21
300

R

308 --- Q199603220014
Scientific Notebook #147 for
Subregional Hydrogeology
Research Project

SASTOTHOFF
210/522-5208
Stothoff@swri.edU

CNWRA
CONTROLLED
COPY 147

Contents | Page

Entries by:

Ross Bagtzoglou

STUART STOTHOFF SAS

Scientific Notebook for "Subregional Hydrogeology" Research Project.
20-5704-174

Pages 1 Through 4 Are Intentionally
Left Blank

1 INTRODUCTION

Record of work performed under Task 4 in the subregional hydrologic flow and transport processes research project.

Records made by Stuart Stothoff. SAS Additional input on the task is anticipated to come from Ross Bagtzoglou, Hannah Castellaw, Brent Henderson, and Kathy Spivey.

SAS 12/18/95

2 Description of Project

The infiltration task, Task 4, of the subregional hydrologic flow and transport processes research project is designed to investigate various approaches for estimating infiltration into the near-surface environment of the Yucca Mountain (YM) site on a subregional scale. In particular, approaches that may be applied by the DOE to support a YM license application are of interest. A secondary objective is to incorporate a numerical code capable of simulating infiltration into the SUFLAT suite of codes. In general, the task involves assessment of the transient behavior and spatial variability of infiltration, groundwater recharge, and vapor migration using mathematical models. As an exercise to test methodologies, estimates of deep infiltration at YM will be calculated. These deep-infiltration estimates will be used to guide boundary conditions in other tasks of the subregional project and may be used for other projects as well.

Four subtasks are identified for Task 4 in the Project Plan.

Subtask 4.1, estimation of spatial distribution of recharge factors at Yucca Mountain, is designed to examine processes active in the near-surface zone, their effects on deep percolation, and the spatial distribution of these processes. From this subtask, estimates of the spatial distribution of the recharge factors will be used to estimate infiltration from the surface into the subsurface at depths large enough to escape surface effects (on the order of tens of meters). The ARC/INFO GIS software will be used to combine data from various sources, using simple phenomenological conceptual models relating the data to deep infiltration in order to estimate potential recharge. A product of this subtask will be maps of the distribution of estimated infiltration.

Subtask 4.2, development of infiltration models, is designed to develop numerical simulators to be used as modules in the SUFLAT suite of codes. The numerical simulators will incorporate alternative conceptual models of infiltration processes, including processes such as liquid and vapor redistribution, air-phase transport, vegetation, evaporation, and overland flow. Such simulators may be in 1D, 2D, or 3D as appropriate. Two candidate simulators for modification under this task are the 1D BREATH code, developed at the CNWRA under PA Research, and CTOUGH, an N-dimensional CNWRA-modified version of V-TOUGH, a code developed at LLNL.

Subtask 4.3, comparison of numerical models with observed data, is designed to evaluate the performance of alternative conceptual models compared to field observations. The ALTS has seen a number of field studies and is a candidate location for the field observations that might be used for evaluations. The evaluations might be simple 1D infiltration models, hillslope transect models, or full watershed models. The scope of the field-scale exercises will be determined by the magnitude of participation by the University of Arizona.

Subtask 4.4, upper boundary conditions for subsurface flow at Yucca Mountain, is designed to provide quasi-steady-state upper boundary conditions for flow models used in Tasks 5 and 6 of the Subregional Research Project. It is recognized that the near-surface processes in a porous medium occur at time scales orders of magnitude faster than occur farther from the surface. An approach which may be appropriate for such a situation is to separate the near-surface from deeper zones, where the transition zone occurs deep enough that moisture redistribution is sufficiently insulated

SAS 12/18/95

from the surface activity that a quasi-steady state is achieved. It is anticipated that this might be several tens of meters from the surface. Under this subtask, detailed 1D (vertical), 2D (hillslope transect), and perhaps 3D (sub-wash scale) simulations may be considered. One or more simulators developed under subtask 4.2 may be used for subtask 4.4.

It is intended that subtask 4.1 be the first subtask started and completed, and subtask 4.4 will be scheduled much later. Subtask 4.2 will feed into subtask 4.3 and subtask 4.4 as needs are identified. Timing and scope of subtask 4.3 will depend greatly on the participation of the University of Arizona.

SAS 12/18/95

3 Detailed Work Record

10/17/94:

Began planning of infiltration tasks. It is assumed that we will be doing watershed-scale modeling in the future. There is no code readily available to the CNWRA which will do watershed modeling, so a decision on how to develop such a code is necessary. I would like to develop a version of BREATH which would handle this scale, but my time is limited for a period of months. SAS

10/24/94:

Discussed with Ross, Hannah, and Brent what would be necessary and feasible to do with the ARC/INFO technology. The discussion reveals that the EarthVision geologic model may be incorrectly wrapping the layers, as Tiva Canyon is (erroneously) shown over entire mountain surface. SAS

10/28/94:

Found alluvium depth data in 74 neutron probe boreholes in the study plan for unsaturated-zone measurements. Relayed this data to Brent for incorporation into the EarthVision database. SAS

11/5/94:

