = fmesf + dble(k-1)*frint
          fgrp2 = fmesf + dble(k)*frint
          if(trlen.ge.fgrp1.and.trlen.lt.fgrp2)
     &        nfrint(k)=nfrint(k)+1
        enddo
      enddo
      endif
c

c Added MAC 4/98 find minimum trace length before excluding
      trcmin = fmax
      do i = ns1,ns2
        trcmin = min((atrace(i)+btrace(i)),trcmin)
      enddo

c... Find fractures that are within range if given
      n = 0
      nfr = 0
      do i = ns1,ns2
        if(dip(i).ge.dipmin.and.dip(i).le.dipmax.and.atrace(i)+
     +    btrace(i).ge.fmin.and.atrace(i)+btrace(i).le.fmax)
     +    then
            n = n + 1
            nfrc(n) = i
            nfr = n
        endif
      enddo
      if (nfr.le.1) go to 999

c
c... Calculate proportion of total fractures
      proptf = dble(nfr)/(dble(ns2-ns1+1))

c
c... Find total trace length
        do n = 1, nfr
          nn = nfrc(n)
          trace(n) = atrace(nn) + btrace(nn)
        enddo
c
c... Find maximum trace length
      trcmax = -1.d5
```


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```
      do n = 1, nfr
        trcmax = max(trace(n),trcmax)
      enddo

c
c... Length of fracture segment for plotting is 0.15 inch/meter
      do n = 1, nfr
        nn = nfrc(n)
        alen(n) = atrace(nn)*0.15d0
        blen(n) = btrace(nn)*0.15d0
      enddo
c
c... Calculate blocksize (interval length)
      blksiz = endp2 - endp1
      blkht = 6.d0
      blkdp = 6.d0
c
c Rev MAC 4/17/98 - moved perm, frac volume, porisity to after
c parameters

c Rev MAC 4/98 - zero sum parameters
      totalht = 0d0
      totaltr = 0d0
      ssqht = 0d0
      ssqtr = 0d0
      sspac = 0d0
      ssqsp = 0d0
      ssqlsp =0d0
      slgsp = 0d0
c     MAC V1.1
      gmlen = 0d0
      intarea = 0d0

c Added MAC 5/98
      do n = 1, intmax
          intspace(n) = 0d0
          intfreq(n) = 0d0
          intnfr(n) = 0
          inttrace(n) = 0d0
      end do
      intn = 0
      intlayer = 0
c
c... Calculate fracture parameters - loop through fractures
        do n = 1, nfr
          nn = nfrc(n)
          totaltr = trace(n) + totaltr
          ssqtr = trace(n)**2 + ssqtr

c         MAC V1.1
          gmlen = gmlen + dlog10(trace(n))

          if(n.gt.1)then
            nm1 = nfrc(n-1)
c rev MAC 4/13/98 - put in if
            spac = dabs(dist(nn)-dist(nm1))
            if (spac.eq.0.0) then
```


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```
              write(*,*)'station overlap',dist(nn),nn,nm1
            end if
2099  format(1x,a5,3(1x,f9.2))


            sspac = spac + sspac
c correction MAC 4/13/98
c             put in '+ slgsp' in place of '+ sspac'
c             put in dlog10 and if-then
            if (spac.ne.0.0) then
               slgsp = dlog10(spac) + slgsp
c correction MAC 4/98
c             put in '+ ssqlsp' in place of '+ ssqsp'
c             put in dlog10
              ssqlsp = (dlog10(spac))**2 + ssqlsp
            else
c rev MAC 4/98 for zero spacing use 0.005 m which is 1/2
c             of the measurement precision
              slgsp = dlog10(5d-3) + slgsp
              ssqlsp = (dlog10(5d-3))**2 + ssqlsp
            end if

            ssqsp = spac**2 + ssqsp


c added MAC 5/98 - for determining frequency and intensity over interval
c             added MAC 7/98 - if-then statment to prevent from
c             overextending interval boundary
              intn = INT((dist(nn)-endp1)/intlength)+1
              if ( (endp1+(intn*intlength)).le.endp2 ) then
                  if (intn.gt.intmax) then
                      write(*,*)'Max number of intervals exceeded -',
     +                        ' program stopped'
                      write(*,*)'Resize intmax - intmax,intn',intmax,intn
                      stop
                  end if
                  intspace(intn) = intspace(intn) + spac
                  intnfr(intn) = intnfr(intn) + 1
                  inttrace(intn) = inttrace(intn) + trace(n)
                  intlayer = intn
              end if
          endif
300       continue
        enddo

          avgsp = sspac/dble(nfr-1)
          freq = 1.d0/avgsp

c added MAC 5/98 - for determining frequency and intensity over interval
          do intn = 1,intlayer
              if (intnfr(intn).gt.1) then
                  intspace(intn) = intspace(intn)/dble(intnfr(intn)-1)
                  intfreq(intn) = 1d0/intspace(intn)
              else
                  intfreq(intn) = 1d0/intlength
              end if
              inttrace(intn) = inttrace(intn)/intlength/blkht
```

```
          end do

c         MAC 5/98 added if-then for small # of fractures
          if (nfr.gt.2) then
c             nfr-1 is the number of pairs used to calculate spacing
              varsp = (ssqsp - ((sspac**2)/dble(nfr-1)))/(dble(nfr-2))
              if (varsp.gt.0.0) then
                  sdspac = sqrt(varsp)
c added comment and put in varsp rather than sdspac**2 by MAC 5/98
c V[f]= V[s]*(-E[s]**-2)**2
                  sdfreq = sqrt((((-avgsp)**(-2))**2)*varsp)
              else
                  sdspac = 0d0
                  sdfreq = 0d0
              end if
          else
              varsp = 0d0
              sdspac = 0d0
              sdfreq = 0d0
          end if

          frcint = totaltr/blksiz/blkht
          avglen = totaltr/dble(nfr)
          varlen = (ssqtr - ((totaltr**2)/dble(nfr)))/dble(nfr-1)
          if (varlen.gt.0.0) then
              sdlen = sqrt(varlen)
          else
              sdlen = 0d0
          end if

c Rev MAC 4/17/98 - calculate b (in um) from airk
          aperture = 1d6*(12d0*(10**logairk(layer))/freq)**(1.0/3.0)

c... Calculate permeability of each fracture and pass to ktensor
      do n = 1, nfr
        aper(n) = aperture*1.d-6
        kfrc(n) = (aper(n)**3)/12.d0
      enddo

c Rev MAC 4/98 - zero sum parameters
      frcvol = 0d0
      frarea = 0d0
      do i = 1,9
          ktens(i) = 0d0
      end do

c... Calculate fracture volume based on penny-shaped fractures
      do n = 1, nfr
        frcrad = trace(n)*0.5d0
        frcvol = pi*aper(n)*frcrad**2 + frcvol
        frarea = aper(n)*frcrad*2.d0 + frarea
c         MAC V1.1 - will divide by block volume after combining
        intarea = pi*frcrad**2 + intarea

      enddo
c... Calculate fracture porosity
      frcpor = frcvol/(blksiz*blkht*blkdp)
```


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```
      frcp2d = frarea/(blksiz*blkht)

c Added MAC 4/22/98 - include 1-D porosity
      frcp1d = freq*aperture*1d-6
c
c... Calculate components associated with each fracture, then sum
        radian = pi/180.d0
      do n = 1, nfr
        nn = nfrc(n)
        if(strike(nn).le.90.d0)then
          stkrad = strike(nn)*radian
          diprad = dip(nn)*radian
        elseif(strike(nn).gt.90.d0.and.strike(nn).le.180.d0)then
          stkrad = strike(nn)*radian
          diprad = (180.d0-dip(nn))*radian
        elseif(strike(nn).gt.180.d0.and.strike(nn).le.270.d0)then
          stkrad = strike(nn)*radian
          diprad = (180.d0-dip(nn))*radian
        else
          stkrad = strike(nn)*radian
          diprad = dip(nn)*radian
        endif
        sdsq = (dsin(diprad))**2
        kxx = 1.d0 - ((dcos(stkrad))**2)*sdsq
        kxy = 0.5d0*dsin(2.d0*stkrad)*sdsq
        kxz = -0.5d0*dsin(2.d0*diprad)*dcos(stkrad)
        kyx = kxy
        kyy = 1.d0 - ((dsin(stkrad))**2)*sdsq
        kyz = 0.5d0*dsin(2.d0*diprad)*dsin(stkrad)
        kzx = kxz
        kzy = kyz
        kzz = sdsq
        kf = kfrc(n)*freq
        ktens(1) = kxx*kf + ktens(1)
        ktens(2) = kxy*kf + ktens(2)
        ktens(3) = kxz*kf + ktens(3)
        ktens(4) = kyx*kf + ktens(4)
        ktens(5) = kyy*kf + ktens(5)
        ktens(6) = kyz*kf + ktens(6)
        ktens(7) = kzx*kf + ktens(7)
        ktens(8) = kzy*kf + ktens(8)
        ktens(9) = kzz*kf + ktens(9)
      enddo

c Added MAC 4/21/98
      kzzkxx = ktens(9)/ktens(1)
      kyykxx = ktens(5)/ktens(1)
      kzzkyy = ktens(9)/ktens(5)

c Added MAC 4/21/98
c     Calculate alpha (see equation 7)
      alpha = aperture*1d-6/2d0/72d-3
c
c Commented out MAC 7/98
c... Open and write permeability components of fracture networks
c      open(11,file=outfile//'.prm',status='unknown')
c        write(11,*)'Permeability Tensor for: ',outfile
```


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111-89 JEA 4/21/00

```
c         write(11,450)'kxx','kxy','kxz','kyx','kyy','kyz','kzx',
c     +    'kzy','kzz'
c         write(11,460)ktens(1),ktens(2),ktens(3),ktens(4),
c     +     ktens(5),ktens(6),ktens(7),ktens(8),ktens(9)
c         write(11,*)'kzz/kxx= ',ktens(9)/ktens(1)
c         write(11,*)'kyy/kxx= ',ktens(5)/ktens(1)
c       close(11)

c... Calculate orientations and open and write GMT plot file
          open(11,file=outfile//'.plt',status='unknown')
       do n = 1, nfr
          nn = nfrc(n)
          if(strike(nn).le.90.d0)then
            adip = dip(nn)
            bdip = dip(nn) + 180.d0
          elseif(strike(nn).gt.90.d0.and.strike(nn).le.270.d0)then
            adip = 180.d0 - dip(nn)
            bdip = 360.d0 - dip(nn)
          else
            adip = dip(nn)
            bdip = dip(nn) + 180.d0
          endif
          write(11,404)dist(nn),adip,alen(n),unitname(layer)
          write(11,404)dist(nn),bdip,blen(n),unitname(layer)
        enddo
       close(11)
c-----------------------------------------------------------------
c      Below by MAC 4/98
c      Completely changed output file formatting
c      now 'all1.par' and 'all2.par' which list data for each subunit
c      Deleted E.S. output file writing

       if (endp2.lt.9999.0) then
          write(13,443)unitname(layer),endp1,endp2,trcmin,fmin,
     +    trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
          write(14,444)unitname(layer),fmin,nfr,freq,
     +    aperture,frcpor,frcp2d,frcp1d,alpha,kzzkxx,kyykxx,kzzkyy
          write(13,443)'      ',dist(ns1),dist(ns2)
       else
c         alcove data & ECRB data
c         ECRB is read in as if it is alcove 9 MAC 3-23-99
          if (endp1.lt.90000.0) then
           write(13,2443)unitname(layer),INT(endp1/10000.0),trcmin,fmin,
     +     trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
          else
           write(13,2445)unitname(layer),trcmin,fmin,
     +     trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
          end if
          write(14,444)unitname(layer),fmin,nfr,freq,
     +    aperture,frcpor,frcp2d,frcp1d,alpha,kzzkxx,kyykxx,kzzkyy
          write(13,2444)(dist(ns2)-dist(ns1))

       end if
441    format(1x,' Unit',1x,'<---Station--->',1x,
     +    ' Min-m',1x,'MinUse',1x,' Max-m',1x,' #Frac',1x,
     +    'Spac-m',1x,'SDSpac',1x,'Fq-1/m',
     +    1x,'SDFreq',1x,'Leng-m',1x,'SDLeng',1x,'Intens')
```


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111-90 JSH 4/21/00

```
442   format(1x,' Unit',1x,
     +    'MinUse',1x,' #Frac',1x,'Fq-1/m'
     +    ,1x,'Apr-um',1x,'   Por-3D',1x,'   Por-2D',1x,'   Por-1D'
     +    ,1x,'    alpha',1x,'kzz/kxx',1x,'kyy/kxx',1x,'kzz/kyy')
443   format(1x,a5,2(1x,f7.2),3(1x,f6.2),1x,i6,7(1x,f6.2))
444   format(1x,a5,1x,f6.2,1x,i6,1x,f6.2,1x,f6.0,4(1x,es9.2),
     +        3(1x,f7.2))
2443  format(1x,a5,4x,'Alcove',i2,4x,3(1x,f6.2),1x,i6,7(1x,f6.2))
2444  format(7x,f7.2,1x,'meters')
2445  format(1x,a5,4x,'ECRB  ',2x,4x,3(1x,f6.2),1x,i6,7(1x,f6.2))

c     Save results for combined output
c     added MAC 4/98
      combine(layer,1)=endp1
      combine(layer,2)=endp2
      combine(layer,3)=trcmin
      combine(layer,4)=trcmax
      combine(layer,5)=dble(nfr)
      combine(layer,6)=avgsp*dble(nfr-1)
      combine(layer,7)=ssqsp
      combine(layer,8)=avglen*dble(nfr)
      combine(layer,9)=ssqtr
      combine(layer,10)=frcpor*blksiz/(aperture*1d-6)
      combine(layer,11)=frcp2d*blksiz/(aperture*1d-6)
      combine(layer,12)=ktens(1)/freq
      combine(layer,13)=ktens(5)/freq
      combine(layer,14)=ktens(9)/freq
      combine(layer,15)=slgsp
      combine(layer,16)=ssqlsp
c     MAC V1.1
      combine(layer,17)=intarea
      combine(layer,18)=gmlen

c Added MAC 5/98 - Output interval results to 'interval.par'
      do intn=1,intlayer
              write(18,2000)unitname(layer),
     +        (endp1+(intn-1)*intlength),
     +        (endp1+(intn)*intlength),
     +        intnfr(intn),intspace(intn),intfreq(intn),
     +        (dble(intnfr(intn))/intlength),inttrace(intn)
      end do
1999  format(1x,' Unit',2(1x,'  Station'),1x,'   #Frac',4x,
     +    'Spacing',2x,'Frequency',3x,'#/Length',2x,'Intensity')
2000  format(1x,a5,2(1x,f9.1),1x,i8,4(1x,f10.2))
c-----------------------------------------------------------------------

c... Write fracture size distributions
      if(ans2.eq.'y')then
      open(12,file=outfile//'.szd',status='unknown')
      do k = 1, ni
          fgrp1 = fmesf + dble(k-1)*frint
          fsiz = fgrp1 + frint*0.5d0
c rev MAC 5/12/97  write(12,470)fsiz,dble(nfrint(k))/dble(ns)
        write(12,475)fsiz,nfrint(k)
      enddo
      close(12)
        fsum = 0.d0
```


111-91 JEH 4/21/00

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```
c          write cumulative size distributions
      open(12,file=outfile//'.csd';status='unknown')
        ftot = 1.d0
        write(12,470)fmesf,ftot
      do k = 1, ni
        fgrpl = fmesf + dble(k)*frint
        fsum = dble(nfrint(k))/dble(ns) + fsum
        write(12,470)fgrpl,1.d0 - fsum
      enddo
      close(12)
      endif
c

c Added MAC 4/17/98
999   continue
      END DO
      close(13)
      close(14)

c-----------------------------------------------------------------------------
---
c     Below is all new code added by MAC 4/98

c     Combine results for single values for each model layer
c
c     Output to files 'comb1.par' & 'comb2.par' - combined results of
c     all1.par & all2.par
c     Output to file 'calibrate.par' - data to be used for inversion
c
      open(13,file='comb1.par',status='unknown')
      open(14,file='comb2.par',status='unknown')
      open(15,file='calibrate.par',status='unknown')
      write(13,1441)
      write(14,442)
      write(15,2501)
      DO i = 1,ntotal
          trcmin = 1d6
          trcmax = 0d0
          nfr = 0
          avgsp = 0d0
          sspac = 0d0
          sdspace = 0d0
          ssqsp = 0d0
          avglen = 0d0
          sdlen = 0d0
          ssqtr = 0d0
          frcpor = 0d0
          frcp2d = 0d0
          blksiz = 0d0
          kxx = 0d0
          kyy = 0d0
          kzz = 0d0
          slgsp = 0d0
          sslgsp = 0d0
c         MAC V1.1
          intarea = 0d0
          gmlen = 0d0
```


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```
            first = modlayer(i)
            if (i.ne.ntotal) then
                last = modlayer(i+1) - 1
            else
                last = nlayers
            end if
            n = last - first + 1
        DO layer = first,last
            trcmin = min(trcmin,combine(layer,3))
            trcmax = max(trcmax,combine(layer,4))
            nfr = nfr + NINT(combine(layer,5))
            sspac = sspac + combine(layer,6)
            ssqsp = ssqsp + combine(layer,7)
            avglen = avglen + combine(layer,8)
            ssqtr = ssqtr + combine(layer,9)
            frcpor = frcpor + combine(layer,10)
            frcp2d = frcp2d + combine(layer,11)
            blksiz = blksiz + combine(layer,2) - combine(layer,1)
            kxx = kxx + combine(layer,12)
            kyy = kyy + combine(layer,13)
            kzz = kzz + combine(layer,14)
c
            slgsp = slgsp + combine(layer,15)
            ssqlsp = ssqlsp + combine(layer,16)

c           MAC V1.1
            intarea = intarea + combine(layer,17)
            gmlen = gmlen + combine(layer,18)

            if ((layer.eq.last).and.(nfr.gt.(n+1))) then
                avgsp = sspac/dble(nfr-n)
                freq = 1.d0/avgsp
c               nfr-n is the number of pairs used to calculate spacing
                varsp = (ssqsp - ((sspac**2)/dble(nfr-n)))/(dble(nfr-n-1))
                if (varsp.gt.0.0) then
                    sdspac = dsqrt(varsp)
                else
                    sdspac = 0d0
                end if
                varlen = (ssqtr - ((avglen**2)/dble(nfr-n))) /
     >                     (dble(nfr-n-1))
                avglen = avglen/dble(nfr)
                if (varlen.gt.0.0) then
                    sdlen = dsqrt(varlen)
                else
                    sdlen = 0d0
                end if
                if (sdspac .gt. 0.0) then
                    sdfreq = dsqrt(varsp/(avgsp**4))
                else
                    sdfreq = 0d0
                end if
                aperture = 1d6*(12d0*(10**logairk(layer))/freq)
     &                     **(1.0/3.0)
                alpha = aperture*1d-6/2d0/72d-3
                frcpor = frcpor*(aperture*1d-6)/blksiz
```


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111-93 JEH 4/21/00

```
              frcp2d = frcp2d*(aperture*1d-6)/blksiz
              frcp1d = freq*aperture*1d-6
c             calculate k ratios (note freq cancels)
              kzzkxx = kzz/kxx
              kyykxx = kyy/kxx
              kzzkyy = kzz/kyy
c             calulate fracture intensity
              frcint = avglen*dble(nfr)/blksiz/6e0
c             MAC V1.1
              gmlen = 10**(gmlen/dble(nfr))
              intarea = intarea/blksiz/(gmlen**2)

              write(13,1443)unitname(layer),trcmin,fmin,
     +         trcmax,nfr,avgsp,sdspac,freq,sdfreq,avglen,sdlen,frcint
              write(14,444)unitname(layer),fmin,nfr,freq,
     +        aperture,frcpor,frcp2d,frcp1d,alpha,kzzkxx,kyykxx,kzzkyy

c
              ssqlsp = (ssqlsp - slgsp**2/dble(nfr-n) )/ dble(nfr-n-1)
              slgsp = slgsp / dble(nfr-n)
              logf = - slgsp
              loga = (1d0/3d0)*(dlog10(12d0)+logairk(layer)-logf)
     >                - dlog10(2d0*72d-3)
              sdalpha = sdfreq*dsqrt(1d0/72d-3) *
     >        ( (10**logairk(layer)) /18d0/(freq**4) )**(1.0/3.0)
              if (ssqlsp.le.0.0) then
                  write(*,2500)unitname(layer),slgsp,ssqlsp
                  ssqlsp = 0.0
              end if

c         MAC V1.1 add new parameters gmlen (gemetric mean length) and
c         intarea (fracture area/block volume where block volume is
c         block length * gmlen^2).  Also changed output for calibrate.pa
      write(15,2500)unitname(layer),fmin,frcp2d,(aperture*1d-6),freq,
     +    intarea,gmlen,alpha,sdalpha,loga,dsqrt(ssqlsp/9d0)
2500  format(1x,a5,5x,f9.2,2(3x,es9.2),3x,f9.2,2(3x,f9.3),
     +    2(3x,es9.2),2(3x,f9.2))
2501  format(1x,' Unit',1x,'Min-Fr-Length',1x,'Fr-Porosity',4x,
     +    'Aperture',3x,'Frequency',2x,'Inter-Area',3x,'Gm-length',
     +    4x,'Fr-Alpha',4x,'SD-Alpha',4x,'LogAlpha',1x,'SD-LogAlpha')
c2500 format(1x,a5,2(1x,f7.2),2(1x,es9.2),3(1x,f7.2),1x,f7.3,1x,f7.2,
c    +    1x,i5,2(1x,f7.2))
c2501 format(1x,' Unit',4x,'Freq',2x,'SDFreq',5x,'alpha',3x,'sdalpha',
c    +    4x,'loga',2x,'logsda',2x,'<loga>',
c    +    1x,'s<loga>',2x,'gmFreq',1x,'#Frac',3x,'Block',3x,'#Freq')

c     added else statement - MAC 6/25/98
          else
              if (layer.eq.last) then
                  write(13,2500)unitname(layer)
                  write(14,2500)unitname(layer)
                  write(15,2500)unitname(layer)
              end if

          end if
      END DO
      END DO
```


