Assessment of Effectiveness
of Geologic Isolation Systems

GEOLOGIC SIMULATION MODEL
FOR A HYPOTHETICAL SITE IN
THE COLUMBIA PLATEAU
VOLUME 2: RESULTS

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January 1982

Prepared for the
Office of Nuclear Waste Isolation
under its Contract with the
U.S. Department of Energy

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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
Under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy \$_____*; Microfiche \$3.00

*Pages	NTIS
	Selling Price
001-025	\$4.00
026-050	\$4.50
051-075	\$5.25
076-100	\$6.00
101-125	\$6.50
126-150	\$7.25
151-175	\$8.00
176-200	\$9.00
201-225	\$9.25
226-250	\$9.50
251-275	\$10.75
276-300	\$11.00

ACKNOWLEDGMENTS

This research was supported by the Assessment of Effectiveness of Geologic Isolation Systems (AEGIS) Program conducted by Pacific Northwest Laboratory (PNL). The program is sponsored by the Office of Nuclear Waste Isolation (ONWI), managed by Battelle Memorial Institute for the Department of Energy under Contract DE-AC06-76RLO 1830.

The AEGIS staff wish to sincerely acknowledge the invaluable word processing support provided by Toni Jewell.

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EXECUTIVE SUMMARY

The Geologic Simulation Model (GSM) for the Columbia Plateau (Petrie et al. 1981) is a quasi-deterministic process-response model which simulates the development of the geologic and hydrologic systems of the ground-water basin containing the Pasco Basin for a million years into the future. Effects of natural processes on the ground-water hydrologic system are modeled principally by rate equations. The combined effects and synergistic interactions of different processes are approximated by linear superposition of their effects during discrete time intervals in a stepwise-integration approach (Figure 1).

Knowledge of natural processes and the modeling of consequences of those processes are subject to varying degrees of uncertainty. Uncertainties may arise because of inhomogeneities of the geologic/hydrologic system which preclude accurate characterization at a reasonable level of data collection and model complexity, because of lack of knowledge of the underlying physics driving some phenomena, or because some phenomena are inherently stochastic. The GSM accommodates these uncertainties by treating many of the input data as probability density functions (PDFs). Data whose behavior is better known, for example scalar quantities or polynomial combinations of other variables, may carry additional PDF terms to express uncertainties in their values.

Input data used in GSM simulations are presented in Appendix A of this report. Of 292 input variables, 131 are PDFs (including uncertainty terms for other variables), 131 are scalar quantities, and 30 are polynomials. Additional variables are arrays containing geologic system geometric parameters, and a quantized version of Kukla's (see Scott et al. 1979) astronomical climate index ACLIN.

These data were assembled from consultant inputs and from internal sources during development of the GSM, and represent the best "first cut" information available during that period (CY-1980, 1981). However, they have not been completely documented, nor have they been subjected to a complete peer review. Such a review, which should include inputs from Rockwell Hanford Operations and experts in the scientific community other than the consultants who provided many of the data, was beyond the scope of the AEGIS GSM development work.

FIGURE 1. Schematic Diagram of the Operation of the AEGIS Geologic Simulation Model

SUMMARY OF RESULTS

The completed AEGIS GSM was used to generate 500 Monte Carlo simulations of the behavior of the geologic/hydrologic system affecting a hypothetical repository in the Pasco Basin over the next million years. As was discussed above, these simulations used data which were not subjected to a review adequate to the needs of a real site performance assessment. However, the general care used in generating the data, and the overall behavior of the GSM suggest that the results are plausible if not defensible at this time.

The 26 million output data generated in the simulations can be summarized by considering the three primary questions to be answered by any consequence analysis: "where," "how much," and "when." The "where" was an input to the hydrologic analysis contained in the GSM; the shortest path (vertical) from the hypothetical repository to the unconfined aquifer (Figure 2) was selected for conservatism and to enable a one-dimensional ground-water flow model to represent the three-dimensional behavior of the confined ground-water system (Petrie et al. 1981). The "how much," and "when" can be determined, for the most part, by examining the estimated Darcy velocity through the repository and instantaneous travel times for ground-water movement from the repository to the Columbia River as functions of time.

Darcy Velocity Through Repository

Figure 3 shows the sum of Darcy velocities through the repository from the northeast and southwest components of the Grande Ronde flow system (see Petrie et al. 1981). Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for the first 20,000 years of simulated time (Figure 3a) and for the full million years (Figure 3b). General behavior of the Darcy velocity is a gradual increase over the first half-million years of a factor of approximately 6, with superimposed increases of the order of the initial value lasting only a few thousand years.

The repository Darcy velocity is a function of head gradients and average hydraulic conductivities in the Grande Ronde flow path. The long-period component of change in Darcy velocity reflects:

FIGURE 2. Schematic Diagram of the GSM Model Cross-Section

FIGURE 3. Total Darcy Velocity Through the Repository (a) for the first 20,000 yrs, and (b) for the entire 10^6 yr. (solid line). Dashed lines are maximum and minimum values in 500 simulations; long-dashed/short-dashed lines show $\pm$ one standard deviation

1. The increase in average hydraulic conductivity of this system caused by increase of the assumed small hydraulic conductivity of the repository induced by seismic shaking.
2. The increase of head gradients of the system resulting from net fluvial erosion of the Pasco Basin which follows glacial advance through the Wallula Gap in the period from 55,000 to 65,000 years of simulated time. This advance eliminates the hydraulic-damming effect of Wallula Gap on future Missoula floods and changes the Pasco Basin regime from one of net deposition to one of net erosion.

The short-term fluctuations of repository Darcy velocity show the effect of climatically-induced recharge enhancement, principally during periods of deglaciation.

Instantaneous Travel Time

The Hydrology Submodel of the GSM calculates an instantaneous travel time from the repository to the Columbia River for each time step using Darcy's Law, the average hydraulic conductivity of the remaining flow path, and the current potentiometric head gradient. This travel time is not a measure of how long it takes an individual particle of water to reach the Columbia River, but rather an indicator to alert the user to major or catastrophic changes in the flow system. Figure 4 shows that instantaneous travel times are large (unrealistically so as will be discussed below), undergo an order-of-magnitude increase with time, and are subject to pronounced short-term fluctuations.

The instantaneous travel time is assumed in the GSM to be controlled by that part of the flow path in the Wanapum-Saddle Mountain layer (Petrie et al. 1981). The increase in travel time is a function of the progressive decrease in hydraulic conductivity of that layer induced by the formation of gorge on minor faults cutting the flow path, tempered by the effects of fluvial erosion which shorten the path length and increase the head gradient as the simulations proceed. Short-term fluctuations appear to be in concert with climatically-induced changes in recharge. The factor-of-16 increase in instantaneous travel time that occurs at 850 years of simulated time is probably the result of a

FIGURE 4. Instantaneous Travel Time from the Repository to the Columbia River, (a) for the first 20,000 yrs, and (b) for the entire 10^6 yr (solid line). Dashed lines are maximum and minimum values in 500 simulations long-dashed/short-dashed lines show $\pm$ one standard deviation

subtle bug in the model because it has no basis in the time histories of hydraulic conductivity, head gradient, or effective porosity (constant).

As was mentioned above, the actual values of instantaneous travel time are unrealistic; initially of the order of 4 million years compared with the order of 15,000 years found in Dove et al. 1982. This difference is a result of incomplete calibration of the GSM Hydrology Submodel against the more detailed ground-water models, and of the fact that the initial GSM value is for an undisturbed repository, compared with the faulted one used in the more detailed analyses. The spread of maximum and minimum values of instantaneous travel times (initially about three orders of magnitude) is also probably unrealistic, being the result of uncertainties contained in the PDFs used by the Undetected Features Submodel to establish the starting values of system parameters (Petrie et al. 1981). More detailed and effective calibration was beyond the scope of the GSM development. However, the instantaneous travel time is linearly dependent upon hydraulic conductivity, head gradient, and effective porosity, so the behavior with time of a calibrated version will be proportional to the results shown in Figure 4.

Of particular note is the behavior of the minimum value of instantaneous travel time, which undergoes a maximum decrease of about a factor of two induced by a very slight long-term decline with superimposed climatically-induced perturbations. If a linear factor is introduced to make these results compatible with the results of the more detailed hydrologic analyses, and a more reasonable uncertainty is introduced for the initial value of travel time, then the shortest travel time experienced during any of the 500 simulations would lie between 5,000 and 10,000 years. This results in spite of the combinations of faulting, erosion, and climatically-enhanced ground-water flow rates that occurred in individual simulations.

DISCUSSION

As has been discussed previously, the results of the GSM simulations are not yet defensible. They are promising, and the general behavior of the GSM over the near-term (20,000 years) and long-term (million years) is plausible.

Thus, in terms of a demonstration of the GSM technology alone, the results indicate that the development effort was a success, and this report indicates what additional effort is required to make the GSM defensible. However, the GSM is a part of a coordinated performance analysis which involves other models as well, and is intended as a primary guide to analyses to be performed in addition to that of the present system. The usefulness of the GSM results reported above to the demonstration of a coordinated performance analysis technology must be determined by considering the validity of the results and how they may be applied realistically (unmodified) to guiding more detailed analyses.

VALIDITY OF RESULTS

Evolution of the GSM hydrologic system resulted primarily from the effects of climatic changes and of movement on local faults. Thus, the time histories of Darcy velocity and travel time shown in Figures 3 and 4 depend upon the accuracy of the Milankovitch climate driver (see Petrie et al. 1981) and ancillary data and subroutines (for example, rainfall rates, glacial advances, Missoula floods, and river erosion), and upon the data and code of the Deformation Sub-model which resulted in insignificant folding, major fault offset, or relative elevation changes between the Pasco Basin and the ground-water recharge areas. Review of input data will be necessary before these results can be relied upon for the full million-year simulations.

However, the first 20,000 years of the simulations are not likely to change much even if the input data are revised substantially because the major uncertainties discussed above are related primarily to slow-acting processes not important in the early stages of the simulations. It is not reasonable to expect significant tectonic warping or major fault displacement in the Columbia Plateau in the next 20,000 years even if changes in rates from their estimated past values are occurring. Similarly, based on the late Quaternary, it is reasonable to expect another stage of continental glaciation and at least one Missoula flood in the next 20,000 years. The first advance of ice estimated by the GSM is similar to advances of the Pinedale stages, which allows uniformitarianism to be as much of a guide to validity of the results as would be an exhaustive peer review of the GSM and its data.

Thus, with the exception of Hydrology Submodel calibrations discussed previously, the GSM results for the first 20,000 years of simulated time have sufficient validity to provide input for the more detailed analyses of a demonstration of coordinated performance analysis technology (Dove et al. 1982). Results for the full million years are plausible, but cannot be relied upon yet as an accurate guide to more detailed performance analysis.

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CHAPTER 1

INTRODUCTION

The geologic simulations reported herein supported the Assessment of Effectiveness of Geologic Isolation Systems (AEGIS) technology demonstration in basalt (Dove et al. 1982) and are a continuation of the release scenario model development effort that began during FY-1976 under the Waste Isolation Safety Assessment Program at the Pacific Northwest Laboratory. Several geologic and hydrologic consultants helped identify and analyze the various natural phenomena that may degrade or disrupt a nuclear waste repository located deep underground, and provided inputs to a modified Delphi analysis of disruptive events used by Dove et al. 1982. Although their work continues, many consultant's reports have been published, several of which are cited in appropriate sections of this document, and others are being prepared for publication. In addition to these detailed, topical reports, several reports that discuss the overall AEGIS approach to geologic simulation modeling have been prepared. Perspectives on the Geological and Hydrological Aspects of Long-Term Release Scenario Analysis by Stottlemire et al. (1980) discusses release scenario development for basalt and other lithologies. Experience gained in this earlier work showed that further progress was dependent on site-specific analyses, and much of the work after FY-1979 focused on geologic simulations for nuclear waste repositories in the Columbia River basalts of the Pasco Basin. A Conceptual Simulation Model for Release Scenario Analysis of a Hypothetical Site in Columbia Plateau Basalts, Stottlemire et al. (1981), describes the geologic considerations and their computerized abstractions that enabled development of the AEGIS Geologic Simulation Model (GSM) for basalts of the Columbia Plateau. Geologic Simulation Model for a Hypothetical Site in the Columbia Plateau by Petrie et al. (1981), the first volume of this two-volume report, describes the computer model used to describe the behavior of the geologic and hydrologic systems containing a hypothetical repository in the Pasco Basin.

The geologic simulations conducted for the AEGIS technology demonstration in basalt are designed to be an integral part of a coordinated performance

analysis. Such an analysis endeavors to describe the behavior of the system modeled (for example the patterns of ground-water and contaminant movement), the likely and possible changes of that behavior over the time period of interest, and the probabilities and uncertainties associated with both the inputs and outputs of the analysis. The complex phenomenological codes described in Dove et al. 1982 are too expensive and unwieldy to be used to explore the consequences of every "scenario" of undesirable system changes devised in site characterization and qualification studies. The performance analysis of a system whose behavior must be studied over substantial periods of time must include a geologic simulation model to quantify potential system changes and their probabilities. This model must include simple versions of the more complex phenomenological codes so that it can act as a filter, allowing the complex codes to be applied to modeling those changed states of the system which have the greatest combination of probabilities and consequences.

In developing the GSM for basalt, numerous potentially disruptive natural phenomena were identified and analyzed. These phenomena form two groups, based on their potential for affecting the repository. The phenomena in Group I--rock deformation (e.g., folding and faulting), volcanism, and meteorite impact--could directly disrupt the repository without the interaction of other phenomena. Group II phenomena could probably cause significant degradation or disruption only in combination with other phenomena or under unusual circumstances. In general, Group II contains phenomena that would only affect the geologic and hydrologic system boundary conditions at the repository. However, such boundary condition changes may act synergistically with other phenomena and eventually lead to significant degradation, or may simply affect the initial conditions for radionuclide transport and consequence analysis.

The geology and environment surrounding a repository will continue to change over geologic time. Projections of the possible evolutionary paths can be made from knowledge of the geologic history of the region, the existing states of the geologic and hydrologic systems, and the scientific understanding of the geologic processes in effect. Based on these considerations, AEGIS methodology identifies and quantifies geologic states that result in a loss of repository integrity and need to be further analyzed (Stottlemire et al. 1981).

Development of AEGIS technology has been driven by the need to provide an auditable method for the derivation and quantification of these geologic states of interest, with estimates of the plausibility and time of occurrence. A computer model is used to assist the AEGIS staff and consultants in the analysis and in keeping track of the potentially large numbers of natural processes and interactions. In this process, the justification can be developed for discarding low-probability future projections as being implausible.

A major aspect of the design of the GSM has been its modular and interactive structure to facilitate peer review and iterative improvement of analyses. It was intended that this review and update accompany analyses, but that turned out to be impractical and could not be done in the timely conduct of simulations. Further, the complex nature of the GSM and the large amounts of data that it produces preclude casual interaction by technical experts unfamiliar with the model. For example, a thorough review by Dr. R. G. Craig in the summer of 1981 required 10 weeks of full-time effort.

This report represents an alternative to the original approach, in that preliminary results are presented in toto. The first round of review can then be a more studied, but non-interactive one. Iterative development of the GSM for basalts of the Columbia Plateau is not within the scope of the current AEGIS Project, but the review will aid in the development of geologic simulation models for other locations which are in the present scope of work.

CHAPTER 2

RESULTS AND DISCUSSION

Approximately 500 "production" simulations were conducted with the Geologic Simulation Model for the Columbia Plateau. These were based upon a code which had been "completely" debugged, a set of "final" input data (Appendix A), and single and multiple pre-production simulations to test for internal consistency and subtle bugs in the code or input data. Output data were processed with the GSM statistical package (Petrie and others 1981, Appendix F); the behavior of selected output variables will be presented and discussed in this chapter.

The results presented here emphatically do not constitute an evaluation of the geologic setting of the Pasco Basin as a potential location for a nuclear waste repository; considerable work, to be discussed in Chapter 3, will be necessary to verify input data and submodels of the GSM before it can be considered a licensing tool. Rather, they represent the first integrated, full-scale test of the GSM which is necessary to guide subsequent model calibration and verification. The results indicate that the GSM is fully developed as a research tool; Chapter 3 will compare the results with what is known of the actual situation and discuss the means by which the research tool can be developed into a licensing tool.

CLIMATE

Results

Figure 2.1 shows the average value of climate state, maximum and minimum values, and standard error for the first 20,000 years of simulated time (Figure 2.1a) and for the entire million years (Figure 2.1b). This same format will also be used in subsequent figures. On a large time scale (Figure 2.1b), average climate for the simulations is repetitive with the climate state varying between full stadial (climate index of 4) and full interglacial (climate index of 1). Little variance is apparent; the climate is very similar to the non-stochastic part of the climate state input derived from ACLIN (Petrie and others 1981, Figure 3.4). In detail (Figure 2.1a), the change from warmer to

FIGURE 2.1. Climate Index. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, show-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

colder climate (increasing climate index) is gradual rather than the abrupt change characteristic of the nonstochastic climate index input. This difference lends a distinct saw-toothed appearance to the future climate state estimate.

Discussion

The stochastic climate state has two components, the nonstochastic climate state input derived from ACLIN, and a random input from large volcanic tephra eruptions which drives the climate to a colder climate state. As the simulations progress through the interstadial (climate index of 3) parts of the nonstochastic climate state, tephra eruptions become more probable resulting in an average cooling behavior that is almost linear with duration of the interstadial. The saw-toothed climate state behavior seen here will be reflected in the behavior of climate-dependent variables to be discussed below.

HEAD VALUES AT THE RECHARGE AREAS

Results

On the large time-scale graphs (Figures 2.2b to 2.5b), head values change synchronously with changes in the climate state (Figure 2.1b). This relation is even more evident in the detailed-20,000 year graph (Figures 2.2a to 2.5a), in which the saw-tooth pattern of the change from interstadial to stadial climate state is evident. Long-period upward or downward trends are not apparent in Figures 2.2 to 2.5, but head values over most of the first 20,000 years are smaller than at present.

Discussion

Head values at the recharge areas appear to be largely a function of climate state. This reflects changes in, for example, precipitation, vegetation cover, and soil characteristics included implicitly in Probability Density Functions (PDFs) 17 through 24 (Appendix A). Long-period changes are not strongly evident because: 1) net uplift or subsidence of the recharge areas is relatively small (see PDF 107, Appendix A), 2) isostatic effects of continental glaciation have been ignored for reasons to be explained in a later section, and 3) orographic effects of elevation changes of the Cascade and

FIGURE 2.2. Head Value in the Southwest Grande Ronde Recharge Area. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.3. Head Value in the Northeast Grande Ronde Recharge Area. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.4. Head Value in the Northeast Wanapum-Saddle Mountain Recharge Area. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.5. Head Value in the Southwest Wanapum-Saddle Mountain Recharge Area. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

eastern ranges have been ignored because those changes were relatively small (Figures 2.6 and 2.7). However, PDFs 9, 10, 13, and 14 (Appendix A) which describe elevation changes of the Cascade and eastern ranges may be in error, as will be discussed in Chapter 3.

Lower head values, compared with present ones, over the first 20,000 years of simulated time are related to glacial effects modeled in the GSM. The two extremes of potential effects of a glacier covering the recharge area completely are elimination of recharge by permafrost under the ice, and enhancement of recharge under a wet-based glacier if meltwater is confined and pressurized by ice loading. In this latter case, 2 to 5 cm yr^{-1} of water would be available for recharge on a continual basis (Bull 1980). The probability and probable duration of pressurized recharge are not known, and the subroutine dealing with pressurized recharge was not used in the simulations. Thus, lower head values under glacial conditions in the recharge areas will always occur in simulations unless pressurized recharge can somehow be quantified.

Figures 2.3 and 2.4 show that northeast system heads have extreme low values that are negative. These negative values are artifacts of the model response to zero recharge. If the recharge is zero, head values at the northeast recharge area are set to the current elevation at the discharge point. This gives a zero head gradient and no-flow conditions in the northeast groundwater system.

GLACIER MOVEMENTS

Results

Figure 2.8b shows that simulated lobes of the Cordilleran Ice Sheet cover the Pasco Basin several times in the million-year simulations. However, for the first 20,000 years of simulated time, glacial advances mimic those of the late Pleistocene. Figure 2.8a shows that simulations had, with little stochastic variation, one major advance, a minor retreat, then initiation of another advance in the first 20,000 years. During this period, maximum ice advance is approximately the same as the Pinedale advance of the late Pleistocene, and as will be discussed in a later section, Missoula floods occur during these advances as they have in the past.

FIGURE 2.6. Elevation Changes in the Mountain Ranges to the East of the Pasco Basin. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.7. Elevation Changes in the Cascade Range. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.8. Distance to the Edge of the Cordilleran Ice Sheet from the Repository. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

The simulated glaciers enter the Pasco Basin for the first time after approximately 60,000 years of simulated time. Several prolonged periods of ice cover follow, with the one from about 500,000 to 600,000 years AP being the longest.

Discussion

Glaciers will introduce several alterations to the environment of the Pasco Basin, including changes in the unconfined ground-water system pathlengths and velocities, permafrost effects, Missoula flooding, erosion and deposition, changes in bedrock hydraulic properties induced by ice loading and isostatic movements, and changes in the recharge area of the northeast ground-water system. All of these factors will be discussed in later sections except for ice loading and isostatic effects on bedrock hydraulic properties.

Subroutines analyzing these last two effects are included in the GSM, but were not used in the simulations. Isostatic effects were not considered because they were thought to be small at the time, and because their removal would be conservative in that head gradients in the northeast groundwater system are greater in the absence of isostatic effects. Further, during the first 20,000 years of simulated time, glaciers did not set close enough to the Model Cross Section (MCS, see Petrie and others 1981) to induce isostatic adjustment (see Figure 8a; and scalar EXTRNE, Appendix A). However, isostatic effects on the ground-water system cannot be dismissed intuitively during the unexpectedly long periods of ice residence in the Pasco Basin suggested by the simulations. This variable should not be "turned off" in future simulations of the Columbia Plateau.

The GSM allows for changes in hydraulic conductivity in response to stresses induced by ice loading. However, at the time that the simulations were run, needed data were not available. A weak consensus among the consultants for the GSM suggested that glacially-induced fracturing would not induce significant changes in the hydraulic conductivity of the basalts of the Pasco Basin; nevertheless, early heuristic runs with test data showed that ice-loading effects could dominate all changes in hydrologic properties. Ice-loading processes were "turned off" so that the effects of other, better-understood phenomena

could be observed in these simulations. Clearly, more study of the hydrologic effects of ice loading is warranted if the behavior of glaciers predicted by the GSM for the Columbia Plateau is verified.

SEA-LEVEL CHANGES

Results

Comparison of Figures 2.8 and 2.9 shows that changes of sea level are in phase with changes in the position of the glacier margin. Maximum depression of sea level below the present value is 150 metres during the entire million years, and about 100 metres during the first 20,000 years of simulated time. Figure 2.9 shows that scatter of sea-level values is larger than that of the corresponding glacier margin position.

Discussion

Maximum depression of sea level is an important parameter because sea level is the ultimate base level for subaerial erosion in the Pasco Basin. In the simulations reported here, it is reasonable to use change of sea level as the relative change between sea level and the repository elevation because vertical tectonic movements in the Pasco Basin were small (see PDF 34, Appendix A). This latter assumption may be based on inaccurate tectonic rate data, and will have to be studied further before it is defensible.

The larger variation for sea-level change relative to that of glacier margin position has two probable causes: 1) sea level may change from its current level because of changes in the volume of present ice sheets (for example, melting of the Greenland and West Antarctic ice sheets could cause a rise of sea level of about 12 metres; Bull 1980), and 2) the relation between sea level and glacier margin position is nonlinear. Thus, variability in the position of the glacier margin is accentuated in the corresponding uncertainty in sea level.

FIGURE 2.9. Time History of Changes of Sea Level from the Present Value. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

RATIO OF TRAVEL TIMES IN THE UNCONFINED AND DEEP BASALT HYDROLOGIC SYSTEMS

Results

Figure 2.10 shows the ratio of the instantaneous travel time of a water packet moving from the top of the Wanapum-Saddle Mountain layer to the Columbia River to that of movement from the repository to the top of the Wanapum-Saddle Mountain layer. The travel time in the unconfined hydrologic system is always much shorter than that in the basalts. Further (Figure 2.11), the ratio increases when glaciers are close to the repository. Comparing Figures 2.10a and 2.8a shows the correlation between position of the glacier margin and ratio of instantaneous travel times.

Discussion

Travel time is a function of ground-water speed (pore velocity) and pathlength. In the unconfined ground-water system, both of these parameters are affected by glaciation. Pathlength may be increased or decreased by glaciation at the repository as shown in Figure 2.12. Permafrost, which reduces ground-water speed, becomes effective in increasing travel time in the periglacial environment near a glacier margin. However, travel time in the unconfined aquifer is such a small part of overall travel times that profound glacial effects on unconfined travel time are not manifested significantly in overall travel times. Thus, a reduction in the level of detail devoted to the unconfined ground-water system in future uses of the Columbia Plateau GSM probably would not significantly affect results.

MISSOULA FLOODING

Results

Figure 2.13 shows erosion and deposition in the Pasco Basin resulting from Missoula Floods. On the average, net deposition by the floods dominates the first 65,000 years of simulated time, followed by net erosion for the remainder of the simulation.