Began working on an abstract for the HLRWM conference. The subject of the abstract is our plan for estimation of recharge factors at YM. The idea is that a series of 1D simulations can be performed to give a response surface for various parameters impacting infiltration. The parameters might include saturated hydraulic conductivity, van Genuchten parameters, and meteorological parameters. Each parameter would have a spatial distribution assigned in the ARC/INFO database. By combining the parameters from the spatial distribution, and using the response surface, an estimate of the actual response can be obtained. Long-term average values of net deep infiltration are the responses obtained from the simulations. SAS

11/11/94:

Sent the abstract to the conference. Technical and programmatic reviews were accomplished over the previous week. SAS

12/7/94:

Examined, with Rick Klar, a DXF file containing the Scott & Bonk map already digitized. The hope is that this file would have each geologic layer broken out separately, as well as the faults. Unfortunately the structure of the file does not allow the geologic layers to be separated, but the alluvium contact line can be extracted straightforwardly. This line will be useful in ARC/INFO models. SAS

SAS 12/18/95

12/14/94:

After a fair amount of balancing costs, available time for development, and current software capability, Ross and I decided that having Mohan Seth add hooks to CTOUGH, so that climatic influences can be accommodated, would be more effective than developing a multidimensional version of BREATH, my 1D finite-volume code, in order to look at watershed-scale models. The code would be developed over a period of months, to be used at the end of this FY or in the next FY. Steven Seida will be used to develop the climate model hooks. SAS

12/28/94:

Steven began work on developing hooks to allow CTOUGH and climate simulations to work together. The plan is to get a climate simulator developed at MIT, called Constrained Stochastic Climate Simulator (CSCS), up and running. This will be modified to fit together with the hooks that Mohan will be developing for CTOUGH, and the combined result will be called ACTOUGH (Atmospheric CTOUGH). CSCS was finished in 1982 and only exists on a stack of cards someplace; however, a printout of the code is available so it will be scanned into electronic form by Steven and modified subsequently. The work of getting CSCS up and running in electronic form will be done under the auspices of the Performance Assessment Research Project; taking the operational model and hooking it into ACTOUGH will be done under the auspices of the Subregional Research Project. I will monitor the progress of the CSCS code modification. SAS

1/20/95:

Examined ARC/INFO capabilities with Hannah. ARC/INFO has a set of hydrologic functions that may prove useful, and the general capabilities are also fairly complete. However, the watershed delineation function does not work, and the language is quite clumsy to work with. I am left with a feeling that I would prefer to program in some other language where possible, using ARC/INFO functions but outputting the resultant grids. SAS

1/23/95:

Discussed an idea with Ross that ties together the recharge indices. The idea is to perform a numerical simulation for each of the combinations of the recharge indices. An extension proposed by Ross is to use the concept of fuzzy logic in the simulations. Rachid Ababou had done some simple unsaturated-flow simulations using fuzzy logic, which may be of use in the process. I will look into this. SAS

1/24/95:

Had idea that perhaps numerical simulator might be augmented with a neural network for subregional infiltration grid, somewhat after my conception of Leah Roger's (LLNL) replacing a transport simulator with a neural network. Discussed this idea with Donna Rizzo (Univ. Vermont) SAS

SAS 12/18/95

who was intrigued, will think about it, and who informed me that Leah actually did not use neural network to do anything more than find closest already-stored simulation based on an input pattern.

Fuzzy logic may be workable in a slightly different way than I had originally understood. The idea would be to have prototypical cases simulated in a table, with the field values at each grid not restricted to prototypical values and using fuzzy logic to assign partial membership in the prototypical cases. The indices currently being investigated would be used to calculate what prototypical cases to simulate. SAS

1/27/95:

After looking at some of the literature, began questioning utility of fuzzy logic for our problem. Simple table lookup of infiltration based on the sensitivity to recharge indices may provide the same kind of information and has the benefit of being much easier to explain. The sensitivity of infiltration to each recharge parameter would come from separate simulations. SAS

2/13/95:

Met with Steven Seida and discussed his meeting with Mohan Seth. Worked out general strategy of interface between ACTOUGH and climate, where ACTOUGH calls a shell for each surface node, providing the vapor density and the temperature and receives the corresponding potential liquid flux, actual vapor flux, energy flux, and temperature of the incoming liquid flux. Also required that ACTOUGH interrogates the atmospheric routines for maximum time step, so that rapidly changing boundary conditions can be accommodated. Ross and I set out overall structure of activities, so that the GIS work is done and reported by September, with 2 possible conferences discussed for parts of it. The GIS work will provide input to the deep recharge work. Phase 2 will examine the wash scale in detail (subtask 4.4), examining if overland flow can affect focused recharge. SAS

4/26/95:

Hannah finalized plots of the spatial distribution of radiation, using ARC/INFO shading functions and a 30 m x 30 m DEM grid of the YM site. The values reported by ARC/INFO are normalized, so that we are not sure of the actual radiation value and will have to check on this in the future. She has already used ARC/INFO functions in the past few weeks to develop distributions of slope, curvature, and some of the hydrologic distributions. These plots will be used for presentations at the HLRWM conference next week. SAS