111-94 JEA 4/21/00

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```
1441  format(1x,' Unit',1x,
     +     ' Min-m',1x,'MinUse',1x,' Max-m',1x,' #Frac',1x,
     +     'Spac-m',1x,'SDSpac',1x,'Fq-1/m',
     +     1x,'SDFreq',1x,'Leng-m',1x,'SDLeng',1x,'Intense')
1443  format(1x,a5,3(1x,f6.2),1x,i6,7(1x,f6.2))
      close(13)
      close(14)


      stop


  400 format(a200)
  404 format(f13.2,1x,f8.4,1x,f9.5,1x,a5)
  408 format(a10)
  410 format(i2,1x,f5.2)
  415 format(a21,2(1x,f7.2))
  420 format(a48,2(1x,f7.3),1x,i5,1x,f5.3)
  425 format(a78)
  430 format(f8.4,5(2x,f8.4),2(2x,e10.4))
  440 format(a40)
  450 format(9(4x,a4,3x))
  460 format(9(1x,e10.3))
  470 format(f10.3,1x,f8.4)
  475 format(f10.3,1x,i8)
c
      stop
      end
```


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NB. Mc-1.1

Frac_Calc V.1.0 Qualification 8/27/98

Frac_Calc was reviewed and qualified as a Multiuser Macro. The approval signature form is below and supporting documentation is on file with LBNL ESD ~~Software Qualification~~. Software Manager Don Mangold. MC 8/27

Attachment 2
Page 1 of 1

YMP-LBNL DOCUMENT REVIEW/COMMENT RESOLUTION FORM (DRCR)

Document No. and Title: Frac_Calc 1.0 SCMS ID: (Form M) Page 1 of 1

Date of Document (or revision, if applicable): 8/10/98

Are Scientific Notebooks or other hardcopy records/documents/data included in the scope of this review? ☒ Yes ☐ No (If yes, identify on Attachment 3)

FORM M
Software Qualification for Multi User Macro

PROCEDURE ID: YMP-LBNL-QIP-8L0 | REV. 3, MOD. 1 | EFFECTIVE: 06/30/98

Software name & version: Frac_Calc Version 1.0	SCMS ID: Frac_calc V 1.0
Preparer name: Mark A. Cushey	Date doc. initiated: 8/10/98

If more space is needed, attach separate sheet(s) and address the points on this form.

Objectives—Changes: Calculate fracture properties for UZ model layers based on detailed line survey data from the ESF.

Scientific Notebook Identifier: YMP-LBNL-GSB-MC-1
YMP-LBNL-GSB-MC-1.1
YMP-LBNL-GSB-MC-1.1A (reference binder)

Page numbers where macro or changes were described and tested: mc-1 60-65, 124/125, 157
mc-1.1 ~~96~~ 101-108
mc-1.1A 88-97 ← code MC 7/21/99

NOTE: If macro is part of a larger code, include results of regression testing of larger code.

Technical Contact Signature: Mark A. Cushey Date: 8/10/98

Technical Review

No mandatory comments, recommend acceptance.

Signature: _____ Date: _____

Mandatory Comments—see attached DRCR form.

Signature: [illegible] Date: 8/25/98

SCM Acceptance

Signature: Donald Mangold Date: 8/26/98

Applicable Manager's signature and date of approval

Name: [illegible] Date: 8/26/98

Mark A

111-96 JEH 4/21/00

8/27/98

it as a
signature form is
is on file
Frac Software

Macros
EFFECTIVE: 08/05/98

Calc V 1.0
ment 8/10/98
ss form:

for U2 model
the ESF

ce binder.)
c-2 60-66, 124, 125, 157
c-1.1 101-106
c-3.14 88-97 ← code
n testing of larger

MC
7/21/98

Date: 8/10/98

1-0-0-0-0-0-0-0-

25/98

26/98

/98

Attachment 2
Page 1 of 1

YMP-LBNL DOCUMENT REVIEW/COMMENT RESOLUTION FORM (DRCR)

Document No. and Title: Frac_Calc 1.0 SCMS ID: (Form M) Page 1 of 1

Date of Document (or revision, if applicable): 8/10/98

Are Scientific Notebooks or other background documents/data included in the scope of this review? ☒ Yes ☐ No (If yes, identify on Attachment 3) identified on Form M

Specific Review Criteria or Governing Procedure:

General Review Criteria: (identify relevant criteria on Attachment 4): Software Review Criteria for Macros

Reviewer Name: Randy Hedegaard

Reviewer Signature: Date: 11 Aug 98 Disposition of Mandatory Comments Completed (initial): RH

REVIEWER'S COMMENTS*			AUTHOR'S RESPONSE*			Reviewer Disposition for Mandatory Comments	
COMMENT NO. MANDATORY (M) NON-MANDATORY (NM)	SECT. AND PAGE NO.	COMMENTS	ACCEPT Initial/Date	REJECT Initial/Date	JUSTIFICATION Justification required for rejected comments only	ACCEPT Initial/Date	REJECT Initial/Date
1-M		List specific software program language used with version number. Also, need to list code compiler and platform software was created on.	MC 8/25/98		Added [redacted] 8/26 ~~Added~~ this information to scientific notebook (YMP-LBNL-658-MC-1.1 page 109).	RH 8/27/98	

* May be on separate sheets to be attached, in which case the comments shall be numbered and this form will be used to track the comments and their resolution according to such numbers.

Office of Quality Assurance Date

YMP-LBNL Management Review (Project Manager Or Designee

Project Manager Date

8/27/98

111-97 RPH 4/21/ED

Sample Input & Output for ~~Calcs~~ Frac-Calc.f MC 8/10/98 8/10/98

Below are the data for ptn25 in the North Ramp.
✓ → indicates that value checks with hand calculations below.

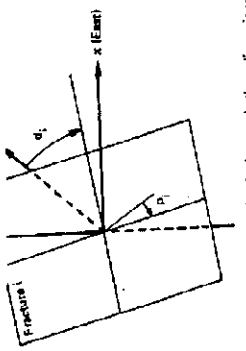


Fig. 4.6. Directions and dip of a fracture in three dimensions.

Sample input data from DLS:

LOCATION	STRIKE	DIP	LENGTH A	LENGTH B
879.700	20.000	8.000	2.000	6.000
882.370	184.000	78.000	3.500	1.670
887.300	299.000	78.000	.000	1.110
893.860	20.000	49.000	.100	.330
893.920	22.000	80.000	.680	.620
894.130	20.000	67.000	1.200	1.600

extracted from 8to10.txt in D:\DLS → DTN: GS 9711 08314224.005 using single user macro Read-TDB (see p. 82-87 in YMP-LBNL-658-mc-1 MC 3/31/99

Sample output from frac_calc.f (for fractures ≥ 1 meter in length)

all1.par

Unit	<---Station--->		Min-m	MinDee	Max-m	#Frac	Spac-m	SDSpac	Fq-1/m	SDFreq	Leng-m	SDLeng	Intens
ptn25	875.80	894.60	.43	1.00	8.00	5	3.61	2.78	.28	.21	3.66	2.91	.16

all2.par see above

Unit	MinDee	#Frac	Fq-1/m	Apr-um	Por-3D	Por-2D	Por-1D	alpha	kzz/kxx	kyy/kxx	kzz/kyy
ptn25	1.00	5	.28	504.	5.93E-05	8.21E-05	1.40E-04	3.80E-03	1.69	1.81	.93

calibrate.par

MC 8/10/98 MC 8/10/98

Unit	~~Freq~~	~~SDFreq~~	~~Alpha~~	~~sdalpha~~	~~loga~~	~~logsda~~	~~<loga>~~	~~sd<loga>~~	~~gmFreq~~	~~#Frac~~	~~Block~~
ptn25	.21	.07	3.85E-03	1.43E-04	-2.41	-3.94	-2.50	.412	.38	5	18.80

Calculations below are by hand (with a calculator)

	length	~~spacing~~ MC 8/10/98
1. 879.7	8	
2. 882.37	5.17	
3. 887.3	1.11	
4. 893.86	0.43 ← exclude since ≤ 1	
5. 893.92	1.3	
6 894.13	2.8	

so # Frac = 5, average length = 3.676 m, std. dev. length = 2.912

Spacing:

2-1 2.67 m
3-2 4.93 m
exclude 4 5 ~~4~~-3 MC 8/10/98 6.62 m
6-5 ~~4~~ MC 8/10/98 0.21 m

average = 3.6075 m sd = 2.784 m

Frequency $\bar{f} = \frac{1}{\bar{x}} = 0.277/m$

$sd = \frac{2.784\,m}{(3.6075\,m)^2} = 0.214/m$

MC 9/23/99

this region assumed that there would be two ptn25 sections on the North ramp and one in the South Ramp. See p 106

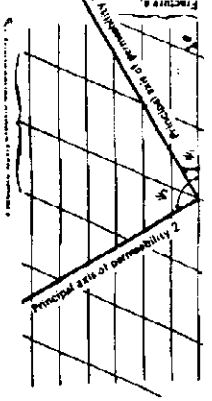


Fig. 4.7. Orientation of the principal axes of anisotropy in a fractured medium in two dimensions. [From Meinzer and Hoxting (1977). Reproduced with permission from the Geological Society of America.]

111-98 JEH 4/21/00

Intensity $I = \frac{\Sigma \text{ trace lengths}}{\text{area}} = \frac{(8+5.17+1.11+1.3+2.8)\,m}{(894.6-875.8)\,m\,(6\,m)}$ 2.8 mc 8/10/98

$I = 0.163\ m/m^2$

Aperture $b = \left(\frac{12k}{f}\right)^{\frac{1}{3}} = \left(\frac{12\ \ 10^{-11.53}\ m^2}{0.277/m}\right)^{1/3} = 5.0377 \times 10^{-4}\,m$

OR 503.8 um

$\log k = -11.53$ from datablk.f
(p. 96-97 in Ref Notebook YMP-LBNL-GSB-MC-1.1A)

Porosity

3D: $\phi_{3D} = \frac{\pi b \left(\Sigma t_i^2\right)/4}{(6m)(6m)(894.6-875.8)m} = 5.933 \times 10^{-5}$ 5 mc 8/10/98

2D: $\phi_{2D} = bI = (5.0377 \times 10^{-4} m)(0.163\ \frac{m}{m^2}) = 8.212 \times 10^{-5}$

1D: $\phi_{1D} = bf = (5.0377 \times 10^{-4} m)(0.277/m) = 1.395 \times 10^{-4}$

Alpha

$$\alpha = \frac{b}{2\tau \cos(0°)} = \frac{5.0377 \times 10^{-4}\ m}{2\,(.072\ N/m)} = 0.003498\ \frac{}{Pa}$$

see note on p. 105, calibrate.par expects 2 layers for ptn25 based on datablk.f. Made temporary modification to datablk.f and rerun program to get appropriate calibrate.par

calibrate.par see all3.par

Unit	Freq	SDFreq	alpha	sdalpha	loga	logsda	<loga>	s<loga>	gmFreq	#Frac	Block
ptn25	.28	.21	3.508-03	2.418-04	-2.46	-3.62	-2.54	.344	.48	5	18.80

see all1.par

assumed 2 degrees of freedom

std dev $\alpha = \frac{\sigma_s}{s^2}\left(\frac{k}{18 f^4}\right)^{1/3} \frac{1}{\tau^{1/2}}$

$= \frac{2.784\,m}{(3.6075\,m)^2}\left(\frac{10^{-11.53}\ m^2}{18\ (0.277/m)^4}\right)^{1/3} \frac{1}{(.072\ N/m)^{1/2}}$

$= 0.00024165\ /Pa$

(see p. 124-125 in YMP-LBNL-MC-1)

$\log a =$

$\log \sigma_a =$ sda mc

$\log f$:

$< lo$

gmF

$< \log a >$

$<$

$s <$

block $-$

k_{ez}/k_{xx}, k

$\frac{k_{ez}}{k_{xx}} =$

2.0 mc 8/10/98

.17+1.1+1.3+0.8)m

99.6 − 875.8)m (6m)

3 m/m²

$\left(\frac{10^{-11.53}\ m^2}{0.277/m}\right)^{1/3} = 5.0371\times10^{-4}\ m$

or 503.8 um

YMP-LBNL-65B-MC-1.1A)

$= 5.933\times10^{-6}$ mc 8/10/98

$2.163\ \frac{m}{m^2}) = 8.212\times10^{-5}$

$0.277/m) = 1.395\times10^{-4}$

$\times10^{-4}\ m$ / N/m) = 0.003498 / Pa

cts 2 layers for ptn25
modification to data blk.f
de calibrate.par

see w112.par

ga>	a<loga>	gmFreq	$Frac	Block
-2.54	.344	.48	5	18.80

assumes 2 degrees of freedom

$\left(\frac{m^2}{77/m)^4}\right)^{1/3}\ \frac{1}{(.072\ N/m)^{1/2}}$

24165 /Pa

-MC-1)

$\log a = \log(\alpha) = -2.456$

$\log \sigma_a$ mc 8/10/98 $= \log(\sigma_a) = -3.6168$

log f:

$\langle \log f \rangle = -\langle \log s \rangle$

and

$\langle \log s \rangle = \frac{\log 2.67 + \log 4.93 + \log 6.62 + \log 0.}{4}$

$= 0.3156$ or geometric mean of spacing.

$\sigma_{\log s} = 0.6823$

gmFreq = geometric mean f $= 10^{\langle \log f \rangle} = 10^{-\langle \log s \rangle}$

$= 10^{-0.3156} = 0.4835\ /m$

$\langle \log a \rangle$, $s\langle \log a \rangle$ see p124-125 in YMP-LBNL-65B-MC-1

$\langle \log a \rangle = \frac{1}{3}(\log 12 + \log k - \langle \log f \rangle) - \log 2\tau$ ($\langle \log \alpha \rangle$)

$= \frac{1}{3}(\log 12 - 11.53 + 0.3156) - \log[(2)(0.072\ N/m)$

$= -2.537$

$s\langle \log a \rangle = \sigma_{\log \alpha} = \frac{1}{3}\sigma_{\log s} = \frac{1}{3}(0.6823)$

$= 0.2274$ assumes 3 degrees of freedom

block – length of block in ESF – station to station that repres stratigraphic unit

894.6m − 875.8m = 18.8 m

k_{zz}/k_{xx}, k_{yy}/k_{xx}, k_{zz}/k_{yy} (see p. 102-104, this notebook)

~~$\frac{k_{zz}}{k_{xx}} = \sin($~~ mc 8/10/98

go to next page

111-100 JEH 4/21/00

strike	dip	true dip	in degrees
20°	8°	8°	
184	78	~~7~~ mc 8/10/98 102	
299	78	78	
22	80	80	
20	67	67	

$\Sigma \sin^2(\text{dip}) = 3.75$

$\Sigma\left(1-\sin^2(\text{strike})\sin^2(\text{dip})\right) = \cancel{4}\ 5$ mc 8/10/98 $\cancel{-1.92875}$ 0.974 $= \cancel{2.07125}$ mc 8/10/98 $\cancel{3.07125}$ 4.026 mc 8/10/98

$\Sigma\left(1-\cos^2(\text{strike})\sin^2(\text{dip})\right) = \cancel{4}\ 5$ mc 8/10/98 $- 2.776 = \cancel{1.224}$ mc 8/10 2.224

$$\frac{k_{zz}}{k_{xx}} = \frac{\cancel{3.75}}{\cancel{1.224}} \text{ mc } 4/23/99 \text{ mc } 8/10/98 = \frac{3.75}{2.224} = 1.686$$

$$\frac{k_{yy}}{k_{xx}} = \frac{\cancel{3.07125}}{2.224} \text{ mc } 8/10/98 \text{ 4.026} = \cancel{1.381} \text{ mc } 8/10/98 = 1.81$$

$$\frac{k_{zz}}{k_{yy}} = \frac{3.75}{4.026} = 0.931$$

All calculations in frac-calc.f check.

Mark A Conley 8/10/98

Compiler I

The program

Mark C

111-101 JF4 4/21/00

Compiler Information for Frac_Calc.f 8/25/98

The program Frac_Calc.f was compiled using

Fortran Powerstation 4.0
Microsoft 1994-1995

Product ID: 36785-411-0083773-30563

(part of Microsoft Developer Studio)

74 mc 8/10/98 4.026 mc 8/10/98
75 = ~~2.07425~~ ~~3.07425~~
76 = ~~1.224~~ mc 8/10 2.224

1.686

= 1.81

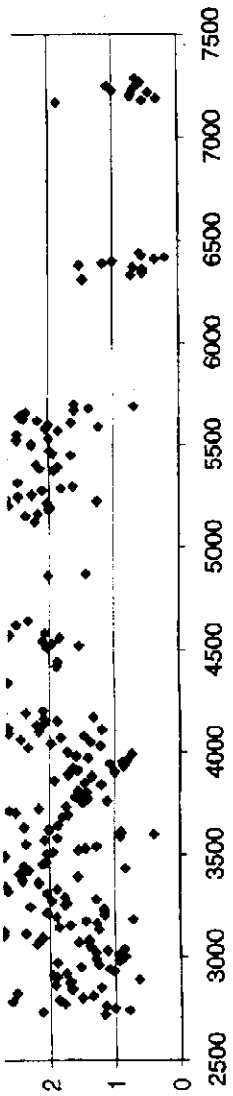
check.

/98

Mark A Carley 8/25/98

can be seen a
41+00 and 52+00.
other interval
Notebook

e.



Version 1.0
MC 7/21/99

Frac-Calc & ESF Fracture Data 8/10/98

The code frac-calc is listed in Reference Notebook YMP-LBNL-GSB-MC-1.1A pages 88-97.
The development of the code was discussed previously on pages 60-69, 124-125, 137 YMP-LBNL-GSB-MC-1
The code was previously listed on p 40-46 in this notebook.
Results are used throughout both notebooks. The most recent code addition is discussed on p. 98 of this notebook.

Also see p.102-103 this notebook MC 8/10/98

Using disalcove.dat (see p. 54-56, this notebook), as input fracture properties were calculated for the model layers (see p. 64, this notebook). More detailed output is given in Reference Notebook YMP-LBNL-GSB-MC-1.1A p. 98-106.
This gives

all1.par & all2.par → properties for individual sections of each layer
comb1.par & comp2.par → properties for each model layer (combines above)
calibrate.par → additional properties for each model layer.

see p. 119 this notebook for qualification MC 8/12/98

Frac-calc is defined as a "Multi-User Macro".
A Form M was completed and submitted to qualify the code as a "macro".

The code is in d:\code\calc_frac\frac-calc.f
and includes datablk.f

8/10/98

111-103 JEH 4/21/00

Fracture Permeability Components Calculations 8/10/98

from Sonnenthal et.al. (1997) ref. on p.60 in YMP-LBNL-GSR-MC-1. mc 9/3/99
page 7-21

The large-scale saturated fracture permeability is dependent on the fracture connectivity and the permeability of individual fractures. Although the connectivity of the fractures is difficult to ascertain, over a large scale the ratios of the permeability components can give some indication as to the preferred flow directions. Assuming an array of infinite fractures in three dimensions, the permeability tensor for a fracture network modified from the conductivity tensor in de Marsily (1986) is given by:

b mc 8/7/98

$$\overline{k_f} = \begin{vmatrix} k_{xx} & k_{xy} & k_{xz} \\ k_{yx} & k_{yy} & k_{yz} \\ k_{zx} & k_{zy} & k_{zz} \end{vmatrix} = \sum_{i=1}^{N} k_{f,i}\overline{R_i} \quad . \tag{16}$$

part 1

The permeability of each fracture is given by the cubic law (Equation (5)), assuming uniform apertures. The tensor $\overline{R_i}$ relates the strike (d_i) and dip (p_i) of each fracture to the components of the permeability tensor, as follows:

$$\overline{R_i} = \begin{bmatrix} 1-\cos^2 d_i \sin^2 p_i & \frac{1}{2}\sin 2d_i \sin^2 p_i & -\frac{1}{2}\sin 2p_i \cos d_i \\ \frac{1}{2}\sin 2d_i \sin^2 p_i & 1-\sin^2 d_i \sin^2 p_i & \frac{1}{2}\sin 2p_i \sin d_i \\ -\frac{1}{2}\sin 2p_i \cos d_i & \frac{1}{2}\sin 2p_i \sin d_i & \sin^2 p_i \end{bmatrix} \tag{17}$$

part 2

The permeabilities in the principal directions would have to be derived from this matrix; however as the UZ model does not at this time incorporate the off-diagonal terms, and because our fracture permeabilities are based on air-injection measurements, this is not necessary at present.

The code ~~calc~~ mc 8/10 frac calc.f includes these calculations. parts 3 & 4
The first portion converts the angle from degrees to radians and gives the dip angle in terms of the "true" dip rather than the "apparent" dip. The second part computes the components of the matrix shown in equation 17 above. The third part then multiplies each component by the fracture permeability (kfrc) and the frequency (f) (see eqn 16 above). The 4th part sums these for all the fractures in the layer. part 5
The 5th and last part (added by myself on 4/21/98) calculations the ratios k_{zz}/k_{xx}, k_{yy}/k_{xx}, & k_{zz}/k_{yy}. Note that the ratios are independent of k and f.

The parts 1-4 were written by Eric Sonnenthal.

The code (excerpt is shown on the next page).

Reference for de Marsily given on p104 (with excerpt).

mc 8/10

c... Cal
ra
dc

c Added
x
x
x

lations 8/10/98

YMP-LBNL-GSB

on p.60 in SA-MC-1

MC 9/21/99

: connectivity and the perme-
s difficult to ascertain, over a
ation as to the preferred flow
permeability tensor for a frac-
iven by:

,98

(16)

part 1

assuming uniform apertures.
ments of the permeability ten-

$$\begin{bmatrix} \sin 2p_i \cos d_i \\ \sin 2p_i \sin d_i \\ \sin^2 p_i \end{bmatrix} \quad (17)$$

part 2

m this matrix; however as the
use our fracture permeabilities

these calculations.

parts 3 & 4

n degrees to
s of the "true"
second part
ix shown in
m multiplies
neability (kfrc)
bove). The 4th
s in the layer.
self (MC 9/21/98)
k_{yy}/k_{xx}, & k_{zz}/k_{yy}.
ent of k and f.

connection.

t page).

(with except)

part 5

from d:\code\calc_frac\frac_calc.f

```
c... Calculate components associated with each fracture, then sum
      radian = pi/180.d0
      do n = 1, nfr
        nn = nfrc(n)
        if(strike(nn).le.90.d0)then
          stkrad = strike(nn)*radian
          diprad = dip(nn)*radian
        elseif(strike(nn).gt.90.d0.and.strike(nn).le.180.d0)then
          stkrad = strike(nn)*radian
          diprad = (180.d0-dip(nn))*radian
        elseif(strike(nn).gt.180.d0.and.strike(nn).le.270.d0)then
          stkrad = strike(nn)*radian
          diprad = (180.d0-dip(nn))*radian
        else
          stkrad = strike(nn)*radian
          diprad = dip(nn)*radian
        endif
        sdsq = (dsin(diprad))**2
        kxx = 1.d0 - ((dcos(stkrad))**2)*sdsq
        kxy = 0.5d0*dsin(2.d0*stkrad)*sdsq
        kxz = -0.5d0*dsin(2.d0*diprad)*dcos(stkrad)
        kyx = kxy
        kyy = 1.d0 - ((dsin(stkrad))**2)*sdsq
        kyz = 0.5d0*dsin(2.d0*diprad)*dsin(stkrad)
        kzx = kxz
        kzy = kyz
        kzz = sdsq
        kf = kfrc(n)*fpm
        ktens(1) = kxx*kf + ktens(1)
        ktens(2) = kxy*kf + ktens(2)
        ktens(3) = kxz*kf + ktens(3)
        ktens(4) = kyx*kf + ktens(4)
        ktens(5) = kyy*kf + ktens(5)
        ktens(6) = kyz*kf + ktens(6)
        ktens(7) = kzx*kf + ktens(7)
        ktens(8) = kzy*kf + ktens(8)
        ktens(9) = kzz*kf + ktens(9)
      enddo

c Added MAC 4/21/98
      kzz/kxx = ktens(9)/ktens(1)
      kyy/kxx = ktens(5)/ktens(1)
      kzz/kyy = ktens(9)/ktens(5)
```

aper MC 8/24/98

but does not effect ratios since it cancels out

Mark A. Conley 8/24/98

111-105 JEH 4/21/00

Sample:

Below are
✓ → indica

Sample input data f

LOCATION	STRIKE
879.700	20.000
882.370	164.000
887.300	299.000
893.860	20.000
893.920	22.000
894.130	20.000

Sample output from

all1.par