FIGURE 2.10. Ratio of Travel Times in the Unconfined and Deep-Basalt Hydrologic Systems. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.11. Behavior of the Ratio of Travel Time in the Unconfined and Deep-Basalt Hydrologic Systems as a Function of Distance to the Edge of the Cordilleran Ice Sheet

FIGURE 2.12. Change of Path Length of the Unconfined Aquifer System Caused by a Continental Glacier Covering the Former Discharge Point

FIGURE 2.13. Net Erosion of the Pasco Basin by Missoula Floods if Glaciers Enlarge Wallula Gap. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

Discussion

Past Missoula floods have had a three-stage effect on the Pasco Basin; erosion of glacio-fluvial and fluvial sediments during the initial, high shear-stress flood pulse, followed by slack-water deposition during the ponding phase caused by hydraulic damming at Wallula Gap, and concluded by a lesser erosional period as the ponded water flowed out Wallula Gap on the waning flood. Input data for the Geomorphic Events Submodel were chosen so that this pattern continued in future Missoula floods so long as flood discharges were large enough to cause hydraulic damming at Wallula Gap. However, at about 65,000 years of simulated time, the Okanogan Lobe of the Cordilleran Ice Sheet crosses the Pasco Basin and encounters the Horse Heaven Hills. It was felt that a valley glacier extruded through Wallula Gap to drain the Okanogan Lobe would profoundly enlarge the Gap, and hydraulic damming would not be possible during subsequent Missoula floods. Thus, after about 65,000 years of simulated time, Missoula floods cause net erosion and do not follow the earlier, three-phase net deposition pattern.

Figure 2.14 shows results of a 100-simulation sensitivity analysis in which glacial erosion of Wallula Gap was not considered. In this case, net deposition dominates (on the average) the entire million-year simulation.

The values for Missoula flood erosion are probably conservative in the main simulations because, during the longer time steps later in each simulation, erosion of the Pasco Basin below sea level is possible if the Geomorphic Events Submodel is called before Sea Level. This "excess" erosion is compensated by deposition when the Sea-Level Submodel is finally called.

DEPTH TO REPOSITORY

Results

Depth to the repository decreased slightly during the first 10,000 years of simulated time, with little variance (Figure 2.15). At the end of that time, the erosional trend is interrupted by a 3000-year depositional period, and the variance increased markedly. A balance between erosion and deposition, with little net change, continued until approximately 65,000 years of simulated

FIGURE 2.14. Net Deposition in the Pasco Basin by Missoula Floods if Wallula Gap Remains a Flow Control. Shown are the average value (solid line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.15. Depth to the Repository from the Overlying Land Surface. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

time, when a period of more rapid erosion began. Net deposition again became dominant after about 715,000 years of simulated time, with occasional erosional episodes.

Discussion

The only erosional process at work in the first 10,000 years of simulated time was "normal" river erosion. Local baselevel is the Columbia River, which occupies a channel in deposits from the last Pleistocene Missoula flood and is armored against flows of lesser magnitude. Thus, the "normal" river erosion rate is controlled by the rate of abrasion of the armoring boulders and behaves more like bedrock erosion than alluvial erosion.

The first Missoula floods occur at approximately 10,000 years of simulated time (Figure 2.13a). Comparison shows that Figure 2.15a is simply Figure 2.13a with superimposed "normal" river erosion. Between 10,000 and about 65,000 years of simulated time, the Pasco Basin regime is one of slight net aggradation as a result of Missoula floods with behavior similar to that of the past. In the period between 65,000 and 715,000 years of simulated time, Wallula Gap has been eliminated as a hydrodynamic dam for Missoula floods, and net erosion by floods and fluvial processes dominates. Glacial erosion and deposition during this same period of time apparently is secondary to that caused by the Missoula floods, but this relative behavior is sensitive to input data for the two processes. More work will be required to verify the relative importance of glacial versus glacio-fluvial erosional and depositional processes.

Erosion to low stadial sea level has occurred by about 715,000 years of simulated time; the minimum value for depth to the repository because, as was discussed previously, vertical tectonic movements of the Pasco Basin were small. Subsequent marine deposition during higher interstadial and interglacial stands of sea level reverses the downward trend of depth to the repository except when interrupted by renewed erosion during low stadial stands around 800,000 years of simulated time.

The erosional curve from 65,000 to 715,000 years is nearly linear, reflecting the conservative nature of the erosion rate law used for Missoula floods. A more realistic rate law would decay exponentially as the slope of the Columbia River decreased during the long period of erosion. However, the analysis itself

cannot be demonstrated to be conservative because the erosion rate for Missoula floods (Polynomial 13, Appendix A) was derived from studies of smaller-scale fluvial erosion of bedrock.

HEAD VALUES AT THE DISCHARGE POINT

Results

Head values for ground-water discharge (Figure 2.16) mimic those for depth to the repository shown in Figure 2.15. However, after approximately 715,000 years of simulated time, the amplitude of variations is larger than that of depth to the repository.

Discussion

The discharge point of the confined ground-water system is assumed to be the Columbia River (Petrie et al. 1981), suggesting that the head value at the discharge point should mimic the elevation of the river. The fact that the discharge head value also mimics the depth to the repository is a result of small vertical tectonic movements of the Pasco Basin, which means that repository depth mimics surface elevation (fixed repository elevation), and that denudation in the Pasco Basin keeps pace with incision of the Columbia River (no canyon or coulee formation). These assumptions and related input data must be subjected to further review.

After about 715,000 years, sea level is used as the discharge head value. Sea-level changes have a larger amplitude than corresponding subaerial erosion or deposition, explaining the greater variances found in this time period for discharge head values than for depth to the repository.

HEAD DIFFERENCES ALONG THE GRANDE RONDE FLOW PATHS

Results

Figures 2.17 and 2.18 show differences in head values between recharge and discharge areas for the southwest and northeast Grande Ronde ground-water flow paths, respectively, and summarize information in Figures 2.5 and 2.15. For the first 20,000 years of simulated time, the most marked feature is the jump

FIGURE 2.16. Potentiometric Head at the Ground-Water Discharge Point. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.17. Head Difference in the Southwest Grande Ronde Flow System. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as function of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.18. Head Difference in the Northeast Grande Ronde Flow System. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

in head differences at about 12,500 years followed by an exponential decay. This jump represents an average net gain of approximately 34% relative to present values. However, for most of the first 20,000 years, head differences are on the order of 14% less than present values. Other long-period trends are not apparent in the first 20,000 years. However, a long-period net change does become apparent after about 65,000 years of simulated time; with a net increase in head differences until approximately 700,000 years followed by a net downward and oscillatory trend for the remainder of the million years.

Discussion

Head differences are affected by the same phenomena as head values discussed previously. Climate dominates changes in head values for the first 65,000 years of simulated time, after which fluvial erosion is most important until the site is eroded to sea level and flooded. On the average, the southwest flow path experiences about a three-fold increase in head difference owing to fluvial erosion, and the northeast path a proportionately smaller increase because of its greater initial difference. Thus, although exposure of the repository by fluvial erosion does not happen in the simulations, such erosion does act to increase substantially ground-water flow through the repository.

A difference between the lower bounds for head difference between Figures 2.17 and 2.18 is that those for the southwest flow path exhibit negative values at the start of the simulation while those for the northeast path are zero. This is an artifact of the way in which zero recharge is handled in the two areas; the head value in the southwest recharge area defaults to that of the discharge point at the start of the simulation while that of the northeast recharge area defaults to that of the present discharge point. This difference was included to allow for glacial effects in the northeast recharge area and does not affect model results.

INCREASES IN HYDRAULIC CONDUCTIVITY DUE TO SWARMS OF MINOR EARTHQUAKES

Results

Swarms of small earthquakes occur in the Hanford area, for example at Wooded Island (Myers et al. 1979), which are not necessarily related to known

faults. Figure 2.19 shows estimated changes in hydraulic conductivity of the repository caused by nearby swarms of earthquakes. It can be seen that the change in hydraulic conductivity increases linearly, that the variance of the hydraulic conductivity also increases linearly, and that changes in hydraulic conductivity are small in comparison with most values used in these simulations (see PDFs 69 to 78, Appendix A) but are large compared with the initial value of repository hydraulic conductivity (see scalar RPOSHC, Appendix A).

Discussion

The behavior shown in Figure 2.19 is an expected result of the way in which the effects of earthquake swarms were modeled. The occurrence of swarms is an independent Poisson-variate driven event (see scalar AVESWM, Appendix A), with the change in hydraulic conductivity caused by each event taken as a fractional amount of the hydraulic conductivity of the repository (see scalar RPOSHC and PDF 131, Appendix A).

CHANGES IN REPOSITORY HYDRAULIC CONDUCTIVITY CAUSED BY DEEP, SUB-BASALT FAULTING

Results

Figure 2.20 shows no changes in hydraulic conductivity of the repository caused by deep-seated faulting until about 398,000 years of simulated time have elapsed. After that, relatively small changes occur.

Discussion

Changes in hydraulic conductivity of the repository resulting from deep-seated earthquakes are functions of distance and magnitude of the earthquakes and of lithostatic confining pressure at the repository. Wight (see Appendix C) indicated that, for basalts of the Pasco Basin, changes in hydraulic conductivity will not occur if cover thickness exceeds about 950 metres because in situ stresses tend to close fractures that open or lengthen during seismic shaking. Even at depths less than 950 metres, confining pressures mitigate effects of seismic shaking. For example, Figure 2.16b shows that minimum cover at the repository is greater than 600 metres during the million-year simulations. At this depth, even if an earthquake is located in the basement directly below

FIGURE 2.19. Changes in Hydraulic Conductivity of the Repository Caused by Swarms of Minor Earthquakes. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.20. Change in Hydraulic Conductivity of the Repository Caused by Sub-Basalt Faulting. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

the repository (greater than 2 km distant), an earthquake with a Richter magnitude greater than 7.5 would be necessary to change hydraulic conductivity at the repository.

AVERAGE HYDRAULIC CONDUCTIVITY OF THE WANAPUM-SADDLE MOUNTAIN LAYER

Results

Figures 2.21 and 2.22 show little change in hydraulic conductivities of the southwest and northeast Wanapum-Saddle Mountain layers during the first 20,000 years of simulated time. However, a decrease in average hydraulic conductivity is apparent over the total million-year simulation.

Discussion

In the GSM, hydraulic conductivity of the Wanapum-Saddle Mountain layer is affected by:

- 1) The initial values of hydraulic conductivity chosen for the various components of the MCS by the Undetected Features Submodel (see Petrie et al. 1981).
- 2) Changes induced by earthquakes in the sub-basalt basement.
- 3) Changes induced by earthquakes in the basalts, but not located on the MCS (for example, located on Gable Mountain).
- 4) Local earthquakes located on the MCS.
- 5) Geochemical "healing" (i.e., a reduction of hydraulic conductivity caused by deposition of chemical precipitates in pore spaces).

"Healing" and local earthquakes located on the MCS act to reduce the average hydraulic conductivity (see PDFs 111, 112, 113, 114, 119, and 129, Appendix A). Figure 2.23 shows the change in hydraulic conductivity resulting from healing, while Figure 2.24 shows changes caused by local fault activity. Comparison of these two figures indicates that, based upon the preliminary input data of Appendix A, local faults effect a greater reduction in hydraulic conductivity than does geochemical healing. Substantial review of these data is necessary before this result can be accepted or dismissed.

FIGURE 2.21. Average Hydraulic Conductivity of the Southwest Wanapum-Saddle Mountain Flow System. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.22. Average Hydraulic Conductivity of the Northeast Wanapum-Saddle Mountain Flow System. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.23. Change of Average Hydraulic Conductivity of the Wanapum-Saddle Mountain Flow System Caused by Secondary Mineralization. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.24. Change of Hydraulic Conductivity of the Wanapum-Saddle Mountain Flow System as a Function of the Number of New Local Faults Crossing the Flow Path

The effects of local and deep-seated fault movement have been considered as opposites in the input data and in the above discussions. The reason is that the sub-basalt faults are assumed to propagate through overlying basalts as a zone of disruption which increases fracture apertures and lengths, hence effective hydraulic conductivity (Petrie et al. 1981). In contrast, discrete local faults which intersect the MCS will have little effect on average hydraulic conductivity if their hydraulic conductivity is greater than that of the undisturbed rock because of the minute fault zone width compared to length of the flow path. Conversely, formation of fault gouge which causes a relatively smaller hydraulic conductivity in the fault zone can act as a "bottleneck" in the flow and reduce the average hydraulic conductivity of the flow path substantially. For example, a one-metre wide fault zone in a 100-metre flow path (Figure 2.25) can reduce average hydraulic conductivity of the flow path by a factor of two if the hydraulic conductivity of the fault zone is an order of magnitude smaller than that of the undisturbed rock (Figure 2.26). A fault zone with greater hydraulic conductivity than the undisturbed rock can also act to reduce flow through the repository by "short-circuiting" the flow path. This flow geometry cannot be accommodated by the one-dimensional analysis in the Hydrology Submodel (Petrie et al. 1981), but its omission is considered to be conservative.

HYDRAULIC CONDUCTIVITY ALONG THE GRANDE RONDE FLOW PATHS

Results

Figures 2.27 and 2.28 show predicted changes in average hydraulic conductivity along the southwest and northeast Grande Ronde flow paths, respectively. Average values show an initial, nonlinear increase with time peaking at about four times the initial value at 345,000 years of simulated time in the southwest flow path and at about 3.5 times the initial value by the end of the million-year simulations in the northeast flow path.

Discussion

In addition to the phenomena affecting the Wanapum-Saddle Mountain system flow paths, average hydraulic conductivities along the Grande Ronde flow paths

FIGURE 2.25. Schematic Diagram of the GSM Analysis of a 1-Metre Wide Fault Zone in a 100-Metre Flow Path

FIGURE 2.26. Relative Average Hydraulic Conductivity of a 100-Metre Flow Path Containing a One-Metre Wide Fault Zone with Smaller Hydraulic Conductivity Than the Surrounding Rock

FIGURE 2.27. Average Hydraulic Conductivity Along the Southwest Grande Ronde Flow Path. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, (short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.28. Average Hydraulic Conductivity Along the Northeast Grande Ronde Flow Path. Shown are the average value (solid line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

are also influenced by swarms of minor earthquakes and by changes in hydraulic conductivity of the shaft seal. The influence of changes in shaft-seal properties is small because the changes are relatively small (Figure 2.29) and because the shaft seal is aligned parallel to the flow and makes a relatively small contribution to the overall flow area.

In contrast, the remaining phenomenon, change of hydraulic conductivity of the repository caused by nearby swarms of minor earthquakes, appears to control the difference in behavior between the Grande Ronde and Wanapum-Saddle Mountain flow paths. This is because the repository was assumed to have a very small hydraulic conductivity compared to the host rock (see Scalar RPOSHC, Appendix A) and thus acts as a "bottleneck" in the flow in the same fashion as local faults in the Wanapum-Saddle Mountain flow paths discussed above. This effect also reduces the variance of the average hydraulic conductivities of the Grande Ronde flow paths in comparison with those of the Wanapum-Saddle Mountain flow paths and with the input data for the basalt components of the Grande Ronde flow paths (see PDFs 69-78, Appendix A). This illustrates that the repository, with small hydraulic conductivity and hydraulic conductivity variance, acts not only as a "bottleneck" to control average hydraulic conductivity of the flow path, but also acts to control its variance (i.e., the variance of the average is dominated by the variance of the least conductive member).

TOTAL DARCY VELOCITY AT THE REPOSITORY

Results

Figure 2.30 shows the sum of Darcy velocities through the repository from the northeast (Figure 2.31) and southwest (Figure 2.32) Grande Ronde flow paths. Following an initial decrease, average Darcy velocity rises to a peak about seven times greater than the initial value by approximately 500,000 years of simulated time. Fluctuations of the same order of magnitude as the initial value are apparent on the average curve in Figure 2.30b, with proportionately larger fluctuations on the plus-one standard error and maximum-value curves.

FIGURE 2.29. Change of Hydraulic Conductivity of the Shaft Seal. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.30. Total Darcy Velocity Through the Repository. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.31. Northeast Flow System Component of Darcy Velocity Through the Repository. Shown are the average value (solid line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

FIGURE 2.32. Southwest Flow System Component of Darcy Velocity Through the Repository. Shown are the average value (solid line), envelope of maximum and minimum values (dashed line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

Discussion

The repository Darcy velocity is a function of head gradients and average hydraulic conductivities in the Grande Ronde flow path. Thus, previous discussion has been structured to show the logic relating these variables, hence repository Darcy velocity, to more fundamental causes. Specifically, the long-period component of change in Darcy velocity reflects:

- 1) The increase in hydraulic conductivity caused by degradation of the "bottleneck" effect of the repository.
- 2) The increase of head gradients resulting from fluvial erosion of the Pasco Basin.

The short-term fluctuations of repository Darcy velocity show the effect of climatically-induced recharge enhancement, principally during periods of deglaciation.

As discussed previously, the head difference along the southwest flow path increased by a factor of approximately three and the hydraulic conductivity by a factor of about four during the million-year simulations. Figure 2.32 shows an increase of Darcy velocity through the repository for the southwest system of a factor of slightly less than 11, which indicates that the head gradient and hydraulic conductivity did not peak simultaneously. Also, the quantitatively more important northeast flow system had an increase of Darcy velocity through the repository of a factor of only 5, which resulted in the overall increase of a factor of about 7.

Although neither the changes in hydraulic conductivity and head gradient, nor changes in Darcy velocities in the northeast and southwest flow paths, necessarily occur simultaneously for the averages shown in Figures 2.30, 2.31, and 2.32, it is entirely possible that all components might act in phase in an individual simulation. This will be discussed in a later section.

INSTANTANEOUS TRAVEL TIME

Results

The Hydrology Submodel of the GSM calculates an instantaneous travel time from the repository to the Columbia River for each time step using Darcy's Law,

the average hydraulic conductivity of the remaining flow path, and the current potentiometric head gradient. This travel time is not, then, a measure of how long it takes an individual particle of water to reach the Columbia River, but rather an indicator to alert the user to major or catastrophic changes in the flow system. Figure 2.33 shows that average instantaneous travel times are large (unrealistically so as will be discussed below), undergo an order of magnitude increase with time, and are subject to pronounced short-term fluctuations.

Discussion

Instantaneous travel time is assumed in the GSM to be controlled by that part of the flow path in the Wanapum-Saddle Mountain layer (Petrie et al. 1981). Thus, the increase in travel time is a function of the progressive decrease in hydraulic conductivity of that layer, tempered by the effects of fluvial erosion which shorten the path length and increase the head gradient as the simulation proceeds. Short-term fluctuations appear to be in concert with climatically-induced changes in recharge.

As was mentioned above, the actual values of instantaneous travel time are unrealistic; of the order of 6×10^7 to 6×10^8 yrs compared with the order of 15,000 yrs found in the detailed study reported by Dove and others (1982). This difference is a result of incomplete calibration of the GSM Hydrology Submodel against the more detailed models, particularly in the area of effective porosity which is needed to calculate pore velocity from Darcy velocity. This calibration was beyond the scope of the work reported herein; however, results of the Hydrology Submodel are linearly dependent on, for example, effective porosity, so should show the correct relative behavior of the instantaneous travel time even if the absolute values are incorrect.

FIGURE 2.33. Instantaneous Travel Time of Water from the Repository to the Discharge Point. Shown are the average value (solid line), and standard deviation (long-dashed, short-dashed line) as functions of time for (a) the first 20,000 yrs of simulated time, and (b) for the full million yrs.

CHAPTER 3

EVALUATION

As has been discussed previously, the results of the GSM simulations of the Columbia Plateau are based upon inadequately reviewed data and are not yet defensible. However, the results are promising, and the general behavior of the GSM over the near-term (20,000 years) and long-term (million years) is plausible. Further, these results provide a basis for evaluating the GSM and suggest specific needs for further work to provide scientific credibility to the analyses. This work includes peer review of the code and input data, and more importantly acts as a guide to the conduct of focused site characterization studies. Finally, the GSM results are the first produced by a simple, integrated model of a repository system (far-field component only), and provide a sample of the capabilities of such models for guiding the application of more physically-based process codes and for determining R&D priorities in the selection, characterization, and licensing of a site for a repository for high-level nuclear waste.

PRELIMINARY EVALUATION OF SUBMODELS

Evolution of the GSM hydrologic system resulted primarily from the effects of climatic changes and of movement on local faults. Thus, the time histories of Darcy velocity and instantaneous travel time shown in Figures 2.30 and 2.33 depend upon the accuracy of the Milankovitch climate driver and ancillary data and subroutines (for example, rainfall rates, glacial advances, Missoula floods, and river erosion), and upon the data and code of the Deformation Submodel which resulted in insignificant folding, major fault offset, or relative elevation changes between the Pasco Basin and the ground-water recharge areas. Review of the GSM data and code can be focused by considering this behavior, studying the relative dominance of simulated processes within the GSM which led to this behavior, and evaluating that balance of processes against knowledge of the real geologic/hydrologic system.

A preliminary review was conducted, aided substantially by inputs from Dr. Richard G. Craig, an AEGIS consultant. Results of that evaluation, and suggestions for further developmental work to improve the credibility of the GSM results, are presented below by submodel.

Climate Submodel

The Climate Submodel was the principal driver for many of the developments that took place in the GSM simulations, and was the basis for some of the great complexity of interactions between other processes. Thus, it is absolutely essential that the Climate Submodel be parameterized and coded without error. Possible inadequacies which should be addressed are:

- The probability of an ashfall significantly affecting climate (scalar PASHFL, see Appendix A). This parameter is difficult to set because no such effects have been documented; for example, no long-lasting climatic changes resulted (apparently) from the Tambora and Krakatoa eruptions and Tunguska event. A better way to treat the possibility is to separate the frequency of large tephra eruptions (for which good control can be found in cores of the Greenland Ice Sheet) from the probability that an eruption of a given size would have a significant and long-lasting effect on climate.
- It appears that probabilities for uplift of the Cascade and eastern ranges (scalars PCASUP and PRKUP, see Appendix A) were provided by consultants in the form of rates, and that an arithmetic error of two orders of magnitude (too small) was made in the rate provided for the uplift rate of the Cascades. The GSM code should probably be modified to draw an amount of gross uplift from a density curve at each time step, and this amount should include elevation gains caused by the accumulation of volcanics as well as tectonic uplift.
- Precipitation values for all recharge areas and climate states should be reviewed. The use of a bimodal curve shape for an interglacial climate in order to include the altithermal interval of the Holocene climate (see PDFs 1 and 5, Appendix A) may not be satisfactory. The altithermal climate lasted approximately 4,000 years; the present GSM configuration allows draws from altithermal and "normal" interglacial precipitation rates on

subsequent time steps. A separate curve and climate state should probably be used for the altithermal. Further, in interpolating interstadial and temperate interstadial precipitation rates between stadial and interglacial climates, the average of altithermal and "normal" interglacial precipitation rates was used; this procedure should be reviewed.

- The balance between reduced evaporation and increased precipitation during stadial climates should be reexamined. If glacial climates have less precipitation than at present, rather than greater as simulated by the GSM (see PDFs 4 and 8, Appendix A), the advance of the simulated Cordilleran Ice Sheet may be less extensive than that of present simulation results.
- Erosion rates of the Cascade and Eastern ranges (PDFs 10 and 14, Appendix A) may be as much as an order of magnitude too small, and do not increase with increasing relief or with increasing precipitation.
- The fraction of precipitation going to recharge (for example, PDF 21, Appendix A) should be calibrated where possible against more sophisticated analyses such as Dove et al. 1982.
- Orographic effects caused by elevation changes of the Cascade and Eastern ranges (Polynomials 1, 2, 3, 4, and PDFs 11, 12, 15, and 16, Appendix A) were included in the GSM code, but no data were available and the subroutines were not active. The most likely orographic effect is increased aridity caused by net uplift of the Cascade Range. It is probably conservative to ignore this effect because increased aridity may limit glacial advances thereby inhibiting the widening of Wallula Gap and subsequent erosion by Missoula floods, and also reduce recharge during all climate states. However, unforeseen effects of increased aridity may not be desirable, and further efforts to acquire data should be made.
- ACLIN itself should be reviewed in detail, and perhaps an alternative considered for a parallel analysis. Since the Climate and Glaciation Submodels are run separately with uniform 100-yr time steps before the main GSM simulations, such an experiment would not be costly. Another modification to be considered is the use of the smoothly-varying ACLIN curve itself, rather than the discrete climate-state step functions now

used, to simulate climate changes more accurately. This latter undertaking could be a major effort.

- The effects of changes of sea level should be included with orographic effects.

Deformation Submodel

The Deformation Submodel determines the direct and indirect effects of folding and faulting upon the simulated hydrologic system. Long-term changes in repository and bedrock hydraulic conductivities were determined by this submodel, as were the relatively insignificant changes in relative elevation between the Pasco Basin and recharge areas and fold and fault deformation within the Pasco Basin. Possible inadequacies which should be addressed are:

- A distinction should be made between the number of swarms per hundred years and the number of earthquakes that occur during a particular swarm event. It may be inappropriate to assume, as the GSM does now, that each earthquake within the swarm will contribute equally to the energy release. Swarm events have (tentatively) been found to increase significantly the degradation of the repository, justifying further evaluation of the phenomenon.
- The time between thrust-fault movements (PDF 87, Appendix A) may be too large, and the present value and code structure almost guarantee that no thrust faulting will occur in the first 10,000 years. This may be an artificial sense of safety, and should be reviewed.
- The statistical basis for fold parameters (PDFs 93 through 97, Appendix A) should be examined carefully; other types of distributions may be more appropriate to the phenomena and data available than those used in the input data.
- The subsidence rate of the Pasco Basin (PDF 106, Appendix A) may be one or more orders of magnitude too small. Further, subsidence in the Pasco Basin could have several effects which are not modeled in the present GSM. For example, a lowered gradient on the Columbia River could lead to temporary ponding behind Wallula Gap and a change of the river to a meandering pattern. This change could result in a shift of the river channel out

of the present, armored channel and in conjunction with renewed downcutting at Wallula Gap to greater rates of channel incision at the repository.