5/2-3/95:

Attended HLRWM conference and presented a talk on our infiltration methodology. Discussed the approach in detail with Lorrie Flint (USGS), who is involved in the characterization of infiltration from the DOE perspective. She feels that vegetation is important to include, but the

SAS 12/18/95

specific model is not critical. Vegetation distributions are being surveyed by EG&G and some of this is being used by USGS in characterization. She notes that wind is quite spatially variable, with vortices forming at Yucca Crest, but feels this factor is not particularly important in estimating infiltration. She also notes that LIDAR has been used in a pilot study at YM to estimate vapor density, and seems to remember vapor pooling (density differences? topographical effects?). SAS

5/13/95:

Began setting up to run sensitivities for weather inputs. The idea is to continue the approach started in the Stothoff IPA auxilliary analysis on shallow infiltration. In the auxilliary analysis, a semi-infinite 1D column of homogeneous media is subjected to a ten-year meteorological record measured at the Desert Rock, NV, airport. The data was obtained from the National Weather Service, and includes hourly readings at 2 m above the ground surface of dry bulb temperature, wet bulb temperature, relative humidity, cloud cover, wind speed, air pressure, and precipitation class. Also available are daily totals for precipitation. Under the IPA analysis, this information was converted into hourly values of precipitation, air temperature, shortwave radiation, longwave radiation, vapor density, and wind speed. The IPA analysis suggests that infiltration is only affected by hourly variability in atmospheric variables during a day or so about a precipitation event, as the temperatures are lower and the relative humidity is higher than average, so a 1-day window about each precipitation event will be used with monthly average values outside the window.

As a first attempt, the sensitivities will be run for a column of a material which provides high infiltration under the IPA study. This material has a permeability of 1e-5 cm^2, pcap0 of 10000 gm cm^{-1} sec^{-2}, van Genuchten m of 0.2, and porosity of 0.3. The base case column will be 30 m, in order to simulate a semi-infinite column. The idea is to change the meteorological inputs to the column uniformly, either by adding/subtracting a constant value (temperature, ± 10 C) or multiplying/dividing by a constant factor (precipitation, */ 2; wind speed, */ 2; vapor density, */ 1.5; atmospheric emissivity, */ 1.5; solar radiation, */ 1.5). For this material, fifty-year sequences should be sufficient to get near cyclic steady state, based on IPA work. The BREATH code (Stothoff, 1994, 1995) will be used for all 1D simulations, and the runs will be stored in subdirectories from */home2/sierra/stothoff/Unsat_1d/Breath/SubReg*. Additional storage of runs will be in subdirectories from */home3/stothoff/Breath*; */home3* is a pseudonym for *mammoth : /workstations/sierra*. SAS

5/18/95:

Examined sensitivity runs. Only one decade was simulated due to a bug in BREATH. Fixed the bug and restarted. SAS

5/31/95:

Examined convergence criteria for BREATH in order to see how timing is affected by the convergence criterion. For a tightening of the convergence criterion from 1e-3 to 1e-7, it appears

SAS 12/18/95

that runtimes double. Mass balance is unacceptable at the looser criterion and adequate at the tight criterion; the tight criterion will be used for all simulations. SAS

6/2/95:

Coded a Matlab function to calculate solar loading (*aas.m* in *~stothoff/AuxRain/Climate*). It appears that an annual average solar load of greater than 10 times variation occurs for extremely north-facing vs. extremely south-facing slopes. It also appears that some of the Arc/Info calculations are misleading, since even the highest winter values are less than the peak summer values, which is contrary to what Arc/Info says. Will run sensitivity analyses for infiltration with solar loads for 4 30-degree slopes, north, south, east, west. SAS

6/5/95:

Not quite the right matrix properties have been used (permeability off); however, it appears that running north-facing (30 degrees) vs. south-facing (30 degrees) only affect longterm infiltration by perhaps 15 to 20 percent, despite the average temperature difference of about 4 degrees C. SAS

6/6/95:

Began looking at proper identification of material properties. Ross pointed out TSPA 93 has properties and we should abstract from these. Alluvium properties are not reported in TSPA 93, however.

Identified a bug in BREATH regarding proper treatment of advective transport of energy out of the system. The proper condition is to assume that the fluid leaving does not change temperature at the boundary, thus the $VC_h(T - T_a)$ term is not included in the equations. The old procedure included this term regardless of the direction of flow; it only was significant with larger net infiltration rates. The error typically manifests as a slight exponential rise or fall in temperature just near the bottom boundary in the solar direction tests. SAS

6/7/95:

Additional simulations with solar radiation variation still show some troubling rise of temperature at the boundary. Played with BREATH advective bcs some more and found some significant formulation errors. Assembly of thermal bc equations to the matrix was not quite right. Previous trouble with this assembly months ago masked the advection problems, which drifted from the formulation in the documentation. The code now matches the documentation, except that the documentation does not call out the switch between exterior and domain temperatures depending on liquid and vapor source sign. Only advective, 3rd-type, and ground longwave radiation conditions are affected.