```
Unit <---Station---> Ni
pcm25 875.80 894.60
```

all2.par ser above

```
Unit Minimum Sprac Pq-1
pcm25  1.00    5    :
```

calibrate.par MC 0

```
Unit
pcm25
```

Calculations bel

1. 879.7
2. 882.37
3. 887.3
4. 891.86
5. 893.92
6. 894.13

so #1

spacing

exclude 1

freq vem

this portion assumed that there would be two planes sections one in the north ramp and one in the south ramp. see p 106

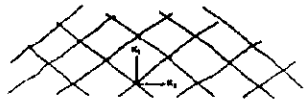


Fig. 4.6. Principal axes of anisotropy of a fractured medium.

For example, in two dimensions, two fracture systems with the same directional conductivity give the principal axes of anisotropy shown in Fig. 4.6. Maini and Hocking (1977) give the following expressions for calculating the directions of anisotropy and the principal hydraulic conductivities of the equivalent medium:

$$\psi_i = \frac{1}{2}\arctan\left(\frac{\sin 2\theta}{\cos 2\theta\, K_a/K_b}\right)$$

$$K_i = \frac{K_a K_b \sin^2\theta}{K_a \sin^2\psi_i + K_b \sin(\theta - \psi_i)}$$

where K_a and K_b are the equivalent directional hydraulic conductivities of the fracture networks a and b, as shown in Fig. 4.7.

In three dimensions, Feuga (1981) gives the following expressions for determining the hydraulic conductivity tensor of a fractured medium with several fracture directions:

$$\mathbf{K} = \frac{1}{l}\sum_{i=1}^{N} e_i k_i \mathbf{R}_i$$

where l is the arbitrary dimension of the side of a square block of the fractured medium, large enough to statistically sample all the families of fractures, N the

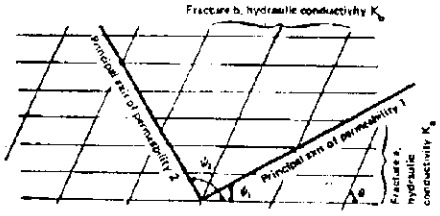


Fig. 4.7. Orientation of the principal axes of anisotropy in a fractured medium in two dimensions. [From Maini and Hocking (1977). Reproduced with permission from the Geological Society of America.]

number of fractures in the block of side l, e_i the aperture of each individual fracture, and k_i the hydraulic conductivity of each individual fracture

$$\mathbf{R}_i = \begin{bmatrix} 1 - \cos^2 d_i \sin^2 p_i & \frac{1}{2}\sin 2d_i \sin^2 p_i & -\frac{1}{2}\sin 2p_i \cos d_i \\ \frac{1}{2}\sin 2d_i \sin^2 p_i & 1 - \sin^2 d_i \sin^2 p_i & \frac{1}{2}\sin 2p_i \sin d_i \\ -\frac{1}{2}\sin 2p_i \cos d_i & \frac{1}{2}\sin 2p_i \sin d_i & \sin^2 p_i \end{bmatrix}$$

In the matrix $\mathbf{R}_i$, the direction d_i and the dip p_i of each fracture are defined as in Fig. 4.8.

Once the tensor $\mathbf{K}$ has been determined, the principal axes of anisotropy and the diagonal components of $\mathbf{K}$ in these directions can be determined by calculating the eigenvalues and the eigenvectors of the matrix $\mathbf{K}$.

This method of the continuous medium approximation is valid for a certain scale of observation: the flow velocities or the hydraulic heads in each fracture are not described with precision, but a mean value of these magnitudes is taken over all the fractures.

The definition of the hydraulic conductivities of each family of fractures may be approached in two ways: either (1) by measuring (or estimating) the mean geometric properties of the fractures (aperture, distance from each other, roughness, etc.) and using the expressions given above, or (2) through *in situ* tests by injecting water and measuring the hydraulic conductivities K_i of the elementary fractures directly.

The drawback of both methods is that they assume the fractures to be infinite and to have the same properties everywhere. Their results must be taken with caution. The directions of the principal axes of the conductivity tensor are probably more accurate than the value of the conductivities; these

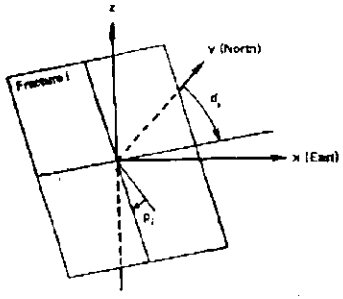


Fig. 4.8. Direction and dip of a fracture in three dimensions.

de Marsily, G. 1986. Quantitative Hydrogeology. Groundwater Hydrology for Engineers. Orlando, Florida: Academic Press. NNA.19910207.0116.

Mel Gray 8/10/98

111-11C 9FH 4/21/00

TDB- fracture properties 4/17/98

Began analyzing fracture data. The first step was to recreate and verify the calculations in Chapter 7 of the Site-Scale Unsaturated Zone Model of Yucca Mountain.

I started with the code from E. Sonnenthal. It is located on hydra.lbl.gov in the directory
/m/ultra~~2~~1/u/esonn/ymp/~~bin~~/src MC 8/25/98

The name of the code is cnvfr2.f
The original data analyzed (which only is up to station 10+00) was in the file

~~these data were only used for testing code results and were not used for YMP Q-work MC 8/28/99~~ ~/ymp/fractures/esf/frcpar.dat
and
~/ymp/fractures/esf/station.dat

All changes to the code are indicated with my initials (MAC) and dated. The new filename for the code is: MC 8/25/98
calc_frac.f
and it is located on NWD-cushey in
d:/code/calc_frac/

This code differs in that MC 8/25/98 it processes all of the DLS data at once. Station numbers are assigned to model layers in data statements.

The following calculations are performed:

$$\text{avg. spacing} = \frac{1}{nf-1}\sum_{i=2}^{nf}(D_i - D_{i-1})$$

where nf - the number of fractures
D_i - is the location of fracture i

$$\text{fracture frequency} = \frac{1}{\text{avg. spacing}} = \frac{1}{\bar{s}}$$

$\bar{s}$ - average spacing

rek MC 8/1/98

Sonnenthal, E.L.; Ahlers, C.F.; and Bodvarsson, G.S. 1997. "Fracture and Fault Properties for the UZ Site-Scale Flow Model." Chapter 7 of *The Site-scale Unsaturated Zone Model of Yucca Mountain, Nevada, for the Viability Assessment*, edited by G.S. Bodvarsson, T.M. Bandurraga, and Y.S. Wu. Yucca Mountain Site Characterization Project Level 4 Milestone SP24UFM4; Report LBNL-40376. Berkeley, California: Lawrence Berkeley National Laboratory. LB970601233129.001 (Q).

SIGNATURE _____ DATE _____ 19 ____
READ AND UNDERSTOOD _____ DATE _____ 19 ____

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$$b = \left(\frac{12\,k}{f}\right)^{\frac{1}{3}}$$

where b - aperture
k - air permeability (frac. perm.)
f - frequency

$$\alpha = \frac{b}{2\tau\cos\theta}$$

where α - van Genuchten α for fractures
b - aperture
τ - surface tension of pure water at 20°C (0.072 N/m)
θ - contact angle (assumed to be 0)

This calculation was not previously in the code

porosities:

$$\phi_{1D} = f\,b$$

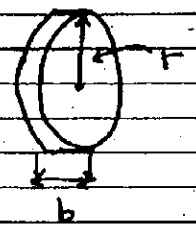
$$\phi_{2D} = \frac{b\sum_{i=1}^{nf} t_i}{\text{area}} = \frac{b\sum_{i=1}^{nf} t_i}{(6m)\ \text{blocklength}}$$

$$\phi_{3D} = \frac{\pi\, b\sum_{i=1}^{nf} r_i^2}{\text{volume}} = \frac{\pi\, b\sum_{i=1}^{nf} r_i^2}{(6m)(6m)\ \text{blocklength}}$$

t_i - trace length of fracture i
block length - length along DLS corresponding to model layer (full length)
r_i - one-half the trace length
$r_i = t_i/2$

For the above calculations, the fractures are assumed to be circular disks.

111-108 JEH 4/21/00



volume in 3D = $b \pi r^2$

The probability that the tunnel cut intersects these disks offcenter is not accounted for.

The area about the DLS centerline is assumed to include a 3 meter band on each side.

MC 4/17/98
The ϕ_{3D} may underestimate porosity since it assumes fracture traces represent fracture diameters

The ϕ_{1D} may overestimate porosity since it assumes infinitely long fractures.

ratios of permeability components:

ratios k_{zz}/k_{xx}, k_{yy}/k_{xx}, and k_{zz}/k_{yy} were calculated as defined in eqns 16 & 17 in Chapter 7.

For spacing, fractures located at the same station were assumed to be at a separation distance of 0.

The minimum measurement precision was 0.01 m for the DLS (Altman, 1997)

ref Altman, S.J. Determining reasonable ranges for van Genuchten fracture α for use in unsaturated flow modeling Sandia National Laboratory
DTN SNT05091597001.003
TDIF 306502
November 25, 1997.

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111-109 JEH 4/21/00

PROJECT NAME _____ NOTEBOOK NO. _____

TDB- fracture properties - verification of code 4/29/98

To verify the code, the original DLS dataset was used and compared to Chapter 7 results.

Data from /m/ultra1/u/esonn/ymp/fractures/esf

stored on NWD-Cushey as dlsall in di/code/

This data was transformed to a readable (numeric) format (convert station numbers to lengths) and stored in ericdls.dat in di/code/calc_frac.

The code was run and results were compared to those in Chapter 7.

To combine disconnected segments the following formulations were used. This is different from the method used original by E. Sonnenthal as noted in the comparison (typically averages of the segments). The below procedure combines all sublayers into one continuous layer (the pairing of fractures for spacing are limited to the sublayers). This is similar to the method used by (Altman, 1997)

see nomenclature on p. 60-61

$$\bar{\xi}_{comb} = \frac{\sum_{j=1}^{ns} \left[\sum_{i=2}^{nf_j} D_{i,j} - D_{i-1,j} \right]}{\sum_{j=1}^{ns} nf_j - j}$$

ns - # of segments
subscript j → segment j
comb - combined

the denominator is the number of pairs of fractures used to calculated the $\bar{\xi}_{comb}$.

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$$\bar{f}_{comb} = \frac{1}{\bar{s}_{comb}}$$

$$b_{comb} = \left(\frac{12k}{\bar{f}_{comb}}\right)^{\frac{1}{3}}$$

$$\phi_{3D} = \frac{\pi\, b_{comb} \sum_{j=1}^{ns} \sum_{i=1}^{nf_j} r_{i,j}^2}{(6m)(6m) \sum_{j=1}^{ns} \text{blocklength}_j}$$

$$\phi_{2D} = \frac{b_{comb} \sum_{j=1}^{ns} \sum_{i=1}^{nf_j} t_{i,j}}{(6m) \sum_{j=1}^{ns} \text{blocklength}_j}$$

$$\phi_{1D} = b_{comb}\, f_{comb}$$

The alternative would be to calculate 12A/B each parameter for each sublayer and then ~~[illegible]~~ computed a weighted average based on the segment length

$$X = \frac{\sum_{j=1}^{ns} x_j \text{ blocklength}_j}{\sum_{j=1}^{ns} \text{blocklength}_j}$$

for any parameter X

The first (continuous layer) method was used since the break-up of layers is arbitrary due to the location of the tunneling. On the other hand, the second method might better capture local phenomena which are averaged out by the averaging over longer

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lengths. Considering though that these parameters are to represent the entire layer over the site, the first (continuous) method is deemed appropriate at this time.

An additional note is that the spacing calculation is along the DLS centerline and is not the "true" spacing. The calculation of "true" spacing will be considered at a later time. (see Geology of the Exploratory Studies Facility Topopah Spring Loop Attachment I
BAB 0 01717-0200-00002
REV 1.)

For the following verification - first the individual sublayers and then the overall layers are compared. Only fractures ≥ 1 m are included

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YMP-LBNL DOCUMENT REVIEW/COMMENT RESOLUTION (DRCR) FORM

Document No. and Title: Frac_Calc Version 1.1 Page 1 of 1

Date of Document / revision no./ draft revision no. (as applicable): Version 1.1 Author: Mark Cushey

Are Scientific Notebooks or other background documents/data included in the scope of this review? ☒ Yes ☐ No (If yes, identify on Attachment 3)

Specific Review Criteria or Governing Procedure: YMP-LBNL-QIP-6.1 & AP-SI.1Q

General Review Criteria: (identify relevant criteria on Attachment 4): 5-7 to 5-10 in YMP-LBNL-QIP-6.1 & Section 5.1 of AP-SI.1Q

☐ Checker ☒ Technical Reviewer ☐ EA Reviewer ☐ OQA Reviewer

Name: Qinhong Hu Signature: [signature] Date: 9/23/99

REVIEWER'S COMMENTS			AUTHOR'S RESPONSE			Reviewer Disposition for Mandatory Comments	
COMMENT NO. MANDATORY (M) NON-MANDATORY (NM)	SECT. AND PAGE NO.	COMMENTS	ACCEPT Initial/Date	REJECT Initial/Date	Response required for all technical mandatory and non-mandatory comments	ACCEPT Initial/Date	REJECT Initial/Date
1 (NM)	16	the application file is frac_calc.11 the Fortran source code file is frac_calc11.f			Added to p.16 and p.67 in reference binder in YMP-LBNL-MC-1.2 MC 9/23/99		
2 (NM)	~~68~~ 82	check the source code file, there should have more codes to be printed out following p.82			source code continues onto pp. 83-87		
3 (NM)	108	cross-out = 3.75			crossed-out 3.75 & initialed & dated		
		comments only: * check the file locations & contents of frac_calc.f, test, all.par, alt.par; no anomaly.		*	* Check the calculation of lower half on p.105 to not mistake notice any		

May be on separate sheets to be attached, in which case the comments shall be numbered and this form will be used to track the comments and their resolution according to such numbers.

Resolution of Disputed Comments

Office of Quality Assurance Date

Project Manager Date

YMP-LBNL Management Approval (Project Manager or Designee)

[signature] for G.S. Bodvarsson 9/23/99

111-113 [signature] 4/21/00

APPLICABLE REFERENCE INFORMATION

Document No. and Title: Frac_Calc Version 1.1

Date of Document (or revision, draft revision number, as applicable): Version 1.1

Pertinent sections of the scientific notebook(s) or other backup documents/data identified below, support the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-MC-1.2	14-16
YMP-LBNL-MC-1.2A	67-~~82~~ 87 MC 9/3/99
YMP-LBNL-MC-1.1	114-115, 105-109, 101-104
YMP-LBNL-MC-1	60-65

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Read_TDB V1.0
Routine/Macro Documentation Form*

Note: All relevant scientific notebook (SN) pages are included in this records package. In some instances, the included SN pages cross-reference other pages that are not included here because these were not essential to the documentation of this routine.

1. Name of routine/macro with version/OS/hardware environment:
   Read_TDB / Version 1.0 / DOS (or Windows with DOS) / PC

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77 / FORTRAN Powerstation 4.0 (see SN YMP-LBNL-GSB-MC-1.2, p. 48)

3. Description and Test Plan.

   - Explain whether this is a routine or macro and describe what it does: (**Read_TDB is a routine**)
     The software routine Read_TDB is a FORTRAN code that reads a text file (ASCII format) downloaded from the Technical Data Management System (TDMS), extracts the selected columns and rows of data for use in standard spreadsheet packages, and converts stations into linear meters. It excludes any rows that have incomplete or missing information and notes the rows excluded with a print out to the screen. It is described on pages 52 and 58 in YMP-LBNL-GSB-MC-1. To install the software, copy frac_calc11.f and datablk11.f from a disk onto the hard drive of a PC. Then, compile frac_calc using a FORTRAN 77 compiler and run executable.

     This software routine is documented in the following scientific notebook pages:

YMP-LBNL-GSB-MC-1	**pp. 52, 58, 82-87**
YMP-LBNL-GSB-MC-1.2	**pp. 48-50**
Reference Binder YMP-LBNL-GSB-MC-1.2A	**pp. 120-124**

     Inputs:

     The code is designed to use fracture property data text files as directly downloaded from the TDMS. The test input which is in this very specific TDMS format is provided on pp. 120-124, Reference Binder YMP-LBNL-GSB-MC-1.2A.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     The FORTRAN code is included on pp. 82-87 in YMP-LBNL-GSB-MC-1

   - Description of test(s) to be performed (be specific):
     A test case is to use a downloaded file from the TDMS that has stations to be converted to linear distance and includes some columns with incomplete data (that are to be excluded by the routine). The test case downloaded file is DTN: GS951108314224.005. It was saved as test.dat and is included as pages 121-122 in Reference Binder YMP-LBNL-GSB-MC-1.2A. This routine is primarily used for processing of Detailed Line Survey (DLS) data and the test case uses a DLS file. The acceptance criteria are that it (1) extract the proper columns, (2) print the correct values for the selected columns, (3) exclude rows that have incomplete data, and (4) convert stations into linear distance.

   - Specify the range of input values to be used and why the range is valid:
     The input is a direct sample from the TDMS and includes the columns with incomplete data and station values to be converted to linear distance. It is considered valid because it is the type of the data that the routine was designed to use.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):

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Test results are shown on pages 49-50 in YMP-LBNL-GSB-MC-1.2 and in Reference Binder YMP-LBNL-GSB-MC-1.2A, pp. 120-124.

- Description of how the testing shows that the results are correct for the specified input:
  The routine correctly (1) extracted the proper columns (see columns/datatypes selected on p. 50 in YMP-LBNL-GSB-MC-1.2 and output on pp. 123-124 in Reference Binder YMP-LBNL-GSB-MC-1.2A, (2) printed the correct values for the selected columns in output file frac.dat (compare values in output with input pp. 123-124, 121-122 in Reference Binder YMP-LBNL-GSB-MC-1.2A, respectively (3) excluded rows that have incomplete data (see p. 50 in YMP-LBNL-GSB-MC-1.2 and output which excludes these rows on pp. 123-124 in Reference Binder YMP-LBNL-GSB-MC-1.2A, and (4) converted stations into linear distance (compare values under LOCATION in output as a linear distance in meters with input as stations on pp. 123-124, 121-122 in Reference Binder YMP-LBNL-GSB-MC-1.2A, respectively).

- List limitations or assumptions to this test case and code in general:
  The input file must be a downloaded file (ASCII or text) from the TDMS. It also assumes that the TDMS will not change its formatting of having the column heading align directly with the value or text within the column. It also assumes that station measurements correpsond to meters (which has been used for the ESF, ECRB and their alcoves)

- Electronic files identified by name and location (include disc if necessary):
  test.dat and frac.dat (input and output) listed on pp. 120-124 in Reference Binder YMP-LBNL-GSB-MC-1.2A. File sizes and other information given on p. 49 of YMP-LBNL-GSB-MC-1.2.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:
   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation.

MAINTAIN PAGES IN THIS ORDER:

1) This 2 page "Routine Documentation" summarization form	
2) YMP-LBNL-GSB-MC-1	pp. 52, 58, 82-87
3) YMP-LBNL-GSB-MC-1.2	pp. 48-50
4) Reference Binder YMP-LBNL-GSB-MC-1.2A	pp. 120-124

***Note that this supplement includes:**
-Addition of this 2-page "Routine Documentation" summarization form

3/1/2000

111-116 JCH 4/21/00

PROJECT NAME (Detailed Line Survey) MC 6/28/99 NOTEBOOK NO.

TDB - Developed code to read in data from DLS of ESF 4/1/98

This code uses the headings to determine the spacing between parameters. This code extracts:

STATION (only 1ST if range)
STRIKE
DIP
LENGTH ABOVE TRACE
LENGTH BELOW TRACE
HEIGHT
WIDTH

If any of the above are Not Recorded (NR) or NA (Not Available) then the entire line is excluded.
If an * is present indicating a possible range for the value, the value given in the table is used.

All of the above data manipulations are printed to the file index.txt

The code allows the concatenation of data files so that all can be placed together for analysis.

This program was necessary because of the text that is present in the TDB files and allows for direct use of the data as numbers.

The code was tested on 11 DLS files available from the TDB. Spot checks were performed and the program was found to work properly.

The following code and executable is on NWD-Cushey
shared folder DLS\read_dls & DLS\read_dls.f
and
d:\code\read_dls\read_dls.f
d:\code\read_dls\read_dls

Read_DLS is the prototype for Read-TDB which is a single user macro checked on page 87 by R. Ahlers MC 3/31/99

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111-117 JEH 4/21/00

PROJECT NAME

TDB – development of code to read any TDB text file 4/13/98

The previous code read_dls.f (p. 52) was revised extensively to allow the extract of any parameter from any data file.

Again, the header is used as a basis for spacing.

The new code allows the user to select any parameter(s) (assumes all names are unique after 8 letters) and print these separately to a file.

If any of the selected parameters is not recorded (NR) or not available (NA), the entire line of data is excluded. (noted in file index.txt) MC 4/13/98

If a * is present, the number is used by a note is recorded in index.txt

Any number of files can be concatenated.

This code is called read_tdb.f and resides in both
D:\code\read_tdb
and
share folder dls
on NWD-Cushey

The code was tested on DLS files and spot checked. It appears to work properly.

The code will put in this Scientific Notebook once it is further tested.

SIGNATURE Mark A Cushey DATE 4/13 19 98
READ AND UNDERSTOOD DATE 19

111-118 JEH 4/21/00

Version 1.0 (MC 7/9/99)

This code is a single user macro MC 3/31/99

see p87 reviewed by F. Ahlers MC 4/1/98

see p.52 and p.58 for initial development & planning of this code MC 6/28/99

```
      program Read_TDB

c     This program reads the data files from the
c     Technical Database.  Output are written
c     unformatted to selected output file.  All messages are
c     recorded to the screen and file 'index.txt'
c     Mark Cushey 4/98

c     Output is limited to 10 numerical datatypes
c     It is assumed that the maximum line length is less than 250

      real anum,bnum,value(10),limvalue(10,2)
      character*4 first
      character*25 filename
      character*250 all
      character*250 datastring
      character*8 astat,bstat,avalue,limtext(10)
      character*1 onestring(250),onedata(8),plus(8),ans
      character*8 dataname(10),limitname(10)
      integer row,iname,istring,idata,icolumn(10),i,loc,rowused,
     +        im,limnum,limtxt,loctype

c     ----------------------------------------

c     open output files
      write(*,*)'Enter name of output file:'
      read(*,1000)filename
      open(unit=20,file=filename)
      open(unit=21,file='index.txt')
      write(*,*)'Details on data retrieval are in index.txt'

c     ----------------------------------------
c     query for different data types to be stored
c
      write(*,*)'List names of data types to be retrieved - up to 10'
      write(*,*)'   Enter only the first 8 letters for each'
      write(*,*)'   Enter the word end for last entry'
      i = 0
40    i = i + 1
      read(*,1010)dataname(i)
      if ((dataname(i).ne.'end').and.
     &       (dataname(i).ne.'END')) go to 40
      iname = i - 1
      write(*,1040)iname
      write(21,1040)iname
      write(20,1041)(dataname(i),i=1,iname)
      write(*,*)'Should header be printed in output file - Y or N'
      read(*,1011)ans
      if ((ans.eq.'Y').or.(ans.eq.'y'))
     &       write(21,1041)(dataname(i),i=1,iname)
1010  format(a8)
1011  format(a1)
1040  format(1x,i7,' datatypes selected')
1041  format(10(2x,a8))
c     ----------------------------------------
```


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```
c       query for limits on outputting data
        limnum = iname
        limtxt = iname
        write(*,*)'Are there limits for the output - Y or N ?'
        read(*,1011)ans
        if ((ans.eq.'Y').or.(ans.eq.'y')) then
                i = iname
c               write(*,*)'Enter the parameter names for numerical limits
'
c               write(*,*)'   Enter only the first 8 letters for each'
c               write(*,*)'   Enter the word end for last entry'
c45             i = i + 1
c               read(*,1010)dataname(i)
c               if ((dataname(i).eq.'end').or.
c       &       (dataname(i).eq.'END')) go to 46
c               write(*,*)'Enter upper and lower value for limit'
c               read(*,*)limvalue(i,1),limvalue(i,2)
c               write(*,*)'Enter next limit or end'
c               go to 45
c46             i = i - 1
c               limnum = i
                write(*,*)'Enter the parameter names for text-defined lim
its'
                write(*,*)'   Enter only the first 8 letters for each'
                write(*,*)'   Enter the word end for last entry'
47              i = i + 1
                read(*,1010)dataname(i)
                if ((dataname(i).eq.'end').or.
        &       (dataname(i).eq.'END')) go to 49
                write(*,*)'Enter text to exclude - up to 8 characters'
                read(*,1010)limtext(i)
                write(*,*)'Enter next limit or end'
                go to 47
49              limtxt = i - 1
                do i=(iname+1),limtxt
                        if (i.le.limnum) then
                                write(*,1045)dataname(i),limvalue(i,1),li
mvalue(i,2)
                                write(21,1045)dataname(i),limvalue(i,1),l
imvalue(i,2)
                        else
                                write(*,1046)dataname(i),limtext(i)
                                write(21,1046)dataname(i),limtext(i)
                        end if
                end do
        end if
1045    format(1x,'Limits on',a8,1x,f9.3,1x,f9.3)
1046    format(1x,'Limits on',a8,1x,'exclude',1x,a8)

c       ----------------------------------------
c       query for input filename and open

50      write(*,*)'Enter next data filename (use MS-DOS filename) or quit
'
        read(*,1000)filename
        if ((filename.eq.'quit').or.(filename.eq.'QUIT'))go to 990
```


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```
      open(unit=10,file=filename,action='READ',
      &       form='FORMATTED',status='old',err=75)
      write(*,*)filename
      write(21,*)'------------------'
      write(21,*)filename
      write(21,*)'------------------'
1000  format(a25)
      go to 80
75    write(*,*)'File does not exist'
      go to 50

c     ----------------------------------------
c     If one of the parameters is LOCATION, determine type
c     If LOCATION is station number along DLS, loctype =0
C   If LOCATION is along alcove, loctype = alcove #.
c     If other, then loctype = -1.
80    loctype = -1
      Do i = 1,iname
              if (dataname(i).eq.'LOCATION') then
                      write(*,*)'Is LOCATION a station number along the
 ,
      +' DLS, alcove, or other - d, a, or o'
                      read(*,*)ans
                      if ((ans.eq.'d').or.(ans.eq.'D')) then
                              loctype = 0
                      else
                              if ((ans.eq.'a').or.(ans.eq.'A')) then
                                      write(*,*)'Which alcove #'
                                      read(*,*)loctype
                              else
                                      loctype = -1
                              end if
                      end if
              end if
      End Do
c     ----------------------------------------

c     find header line (between rows of asteriks)
82    read(10,1001)first
      if (first.ne.'****') go to 82
1001  format(a4)

c     ----------------------------------------

c     find location where different data starts (use header)

      do i=1,limtxt
              icolumn(i)=0
      end do

      read(10,1020)datastring
      read(datastring,1021)(onestring(istring),istring=1,250)
      do i = 1,limtxt
              read(dataname(i),1022)(onedata(idata),idata=1,8)
              do istring = 1,250
               do idata = 1,8
```


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```
                 if( (onestring(istring+idata-1).ne.onedata(idata)) )
     &                go to 98
                end do
98              if (idata.eq.9) go to 99
               end do
99             if (istring.ne.251) then
                       icolumn(i)=istring
               else
                       write(*,1023)dataname(i)
                       pause
                       stop
               end if
       end do

       write(*,1003)(icolumn(i),i=1,iname)
       write(21,1003)(icolumn(i),i=1,iname)
1003   format(1x,'Column headers at',10(1x,i5))
1020   format(a250)
1021   format(250(a1))
1022   format(8(a1))
1023   format(1x,a8,' not found in file -- stopped')

c      ------------------------------------
c      move forward to first data row

105    read(10,1001)first
       if (first.ne.'****') go to 105
c      skip blank line
     read(10,1002)all
1002   format(a72)

c      ----------------------------------------

c      read data lines from file and get values
       rowused = 0
       row = 0
200    read(10,2001,err=900,end=900)datastring
       if (datastring.eq.'End of Report') go to 900
       if (datastring.eq.'              ') go to 200
       row = row + 1
       write(*,*)row

c      first see if data is within text-defined limits
       do ii=(limnum+1),limtxt
               loc = icolumn(ii)
               read(datastring,1999)all
               if (all.eq.limtext(ii)) then
                       write(*,2025)row,dataname(ii),limtext(ii)
                       write(*,2026)datastring
                       write(21,2025)row,dataname(ii),limtext(ii)
                       write(21,2026)datastring
                       go to 200
               end if
       end do
```