- Uplift rates for local mountains (PDFs 107 through 110) may be too small. However, the present data in the GSM yield a greater uplift in a million years for the Rattlesnake Hills than for the Cascade Range, suggesting that all uplift rates should be scrutinized. Uplift and erosion should also be considered for the northeast recharge area, where they could have effects both on the amount of precipitation and on the hydraulic gradient affecting the confined flow systems.
- Because of the way that the GSM is now coded, only one new fold is allowed to be active in the area (see Petrie et al. 1981). If another forms, it eliminates the earlier one. The GSM uses a moderately elaborate approach to define the geometric characteristics of the new fold; however, these details have little direct effect upon other variables. Fold modifications of the ground-water system and rates of river erosion, and subaerial erosion of the fold should also be considered.
- The effects of faults and faulting on hydraulic conductivity appear to have several inconsistencies. These are the result of data inputs from several consultants, which were made at a time when the work schedule did not allow flexibility for discussions and interchanges of data between consultants. The differences may be related to failure to distinguish between "faulting," which may increase local hydraulic conductivity in brittle rocks by orders of magnitude, and "faults," which may now be areas of reduced hydraulic conductivity caused by subsequent healing processes such as are modeled in the GSM. Experience with the present GSM code and data set should be used as a guide to revisions which will achieve the most credible sophistication within the limits of available data.
- The effects of folds and fold growth upon hydraulic conductivities should receive further work; at present they are either not used or not considered.
- Other phenomena which should possibly be considered are the effects of earthtides and temperature changes on permeability or hydraulic conductivity, and the effects of continental drift which may amount to 20 to 50 kilometres in a million years.

Geomorphic Events Submodel

The major phenomenon acting in this submodel is catastrophic flooding caused by the failure of ice dams in the region of Pend Orielle, Idaho. Such flooding is known to have occurred in the past and the necessary boundary conditions still exist. The last effect of the most recent flood was the deposition of a thick layer of cobble gravel over the repository site. However, it is probable that deep scouring of the bed of the Columbia River and adjacent areas occurred in the earliest flood stages. Further, elimination of Wallula Gap as a flow restriction could extend the period of intense erosion throughout succeeding floods. It is especially important that careful examination of the boundary conditions and dynamic response of the system be made, and that the submodel be consistent with applicable geomorphic theory and available field evidence. Peripheral events which could mediate or accentuate flood-related erosion should also be considered. Possible inadequacies which should be addressed are:

- A portion of the Geomorphic Events Submodel is devoted to normal fluvial erosion. In comparison to the effects of catastrophic floods, the potential for disruption of a repository appears to be much less. However, the possibility that the effects of normal erosion may interact with the catastrophic floods to yield unanticipated results should be considered.
- The average number of Missoula floods per 100 years (scalar AVEFLD, Appendix A) may be inaccurate in that it is based on data which include the flood resulting from the catastrophic draining of Lake Bonneville and on a perhaps inaccurate interpretation of the Pleistocene record. The code should be reworked to separate other catastrophic floods from those emanating from Lake Missoula, and more accurate data should be derived for Missoula floods. This latter effort may include the need for well-directed field work.
- By comparison with the rates of rise of pluvial lakes in the Great Basin, a rough calculation suggests that the filling of Lake Missoula should take on the order of 400 years. Thus, Missoula floods should not be possible in consecutive 100-year time steps, and a conditional probability of occurrence should be used based upon more refined calculations.

- The erosion factor for folds affected by Missoula floods (scalar EFOLDE, Appendix A) is not supported by documented data. Suitably-reviewed discussion of the derivation of this value should be developed.
- The minimum Missoula flood-flow for hydraulic damming at Wallula Gap (scalar QDAM, Appendix A) should be reviewed, and the effects of changes of gradient of the area upstream and changes of the cross-sectional area and shape of Wallula Gap included in the code.
- The maximum radius from the repository for stream capture by a growing fold (scalar RIVCAP, Appendix A) should be related to the current size of the fold.
- The amount of northeast recharge area still covered by loess, and therefore not available for recharge of the confined aquifers of the Pasco Basin (scalar RNELF, Appendix A) is currently equal to the total area of the northeast system, ignoring extensive stripping of loess cover within scabland flood channels. This is an oversight that should be corrected. The fractional reduction of loess cover with each Missoula flood (scalar RNERED, Appendix A) should be rederived as a function of AVEFLD and RNELF.
- Changes of river slope caused by various events (PDFs 46 through 50, Appendix A) should be reevaluated for accuracy and consistent treatment, and the error checking limits (scalars SLOPHI and SLOPLW, Appendix A) adjusted accordingly.
- River discharges (PDFs 56 through 59, Appendix A) should be reevaluated, and the PDFs reformulated from their present point-by-point format to a standard type for discharge data (for example, the Gumbel or Pearson distributions).
- Missoula flood discharge (PDF 64, Appendix A) and the treatment in the GSM code of the relation between discharge and flow parameters appear to have discrepancies with values reconstructed for past floods, and may also contain errors. This part of the submodel is critical to the present results of the GSM, and should be reviewed carefully.

- Deposition during a Missoula flood (PDF 68, Appendix A) should be related to the magnitude of the flood and possibly other parameters. This variable should be a polynomial.
- Stream erosion and erosion during Missoula floods (Polynomials 13 and 14, Appendix A) are functions both of the submodel code and data; both should be reviewed for adequacy and accuracy. This is a key effect of the present GSM, and one of the less expensive and time-consuming areas for further investigations related to increasing both accuracy and precision of the results.
- Consideration should be given to the possibility of an increase or decrease in drainage area of the Columbia River related to upstream stream capture(s) or glacial effects, to migration of the confluences of the Snake or Yakima Rivers, and to diversions resulting from combinations of tectonic, glacial, and catastrophic flooding processes.
- If the site is inundated by the sea, the effects of wave planation and shoreline retreat should be considered.

Continental Glaciation Submodel

Continental glaciation can affect the ground-water system directly through increases or decreases in recharge, indirectly through modifications of the surficial geologic systems, and also by changing stream discharges and sea level. Both the direct and indirect effects of such glaciations appear to be important in the GSM results. Unfortunately, lack of data required that some parts of the Continental Glaciation Submodel code not be used. In addition, some potentially important phenomena were not included in the GSM. Suggestions for improving the Continental Glaciation Submodel are:

- The calculation of glacier volume and the relation of sea level to the volume of the Cordilleran Ice Sheet should be reevaluated. A more sophisticated treatment would require that the glacier profile be controlled by shape factors based on more relevant ice sheets (compared with the present use of the Antarctic Ice Sheet), and the use of moraines from past Cordilleran Ice Sheets to guide the generation of a more realistic shape of simulated future ice sheets.

- Modeling of glacial erosion should be reviewed; perhaps 5 to 150 metres of erosion are possible during the million-year simulations, based upon data from other locations. Such erosion in the Pasco Basin would be a significant contribution to that already simulated by the GSM. Also, a more sophisticated consideration of glacial erosion of Wallula Gap should be considered. At present, the GSM is coded to eliminate Wallula Gap as a constriction to Missoula floods immediately after the first glacial advance to that location. The extent of glacial scouring could be modeled more precisely based on comparisons to the depth and width of valleys scoured by past advances of the Okanogan Lobe.
- At Chelan, the original valley was blocked by the Okanogan Lobe and a second outlet carved. A similar diversion by a piedmont lobe of the Central Montana Ice Cap was documented by Foley (1980). Such an occurrence near Wallula Gap could result in more extreme hydraulic damming of Missoula floods than has occurred in the past, and should be included in the GSM.
- Glacially-induced fracturing, which can enhance fracture permeability of the ground-water system, was modeled by the GSM, but so dominated trial runs with test data that the subroutine was deactivated pending better data. Those data were never obtained, and future development of the GSM for the Columbia Plateau should include further consideration of this phenomenon.
- Past glaciations were accompanied by the accumulation of extensive and thick deposits of loess, which may act to reduce recharge to the confined aquifers. Future use of the GSM should probably include simulations of similar accumulations of loess. Although it may be conservative to ignore this phenomenon, an in-depth consideration of all of the effects may suggest some which are not conservative to neglect.

Hydrology Submodel

The Hydrology Submodel is central to the evaluation of the desirability or undesirability of future states of the system modeled. The phenomena which could disrupt the repository directly have much smaller probabilities than the gradual changes of the ground-water system which could degrade the performance

of the repository slowly over time. Other submodels take on importance in proportion to their effects on this one, which should be reviewed carefully. Suggestions for improving this submodel in addition to the calibration discussed in Chapter 2 include:

- The calculation of reduction of pore volume by secondary mineralization (see Petrie et al. 1981) assumes a 100-year residence time. Results of more sophisticated analyses (Dove et al. 1982), and of the GSM simulations suggest that residence times should be 10,000 years or longer. This difference should be factored into the calculations.
- The very small hydraulic conductivity of the repository host rock (scalar RPOSHC, Appendix A) may be overly optimistic, and should be reviewed as site characterization proceeds.
- The speed of unconfined ground water (PDFs 124 through 127, Appendix A) should be reviewed in comparison with values reported in Dove et al. 1982.
- The entire suite of hydraulic conductivities, effective porosities, and changes in these parameters with time and various geological developments should be reviewed in comparison with the results of Dove et al. 1982, and by the use of physically-based fracture flow models to estimate more accurately the effects of deformation, shaking, and other processes on the porous-medium equivalent hydrologic properties of the basalts.
- Pressurized recharge by a glacier covering the northeast recharge area is included in the code, although it was deactivated for the simulations discussed in Chapter 2. The phenomenon should also be considered for the southwest recharge area, and input data developed to permit its use in future simulations.
- The possibility that the Pasco Basin could be flooded by the sea was realized in the GSM simulations. The code should be modified to model the effects of overlying saline waters on the ground-water system and on secondary mineralization.
- Decreases of head at the recharge areas, for example in the northeast recharge area when a glacier advances across it, probably are not

"instantaneous" as now modeled by the GSM. The long residence time of ground water in the confined system argues for an exponential decrease with time.

- The possibility of recharge to the southwest ground-water system by the Yakima River should be considered.
- The present one-dimensional (quasi-three dimensional, see Petrie et al. 1981) confined ground-water system does not allow the future ground-water system to develop a general flow direction oblique to the Model Cross-Section, to have flow paths diverted around the repository by new faults, or to discharge to or receive recharge from existing or future coulees. The desirability of including a more sophisticated spatial representation of the ground-water system should be considered.
- The definition of a threshold flow through the repository of an order of magnitude greater than initial flow as an indicator of significant degradation of the repository (Zellmer and Lindberg 1981) proved unuseable in analyzing results of the GSM simulations. A statistical approach based on simulation results (Zellmer and Lindberg 1981) should be tried, and time dependence of the threshold based upon remaining inventory of radio-nuclides should be considered.

Magmatic Events Submodel

The probability of a magmatic event in the Pasco Basin may be too large; far more events occurred in the simulations than have occurred in the past million years. The input data (scalar AVE MAG, Appendix A) should be reviewed for accuracy.

Meteorite Impact Submodel

Meteorite crater diameter (PDF 34, Appendix A) is a point-by-point frequency distribution at present. A lognormal distribution consistent with empirical and theoretical ones developed for terrestrial and planetary craters should be substituted.

Sea-Level Fluctuations Submodel

Fluctuations of sea level affect the ultimate base level of the Columbia River, and in combination with a possible local base level at Wallula Gap and vertical tectonic movements of the Pasco Basin, control fluvial erosion near the repository. In a million-year simulation, sea level is affected primarily by the volume of ice on the continents and to a lesser extent by tectonics of the ocean basins. Both influences are now lumped in the Sea-Level Fluctuations Submodel (Petrie et al. 1981) in what may be a simplistic approach that adds more uncertainty than is necessary. Glacio-eustatic and tectono-eustatic variations of sea level should be separated. Further, glacio-eustatic changes should not be tied directly to fluctuations of the Cordilleran Ice Sheet, which forms a small fraction of world ice volume at maximum extent. Petrie et al. 1981, have discussed the conservatism and practicality of the present approach. In retrospect, a much simpler and less uncertain approach would be to compute sea level directly from ACLIN, which was justified and calibrated initially on the assumption that it should correspond to glacio-eustatic sea-level changes.

Sub-Basalt Faulting Submodel

The basis for many of the relations between the physical characteristics of faults and the characteristics of earthquakes occurring on them is a consulting report by Wight et al. included in this report as Appendix C. Review of Appendix C and the way in which relations are coded in the GSM will be necessary to assure proper behavior of this submodel. Such variables as PDF 104 (see Appendix A), the distribution of earthquake magnitudes, should be reviewed in comparison with the latest seismic data and interpretations for the Pasco Basin and Columbia Plateau.

Undetected Features Submodel

The Undetected Features Submodel sets values of many of the hydrologic system parameters at the beginning of each simulation. Results discussed in Chapter 2 suggest that system hydrologic properties and their uncertainties are not in agreement with the results of more sophisticated analyses of the present hydrologic system. Thus, the entire suite of initial hydrologic data

(for example, PDFs 70 through 83, Appendix A) should be reevaluated in comparison with results of analyses such as that of Dove et al. 1982. The treatment of existing faults in the recharge area also needs review for consistency both internally and with data gathered during site characterization studies.

Shaft-Seal Failure Submodel

This submodel is in its infancy, and actually is a simple subroutine. Consideration of this subject should be made in coordination with repository design and sealing studies, and is a precursor of near-field phenomena which should be modeled in future development of the GSM.

Probability Density Functions

The appropriateness of the form of many of the PDFs in the input data set can, in retrospect, be questioned. In many cases, a standard form can be justified in place of the point-by-point or alternate standard forms developed for the preliminary input data. In others, present knowledge of some variables is inadequate to justify departure from some standard form such as a normal distribution for the PDF. The code and input data need to be reviewed by a statistician and geostatistician to assure internal consistency and consistency with knowledge of the behavior of individual processes.

VALIDITY OF PRELIMINARY RESULTS

The above discussion has shown that none of the primary GSM subroutines and data which gave the results discussed in Chapter 2 can be proven valid without thorough review and adjustment. Specifically, tectonic movements of the Pasco Basin and recharge areas were insignificant but were based upon rate of movement data which may be too small by several orders of magnitude; glacial advances were based on climatic data which should be reviewed and the effects of alternative formulations considered, and may not have included consideration of relevant data describing local climates during glaciations; and glacial effects at Wallula Gap the opposite of those modeled were not considered.

However, the first 20,000 years of the simulations are not likely to change much even if the input data are revised substantially because the major uncertainties discussed above are related primarily to slow-acting processes not

important in the early stages of the simulations. It is not reasonable to expect significant tectonic warping or major fault displacement in the Columbia Plateau in the next 20,000 years even if changes in rates from their estimated past values are occurring. Similarly, based on the late Quaternary record, it is reasonable to expect another stage of continental glaciation and at least one Missoula flood in the next 20,000 years. The advance of ice estimated by the GSM is similar to advances of the Pinedale stades, which allows uniformitarianism to be as much of a guide to validity of the results as would be an exhaustive peer review of the GSM and its data.

Thus, with the exception of calibration of the Hydrology Submodel discussed in Chapter 2, the GSM results for the first 20,000 years of simulated time have sufficient validity to provide input for the more detailed analyses of the demonstration of coordinated performance analysis technology for basalt reported in Dove et al 1982. Results for the full million years are plausible, but cannot be relied upon as an accurate guide to more detailed performance analyses.

RARE (CATASTROPHIC) EVENTS

The usual distinction between events and processes is that the processes act continuously over time, while events are nearly-instantaneous occurrences which may change some physical parameter discontinuously. The geologic record makes little distinction between events and processes because it is long compared to the recurrence interval of most events. Indeed, modern studies of many geologic "processes" suggest that their effects are the result of many "mini-catastrophes" rather than of a continuous, gradual change. Modeling of processes as continua or as aggregates of discrete "events" thus is determined by the time period modeled compared to the time between events and the detail desired in the interval between the beginning and end of the simulation. The GSM does not distinguish between events and processes philosophically, but models each in as realistic a manner as possible. The result is that some events such as earthquakes, which may cause time-discontinuous development of the hydrologic system during the period simulated with 100-yr time steps, become processes during the 1,000 and 10,000-yr time steps because enough events happen to form a statistical population in the model as a whole.

However, some events, such as large meteorite impacts on earth in the last billion years or more, have such long recurrence intervals that they must be considered individually. Further, the formation of new faults, which may be a "process" in the GSM as a whole, becomes an "event" if the new fault intersects the repository. The probability of such an occurrence is so small that it may not happen during several hundred million-year simulations, yet the consequences may be of sufficient interest to warrant consideration. Experience with the simulations conducted to date with the GSM suggests that these rare, catastrophic events be considered separately from the main GSM simulations. Because of problems with computer roundoff errors, special care would have to be taken to assure accurate treatment of such low-probability occurrences and orders of magnitude more simulations conducted. A better approach would be to superimpose these rare events on the system manually. The superposition of rare events upon degraded states of the containment system could be based on the joint probabilities, and a cutoff probability used to guide those combined degradations that would be subjected to further analysis.

CHAPTER 4

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The AEGIS Geologic Simulation Model (Petrie et al. 1981) has been run in the Monte Carlo mode to generate several hundred possible future developments of the geologic/hydrologic system of the Columbia Plateau. Results of these analyses are plausible but not yet defensible because they are based on insufficiently documented and peer-reviewed input data and code. The GSM is completely developed as a research tool, but needs substantial review and polishing before it will be useful as a licensing tool. An important benefit of this "calibration" process is that it will help focus detailed site-characterization studies and provide a framework in which to test the consistency of geologic and hydrologic field data.

The principal, simulation-oriented findings from completion and running of the GSM were:

- Such a simulation is in fact possible. The GSM performed well, was stable, and produced plausible results.
- The GSM is greater than the sum of its parts. Synergistic interactions between processes did occur, and some processes had results quite different from those predicted by expert consultants. This clearly indicates that some model like the GSM is necessary in the performance assessment of complex geologic/hydrologic systems. Delphi or similar processes are inadequate to the task of forming a gestalt of such a system and testing its limits.
- The GSM is a unique tool for organizing geologic and hydrologic data, showing which data appear to have a controlling influence on knowledge of the behavior of the system, and showing where data or understanding of phenomena are lacking. This process allows problem areas to be identified early enough in the investigation to allow time for their solution, and helps detect errors in data.

- Documentation of the GSM and its input data provides an organized "audit trail," showing assumptions and decisions made during a continuously-refined analysis spanning several years.
- A working GSM allows rapid incorporation of new data or scientific developments into the analyses, and facilitates exploration of the implications of both sides of any relevant scientific controversies.

The GSM does not yet produce scientifically-defensible results. An in-depth peer review by Professor Richard Craig of Kent State University suggested many areas where input data and/or simulation code were incompletely documented, inconsistent, or possibly in error. These recommendations, a summary of which follows, do not detract from the fundamental soundness of the model, but rather from its immediate applicability to licensing of the Hanford site.

The Climate Submodel of the GSM is extremely important because it acts as a driver to other submodels, particularly those handling geomorphology, sea-level changes, glaciation, and the hydrologic system. Climate is the principal dynamic component of the GSM besides tectonics, and contributes about half of the complexity of the model. Initial runs of the GSM suggest that climatic changes have profound effects on the ground-water system affecting a repository in the Pasco Basin, both beneficial and deleterious at different times in the "future." Thus, the components of the Climate Submodel need careful review. The Climate Submodel is composed of two basic parts, the climate state predictor, and input data to characterize the hydrologic parameters of the different climate states (for example, rainfall, runoff, recharge). The climate state predictor employs a Milankovitch driver (ACLIN) developed for AEGIS by George Kukla of Lamont-Doherty, with a small stochastic input to account for large tephra eruptions (Petrie et al. 1981). The scientific community is not in complete agreement on the basis of climatic change, and would credit a model such as ACLIN with explaining only 40% to 65% of the variability of past climates. A way to forestall criticism of a site performance analysis made with the GSM would be to test the effects of using other climate state bases in place of ACLIN in separate analyses. The GSM was designed to facilitate such sensitivity analyses and would quickly demonstrate the effects of different approaches to the prediction of climate.

A more ambitious approach would be to charter a detailed study, for example by the CLIMAP group, to generate a state-of-the-art climate state driver. Such a study is probably beyond the scope of NWTs site characterization work. However, the flexibility of the GSM in dealing with new data would permit rapid assessment of the effects of such a model should it be developed independently at some future date.

Input data to characterize the climate states can probably be developed from paleoclimatic parameters developed for a Site Characterization Report. Some parameters, such as the orographic effects of changes of relative elevation between the Pasco Basin and the Cascades and Rockies for the Hanford site, or of changes of sea level, may require limited original work by outside consultants, but not of a scale or generality to be excluded from the scope of site characterization work.

A related area of effort for the Columbia Plateau GSM is that of growth of the Cordilleran Ice Sheet and its relation to the Laurentide Ice Sheet or global continental glacial activity and to sea level. The present Continental Glaciation Submodel has a simplistic representation of the Cordilleran Ice Sheet as circular and synchronous with global glacial advances and retreats. Such a representation would probably have been adequate if future glaciers had not been predicted to cross the Pasco Basin repeatedly. A more sophisticated representation is clearly needed now, and like climate can probably be approached from a relatively site-specific basis within the scope of site characterization work or from a more fundamental direction. Again, the GSM provides the means to do the former while retaining flexibility to accommodate the latter as fundamental models are developed elsewhere.

The effects of Missoula-type flooding as modeled in the GSM are to cause net deposition in the Pasco Basin, or net erosion if Wallula Gap is seriously affected by future glacial advances. Results of the present modelling effort suggest that net erosion by Missoula floods will not threaten a repository in the Pasco Basin directly, but will change potentiometric gradients in the confined ground-water system affecting such a repository. Topics which need

further work in the GSM simulation of Missoula floods include the timing of floods relative to glacial advances; the likely magnitudes of the floods in relation to their timing; amounts of deposition of glacio-fluvial sediments in the Pasco Basin as a function of flood volume and the state of Wallula Gap; more detailed work on the relation between flood volume, flow parameters, and erosion to be expected; and an estimate of how the hydraulic damming characteristics of Wallula Gap will change with time.

Changes in bedrock hydrologic properties with deformation, faulting or seismic shaking, and glacially-induced stresses were significant in the GSM runs made to date. However, treatment of these phenomena has been inconsistent because different consultants were responsible for parameterizing and characterizing different aspects of stress- or deformation-related changes. A uniform and more studied approach is necessary to the entire problem of the hydrologic characteristics of fractured rock and how those characteristics change with changes of stress or with deformation of the rock. This information is necessary both for the GSM and for more detailed hydrologic modeling, and should be a multi-disciplinary effort involving geologists, geophysicists, and hydrologists.

Many other aspects of the GSM are in need of review and possible refinement, but not in terms of their fundamental correctness. For the most part, they are data that are not properly documented as to origin or assumptions used in deriving them, data which appear to be incorrect, or phenomena such as geochemical healing which appear to have a simplistic treatment. In most cases, these data have been received from consultants and could probably be refined by those consultants. However, this process still does not contain the needed peer review of the data, nor does it capitalize on the data and expertise gained during site characterization work. Further, some of the data may need further field work, and the data needs themselves may be a guide to future site characterization activities. These data are too numerous to list here, but in general all of the GSM data should be subjected to interactive scrutiny by geologists and hydrologists engaged in site characterization.

Examination of the above examples of data needs shows that many can be generated during site characterization, some can be produced inexpensively as

Masters or Ph.D theses, some will require extensive research efforts, and some appear impossible. It is for the latter that the unique character of the GSM is important--those parameters which appear unquantifiable at our present level of knowledge. A fundamental basis of the GSM is the use of Probability Density Functions (PDF's) for many of the input data. This allows uncertainty or subjectivity to be accommodated, with resulting effects on uncertainty in output data being quantified by Monte Carlo analysis. This type of analysis allows a new approach to modeling of complex natural systems and is a major advantage of the GSM over more conventional risk assessment techniques.

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APPENDIX A

INPUT DATA

APPENDIX A

INPUT DATA

The heart of the Geologic Simulation Model is the code which describes the natural phenomena (see Appendix D), and the data which drive the code and allow it to describe the behavior of a specific location. Input data for the GSM for the Columbia Plateau consist of scalars, probability density functions, polynomials, arrays, and ACLIN. ACLIN is described further in Appendix B. Values of the scalar and array variables, having names consisting of four to six letters, and probability density functions and polynomials identified by number are presented in this appendix. The data descriptions and values are machine-generated to assure that the data presented here are those that were used in the simulations reported. Table A.1 describes the "Quality Keys" used to describe the relative merit of the values used for individual variables.

TABLE A.1. Description of Quality Keys

Type	Description
Test Data	Datum is currently unknown. A best guess is used as a stopgap measure to allow the model to be exercised and tested until the "real" datum comes in.
Data from the Literature	Datum was found in the open literature. The corresponding reference is given in the "long" text field.
Data from Relative Frequency	Probability density function values were derived from a relative-frequency histogram.
Data by Transform	Datum was created by transformation of a known quantity by way of a relating function. For example, a probability density function showing the amount of river erosion could be derived from one for river flow if an equation relating river flow to river erosion was known.
Data from Curve Matching	In this case, a limited amount of data are combined with geologic knowledge of the processes involved to define a probability density function. For instance, 10 points may be used to estimate the mean for a normal distribution; the use of a normal distribution being justified from a knowledge of the geologic processes at work.
DELPHI	Datum was developed in a DELPHI-type process.
Expert Judgement	Datum is the best subjective guess of an expert.
Judgement and Data	Datum is the best guess of an expert constrained by at least a limited amount of data.
Depends on Repository	Datum is a function of repository design. While the datum currently used is only a best guess of what will be used, it is expected that by the time the GSM is run for licensing this value will be well defined.
Inactive for Future Use	This datum is not currently being used by the model.
Variance-for Future Use	Denotes that a probability density function, used as a error term with a polynomial, is currently not being used.