Solar radiation results are somewhat surprising. The four sets done so far are 30 degree tilts towards N, W, S, and E, using the highly infiltratable alluvium. Rank in terms of high to low net

SAS 12/18/95

infiltration runs E, N, W, S, spanning 2.9 cm/yr to 2.2 cm/yr. SAS

6/8/95:

Examined the results of re-running the N and E cases with the revised boundary condition coding. Indistiguishable long-term results. Horizontal (Z) case yields slightly more infiltration than even the E case!

Discussed surprising infiltration results with several folks. Some of the east/west variation might be explained by the occasional large afternoon/evening rainstorms in the summer. Rainfall is bimodal, with maxima in January and summer. It might be concluded that frontal/type storms don't discriminate as to what time of day, but convective storms have a strong preference to afternoon, since there is only a strong bias towards time of day for rainfall in the summer. If the rainstorm hits in afternoon, the eastern slope is already generally cooling whereas the western slope may still be hot. No ready explanation for why the Z and E cases yield more infiltration than the N case. Started off the same met cases with the 1e-2 cm^2 permeability case to see if H_2O storage near the surface will spread the effect – otherwise it would not necessarily be considered particularly significant. SAS

6/11/95:

Restarted simulations for the high-permeability materials to get closer to steady state. SAS

6/12/95:

Finally investigated sensitivities generated over the past month. A rough calculation indicates that linear temperature and vapor density variation with elevation would not vary infiltration by more than a factor of two, at least for the 1e-5 cm^2 permeability case. If precipitation also varied linearly with elevation, another factor of 3 to 4 might be expected. Other factors either don't vary much or the results are insensitive. SAS

6/13/95:

Put a simple scale and shift of input met data into BREATH. Created a C shell script that builds simple input BREATH files with argument-specified modifications. SAS

6/14/95:

Finished csh script for generalized runs. SAS

6/15/95:

Set up a run regenerating results for GW weather variability sensitivity using k=1e-5, p0=2e4, m=0.2 (middle parameter set for YM). Entailed continuing several decades to get close to steady state, setting up shell script for entire sequence. SAS

SAS 12/18/95

6/20/95:

Looked at sequences of weather parameters ran while away. The strongest conclusion that I can come up with based on this is that neglecting rain variability is not good. Other trends are not apparent, perhaps because for this material most sets are within 10 to 20 percent of the median value. Noise is apparently a factor. Also, proper nodal spacing is also a question, since it may not be fine enough for one or two low-permeability cases. SAS

6/28/95:

Created run files for a set of weather sensitivity checks for both a fracture representative of the mean values reported in TSPA93 for TSw, and for a k=1e-2,m=0.2,p=1e4 alluvium (the same that has already been checked for solar angle). The simulations were fired. SAS

6/29/95:

Most of day writing up Subregional Semiannual. Found that some of the new simulations fired off had bad initial conditions and refired. Fracture simulations with no alluvium are dreadfully slow, and with 2 cm of alluvium are about an order of magnitude slower than alluvium. Fired a sequence with 5 cm of alluvium.

Found that Hannah had divided GIS hillshade command output by the number of grids during daylight hours, which mucked with summer's mean relative to winter. There was one grid every 15 minutes. Also found that midday summer value histograms are truncated at 255, but without a spike, which makes me wonder whether this might be correct. Midmorning/afternoon values have a suspicious quick tail down to 255, lending credence to the idea that the calculated values might just be real. SAS

6/30/95:

Some more time on Subregional Semiannual.

Fracture sequences badly misbehaved. At a meter or two, a blob of saturation blocked all flow for years. Switched to a gaswitch flag, which gently turns on arithmetic averaging if the conductivity contrast is too high. This appears to have fixed the clogging problem. Now it appears that the bottom node or two has occasional perched water. Is the gravity drainage assumption not valid with perching? Is this occurring due to large elements? SAS

7/4/95:

Restarted weather simulations for k=1e-2 case, for e=0.67 and r=0.67, with reset bcs. Fracture simulations had only gotten through 4 1/2 cases. The second decade already converged for each case, so restarted remainder with two-decade cycle. Turned on mobility derivative but this is indeed a horrible idea for the alluvium/fracture case. SAS

SAS 12/18/95

7/10/95:

Decided on reasonable fracture properties to consider. The TSPA93 max/min/E(x) values guide a 3-point range. For matrix properties, 3 depths (5/25/100 cm) with 2 permeabilities and similar 3-point range for vgm, perm, and poros seem reasonable. This is a huge set of possibilities to do exhaustively... Created a set assuming alluvium depth/permeability vary, and high/low sensitivities for fracture. This set has 102 members. Started off the middle fracture case with 6 depth/permeability cases. SAS

7/11/95:

Set off a sequence of 25 cm deep, $k = 10^{-3}$ cm^2 alluvium w/ fracture ranges. SAS

7/12/95:

Found I generated wrong fracture cases (fracture permeability too small). Looked at cases already done – 25 cm alluvia do not allow fluxes. Regenerated and restarted. SAS

7/23/95:

Fired a 100-m alluvium/fracture sequence to check if a fracture far below the evaporation penetration depth could begin dripping continuously. Did the *kmpo*5223 case for alluvium with equilibrium initial conditions. The notation refers to permeability (k), with the 5 representing the negative of the power of ten when k is in cm^2; van Genuchten m, with the 2 representing 0.2; capillary pressure P_0, with the 2 representing 2×10^5 Pa; and porosity (o), with the 3 representing 0.3. The first few years show no flux across interface but pressure building steadily. The hypothesis is that an equilibrium condition will be reached shy of perching that will switch on fracture flow at the alluvium rate whenever evaporation doesn't reach the high-pressure mound.