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```
        do i=1,iname
                loc = icolumn(i)
                read(datastring,1999)avalue

c               first check to see if any are not recorded (NR) or
c               special (*) -- exclude NR and use *
                read(avalue,2002)(onedata(idata),idata=1,8)
                do idata=1,8
                        if ((onedata(idata)).eq.'N') then
c                       the entire line is excluded
                         write(*,2020)row,onedata(idata),onedata(idata+1)
,
        &                       dataname(i)
                         write(21,2020)row,onedata(idata),onedata(idata+1
),
        &                       dataname(i)
                         go to 200
                        end if
                if (onedata(idata).eq.'*') then
                        write(*,2021)row
                        write(21,2021)row
                        read(avalue,2024)avalue
                end if
                end do

c               check if entry is a station number -- if loctype = 0
c               LOCATION is station number along DLS, if loctype = +#
c               LOCATION is along alcove (number loctype)

                If ((loctype.ge.0).and.(dataname(i).eq.'LOCATION')) then
c                       get station number
                        read(avalue,2005)(plus(ip),ip=1,8)
                        do ip=1,8
                                if (plus(ip).eq.'+') go to 215
                        end do
215                     read(avalue,2010)astat,all,bstat
                        read(astat,*)anum
                        read(bstat,2005)(plus(im),im=1,(8-ip))
                        do im = 1, (8-ip)
                                if (plus(im).eq.'-') go to 216
                        end do
216                     read(bstat,2011)astat
                        read(astat,*)bnum

                        if (loctype.eq.0) then
                                value(i) = anum*100 + bnum
                        else
                                value(i) = real(loctype)*10000 + anum*100
 + bnum
                        end if
                else
                        read(avalue,*)value(i)
                end if

        end do
```


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```
2001    format(a250)
c       change a8 to larger value if number is more than 8 digits
1999    format(<loc-1>x,a8)
2002    format(8(a1))
2005    format(8(a1))
2010    format(a<ip-1>,a1,a8)
2011    format(a<im-1>)
2020    format(1x,'Row',i5,' has a ',a1,a1,' for ',a8,
        &              ' - this data row is not used')
2021    format(1x,'Row',i5,' has a * - printed value will be used')
2024    format(a<idata-1>)

2025    format(1x,'Row',i5,' excluded ',a8,' is ',a8)
2026    format(5x,a40)


c       write data to output file and read next line

        write(20,3000)(value(i),i=1,iname)

3000    format(10(f10.3))
        rowused = rowused + 1
        go to 200

900     close(10)
        write(*,*)row,' rows read and',rowused,' used'
        write(21,*)row,' rows read and',rowused,' used'
c       ask for next file
        go to 50

990   close(20)
        close(21)
        pause
        stop
999     write(*,*)'Error in file formatting -- stopped'
        write(*,*)'Error in file formatting -- stopped'
        close(20)
        close(21)
        close(10)
        pause
        stop
        end
```

This code has been reviewed and performs the task intended C Frohlich 7/1/98

SIGNATURE [signature] DATE 5/7 19 98
READ AND UNDERSTOOD _____ DATE _____ 19 _____

111-124 gsH 4/21/00

PROJECT NAME QA:L NOTEBOOK NO.

Compiler information for Read_TDB.f 12/2/99

The routine Read_TDB Version 1.0 was compiled using:

FORTRAN Powerstation 4.0
Microsoft 1994-1995

Product ID: 36785-411-0088773-30563

(part of Microsoft Developer Studio)

SIGNATURE [signature] DATE 12/2 19 99
READ AND UNDERSTOOD 111-125 AA4 4/21/00 DATE 19

Files used in testing Read_TDB Version 1.0 12/2/99

Read_TDB was previously tested (see YMP-LBNL-GSR-MC-1, p. 58) and reviewed. The test case though was not included in the notebook, though. The files used to test are given below. This case was run on 4/13/98.

```
Volume in drive D is YMP
Volume Serial Number is 0758-0AD0
Directory of D:\code\read_tdb

.              <DIR>          04-13-98 11:11a .
..             <DIR>          04-13-98 11:11a ..
READ_TDB F          8,675     05-21-98  4:31p read_tdb.f
READ_TDB MAK        4,797     04-13-98  2:36p read_tdb.mak
DEBUG          <DIR>          04-13-98 12:16p Debug
TEST     TXT       49,900     04-13-98 12:48p test.txt
FRAC     DAT        7,488     04-13-98  2:56p frac.dat
DIR      TXT            0     12-02-99  3:22p dir.txt
READ_TDB MDP       33,792     06-11-98  2:41p read_tdb.mdp
DUMMY              24,800     04-20-98  3:19p dummy
DLS      DAT       16,596     04-29-98  3:19p dls.dat
ALCOVE3  DAT        4,960     05-04-98  3:16p alcove3.dat
         9 file(s)        151,008 bytes
         3 dir(s)   1,693,548,544 bytes free
```

input file → TEST
output file → FRAC

The files Test.dat and frac.dat are in Reference Binder YMP-LBNL-MC-1.2A pp. 120-124

test.dat is the input - it is a direct example from the TDMS
frac.dat is the output

These can be used to test Read_TDB on other personal computers.

The screen printout that is saved to 'index.txt' is on the next page.

```
      7 datatypes selected
 LOCATION  STRIKE    DIP       LENGTH A  LENGTH B  HEIGHT    WIDTH
-----------------
d:\code\read_tdb\test.txt
-----------------
Column headers at    28    70    87   104   121   138   155
Row    2 has a NR for LENGTH A - this data row is not used
Row    4 has a * - printed value will be used
Row    5 has a NR for LENGTH B - this data row is not used
Row   18 has a NR for LENGTH B - this data row is not used
Row   19 has a NR for LENGTH B - this data row is not used
Row   20 has a NR for LENGTH B - this data row is not used
Row   24 has a NR for LENGTH B - this data row is not used
Row   26 has a NR for LENGTH B - this data row is not used
Row   29 has a NR for LENGTH B - this data row is not used
Row   30 has a NR for LENGTH B - this data row is not used
Row   31 has a NR for LENGTH B - this data row is not used
Row   34 has a NR for LENGTH A - this data row is not used
Row   63 has a NR for LENGTH A - this data row is not used
Row   70 has a NR for LENGTH B - this data row is not used
Row   72 has a NR for LENGTH B - this data row is not used
Row   81 has a NR for LENGTH B - this data row is not used
Row   82 has a NR for LENGTH B - this data row is not used
Row   84 has a NR for LENGTH B - this data row is not used
Row   86 has a NR for LENGTH B - this data row is not used
Row   87 has a NR for LENGTH B - this data row is not used
Row   95 has a NR for LENGTH B - this data row is not used
       123 rows read and        103 used
```

↑ from file 'index.txt'

SIGNATURE [signature] DATE 12/2 19 99
READ AND UNDERSTOOD 11-127 DATE _____ 19 _____

Files used in checking Read_TDB Version 1.0
(a software routine)

test.dat – input test file
frac.dat – output test file

These files were created on 4/13/98

LOCATION	STRIKE	DIP	LENGTH A	LENGTH B	HEIGHT	WIDTH
801.360	200.000	86.000	2.450	.700	3.100	.400
802.580	.000	90.000	.700	.200	.900	.100
803.180	325.000	83.000	.850	3.000	3.500	2.600
804.150	220.000	73.000	2.500	.900	3.000	.400
804.640	255.000	85.000	.750	1.300	1.900	.060
804.830	15.000	78.000	.270	.900	1.100	.030
805.600	170.000	50.000	2.500	.500	3.000	.400
806.290	220.000	84.000	1.400	1.100	2.500	.100
806.420	215.000	84.000	4.000	1.000	5.000	.500
806.860	220.000	85.000	1.500	.750	2.250	.080
807.750	210.000	74.000	2.200	2.500	4.500	1.500
808.340	225.000	80.000	4.000	1.300	5.000	.600
808.650	230.000	83.000	6.000	1.000	6.000	3.000
808.900	225.000	83.000	1.800	.900	2.400	.150
809.840	230.000	75.000	.660	.350	1.000	.030
814.960	30.000	84.000	1.200	.700	1.900	.100
815.310	235.000	75.000	4.000	.100	3.500	3.000
816.180	200.000	80.000	5.000	.200	5.000	4.000
817.880	180.000	48.000	1.900	.150	2.000	.100
819.450	230.000	75.000	2.500	1.200	3.500	.800
819.730	170.000	85.000	.950	.500	1.400	.050
824.180	176.000	56.000	.650	.600	1.250	.050
829.830	225.000	77.000	4.000	2.000	5.500	1.500
836.650	195.000	85.000	1.200	.170	1.330	.050
839.950	15.000	78.000	1.790	2.330	3.850	.900
843.310	225.000	77.000	3.000	2.100	4.800	.300
844.580	193.000	80.000	2.150	1.600	3.500	.100
845.000	300.000	84.000	5.400	1.900	7.000	8.000
849.920	197.000	65.000	2.900	1.600	4.400	.200
857.390	.000	40.000	.700	.850	1.500	.050
857.610	230.000	60.000	.550	1.250	1.750	.050
859.370	216.000	55.000	.470	1.500	1.970	.350
859.620	13.000	71.000	1.110	.210	1.300	.100
859.810	20.000	79.000	.730	1.020	1.700	.750
862.840	12.000	82.000	1.020	.220	1.170	.200
863.770	24.000	7.000	.340	2.800	3.000	.250
864.180	212.000	61.000	.570	.800	1.200	.080
864.700	21.000	15.000	.600	.490	1.000	.030
865.370	172.000	68.000	2.750	.490	3.000	.250
865.420	28.000	4.000	.030	.030	.060	.010
865.450	180.000	64.000	.150	.560	.650	.050
865.600	20.000	10.000	3.600	.200	3.400	.030
868.550	5.000	66.000	4.500	2.500	6.500	2.500
868.650	15.000	20.000	5.000	.100	5.000	.300
873.970	176.000	68.000	4.500	1.650	6.000	4.000
874.030	97.000	84.000	.560	.350	.850	.100
874.410	14.000	66.000	.230	.600	.780	.060
874.580	345.000	69.000	.570	.120	.650	.050
875.220	.000	74.000	2.600	.030	2.400	.400
879.700	20.000	8.000	2.000	6.000	8.000	1.500
882.370	184.000	78.000	3.500	1.670	4.000	2.000
893.860	20.000	49.000	.100	.330	.400	.010
893.920	22.000	80.000	.680	.620	1.250	.050
894.130	20.000	67.000	1.200	1.600	2.700	.900
896.190	225.000	50.000	2.660	1.480	3.800	.350

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899.090	220.000	61.000	4.500	1.500	5.500	1.000
904.670	220.000	82.000	3.000	2.300	5.000	1.500
911.550	240.000	58.000	15.000	.200	6.000	10.000
916.700	300.000	49.000	5.000	2.500	7.200	9.000
921.670	165.000	76.000	15.000	2.000	8.000	7.000
922.000	205.000	90.000	1.000	1.800	2.500	1.400
923.570	5.000	85.000	1.700	1.800	3.100	1.300
923.950	30.000	80.000	6.000	1.650	7.000	2.700
926.550	15.000	83.000	2.700	1.400	3.500	.800
927.000	15.000	65.000	.400	.200	.500	.200
927.100	175.000	60.000	.500	.600	1.000	.150
929.570	195.000	87.000	13.000	10.000	8.000	8.000
931.760	220.000	90.000	2.700	1.500	3.500	.700
938.700	165.000	73.000	7.500	2.300	7.000	7.000
938.900	190.000	82.000	3.300	.800	3.000	.300
939.900	195.000	60.000	18.000	5.000	12.000	8.000
940.610	210.000	70.000	8.000	3.000	9.000	2.500
942.050	215.000	64.000	.700	.500	1.200	.150
942.430	210.000	65.000	5.000	.800	5.500	1.000
944.780	215.000	64.000	1.800	.900	2.600	.400
955.800	170.000	74.000	1.000	1.100	1.700	.300
956.430	188.000	66.000	18.000	5.000	12.000	8.000
958.020	330.000	82.000	4.000	1.400	5.000	2.200
962.000	200.000	90.000	.600	1.600	2.100	.200
963.230	150.000	84.000	3.500	1.800	5.000	1.000
965.390	160.000	66.000	1.000	1.200	2.000	.300
965.490	180.000	59.000	5.000	1.800	6.500	1.000
969.750	340.000	83.000	7.000	2.000	7.500	3.800
970.030	190.000	75.000	.500	.200	.700	.050
970.070	15.000	85.000	.700	.140	.800	.050
970.210	.000	80.000	4.000	1.900	5.900	1.000
973.600	190.000	70.000	1.200	1.100	2.200	.500
973.740	190.000	75.000	3.300	.220	3.000	.300
974.670	210.000	78.000	2.200	1.800	3.900	.900
983.470	200.000	58.000	5.000	1.900	6.000	1.000
984.760	350.000	88.000	.500	2.000	2.400	1.400
985.140	210.000	75.000	6.000	2.000	7.000	3.800
986.450	340.000	78.000	.700	2.300	2.200	1.900
986.850	210.000	87.000	.050	.900	.900	.300
987.860	190.000	74.000	.400	.600	1.000	.100
991.280	355.000	84.000	1.700	2.450	4.000	2.000
991.610	5.000	85.000	.900	2.400	3.000	2.000
991.870	215.000	88.000	4.000	2.400	6.000	1.500
994.150	340.000	82.000	2.000	2.200	4.000	2.100
995.940	195.000	64.000	.800	2.000	2.500	1.000
996.270	210.000	47.000	2.500	.400	2.700	.300
997.570	.000	82.000	2.400	2.600	4.500	2.200
998.430	340.000	76.000	2.700	3.200	4.500	2.200

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View Unit Descriptions

Start of Report...

INGRES REPORT Copyright (c) 1981, 1995 Computer Associates Intl, Inc.
Reading report specifications and preparing query . . .
Retrieving data . . .

TECTONIC CHARACTERISTICS DATA REPORT

TABLE DESCRIPTION:
Fracture Type data from North Ramp Tunnel - ESF, and Yucca Mountain Project Detailed Line Survey-Data from Station 8+01.36 to 9+98.43; collected under GP-32, R0, SCP Study Number 8.3.1.4.2.2.4., 06/02/1995 to 06/20/1995.

TDIF: 305055

DTN: GS951108314224.005

FOOTNOTES: Traceline is generally 0.9 meters below right wall springline; BED-Bedding; F-Fracture; FLT-Fault; SH-Shear; RK-Ends blindly in rock mass; ST-End not visible behind ground support; IN-Fracture extends under precast invert segments; Air-Fracture (usually subparallel to tunnel) termination has been excavated; CR-Crown; P-Planar; I-Irregular; U-Undulating; NR-Not recorded; R1-Stepped, Near-normal steps and ridges occur on the fracture surface; R2-Rough, Large, angular asperities can be seen; R3-Moderately rough, asperities are clearly visible and fracture surface feels abrasive; R4-Slightly rough, small asperities on the fracture surface are visible and can be felt; R5-Smooth, no asperities, smooth to the touch; R6- Polished, extremely smooth and shiny; Ja.11-Tightly healed, hard filling; Ja.12-unaltered surface stain only; Ja.13-slightly altered, non softening coating, sandy particles; Ja.14-silty or sandy clay coatings, little clay; Ja.15-softening or clay mineral coatings;

ADDNL FOOTNOTES: Ja.31-zones of disintegrated or crushed rock; Ja.32-zones of silty or sandy clay.

11-131 [illegible] 4/24/00

ROW#	Q	FRACTURE TYPE	LOCATION	DATE	STRIKE (^o)	DIP (^o)	LENGTH ABOVE TRACELINE (m)	LENGTH BELOW TRACELINE (m)	HEIGHT (m)	WIDTH (m)	FRACTURE ENDS VISIBLE	UPPER TERMINATION
1	Y	F	8+01.36	06/02/95 - 06/20/95	200	86	2.45	0.7	3.1	0.4	2	RK
2	Y	F	8+02.40	06/02/95 - 06/20/95	10	83	NR	1.5	1.3	1	2	RK
3	Y	F	8+02.58	06/02/95 - 06/20/95	0	90	0.7	0.2	0.9	0.1	2	RK
4	Y	F	8+03.18	06/02/95 - 06/20/95	325*	83	0.85	3	3.5	2.6	1	F
5	Y	F	8+03.60	06/02/95 - 06/20/95	210	77	3	NR	3	0.5	2	RK
6	Y	F	8+04.15	06/02/95 - 06/20/95	220	73	2.5	0.9	3	0.4	2	F
7	Y	F	8+04.64	06/02/95 - 06/20/95	255	85	0.75	1.3	1.9	0.06	2	F
8	Y	F	8+04.83	06/02/95 - 06/20/95	15	78	0.27	0.9	1.1	0.03	2	RK
9	Y	F	8+05.60	06/02/95 - 06/20/95	170	50	2.5	0.5	3	0.4	2	F
10	Y	F	8+06.29	06/02/95 - 06/20/95	220	84	1.4	1.1	2.5	0.1	2	F
11	Y	FLT	8+06.42	06/02/95 - 06/20/95	215	84	4	1	5	0.5	2	F
12	Y	FLT	8+06.86	06/02/95 - 06/20/95	220	85	1.5	0.75	2.25	0.08	2	RK
13	Y	F	8+07.75	06/02/95 - 06/20/95	210	74	2.2	2.5	4.5	1.5	1	F
14	Y	F	8+08.34	06/02/95 - 06/20/95	225	80	4	1.3	5	0.6	2	F
15	Y	F	8+08.65	06/02/95 - 06/20/95	230	83	6	1	6	3	2	RK
16	Y	F	8+08.90	06/02/95 - 06/20/95	225	83	1.8	0.9	2.4	0.15	2	F

⋮

(Abridged version of file included here.
Full printout can be found on pp. 121-122 of Reference Notebook YMP-LBNL-GSB-MC-1.2A (for Scientific Notebook YMP-LBNL-GSB-MC-1.2) under ACC: MCL.19990903.0031)

⋮

107	Y	F	9+73.60	06/02/95 - 06/20/95	190	70	1.2	1.1	2.2	0.5	2	F
108	Y	F	9+73.74	06/02/95 - 06/20/95	190	75	3.3	0.22	3	0.3	2	RK
109	Y	F	9+74.67	06/02/95 - 06/20/95	210	78	2.2	1.8	3.9	0.9	2	F
110	Y	F	9+83.47	06/02/95 - 06/20/95	200	58	5	1.9	6	1	2	RK
111	Y	F	9+84.76	06/02/95 - 06/20/95	350	88	0.5	2	2.4	1.4	2	RK
112	Y	F	9+85.14	06/02/95 - 06/20/95	210	75	6	2	7	3.8	1	RK
113	Y	F	9+86.45	06/02/95 - 06/20/95	340	78	0.7	2.3	2.2	1.9	1	RK
114	Y	F	9+86.85	06/02/95 - 06/20/95	210	87	0.05	0.9	0.9	0.3	2	RK
115	Y	F	9+87.86	06/02/95 - 06/20/95	190	74	0.4	0.6	1	0.1	2	RK
116	Y	F	9+91.28	06/02/95 - 06/20/95	355	84	1.7	2.45	4	2	1	F
117	Y	F	9+91.61	06/02/95 - 06/20/95	5	85	0.9	2.4	3	2	1	F
118	Y	F	9+91.87	06/02/95 - 06/20/95	215	88	4	2.4	6	1.5	0	ST
119	Y	F	9+94.15	06/02/95 - 06/20/95	340	82	2	2.2	4	2.1	1	F
120	Y	F	9+95.94	06/02/95 - 06/20/95	195	64	0.8	2	2.5	1	1	F
121	Y	F	9+96.27	06/02/95 - 06/20/95	210	47	2.5	0.4	2.7	0.3	2	RK
122	Y	F	9+97.57	06/02/95 - 06/20/95	0	82	2.4	2.6	4.5	2.2	1	RK
123	Y	F	9+98.43	06/02/95 - 06/20/95	340	76	2.7	3.2	4.5	2.2	1	RK

End of Report

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LOWER TERMINATION	PLANARITY	JOINT ALTERATION NUMBER	FRACTURE ROUGHNESS	MINIMUM APERTURE (mm)	MAXIMUM APERTURE (mm)
RK	P	14	4	0	0
RK	I	14	3	0	0
RK	I	15	3	0	0
IN	P	15	4	0	0
RK	I	15	4	0	0
RK	P	15	5	0	0
F	I	15	4	0	0
F	I	11	3	0	0
F	U	15	6	0	5
RK	P	13	4	0	3
RK	P	15	4	0	3
RK	U	13	4	0	0
IN	U	14	5	0	2
RK	P	15	4	0	10
RK	P	15	4	0	5
RK	P	15	4	0	0
⋮					
RK	I	11	3	0	0
F	I	11	3	0	0
RK	I	12	3	0	0
RK	I	13	3	0	0
RK	I	13	3	0	0
IN	I	13	3	0	0
IN	I	13	3	0	0
RK	I	13	3	0	0
RK	I	15	3	0	0
IN	I	15	3	0	0
IN	I	15	3	0	0
IN	I	15	3	0	0
IN	P	14	3	0	0
IN	I	14	3	0	0
RK	I	14	3	0	0
IN	U	15	3	0	0
IN	I	15	3	0	0

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COMMENTS

upper termination in stratigraphic pumice bed, 1 to 2mm clay coating, mostly in middle of fracture
upper termination at trace line, has small finger fracture coming off which intersects fracture at sta. 8+02.58, finger comes off at 0.15m below trace line, 1 to 2mm clay coating
at 0.65m above trace line fracture has finger that comes off with change in azimuth to 170, dip 90 degrees, this fracture can be traced from 3m to fracture
upper termination in fracture 8+03.60, fracture thinning at bottom, 2 to 3mm clay infilling
2 to 3mm altered clay infilling, zone of alteration on fracture sides, ends in highly altered zone
up to 2mm soft orange colored clay infilling
dip varies + or - 5 degrees along trace
no coatings
amplitude 0.04m, wave length 0.7m, up to 10mm orange clay infilling, fracture surface slicken sided, rake 70 degrees
clean to local patches of up to 1mm thick orange clay infilling
this has movement with 0.1m offset, west side down, up to 1mm clay infilling
0.15m offset, west side down, locally clean, local 1mm clay infilling, unable to determine amplitude and wave length
0 to 10mm orange clay infilling
1mm to 3cm orange clay infilling
0 to 10mm clay (average approx. 4mm) infilling
1 to 3mm orange clay infilling

see next fracture 9+73.74, upper termination has apparent curves into 9+73.74, while the lower termination dies, next fracture is subparallel
see 9+73.60, the lower termination curves near tapeline to intersect 9+73.60
hard to see ends
bottom 1.0m (plus or minus) is in an altered, discolored zone, in local zones, especially at the bottom are up to 15mm mineralized infilling
upper termination is faint, dies out, lower termination is in altered, discolored zone, bottom of fracture anastomoses, has mineralized infilling
local mineralized infilling, especially in bottom altered zone
mineralized infilling, especially in bottom altered zone, up to 30mm (plus or minus)
mineralized infilling, up to 15mm thick, extending about 0.3m above altered zone
mineralized infilling along total height, thickness of mineralized infilling up to 10cm
mineralized infilling 0 to 5cm thick
mineralized infilling 0 to 3.5cm, becomes very faint towards SW invert
mineralized with dark minerals, varies from 0 to 3cm
mineralized with dark minerals, varies from 0 to 4mm
slightly mineralized 0 to 3mm
slightly mineralized 0 to 2mm, fracture is faint and hard to trace in some locations
mineralized 4 to 10mm, fracture terminates at top of hydrothermal alterations
mineralized 3 to 5mm

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YMP-LBNL DOCUMENT REVIEW/COMMENT RESOLUTION (DRCR) FORM

Document No. and Title: Software Macro Read_TDB Version 1.0 _____ Page __1__of _1___

Date of Document / revision no./ draft revision no. (as applicable):_____Version 1.0_____ Author:____Mark Cushey_____

Are Scientific Notebooks or other background documents/data included in the scope of this review? ☒ Yes ☐ No (If yes, identify on Attachment 3)

Specific Review Criteria or Governing Procedure: AP-SI.1Q, Rev 1, ICN 0 and YMP-LBNL-QIP-6.1, Rev. 4, Mod. 0 _____

General Review Criteria: (identify relevant criteria on Attachment 4): Section 5.1 of AP-SI.1Q and Software Review Criteria S-7 to S-10 _____

☐ Checker ☒ Technical Reviewer ☐ EA Reviewer ☐ OQA Reviewer

Name:_____C.F. Ahlers_____ Signature: _____ Date: __9/23/99_____

REVIEWER'S COMMENTS			AUTHOR'S RESPONSE			Reviewer Disposition for Mandatory Comments	
COMMENT NO. MANDATORY (M) NON-MANDATORY (NM)	SECT. AND PAGE NO.	COMMENTS	ACCEPT Initial/Date	REJECT Initial/Date	Response required for all technical mandatory and non-mandatory comments	ACCEPT Initial/Date	REJECT Initial/Date
		No comments					

May be on separate sheets to be attached, in which case the comments shall be numbered and this form will be used to track the comments and their resolution according to such numbers.