Scalar "ACELCT " Sub-Basalt Quake Critical Acceleration
 Entered by "Alan James Baldwin " on 27-FEB-81 equals 490,00000
 For use in submodel Sub-Basalt Faulting
 Judgement and Data
 Error checking bounds are : 0,0000000 980,0000
 Unit = centimeters / sec**2
 Source =PNL ==
 Minimum earthquake acceleration (cm/sec**2) from sub-basalt
 basement earthquake that potentially could initiate (or
 reactivate) basalt folding or faulting.

Scalar "ACFTMN " Sub-Basalt Quake Critical Acceleration
 Entered by "Alan James Baldwin " on 27-FEB-81 equals 245,00000
 For use in submodel Sub-Basalt Faulting
 Judgement and Data
 Error checking bounds are : 0,0000000 980,0000
 Unit = centimeters / sec**2
 Source =PNL ==
 Minimum earthquake acceleration (cm/sec**2) from sub-basalt
 basement earthquake that potentially could initiate (or
 reactivate) basalt folding or faulting.

Scalar "ACLCRT " Critical Acceleration For Shaft Seal
 Entered by "Jon Lindberg & Alan Baldwin" on 15-JAN-81 equals 534,29999
 For use in submodel Shaft Seal
 Judgement and Data
 Error checking bounds are : 0,0000000 980,0000
 Unit = centimeters / sec**2
 Source =PNL ==
 Minimum earthquake acceleration (cm/sec**2) that could
 potentially change the hydraulic conductivity of the shaft
 seal.

Scalar "ANCROS " Angle From North of Model Cross Section(MCS)
 Entered by "Jon Lindberg & Alan Baldwin" on 15-JAN-81 equals 52,000000
 For use in submodel Undetected Features
 Unpublished Data
 Error checking bounds are : 42,00000 62,00000
 Unit = degrees
 Source =PNL ==
 Angle (degree) from north to line of the MCS.
 The M.C.S. extends from Sunnyside ,Wa to Spokane, Wash ,
 and passes over the reference site of a hypothetical nuclear
 waste repository at Hanford.

Scalar "ANCRUN " Critical Angle For faults Parallel to MCS
 Entered by "Jon Lindberg & Alan Baldwin" on 15-JAN-81 equals 10,000000
 For use in submodel Undetected Features
 Data from Expert Judgement
 Error checking bounds are : 0,0000000 30,00000
 Unit = degrees
 Source =PNL ==
 Critical angle (degrees) for the maximum angle in the
 horizontal plane measured from the MCS. Faults with strikes
 that are between the MCS and ANCRUN are considered to be
 essentially parallel to the MCS.

horizontal plane measured from the MCS. Faults with strikes that are between the MCS and ANCRUN are considered to be essentially parallel to the MCS.

Scalar "ARCRAD" Radius of Unconfined Aquifer Discharge Arc
Entered by "Alan James Baldwin" on 20-FEB-81 equals 40.000000
For use in submodel Undetected Features
Judgement and Data
Error checking bounds are : 34.00000 94.00000
Unit = kilometers
Source =PNL ==
The unconfined aquifer discharges to the Columbia River. The discharge arc schematically represents the Columbia River in the Pasco Basin. ARCRAD is the radius of the arc. Scalar variables XSTART and YSTART define the center of the discharge arc.

Scalar "AVEFLD" Average Number of Missoula Floods Per 100 Yr
Entered by "Gregg Petrie" on 17-MAY-81 equals 0.66999998E=02
For use in submodel Geomorphic Events
Judgement and Data
Error checking bounds are : 0.0000000 7.0000000E=02
Unit = Number Of Events Per 100 Years
Source =Donald Easterbrook
Average number of Missoula-type floods per 100 years when the continental glacier is within a sensitive zone. The sensitive zone is defined by two latitude lines that are north of the Hanford site. See RLATHI and RLATLW (scalar variables).

Scalar "AVEGAB" Average No Gable Mtn Events (STGABT)/100 Yrs
Entered by "Gregg Petrie" on 17-MAY-81 equals 0.00000000
For use in submodel Deformation
Data From Expert Judgement
Error checking bounds are : 0.0000000 3.0000000
Unit = Number Of Events Per 100 Years
Source =Steve Malone
Average number of significant earthquakes on the Gable Mountain structure per 100 years. Significant earthquakes occur only when the strain rate is greater than or equal to, the value of the scalar variable STGABT. The Gable Mountain structure also includes Umtanum Ridge.
See change memo of May /14/81 to see the rationals for setting the value to zero

Scalar "AVEMAG" Av. No. Mag Events/100 Yr In The Pasco Basin
Entered by "Alan James Baldwin" on 16-APR-81 equals 0.52000001E=01
For use in submodel Magmatic Events
Unpublished Data
Error checking bounds are : 0.0000000 1.0000000
Unit = Number Of Events Per 100 Years
Source =PNL == Kurt Schmieder
Average number of magmatic events (active volcanoes) per 100 years in the Pasco Basin. This value was obtained from 1 by 2 degree quadrangle maps produced from the RWIP project (a Rockwell subcontract) along with U-2 photos, LANDSAT and ERTS satellite imagery. The most detailed level of mapping used mylar overlays on U-2 Photos (9 x 9 in.) at a scale of 1:125,000 (1 in. approx. 2 miles). The data used were:

Map	Centers	Map	Centers	Map	Centers
Wenatchee	0	Ritzville	12	Pendleton	1
Pullman	3	Grangeville	0	Yakima	67
Dalles	31	Spokane	5	Okanogan	0
Hoquiam	2	Concrete	0	Sandpoint	0
Walla Walla	0	Canyon City	1	Baker	5
Hamilton	0	Elk City	0	Boise	0

Scalar "AVENAS " Aftershocks Per Sub-Basalt Earthquake
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 2,0000000
 For use in submodel Sub-Basalt Faulting
 Test Data
 Error checking bounds are : 0,0000000 4,000000
 Unit = Number of Aftershocks Per Sub-Basalt Quake
 Source = Lawrence H. Nigh
 Average number of aftershocks per sub-basalt basement
 earthquake.

Scalar "AVESWH " Average No. of Swarm Events In Repository
 Entered by "Alan James Baldwin " on 29-APR-81 equals 0,20000000
 For use in submodel Sub-Basalt Faulting
 Data From Expert Judgement
 Error checking bounds are : 0,0000000 1,000000
 Unit = Number of events per 100 years
 Source = Steve Malone
 The average number of swarm events directly intersecting the
 repository during a 100-year period

Scalar "AVGABF " Av. No. Gable Mtn Events (FAULT and STGABT)
 Entered by "Grega Petrie " on 17-MAY-81 equals 0,00000000
 For use in submodel Deformation
 Inactive - For Future Use
 Error checking bounds are : 0,0000000 3,000000
 Unit = Number Of Events Per 100 Years
 Source = Steve Malone
 Average number of significant earthquakes in the Gable
 Mountain and Untamum Ridge structures per 100 years when a
 major sub-basalt basement fault has occurred. Significant
 earthquakes occur only when the strain rate of the structure
 is equal to, or greater than, the value of the scalar
 variable STGABT.
 See change memo of May/14/81 for the rationale for setting
 this number to zero.

Scalar "AVLAND " Average Number Of Landslides Per 100 Years
 Entered by "Grega Petrie " on 17-MAY-81 equals 0,00000000
 For use in submodel Geomorphic Events
 Data From Expert Judgement
 Error checking bounds are : 0,0000000 1,000000
 Unit = Number Of Events Per 100 Years
 Source = Donald Easterbrook
 Average number of landslides per 100 years that sufficiently
 block the river to change the river gradient or divert the
 flow.
 The chance of landslides affecting the river is large
 enough to include in the 'normal' change in slope and
 path length density curves (see the documentation for curves
 46 and 51).

Scalar "RMULTF " Breach Multiplication Factor
 Entered by "Alan James Baldwin " on 13-MAY-81 equals 10,000000
 For use in submodel Sub-Basalt Faulting
 Judgement and Data
 Error checking bounds are : 0,0000000 20,00000

Unit = unitless
 Source =PNL
 This breach multiplication factor uses the starting Darcy velocity through the repository to derive the limits for defining a breach to the repository.

Scalar "CGLSTR " Radial Stress For Rock Fracturing
 Entered by "Alan James Baldwin " on 22-MAY-81 equals 10000.000
 For use in submodel Continental Glaciation
 Inactive = For Future Use
 Error checking bounds are : 0.0000000 10000.00
 Unit = pascals
 Source =PNL == Mike Foley & Gregg Petrie
 Minimum radial stress (pascals) from glacial loading that will fracture basalt.
 Note : During initial runs of the simulation, glacially induced fracturing consistently produced the same results at the same times. For early runs of the model it was decided to speed the model up by effectively removing the glacial fracturing and adding it during the analysis. The initial runs demonstrated a need to study the effects of glacial fracturing on hydraulic conductivity.

Scalar "CGLSTI " Tangential Stress For Rock Fracturing
 Entered by "Alan James Baldwin " on 22-MAY-81 equals 10000.000
 For use in submodel Continental Glaciation
 Inactive = For Future Use
 Error checking bounds are : 0.0000000 10000.00
 Unit = pascals
 Source =PNL == Gregg Petrie & Alan Baldwin
 Minimum tangential stress (pascals) from glacial loading that will fracture basalt.
 Note : During initial runs of the simulation, glacially induced fracturing consistently produced the same results at the same times. For early model run it was decided to speed the model up by effectively removing the glacial fracturing and adding it during the analysis. The initial runs demonstrated a need to study the effects of glacial fracturing on hydraulic conductivity.

Scalar "CONVN " Conversion Factor For Old Fracture Healing
 Entered by "Alan James Baldwin " on 21-MAY-81 equals 0.14000000E+03
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 0.0000000 1.000000
 Unit = 1.0 / ppm
 Source =PNL == Bill Deutch
 A multiplication factor to change the units of ion concentration, length of time steps of computer model, and ion residence time to decrease in hydraulic conductivity for old fractures. This scalar variable helps to calculate the change in rock hydraulic conductivity caused by mineralization.

Scalar "CONVS " Conversion Factor For New Fracture Healing
 Entered by "Alan James Baldwin " on 21-MAY-81 equals 0.14000000E+03
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 0.0000000 1.000000
 Unit = 1.0 / ppm
 Source =PNL == Bill Deutch
 A multiplication factor to change the units of ion

concentration, length of computer time step, and ion resident time to a decrease in hydraulic conductivity of new basalt fractures. This scalar variable assists in the calculation of the change in rock hydraulic conductivity caused by mineralization

Scalar "CORBED" " River Slope Correction For Bedrock
Entered by "Alan James Baldwin" on 16-MAY-81 equals 1.0000000
For use in submodel Geomorphic Events
Data From Expert Judgement
Error checking bounds are : 0.0000000 1.0000000
Unit = unitless
Source =Donald Easterbrook
Changes in river slope are normally calculated with the assumption that the river is not eroding bedrock in the Pasco Basin. When the river is eroding bedrock, the scalar variable CORBED (multiplication factor) converts the slope changes from sediment erosion to bedrock erosion.
Note : Dr. Easterbrook recommends the multiplication factor of 1.0 (no difference):
"Comparison of gradients of segments of the Columbia in basalt and in sediments is made difficult by dams on the river. One 27 km segment of the Columbia presently flowing in basalt has a gradient of 0.44 m/km, only slightly higher than river flow in sediments in the Pasco Basin. ... from 0.3-0.6 m/km, spanning the gradient of the Columbia flowing in Basalt." (Easterbrook, 1981)

Scalar "COSBNE" " Angle From Repository to Grande Ronde NE
Entered by "Jon Lindberg & Alan Baldwin" on 16-JAN-81 equals 0.99989998
For use in submodel Hydrology
Depends on Repository Design
Error checking bounds are : 0.0000000 1.0000000
Unit = cosine
Source =PNL
The cosine of a vertical angle between the horizontal and an imaginary straight line extending from the hypothetical repository to a point in the Grande Ronde Formation at the northeast edge of the Pasco Basin. The point is located midway between the top and bottom of the Grande Ronde Formation and lies on the MCS. The vertical angle helps define a vector which schematically represents the flow of Grande Ronde Formation ground water from the northeast to the repository.

Scalar "COSRSW" " Angle From Repository To Grande Ronde SW
Entered by "Jon Lindberg & Alan Baldwin" on 16-JAN-81 equals 0.99930000
For use in submodel Hydrology
Depends on Repository Design
Error checking bounds are : 0.0000000 1.0000000
Unit = cosine
Source =PNL
The cosine of a vertical angle between the horizontal and an imaginary straight line extending from the repository to a point in the Grande Ronde Formation at the southwest edge of the Pasco Basin. The point is located midway between the top and bottom of the formation and lies on the MCS. The angle helps define a vector which represents flow of ground water from the Grande Ronde Formation into the Pasco Basin from the southwest.

Scalar "CRPMFS" " Critical Distance To Glacier For Permafrost

Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 300,00000
 For use in submodel Hydrology
 Data From Expert Judgement
 Error checking bounds are : 0,0000000 500,0000
 Unit = kilometers
 Source =PNL
 Distance (km) from site (to north only) to continental
 glacier when permafrost conditions begin to affect ground-
 water flow in the northeast recharge area.

Scalar "CUNERC " Current Starting Northeast Recharge
 Entered by "Alan James Baldwin " on 16-MAY-81 equals 6,4000001
 For use in submodel Sub-Basalt Faulting
 Judgement and Data
 Error checking bounds are : 0,0000000 50,00000
 Unit = centimeters / year
 Source =PNL == Gregg Miles Petrie
 Current starting recharge in the Northeast Recharge area
 (cm/year) for calculating the breach criteria.
 Notes: Gregg Petrie states that this data value is actually
 the amount of precipitation that goes into the ground at
 this time.

Scalar "CUSWRC " Current Starting Southwest Recharge
 Entered by "Alan James Baldwin " on 16-MAY-81 equals 2,4000001
 For use in submodel Sub-Basalt Faulting
 Judgement and Data
 Error checking bounds are : 0,0000000 50,00000
 Unit = centimeters / year
 Source =PNL == Gregg Miles Petrie & Alan Baldwin
 Current starting recharge in the Southwest Recharge area
 (cm/year) for calculating the breach criteria.
 Notes: Gregg Petrie states that this data value is actually
 the amount of precipitation that goes into the ground at
 this time.

Scalar "DBASE " Basement To Grande Ronde Fm Thickness
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 1494,0000
 For use in submodel Fault Creation
 Data From The Literature
 Error checking bounds are : 1000,000 2000,000
 Unit = meters
 Source =PNL
 Vertical distance (m) from the base of the Grande Ronde
 Formation to basement rock.

Scalar "DCORBS " Fault Width Depth Correction For Pasco Basin
 Entered by "Alan James Baldwin " on 15-MAY-81 equals 1,0000000
 For use in submodel Hydrology
 Inactive = For Future Use
 Error checking bounds are : 1,000000 3,000000
 Unit = unitless
 Source =PNL
 Assuming that tectonic stress is largely released on already
 existing faults, then faults in the older Grande Ronde
 Formation have greater displacements and wider fault zones
 than faults in the younger Wanapum and Saddle Mountain
 Formations. The scalar variable DCORBS is a multiplication
 factor to correct (or widen) the older faults of the Grande
 Ronde Formation in the Pasco Basin as compared to the faults
 in the younger Wanapum and Saddle Mountain Formations.
 Notes: By setting the value to 1, we have the 'worst case'
 because current data suggest that faulting decreases the
 hydraulic conductivity (personal communication with Dr.
 James Crosby).

Scalar "DCORNE " Fault Width Depth Correction For The NE
 Entered by "Alan James Baldwin " on 15-MAY-81 equals 1.0000000
 For use in submodel Hydrology
 Inactive = For Future Use
 Error checking bounds are : 1.000000 3.000000
 Unit = unitless
 Source =PNL

Assuming that tectonic stress is largely released on already existing faults, then faults in the older Grande Ronde Formation have greater displacements and wider fault zones than faults in the younger Wanapum and Saddle Mountain Formations. The scalar variable DCORNE is a multiplication factor to correct (or widen) the older faults in the Grande Ronde Formation northeast of the Pasco Basin as compared to the faults in the younger Wanapum Formation.

Notes by setting the value to 1, we have the 'worst case' because current data suggest that faulting decreases the hydraulic conductivity (personal communication with Dr. James Crosby).

Scalar "DCORSW " Fault Width Depth Correction For the SW
 Entered by "Alan James Baldwin " on 15-MAY-81 equals 1.0000000
 For use in submodel Hydrology
 Inactive = For Future Use
 Error checking bounds are : 1.000000 3.000000
 Unit = unitless
 Source =PNL

Assuming that tectonic stress is largely released on already existing faults, then faults in the older Grande Ronde Formation have greater displacements and wider fault zones than faults in the younger Wanapum and Saddle Mountain Formations. The scalar DCORSW is a multiplication factor to correct (or widen) the older faults in the Grande Ronde Formation southwest of the Pasco Basin as compared to the faults in the younger Wanapum and Saddle Mt Formations.

Notes By setting the value to 1, we have the 'worst case' because current data suggests that faulting decreases the hydraulic conductivity (personal communication with Dr. James Crosby).

Scalar "DEADZ " Minimum Sea Depth For Sediment Deposition
 Entered by "Alan James Baldwin " on 15-MAY-81 equals 5.0000000
 For use in submodel Sea Level Fluctuations
 Judgement and Data
 Error checking bounds are : 2.000000 6.000000
 Unit = meters

Source =PNL == Gregg Miles Petrie & Mike Foley
 Minimum depth (m) of the sea over the repository site before deposition of sediment by the sea can occur in the Pasco Basin.

Notes This value is the value for the tidal range of the West coast.

Scalar "DEPPAS " Vertical Distance Of Repository To Basement
 Entered by "J.W.L. & Alan James Baldwin " on 16-JAN-81 equals 2134.0000
 For use in submodel Fault Creation
 Depends on Repository Design

Error checking bounds are : 1500,000 2500,000
 Unit = meters
 Source =PNL
 Vertical distance (m) from the base of the repository to the top of basement rock.

Scalar "DEPHIN " Sub-Basalt Minimum Depth For H₂O Change
 Entered by "Alan James Baldwin" on 29-APR-81 equals 950,00000
 For use in submodel Sub-Basalt Faulting
 Data From Expert Judgement
 Error checking bounds are : 0,0000000 1000,000
 Unit = meters
 Source =Lawrence H. Wight
 The lowest depth(m) at which an earthquake will change the hydraulic conductivity. Below this depth, Lithostatic pressure eliminates any changes to hydraulic conductivity.

Scalar "DEPTNE " Half Wan-Sad Thickness at NE Basin Edge
 Entered by "Jon Lindberg & James Baldwin" on 16-JAN-81 equals 426,00000
 For use in submodel Undetected Features
 Depends on Repository Design
 Error checking bounds are : 200,0000 600,0000
 Unit = meters
 Source =PNL
 Half the thickness (m) of the basalt and intercalculated sediments of the Wanapum and Saddle Mountain Formations at the northeast edge of the Pasco Basin. This point represents the entrance of Wanapum-Saddle Mountains ground water into the Pasco Basin.

Scalar "DEPTSW " Half Wan-Sad Thickness at SW Basin Edge
 Entered by "Jon Lindberg & James Baldwin" on 16-JAN-81 equals 518,00000
 For use in submodel Undetected Features
 Depends on Repository Design
 Error checking bounds are : 300,0000 700,0000
 Unit = meters
 Source =PNL
 Half the thickness (m) of the basalt and intercalculated sediments of the Wanapum and Saddle Mountain Formations at the southwest edge of the Pasco Basin. This point represents the entrance of Wanapum-Saddle Mountains ground water into the Pasco Basin.

Scalar "DSMTMX " Max. Radius From Site For Meteorite Impact
 Entered by "Jon Lindberg & James Baldwin" on 16-JAN-81 equals 50,000000
 For use in submodel Meteorite Impact
 Data From Expert Judgement
 Error checking bounds are : 25,00000 75,00000
 Unit = kilometers
 Source =PNL
 Maximum radius (km) from site that would be considered for meteorite impact. Meteorite impacts at radii greater than DSMTMX supposedly would be of minor concern for this model.

Scalar "EDGE NE " Distance From Site To Basin Edge NE
 Entered by "Jon Lindberg & James Baldwin" on 16-JAN-81 equals 36,000000
 For use in submodel Undetected Features
 For use in submodel Hydrology
 Depends on Repository Design
 Error checking bounds are : 30,00000 40,00000
 Unit = kilometers
 Source =PNL
 The distance (km) from the repository site to the edge of the Pasco Basin along the MCS.

Scalar "EDGESW " Distance From Site To Basin Edge SW
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals -11,900000
 For use in submodel Undetected Features
 For use in submodel Hydrology
 Depends on Repository Design
 Error checking bounds are : -15,00000 -5,000000
 Unit = kilometers
 Source =PNL
 The distance (km) from the repository site to the edge of
 the Pasco Basin along the MSC

Scalar "EGAB " Elevation Of Geble Mountain
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 331,00000
 For use in submodel Deformation
 Data From The Literature
 Error checking bounds are : 300,0000 360,0000
 Unit = meters
 Source =PNL
 Average elevation (m) of the top of the Geble Mountain
 structure.

Scalar "ERATTL " Elevation of Rattlesnake Mountain
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 869,00000
 For use in submodel Deformation
 Data From The Literature
 Error checking bounds are : 600,0000 1100,000
 Unit = meters
 Source =PNL
 Elevation (m) of the Rattlesnake Mountain structure at the
 intersection of the MCS

Scalar "ESENT " Elevation Of Sentinel Gap At Old River Level
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 144,00000
 For use in submodel Deformation
 Data From The Literature
 Error checking bounds are : 110,0000 170,0000
 Unit = meters
 Source =PNL
 Elevation (m) of Sentinel Gap at river bottom.

Scalar "EWALL " Elevation Wallula Gap At Old River Level
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 85,000000
 For use in submodel Deformation
 Data From The Literature
 Error checking bounds are : 65,00000 105,0000
 Unit = meters
 Source =PNL
 Elevation (m) of Wallula Gap at river bottom.

Scalar "EFOLDE " Erosion Factor For Folds Caused By Miss. Flo
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 10,000000
 For use in submodel Geomorphic Events
 Data From Expert Judgement
 Error checking bounds are : 1,000000 100,0000
 Unit = unitless
 Source =PNL
 Factor to increase erosion on fold during Missoula-type
 flood. 'Increase' is over what is expected for non-fold
 areas.

Scalar "EXTRNE " Distance From Site To NE Recharge Point
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals -76.190002
 For use in submodel Continental Glaciation
 Data From Expert Judgement
 Error checking bounds are : -100.0000 -50.00000
 Unit = kilometers
 Source =PNL
 A multiplication factor to increase erosion on folds (as compared to non-fold areas) during a Missoula-type flood,

Scalar "EXTRSW " Distance North Of Site to SW Recharge Point
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 9.4799995
 For use in submodel Continental Glaciation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 20.00000
 Unit = kilometers
 Source =PNL
 Distance (km) from site to a point along the MCS that is a central location of the southwest recharge area. This point is considered the average point of the SW area recharge

Scalar "FMAXD " Max. Distance From Site For Sub-basalt Fault
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 60.000000
 For use in submodel Undetected Features
 For use in submodel Fault Creation
 Data From Expert Judgement
 Error checking bounds are : 20.00000 100.0000
 Unit = kilometers
 Source =PNL ==
 Distance (km) from site along the MCS to a point that is a central location of the southwest recharge area. This point is considered the average point of southwest area recharge.

Scalar "FOLDMX " Max. Distance From Site For New Fold
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 75.000000
 For use in submodel Fold Creation
 Data From Expert Judgement
 Error checking bounds are : 50.00000 100.0000
 Unit = kilometer
 Source =PNL
 Maximum distance (km) from site for consideration of new fold growth. New fold growth beyond FOLDMX would have a negligible effect on the site.

Scalar "FRAC(1) " Ratio Shaft Area to Repository Area
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.26000000E=04
 For use in submodel Shaft Seal
 Depends on Repository Design
 Error checking bounds are : 1.0000000E=10 0.1000000
 Unit = unitless
 Source =PNL
 Ratio of the shaft area to the total repository area,
 (Note: This value depends on the design of the repository, and allows the user to 'redesign the repository'.)

Scalar "FREFNE " Time Reset Fraction For NE Fault System
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.10000000
 For use in submodel Undetected Features
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.000000
 Unit = unitless
 Source =PNL
 Time between basalt earthquakes northeast of the Pasco Basin is set by density curve 91. FREFNE is a fraction of the time between earthquakes. When a major sub-basalt basement earthquake occurs between basalt earthquakes and before FREFNE time has passed the next basalt earthquake occurs as normally scheduled by curve 91. However, when a major sub-basalt earthquake occurs after FREFNE time has passed since the last basalt earthquake, a basalt earthquake will occur simultaneously. The scheduling of the next basalt earthquake will then be determined by density curve 91, with the timing reset by the simultaneous earthquakes.

Scalar "FREFSW " Time Reset Fraction For SW Fault System
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.10000000
 For use in submodel Undetected Features
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.000000
 Unit = unitless
 Source =PNL
 Time between basalt earthquakes southwest of the Pasco Basin is set by density curve 90. FREFSW is a fraction of the time between basalt earthquakes. When a major sub-basalt basement earthquake occurs between basalt earthquakes and before FREFSW time has passed, the next basalt earthquake occurs as normally scheduled by curve 90. However, when a major sub-basalt basement earthquake occurs after FREFSW time has passed since the last basalt earthquake, a basalt earthquake will occur simultaneously. The scheduling of the next basalt earthquake will then be determined by density curve 90, with the timing reset by the simultaneous earthquake.