Played with flux BC in BREATH. Changed the hydraulic conductivity from the geometric mean of the last two elements to the last element's value. This should fix the observed problems with draining the last element in fractures. SAS

7/25/95:

Fired up a fracture-only case for close examination. After some experimentation, found that it is critical to cut the time step after rain stops, or the top node doesn't respond with the rest and bolluxes. Also, it appears that cutting off pond-sticking is desirable (pond-sticking enforces the rule that once the top boundary reaches saturation, it stays saturated until the rainfall rate changes). SAS

7/27/95:

Incorporated upstream weighting of mobilities into BREATH. Test case is *Kmao*0802 fracture (large permeability and porosity). Much different behavior of fractures (e.g., no full saturation)

SAS 12/18/95

with upstream weighting. Also, fractures drain out the bottom, unlike before. Some problems appeared as well, with crashing due to temperature spasms arising from large burst of water into an element with miniscule capacitance. Incorporated additional checks on maximum allowable change in pressure and temperature, but for fractures this is only successful with small-enough minimum time step. Essentially all of the time steps for the fracture case are during rain events. Tried cases with elements of 0.5, 1, and 2 cm with quite similar results but modestly more infiltration (10 percentish) with finer grids. Perhaps this is due to better response to drying event. SAS

7/28/95:

Set up sets of runs for while I'm in Las Vegas. On sisyphus am rerunning the various alluvia for the representative fracture, which was dreadfully slow before and crapped out 5-cm layers. Upstream weighting appears to do great things for speedup. On performer checking out the fracture extreme cases. On sierra checking convergence of fracture element size. The results from all runs will come back to sierra for analysis. SAS

8/3/95:

Examined the fracture runs left over the weekend. Some of the runs are reasonable, such as the alluvium/fracture sequence, but some of the fracture-only sequences are obviously wrong since an order of magnitude greater fluxes go through than actually rain. SAS

8/6/95:

Found that the routine calculating partial of mobility wrt moisture content divides by zero when saturated. Fixed. Also added evaporation flux calculations to nodes in the domain. Found that arithmetic mean does not take so many iterations to converge on rainfall events as the geometric mean. SAS

8/11/95:

Demonstrated to Hannah how to do slope calculation with grid index. SAS

8/12,13/95:

Thought about GIS. Preliminary results will be all that are available. Characteristic top/side/botto are necessary. Perhaps 2-cm/5-cm/alluvium for the three cases. SAS

8/16/95:

Examined some fracture simulations. It appears that the newer simulations don't have the accounting problems that earlier runs had. Fired some more, particularly refiring questionable fracture-only cases.

It may be okay to use just curvature results for indexing top/side/wash distribution. SAS

SAS 12/18/95

8/17/95:

Sat with Hannah to try and get index interpolation for ridge top/ side slope/wash bottom. Curvature was not sufficient, since it was displaced from elevations. Came up with formula for interpolating curvature and slope, simply linearly interpolating slope from maximum to zero while interpolating curvature. Formula is $1/2[v1(1 - a1 + b1) + v2(1 + a1 - b1)]$, where $a1$ and $b1$ are normalized values of curvature and slope, and $v1$ and $v2$ are index values. It appears this underemphasizes slope. Next step is to try assigning a cutoff slope.

It appears that BREATH modifications have fixed problems in calculating fracture fluxes. Refired some more of the questionable cases. SAS

8/18/95:

Started outlining poster for Kearney with attention to figures. Also had AAP plotted based on regression in Hevesi *et al.* (1994) paper. It appears that DR data was unusually wet, since it corresponds to roughly Yucca Crest, which is a thousand or two feet higher. Alluvium in some of the washes is at almost this wet. Discussed estimation of alluvium depth with Brent. We figured that supplying an Arc/Info elevation grid with points missing wherever there is alluvium, and using the minimum-tension surface algorithm to find elevations at alluvium locations, could give us a possible surface. Subtracting this from surface elevation gives depth. A quick test reveals that getting a DEM grid into EarthVision is no big deal, but getting one back is non-trivial. Also, there may be problems with no-data points. SAS

8/19/95:

Worked out formula for scaling of infiltration due to temperature, precipitation, and vapor density. Assigned global values based on linear scaling with elevation between DR and central NV, Hevesi *et al.* (1992), and loglinear scaling with elevation between DR and central NV, respectively. The two materials with extensive sensitivities (k=-2 and k=-5) have different behaviors, but basically there is a factor of 11 and 4 respectively for elevations within study grid. The factor is squashed for YM. Got elevation grid into Matlab for this manipulation, starting a new directory for Matlab manipulations of DEM data (*~stothoff/Subreg/YMElev*). SAS