Resolution of Disputed Comments

Office of Quality Assurance _____ Date

Project Manager _____ Date

YMP-LBNL Management Approval (Project Manager or Designee) for GS Bodvarsson 9/23/99

111-135 9/24/00

APPLICABLE REFERENCE INFORMATION

Document No. and Title: Software Macro : Read_TDB Version 1.0

Date of Document (or revision, draft revision number, as applicable):
Version 1.0

Pertinent sections of the scientific notebook(s) or other backup documents/data identified below, support the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-MC-1	pp. 52, 58, 82-87

111-136 PDH 4/24/00

mddf_cc.f v.1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment:
   mddf_cc.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     This routine is based on the routine mddf.f v1.0 and is used to cut out a 3 x 2 meter rock-fall around the crown of the drift in a ITOUGH2 V3.2_drift MESH file. The new MESH file as saved with a new filename.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 118-123 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     First, the MESH will be cut with a cylinder with radius R through the center of the original 3D MESH. Second, the code will then remove a 3 x 2 x 1meter set of elements representing a "rock-fall" at the crown of the drift. Third, the elements that are within the removed area will be renamed to indicate their position. The connections will then be defined for those elements on the drift/rock-fall wall. The connection information for the drift and rock-fall neighboring elements will be used to form a new MESH file named MESHSF_cc. The test will be checked by successfully running the code without error messages and by visually checking the MESH file as well as a 3D rendering of the output MESH to verify that the changes in formatting are correct. The visual check will consist of verifying that the elements at the XYZ coordinates specified in the input are in fact removed correctly from the output. The 3D visual-check method is also used because the output data is very large and it is most effective to visually check the results in 3D rather than check the output data line by line.

   - Specify the range of input values to be used and why the range is valid
     The input is the original MESH file, a radius value of 2.75 and the rock cut dimensions given on pp. 153-154, S/N YMP-LBNL-CFT-GL-1. This test case input range is deemed valid because the input data set is the data set used to model the drift scale problem.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input)
     The output from the test is the file MESHSF. A graphic display of this MESH is printed on p. 154 , S/N YMP-LBNL-CFT-GL-1 and file MESHSF_cc is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf_cc/. Any ITOUGH2 V.3.2_drift MESH file of comparable size to this model could possibly be used. Any radius or rock-cut size used for a problem would have to be small enough so that the cylinder or drift would not intersect the outer boundary of the MESH.

111-137 JEH 4/21/00

- Description of how the testing shows that the results are correct for the specified input.
  Visual inspection of both the input and output data files provided on the accompanying CD, as well as a 3D visualization of the final output (MESHSF_cc) shows that the routine successfully removes the elements represented by the drift/rock fall and that all connections and elements are redefined properly. In addition, the test was successful because the routine successfully ran without error messages and the new MESHSF_cc was successfully imported into ITOUGH2 V3.2_drift without errors. Therefore, the test case and routine are acceptable.

- List limitations or assumptions to this test case and code in general
  The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 V3.2_drift models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift. This routine assumes that the drift is perfectly cylindrical and straight and that the rock fall occurs as a square 3 x 2 x 1 meter block at the crown of the drift.

- Electronic files identified by name and location (include disc if necessary)
  The routine, test files and its description can be found on pp. 153-154, from S/N YMP-LBNL-CFT-GL-1 and pp. 118-123 from S/N YMP-LBNL-CFT-GL-1A Reference Binder. The routine (mddf_cc.fV1.0), input file (MESH) and output file (MESHSF_cc) are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf_cc/

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated.

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 153-154 for S/N YMP-LBNL-CFT-GL-1; and pp. 118-123 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

p153

(Version 1.0) G.L. 2/18/00

Δ Extended Rock failure at the ceiling

Code, mddf_cc.f, modified from mddf.f (See page 33-36, 131, 146), is used to cut 3 m depth and 2m from the drift crown in mesh file.

SIGNATURE [signature] DATE 2-18 19 2000

READ AND UNDERSTOOD [signature] DATE 19

111-139 JEH 4/21/00

PROJECT NAME (version 1.0) G.C. 2/18/00 NOTEBOOK NO.

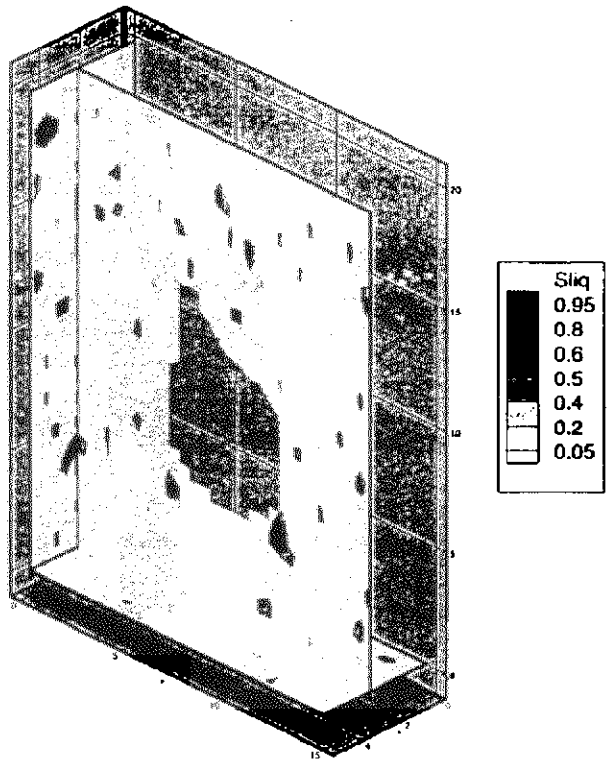
mddf_cc.f (under gnomin/0999/prog_ir/)

```
c check radius
        rr=sqrt(dy*dy+dz*dz)
        if(rr.lt.rdrift) goto 10

      if(x1.gt.2.2.and.x1.lt.3.0)then

      if((y1.gt.7.0 and.y1.lt.7.5).and.(z1.gt.8.0.and.z1.lt.11.0))then
         go to 10
      elseif((y1.gt.6.5.and.y1.lt.7.0).and.(z1.gt.8.0.and.z1.lt.11.5))then
         go to 10
      elseif((y1.gt.6.0.and.y1.lt.6.5).and.(z1.gt.8.0.and.z1.lt.12.0))then
         go to 10
      elseif((y1.gt.5.5.and.y1.lt.6.0).and.(z1.gt.8.0.and.z1.lt.13.0))then
         go to 10
      end if

      end if


c        if(ncall/nz*nz.eq.ncall)then
c        text='2'
```

cut out a drift

cut out 0.5-3m depth and 2m width from the drift crown.

Following figure shows the cutted rock-fall and drift.



This figure can be produced from the data file named 500_ath_cc.plt under PC's directory:

c:/0999 fig/

Seepage rate:	Case
4.47	Case B
4.52	1 m³ rock-fall from crown
4.47	1 m³ : : spring line
5.82	3 m depth ~ 2 m width : : ceiling

G.C. 10/28/99

All input and output files saved under gnomin/0999/drift_geo/ drift_cc, drift_cc8 and drift_cc8.

SIGNATURE [signature] DATE 10-28 19 99

READ AND UNDERSTOOD 111-140 [signature] 4/21/00 DATE 19

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 2

3. Originator: Guomin Li
4. Document Title: Scale Mfit Notebook, page 154 for Macro/Routine mddf_cc.f v1.0
5. Document Number: YMP-LBNL-CFT-GL-1
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria: Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
    ☐ Source:
12. Comment Documentation:
    ☒ Comment Sheets
    ☐ Review Copy Mark-up
    ☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
    ☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL/Hydrol.	Technical			

COMMENTS DUE:

15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold (Print Name)

REVIEW BY:

17. Hui Hai Liu (Print Name)
18. (Signature) 11-30-99 (Date)
19. Mandatory Comments: ☐ Yes ☒ No

CONCURRENCE:

21. Document Draft No: N/A Date:
22. Reviewer: (Signature) 12/9/99 (Date)
23. PM: (Signature) 12/10/99 (Date)

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. (Print Name/Signature) (Date)

DISPUTE RESOLUTION: (if applicable)

24. PM: (Signature) (Date)

01/14/00 page 154

YMP-LBNL

APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook : (page 154) YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

GL. 12-9-11

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	pages 154

1111-142 Jan 4/2/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 154			2. Page 1 of 1
3. Document No. YMP-LBNL-CFT-GL-1	4. Revision/ Change/Mod:	5. Draft	6. ☒ Q ☐ NQ
7. Reviewer: H. H. Liu			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually the code and no error is found checked visually the test results and found that they are acceptable		

111-143 JCH 4/21/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin LI
4. Document Title: Documentation for Routine mddf_cc.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)

11. ☐ Specific Review Criteria:
☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)

12. Comment Documentation:
☑ Comment Sheets
☐ Review Copy Mark-up

☐ Attached:

☐ Scientific notebook/data associated with this review as noted on Attachment 3

13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000

16. Originator/Review Coordinator: Guomin Li
Print Name

REVIEW BY:

17. Randall F. Hedegaard
Print Name

18. [signature] 2-28-00
Signature Date

19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li [signature] 2-28-00
Print Name/Signature Date

CONCURRENCE:

21. Document Draft No: NA Date:

22. Reviewer: [signature] 2-28-00
Signature Date

23. PM: [signature] 2/29/00
Signature Date

DISPUTE RESOLUTION: (if applicable)

24. PM:
Signature Date

111-144 PEB 4/12/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for mddf_cc.f V1.0**			2. Page 1 of 1
3. Document No. **N/A**	4. Revision/ Change/Mod: **N/A**	5. Draft **N/A**	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

111-145 9/24/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mddf_cc.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 153-154
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 118-123
Routine Documentation Sheet	pp. 1 & 2

111-146 pgs 4/24/00

mddf_cc8.f v.1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment:
   mddf_cc8.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     This routine is based on the routine mddf.f v1.0 and is used to cut out a 1 cubic meter rock-fall around the crown of the drift in a ITOUGH2 V3.2_drift MESH file. The new MESH file as saved with a new filename.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 106-111 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     First, the MESH will be cut with a cylinder with radius R through the center of the original 3D MESH. Second, the code will then remove a 1 x 1 x 1meter set of elements representing a "rock-fall" at the crown of the drift. Third, the elements that are within the removed area will be renamed to indicate their position. The connections will then be defined for those elements on the drift/rock-fall wall. The connection information for the drift and rock-fall neighboring elements will be used to form a new MESH file named MESHSF_cc8. The test will be checked by successfully running the code without error messages and by visually checking the MESH file as well as a 3D rendering of the output MESH to verify that the changes in formatting are correct. The visual check will consist of verifying that the elements at the XYZ coordinates specified in the input are in fact removed correctly from the output. The 3D visual-check method is also used because the output data is very large and it is most effective to visually check the results in 3D rather than check the output data line by line.

   - Specify the range of input values to be used and why the range is valid
     The input is the original MESH file, a radius value of 2.75 and the rock cut dimensions given on pp. 153, S/N YMP-LBNL-CFT-GL-1. This test case input range is deemed valid because the input data set is the data set used to model the drift scale problem.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input)
     The output from the test is the file MESHSF_cc8. A graphic display of this MESH is printed on p. 125 , S/N YMP-LBNL-CFT-GL-1 and file MESHSF_cc8 is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf_cc8/. Any ITOUGH2 V.3.2_drift MESH file of comparable size to this model could possibly be used. Any radius or rock-cut size used for a problem would have to be small enough so that the cylinder or drift would not intersect the outer boundary of the MESH.

- Description of how the testing shows that the results are correct for the specified input.
  Visual inspection of both the input and output data files provided on the accompanying CD, as well as a 3D visualization of the final output (MESHSF_cc) shows that the routine successfully removes the elements represented by the drift/rock fall and that all connections and elements are redefined properly. In addition, the test was successful because the routine successfully ran without error messages and the new MESHSF_cc was successfully imported into ITOUGH2 V3.2_drift without errors. Therefore, the test case and routine are acceptable.

- List limitations or assumptions to this test case and code in general
  The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 V3.2_drift models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift. This routine assumes that the drift is perfectly cylindrical and straight and that the rock fall occurs as a square 1 x 1 x 1 meter block at the crown of the drift.

- Electronic files identified by name and location (include disc if necessary)
  The routine, test files and its description can be found on pp. 153 and 125, from S/N YMP-LBNL-CFT-GL-1 and pp. 106-111 from S/N YMP-LBNL-CFT-GL-1A Reference Binder. The routine (mddf_cc8.fV1.0), input file (MESH) and output file (MESHSF_cc8 are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf_cc8/

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated.
   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 153 and 125 for S/N YMP-LBNL-CFT-GL-1; and pp. 106-111 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

111-148 JEH 4/24/00

PROJECT NAME _____ NOTEBOOK NO. _____

10-28-99

Effects of Rock Fall

(Version 1.0) G.L. 2/18/00

1 cubic meter (rock) fall from crown.

Code, mddf_cc8.f, modified from mddf.f (See page 33-36, 131, 146) to cut out 1 m^3 (2x2x2 grids) from the crown in mesh file.

mddf_cc8.f (under gnomin/0999/~~drift-geo/drif~~ prog-ir/) G.L. 10/18/99

```
c check radius
          rr=sqrr(dy*dy+dz*dz)
          if(rr.lt.rdrift) goto 10

        if(x1.gt.2.2.and.x1.lt.3.0)then
        if(y1.gt.7.1.and.y1.lt.7.9)then
        if(z1.gt.10.20.and.z1.lt.11.30)then

           go to 10

        end if
        end if
        end if


c         if(neall/nz*nz.eq.neall)then
c         text='2'
```

- cut out a round tunnel

- cut out 2x2x2 grids around the crown.

The figure on page 125 shown this routine successfully cut out a drift and rock-fall from the crown.

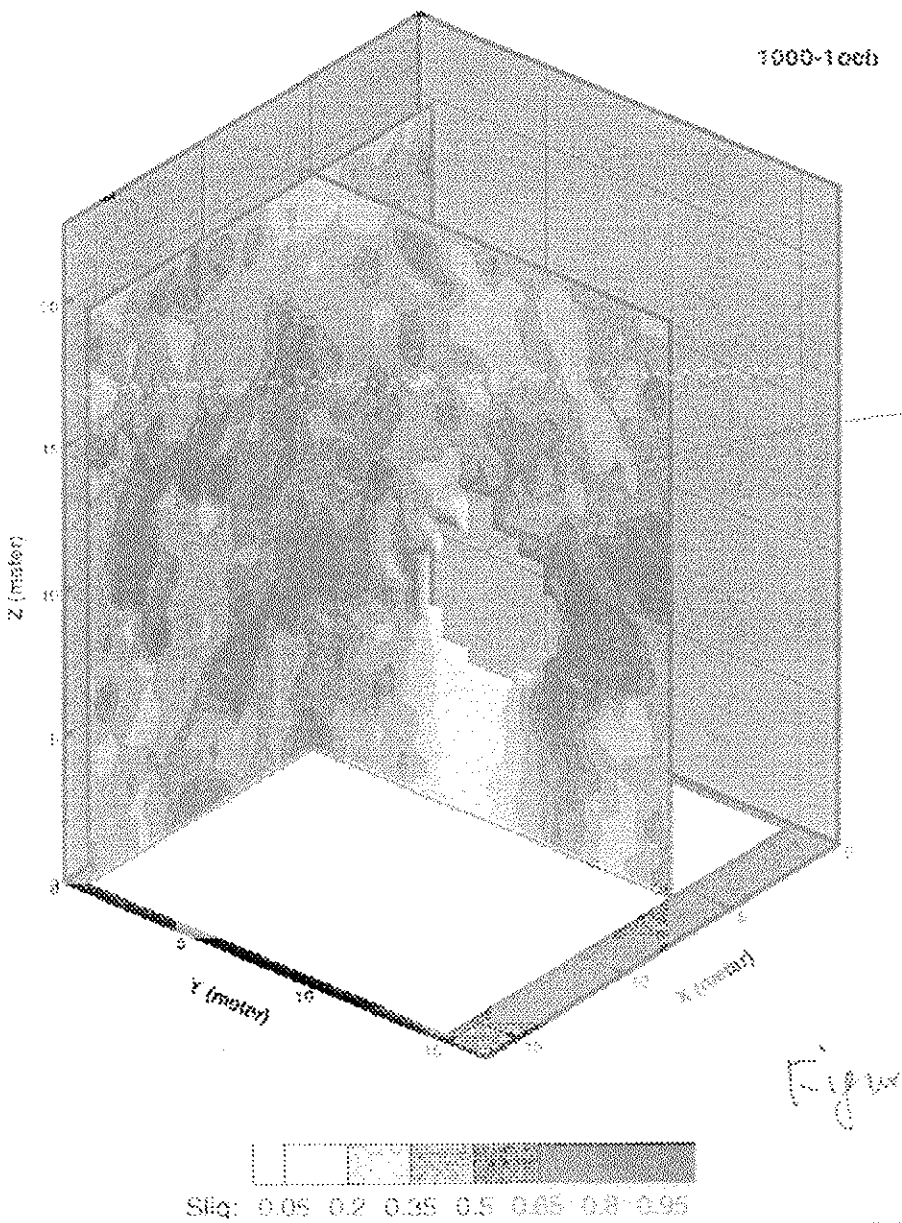
8-8-99

Seepage rate affected by drift-collapse.

Model: as that described on page 22-38 of this notebook.

Percolation flux: 1000 mm/yr.
Realization 1

Figure 1 shows the saturation contours on vertical plates for 1 cubic meter rock-fall from the drift-crown.



rock-fall position

Figure 1

SIGNATURE _____ DATE ~~2-18-19 2000~~ 1-21-00
READ AND UNDERSTOOD _____ DATE _____ 19 _____

III-150 JEH 6/7/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of: 2

3. Originator: Guomin Li GL. 12/9/99 MC 12/10/99
4. Document Title: Scale Mtz Notebook: page ~~145~~, 153, 33-36, 125 for Mizero/Boodine mddf-CCB.f V1.0
5. Document Number: YMP-LBNL-CFT-GL-1 6. Revision/Mod.: N/A 7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q 9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
☐ Source:
12. Comment Documentation:
☒ Comment Sheets
☐ Review Copy Mark-up
☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL/Hydrol.	Technical			

COMMENTS DUE:
15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold (Print Name)

REVIEW BY:
17. Hui Hai Liu (Print Name)
18. [signature] 11-30-99 (Signature / Date)
19. Mandatory Comments: ☐ Yes ☒ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):
20. Donald Mangold 12/9/99 (Print Name/Signature / Date)

CONCURRENCE:
21. Document Draft No: N/A Date:
22. Reviewer: [signature] 12/9/99 (Signature / Date)
23. PM: [signature] 12/10/99 (Signature / Date)

DISPUTE RESOLUTION: (if applicable)
24. PM: (Signature / Date)

1/1-151 BH 4/24/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook : (page ~~145~~ 33-36, 153, 125) YMP-LBNL-CFT-GL-1
GL 12-9-99

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

G.L. 12-9-99

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	pages ~~145~~, 153, 33-36, 125 G.L. 12-9-99

111-152 Rev 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 33-36, 153, 125				2. Page 1 of 1
3. Document No. YMP-LBNL-CFT-GL-1	4. Revision/ Change/Mod:	5. Draft	6. ☒ Q ☐ NQ	
7. Reviewer: H. H. Liu				

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually the code and no error is found. checked visually the test results and found that they are acceptable		

111-153 page 4/21/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin Li
4. Document Title: Documentation for Routine mddf_cc8.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)
11. ☐ Specific Review Criteria:
    ☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)
    ☐ Attached:
    ☐ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
    ☑ Comment Sheets
    ☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewer / Org./Discipline / Review Criteria

Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical

Reviewer	Org./Discipline	Review Criteria

COMMENTS DUE:

15. Due Date: 25 FEB 2000
16. Originator/Review Coordinator: Guomin Li (Print Name)

REVIEW BY:

17. Randall F. Hedegaard (Print Name)
18. [signature] 2-28-00 (Signature / Date)
19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li [signature] 2-28-00 (Print Name/Signature / Date)

CONCURRENCE:

21. Document Draft No: NA Date:
22. Reviewer: [signature] 2-28-00 (Signature / Date)
23. PM: [signature] 2/29/00 (Signature / Date)

DISPUTE RESOLUTION: (if applicable)

24. PM: (Signature / Date)

1/1-154 RH 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for mddf_cc8.1 V1.0**			2. Page 1 of 1
3. Document No. **N/A**	4. Revision/ Change/Mod: **N/A**	5. Draft **N/A**	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

01/24/00 RFH 551-111

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mddf_cc8.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 153 & 125
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 106-111
Routine Documentation Form	pp 1 & 2

111-156 JEH 4/21/00

mddf_cs8.f v.1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment:
   mddf_cs8.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     This routine is based on the routine mddf.f v1.0 and is used to cut out a 1 cubic meter rock-fall around the spring-line of the drift in a ITOUGH2 V3.2_drift MESH file. The new MESH file as saved with a new filename.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 112-117 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     First, the MESH will be cut with a cylinder with radius R through the center of the original 3D MESH. Second, the code will then remove a 1 x 1 x 1meter set of elements representing a "rock-fall" at the spring line of the drift. Third, the elements that are within the removed area will be renamed to indicate their position. The connection information for the drift and rock-fall neighboring elements will be used to form a new MESH file named MESHSF_cs8. The test will be checked by successfully running the code without error messages and by visually checking the MESH file as well as a 3D rendering of the output MESH to verify that the changes in formatting are correct. . The visual check will consist of verifying that the elements at the XYZ coordinates specified in the input are in fact removed correctly from the output. The 3D visual-check method is also used because the output data is very large and it is most effective to visually check the results in 3D rather than check the output data line by line.

   - Specify the range of input values to be used and why the range is valid
     The input is the original MESH file, a radius value of 2.75 and the rock cut dimensions given on pp. 153, S/N YMP-LBNL-CFT-GL-1. This test case input range is deemed valid because the input data set is the data set used to model the drift scale problem.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input)
     The output from the test is the file MESHSF. A graphic display of this MESH is printed on p. 126 , S/N YMP-LBNL-CFT-GL-1 and file MESHSF_cs8 is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf_cs8/. Any ITOUGH2 V.3.2_drift MESH file of comparable size to this model could possibly be used. Any radius or rock-cut size used for a problem would have to be small enough so that the cylinder or drift would not intersect the outer boundary of the MESH.

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- Description of how the testing shows that the results are correct for the specified input.
  Visual inspection of both the input and output data files provided on the accompanying CD, as well as a 3D visualization of the final output (MESHSF_cs8) shows that the routine successfully removes the elements represented by the drift/rock fall and that all connections and elements are redefined properly. In addition, the test was successful because the routine successfully ran without error messages and the new MESHSF_cs8 was successfully imported into ITOUGH2 V3.2_drift without errors. Therefore, the test case and routine are acceptable.

- List limitations or assumptions to this test case and code in general
  The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 V3.2_drift models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift. This routine assumes that the drift is perfectly cylindrical and straight and that the rock fall occurs as a square 1 x 1 x 1meter block at the spring line of the drift.

- Electronic files identified by name and location (include disc if necessary)
  The routine, test files and its description can be found on pp. 153 and 126, from S/N YMP-LBNL-CFT-GL-1 and pp. 112-117 from S/N YMP-LBNL-CFT-GL-1A Reference Binder. The routine (mddf_cs8.fV1.0), input file (MESH) and output file (MESHSF_cs8) are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf_cs8/

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated.
   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 153 and 126 for S/N YMP-LBNL-CFT-GL-1; and pp. 112-117 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

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p153

Δ 1 cubic meter rock-fall from spring line:
code, mddf_cs8.f1, modified from mddf.f (see page 33-36, 131, 146) to cut/out 2x2x2 grids from spring line in mesh file. (version 1.0) G.C. 4/18/00)
mddf_cs8.f1 (under guomin/0999/prog-ir/)

```
c check radius
          rr=sqrt(dy*dy+dz*dz)
          if(rr.lt.rdrift) goto 10

        if(x1.gt.2.2.and.x1.lt.3.0)then
        if(y1.gt.3.9.and.y1.lt.4.9)then
        if(z1.gt.7.5.and.z1.lt.8.5)then

          go to 10

        end if
        end if
        end if



c         if(neall/nz*nz.eq.neall)then
c         text='2'
```

— cut out a round tunnel

— cut out 2x2x2 grids from spring line

The figure on page 126 shown one of this kind results. (version 1.0) G.C. 4/18/00

Figure 2 shows the saturation contours on vertical plates for 1 m^3 rock-fall around spring line.