Scalar "FRESFT " Time Reset Fraction For Local Faults
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.10000000
 For use in submodel Undetected Features
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.000000
 Unit = unitless
 Source =PNL
 Time between local earthquakes in the Pasco Basin is set by density curve 85. FRESFT is a fraction of the time between local earthquakes. When a major sub-basalt basement earthquake occurs between local earthquakes and before FRESFT time has passed, the next local earthquake occurs as normally scheduled by density curve 85. However, when a major sub-basalt basement earthquake occurs after FRESFT time has passed since the last local earthquake, a local earthquake will occur simultaneously. The scheduling of the next local earthquake will then be determined by density curve 85, with the timing reset by the simultaneous earthquakes.

Scalar "FRESTR " Time Reset Fraction For Thrust Faults
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.10000000
 For use in submodel Undetected Features
 For use in submodel Deformation

Data From Expert Judgement

Error checking bounds are : 0.0000000 1.0000000

Unit = unitless

Source =PNL

Time between thrust-fault earthquakes in the Pasco Basin is determined by density curve 87. FRESTR is a fraction of the time between thrust-fault earthquakes. When a major sub-basalt earthquake occurs between thrust-fault earthquakes and before FRESTR time has passed, the next thrust-fault earthquake occurs as normally scheduled by density curve 87. However, when a major sub-basalt basement earthquake occurs after FRESTR time has passed since the last thrust-fault earthquake, a thrust-fault earthquake will occur simultaneously. The scheduling of the next thrust-fault earthquake will then be determined by density curve 87 with the timing reset by the simultaneous earthquakes.

Scalar "FTHCSS " H₂O Change Factor When Local Fault Is New
 Entered by "Alan James Baldwin " on 15-MAY-81 equals 1.0000000
 For use in submodel Deformation

Inactive - For Future Use

Error checking bounds are : 0.0000000 100.0000

Unit = unitless

Source =PNL -- Gregg Petrie & Alan Baldwin

Multiplication factor to correct hydraulic conductivity change when local fault is new, rather than a reactivation of an existing local fault.

Note: We will update this value when we get new information

Scalar "GLATNE " Upper Latitude of NE Recharge Area
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 47.849998
 For use in submodel Hydrology

Unpublished Data

Error checking bounds are : 47.00000 49.00000

Unit = Degrees of latitude

Source =James W. Crosby

Upper latitude (degrees) of northeast recharge area of the basalt aquifers. See Appendix A.1, Figure 1 for NE recharge area definition

Scalar "GLTNEL " Lower Latitude of NE Recharge Area
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 46.230000
 For use in submodel Hydrology

Unpublished Data

Error checking bounds are : 45.00000 48.00000

Unit = Degrees Of Latitude

Source =James W. Crosby

Lower latitude (degrees) of northeast recharge area of basalt aquifers. See Appendix A.1, Figure 1, for northeast recharge area.

Scalar "GRLNNE " Site To NE Recharge Area Distance In G Ronde
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 85.000000
 For use in submodel Hydrology

Depends on Repository Design

Error checking bounds are : 70.00000 100.0000

Unit = kilometers

Source =James W. Crosby and PNL

Distance (km) along MCS from the repository site to a central location of the northeast recharge area in the Grande Ronde Formation.

Scalar "GRSKLN " Site To SW Recharge Area Distance In G Ronde
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 16,070000
 For use in submodel Hydrology
 Depends on Repository Design
 Error checking bounds are : 10,00000 20,00000
 Unit = kilometers
 Source =James W. Crosby and PNL
 Distance (km) along MCS from the repository site to a
 central location of the southwest recharge area in the
 Grande Ronde Formation.

Scalar "HARDFC " Erosion Rate Fraction For Bedrock in M Flood
 Entered by "Alan James Baldwin " on 16-MAY-81 equals 1,0000000
 For use in submodel Geomorphic Events
 Data From Expert Judgement
 Error checking bounds are : 1,0000000E-03 2,000000
 Unit = unitless
 Source =Donald Easterbrook
 River erosion rates normally calculated in this model use
 the assumption that the river does not erode bedrock, but
 does erode sediments. When the river erodes, the scalar
 value of HARDFC converts the erosion rates to those for
 bedrock. Note that Dr. Easterbrook states :
 "Erosion rates in basalt can be estimated by comparison with
 incision in basalt at Moses Coulee, Grande Coulee and other
 channels cut in basalt. Erosion rates in basalt during
 Missoula floods were very high, largely because much of the
 basalt is highly jointed and basalt columns are therefore
 easily plucked. Erosion rates for Moses and Grande Coulees
 are so high (424m in a few days) that I recommend using a
 multiplication factor of 1,0 (no difference...)."

Scalar "HONEGR " Ave. Head Elevation For NE Grande Ronde F
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 457,00000
 For use in submodel Continental Glaciation
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 300,0000 600,0000
 Unit = meters
 Source =James W. Crosby and PNL
 Average head value (m) of Grande Ronde Formation aquifer in
 the northeast recharge area.

Scalar "HONEWS " Avg. Head Elevation For NE Wan-Sad F
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 518,00000
 For use in submodel Continental Glaciation
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 400,0000 600,0000
 Unit = meters
 Source =James W. Crosby and PNL
 Average head value (m) of the Wanapum Formation and Saddle
 Mountain Formations aquifer in the northeast recharge area.

Scalar "HDSHGR " Avg. Head Elevation For SW Grande Ronde F
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 213,00000
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 100,0000 300,0000
 Unit = meters
 Source =James W. Crosby and PNL
 Average head value (m) of the Grande Ronde Formation aquifer
 in the southwest recharge area.

Scalar "HDSWHS " Avg. Head Elevation For SW Wan-Sad F
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 274,00000
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 200,0000 400,0000
 Unit = meters
 Source = James W. Crosby and PNL
 Average head value (m) of the Wanapum and Saddle Mountain
 Formations aquifer in the southwest recharge area.

Scalar "HEADBS " Avg. Head Elev. For Basin Unconfined Aquifer
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 115,00000
 For use in submodel Deformation
 For use in submodel Continental Glaciation
 For use in submodel Deformation
 Judgement and Data
 Error checking bounds are : 50,00000 150,0000
 Unit = meters
 Source = PNL
 Average elevation (m) of the discharge site for the
 unconfined aquifer in the Pasco Basin. The Columbia River
 is the discharge site of the unconfined aquifer in the Pasco
 Basin.

Scalar "HIPATH " Maximum Unconfined Aquifer Path Length
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 39,000000
 For use in submodel Geomorphic Events
 Judgement and Data
 Error checking bounds are : 10,00000 70,00000
 Unit = kilometer
 Source = PNL
 Maximum distance (km) that ground water would flow in the
 unconfined aquifer is recharged with ground water from the
 confined aquifer that contains the hypothetical repository.

Scalar "HMNEGR " Maximum Head of NE Grande Ronde
 Entered by "Alan James Baldwin " on 12-MAY-81 equals 900,00000
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 0,0000000 1000,000
 Unit = meters
 Source = PNL -- Charles Cole
 Maximum hydraulic head (meters) for the Northeast Grande
 Ronde subsystem.
 (Note: currently, the best estimate of HMNEGR
 seems to be the average elevation difference between the
 Columbia River and the recharge area.)

Scalar "HMNEWS " Maximum Head of NE Wannapum Saddle Mtn.
 Entered by "Alan James Baldwin " on 12-MAY-81 equals 900,00000
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 0,0000000 1000,000
 Unit = meters
 Source = PNL -- Charles Cole
 Maximum hydraulic head (meters) for the northeast Wannapum-
 Saddle Mountain Subsystem.
 (Note: Currently, the best estimate of HMNEWS
 seems to be the average elevation difference between the
 Columbia River and the recharge area.)

Scalar "HMSWGR " Maximun Head of SW Grande Ronde
 Entered by "Alan James Baldwin " on 12-MAY-81 equals 665,00000
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 0,0000000 800,0000
 Unit = meters
 Source #PNL -- Charles Cole
 Maximum hydraulic head (meters) for the Southwest Grande
 Ronde Subsystem.
 (Notes: Currently, the best estimate of HMSWGR
 seems to be the average elevation difference between the
 Columbia River and the recharge area.)

Scalar "HMSWWS " Maximum Head of SW Wannepum Saddle Mtn,
 Entered by "Alan James Baldwin " on 12-MAY-81 equals 665,00000
 For use in submodel Hydrology
 Judgement and Data
 Error checking bounds are : 0,0000000 800,0000
 Unit = meters
 Source #PNL -- Charles Cole
 Maximum hydraulic head (meters) for the Southwest Wannepum
 Saddle Mountain Subsystem.
 (Notes: Currently, the best estimate of HMSWWS
 seems to be the average elevation difference between the
 Columbia River and the recharge area.)

Scalar "IRLAYR " Repository Layer Number
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 4,0000000
 For use in submodel Hydrology
 See Text For Explanation
 Error checking bounds are : 1,000000 4,000000
 Unit = unitless
 Source #PNL
 The model accounting number assigned to the layer of rock
 that contains the hypothetical repository.

Scalar "ITDP " Surface Layer Number at Run Start
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 1,0000000
 For use in submodel Undetected Features
 See Text For Explanation
 Error checking bounds are : 1,000000 4,000000
 Unit = unitless
 Source #PNL
 The model accounting number assigned to the present surface
 layer (the surface sediments).

Scalar "LAYRGR " Grande Ronde F Layer Number
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 4,0000000
 For use in submodel Deformation
 For use in submodel Hydrology
 See Text For Explanation
 Error checking bounds are : 1,000000 4,000000
 Unit = unitless
 Source #PNL
 The model accounting number assigned to the Grande Ronde
 Formation.

Scalar "PFLATF" " Prob. of Fold Growth With Faulting
 Entered by "Jon Lindberg & Alan Baldwin" on 16-JAN-81 equals 0.50000000
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that a new fold will begin to uplift within the radius from the site determined by FOLDMX. The probability is with the potential influence of a major sub-basalt basement fault.

Scalar "PFOLD" " Prob. of Undetected Fold in Pasco Basin
 Entered by "Jon Lindberg & Alan Baldwin" on 16-JAN-81 equals 0.52999999E-04
 For use in submodel Undetected Features
 Data From Expert Judgement
 Error checking bounds are : 9.9999999E-09 9.9999997E-05
 Unit = unitless
 Source =Robert D. Bentley
 Probability that a fold will go undetected within the Pasco Basin.

Scalar "PFTNEW" " Prob. For New Sub-basalt Fault
 Entered by "Alan James Baldwin" on 12-MAY-81 equals 1.00000000
 For use in submodel Sub-Basalt Faulting
 Data From Expert Judgement
 Error checking bounds are : 0.00000000 1.0000000
 Unit = unitless
 Source =Lawrence H. Wight
 Probability in a 100-year period that a new sub-basalt basement fault will be created within a radius of the site determined by scalar variable FMAXD.

Scalar "PGLCH" " Prob. of Recharge When Glaciers Cover the NE
 Entered by "Alan James Baldwin" on 15-MAY-81 equals 0.00000000
 For use in submodel Hydrology
 Inactive - For Future Use
 Error checking bounds are : 0.00000000 1.0000000
 Unit = unitless
 Source =PNL == Gregg Petrie & Alan Baldwin
 Probability that continental glacier will recharge basalt aquifers in the northeast recharge area when the northeast recharge area is covered by a continental glacier.
 Note : These effects will be added after the main Monte Carlo runs

Scalar "PMAGST" " Prob. of Mag. Ev. on Site when One in Basin
 Entered by "Alan James Baldwin" on 16-APR-81 equals 0.24000001E+02
 For use in submodel Magmatic Events
 Unpublished Data
 Error checking bounds are : 0.00000000 1.0000000
 Unit = unitless
 Source =PNL --- Kurt Schmieder
 Probability that a magmatic event will occur at the repository site when the probability of occurrence in the Pasco-Basin is 1.0. The radius of the site is determined by the scalar variable SITRAD. To generate this probability, the area of the repository was divided by the area of the Pasco Basin.

Radius of repository site	= 2 km
Area of repository site	= (3.1415926535) * r ²
	= 12.57 km ²
Area (repository)	12.57 km ²
-----	= 0.0024
Area (Pasco Basin)	5260 km ²

Scalar "LAYRHS " Manapum-Saddle F Layer Number
 Entered by "Gregg Petre " on 17-MAY-81 equals 2,0000000
 For use in submodel Deformation
 For use in submodel Hydrology
 See Text For Explanation
 Error checking bounds are : 1,000000 4,000000
 Unit = unitless
 Source =PNL
 The model accounting number assigned to the Manapum and
 Saddle Mountain Formations layer.

Scalar "NLAVER " Number of Layers in the Model
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 4,0000000
 For use in submodel Undetected Features
 For use in submodel Hydrology
 See Text For Explanation
 Error checking bounds are : 1,000000 10,00000
 Unit = unitless
 Source =PNL
 The total number of model layers at the start of the run.

Scalar "PASHFL " Prob. of Large Ashfall Changing Climate
 Entered by "Alan James Baldwin " on 15-MAY-81 equals 0,50000001E=01
 For use in submodel Climate
 Judgement and Date
 Error checking bounds are : 9,9999997E=06 1,000000
 Unit = unitless
 Source =Stottlemire et. al. (1981)
 Probability in a 100-year period that a volcano will produce
 a large ashfall that changes the climate significantly.
 Note : This value comes out of Stottlemire (1981)

Scalar "PCASUP " Prob. of Cascade Mountains Uplift
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0,19999999E=03
 For use in submodel Climate
 Judgement and Date
 Error checking bounds are : 9,9999997E=05 9,9999998E=03
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that the Cascade Range will
 be significantly uplifted and the climate of the Columbia
 Plateau will be affected significantly.

Scalar "PFAULT " Prob of Sub-basalt Fault Exists at Run Start
 Entered by "Alan James Baldwin " on 12-MAY-81 equals 1,0000000
 For use in submodel Undetected Features
 Data From Expert Judgement
 Error checking bounds are : 0,0000000 1,000000
 Unit = unitless
 Source =Lawrence H. Wright
 Probability that a significant sub-basalt basement fault
 exists (within radius of the site determined by scalar
 variable FMAXD).

Scalar "PFLAT " Prob. of Fold Growth Without Faulting
 Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0,39999999E=04
 For use in submodel Deformation
 Judgement and Date
 Error checking bounds are : 0,0000000 1,000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability that a significant sub-basalt basement fault
 exists (within the radius of the site determined by scalar
 variable FMAXD).

Scalar "PMETRT " Prob. of Meteorite Impacting Site
Entered by "Alan James Baldwin " on 24-APR-81 equals 0.39609999E+09
For use in submodel Meteorite Impact

Unpublished Data

Error checking bounds are : 0.0000000 1.0000000

Unit = unitless

Source =William K. Hartman

Probability in a 100-year period that a meteorite of significant size will impact the repository site. Significant meteorite size is determined by scalar RADCRT, and site radius is determined by scalar variable SITRAD.

This value was calculated from the formula :

$$Nd = (\text{Formation rate for craters of diameter } > \text{RADCRT}) \\ = 1.82 * (10^{**13}) * (\text{RADCRT}^{*-1.8})$$

Hartmann, W. K., 1979. "Long-term Meteorite Hazards to Buried Nuclear Waste". In 'A Summary of FY 1978 Consultant Input For Scenario Methodology Development', pp. VI-1 - VI-15, PNL-2857, Pacific Northwest Laboratories, Richland, Washington.

Scalar "PMISFT " Prob. of Undetected Fault in Repository Host
Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.99999998E+02
For use in submodel Undetected Features

Data From Expert Judgement

Error checking bounds are : 0.0000000 1.0000000

Unit = unitless

Source =PNL

Probability that the repository host rock will contain an undetected fault. The repository host rock is the Grande Ronde Formation in the immediate vicinity of a hypothetical repository.

Scalar "PNEEXF " Prob of Renewed NE Faulting With Major Fault
Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.50000000
For use in submodel Deformation

Data From Expert Judgement

Error checking bounds are : 0.0000000 1.0000000

Unit = unitless

Source =Robert D. Bentley

Probability in a 100-year period that a fault northeast of the Pasco Basin will be reactivated. The probability is within the potential influence of a major sub-basalt basement fault. The area northeast of the Pasco Basin that is of concern is the area between the Pasco Basin edge and the edge of the Columbia Plateau.

Scalar "PNWFD " Prob. of New Fold Growth Without Faulting
Entered by "Jon Lindberg & Alan Baldwin " on 16-JAN-81 equals 0.10000000E+05
For use in submodel Deformation

Data From Expert Judgement

Error checking bounds are : 0.0000000 1.0000000

Unit = unitless

Source =Robert D. Bentley

Probability in a 100-year period of a new fold growth (within a radius of the site determined by scalar variable FOLDNX) when a major sub-basalt earthquake has not occurred during the same time step.

Scalar "PNWFDF" Prob. of New Fold Growth With Faulting
 Entered by "Jon Lindberg & Alan Baldwin" on 16-JAN-81 equals 0.40000000E+05
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period of new fold growth (within
 a radius of the site determined by FOLDMX) when a major
 sub-basalt earthquake has occurred during the same time
 step.

Scalar "PNWFI" Prob. of New Fault Without Major Faulting
 Entered by "Jon Lindberg & Alan Baldwin" on 16-JAN-81 equals 0.10000000E+05
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that a new fault will be
 created in the Pasco Basin. The probability is without the
 potential influence of a major sub-basalt basement fault in
 the Pasco Basin.

Scalar "PNWFTF" Prob. of New Basalt Fault With Major Faulting
 Entered by "Jon Lindberg & Alan Baldwin" on 16-JAN-81 equals 0.40000000E+05
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that a new basalt fault
 will be created in the Pasco basin. The probability is with
 the potential influence of a major sub-basalt earthquake.

Scalar "PNWTR" Prob. of New Thrust Without Major Faulting
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.10000000E+05
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that a new thrust fault
 will intersect the repository when a major sub-basalt
 earthquake does not occur during the same time step.

Scalar "PNWTRF" Prob. of New Thrust With Major Faulting
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.40000000E+05
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that a new thrust fault
 will intersect the repository when a major sub-basalt fault
 occurs during the same time step.

Scalar "PRKUP" " Prob. of E Uplift Affecting Climate /100 Yrs
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.30000001E=03
 For use in submodel Climate
 Judgement and Data
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source #Robert D. Bentley
 Probability in a 100-year period that mountains to the east
 (Rocky Mountains or Blue Mountains) will be uplifted enough
 to significantly change the climate (precipitation rate) in
 the Pasco Basin.

Scalar "PRVMAG" " Prob. of Mag. Event Affecting River Gradient
 Entered by "Alan James Baldwin" on 16-APR-81 equals 0.31200001
 For use in submodel Magmatic Events
 Unpublished Data
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source #PNL --- Kurt Schmieder
 Probability that a magmatic event (such as a volcano) will
 change the gradient of the Columbia River or divert the flow
 in the Pasco Basin. (Given: the probability of a magmatic
 event in the Pasco Basin is 1.0)
 To generate this probability, the length of the Columbia
 River channel through the Pasco Basin was measured and
 multiplied by twice the average maximum length of lava flows
 from volcanic centers (5 km) as they occur over the CRB
 expanse. This gave an average flow incursion area for
 volcanic centers which would disrupt the flow of the river
 in the Pasco Basin. Dividing this area by the total area of
 the Pasco Basin yields the PRVMAG probability.
 Area flow incursion on Columbia river = 1640 km²
 Area of Pasco Basin = 5260 km²

Scalar "PSEAEX" " Prob. of Sea Level Rise in Climate 1
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.15000000E=04
 For use in submodel Sea Level Fluctuations
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source #Marice L. Schwartz
 Probability in a 100-year period during an interglacial
 climate that the sea level will be raised above the present
 sea level.

Scalar "PSSEXF" " Prob. of Renewed Local Faulting With SB Fault
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.75000000
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source #Robert D. Bentley
 Probability in a 100-year period that a local fault in the
 Pasco Basin will be reactivated when a sub-basalt basement
 earthquake occurs during the same time step.

Scalar "PSSFTR" " Prob. of Local Fault System in Pasco Basin
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.75000000
 For use in submodel Undetected Features
 Judgement and Data
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source #Robert D. Bentley
 Probability that a local fault system exists in the Pasco
 Basin.

Scalar "PSWEXF" Prob of Renewed SW Faulting With Major Fault
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.25000000
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that a fault in the southwest fault system will be reactivated when a major sub-basalt basement earthquake occurs during the same time step.

Scalar "PTREXF" Prob. of Renewed Thrusting With Major Fault
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.75000000
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =Robert D. Bentley
 Probability in a 100-year period that a thrust fault in the Pasco Basin will be reactivated when a major sub-basalt basement earthquake occurs during the same time step.

Scalar "PUNTHS" Prob. of Undetected Thrust in Repos. Host
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.99999998E-02
 For use in submodel Undetected Features
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 1.0000000
 Unit = unitless
 Source =PNL
 Probability that a thrust fault will go undetected in the repository host rock.

Scalar "QDAM" Min. Flow For Hydraulic Dam at Wallula Gap
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 2200000.0
 For use in submodel Geomorphic Events
 Data From The Literature
 Error checking bounds are : 10000.00 1.0000000E+08
 Unit = meters**3 / second
 Source =Donald Easterbrook
 Minimum discharge (m**3/sec) of a major flood(Missoula-type) in the Pasco Basin that would cause sufficient hydraulic damming at Wallula Gap to pond water to the elevation of the ground surface at the repository site.

Scalar "RADCRT" Sphere Radius Separates Big & Little Craters
 Entered by "Jon Lindberg & Alan Baldwin" on 19-JAN-81 equals 0.50000000
 For use in submodel Meteorite Impact
 Data From Expert Judgement
 Error checking bounds are : 5.0000001E-02 1.0000000
 Unit = kilometers
 Source =PNL
 Radius (km) of an imaginary sphere with its center at the hypothetical repository. The model will account for the potential effects of meteorite craters that intersect the sphere with radius RADCRT. The effects of meteorite craters that do not intersect the imaginary sphere with radius RADCRT will be interpreted following the model run.

Scalar "RCARNE " Starting Area of the NE Recharge Area
 Entered by "Alan James Baldwin " on 20-APR-81 equals 39390,000
 For use in submodel Hydrology
 Data From Expert Judgement
 Error checking bounds are : 1000,000 100000,0
 Unit = kilometer**2
 Source = James W. Crosby
 Total area (km**2) of the northeast recharge area at the
 start of the run.

Scalar "RCARSW " Starting Area of SW Recharge Area
 Entered by "Alan James Baldwin " on 12-MAY-81 equals 62,000000
 For use in submodel Hydrology
 Data From Expert Judgement
 Error checking bounds are : 50,00000 100,0000
 Unit = kilometer**2
 Source = James W. Crosby
 Total area (km**2) of the southwest recharge area at the
 start of the run.

Scalar "RDEPTH " Depth To The Repository From Ground Surface
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 1067,0000
 For use in submodel Hydrology
 Data From The Literature
 Error checking bounds are : 750,0000 1250,000
 Unit = meters
 Source = PNL
 Depth (m) from the present ground surface to the
 hypothetical repository.

Scalar "RESCON " Response Constant for Climate Change
 Entered by "Alan James Baldwin " on 14-MAY-81 equals 69,720001
 For use in submodel Climate
 For use in submodel Continental Glaciation
 Judgement and Data
 Error checking bounds are : 0,0000000 1000,000
 Unit = Unitless
 Source = PNL == Gregg Petrie and Mike Foley
 Response time constant for glacial advance from climate
 changes.
 Note: This data value comes from an empirical fit of known
 glacial positions to calibrated model results.

Scalar "RESPN1 " Distance Response Constant For Glacier Adv.
 Entered by "Alan James Baldwin " on 05-MAY-81 equals 0,15779999E+03
 For use in submodel Continental Glaciation
 Judgement and Data
 Error checking bounds are : 0,0000000 1000,000
 Unit = 1,0 / Kilometers
 Source = PNL == Gregg Petrie and Mike Foley
 Distance response constant from fitting the Continental
 Glacial positions.
 Note: This data value is from an empirical fit of known
 Glacial positions.
 Note: This data value is from an empirical fit of known
 glacial positions

Scalar "RESPN2 " Time Response Constant For Glacier Advance
 Entered by "Alan James Baldwin " on 01-MAY-81 equals 0.16480000E+03
 For use in submodel Continental Glaciation
 Judgement and Data
 Error checking bounds are : 0.0000000 1000.000
 Unit = 1.0 / Years
 Source =PNL --- Gregg Petrie and Mike Foley
 Time response constant from fitting the Continental Glacial
 positions.
 Notes: This data value is from an empirical fit of known
 glacial positions to calibrated model.

Scalar "RIVCAP " Max. Radius From Site For River Capture
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 5.0000000
 For use in submodel Geomorphic Events
 Data From Expert Judgement
 Error checking bounds are : 2.000000 8.000000
 Unit = kilometers
 Source =PNL
 Maximum radius (km) from repository site for river capture
 by an uplifting basalt fold. When an uplifting basalt fold
 intersects the river and the intersection is within the radius
 RIVCAP of the site, the river becomes entrenched in the fold
 for the remainder of the run. When the intersection is
 outside the radius RIVCAP, the river does not become
 entrenched over the repository site and therefore remains
 free to meander over the repository site.

Scalar "RKMNE " Distance N of Site For All NE Area Covered
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals =30.000000
 For use in submodel Continental Glaciation
 Judgement and Data
 Error checking bounds are : =60.00000 60.00000
 Unit = kilometers
 Source =James W. Crosby and PNL
 The distance (km) north of the repository site to the
 latitude of the southernmost portion of the northeast
 recharge area. When the continental glacier reaches the
 latitude indicated by RKMNE, the northeast recharge area is
 considered to be completely covered.