8/20/95:

Fired sequences for temperature/precip/radiation for 2-cm/5-cm cases, *kmpo*5223_*Kmao*2713. Here the *kmpo* notation is the same as before, with *Kmao* representing fracture properties. K is the negative of the power of ten for saturated hydraulic conductivity, with units of cm/sec; m and o are van Genuchten m and porosity, respectively; and a is van Genuchten α. Plotted AAP, AAT, and resultant sensitivities. SAS

8/21/95:

SAS 12/18/95

Checked some runs and refired. Sat with Ross to go over progress. Sat with Hannah to get some idea of progress with EarthVision. Seems like some I/O problems between EarthVision and Arc/Info, since calculated alluvium depths from EarthVision do not match alluvium outlines. Plotted annual average solar radiation table. SAS

8/22/95:

Worked out poster design. Still need to run a few sequences. Hannah got geologic maps overlaid; Ross and I decided to go with EarthVision model for all our needs. Brent found we will be able to get depth information on a block-by-block basis and extract this to a regular grid. Performer going down regularly. SAS

8/23/95:

Verified that I can do DEM plots in Matlab with contour & interp. Fought to get an idea of the pressure-rise distance arising from an alluvium/fracture contact. It appears this is roughly 5 m for the $kmpo5223\_Kmao2713$ case. Fired alluvium-depth sequence. Time with Hannah on geological plots and trying to get alluvium. It appears that the minimum-tension surface interpolation does not do well handling fine features. It may be that interpolation needs to be broken into watersheds.

There may be a bug in BREATH reading from the met file for the richrun option. SAS

8/24,25,26,27/95:

All time spent creating figures for poster. Created a set of fancy-plot routines for YM DEM plotting on Matlab. All annual-average and sensitivity plots are available in fancy form. Created an overland-flow algorithm to crudely estimate shallow alluvium depth, solving $\nabla(q) + src = 0$, where $q = -depth\nabla(elev)$ and $src = a(1 - \exp(-slope/slope0))$. Deep alluvium is estimated using an exponential fit Ross came up with, $depth = 47\exp(-0.32 slope)$, with a correlation coefficient of 61 percent. Performer up and down. SAS

8/28/95:

Worked on poster and discussed mass wasting algorithms. SAS

8/29,30/95:

Worked on poster. Most figures and text in place. Will need to have it FedEx'ed to Davis. SAS

8/31/95:

Wrapped up including all text and figures for poster. SAS

9/1/95:

SAS 12/18/95

A few touchups on poster. Noise and commotion to get it to the printers, but not soon enough. Budhi objected to the inclusion of mountain-scale infiltration rate information on the poster. Decided amongst us to send to NRC for approval after amending text and doing technical review. Made changes and started printing figures. SAS

9/2/95:

Touched up alignment, captions for poster. Everything made ready for reviews.

Decided to run a set of sensitivities for each material property in alluvium/fracture range, for range of shallow depths. Generated run files. Requires some additional setup work. SAS

9/3/95:

Started off sets of alluvium/fracture sensitivities intended to run entire time on travel. SAS

9/5-9/10/95:

On travel to Kearney conference on vadose zone hydrology. Conference initiates 9/6 evening and lasts through 9/8 evening. Presented poster. SAS

9/11/95:

Ross needs some additional infiltration plots for presentation to NRC and ACNW. Spent day manipulating infiltration to try and smooth out noise from alluvium depth calculations. Used Laplace smoothing, up to 100 times, but still some cross-hatching exists. SAS

9/12/95:

Continued fooling with infiltration plots. This time smoothed alluvium depth. Drastic effect on infiltration predictions; one smoothing pass drops average infiltration by more than a factor of with exponential or power-law decrease with additional passes. Note this is not the same as smoothing infiltration!

Began putting together HydroGIS paper. Coalesced Kearney poster text into Latex, rewrote introduction. Text without figures starts out at page limit, so most figures and associated text will need to go. SAS

9/13/95:

Trimmed HydroGIS paper to 6 pages, put references into bibtex database, created figure captions. Figures will need to be 1/4 page apiece to hit 8-page limit. Full Latex format. Gave paper to Ross to look over. SAS

9/14/95:

SAS 12/18/95

Put figures into HydroGIS text sized and placed in final form. It took some fooling with Latex formats before everything was pretty. SAS

9/15/95:

Revisited depth of alluvium calculations. Changed the source term from exponentially decaying with slope to exponentially decaying with alluvium depth. Result is much smoother distributions of alluvium, with little in the way of numerical noise. Very similar predictions for areally averaged infiltration occur. Shallowest alluvium seems to be limited primarily to north-facing slopes in some washes. SAS

9/16/95:

Noticed that alluvium depth is predicted to be much shallower for northfacing slopes than for southfacing slopes using the new source term, and most of the infiltration actually occurs on northfacing slopes. Photo of UZ14 rig and wash backs up the observation that northfacing slopes are somewhat steeper than southfacing slopes. Some sort of freeze/thaw enhanced weathering?