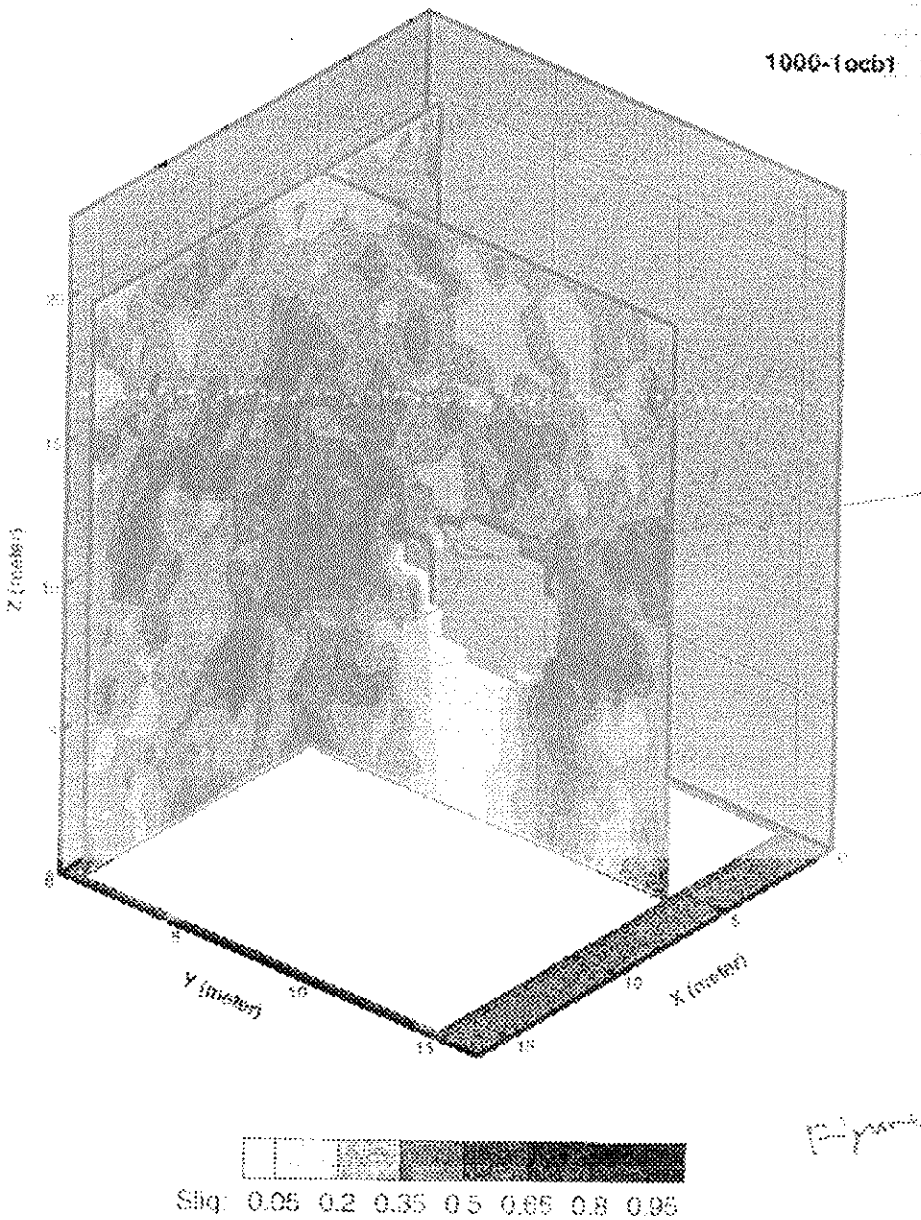

Figure 2

The data files are saved under a directory on hydra: guomin/0799/cb

Seepage rates compare with the old case (before rock fall).

Case	Old	1 m^3 rock-fall from crown	1 m^3 around spring line
Seepage rate	35.43 %	35.75	36.04

SIGNATURE _____ DATE 8-8 19 99
READ AND UNDERSTOOD _____ DATE _____ 19 _____

YMP-LBNL
REVIEW RECORD

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

3. Originator: Guomin Li
4. Document Title: Scale Mfg Notebook: page 33-36, 153, 126 for Macro/routine mdd for CSS.f v1.0 mc 12/10/99
5. Document Number: YMP-LBNL-CFT-GL-1
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria: Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
    ☐ Source:
12. Comment Documentation:
    ☒ Comment Sheets
    ☐ Review Copy Mark-up
    ☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
    ☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewers

Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL/Hydrol.	Technical			

COMMENTS DUE:

15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold (Print Name)

REVIEW BY:

17. Hui Hai Liu (Print Name)
18. Signature — Date: 11-30-99
19. Mandatory Comments: ☐ Yes ☒ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Donald Mangold (Print Name/Signature) — Date: 12/9/99

CONCURRENCE:

21. Document Draft No: N/A Date:
22. Reviewer: Signature — Date: 12/9/99
23. PM: Signature — Date: 12/10/99

DISPUTE RESOLUTION: (if applicable)

24. PM: Signature — Date:

00/K/4 H38 191-111

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook : (page 33-36, 153, 126) YMP-LBNL-CFT-GC-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

G.C. 12-9-99

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GC-1	pages 33-36, 153, 126

00/14/11 RBB 291-1112

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 33-36, 153, 126			2. Page 1 of 1
3. Document No. YMP-LBNL-CFT-GL-1	4. Revision/ Change/Mod:	5. Draft	6. ☒ Q ☐ NQ
7. Reviewer: H. H. Liu			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
	hhl 11-30-99	~~no comment~~ hhl 11-30-99 visually checked code and no error was found visually checked test results and found that they are acceptable		

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YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin LI
4. Document Title: Documentation for Routine mddf_cs8.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)
11. ☐ Specific Review Criteria:
    ☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)
    ☐ Attached:
    ☐ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
    ☑ Comment Sheets
    ☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewer

Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000
16. Originator/Review Coordinator: Guomin Li (Print Name)

REVIEW BY:

17. Randall F. Hedegaard (Print Name)
18. Signature 2-28-00 Date
19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li (Print Name/Signature) 2-28-00 Date

CONCURRENCE:

21. Document Draft No. NA Date:
22. Reviewer: Signature 2-28-00 Date
23. PM: Signature 2/29/00 Date

DISPUTE RESOLUTION: (if applicable)

24. PM: Signature Date

1/1-1/64 feed 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for mddf_cs8.f V1.0**			2. Page 1 of 1
3. Document No. **N/A**	4. Revision/ Change/Mod: **N/A**	5. Draft **N/A**	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS-- The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

111-165 JGH 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mddf_cs8.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 153 & 126
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 112-117
Routine Documentation Sheet	pp. 12

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mddf.f v.1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment :
   mddf.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     This routine takes an existing ITOUGH2 V3.2_drift MESH file and removes model elements within a defined radius and XYZ location (i.e. cuts out a cylindrical drift) to create an updated MESH file.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 92-97 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     First, the MESH will be cut with a cylinder with radius R through the center of the original 3D MESH. Second, the elements that are within the radius will be renamed to indicate their position. Third, the connections will be defined for those elements on the drift wall. This connection information for the drift neighboring elements will be used to form a new MESH file named MESHSF. The test will be checked by successfully running the code without error messages and by visually checking the MESH file as well as a 3D rendering of the output MESH to verify that the changes in formatting are correct. The visual check will consist of verifying that the elements at the XYZ coordinates specified in the input are in fact removed correctly from the output. The 3D visual-check method is also used because the output data is very large and it is most effective to visually check the results in 3D rather than check the output data line by line.

   - Specify the range of input values to be used and why the range is valid:
     The input is the original MESH file and a radius value of 2.75. This test case input range is deemed valid because the input data set is the data set used to model the drift scale problem.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):
     The output from the test is the file MESHSF. A graphic display of this MESH is printed on p. 146 , S/N YMP-LBNL-CFT-GL-1 and file MESHSF is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf/. Any ITOUGH2 V.3.2_drift MESH file of comparable size to this model could possibly be used. Any radius used for a problem would have to be small enough so that the cylinder or drift would not intersect the outer boundary of the MESH.

   - Description of how the testing shows that the results are correct for the specified input:
     Visual inspection of both the input and output data files provided on the accompanying CD, as well as a 3D visualization of the final output (MESHSF) shows that the routine successfully removes the elements represented by the drift and that

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all connections and elements are redefined properly. In addition, the test was successful because the routine successfully ran without error messages and the new MESHSF was successfully imported into ITOUGH2 V3.2_drift without errors. Therefore, the test case and routine are acceptable.

- List limitations or assumptions to this test case and code in general:
  The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 V3.2_drift models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift. This routine assumes that the drift is perfectly cylindrical and straight.

- Electronic files identified by name and location (include disc if necessary):
  The routine (mddf.fV1.0) and test files (MESH and MESHSF) are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mddf/.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 146 for S/N YMP-LBNL-CFT-GL-1; and pp. 92-97 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

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PROJECT NAME _____ NOTEBOOK NO. _____

9-22-99 (version 1.0) G.L. 2/18/00

Description and Testing of Software Routine or Macro

Minimipresf.f (~~see page 130~~) G.M.L. 2-24/00

```
      * * * * * *
c read and write incon
      open(unit=1,file='MESH',status='old')
      rewind(1)
      open(unit=2,file='inconsf.out',status='unknown')

      rewind(2)
c
      read(1,'(a)')dddd
      write(2,*)'INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY'
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      read(1,'(a,14x,a,2e10.4,10x,3e12.5)')name
c      sat=sini

      if(k.eq.1)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,2,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif
      goto 99
      endif

      if(k.eq.nz)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,nz-1,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,nz,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500
      endif
      goto 99
      endif


      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,k,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,k-1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif

 99 continue
c
      por=porm
      write(2,'(a5,2i5,e15.9,5e10.4)')name,idum,idum,porm,xkf,alfa0
      write(2,'(2e20.14)')sat
      enddo
      enddo
      enddo
      enddo
      texte=
      write(2,'(a)')texte
      write(2,*)
      close(1)
      close(2)
      stop
      end
```

See pp. 15/N YMP-LBNL-CFT-GL-1A for whole code.

Part of input file MESH

```
ELEME
.....
A21 1        SOILF0.2875E-010.0000E+00        0.5750E-010.2500E+000.2500E+00
......
B7U12        BUNOF0.1150E-060.5750E-01        0.5173E+010.1475E+020.2000E+02
......
```

Part of input file permcnt.dat

```
12x30x42 values
......
-0.14350E+02
......
```

→ $\log_{10} K$ $K = 0.4467 \cdot 10^{-14}$

Part of output file inconsf.out

```
INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY
.....
A21 1    0    00.124000000E-030.4467E-140.1000E+04
0.11000000000000E-01
......
```

check also applies to minimipresf_ir.f. G.L. 2/18/00

The macro is easily to be tested by visually checking the input and output files. G.L. 2/18/00

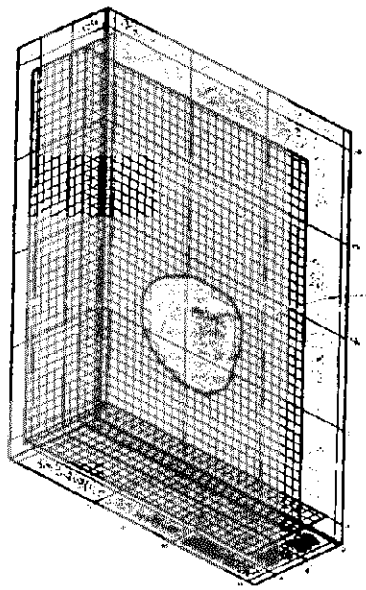
SIGNATURE _____ DATE ~~2-18-19~~ 2000

READ AND UNDERSTOOD _____ DATE _____ 19

(version 1.0) G.C. 2/18/00

Mddf.fl (See the description on page 131):
the part of the macrowrs listed on page 33-36.
Whole code is listed on pp. S/N YMP-LBNL-CFT-GL-1
This macro was used to cut a round drift with radius R (This report, R = 2.75 meter) in 3D Mesh. Then a new mesh was generated without dr

Following figures clearly show the macro successf cut out a round tunnel with radius 2.75 me



The figure com produced from t data file named 500-9th-2.plt under a directo on PC: (LBL/DOE 6335458) G.C. 12/ C:\0999fig\

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of: 2

3. Originator: Guomin Li — 12/10/99
4. Document Title: Scientific Notebook, page 33-36, 131, 146 for Macro/routine mdd.f-f V1.0
5. Document Number: YMP-LBNL-CFT-GL-1
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria: Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
    ☐ Source:
12. Comment Documentation:
    ☒ Comment Sheets
    ☐ Review Copy Mark-up
    ☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
    ☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewers

Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL / Hydrol.	Technical			

COMMENTS DUE:

15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold (Print Name)

REVIEW BY:

17. Hui-Hai Liu (Print Name)
18. Signature — Date: 11-29-99
19. Mandatory Comments: ☐ Yes ☒ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Donald Mangold (Print Name/Signature) — Date: 11/29/99

CONCURRENCE:

21. Document Draft No: N/A — Date:
22. Reviewer: Signature — Date: 12/8/99
23. PM: Signature — Date: 12/10/99

DISPUTE RESOLUTION: (if applicable)

24. PM: Signature — Date

00/4/21 gsh 12/1-/11

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook. (pages 33-36, 131, 146) YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	33-36, 131, 146

00/12/4 HEH 4/21/00

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YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 33-36, 131, 146

2. Page 1 of 1

3. Document No. YMP-LBNL-CFT-GL-1

4. Revision/ Change/Mod:

5. Draft

6. ☒ Q ☐ NQ

7. Reviewer: H. H. Liu

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually the code and no error is found checked visually the test results and found that they are acceptable.		

111-173 gsH 4/21/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin Li
4. Document Title: Documentation for Routine mddf.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A 6. Revision/Mod.: N/A 7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q 9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)

11. ☐ Specific Review Criteria:
☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)

12. Comment Documentation:
☑ Comment Sheets
☐ Review Copy Mark-up

☐ Attached:

☐ Scientific notebook/data associated with this review as noted on Attachment 3

13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000

16. Originator/Review Coordinator: Guomin Li
Print Name

REVIEW BY:

17. Randall F. Hedegaard
Print Name

18. [signature] 2-28-00
Signature Date

19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li [signature] 2-29-00
Print Name/Signature Date

CONCURRENCE:

21. Document Draft No: NA Date:

22. Reviewer: [signature] 2-28-00
Signature Date

23. PM: [signature] 2/29/00
Signature Date

DISPUTE RESOLUTION: (if applicable)

24. PM:
Signature Date

111-174 9/24/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Routine Documentation for mddf.f V1.0			2. Page 1 of 1
3. Document No. N/A	4. Revision/ Change/Mod: N/A	5. Draft N/A	6. ☑ Q ☐ NQ
7. Reviewer: Randall F. Hedegaard			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

04/21/00 RFH 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mddf_.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 146
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 92-97
Routine Documentation Sheet	pp 1+2

111-17L 6PH 4/21/00

meshbd.f v.1.0

Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment:
   meshbd.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or routine and describe what it does:
     This routine reformats the ITOUGH2 V3.2_drift MESH file by doing 3 things. In the ELEM section of the MESH file it renames the boundary condition term for each element and changes the "Z" direction. In the CONN section of MESH file it changes the top boundary layer area value to a number in the routine. The new MESH file is saved to a new filename which is the output.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 86-87 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     During the test the routine will take one of 3 element type names (DRAIN, SOIL and BUNOF) and assign a term to the proper ITOUGH2 element based on the element's boundary condition. The test will also change the sign of the "Z" direction from positive to negative by adding a "-" sign. Lastly, the test will replace the "area" value for each element at the top boundary interface to "0.1E+03". The routine test will be checked by visually comparing a sampling of rows from the output with the input to verify that the changes in formatting are correct.

   - Specify the range of input values to be used and why the range is valid:
     The range of input values includes several lines of the ELEM section of the MESH file. These lines of text are printed on p. 129, S/N YMP-LBNL-CFT-GL-1. This test case input range is deemed valid because the routine's formatting changes can be successfully inspected using only a small sampling of lines from the very large input and output files.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):
     The output from the test is printed on p. 129, S/N YMP-LBNL-CFT-GL-1. Since this routine only performs administrative formatting of the MESH file it is assumed that the routine is valid for use with any ITOUGH2 MESH file as input provided the Z values of the input file are positive.

   - Description of how the testing shows that the results are correct for the specified input:
     By visual inspection of the formatting of the input and output files, it can be seen that the routine successfully replaces the boundary condition term, changes the "Z" direction and modifies the top boundary layer area. Therefore, the test case and routine are acceptable.

   - List limitations or assumptions to this test case and code in general:

111-177 JEH 4/21/00

The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 V3.2_drift models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift.

- Electronic files identified by name and location (include disc if necessary):
  The routine is printed on pp. 86-87 from S/N YMP-LBNL-CFT-GL-1A Reference Binder and is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /meshbd/. The test input and output are printed on pp. 129, S/N YMP-LBNL-CFT-GL-1.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 128-129 for S/N YMP-LBNL-CFT-GL-1; and pp. 86-87 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

(Version 1.0) G.C. 2/18/00

Code, meshbd.f, is developed to replace the bottom and top boundary, change mesh order, of z direction from "-" to "+"; and interface at top boundary:

```
c
c change mesh order
c change z direction from "-" to "+"
c change interface at top boundary
c
      implicit double precision (a-h,o-z)
      integer nc,ne
      integer me,mc,nh
      parameter (me  = 88500)
      parameter (mc  =310000)
      parameter (nh  = 1000)
      double precision voll(mc),aa(mc)
      character*5 dddd,ccc,cccc
      character*5 texte
      character*1 text
      character*5 wrd,wrd2
      nx=12
      ny=30
      nz=42
c
      open(unit=2,file='MESH',status='unknown')
      rewind(2)
      texte='ELEME'
      write(2,'(a)')texte
c
      open(unit=1,file='meshm.mes',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
c
      ne = 0
      nesum = 0
      locat = 1
      do i=1,nx
        do j=1,ny
         do k=1,nz
           ne=ne+1
           read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     dddd,texte,voll(ne),v1,x1,y1,z1
         nesum = nesum + 1
           if(k.eq.nz)then
             texte='BUNOF'
           elseif(k.eq.1)then
             texte='DRAIN'
           voll(ne)=1.0e+50
           else
             texte='SOILF'
           endif
           write(2,'(a,10x,a,2e10.4,10x,3e10.4)')
     &     dddd,texte,voll(ne),v1,x1,y1,-z1
```

SIGNATURE _____ DATE 2-18 19 2000

READ AND UNDERSTOOD _____ DATE _____ 19 _____

Jeff 2/21/00

```
            enddo
          enddo
        enddo
c
      read(1,*)
      read(1,'(a)')cccc
      write(2,*)
      cccc='CONNE'
      write(2,'(a)')cccc

      nc=0
      locat =1
30    read(1,'(2a,19x,a,4e10.4)',end=40)wrd,wrd2,text,v1,v2,aa(nc+1),v3
      if(wrd.ne. '      ' .and.wrd.ne.'+++   ')then
       if(wrd(1:2).eq.'B7'.and.wrd2(1:2).eq.'B7')aa(nc+1)=100.0
      write(2,'(2a,19x,a,4e10.4)')wrd,wrd2,text,v1,v2,aa(nc+1),v3
         nc=nc+1
         goto 30
      endif

c
      texte='      '
      write(2,'(a)')texte
      close(1)
      close(2)
      stop
   40 stop'Premature End of File'
      end
```

The code is tested by check the input and output files.

input data →

```
ELEME    NX=  12  NY=  30  NZ=  42
A11 1              10.1150E-070.5750E-01          0.5750E-010.2500E+00-.1000E-06
......
B71 1              10.1150E-060.5750E-01          0.5750E-010.2500E+00-.2000E+02
A12 1              10.1150E-070.5750E-01          0.5750E-010.7500E+00-.1000E-06
A22 1              10.2875E-010.0000E+00          0.5750E-010.7500E+00-.2500E+00
......

CONNE
A11 1A11 2                 10.5750E-010.2500E+000.1000E-06
......
B71 1B71 2                 10.5750E-010.2500E+000.1000E-05
```

G. L. 2-24-60

output data

```
ELEME
A11 1          DRAIN0.1000E+510.5750E-01          0.5750E-010.2500E+000.1000E-06
......
B71 1          BUNOF0.1150E-060.5750E-01          0.5750E-010.2500E+000.2000E+02
A12 1          DRAIN0.1000E+510.5750E-01          0.5750E-010.7500E+000.1000E-06
A22 1          SOILF0.2875E-010.0000E+00          0.5750E-010.7500E+000.2500E+00
......

CONNE
A11 1A11 2                 10.5750E-010.2500E+000.1000E-060.0000E+00
......

B71 1B71 2                 10.5750E-010.2500E+000.1000E+030.0000E+00
```

SIGNATURE _____ DATE 8-15 19 99
READ AND UNDERSTOOD _____ DATE _____ 19 _____

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of: 2

3. Originator: Guomin Li
4. Document Title: Scientific Notebook page 128-129 for Routine/macro MeshBuf V1.0
5. Document Number: YMP-LBNL-CFT-GL-1
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria: Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
    ☐ Source:
    ☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
    ☒ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
    ☒ Comment Sheets
    ☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewer

Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL/hydrol.	Technical			

COMMENTS DUE:

15. Due Date: 11/28/99
16. Originator/Review Coordinator: Donald Mangold (Print Name)

REVIEW BY:

17. Hui Hai Liu (Print Name)
18. Signature — Date: 11-30-99
19. Mandatory Comments: ☐ Yes ☒ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Donald Mangold (Print Name/Signature) — Date: 12/9/99

CONCURRENCE:

21. Document Draft No: N/A — Date:
22. Reviewer: Signature — Date: 12/9/99
23. PM: Signature — Date: 12/10/99

DISPUTE RESOLUTION: (if applicable)

24. PM: Signature — Date

111-18 JBH 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	128-129

111-182 [illegible] 4/22/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 128-129

2. Page 1 of 1

3. Document No. YMP-LBNL-CFT-GL-1

4. Revision/ Change/Mod:

5. Draft

6. ☒ Q ☐ NQ

7. Reviewer: H. H. Liu

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually code and error is not found. checked visually the test results and found that they are acceptable		

111-163 JEH 4/21/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin Li
4. Document Title: Documentation for Routine meshbd.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)
11. ☐ Specific Review Criteria:
☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)
☐ Attached:
☐ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
☑ Comment Sheets
☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewer: Randall Hedegaard; Org./Discipline: LBNL/Hydrogeologist; Review Criteria: Technical

Reviewer	Org./Discipline	Review Criteria

COMMENTS DUE:
15. Due Date: 25 FEB 2000
16. Originator/Review Coordinator: Guomin Li
Print Name

REVIEW BY:
17. Randall F. Hedegaard
Print Name
18. 2-28-00
Signature Date
19. Mandatory Comments: ☐ Yes ☑ No

CONCURRENCE:
21. Document Draft No: NA Date:
22. Reviewer: 2-28-00
Signature Date
23. PM: 2/29/00
Signature Date

ORIGINATOR/REVIEW COORDINATOR (After response completed):
20. Guomin Li 2-28-00
Print Name/Signature Date

DISPUTE RESOLUTION: (if applicable)
24. PM:
Signature Date

111-184 JBH 4/24/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for meshbd.f V1.0**				2. Page 1 of 1
3. Document No. N/A	4. Revision/ Change/Mod: N/A	5. Draft N/A	6. ☒ Q ☐ NQ	
7. Reviewer: **Randall F. Hedegaard**				

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

RFH 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for meshbd.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	p. 129
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 86-87
Documentation sheet	pp. 1 & 2

111-186 gah 4/24/00

mininipresf.f v. 1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment :
   mininipresf.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     This routine creates a portion of the ITOUGH2 V3.2_drift INCON file by taking input from the MESH file and a second file containing permeability values. The routine takes data from the two files and reformats it into the INCON file. The only calculation that takes place is converting the $\log_{10}k$ values in the input permeability file to non-log numbers in the final INCON file.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 88-91 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     The routine will merge the permeability data into the INCON file in the appropriate column and the values will be converted from log to non-log to 4 units of precision. The routine will be checked by visually checking the certain lines of the output INCON file against the input MESH and permeability file to verify that the changes in formatting and log to non-log calculation is correct.