Scalar "RLATHI " Upper Lat. of Glacier For Missoula Flooding
 Entered by "Gregg Petrie " on 17-MAY-81 equals 48.500000
 For use in submodel Geomorphic Events
 Judgement and Data
 Error checking bounds are : 48.00000 49.00000
 Unit = Degrees of Latitude
 Source =Donald Easterbrook
 The upper latitude (degrees) of the sensitive zone for
 potential Missoula-type flooding. The sensitive zone lies
 between two latitude lines and is the area where the glacier
 terminus may cause ice damming and subsequent catastrophic
 flooding.
 Because the model 'follows' the Okanogan lobe, which was
 'larger' than the glacier lobe at the Washington-Idaho
 boundary, the value given RLATHI was increased over the
 original value

Scalar "RLATLW " Lower Lat. of Glacier For Missoula Flooding
Entered by "Gregg Petrie " on 17-MAY-81 equals 47,000000

For use in submodel Geomorphic Events

Judgement and Data

Error checking bounds are : 47,00000 49,00000

Unit = Degrees of Latitude

Source =Donald Easterbrook

The lower latitude (degrees) of the sensitive zone for potential Missoula-type flooding. The sensitive zone lies between two latitude lines and is the area where the continental glacier terminus may cause ice damming and subsequent catastrophic flooding.

Because the model 'follows' the Okanogen lobe, which was 'larger' than the lobe at the Washington-Idaho boundary, the value given RLATLW was decreased from the first value used

Scalar "RNELF " Amount of NE Recharge Area Still Covered
Entered by "Gregg Petrie " on 18-MAY-81 equals 39390,000

For use in submodel Geomorphic Events

Judgement and Data

Error checking bounds are : 0,0000000 100000,0

Unit = kilometer**2

Source =PNL -- Gregg Petrie

Amount of recharge area still covered by soil that diverts water from the ground water system to the surface rivers.

Scalar "RNERED " Fraction of Reduction in NE Cover/Flood
Entered by "Gregg Petrie " on 18-MAY-81 equals 0,99999998E-02

For use in submodel Geomorphic Events

Judgement and Data

Error checking bounds are : 0,0000000 0,5000000

Unit = unitless

Source =PNL

Fractional reduction of that part of the NE recharge area still covered by soil during a 'Missoula' flooding event.

Scalar "RPGLNE " Average NE Glacier Recharge Point
Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 88,800003

For use in submodel Continental Glaciation

Data From Expert Judgement

Error checking bounds are : 50,00000 100,0000

Unit = kilometers

Source =James W. Crosby and PNL

The distance (km) north of the repository site to the latitude line that intersects the central point in the northeast recharge area. The central point in the northeast recharge area is considered to be a point somewhat central in location to the area recharged by total glacier coverage.

Scalar "RPOSHC " H.C. of Repository Host-Rock
Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 0,10000000E-06

For use in submodel Hydrology

Depends on Repository Design

Error checking bounds are : 9,9999997E-10 9,9999998E-03

Unit = meters / day

Source =James W. Crosby

The hydraulic conductivity (m/day) of the Grande Ronde Formation in the immediate vicinity of the hypothetical repository.

Scalar "RPOSTH " Repository Thickness
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 67,000000
 For use in submodel Undetected Features
 For use in submodel Deformation
 For use in submodel Hydrology
 Data From The Literature
 Error checking bounds are : 50,00000 100,0000
 Unit = meters
 Source =PNL
 The thickness (m) of the hypothetical repository.

Scalar "SEAMAX " Max. Elevation of Sea-Level Rise
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 100,00000
 For use in submodel Sea Level Fluctuations
 Data From Expert Judgement
 Error checking bounds are : 0,0000000 200,0000
 Unit = meters
 Source =Marice L. Schwartz
 Maximum elevation (m) of the sea during an interglacial climate.
 Schwartz, M. L., 1979, "Sea Level Report", In 'A Summary of FY-1978 Consultant Input For Scenario Methodology Development', pp. IX-1 - IX-8, PNL-2857, Pacific Northwest Laboratories, Richland, Washington.

Scalar "SELEV " Site Elevation at Ground Surface
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 220,00000
 For use in submodel Deformation
 Unpublished Data
 Error checking bounds are : 200,0000 240,0000
 Unit = meters
 Source =PNL
 The elevation (m) of the hypothetical repository site at the ground surface.

Scalar "SILAT " Site Latitude
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 46,500000
 For use in submodel Continental Glaciation
 Unpublished Data
 Error checking bounds are : 46,00000 47,00000
 Unit = Degrees of Latitude
 Source =PNL
 The latitude (degrees) of the hypothetical repository site.

Scalar "SITRAD " Radius of Site
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 2,0000000
 For use in submodel Undetected Features
 For use in submodel Deformation
 For use in submodel Geomorphic Events
 Depends on Repository Design
 Error checking bounds are : 1,000000 10,00000
 Unit = kilometers
 Source =PNL
 The radius (km) of the hypothetical repository site.

Scalar "SLOPHI " Highest Possible River Gradient
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 0,11200000E-02
 For use in submodel Geomorphic Events
 Unpublished Data
 Error checking bounds are : 0,0000000 1,000000
 Unit = meters / meter
 Source =Donald Easterbrook
 The highest possible river gradient (m/m) in the Pasco Basin

Scalar "SLOPLW " Lowest Possible River Gradient
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 0.30000001E-03
 For use in submodel Geomorphic Events
 Unpublished Data
 Error checking bounds are : 0.0000000 1.000000
 Unit = meters /meter
 Source #Donald Easterbrook
 The lowest possible river gradient (m/m) in the Pasco Basin,

Scalar "SOURCE " Latitude of Glacier's Source
 Entered by "Alan James Baldwin " on 12-MAY-81 equals 57.000000
 For use in submodel Sea Level Fluctuations
 For use in submodel Continental Glaciation
 Judgement and Data
 Error checking bounds are : 49.00000 65.00000
 Unit = Degrees of Latitude
 Source #PNL
 The latitude (degrees) of the source of continental glaciation between the Rocky Mountains and the Coast Range. The source is the point where the continental glacier begins to accrete (presumably, somewhere in Canada).
 (Note: This value is one of the parameters that can be set in the program to empirically fit the past positions of glacial edge advances to the climate model. Mike Foley fit this data to obtain the best normalized data for input to our model.)

Scalar "STFLT " First Fault West of Basin Approx. on MCS
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals -25.700001
 For use in submodel Undetected Features
 Data From The Literature
 Error checking bounds are : -50.00000 -2.000000
 Unit = kilometers
 Source #PNL
 The distance (km) to the nearest non-thrust fault west of the Pasco Basin along the MCS.

Scalar "SIGABT " Uplift Rate on Gable Mtn (For Check MC)
 Entered by "Alan James Baldwin " on 29-APR-81 equals 0.00000000
 For use in submodel Deformation
 Data From Expert Judgement
 Error checking bounds are : 0.0000000 0.1250000
 Unit = meters / year
 Source #Steve Malone
 The minimum uplift rate (m/yr) on Gable Mountain (and Utenum Ridge structure) that would allow for checking for a change in hydraulic conductivity.

Scalar "THABOV " Grande Ronde Thickness Above Repository
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 305.00000
 For use in submodel Hydrology
 Depends on Repository Design
 Error checking bounds are : 200.0000 400.0000
 Unit = meters
 Source #PNL
 The thickness (m) of the Grande Ronde formation above the hypothetical repository.

Scalar "TRSTRT " Conversion Factor For New Thrusting MC
 Entered by "Alan James Baldwin " on 15-MAY-81 equals 1.0000000
 For use in submodel Deformation
 Inactive = For Future Use

Error checking bounds are : 0.0000000 100.0000

Unit = unitless

Source =PNL

The multiplication factor that changes the value for the changes in hydraulic conductivity in a currently active thrust-fault zone to the changes in hydraulic conductivity in a newly created thrust-fault zone.

Note : We have not found any data that would justify a value other than 1.0 (A new fault is treated like an old fault.)

Scalar "VHRCOR " Horizontal to Vertical H.C. Ratio
 Entered by "Alan James Baldwin " on 01-JUN-81 equals 100.00000
 For use in submodel Hydrology

Judgement and Data

Error checking bounds are : 0.0000000 10000.00

Unit = unitless

Source =PNL

Correction for travel time because of decrease in hydraulic conductivity in the vertical direction.

(Note: These data were derived from C. Cole's(PNL) values for hydraulic conductivity in the horizontal and vertical directions.)

Scalar "WGLAT " Latitude of Wellula Gap
 Entered by "Alan James Baldwin " on 03-JUN-81 equals 46.029999
 For use in submodel Continental Glaciation

Data From The Literature

Error checking bounds are : 0.0000000 90.00000

Unit = degrees latitude

Source =PNL -- Gregg Petrie & Alan Baldwin

Latitude of Wellula Gap (degrees).

Scalar "WSNELN " Wanapum-Saddle Path Length For the NE
 Entered by "Alan James Baldwin " on 20-APR-81 equals 85.000000
 For use in submodel Hydrology

Data From Expert Judgement

Error checking bounds are : 70.00000 100.0000

Unit = kilometers

Source =James W. Crosby and PNL

The distance (km) of ground-water flow along the MCS in the Wanapum and Saddle Mountain Formations from the central point in the northeast recharge area to the repository site.

Scalar "WSSWLN " Wanapum-Saddle Path Length For The SW
 Entered by "Jon Lindberg & Alan Baldwin " on 19-JAN-81 equals 4.1799998
 For use in submodel Hydrology

Judgement and Data

Error checking bounds are : 1.000000 10.00000

Unit = kilometers

Source =James W. Crosby

The distance (km) of ground-water flow along the MCS in the Wanapum and Saddle Mountain Formations from the central location point in the southwest recharge area to the repository area to the repository site.

Scalar "XSTART" " X Coordinate of Discharge Arc Center
 Entered by "Alan James Baldwin" " on 20-FEB-81 equals -15,000000
 For use in submodel Undetected Features
 Judgement and Data
 Error checking bounds are : -30,00000 -1,000000
 Unit = kilometers
 Source =PNL
 The X coordinate of the center of the unconfined aquifer
 discharge arc (a schematic representation of the Columbia
 River in the Pasco Basin). The coordinate system has an
 ordinate at the repository site and the X-axis corresponds
 to the MCS. Positive Y is to the southeast
 Units of the coordinate system are kilometers.

Scalar "YSTART" " Y Coordinate of Discharge Arc Center
 Entered by "Alan James Baldwin" " on 20-FEB-81 equals -20,000000
 For use in submodel Undetected Features
 Judgement and Data
 Error checking bounds are : -100,0000 -1,000000
 Unit = kilometers
 Source =PNL
 The Y coordinate of the center of the unconfined aquifer
 discharge arc (a schematic representation of the Columbia
 River in the Pasco Basin). The coordinate system has an
 ordinate at the repository site and the X-axis corresponds
 to the MCS. Positive Y is to the southeast.
 Units of the coordinate system are kilometers.

Quality Distribution

Test Data	has	1 scalars
Data From The Literature	has	10 scalars
See Text For Explanation	has	5 scalars
Unpublished Data	has	11 scalars
Judgement and Data	has	39 scalars
Data From Expert Judgement	has	43 scalars
Depends on Repository Design	has	13 scalars
Inactive - For Future Use	has	9 scalars
* This Data has no class *	has	0 scalars

Total Scalars entered to date =131

NE Precip. Change Fraction For Cascade Mtns

Polynomial 1.

Submodel(s) :

Climate

Inactive - For Future Use

No Transform on X

No Transform on Y

-.25000050 to .25000050 values of Y

-1000.00201416 to 1000.00201416 values of X

1. Order Polynomial

Coefficients :

0. 0.0000000000

1. 0.0000000000

Units for X meters

Units for Y unitless

Source George Kukla

Calculates the change of precipitation rate (cm/yr) in the northeast recharge area from the change in elevation (m) of the Cascade Range.

SW Precip Change Fraction For Cascade Mtns
Polynomial 2.

Submodel(s) :
Climate

Inactive - For Future Use

No Transform on X

No Transform on Y

-.250000050 to .250000050 values of Y
-1000.00201416 to 1000.00201416 values of X

1. Order Polynomial

Coefficients :

0. 0.000000000000
1. 0.000000000000

Units for X meters
Units for Y unitless
Source George Kukla

Calculates the change of precipitation rate (cm/yr) in the southwest recharge area from the change in elevation (m) of the Cascade Range.

NE Precip Change Fraction For Rocky Mtns

Polynomial 3.

Submodel(s) :

Climate

Inactive - For Future Use

No Transform on X

No Transform on Y

-.25000050 to .25000050 values of Y

-1000.00201416 to 1000.00201416 values of X

1. Order Polynomial

Coefficients :

0. 0.0000000000

1. 0.0000000000

Units for X meters

Units for Y unitless

Source George Kukla

Calculates the change of precipitation rate (cm/yr) in the northeast recharge area from the change in elevation (m) of the Rocky Mountains or the Blue Mountains.

SW Precip Change Fraction For Rocky Mtns

Polynomial 4.

Submodel(s) :

Climate

Inactive - For Future Use

No Transform on X

No Transform on Y

-2.50000500 to 2.50000500 values of Y

-1000.00201416 to 1000.00201416 values of X

1. Order Polynomial

Coefficients :

0. 0.0000000000

1. 0.0000000000

Units for X meters

Units for Y unitless

Source George Kukla

Calculates the change of precipitation rate (cm/yr) in the southwest recharge area from the change in elevation (m) of the Rocky Mountains or Blue Mountains.

Glacier Rebound Rate With Less Ice
Polynomial 6.

Submodel(s) :

Continental Glaciation

See Text For Explanation

No Transform on X

No Transform on Y

0.000000000 to .007300001

values of Y

-1500.00305175 to -1.00000202

values of X

0. Order Polynomial

Coefficients :

0. 0.0000000000

Units for X meters

Units for Y meters / year

Source Colin Bull

Calculates the ground surface rebound rate (m/yr) due to glacial unloading from the decrease of glacial ice thickness (m).

(Note : Dr. Colin Bull (1981)* states :

"... uplift and subsidence there (Pasco) is going to be minute. I really think you can forget it in the model at this stage.")

* Unpublished consultant's report to PNL from Dr. Colin Bull of Ohio State University on April 3, 1981.

Prob. of H.C. Change in Shaft Seal With Time
Polynomial 5.

Submodel(s) :
Shaft Seal

Depends On Repository Design

No Transform on X

No Transform on Y

0.000000000 to 1.00000202 values of Y

1.00000202 to 1000002.00000000 values of X

1. Order Polynomial

Coefficients :

0. 0.000000000000

1. .0000010000

Units for X years

Units for Y unitless

Source PNL -- Gregg Petrie

Calculates the probability of change in hydraulic conductivity of the shaft seal from the elapsed simulated time.

Glacial Rebound Rate When Ice is Gone

Polynomial 7.

Submodel(s) :

Continental Glaciation

See Text For Explanation

No Transform on X

No Transform on Y

0.000000000 to .007300001 values of Y

1.000000202 to 100000.20312500 values of X

0. Order Polynomial

Coefficients :

0. 0.00000000000

Units for X years

Units for Y meters / year

Source Colin Bull

Calculates the ground surface rebound rate (m/yr) due to glacial unloading from the number of years since the glacier retreated from the area.

(Note : Dr. Colin Bull (1981)* states :
"..., uplift and subsidence there (Pasco) is going to be minute. I really think you can forget it in the model at this stage.")

* Unpublished consultant's report to PNL from Dr. Colin Bull of Ohio State University on April 3, 1981.

Glacial Subsidence Rate From Ice Thickness
Polynomial 8.

Submodel(s) :

Continental Glaciation

See Text For Explanation

No Transform on X

No Transform on Y

-.00730001 to -.00730001 values of Y

1.00000202 to 1500.00305175 values of X

0. Order Polynomial

Coefficients :

0. 0.0000000000

Units for X meters

Units for Y meters / year

Source Colin Bull

Calculates the ground surface subsidence rate (m/yr) caused by glacial loading from the thickness of glacial ice (m).

(Note : Dr. Colin Bull (1981)* states :

"... uplift and subsidence there (Pasco) is going to be minute. I really think you can forget it in the model at this stage.")

* Unpublished consultant's report to PNL from Dr. Colin Bull of Ohio State University on April 3, 1981.

Radial Stress From Glacier Distance

Polynomial 9.

Submodel(s) :

Continental Glaciation

Subjective Guess With Data

No Transform on X

No Transform on Y

-7.20001459 to 15.00003051 values of Y

0.00000000 to 200.00041198 values of X

1. Order Polynomial

Coefficients :

0. 10.5600214004

1. -.0613261222

Units for X kilometers

Units for Y pascals

Source Colin Bull

Calculates the radial stress (pascals) of glacial loading from the distance (km) to the glacier terminus.

Note : Dr. Colin Bull cites Brotchie and Silvester (1969) as his source for this data.

Tangential Stress From Glacier Distance
Polynomial 10.

Submodel(s) :

Continental Glaciation

Subjective Guess With Data

No Transform on X

No Transform on Y

-7.00001430 to 15.00003051 values of Y

0.00000000 to 200.00041198 values of X

1. Order Polynomial

Coefficients :

0. 1.5920032501

1. -.0085071172

Units for X kilometers

Units for Y pascals

Source Colin Bull

Calculates the tangential stress (pascals) of glacial loading from the distance (km) to the glacier terminus.
Note : Dr. Colin Bull cites Brotchie and Silvester (1969) as his source for this data.

Change in HC With Radial Stress From Glacier
Polynomial 11.

Submodel(s) :

Continental Glaciation

Subjective Guess With Data

No Transform on X

e To The Y Power

.00000010 to .50000100 values of Y

0.00000000 to 10.00002002 values of X

1. Order Polynomial

Coefficients :

0. -2.5540051460

1. .1690003395

Units for X pascals

Units for Y meters / day

Source James W. Crosby & Alan J. Baldwin

Calculates the change in hydraulic conductivity (m/day) of basalt from the radial stress (pascals) of glacial loading.

Note : This polynomial was derived by comparing Dr. James Crosby's estimates of change in hydraulic conductivity with distance from glacier edge to Brotchie & Silvester's estimates (1969) of stresses from distance to glacial edge.

Crosby, J. W., 1980. Unpublished Report to PNL, Nov. 1980.

Change In HC With Glacial Tangential Stress
Polynomial 12.

Submodel(s) :

Continental Glaciation

Subjective Guess With Data

No Transform on X

e To The Y Power

.00000010 to .50000100 values of Y

0.00000000 to 1.50000309 values of X

1. Order Polynomial

Coefficients :

0. -5.0940103530

1. .0017493037

Units for X pascals

Units for Y meters / day

Source PNL -- Alan Baldwin & James Crosby *

Calculates the change in hydraulic conductivity (m/day) of basalt from the tangential stress (pascals) of glacial loading.

Note : This polynomial was derived by comparing Dr. James Crosby's estimates of change in hydraulic conductivity with distance from glacier edge to Brotchie & Silvester's estimates (1969) of stresses from distance to glacial edge.

* Unpublished consultant's report to PNL from James W. Crosby of Washington State University on Nov. 1980.

Erosion From Stream Power
Polynomial 13.

Submodel(s) :

Geomorphic Events

From Expert Judgement

No Transform on X

No Transform on Y

-.001000000 to .300000061 values of Y

0.000000000 to .001000000 values of X

1. Order Polynomial

Coefficients :

0. 0.000000000000

1. -9.6430187225

Units for X meters**3 / seconds*(meters/meter)

Units for Y meters / year

Source PNL -- Mike Foley and Gregg Petrie

Calculates erosion rate (m/yr) by the Columbia River from
stream power (discharge times gradient).
See variables SLOPHI and SLOPLW and density curves 56-59.

(Data from Mike Foley and Gregg Petrie of PNL on Feb. 26,
1981.)

M of Missoula Flood Erosion From Stream Power
Polynomial 14.

Submodel(s) :

Geomorphic Events

From Expert Judgement

No Transform on X

No Transform on Y

-10.00002002 to 0.000000000 values of Y

67.20013427 to 24000.04882812 values of X

1. Order Polynomial

Coefficients :

0. 0.00000000000

1. -.00170000035

Units for X meters**3 / second(meters/meter)

Units for Y meters

Source Donald Easterbrook

Calculates erosion rate (m/yr) by a Missoula-type flood from stream power (discharge times gradient).

Correction Factor of Intersection Angle
Polynomial 15.

Submodel(s) :
Fault Creation

Inactive - For Future Use
No Transform on X
No Transform on Y

1.00000202 to 1.00000202 values of Y
0.00000000 to 90.00018310 values of X

0. Order Polynomial

Coefficients :

0. 1.0000020265

Units for X degrees

Units for Y unitless

Source PNL -- Gregg Petrie

Calculates the reduction or enhancement of earthquake acceleration (multiplication factor or fraction of the acceleration when the wave direction is directly along the model cross section from the northeast) from the angle between the model cross section and the direction of earthquake wave direction.

Fault Area From Earthquake Magnitude
Polynomial 16.

Submodel(s) :

Sub-Basalt Faulting

Unpublished Data

Exponential Form X

No Transform on Y

.00010000 to 100000.20312500 values of Y

1.00000202 to 8.00001621 values of X

2. Order Polynomial

Coefficients :

0. 0.00000000000

1. .0012769025

2. 1.1910023689

Units for X Richter magnitude

Units for Y kilometers2**

Source Lawrence H. Wight

Calculates the displacement area (km2) of a fault plane from the magnitude of the earthquake associated with the fault movement.**

See L. H. Wight in Appendix B.

Earthquake Frequency From Magnitude
Polynomial 17.

Submodel(s) :

Sub-Basalt Faulting

From The Literature

No Transform on X

No Transform on Y

0.00000000 to 16.00003242 values of Y

2.00000405 to 8.00001621 values of X

1. Order Polynomial

Coefficients :

0. -.1660003423

1. .0830001735

Units for X Richter Magnitude

Units for Y cycles / second

Source PNL -- Steve Blair

Calculates earthquake frequency (Hz) from magnitude.
(Gutenberg and Richter, 1956)

Earthquake Duration From Magnitude
Polynomial 18.

Submodel(s) :

Sub-Basalt Faulting

From The Literature

No Transform on X

10 To The Y Power

-.320000064 to 20.00004005 values of Y

1.000000202 to 8.00001621 values of X

1. Order Polynomial

Coefficients :

0. -1.4000028610

1. .32000006484

Units for X Richter magnitude

Units for Y Seconds

Source PNL -- Steve Blair

Calculates earthquake duration (sec) from earthquake
magnitude.
(Gutenberg and Richter, 1956)

Relation Between H.C. and Effective Porosity
Polynomial 19.

Submodel(s) :
Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.00000000 to .10000020 values of Y

0.00000000 to .00380000 values of X

0. Order Polynomial

Coefficients :

0. .0350000715

Units for X meters / day

Units for Y Effective Porosity

Source PNL -- Charles Cole and Gregg Petrie

Relates effective porosity and hydraulic conductivity.

(Note: Until a better relationship for the Wanapum Basalts becomes available, Gregg Petrie and Alan Baldwin have decided to use an average effective porosity for the Pasco Basin basalts.)

Recharge From Glacier Thickness
Polynomial 20.

Submodel(s) :
Hydrology

Inactive - For Future Use

No Transform on X

No Transform on Y

5.00001001 to 30.00006103 values of Y

0.00000000 to 1500.00305175 values of X

1. Order Polynomial

Coefficients :

0. 6.4000129699

1. 0.0000000000

Units for X meters

Units for Y centimeters / year

Source Colin Bull

Calculates from the thickness of glacial ice (m) the amount of water (cm/yr) that is recharged to basalt aquifers in the northeast recharge area when the area is covered by a continental glacier.

(Note : This polynomial function will be used when we obtain adequate data. Currently, we use the value of the recharge in the northeast recharge area.)

SW Head Change From Recharge Rate, Climate 1
Polynomial 21.

Submodel(s) :
Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.00000000 to 1000.00201416 values of Y

0.00000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.0000000000

1. 50.0001029968

Units for X centimeters / year

Units for Y meters

Source James W. Crosby

Calculates hydraulic head change (m) of basalt aquifers in the southwest recharge area during an interglacial climate state from the recharge rate (cm/yr).

SW Head Change From Recharge Rate, Climate 2
Polynomial 22.

Submodel(s) :

Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.00000000 to 1000.00201416 values of Y

0.00000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.00000000000

1. 29.2700595855

Units for X centimeters / year

Units for Y meters

Source James W. Crosby

Calculates hydraulic head change (m) of basalt aquifers in the southwest recharge area during a temperate interstadial climate from the recharge rate (cm/yr).

SW Head Change From Recharge Rate, Climate 3
Polynomial 23.

Submodel(s) :
Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.00000000 to 1000.00201416 values of Y

0.00000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.0000000000

1. 23.5300483703

Units for X centimeters / year

Units for Y meters

Source James W. Crosby

Calculates hydraulic head change (m) of basalt aquifers in the southwest recharge area during an interstadial climate state from the change in recharge rate (cm/yr).

SW Head Change From Recharge Rate, Climate 4
Polynomial 24.

Submodel(s) :

Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.00000000 to 1000.00201416 values of Y

0.00000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.00000000000

1. 40.0000801086

Units for X centimeters / year

Units for Y meters

Source James W. Crosby

Calculates the hydraulic head change (m) of basalt aquifers in the southwest recharge area during a stadial climate state from the recharge rate (cm/yr).

NE Head Change From Recharge Rate, Climate 1
Polynomial 25.