Put together alluvium/fracture sets calculated to date. Varying fracture properties has little effect, with most occuring for shallowest cases and for fracture porosity. Alluvium property variation impacts infiltration more, but still not tremendously. The variations between material-property cases are minor compared to the variation between semi-infinite alluvium cases, although depth of alluvium is still the most critical parameter. SAS

9/20/95:

Some time responding to verbal comments on HydroGIS paper. SAS

9/22/95:

Incorporated technical comments into HydroGIS paper, sent to programmatic. SAS

11/2/95:

Coded up an automated estimator so that the mean values for the last snapshots of variables can be determined. Estimating by eye had become very tedious. SAS

11/3/95:

Checked out some fracture simulations. SAS

11/4/95:

Managed to erase everything in RunFSens directory on performer, where all fracture sensitivity runs were generated before transferal to permanent storage on sierra, so had to regroup. Planned

SAS 12/18/95

semiannual chapter. SAS

11/6/95:

Began outlining semiannual report. Many of the plots from the Austria paper/Kearney poster will be reused. Talked with Lorrie Flint (USGS) and found that there is indeed a ARC/INFO map of alluvial depth, based on a number of factors. She also noted that this map extends to Bare Mountain, and that flows can be significant due to focusing. Her cutoff depth for alluvium yielding net infiltration seems to be roughly 5 meters. Got to the point where tried converting mass from one grid to another in Matlab, using the new algorithm. The resulting transfer is not stable; coding may be to blame. Runs are finished for alluvium/fracture sensitivities for weather. SAS

11/7/95:

Began manipulating alluvium/fracture/weather combinations. An interesting plot develops for ln(q) vs. sat, clearly showing that variation due rain and temperature do not vary along the same line as occurred for semi-infinite media. The shallowest case (2 cm alluvium) shows strange behavior, while the deepest case (25 cm alluvium) has an oddball point for the base case. Started the base case once again to double-check predictions. Some Matlab code generated to help with examination. SAS

11/8/95:

Continued outlining semi-annual report. Also, talked with Dave Hudson (USGS) regarding the flux estimates he is making at YM. The USGS has 86 neutron probe boreholes, with records as long as 10 years and as short as 2 years. The protocol settled on is to use data from a depth of 2 m into bedrock and accumulate increases in moisture content to correspond to infiltration. Decreases or "hold-steady" values are discarded. Thus, only wetting pulses are used and steady fluxes are neglected. Based on these calculations, infiltration rates are as high as 75 mm/yr and as low as 0 mm/yr, with an average of 20 mm/yr (roughly twice my ballpark estimate with faux alluvium depths...). In order to transfer these point estimates to areal coverages, GIS is being heavily used. Several classes of information are being overlain: annual average precipitation (AAP), based on Hevesi's model cokriging AAP and elevation data; geomorphology (channel/terrace/foot of slope/sideslope/shoulder/ridgetop); depth to bedrock (0-0.5 m/0.5-3 m/ 3-6 m/> 6 m); and neutron probe borehole information. The current equation for annual average infiltration (AAI) is (in mm/yr): 0.3 AAP - a1 - a2, where a1 is 36.4 if deep cover (> 3 m) and 0 otherwise, and a2 is (42.2: channel/49.9: terrace/ 56.3: foot of slope/58.9: sideslope/31.6: ridge or shoulder). Note that AAP must be > 262 mm/yr for positive AAI for a channel or terrace with alluvium > 3 m, but only 141 mm/yr for a shallow channel. In order to classify geomorphology, a surficial deposit map was used and aggregated into alluvium/colluvium/eolian/other, which was combined with slope information and an active channel layout from a Genesis database(?). Sideslopes are > 15 degrees. Ridgetops and shoulders have colluvium and slopes < 15; ridgetops have slopes < 5. Foot-of-slopes are <

SAS 12/18/95

15 and exhibit colluvium; channels are 6 m wide and anything left over is a terrace. Ridgetops, shoulders, and sideslopes have alluvial cover 0-0.5 m; Foot-of-slope has 0.5-3 m; terrace and channel has depth of 3-6 m within 30 m of valley side (edge of sideslope?) and > 6 m otherwise. The soil maps are USGS Water Resources Reports by Scott Lundstrom and others, which may not be public yet. Lundstrom, S.C., Mahan, S.A., and Pases(?), J.B. Preliminary Surficial Deposit Map of the NE Quarter of the Busted Butte 7.5' Quadrangle. USGS Open-File Report 94-341. Scale 1:12000 (in press?). Lundstrom, S.C., Mahan, S.A., and Pases(?), J.B. Preliminary Surficial Deposit Map of the NW Quarter of the Busted Butte 7.5' Quadrangle. USGS Open-File Report 95-133. Scale 1:12000 (in press?). Lundstrom, S.C., and Taylor, E. Preliminary Surficial Deposit Map of the S Half of the Topopah Springs NW 7.5' Quadrangle. USGS Open-File Report 95-132. Scale 1:12000 (in press?). SAS

11/9/95:

Looked at maximum flux rates through fractures as a function of depth of alluvium. For base case, 2/5/10/15 cm alluvium had same max rate, 25 cm considerably less. The implication is that gravity drainage is controlling in the fracture, but for shorter time periods with alluvium depth. Also coded up the USGS formula for infiltration and tested with my alluvium. It appears that my alluvium covers are perhaps too deep. I come up with entirely different estimates of infiltration than reported. Doublechecking, positive infiltration for footslope/sideslope/ridge requires 188/196/105 mm/yr AAP. Thus ridge/shoulder are only areas with positive infiltration! SAS

11/10/95:

Started on semiannual report chapter. Did rough draft of section on sensitivity analyses, replotting sensitivities as ideas came. Began coding a C version of the mass wasting algorithm. SAS

11/11/95:

Worked out integrations for mass-wasting using finite elements on a rectangular grid and coded most of the algorithm in C. SAS

11/14/95:

Talked with Dave Hudson. It turns out that 36.2 should be added if depth < 3 m, rather than subtracted if depth > 3 m. Accordingly, infiltration amounts are vastly larger. SAS

11/15/95:

Started including two-layer work in an infiltration sensitivity paper started under IPA. May include weather sensitivity as well. SAS

11/16/95:

SAS 12/8/95

Worked on infiltration paper. Polished text. SAS

11/17/95:

Surfed net to identify interesting AGU presentations. SAS

11/18/95:

Examined flux traces for base case 52232713 with differing depths. Picked out a half-year stretch around 9 years into the sequence that very clearly demonstrates the effect of alluvial depth with five storms. SAS

11/19/95:

Wrote abstract for GSA invited paper. Also set off a sequence of d2, d5, d10, and d15 for 52232713 base case with trace output every day for better trace plots. Found that multiplying d1000 flux by 100-1000 makes it visible on d2 scale. SAS

11/27/95:

Created trace plots for moisture content over same 4-month period as the flux plots for the base case. Wrote this up in semi-annual chapter and started on spatial distribution section. SAS

11/28/95:

Continued on spatial distribution section. Began revisiting film-flow code. After writing up description, a DEM-based data structure is suggested. Looked into C++ implementation. SAS

11/29/95:

Mostly spent trying to figure out C++ implementation of alluvium flow code. Painfully slow progress. SAS

11/30/95:

Got most of a DEMType class defined and working in C++, including numeric operator overloading and I/O. Also polished the abstract for the stochastic BEM paper. SAS

12/1/95:

Continued trying to get alluvium code working, but switched to Matlab for testing purposes (~*stothoff/Subreg/YMElev/MassWaste/MatMod*). SAS

12/2/95:

SAS 12/8/95

Got FE alluvium code going in Matlab. Boundary conditions don't work yet. Set off a long sequence with no-flow boundaries. SAS

12/3/95:
Fixed boundary conditions so that no alluvium enters but alluvium can leave, and played some. Once boundaries were fixed, rapid readjustment occurred. Picked coefficients for the source term $A \exp(-D/D0)$, where $A = 0.5$ and $D0 = 2$ cm and let readjust over a long sequence. SAS

12/4/95:
Straw polled John Stamatakos, Mike Miklas, and Larry McKague regarding source term for colluvium, with estimates ranging from a factor of 2 to an order of magnitude for increase due to slope increasing from 0 to max. Miklas figures a factor of 4 for minimum to maximum solar loading as well. Put these into the model, with $source = A \exp(-D/D0) \exp(\alpha slope) \exp(\beta dZ/dY)$, *slope* and gradient normalized to respective max values. Not a great deal of depth difference with additional terms, but predictions of infiltration are nominally smaller. Also figured out an age-balance equation for perched water as per Ross's instructions. SAS

12/5/95:
Continued with alluvium depth examination and began writing up for semi-annual. As A in the source term decreases, infiltration increases (0.5->0.25->0.1 yields spatial average over DEM of 10.9->13.7->18.9 mm/yr and over rectangle circumscribing the repository 11.8->15.0->20.8 mm/yr). Depths on Yucca Crest and on hillslopes decrease with A; however, average depths appear to increase slightly, which may be because a larger area contributes to generation or because one simulation uses the previous' solution. SAS

12/6/95:
Continued with alluvium depth writeup. Put in a Matlab table for alluvium/fracture cases, to evaluate infiltration, thus more consistently taking into account meteorological effects. This also allows the calculation of minimum and maximum cases from alluvium/fracture combinations. Also spent time going over the analytic solution for concentration in a perched zone with Ross. Mathematica does a nice job of evaluating the differential equation. Apparently the ages calculated with the procedure are reasonable. SAS

12/7/95:
Continued with semi-annual. Tracked down some problems in evaluating infiltration, which had popped up in evaulating statistical descriptions. Rewrote Ross' GSA abstract for him. SAS

12/8/95:

SAS 12/18/95

Got together depth histogram for semi. SAS

12/9/95:
Made color figures for Austria into b/w. Polished semiannual text, finalized most of the figures. Left a few to do when I get back from San Francisco. SAS

SAS 12/18/95

Project terminated at the end of January 1996 due to CNWRA reorganization.

No entries beyond this point

[signature] 3/21/96