   - Specify the range of input values to be used and why the range is valid:
     Since the routine reformats text and performs one inverse log calculation, the routine will be verified using a sampling of the input and output files. This sampling is printed on p. 145, S/N YMP-LBNL-CFT-GL-1 under the headings of "part of input file". This test case input range is deemed valid because the routine's formatting changes can be inspected using only a small sampling of lines from the very large output file.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):
     The output from the test is printed on p. 145, S/N YMP-LBNL-CFT-GL-1 under the heading "part of output file". This output is a sampling of the INCON file. Since this routine only reformats text and does one inverse log calculation, it is assumed that the routine is valid for use with any range of values acceptable as a ITOUGH2 V3.2_drift MESH file and any set of $\log_{10}k$ permeability values as input.

   - Description of how the testing shows that the results are correct for the specified input:
     By visual inspection of the formatting of the input and output files and a hand calculation of the log to inverse log calculation to 4 point precision (see p. 145), it can be seen that the routine successfully creates the portion of the INCON file as designed. Therefore, the test case and routine are acceptable.

   - List limitations or assumptions to this test case and code in general:

111-187 JEA 4/21/00

The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift. The log to non-log conversion was only carried out to 4 point precision.

- Electronic files identified by name and location (include disc if necessary):
  The input and output test data are printed on pp. 145, S/N YMP-LBNL-CFT-GL-1. The routine is printed on pp. 88-91 from S/N YMP-LBNL-CFT-GL-1A Reference Binder and is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /minimipresf/. The test input and output are printed on pp. 145, S/N YMP-LBNL-CFT-GL-1.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 145 for S/N YMP-LBNL-CFT-GL-1; and pp. 88-91 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

111-188 JEA 4/21/00

PROJECT NAME _____ NOTEBOOK NO. _____

9-22-99 (version 1.0) G.L. 2/8/00

Description and Testing of Software Routine or Macro

Minimipresf.f (~~see page 130~~) G.M.L. 2-24/00

```
......
c read and write incon
      open(unit=1,file='MESH',status='old')
      rewind(1)
      open(unit=2,file='inconsf.out',status='unknown')

      rewind(2)
c
      read(1,'(a)')dddd
      write(2,*)'INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY'
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      read(1,'(a,14x,a,2e10.4,10x,3e12.6)')name
c      set=eini

      if(k.eq.1)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,2,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif
      goto 99
      endif

      if(k.eq.nz)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,nz-1,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,nz,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500
      endif
      goto 99
      endif


      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,k,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,k-1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif

 99 continue
c
      porsporm
      write(2,'(a5,2i5,e15.9,5e10.4)')name,idum,idum,porm,xkf,alfa0
      write(2,'(2e20.14)')sat
      enddo
      enddo
      enddo
      enddo
      texte=' '
      write(2,'(a)')texte
      write(2,*)
      close(1)
      close(2)
      stop
      end
```

See pp. 88-91 N YMP-LONL-CFT-GL-1A for whole code.

Part of input file MESH

```
ELEME
.....
A21 1        SOILF0.2875E-010.0000E+00        0.5750E-010.2500E+000.2500E+00
......
B7U12        BUNOF0.1150E-060.5750E-01        0.5173E+010.1475E+020.2000E+02
......
```

Part of input file permcnt.dat

```
12x30x42 values
.....
-0.14350E+02
.....
```

→ $\log_{10} K$ $K = 0.4467 \cdot 10^{-14}$

Part of output file inconsf.out

```
INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY
.....
A21 1    0    00.124000000E-030.4467E-140.1000E+04
0.11000000000000E-01
......
```

check also - applies to minimipresf_ir.f. G.L. 2/8/00

The macro is easily to be tested by visually checking the input and output files G.L. 2/8/00

SIGNATURE _____ DATE ~~2-18-00~~

READ AND UNDERSTOOD _____ DATE _____ 19

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of: 2

3. Originator: Guomin Li
4. Document Title: Scientific Notebook Page 130, 145 for Routine/Macro minimizreef.f V1.0
5. Document Number: YMP-LBNL-CFT-GL-1
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria: Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
    ☐ Source:
    ☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
    ☒ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
    ☒ Comment Sheets
    ☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewer / Org./Dicipline / Review Criteria

Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL/Hydrol.	Technical

Reviewer	Org./Discipline	Review Criteria

COMMENTS DUE:

15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold (Print Name)

REVIEW BY:

17. Hui Hai Liu (Print Name)
18. Signature — Date: 11-29-99
19. Mandatory Comments: ☐ Yes ☒ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Donald Mangold — Print Name/Signature — Date: 12/9/99

CONCURRENCE:

21. Document Draft No: N/A — Date:
22. Reviewer: Signature — Date: 12/9/99
23. PM: Signature — Date: 12/10/99

DISPUTE RESOLUTION: (if applicable)

24. PM: Signature — Date

111-190 Left 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook. YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	130, 145

00/4/4 #38 191-111

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 130, 135

2. Page 1 of 1

3. Document No. YMP-LBNL-CFT-GL-1

4. Revision/ Change/Mod:

5. Draft

6. ☒ Q ☐ NQ

7. Reviewer: H. H. Liu

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked ~~code~~ visually and found no error checked visually the test results and found that they are acceptable.		

111-192 PAH 4/21/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin LI
4. Document Title: Documentation for Routine mininipresf.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)

11. ☐ Specific Review Criteria:
☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)

12. Comment Documentation:
☑ Comment Sheets
☐ Review Copy Mark-up
☐ Attached.
☐ Scientific notebook/data associated with this review as noted on Attachment 3

13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000

16. Originator/Review Coordinator: Guomin Li
Print Name

REVIEW BY:

17. Randall F. Hedegaard
Print Name

18. [signature] 2-28-00
Signature Date

19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li [signature] 2-28-00
Print Name/Signature Date

CONCURRENCE:

21. Document Draft No. NA Date:

22. Reviewer: [signature] 2-28-00
Signature Date

23. PM: [signature] 2/29/00
Signature Date

DISPUTE RESOLUTION: (if applicable)

24. PM:
Signature Date

111-193 pg 4 of 4 02/24/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for mininipresf.f V1.0**			2. Page 1 of 1
3. Document No. **N/A**	4. Revision/ Change/Mod: **N/A**	5. Draft **N/A**	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

4/21/00 1/1-1/94

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mininipresf.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 145
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 88-91
Routine Documentation Sheet	pp. 1+2

04/24/00 JEM 4/24/00

minimipresf_ir.f v1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment :
   minimipresf_ir.f v1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     This routine creates a portion of the ITOUGH2 V3.2_drift INCON by taking input from the MESH file and a file containing permeability values. The routine takes data from the property set and the MESH and reformats it into the INCON file. The code takes the original permeability set (A) and multiplies it by a factor to create a second (B) property set. The routine applies the A and B property sets such that property set B is applied to the elements nearest the drift and property set A is applied to the rest of the model elements. The routine also converts the property values (permeability) which are $\log_{10}$k values to non-log numbers in the final INCON file.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 102-105 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     First the test will enable the routine to merge the permeability data into the INCON file in the appropriate column based on the elements XYZ coordinate. Secondly, the code will create 2 sets of permeability values from the input permeability file. Next the B permeability property set will be applied to the elements nearest the drift and property set A is applied to the rest of the model elements. The values will be converted from log to non-log to 4 units of precision. The routine will be checked by visually comparing the output INCON file against the input MESH and two property sets files. The permeability data will also be visualized in 3D to inspect completeness and to verify that the changes in formatting and log to non-log calculation is correct.

   - Specify the range of input values to be used and why the range is valid:
     The 2 distinct permeability sets are applied to 2 distinct spatial areas of the model, so the entire input (MESH and the property file) will be used as the test input range so that correct spatial distribution of properties is accomplished. Since the routine also reformats text and performs one inverse log calculation, the routine will be verified using a sampling of the input and output files. This sampling is printed on p. 145, S/N YMP-LBNL-CFT-GL-1 under the headings of "part of input file". The input files (MESH and permcut.dat) are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /minimipresf/. This test case input range is deemed valid because the routine's formatting changes can be inspected using only a small sampling of lines from the very large output file.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):

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A portion of the output from the test is printed on p. 145, S/N YMP-LBNL-CFT-GL-1 under the heading "part of output file" and is provided in the INCON file (inconsf.out) on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mininipresf_ir/. The output on p. 145 is a sampling of the INCON file. Since this routine only reformats text and does one inverse log calculation, it is assumed that the routine is valid for use with any range of values acceptable as a ITOUGH2 MESH file and any set of $\log_{10}$k permeability values as input.

- Description of how the testing shows that the results are correct for the specified input:
  By visual inspection of the formatting (see p. 145) of the input and output files and a hand calculation of the log to inverse log calculation to 4 point precision (see p. 145, S/N YMP-LBNL-CFT-GL-1), it can be seen that the routine successfully creates the portion of the INCON file as designed. The 3D visualization of the final INCON file results on p. 152, S/N YMP-LBNL-CFT-GL-1 demonstrates that the 2 permeability data sets are properly assigned to the model elements by observing that the lower liquid saturation values (therefore higher permeability) of set B are nearest the drift. Therefore, the test case and routine are acceptable.

- List limitations or assumptions to this test case and code in general:
  The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift or greater. The log to non-log conversion was only carried out to 4 point precision.

- Electronic files identified by name and location (include disc if necessary):
  The routine (mininipresf_ir.fV1.0) and test files (MESH, permcut.dat) are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mininipresf_ir/.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 145 and 152 for S/N YMP-LBNL-CFT-GL-1 and pp. 102-105 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

111-197 JeH 4/21/02

PROJECT NAME _____ NOTEBOOK NO. _____

9-22-99 (version 1.0) G.L. 2/18/00

Description and Testing of Cartesiwave Routine or Macro

Minipresf.f (~~see page 130~~) G.M.L. 2-24/00

```
      * * * * * *
c read and write incon
      open(unit=1,file='MESH',status='old')
      rewind(1)
      open(unit=2,file='inconsf.out',status='unknown')

      rewind(2)
c
      read(1,'(a)')dddd
      write(2,*)'INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY '
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      read(1,'(a,14x,a,2e10.4,10x,3e12.6)')name
c      sat=sini

      if(k.eq.1)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,2,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif
      goto 99
      endif

      if(k.eq.nz)then
c permeability of top element equal next element
      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,nz-1,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,nz,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500
      endif
      goto 99
      endif


      if(kk.eq.1)then
      xkf=(10.0**xfield(i,j,k,kk))
      porm=0.000124
      sat=0.011
      alfa0=1000.
      else
      xkf=xfield(i,j,k-1,kk)
      porm=0.089
      sat=0.92
      alfa0=1562500.
      endif

 99 continue
c
      por=porm
      write(2,'(a5,2i5,e15.9,5e10.4)')name,idum,idum,porm,xkf,alfa0
      write(2,*(2e20.14)')sat
      enddo
      enddo
      enddo
      enddo
      texte='
      write(2,'(a)')texte
      write(2,*)
      close(1)
      close(2)
      stop
      end
```

See pp. 88-91 S/N YMP-LONL-CFT-GL-1A for whole code.

Part of input file MESH

```
ELEME
......
A21 1        SOILF0.2875E-010.0000E+00        0.5750E-010.2500E+000.2500E+00
......
B7U12        BUNOF0.1150E-060.5750E-01        0.5173E+010.1475E+020.2000E+02
......
```

part of input file permcnt.dat

```
12x30x42 values
......
-0.14350E+02
......
```

→ $\log_{10} K$ $K = 0.4467 \cdot 10^{-14}$

part of output file inconsf.out

```
INCON -- INITIAL CONDITIONS FOR DUAL PERMBILITY
....
A21 1    0    00.124000000E-030.4467E-140.1000E+04
0.11000000000000E-01
......
```

check also - applies to minipresf-ir.f. G.L. 2/18/00

The macro is easily to be tested by visually checking the input and output files G.L. 3/09/00

SIGNATURE _____ DATE ~~2-18-19~~ 2000

READ AND UNDERSTOOD _____ DATE _____ 19 _____

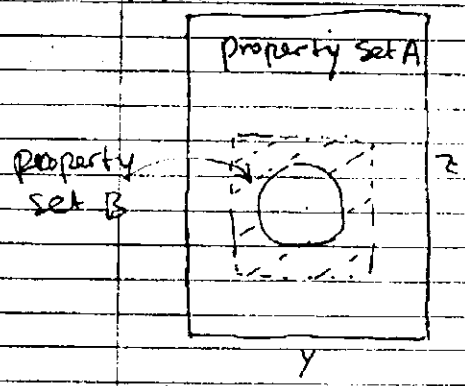
III - 198 JEH 6/7/00

10-27-99

Effect of fracture dilation

minimipresf-ir.f (under guomin/o999/prog-i

Model

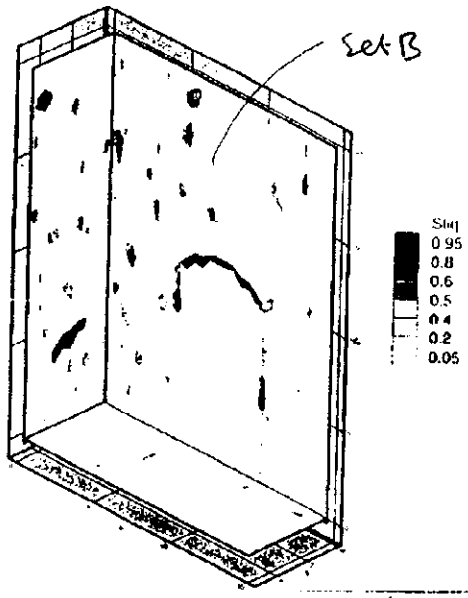


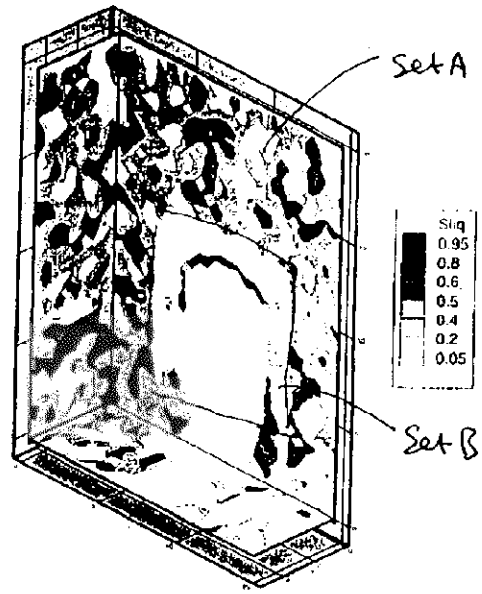

```
yyy=(j-1)*0.5+0.25
zzz=(k-2)*0.5+0.25

if(kk.eq.1)then
if((yyy.gt.3.0.and.yyy.lt.11.5).and.
  (zzz.gt.3.5.and.zzz.lt.12.0))then
xkf=10.0*(10.0**((xfield(i,j,k,kk)+13.05)*0.860-13.05))
  alfa0=100.
else
xkf=(10.0**xfield(i,j,k,kk))
  alfa0=1000
end if
porm=0.000124
sat=0.011
else
xkf=xfield(i,j,k-1,kk)
porm=0.089
sat=0.92
alfa0=1562500.
endif
```

(version 1.0) G.C. 2/18/00

The code, minimipresf-ir.f, is modified from minimipresf.f. This routine is used to reform property set B around drift ($11.5 \geq y \geq 3.0$, $12.0 \geq z \geq 3.5$ meter) and property set A elsewhere. The figure on page 147 shown the saturation contours with property set A. The figure bellow on left shows the saturation contours with property set B. And the figure on right shows the saturation contours of the new model.





	Case A	CASE B	New model
Seepage rate	9.53	4.47	9.53

All data files saved under guomin/o999/drift_goo/drift_kzone/

SIGNATURE _____ DATE 10-27 19 99

READ AND UNDERSTOOD 11-1-99 Jeff 4/21/00 DATE _____ 19 _____

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of: 2

3. Originator: Guomin Li
4. Document Title: Scientific Notebook: page 145, 152 for Macro/routine mininiprofiling v1.0
5. Document Number: YMP-LBNL-CFT-GL-1 6. Revision/Mod.: N/A 7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q 9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
☐ Source:
12. Comment Documentation:
☒ Comment Sheets
☐ Review Copy Mark-up
☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL/Hydrol.	Technical			

COMMENTS DUE:
15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold
Print Name

REVIEW BY:
17. Hui Hai Liu
Print Name
18. 11-29-99
Signature Date
19. Mandatory Comments: ☐ Yes ☐ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):
20. Donald Mangold 12/9/99
Print Name/Signature Date

CONCURRENCE:
21. Document Draft No: N/A Date:
22. Reviewer: 12/9/99
Signature Date
23. PM: 12/10/99
Signature Date

DISPUTE RESOLUTION: (if applicable)
24. PM:
Signature Date

03/21/00 4:27 PM 111-200

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook : (page 145, 152) YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

G.L. 12-9-99

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	pages 145, 152

111-201 Rev 4 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 145, 152	2. Page 1 of 1
3. Document No. YMP-LBNL-CFT-GL-1	4. Revision/ Change/Mod: 5. Draft 6. ☒ Q ☐ NQ
7. Reviewer: H. H. Liu	

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually the code and no error is found. checked visually the test results and found that they are acceptable.		

1/1-202 Bell 4/21/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin Li
4. Document Title: Documentation for Routine mininiprest_ir.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A 6. Revision/Mod.: N/A 7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q 9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)

11. ☐ Specific Review Criteria:
☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)

12. Comment Documentation:
☑ Comment Sheets
☐ Review Copy Mark-up

☐ Attached:

☐ Scientific notebook/data associated with this review as noted on Attachment 3

13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000

16. Originator/Review Coordinator: Guomin Li
Print Name

REVIEW BY:
17. Randall F. Hedegaard
Print Name
18. [signature] 2-28-00
Signature Date
19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):
20. Guomin Li [signature] 2-28-00
Print Name/Signature Date

CONCURRENCE:
21. Document Draft No: N/A Date: 2-28-00
22. Reviewer: [signature] 2-28-00
Signature Date
23. PM: [signature] 2/28/00
Signature Date

DISPUTE RESOLUTION: (if applicable)
24. PM:
Signature Date

111-203 [signature] 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for mininipreaf_ir.f V1.0**			2. Page 1 of 1
3. Document No. **N/A**	4. Revision/ Change/Mod: **N/A**	5. Draft **N/A**	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

1111-204 RFH 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mininipresf_ir.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 145 & 152
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 102-105
Routine Documentation Sheet	pp 1 + 2

111-205 Rev. 4/4/00

minrefine3d.f v.1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment:
   minrefine3df.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     The routine will reform the ITOUGH2 V3.2_drift file INCONsf and remove the grid cells in the cut "drift" domain. Two input files will be needed: MESHsf.new generated from the routine mddf.f v1.0 inconsf.out generated from the routine mininipresf.f v1.0.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 124-125 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     The test or running of the routine will reform INCONsf and remove the grid cells in the cut "drift" domain. Two input files will be needed: MESHsf.new generated from the routine mddf.f v1.0 and inconsf.out generated from the routine mininipresf.f v1.0. This is done by simply identifying the elements removed in the MESH file and ensuring that the same elements are removed from the INCON information.The routine will be verified by visually checking raw data files as well as the 3D plot of the ITOUGH2 V3.2_drift output. If the macro has any problem, the simulation will produce an error result. The visual-check method is preferred because the output data is very large and it is most effective to visually check the results in 3D space rather than check the output data line by line. The visual check will consist of verifying that the elements at the XYZ coordinates specified in the input are in fact removed correctly from the output.

   - Specify the range of input values to be used and why the range is valid:
     The range of input values are the input files: MESHsf.new generated from the routine mddf.f v1.0 and inconsf.out generated from the routine mininipresf.f v1.0 which are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /minrefine3df/. No special range of input values is necessary to perform the macro. This macro is used to reform a new INCON file from two existing ITOUGH2 V3.2_drift files.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):
     The resulting INCON data is written to the file INCONsf which is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /minrefine3df/. Since this routine simply reformats the INCON data, it is assumed that the routine is valid for use with any range of values acceptable as a ITOUGH2 V3.2_drift MESH file and any set of similar model characteristics.

111-20. JEH 4/21/00

- Description of how the testing shows that the results are correct for the specified input:
  The running of the routine and then importing the INCON file into ITOUGH2 successfully shows that the routine does not produce errors. Secondly, a line by line visual inspection of the output was conducted and it can be seen that the routine successfully produced the INCON properties for the for the cut out "drift". Thirdly, The 3D visualization of the model results on pp. 147, S/N YMP-LBNL-CFT-GL-1 indicates that the routine is successfully removed the "drift" properties. Therefore, the test is valid and the routine is acceptable.

- List limitations or assumptions to this test case and code in general:
  The routine was tested using an input data set that is comparable to that of 3D ITOUGH2 V3.2_drift models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift.

- Electronic files identified by name and location (include disc if necessary):
  The input files (MESHsf.new and inconsf.out) and output (INCONsf) are provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /minrefine3df/.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation.

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 146-147 for S/N YMP-LBNL-CFT-GL-1; pp. 124-125 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

111-207 JEH 4/21/00

(version 1.0) G.C. 2/18/00

△ Minrefine3dff.f (See the description on page 131)

It is used to reform a new file of initial grid's properties from the old one "inconsf.out". The new file named INCONsf corresponds the grids listed in the new mesh file without the drift.

The new incon file and new mesh file should be used to perform the simulation by the software ITOUGH2 V3.2 drift. If the "Minrefine3dff.f" had any problem, the simulation should have produced an error result with the improper initial condition (Incon file). Otherwise, we could get a calculation results. The following figure can provide the identity of the macro.

SIGNATURE _____ DATE 2-18 19-2000

READ AND UNDERSTOOD _____ DATE _____ 19 ____

111-208 4/21/00

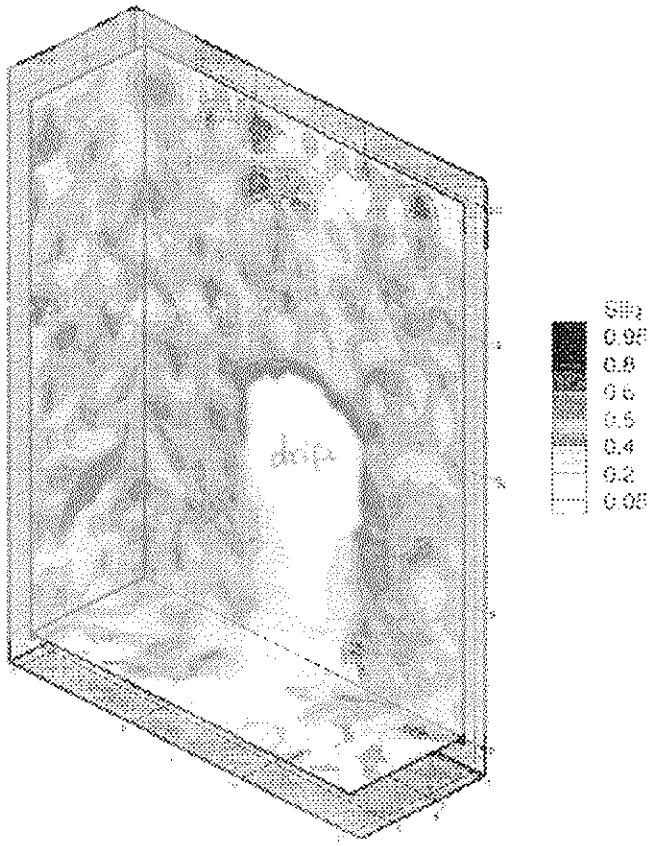
```
c
      implicit double precision(a-h,o-z)
      character*5 name,wrd
      character head*60
      character*1 text
      character*5 irock
      dimension x(160000),y(160000),z(160000)
      dimension por(70,45,55,5),xperm(70,45,55,5),
     j     xalfa(70,45,55,5)
      dimension xsat(70,45,55,5)
      character*5 id(160000)
      character*5 iinc(70,45,55,5)
c
c read refined mesh

      ndual=1

      open(unit=1,file='MESHsf.new',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'eleme' .and. wrd .ne. 'ELEME') then
         stop 'no eleme in MESH'
      endif
      ne = 0
   10 read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),irock,vol,v1,x1,y1,z1
      if(id(ne+1) .eq. '     ') goto 100
      ne = ne + 1
      x(ne) = x1
      y(ne) = y1
      z(ne) = z1
      goto 10
  100 close(1)
c
c read incon    (not refined)
      nx=12
      ny=30
      nz=42
c
      open(unit=1,file='inconsf.out',status='old')
      rewind(1)
      read(1,'(a60)')head
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      read(1,'(a5,2i5,e15.9,2e10.4)')
     &iinc(i,j,k,kk),idum,idum,por(i,j,k,kk),xperm(i,j,k,kk),
     j   xalfa(i,j,k,kk)
      read(1,'(e20.14)')xsat(i,j,k,kk)
      enddo
      enddo
      enddo
      enddo

c
      open(unit=2,file='INCONsf',status='unknown')
      rewind(2)
      write(2,'(a60)')head
      do i=1,nx
      do j=1,ny
      do k=1,nz
      do kk=1,ndual
      do nn=1,ne
      if(id(nn).eq.iinc(i,j,k,kk))then
         write(2,'(a5,2i5,e15.9,2e10.4)')
     &     id(nn),idum,idum,por(i,j,k,kk),xperm(i,j,k,kk),
     &     xalfa(i,j,k,kk)
         write(2,'(e20.14)')xsat(i,j,k,kk)
      endif
      enddo
      enddo
      enddo
      enddo
      enddo

c
      write(2,*)
      close(1)
      close(2)
      stop
   40 stop 'Premature EOF on MESH'
      end
```



Saturation contours on vertical plates in 3D block.