Submodel(s) :
Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.000000000 to 1000.00201416 values of Y

0.000000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.00000000000

1. 78.1201629638

Units for X centimeters / year

Units for Y meters

Source James W. Crosby

Calculates the hydraulic head change (m) of basalt aquifers in the northeast recharge area during an interglacial climate state from the recharge rate (cm/yr).

NE Head Change From Recharge Rate, Climate 2
Polynomial 26.

Submodel(s) :

Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.00000000 to 1000.00201416 values of Y

0.00000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.000000000000

1. 92.5901870727

Units for X centimeters / year

Units for Y meters

Source James W. Crosby

Calculates the hydraulic head change (m) of basalt aquifers in the northeast recharge area during a temperate interstadial climate state from the recharge rate (cm/yr).

NE Head Change From Recharge Rate, Climate 3
Polynomial 27.

Submodel(s) :

Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.00000000 to 1000.00201416 values of Y

0.00000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.00000000000

1. 73.5301513671

Units for X centimeters /year

Units for Y meters

Source James W. Crosby

Calculates the hydraulic head change (m) of basalt aquifers in the northeast recharge area during an interstadial climate state from the recharge rate (cm/yr).

NE Head Change From Recharge Rate, Climate 4
Polynomial 28.

Submodel(s) :
Hydrology

Subjective Guess With Data

No Transform on X

No Transform on Y

0.000000000 to 1000.00201416 values of Y

0.000000000 to 6.00001239 values of X

1. Order Polynomial

Coefficients :

0. 0.00000000000

1. 63.2901306152

Units for X centimeters / year

Units for Y meters

Source James W. Crosby

Calculates the hydraulic head change (m) of basalt aquifers in the northeast recharge area during a stadial climate state from the recharge rate (cm/yr).

GW Velocity Reduction From Glacier Distance
Polynomial 29.

Submodel(s) :
Hydrology

From Expert Judgement

No Transform on X

No Transform on Y

.27560055 to 1.00000202 values of Y

0.00000000 to 300.00061035 values of X

1. Order Polynomial

Coefficients :

0. .2756005525

1. .0024100048

Units for X kilometers

Units for Y unitless

Source PNL -- Gregg Petrie

Calculates the reduction of ground-water velocity (fraction of normal velocity) due to permafrost conditions from the distance to the terminus of the continental glacier (km).

NE Recharge Area Reduction From Glacier Dist
Polynomial 30.

Submodel(s) :

Hydrology

From Expert Judgement

No Transform on X

No Transform on Y

0.00000000 to 1.00000202 values of Y

46.23009490 to 47.85009384 values of X

1. Order Polynomial

Coefficients :

0. -28.5300579071

1. .6173012256

Units for X Degrees of latitude

Units for Y Unitless

Source James W. Crosby

Calculates the reduction fraction of the northeast recharge area from the distance (degrees of latitude) of the glacial terminus to the southernmost latitude of the northeast recharge area.

NE Precipitation Rate for Climate State 1
Density Curve 1.

Submodel(s) :
Climate

Data From Transformation
No transform on X

0.000000000 to 105.00021362 error bounds on X
0.000000000 to 105.00021362 values of X

Point by Point
Density Points :

0. .0000000010
1. .0000000010
2. .0194590387
3. .1045002102
4. .0741541433
5. .0130650269
6. .0087705183
7. .0130770266
8. .0253470516
9. .0455670928
10. .0743591499
11. .1042002081
12. .1229002475
13. .1231002449
14. .1043002128
15. .0775511550
16. .0467580938
17. .0257400512
18. .0127410268
19. .0045147089
20. .0000000010

Units for X centimeters / year
Source George Kukla *

Average precipitation rate (cm/yr) in the northeast recharge area during an interglacial climate state.

* Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.

NE Precipitation Rate for Climate State 2

Density Curve².

Submodel(s) :

Climate

Data From Expert Judgement

No transform on X

0.00000000 to 150.00030517 error bounds on X

0.00000000 to 131.40025329 values of X

Point by Point

Density Points :

0.	0.0000000000
1.	.3000006198
2.	3.4000070095
3.	6.0000123977
4.	.8000016212
5.	.4000008106
6.	1.0000020265
7.	2.3000047206
8.	4.6000094413
9.	6.7000131607
10.	8.0000162124
11.	7.7000155448
12.	6.6000132560
13.	4.6000094413
14.	3.6000072956
15.	3.0000061988
16.	2.3000047206
17.	1.5000030994
18.	.9000018119
19.	.5000010013
20.	.3000006198

Units for X centimeters / year

Source George Kukla *

Average precipitation rate (cm/yr) in the northeast recharge area during a temperate interstadial climate state.

* Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.

NE Precipitation Rate for Climate State 3

Density Curve 3.

Submodel(s) :

Climate

Data From Expert Judgement

No transform on X

0.00000000 to 150.00030517 error bounds on X

6.56801319 to 137.90026855 values of X

Point by Point

Density Points :

0. .2000004053
1. 1.2000024318
2. 2.5000050067
3. .5000010013
4. .3000006198
5. .7000014305
6. 1.5000030994
7. 2.7000055313
8. 4.0000081062
9. 5.5000109672
10. 6.5000133514
11. 7.1000142097
12. 7.2000145912
13. 7.1000142097
14. 6.5000133514
15. 5.2000102996
16. 3.7000074386
17. 2.4000048637
18. 1.3000025749
19. .7000014305
20. .4000008106

Units for X centimeters / year

Source George Kukla *

Average precipitation rate (cm/yr) in the northeast recharge area during a stadial climate state.

* Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.

NE Precipitation Rate for Climate State 4
Density Curve⁴.

Submodel(s) :
Climate

Data From Expert Judgement
No transform on X

5.00001001 to 153.00030517 error bounds on X
52.55010604 to 131.40025329 values of X

Normal Curve
Density Points :

0.	.0044319090
1.	.0104210221
2.	.0223950457
3.	.0439840888
4.	.0789501619
5.	.1295002698
6.	.1942003822
7.	.2661005258
8.	.3332006931
9.	.3814007759
10.	.3989008235
11.	.3814007759
12.	.3332006931
13.	.2661005258
14.	.1942003822
15.	.1295002698
16.	.0789501619
17.	.0439840888
18.	.0223950457
19.	.0104210221
20.	.0044319090

Units for X centimeters / year
Source George Kukla *

Average precipitation rate (cm/yr) in the northeast recharge area during a stadial climate state.

* Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.

SW Precipitation Rate for Climate State 1
Density Curve⁵.

Submodel(s) :
Climate

Data From Transformation
No transform on X

0.00000000 to 40.00008010 error bounds on X
0.00000000 to 40.00008010 values of X

Point by Point
Density Points :

0. .0000000010
1. .0000000010
2. .0295250606
3. .1048002123
4. .0682341384
5. .0127900254
6. .0086637172
7. .0132690262
8. .0258920526
9. .0465750932
10. .0754821586
11. .1054002165
12. .1231002449
13. .1226002454
14. .1027002096
15. .0756711626
16. .0447340917
17. .0245240497
18. .0121340239
19. .0038810076
20. .0000000010

Units for X centimeters / year
Source George Kukla *

Average precipitation rate (cm/yr) in the southwest recharge area during an interglacial climate state.

* Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.

SW Precipitation Rate for Climate State 2

Density Curve 6.

Submodel(s) :

Climate

Data From Expert Judgement

No transform on X

0.00000000 to 100.00020599 error bounds on X

0.00000000 to 95.81018829 values of X

Point by Point

Density Points :

0.	0.0000000000
1.	.3000006198
2.	3.4000070095
3.	6.0000123977
4.	.8000016212
5.	.4000008106
6.	1.0000020265
7.	2.3000047206
8.	4.6000094413
9.	6.7000131607
10.	8.0000162124
11.	7.7000155448
12.	6.6000132560
13.	4.6000094413
14.	3.6000072956
15.	3.0000061988
16.	2.3000047206
17.	1.5000030994
18.	.9000018119
19.	.5000010013
20.	.3000006198

Units for X centimeters / year

Source George Kukla *

Average precipitation rate (cm/yr) in the southwest recharge area during a temperate interstadial climate state.

* Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.

SW Precipitation Rate for Climate State 3

Density Curve⁷.

Submodel(s) :

Climate

Data From Expert Judgement

No transform on X

0.00000000 to 110.00022125 error bounds on X

4.79000949 to 100.60020446 values of X

Point by Point

Density Points :

0. .2000004053
1. 1.2000024318
2. 2.5000050067
3. .5000010013
4. .3000006198
5. .7000014305
6. 1.5000030994
7. 2.7000055313
8. 4.0000081062
9. 5.5000109672
10. 6.5000133514
11. 7.1000142097
12. 7.2000145912
13. 7.1000142097
14. 6.5000133514
15. 5.2000102996
16. 3.7000074386
17. 2.4000048637
18. 1.3000025749
19. .7000014305
20. .4000008106

Units for X centimeters / year

Source George Kukla *

Average precipitation rate (cm/yr) in the southwest recharge area during an interstadial climate state.

*** Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.**

SW Precipitation Rate for Climate State 4
Density Curve⁸.

Submodel(s) :
Climate

Data From Transformation
No transform on X

5.00001001 to 100.00020599 error bounds on X
19.94004058 to 49.84009933 values of X

Normal Curve
Density Points :

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X centimeters / year
Source George Kukla *

Average precipitation rate (cm/yr) in the southwest recharge area during a stadial climate state.

* Unpublished consultant's report to PNL from George Kukla of Lamont-Doherty Geological Observatory on Feb. 4, 1981.

**Cascade Mountain Range Uplift Rate
Density Curve⁹.**

Submodel(s) :
Climate

Judgement and Data
Log transform on X

-6.000001239 to -3.000000619 error bounds on X
-5.000001001 to -4.000000810 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year
Source Robert D. Bentley *

Cascade range uplift rate (m/yr). This rate is the net uplift rate when the erosion rate is subtracted from the total uplift rate.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.

Cascade Mountain Range Erosion Rate
Density Curve 10.

Submodel(s) :
Climate

Judgement and Data

Log transform on X

-6.00001239 to -3.00000619 error bounds on X
-5.00001001 to -4.00000810 values of X

Normal Curve
Density Points :

0.	.0044320092
1.	.0104200220
2.	.0223900461
3.	.0439800882
4.	.0789501619
5.	.1295002698
6.	.1942003822
7.	.2661005258
8.	.3332006931
9.	.3814007759
10.	.3989008235
11.	.3814007759
12.	.3332006931
13.	.2661005258
14.	.1942003822
15.	.1295002698
16.	.0789501619
17.	.0439800882
18.	.0223900461
19.	.0104200220
20.	.0044320092

Units for X meters / year
Source Robert D. Bentley *

Cascade Range erosion rate (m/yr). This rate is the net erosion rate when the uplift rate is subtracted from the total erosion rate.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.

Variance of Polynomial Number 1
Density Curve 11.

Submodel(s) :
Climate

Variance - For Future Use
No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X centimeters / year
Source George Kukla

Variance or error (cm/yr) of polynomial number 1.

Variance of Polynomial Number 2
Density Curve¹².

Submodel(s) :
Climate

Variance - For Future Use
No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X centimeters / year
Source George Kukla

Variance or error (cm/yr) of polynomial number 2.

**Uplift Rate of Eastern Mountains
Density Curve 13.**

Submodel(s) :
Climate

Judgement and Data
Log transform on X

-7.00001430 to -4.00000810 error bounds on X
-5.22001028 to -5.00001001 values of X

Normal Curve
Density Points :

0.	.0044320092
1.	.0104200220
2.	.0223900461
3.	.0439800882
4.	.0789501619
5.	.1295002698
6.	.1942003822
7.	.2661005258
8.	.3332006931
9.	.3814007759
10.	.3989008235
11.	.3814007759
12.	.3332006931
13.	.2661005258
14.	.1942003822
15.	.1295002698
16.	.0789501619
17.	.0439800882
18.	.0223900461
19.	.0104200220
20.	.0044320092

Units for X meters / year
Source Robert D. Bentley *

Uplift rate (m/yr) on mountains to the east of the Pasco Basin (Blue Mountains or Rocky Mountains). This rate is the net uplift rate. Total uplift rate minus erosion rate equals the net uplift rate.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.

Erosion rate on Eastern Mountains

Density Curve 14.

Submodel(s) :

Climate

Judgement and Data

Log transform on X

-7.00001430 to -3.00000619 error bounds on X
-6.00001239 to -4.00000810 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year

Source Robert D. Bentley *

Erosion rate (m/yr) on mountains to the east of the Pasco Basin (Blue Mountains or Rocky Mountains). This rate is the net erosion rate. Total erosion rate minus uplift rate equals net erosion rate.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.

Variance of Polynomial Number 3

Density Curve 15.

Submodel(s) :

Climate

Variance - For Future Use

No transform on X

0.000000000 to 0.000000000 error bounds on X

0.000000000 to 0.000000000 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X centimeters / year

Source George Kukla

Variance or error (cm/yr) of polynomial number 3.

Variance of Polynomial Number 4
Density Curve 16.

Submodel(s) :

Climate

Variance - For Future Use

No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X centimeters / year

Source George Kukla

Variance or error (cm/yr) of polynomial number 4.

Fraction of Precip. Recharged NE Climate 1
Density Curve 17.

Submodel(s) :
Climate

Judgement and Data
No transform on X

0.00000000 to .50000100 error bounds on X
0.00000000 to .20000040 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless
Source James W. Crosby *

Fraction of the total annual precipitation in the northeast recharge area that recharges basalt aquifers during an interglacial climate state.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

**Fraction of Precip. Recharged NE Climate 2
Density Curve 18.**

Submodel(s) :
Climate

Judgement and Data
No transform on X

0.00000000 to .50000100 error bounds on X
0.00000000 to .20000040 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless
Source James W. Crosby *

**Fraction of the total annual precipitation in the northeast
recharge area that recharges basalt aquifers during a
temperate interstadial climate state.**

* Unpublished consultant's report to PNL from James W.
Crosby III of Washington State University on Aug. 1980.

Fraction of Precip. Recharged NE Climate 3
Density Curve 19.

Submodel(s) :
Climate

Judgement and Data

No transform on X

0.00000000 to .50000100 error bounds on X
0.00000000 to .20000040 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless
Source James W. Crosby *

Fraction of the total annual precipitation in the northeast recharge area that recharges basalt aquifers during an interstadial climate state.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

Fraction of Precip. Recharged NE Climate 4
Density Curve 20.

Submodel(s) :
Climate

Data From Expert Judgement
No transform on X

0.000000000 to .50000100 error bounds on X
0.000000000 to .10000020 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless
Source James W. Crosby *

Fraction of the total annual precipitation in the northeast
recharge area that recharges basalt aquifers during a
stadial climate state.

* Unpublished consultant's report to PNL from James W.
Crosby III of Washington State University on Aug. 1980.

Fraction of Precip. Recharged SW Climate 1
Density Curve 21.

Submodel(s) :
Climate

Judgement and Data

No transform on X

0.00000000 to .50000100 error bounds on X
0.00000000 to .20000040 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless

Source James W. Crosby *

Fraction of the total annual precipitation in the southwest recharge area that recharges basalt aquifers in an interglacial climate state.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

Fraction of Precip. Recharged SW Climate 2
Density Curve 22.

Submodel(s) :
Climate

Judgement and Data
No transform on X

0.000000000 to .50000100 error bounds on X
0.000000000 to .20000040 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless
Source James W. Crosby *

Fraction of the total annual precipitation in the southwest recharge area that recharges basalt aquifers in a temperate interstadial climate state.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

Fraction of Precip. Recharged SW Climate 3
Density Curve 23.

Submodel(s) :
Climate

Judgement and Data

No transform on X

0.00000000 to .50000100 error bounds on X
0.00000000 to .20000040 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless

Source James W. Crosby *

Fraction of the total annual precipitation in the southwest recharge area that recharges basalt aquifers in an interstadial climate state.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

Fraction of Precip. Recharged SW Climate 4
Density Curve²⁴.

Submodel(s) :
Climate

Data From Expert Judgement
No transform on X

0.00000000 to .50000100 error bounds on X
0.00000000 to .10000020 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless
Source James W. Crosby *

Fraction of the total annual precipitation in the southwest recharge area that recharges basalt aquifers in a stadial climate state.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

Sea-Level Rise Above Present Elev. Climate 1
Density Curve²⁵.

Submodel(s) :

Sea Level Fluctuations

Data From Expert Judgement

No transform on X

0.00000000 to 100.00020599 error bounds on X
0.00000000 to 100.00020599 values of X

Point by Point

Density Points :

0. 0.0000000000
1. 11.0000219345
2. 28.0000572204
3. 57.0001144409
4. 83.0001678466
5. 98.0001983642
6. 90.0001831054
7. 68.0001373291
8. 43.0000877380
9. 21.0000419616
10. 12.0000247955
11. 9.0000181198
12. 8.0000162124
13. 7.0000143051
14. 7.0000143051
15. 6.0000123977
16. 6.0000123977
17. 5.0000100135
18. 5.0000100135
19. 4.0000081062
20. 4.0000081062

Units for X meters

Source Marice L. Schwartz (1979)

The amount of sea-level rise (m) above present sea-level
that would occur in an interglacial climate state.

Schwartz, M. L. 1979. "Sea Level Report." In 'A Summary
of FY-1978 Consultant Input for Scenario Methodology
Development', pp. IX-1 - IX-8. PNL-2857, Pacific Northwest
Laboratory, Richland, Washington.

**Deposition by Sea Flooding
Density Curve²⁶.**

Submodel(s) :

Sea Level Fluctuations

Data From The Literature

Log transform on X

-5.69901132 to .30100059 error bounds on X
-4.69900941 to -.69900145 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year

Source Marice L. Schwartz

The depth (m) of sediments that would be deposited by an encroachment of the sea into the Pasco Basin.

Schwartz, M. L. 1979. "Sea Level Report." In 'A Summary of FY-1978 Consultant Input for Scenario Methodology Development', pp. IX-1 - IX-8. PNL-2857, Pacific Northwest Laboratory, Richland, Washington.

**Hydraulic Conductivity Change for Shaft Seal
Density Curve²⁷.**

Submodel(s) :
Shaft Seal

Depends on Repository Design
Log transform on X

-7.00001430 to 1.00000202 error bounds on X
-6.00001239 to 0.00000000 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / day
Source PNL -- Gregg Petrie

The change in hydraulic conductivity (m/day) of the shaft seal when it is known to have occurred.

**Fraction Waste to Air in Phreatic Mag. Event
Density Curve²⁸.**

Submodel(s) :

Magmatic Events

Data From Expert Judgement

No transform on X

**0.00000000 to 1.00000202 error bounds on X
.15000030 to .35000071 values of X**

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless

Source PNL -- Jon Lindberg

**Fraction of the waste that is discharged to the atmosphere
when a phreatic magmatic event intersects the repository.**

**Frac. Waste to Water in Phreatic Mag. Event
Density Curve²⁹.**

Submodel(s) :

Magmatic Events

Data From Expert Judgement

No transform on X

0.00000000 to 1.00000202 error bounds on X
.25000050 to .45000090 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless

Source PNL -- Jon Lindberg

**Fraction of the waste that is discharged to the water when a
phreatic magmatic eruption intersects the repository.**

Frac. Waste to Air in Nonphreatic Mag. Event
Density Curve³⁰.

Submodel(s) :

Magmatic Events

Data From Expert Judgement

No transform on X

0.000000000 to 1.00000202 error bounds on X

0.000000000 to .10000020 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless

Source PNL -- Jon Lindberg

Fraction of the waste that is discharged to the atmosphere
when a nonphreatic magmatic eruption intersects the
repository.

**Frac Waste to Water in Nonphreatic Mag Event
Density Curve 31.**

Submodel(s) :

Magmatic Events

Data From Expert Judgement

No transform on X

0.00000000 to 1.00000202 error bounds on X
.05000010 to .25000050 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X Unitless

Source PNL -- Jon Lindberg

**Fraction of the waste that is discharged to water when a
nonphreatic magmatic eruption intersects the repository.**

Frac Radius of DSMTMX for Meteorite Impact
Density Curve³².

Submodel(s) :

Meteorite Impact

Data From Expert Judgement

No transform on X

0.000000000 to 1.00000202 error bounds on X
0.000000000 to 1.00000202 values of X

Position Vector

Density Points :

0. 0.0000000000
1. 1.0000020265
2. 2.0000040531
3. 3.0000061988
4. 4.0000081062
5. 5.0000100135
6. 6.0000123977
7. 7.0000143051
8. 8.0000162124
9. 9.0000181198
10. 10.0000200271
11. 11.0000219345
12. 12.0000247955
13. 13.0000267028
14. 14.0000286102
15. 15.0000305175
16. 16.0000324249
17. 17.0000343322
18. 18.0000362396
19. 19.0000381469
20. 20.0000400543

Units for X Unitless

Source PNL -- Gregg Petrie

The length of the "meteorite crater position vector". The length of the vector is a fraction of the scalar variable DSMTMX (which is the maximum distance from the repository site for meteorite impact). The vector extends from the repository site to the meteorite crater.

Angle From N for Meteorite Position Vector
Density Curve 33.

Submodel(s) :
Meteorite Impact

Data From Expert Judgement
No transform on X

0.00000000 to 360.00073242 error bounds on X
0.00000000 to 360.00073242 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X Degrees
Source PNL -- Gregg Petrie

The angle (degrees) in the horizontal plane from north for the trend of the "meteorite crater position vector". The vector extends from the repository site to the meteorite crater.

Meteorite Crater Diameter
Density Curve³⁴.

Submodel(s) :

Meteorite Impact

Data From The Literature

No transform on X

0.00000000 to 210.00042724 error bounds on X
.25000050 to 200.00041198 values of X

Point by Point

Density Points :

0. 2.5600051879
1. .0000840001
2. .0000120000
3. .0000039000
4. .0000017000
5. .0000009200
6. .0000005500
7. .0000003600
8. .0000002500
9. .0000001800
10. .0000001300
11. .0000001000
12. .0000000800
13. .0000000640
14. .0000000520
15. .0000000430
16. .0000000360
17. .0000000300
18. .0000000260
19. .0000000220
20. .0000000190

Units for X kilometers

Source William K. Hartmann (1979)

The diameter (km) of a meteorite crater that lies within a radius of the site determined by the scalar variable DSTMX.

Hartmann, W. K., 1979. "Long-Term Meteorite Hazards to Buried Nuclear Waste." In 'A Summary of FY1978 Consultant Input for Scenario Methodology Development', pp. VI-1 - VI-15. PNL-2857, Pacific Northwest Laboratory, Richland, Washington.

Glacier Decay Rate for Climate State 1
Density Curve 35.

Submodel(s) :

Continental Glaciation

Data From Curve Matching

No transform on X

-1.00000202 to 1.00000202 error bounds on X
.09500020 to .10500020 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X kilometers /year

Source PNL -- Mike Foley, Gregg Petrie & Colin Bull

Continental glacier retreat rate (km/yr) during an inter-glacial climate state.

(Note: This curve is calibrated for this model by comparing different advance/retreat rates with the climate file to obtain glacial positions that match current geological knowledge of past and currently expected glacial advances.)

Glacier Decay Rate for Climate State 2
Density Curve 36.

Submodel(s) :

Continental Glaciation

Data From Curve Matching

No transform on X

-1.00000202 to 1.00000202
.09500020 to .10500020

error bounds on X
values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X kilometers / year

Source PNL -- Mike Foley, Gregg Petrie & Colin Bull

Continental glacier retreat rate (km/yr) for a temperate interstadial climate state.

(Note: This curve is calibrated for this model by comparing different advance/retreat rates with the climate file to obtain glacial positions that match current geological knowledge of past and currently expected glacial advances.)

**Glacier Decay Rate for Climate State 3
Density Curve³⁷.**

Submodel(s) :

Continental Glaciation

Data From Curve Matching

No transform on X

-1.00000202 to 1.00000202
.09500020 to .10500020

**error bounds on X
values of X**

**Uniform Curve
Density Points :**

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X kilometers / year

Source PNL -- Mike Foley, Gregg Petrie & Colin Bull

**Continental glacier retreat rate (km/yr) for an interstadial
climate state.**

(Note: This curve is calibrated for this model by comparing
different advance/retreat rates with the climate file to
obtain glacial positions that match current geological
knowledge of past and currently expected glacial advances.)

Glacier Rate for Preprotostadial Climate 4
Density Curve 38.

Submodel(s) :

Continental Glaciation

Data From Curve Matching

No transform on X

-1.00000202 to 1.00000202
.06319713 to .06985013

error bounds on X
values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X kilometers / year

Source PNL -- Mike Foley, Gregg Petrie & Colin Bull

Continental glacier advance or retreat rate (km/yr) for a preprotostadial climate state.

(Note: This curve is calibrated for this model by comparing different advance/retreat rates with the climate file to obtain glacial positions that match current geological knowledge of past and currently expected glacial advances.)

Glacier Rate for Plenistadial Climate 5
Density Curve³⁹.

Submodel(s) :

Continental Glaciation

Data From Curve Matching

No transform on X

-1.00000202 to 1.00000202 error bounds on X
.07577815 to .08375516 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X Kilometers / year

Source PNL -- Mike Foley, Gregg Petrie & Colin Bull

Continental glacier advance or retreat rate (km/yr) for a
plenistadial climate state.

(Note: This curve is calibrated for this model by comparing
different advance/retreat rates with the climate file to
obtain glacial positions that match current geological
knowledge of past and currently expected glacial advances.)

Glacier Rate for Postprotostadial Climate 6
Density Curve 40.

Submodel(s) :

Continental Glaciation

Data From Curve Matching

No transform on X

0.00000000 to 1.00000202 error bounds on X
.06399012 to .07821016 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X kilometers / year

Source PNL -- Mike Foley, Gregg Petrie & Colin Bull

Continental glacier advance or retreat rate (km/yr) for a postprotostadial climate state.