This figure is produced from the data file named 500_atk_0.plt under a directory on PC:

C:\0999fig\

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of: 2

3. Originator: Guomin Li
4. Document Title: Scale-up & Notebook: page 131, 146-147 for Macro/Routine MINIEFINE 3DFF V2.0
5. Document Number: YMP-LBNL-CFT-GL-1 6. Revision/Mod.: N/A 7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q 9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
☐ Source:
12. Comment Documentation:
☒ Comment Sheets
☐ Review Copy Mark-up
☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL / Hydrol.	Technical			

COMMENTS DUE:
15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold
Print Name

REVIEW BY:
17. Hui Hai Liu
Print Name
18. [signature] 11-29-99
Signature Date
19. Mandatory Comments: ☐ Yes ☒ No

CONCURRENCE:
21. Document Draft No.: N/A Date:
22. Reviewer: [signature] 12/9/99
Signature Date
23. PM: [signature] 12/10/99
Signature Date

ORIGINATOR/REVIEW COORDINATOR (After response completed):
20. Donald Mangold [signature] 12/9/99
Print Name/Signature Date

DISPUTE RESOLUTION: (if applicable)
24. PM:
Signature Date

111-210 Rev 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook : (page 131, 146-147) YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

GL. 129-11

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	pages 131, 146-147

111-211 [illegible] 4/24/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin Li
4. Document Title: Documentation for Routine minrefine3df.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)
11. ☐ Specific Review Criteria:
☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)
☐ Attached:
☐ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
☑ Comment Sheets
☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14.

Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000

16. Originator/Review Coordinator: Guomin Li
Print Name

REVIEW BY:

17. Randall F. Hedegaard
Print Name
18. 2-28-00
Signature Date
19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li 2-28-00
Print Name/Signature Date

CONCURRENCE:

21. Document Draft No: NA Date:
22. Reviewer: 2-28-00
Signature Date
23. PM: 2/29/00
Signature Date

DISPUTE RESOLUTION: (If applicable)

24. PM:
Signature Date

111-212 JOH 2/29/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for minrefine3df.f V1.0**			2. Page 1 of 1
3. Document No. N/A	4. Revision/ Change/Mod: N/A	5. Draft N/A	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

111-215 Gath 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 131, 146-147				2. Page 1 of 1
3. Document No. YMP-LBNL-CFT-GL-1	4. Revision/ Change/Mod:	5. Draft	6. ☒ Q ☐ NQ	
7. Reviewer: H. H. Liu				

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually the code and no error is found.		
		checked visually the test results and found that they are acceptable		

111-314 pg 131 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for minrefine3df.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 146-147, 131
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 124-125
Reference Documentation Sheet	pp. 1&2

111-215 pg 4 4/24/00

mk_gener.f v1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment :
   mk_gener.f v1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     The routine produces percolation flux values for every node at the top boundary of the 3D model. This routine creates a portion of the ITOUGH2 V3.2_drift input (the GENER data) by taking input from the MESH file and a user defined percolation flux value.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 98-99 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     The test will run the routine and produce individual percolation flux values for nodes at the top boundary of the 3D model given a single average percolation flux. The code will take the top boundary area for the each element and multiply this area by the average percolation flux to come up with element specific percolation flux value. This routine will create a portion of the ITOUGH2 input (the GENER data) by taking input from the MESH file and the user defined percolation flux value. Since the routine's calculations can be successfully checked using sample data that do not cover the full range of possible top boundary areas, only a select number of elements will be tested.

   - Specify the range of input values to be used and why the range is valid:
     The input range is an overall percolation flux of 5 mm/yr and 3 sample elements from the original MESH (see left margin p. 148, S/N YMP-LBNL-CFT-GL-1). This test case input range is deemed valid because the routine's formatting changes can be inspected using only a small sampling of lines from the very large output file.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):
     The output from the test is printed on p. 148, S/N YMP-LBNL-CFT-GL-1 under the heading "TESTING". These test case input ranges are deemed valid because the routine's calculations can be successfully checked using sample data that do not cover the full range.

   - Description of how the testing shows that the results are correct for the specified input:
     Hand calculation confirms that the output is correct to the significant figures given (shown on p. 148, S/N YMP-LBNL-CFT-GL-1).

   - List limitations or assumptions to this test case and code in general:

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The input percolation flux is valid from 0 to infinity. The routine was tested using an input data set that is comparable to that of 3D models necessary to model drift scale type problems. The routine is only valid for files compatible with ITOUGH2 V3.2_drift.

- Electronic files identified by name and location (include disc if necessary):
  The routine is printed on pp. 98-99 from S/N YMP-LBNL-CFT-GL-1A Reference Binder and is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mk_gener/. The test input and output are printed on pp. 145, S/N YMP-LBNL-CFT-GL-1.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 148 for S/N YMP-LBNL-CFT-GL-1; and pp. 98-99 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

1/1-217 JEH 4/21/00

△ MK_gener.f (See the description on page 131)
(Version 1.0) G.L. 2/18/00

This macro is used to add the percolation flux at the top boundary grid.
It can be tested by checking the input and output files.

```
      implicit double precision (a-h,o-z)
      integer ne,ixyz
      integer me,mc,nh
      parameter (me  =100000)
      parameter (mc  =700000)
      parameter (nh  = 2500)
      character*5 id(me)
      character*5 tfeld(me)
      double precision x(3,me)
      double precision s(mc),voll(me)
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      call rmesh
     &(rdrift,ne,id,tfeld,x,ec,e,s,cc,hsh,ind,me,mc,nh,ixyz,voll)
      stop
      end

c
      subroutine rmesh
     &(rdrift,ne,id,tfeld,x,ec,e,s,cc,hsh,ind,me,mc,nh,ixyz,voll)
      implicit double precision (a-h,o-z)
      character*5 id(me)
      character*5 texte
      character*5 tfeld(me)
      double precision x(3,me)
      double precision s(mc)
      integer ec(me)
      integer e(2,mc)
      integer cc(2,mc)
      integer hsh(nh)
      integer ind(me)
      double precision voll(me)
      character*5 wrd

c
      write(*,*)'Infiltration Rate in mm/a'
      read(*,*)rinf

c
      open(unit=2,file='GENERsf',status='unknown')
      rewind(2)
      texte='GENER'
      write(2,'(a)')texte
      iw1=0
      iw2=0

c
      open(unit=1,file='MESHSF',status='old')
      rewind(1)
      read(1,'(a)',end=40) wrd
      if(wrd .ne. 'elemm' .and. wrd .ne. 'ELEME') then
         stop 'no elemc in MESH'
      endif

c
      ne = 0
      nesum = 0
      locat = 1
 10   read(1,'(a,10x,a,2e10.4,10x,3e10.4)',end=40)
     &     id(ne + 1),texte,voll(ne+1),v1,x1,y1,z1
      nesum = nesum + 1
      if(id(ne+1) .ne.  '     ') then
c        if(vol .eq. 0.) goto 10
         if(texte.eq.'BUNOF')ne = ne + 1
       goto 10
      endif

c
      volsum=0.0
      do i=1,ne
      volsum=volsum+voll(i)
      enddo

c
      do i=1,ne
      fakt=voll(i)/volsum
      write(2,'(2a,i4,25x,a,e10.4)')
     &id(i),'I',i,'WATE ',fakt*rinf*78.45*3.171e-08
      enddo

c
      close(1)
      close(2)
      stop
 40   stop'Premature End of File'
      end
```

part of input file MESHSF

```
B77 2I  37
B78 2I  38
B79 2I  39
```

```
BUNOF0.5000E-060.2500E+00  0.3650E+000.3250E+010.2000E+02
BUNOF0.5000E-060.2500E+00  0.3650E+000.3750E+010.2000E+02
BUNOF0.5000E-060.2500E+00  0.3650E+000.4250E+010.2000E+02
```

Testing.
input the percolation flux 5 mm/yr

For a grid with a surface area 0.5x0.5 m², the number of the percolation flux should be added.

5 mm/yr x 0.25 m²

= 0.005 x 25 (m³) / 365 x 24 x 3600 (s)

= 0.3964 (kg/s)
x10⁻⁷ G.L. 2/18/00

The output file also shown the correct results.

```
GENER
......
B77 2I  37                WATE 0.3964E-07
B78 2I  38                WATE 0.3964E-07
B79 2I  39                WATE 0.3964E-07
......
```

```
ELEME
B77 2
B78 2
B79 2
```

SIGNATURE _____ DATE 9-22 19 99
READ AND UNDERSTOOD DATE 19

III-218 JEH 6/7/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 2

3. Originator: Guomin Li
4. Document Title: Scientific Notebook: page 31-32, 131, 148 for macro/routine mk-genec.f v.10
5. Document Number: YMP-LBNL-CFT-GL-1 6. Revision/Mod.: N/A 7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q 9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria: Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
☐ Source:
12. Comment Documentation:
☒ Comment Sheets
☐ Review Copy Mark-up
☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL / Hydrol.	Technical			

COMMENTS DUE:
15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold
Print Name

REVIEW BY:
17. Hui Hai Liu
Print Name
18. 11-29-99
Signature Date
19. Mandatory Comments: ☐ Yes ☒ No

CONCURRENCE:
21. Document Draft No: N/A Date:
22. Reviewer: 12/9/99
Signature Date
23. PM: 12/10/99
Signature Date

ORIGINATOR/REVIEW COORDINATOR (After response completed):
20. Donald Mangold 12/9/99
Print Name/Signature Date

DISPUTE RESOLUTION: (if applicable)
24. PM:
Signature Date

11-29 HH 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook : (page 31-32, 131, 148) YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	pages 31-32, 131, 148

111-220 RH 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 31-32, 131, 148				2. Page 1 of 1
3. Document No. YMP-LBNL-CFT-GL-1	4. Revision/ Change/Mod:	5. Draft	6. ☒ Q ☐ NQ	
7. Reviewer: H. H. Liu				

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually the code and no error is found.		
		Checked visually the test results and found that they are acceptable		

01/24/00 Page 121-111

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin Li
4. Document Title: Documentation for Routine mk_gener.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)
11. ☐ Specific Review Criteria:
    ☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)
    ☐ Attached:
    ☐ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
    ☑ Comment Sheets
    ☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14. Reviewers

Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000
16. Originator/Review Coordinator: Guomin Li (Print Name)

REVIEW BY:

17. Randall F. Hedegaard (Print Name)
18. Signature 2-28-00 Date
19. Mandatory Comments: ☐ Yes ☑ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li 2-28-00 (Print Name/Signature, Date)

CONCURRENCE:

21. Document Draft No: N/A Date:
22. Reviewer: 2-28-00 (Signature, Date)
23. PM: 2/25/00 (Signature, Date)

DISPUTE RESOLUTION: (if applicable)

24. PM: (Signature, Date)

111-222/184 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for mmk_gener.f V1.0**			2. Page 1 of 1
3. Document No. **N/A**	4. Revision/ Change/Mod: **N/A**	5. Draft **N/A**	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

111-223 Dan 4/24/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mk_gener.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 148
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 98-99
Routine Documentation Form	pp 1+2

1111 - 224 Jeff 4/21/00

mk_scale_k.f v.1.0
Routine/Macro Documentation Form

The following information can be included in the scientific notebook. Attach and reference notebook pages and diskettes with files as needed when submitting routine/macro to records.

1. Name of routine/macro with version/OS/hardware environment:
   mk_scale_k.f v.1.0 (routine) / UNIX SUNOS Solaris 5.5.1/Sun workstation

2. Name of commercial software with version/OS/hardware used to develop routine/macro:
   FORTRAN 77/UNIX SUNOS Solaris 5.5.1/Sun workstation

3. **Test Plan.**

   - Explain whether this is a routine or macro and describe what it does:
     This routine is used to scale a heterogeneous field by changing the parameter A in the following formula: $K' = (K - \underline{K})A + \underline{K}$
     where, K = old log permeability; $\underline{K}$ = old mean log permeability; K' = new log permeability; A = scaled factor. Special conditions for A: unchanged heterogeneous field when A = 1, K' = K; homogeneous field when A = 0, K' = K; higher heterogeneous field when A>1; or a lower heterogeneous field if A < 1.

   - Source code: (including equations or algorithms from software setup (LabView, Excel, etc.):
     pp. 100-101 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

   - Description of test(s) to be performed (be specific):
     The routine is checked by taking a set of permeability values as input, and then comparing the results with a hand calculation of standard deviation. These results will be checked by hand calculating the output and input data to verify that the standard deviation of log permeability has been correctly scaled.

   - Specify the range of input values to be used and why the range is valid:
     The range of input values are the permeability values in file (permd5_r1.dat) which is provided on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mk_scale_k/.

4. **Test Results.**

   - Output from test (explain difference between input range used and possible input):
     The output file from the test is saved as perm.new on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mk_scale_k/. Since this routine does one standard deviation calculation that is valid on real numbers, it is assumed that the routine is valid for use with any range of values acceptable as a ITOUGH2 V3.2_drift MESH file and any set of similar permeabilities.

   - Description of how the testing shows that the results are correct for the specified input:
     When the value of the input parameter A is 1.292, the standard deviation of the log permeability is 2.503 (see p. 149, S/N YMP-LBNL-CFT-GL-1, from the output file perm.new). By hand calculation of the standard deviation it is apparent that the code correctly scales the permeability values. Therefore, the test case is valid.

   - List limitations or assumptions to this test case and code in general:
     The limitation of the input value of the scale factor: A >= 0.0.

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- Electronic files identified by name and location (include disc if necessary):
  The output file (perm.new) and input file (permd5_r1.dat) are saved on the accompanying CD entitled YMP-LBNL-CFT-GL-1 (routines) in directory /mk_scale_k/.

5. Supporting Information. Include background information, such as revision to a previous routine or macro, or explanation of the steps performed to run the software. Include listings of all electronic files and codes used. Attach Scientific Notebook pages with appropriate information annotated:

   See attached pages for technical review forms, referenced scientific notebook pages and other supporting documentation.

   MAINTAIN NOTEBOOK PAGES IN THIS ORDER:
   pp. 149, 123 for S/N YMP-LBNL-CFT-GL-1; pp. 100-101 from S/N YMP-LBNL-CFT-GL-1A Reference Binder

111-226 JEH 4/21/00

9-24-99

Description and testing the software routine for scaling the heterogeneous field

See page 123 and 133–134. The following routine is used for scaling the heterogeneous field by the formula listed on page 123

mk-scale-k.f (version 1.0) G.L. 2/18/00

```
      implicit double precision(a-h,o-z)
      character name*5,head*80
      dimension xfield(100,100,100,20),class(100)
      nx=42
      ny=30
      nz=12
      ndual=1
c read kfield
      open(unit=1,file='permd5_r1.dat',status='old')
      rewind(1)
      read(1,*)
      do k=1,nz
      do j=1,ny
      do i=1,nx
      read(1,*)xfield(i,j,k,1)
      enddo
      enddo
      enddo
      close(1)

      do k=1,nz
      do j=1,ny
      do i=1,nx
      xmeans=xmeans + xfield(i,j,k,1)
      enddo
      enddo
      enddo
```

G.L. 2/24/00

```
      xmeans=xmeans/dble(12*30*42)
      do k=1,nz
      do j=1,ny
      do i=1,nx
      sss=sss+(xfield(i,j,k,1)-xmeans)*(xfield(i,j,k,1)-xmeans)
      enddo
      enddo
      enddo

      sss=sss/dble(12*30*42)
      ssd=sqrt(sss)
      open(unit=3,file='perm.new',status='unknown')
      rewind(3)
      write(3,*)'MEAN IN Log10 ',xmeans
      do k=1,nz
      do j=1,ny
      do i=1,nx
      scalek=(xfield(i,j,k,1)-xmeans)*1.292+xmeans
      write(3,*)scalek
      enddo
      enddo
      enddo

      close(3)
      stop
      end
```

Testing:

input file permd5_r1.dat with $\sigma(\ln k) = 1.937$
$\log_{10} k = -13.04$

output file perm.new with $\sigma(\ln k) = 2.50$
(Scaling by factor A = 1.292) $\log_{10} k = -13.04$

III-227 JEH 6/7/00

8-2-99

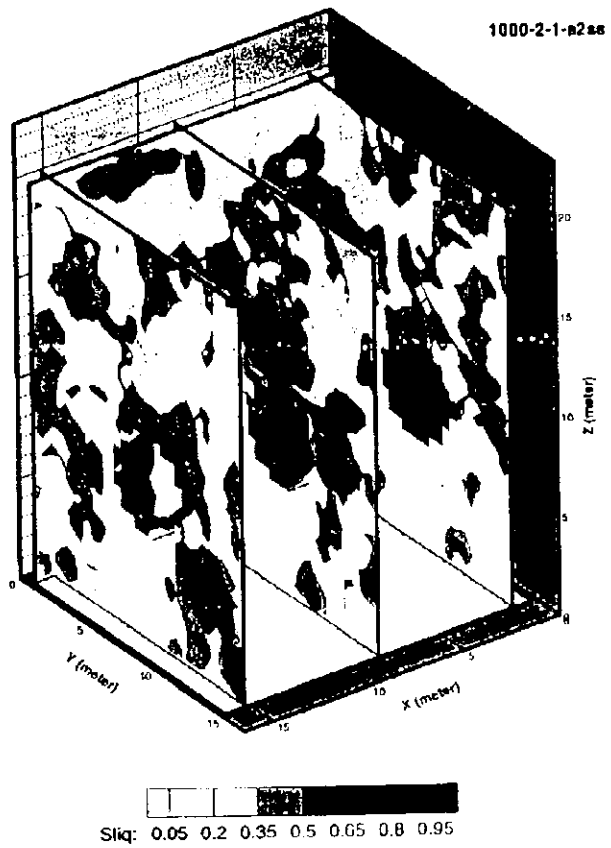
Presentation of the saturation contours on vertical planes for 2 correlation lens upscaled by simple factor.

We try to upscale the heterogeneity field by a simple formula bellow:

$$K' = (K - \bar{K}) * A + \bar{K}$$

Where K — old hypermeability, $\bar{K}$ — mean log10 permeability, K' — new log10 permeability, A — upscaled factor. A = 1, K' = K; Same heterogeneity field;
A = 0, K' = $\bar{K}$, Homogeneous field;
A > 1, higher heterogeneous field generated;
A < 1, lower " " " "

Follow figures show the saturation contours for 2 upscaled heterogeneity fields with the factor A of 0.5 and 2.



Percolation flux 1000 mm/yr; Steady State;

A = 2.

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 2

3. Originator: Guomin Li G. Li 11/99
4. Document Title: Scale-up Notebook: page 123, 133-134, & 149 for macro routine mk_scale-k.f v1.0 m Validation
5. Document Number: YMP-LBNL-CFT-GL-1 6. Revision/Mod.: N/A 7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q 9. Revision/Mod: 2/1

REVIEW CRITERIA

10. ☒ Standard Review Criteria: Technical (Taken from Attachment 5)
11. ☒ Specific Review Criteria:
☐ Source:
12. Comment Documentation:
☒ Comment Sheets
☐ Review Copy Mark-up
☒ Attached: YMP-LBNL Software Routine/Macro Documentation - Option 1
☒ Scientific notebook/data associated with this review as noted on Attachment 3
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson

14. Reviewer	Org./Dicipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
H.H. Liu	LBNL/Hydrol.	Technical			

COMMENTS DUE:
15. Due Date: 11/29/99
16. Originator/Review Coordinator: Donald Mangold
Print Name

REVIEW BY:
17. Hui Hai Liu
Print Name
18. [signature] 11-29-99
Signature Date
19. Mandatory Comments: ☐ Yes ☒ No

ORIGINATOR/REVIEW COORDINATOR (After response completed):
20. Donald Mangold 12/9/99
Print Name/Signature Date

CONCURRENCE:
21. Document Draft No: N/A Date:
22. Reviewer: [signature] 12/9/99
Signature Date
23. PM: [signature] 12/10/99
Signature Date

DISPUTE RESOLUTION: (if applicable)
24. PM:
Signature Date

111-229 Draft 4/4/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Scientific Notebook : (pages 123, 133-134, 145) YMP-LBNL-CFT-GL-1

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data G.L. 12/9/99	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1	pages 123, 133-134, 145

111-230 pg 4 of 100

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: Scientific Notebook page 123, 133-134, 148			2. Page 1 of 1
3. Document No. YMP-LBNL-CFT-GL-1	4. Revision/ Change/Mod:	5. Draft	6. ☒ Q ☐ NQ
7. Reviewer: H. H. Liu			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		checked visually code and no error is found.		
		checked visually test results and found that they are acceptable		

111-231 JEH 4/21/00

YMP-LBNL
REVIEW RECORD

1. QA: L
2. Page 1 of 1

3. Originator: Guomin Li
4. Document Title: Documentation for Routine mk_scale.f V1.0 (Option 1 per AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1)
5. Document Number: N/A
6. Revision/Mod.: N/A
7. Draft: N/A
8. Governing Procedure Number: AP-SI.1Q
9. Revision/Mod: 2/4

REVIEW CRITERIA

10. ☐ Standard Review Criteria N/A (Taken from Attachment 5)
11. ☐ Specific Review Criteria:
    ☑ Source: AP-SI.1Q/Rev. 2/ICN4, Sec. 5.1.1 (One time use routine)
    ☐ Attached:
    ☐ Scientific notebook/data associated with this review as noted on Attachment 3
12. Comment Documentation:
    ☑ Comment Sheets
    ☐ Review Copy Mark-up
13. YMP-LBNL Project Manager (PM): Gudmundur S. Bodvarsson
14.

Reviewer	Org./Discipline	Review Criteria	Reviewer	Org./Discipline	Review Criteria
Randall Hedegaard	LBNL/Hydrogeologist	Technical			

COMMENTS DUE:

15. Due Date: 25 FEB 2000
16. Originator/Review Coordinator: Guomin Li
    Print Name

REVIEW BY:

17. Randall F. Hedegaard
    Print Name
18. 2-28-00
    Signature Date
19. Mandatory Comments: ☐ Yes ☑ No

CONCURRENCE:

21. Document Draft No: NA Date:
22. Reviewer: 2-28-00
    Signature Date
23. PM: 2/29/00
    Signature Date

ORIGINATOR/REVIEW COORDINATOR (After response completed):

20. Guomin Li 2-28-00
    Print Name/Signature Date

DISPUTE RESOLUTION: (if applicable)

24. PM:
    Signature Date

1/1-282 4/21/00

YMP-LBNL
COMMENT SHEET

QA: L

1. Document Title: **Routine Documentation for mk_scale.f V1.0**			2. Page 1 of 1
3. Document No. **N/A**	4. Revision/ Change/Mod: **N/A**	5. Draft **N/A**	6. ☑ Q ☐ NQ
7. Reviewer: **Randall F. Hedegaard**			

8. NO. CODE	9. SECT./PARA./P#	10. COMMENT	11. RESPONSE	12. ACCEPT
		--NO COMMENTS— The documentation for this routine was reviewed and it was found to meet the requirements of AP-SI.1Q/Rev. 2/ICN4. The test case was checked by both hand calculation and by running the code as needed to fully check the test case. The test case fully checks the routine for the input specified and proves that the routine produces acceptable results.		

111-233 4/21/00

YMP-LBNL
APPLICABLE REFERENCE INFORMATION

Document No.and Title: Notebook pages for Routine Documentation for mk_scale_k.f V1.0

Date of Document (or revision, draft revision number, as applicable):

Pertinent sections of scientific notebook(s) or other backup documents and/or data DTN# are identified below, supporting the document which is the subject of this review. These documents/data shall be included in the scope of this review.

Document(s) Title/Data	Relevant Sections/Pages
YMP-LBNL-CFT-GL-1 Scientific Notebook	pp. 149
YMP-LBNL-CFT-GL-1A Scientific Notebook for Reference Binder	pp. 100-101
Routine Documentation Form	pp 1-2

111-234 . 004 4/21/00