(Note: This curve is calibrated for this model by comparing different advance/retreat rates with the climate file to obtain glacial positions that match current geological knowledge of past and currently expected glacial advances.)

Glacier Erosion / Deposition Rate

Density Curve⁴¹.

Submodel(s) :

Continental Glaciation

Data From Expert Judgement

No transform on X

-20.00004005 to 20.00004005

error bounds on X

-.00040000 to 0.00000000

values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year

Source Colin Bull *

Net continental glacier erosion or deposition rate. The net rate includes both erosion and deposition by the glacier.

* Unpublished consultant's report to PNL from Colin Bull of Ohio State University on April 3, 1981.

Variance of Polynomial Number 6
Density Curve⁴².

Submodel(s) :

Continental Glaciation

Variance - For Future Use

No transform on X

0.00000000 to 0.00000000

error bounds on X

0.00000000 to 0.00000000

values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / year

Source Colin Bull

Variance or error (m/yr) of polynomial number 6.

Variance of Polynomial Number 7
Density Curve 43.

Submodel(s) :
Continental Glaciation

Variance - For Future Use
No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / year
Source Colin Bull

Variance or error (m/yr) of polynomial number 7.

Variance of Polynomial Number 8

Density Curve ⁴⁴4.

Submodel(s) :

Continental Glaciation

Variance - For Future Use

No transform on X

0.00000000 to 0.00000000 error bounds on X

0.00000000 to 0.00000000 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

0.000 0.000
meters / year

Units for X meters / year

Source Colin Bull

Variance or error (m/yr) of polynomial number 8.

Variance of Polynomials 11 and 12
Density Curve⁴⁵.

Submodel(s) :

Continental Glaciation

Variance - For Future Use

No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X Pascals

Source James W. Crosby

Variance or error (pascals) of polynomial numbers 9 and 10.

Normal Change in River Gradient of Columbia
Density Curve⁴⁶.

Submodel(s) :

Geomorphic Events

See Text For Explanation

No transform on X

-.00040000 to .00120000 error bounds on X
-.00000003 to .00000011 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / meters / year

Source Donald Easterbrook *

The annual change in gradient (m/m/yr) of the Columbia River

(Note: Easterbrook recommends using the current Columbia river gradient ($-0.3E-3$ to $1.12E-3$ m/m) with no "normal change" in slope over the next one million years. He believes that changes in river gradient other than "normal" changes can be dealt with using curves for specific effects.)

* Unpublished Consultant's Report to PNL from Donald Easterbrook of Western Washington University on Dec. 1980
Mackin, J.H., 1948, Concept of the Graded River, Geol. Soc. Amer. Bull., v. 59, p.463-512.

**Change in River Gradient Due to Glaciation
Density Curve⁴⁷.**

**Submodel(s) :
Geomorphic Events**

**Data From Relative Frequency
No transform on X**

**-.00400000 to .02000004 error bounds on X
.00378800 to .01136002 values of X**

**Uniform Curve
Density Points :**

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

**Units for X meters / meter
Source Donald Easterbrook ***

**The change in gradient (m/m) of the Columbia river in the
Pasco Basin immediately following glaciation of the Pasco
Basin.**

*** Unpublished Consultant's Report to PNL from Donald
Easterbrook of Western Washington University on Dec. 1980**

Change in Gradient Due to Flooding by Sea
Density Curve⁴⁸.

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

0.00000000 to 10.00002002 error bounds on X
0.00000000 to .00189300 values of X

Point by Point
Density Points :

0. 0.0000000000
1. 0.0000000000
2. .1211002469
3. .2421005010
4. .2263004541
5. .2105004310
6. .1053002238
7. 0.0000000000
8. 0.0000000000
9. 0.0000000000
10. 0.0000000000
11. 0.0000000000
12. 0.0000000000
13. 0.0000000000
14. 0.0000000000
15. 0.0000000000
16. 0.0000000000
17. 0.0000000000
18. .0157900323
19. .0315800642
20. .0473701000

Units for X meters / meter

Source Donald Easterbrook *

The change in gradient (m/m) of the Columbia River in the
Pasco Basin immediately following flooding by the sea in the
Pasco Basin.

* Unpublished Consultant's Report to PNL from Donald
Easterbrook of Western Washington University on Dec. 1980

Change in Gradient Due to Volcanic Event
Density Curve⁴⁹.

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-.01000002 to 0.00000000 error bounds on X
-.00950002 to -.00063000 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / meter

Source Donald Easterbrook *

The change in gradient (m/m) of the Columbia River in the Pasco Basin due to a volcanic (magmatic) eruption in the Pasco Basin.

* Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on Dec. 1980

Change in Gradient Due to Landsliding
Density Curve⁵⁰.

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-.010000002 to 10.00002002 error bounds on X
0.000000000 to .003900000 values of X

Point by Point
Density Points :

0. .5000010013
1. .5000010013
2. .3700007438
3. .2000004053
4. .1500003099
5. .1000002026
6. .0750001573
7. .0500001001
8. .0250000500
9. .0230000472
10. .0220000457
11. .0210000419
12. .0200000405
13. .0200000405
14. .0200000405
15. .0200000405
16. .0200000405
17. .0200000405
18. .0200000405
19. .0200000405
20. .0200000405

Units for X meters / meter

Source Donald Easterbrook *

The change in gradient (m/m) of the Columbia River in the Pasco Basin due to landsliding near the Columbia River in the Pasco Basin.

* Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on Dec. 1980

Normal Change in Path Length
Density Curve⁵¹.

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-1.00000202 to 50.00010299 error bounds on X
-.00015000 to .00015000 values of X

Normal Curve
Density Points :

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X kilometers / year

Source PNL -- GMP, AJB, MPF & Donald Easterbrook *

The annual change (km/yr) in the distance that possible waste-bearing ground water must travel in the unconfined aquifer from recharge by deep basalt aquifers (one contains the repository) to the Columbia River.

(Note : Dr. Easterbrook gives the maximum average value for normal change in path length of the Columbia River as 1.54×10^{-4} km/yr. He states that most of the changes will come from other curves. Gregg Petric, Alan Baldwin, and Mike Folcy agreed that because of the small range of this value, a normal curve is the best approximation.)

* Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on May 1981.

**Change in Path Length Due to Glacier
Density Curve⁵².**

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-40.00008010 to 40.00008010 error bounds on X
-40.00008010 to .00000400 values of X

**Normal Curve
Density Points :**

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X Kilometers

Source Donald Easterbrook *

The change in distance (km) that possible waste-bearing ground water must travel (in the unconfined aquifer of the Pasco Basin) due to continental glaciation of the Pasco Basin. The change would be after the glacier had left the Pasco Basin.

* Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on Dec. 1980

**Change in Path Length Due to Sea Flooding
Density Curve⁵³.**

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-40.00008010 to 40.00008010 error bounds on X

-40.00008010 to 40.00008010 values of X

Point by Point

Density Points :

0. .0600001239
1. .0700001430
2. .0800001621
3. .0900001811
4. .1000002026
5. .1100002288
6. .1300002694
7. .1350002765
8. .1250002503
9. .1000002026
10. .1000002026
11. .1000002026
12. .1250002503
13. .1350002765
14. .1300002694
15. .1100002288
16. .1000002026
17. .0900001811
18. .0800001621
19. .0700001430
20. .0600001239

Units for X kilometers

Source Donald Easterbrook *

The change in distance (km) that possible waste-bearing ground water must travel (in the unconfined aquifer of the Pasco Basin) due to flooding by the sea in the Pasco Basin. The change would be after the sea had retreated from the Pasco Basin.

*** Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on May 1980.**

**Change in Path Length Due to Volcanic Event
Density Curve⁵⁴.**

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

**-50.00010299 to 50.00010299 error bounds on X
-40.00008010 to 40.00008010 values of X**

Point by Point

Density Points :

0. .0600001239
1. .0700001430
2. .0800001621
3. .0900001811
4. .1000002026
5. .1100002288
6. .1300002694
7. .1350002765
8. .1250002503
9. .1000002026
10. .1000002026
11. .1000002026
12. .1250002503
13. .1350002765
14. .1300002694
15. .1100002288
16. .1000002026
17. .0900001811
18. .0800001621
19. .0700001430
20. .0600001239

Units for X kilometers

Source Donald Easterbrook *

The change in distance (km) that possible waste-bearing ground water must travel (in the unconfined aquifer of the Pasco Basin) due to a volcanic eruption in the Pasco Basin.

*** Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on May 1980.**

**Change in Path Length Due to Landsliding
Density Curve⁵⁵.**

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-40.00008010 to 40.00008010 error bounds on X
-4.00000810 to 4.00000810 values of X

Normal Curve

Density Points :

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X kilometers

Source Donald Easterbrook *

The change in distance (km) that possible waste-bearing ground-water must travel (in the unconfined aquifer of the Pasco Basin) due to a landslide near the Columbia River.

*** Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on May 1981.**

River Discharge for Climate State 1
Density Curve⁵⁶.

Submodel(s) :
Geomorphic Events

Data From The Literature
No transform on X

0.00000000 to 20000.04101562 error bounds on X
0.00000000 to 20000.04101562 values of X

Point by Point
Density Points :

0.	92.0001831054
1.	161.0003204345
2.	137.5002746582
3.	114.0002288818
4.	77.5001602172
5.	41.0000839233
6.	28.5000572204
7.	16.0000324249
8.	24.0000495910
9.	32.0000648498
10.	24.0000495910
11.	16.0000324249
12.	13.5000276565
13.	11.0000219345
14.	8.0000162124
15.	5.0000100135
16.	3.5000071525
17.	2.0000040531
18.	0.0000000000
19.	2.0000040531
20.	0.0000000000

Units for X meters**3 / second
Source Donald Easterbrook *

Columbia river discharge (m^3/sec) in an interglacial
climate state in the Pasco Basin.

* Unpublished consultant's report to PNL from Donald
Easterbrook of Western Washington University on May 1981.

**River Discharge for Climate State 2
Density Curve⁵⁷.**

Submodel(s) :

Geomorphic Events

Judgement and Data

No transform on X

0.00000000 to 200000.40625000 error bounds on X

0.00000000 to 32000.06445312 values of X

Point by Point

Density Points :

0.	92.0001831054
1.	161.0003204345
2.	137.5002746582
3.	114.0002288818
4.	77.5001602172
5.	41.0000839233
6.	28.5000572204
7.	16.0000324249
8.	24.0000495910
9.	32.0000648498
10.	24.0000495910
11.	16.0000324249
12.	13.5000276565
13.	11.0000219345
14.	8.0000162124
15.	5.0000100135
16.	3.5000071525
17.	2.0000040531
18.	0.0000000000
19.	2.0000040531
20.	0.0000000000

Units for X meter3 / second**

Source Donald Easterbrook *

Columbia River discharge (m3/sec) in a temperate
interstadial climate state in the Pasco Basin.**

*** Unpublished consultant's report to PNL from Donald
Easterbrook of Western Washington University on May 1981.**

River Discharge for Climate State 3
Density Curve 58.

Submodel(s) :
Geomorphic Events

Judgement and Data
No transform on X

0.00000000 to 200000.40625000 error bounds on X
0.00000000 to 44000.08984375 values of X

Point by Point
Density Points :

0.	92.0001831054
1.	161.0003204345
2.	137.5002746582
3.	114.0002288818
4.	77.5001602172
5.	41.0000839233
6.	28.5000572204
7.	16.0000324249
8.	24.0000495910
9.	32.0000648498
10.	24.0000495910
11.	16.0000324249
12.	13.5000276565
13.	11.0000219345
14.	8.0000162124
15.	5.0000100135
16.	3.5000071525
17.	2.0000040531
18.	0.0000000000
19.	2.0000040531
20.	0.0000000000

Units for X meter**3 / second
Source Donald Easterbrook *

Columbia River discharge (m^3/sec) in an interstadial
climate state in the Pasco Basin.

* Unpublished consultant's report to PNL from Donald
Easterbrook of Western Washington University on May 1981.

River Discharge for Climate State 4
Density Curve⁵⁹.

Submodel(s) :
Geomorphic Events

Data From The Literature
No transform on X

0.00000000 to 62000.12500000 error bounds on X
0.00000000 to 56000.11328125 values of X

Point by Point
Density Points :

0. .2000004053
1. .4000008106
2. .3400007009
3. .2800005722
4. .1900003910
5. .1000002026
6. .0700001430
7. .0400000810
8. .0600001239
9. .0800001621
10. .0600001239
11. .0400000810
12. .0350000715
13. .0300000619
14. .0200000405
15. .0100000202
16. 0.0000000000
17. .0100000202
18. 0.0000000000
19. .0100000202
20. 0.0000000000

Units for X meter**3 / second
Source Donald Easterbrook *

Columbia River discharge (m^3/sec) in a stadial climate in the Pasco Basin. The discharge includes ablation effects.

* Unpublished consultant's report to PNL from Donald Easterbrook of Western Washington University on May 1981.

Variance of Polynomial 13 in Climate 1
Density Curve 60.

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-.00010000 to 0.00000000 error bounds on X
-.00009280 to -.00005570 values of X

Normal Curve

Density Points :

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X meters / year

Source PNL -- Mike Foley and Gregg Petrie

Variance or error (m/yr) for polynomial number 13 during an
interglacial climate state.

**Variance of Polynomial 13 in Climate 2
Density Curve**

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

**-.00010000 to 0.00000000 error bounds on X
-.00009280 to -.00005557 values of X**

**Normal Curve
Density Points :**

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X meters / year

Source PNL -- Mike Foley and Gregg Petrie

**Variance or error (m/yr) for polynomial 13 during a
temperate interstadial climate state.**

Variance of Polynomial 13 in Climate 3
Density Curve⁶².

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-.00010000 to 0.00000000 error bounds on X
-.00009280 to -.00005570 values of X

Normal Curve

Density Points :

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X meters / year

Source PNL -- Mike Foley and Gregg Petrie

Variance or error (m/yr) for polynomial number 13 during an interstadial climate state.

Variance of Polynomial 13 in Climate 4
Density Curve 63.

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-.00011100 to .00010000 error bounds on X
-.00011100 to .00003710 values of X

Point by Point

Density Points :

0. 1.0000020265
1. 1.1000022888
2. 1.6000032424
3. 2.5000050067
4. 4.8000097274
5. 6.0000123977
6. 4.8000097274
7. 2.5000050067
8. 1.6000032424
9. 1.1000022888
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.2000024318
16. 1.6000032424
17. 2.0000040531
18. 2.0000040531
19. 1.6000032424
20. 1.2000024318

Units for X meter / year

Source PNL -- Mike Foley and Gregg Petrie

Variance or error (m/yr) for polynomial number 13 during a
stadial climate state.

**Missoula Flood Discharge
Density Curve⁶⁴.**

**Submodel(s) :
Geomorphic Events**

**Data From Expert Judgement
No transform on X**

**0.00000000 to 40000080.000000 error bounds on X
9100018.00000 to 21300044.000000 values of X**

**Normal Curve
Density Points :**

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X meter3 / second
Source Donald Easterbrook ***

Missoula-type flood discharge (m3/sec) into the Pasco
Basin.**

*** Unpublished consultant's report to PNL from Donald
Easterbrook of Western Washington University on Jan. 1981**

Variance of Polynomial Number 14
Density Curve 65.

Submodel(s) :

Geomorphic Events

Variance - For Future Use

No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters

Source Donald Easterbrook

Variance or error (m) of polynomial number 14.

**Change in Gradient Due to Missoula Flooding
Density Curve 66.**

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-.00100000 to .00100000 error bounds on X
0.00000000 to 0.00000000 values of X

**Uniform Curve
Density Points :**

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / meters

Source Donald Easterbrook *

**Change in gradient (m/m) of the Columbia River in the Pasco
Basin due to Missoula-type flooding.**

*** Unpublished consultant's report to PNL from Donald
Easterbrook of Western Washington University on May 1981.**

**Change in Path Length From Missoula Flooding
Density Curve⁶⁷.**

Submodel(s) :

Geomorphic Events

Data From Expert Judgement

No transform on X

-40.00008010 to 40.00008010 error bounds on X

-40.00008010 to 40.00008010 values of X

Normal Curve

Density Points :

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X kilometers

Source Donald Easterbrook *

**The change in distance (km) that possible waster-bearing
ground water must travel (in the unconfined aquifer in the
Pasco Basin) due to Missoula-type flooding.**

*** Unpublished consultant's report to PNL from Donald
Easterbrook of Western Washington University on May 1981.**

**Deposition During a Missoula Flood
Density Curve 68.**

**Submodel(s) :
Geomorphic Events**

**Data From Expert Judgement
No transform on X**

0.000000000 to 100.00020599 error bounds on X
0.000000000 to 100.00020599 values of X

**Point by Point
Density Points :**

0. 0.000000000
1. .0470600986
2. .1353002667
3. .2235004425
4. .1588003396
5. .0941201972
6. .0882401752
7. .0823501682
8. .0529401063
9. .0235300493
10. .0176500368
11. .0117600250
12. .0058820123
13. 0.0000000000
14. .0058820123
15. .0117600250
16. .0058820123
17. 0.0000000000
18. .0058820123
19. .0117600250
20. .0176500368

**Units for X meters
Source Donald Easterbrook ***

**Deposition (m) in the Pasco Basin during a Missoula-type
flood. Erosion is accounted for polynomial number 14.**

*** Unpublished consultant's report to PNL from Donald
Easterbrook of Western Washington University on Oct. 1980**

H.C. of Sediments in The Pasco Basin
Density Curve 69.

Submodel(s) :

Undctected Features

Data From Expert Judgement

No transform on X

-1.00000202 to 150.00030517 error bounds on X
0.00000000 to 147.30030822 values of X

Point by Point
Density Points :

0.	0.0000000000
1.	95.1601943969
2.	1.2100025415
3.	1.2100025415
4.	0.0000000000
5.	0.0000000000
6.	0.0000000000
7.	.4000008106
8.	.8100016593
9.	0.0000000000
10.	.4000008106
11.	0.0000000000
12.	0.0000000000
13.	.4000008106
14.	0.0000000000
15.	0.0000000000
16.	0.0000000000
17.	0.0000000000
18.	0.0000000000
19.	0.0000000000
20.	0.0000000000

Units for X meters / day

Source PNL -- Charles Cole & Alan Baldwin

Hydraulic Conductivity (m/day) of the unconfined aquifer in
the Pasco Basin.

**H.C. of Aquitard Near Vantage Horizon S.W.
Density Curve 70.**

Submodel(s) :

Undetected Features

Data From Expert Judgement

Log transform on X

-6.00001239 to 17.50003623 error bounds on X
-5.29801082 to .55960111 values of X

Point by Point

Density Points :

0. .0150000309
1. .0171600356
2. .0196200380
3. .0224400448
4. .0256600522
5. .0293500614
6. .0335600686
7. .0383800821
8. .0438900899
9. .0506901025
10. .0586801242
11. .0679201364
12. .0786201620
13. .0910101795
14. .1047002077
15. .0902501869
16. .0778001546
17. .0670701313
18. .0515601062
19. .0136300277
20. .0030005061

Units for X meters / day

Source James W. Crosby *

Hydraulic Conductivity (m/day) of aquitard near the Vantage horizon in the southwest recharge area.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980

**H.C. of Vantage Horizon in Pasco Basin
Density Curve⁷¹.**

Submodel(s) :

Undetected Features

Data From Expert Judgement

No transform on X

0.00000000 to 3.00000619 error bounds on X
0.00000000 to 3.00000619 values of X

**Point by Point
Density Points :**

0. .0128700256
1. .0225300478
2. .0321800684
3. .0482700967
4. .0643601369
5. .0804501628
6. .0901001834
7. .0997602081
8. .1094002246
9. .1017002105
10. .0852801704
11. .0688601446
12. .0537401103
13. .0411900806
14. .0286400585
15. .0160900344
16. .0131900286
17. .0103000211
18. .0074010152
19. .0066710138
20. .0070220141

Units for X meters / day

Source James W. Crosby *

The hydraulic conductivity (m/day) of the Vantage horizon in the Pasco Basin.

*** Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980**

**H.C. of Aquitard Near Vantage Horizon NE
Density Curve⁷².**

Submodel(s) :

Undetected Features

Data From Expert Judgement

Log transform on X

-6.00001239 to 17.50003623 error bounds on X
-5.29801082 to .55960111 values of X

**Point by Point
Density Points :**

0. .0150000309
1. .0171600356
2. .0196200380
3. .0224400448
4. .0256600522
5. .0293500614
6. .0335600686
7. .0383800821
8. .0438900899
9. .0506901025
10. .0586801242
11. .0679201364
12. .0786201620
13. .0910101795
14. .1047002077
15. .0902501869
16. .0778001546
17. .0670701313
18. .0515601062
19. .0136300277
20. .0030010063

Units for X meters / day

Source James W. Crosby *

**Hydraulic conductivity (m/day) of the aquitard near the
Vantage horizon in the northeast recharge area.**

*** Unpublished consultant's report to PNL from James W.
Crosby III of Washington State University on Aug. 1980**

**H.C. of Wanapum-Saddle Basalts in The SW
Density Curve⁷³.**

Submodel(s) :

Undetected Features

Data From Expert Judgement

No transform on X

-1.000000202 to 50.00010299 error bounds on X
0.000000000 to .01431502 values of X

**Point by Point
Density Points :**

0.	0.0000000000
1.	40.2400817871
2.	18.1200370788
3.	11.7600240707
4.	11.2900228500
5.	7.7600159645
6.	1.1800023365
7.	1.6500033378
8.	2.1200041770
9.	.9400018692
10.	.2400004863
11.	.2400004863
12.	.7100014209
13.	.9400018692
14.	.4700009346
15.	0.0000000000
16.	.9400018692
17.	.9400018692
18.	0.0000000000
19.	.2400004863
20.	0.0000000000

Units for X meters /day

Source PNL -- Charles Cole & Alan Baldwin

**The hydraulic conductivity (m/day) of the Wanapum and Saddle
Mountain formations in the southwest recharge area.**

H.C of Wanapum-Saddle Basalts in Pasco Basin

Density Curve⁷⁴.

Submodel(s) :

Undetected Features

Data From Expert Judgement

No transform on X

-1.00000202 to 50.00010299 error bounds on X

0.00000000 to .01431502 values of X

Point by Point

Density Points :

0. 0.0000000000
1. 40.2400817871
2. 18.1200370788
3. 11.7600240707
4. 11.2900228500
5. 7.7600159645
6. 1.1800023365
7. 1.6500033378
8. 2.1200041770
9. .9400018692
10. .2400004863
11. .2400004863
12. .7100014209
13. .9400018692
14. .4700009346
15. 0.0000000000
16. .9400018692
17. .9400018692
18. 0.0000000000
19. .2400004863
20. 0.0000000000

Units for X meters /day

Source PNL -- Charles Cole & Alan Baldwin

The hydraulic conductivity (m/day) of the Wanapum and Saddle Mountain formations in the Pasco Basin.

**H.C. of Wanapum-Saddle Basalts in the NE
Density Curve⁷⁵.**

Submodel(s) :

Undetected Features

Data From Expert Judgement

No transform on X

**-1.00000202 to 50.00010299 error bounds on X
0.00000000 to .01431502 values of X**

**Point by Point
Density Points :**

0. 0.0000000000
1. 40.2400817871
2. 18.1200370788
3. 11.7600240707
4. 11.2900228500
5. 7.7600159645
6. 1.1800023365
7. 1.6500033378
8. 2.1200041770
9. .9400018692
10. .2400004863
11. .2400004863
12. .7100014209
13. .9400018692
14. .4700009346
15. 0.0000000000
16. .9400018692
17. .9400018692
18. 0.0000000000
19. .2400004863
20. 0.0000000000

Units for X meters / day

Source PNL -- Charles Cole & Alan Baldwin

**The hydraulic conductivity (m/day) of the Wanapum Formation
in the northeast recharge area.**

H.C. of Grande Ronde Basalts in the SW
Density Curve⁷⁶.

Submodel(s) :

Undetected Features

Data From Relative Frequency

No transform on X

-1.00000202 to 50.00010299 error bounds on X
0.00000000 to .00349230 values of X

Point by Point

Density Points :

0.	0.0000000000
1.	60.1801223754
2.	5.0500102043
3.	4.3200087547
4.	3.4200069904
5.	2.5200049877
6.	3.9600081443
7.	3.0600061416
8.	2.1600043773
9.	1.4400029182
10.	1.2600024938
11.	1.6200033664
12.	1.4400029182
13.	1.4400029182
14.	1.0800021934
15.	1.4400029182
16.	1.0800021934
17.	.5400011062
18.	.9000018119
19.	1.4400029182
20.	1.6200033664

Units for X meters / day

Source PNL -- Charles Cole & Alan Baldwin

The hydraulic conductivity (m/day) of the Grande Ronde
formation in the southwest recharge area.

H.C. of Grande Ronde Basalts in Pasco Basin
Density Curve⁷⁷.

Submodel(s) :

Undetected Features

Data From Expert Judgement

No transform on X

-1.00000202 to 50.00010299 error bounds on X
0.00000000 to .00349230 values of X

Point by Point
Density Points :

0.	0.0000000000
1.	60.1801223754
2.	5.0500102043
3.	4.3200087547
4.	3.2400066852
5.	2.5200049877
6.	3.9600081443
7.	3.0600061416
8.	2.1600043773
9.	1.4400029182
10.	1.2600024938
11.	1.6200033664
12.	1.4400029182
13.	1.4400029182
14.	1.0800021934
15.	1.4400029182
16.	1.0800021934
17.	.5400011062
18.	.9000018119
19.	1.4400029182
20.	1.6200033664

Units for X meters / day

Source PNL -- Charles Cole & Alan James Baldwin

The hydraulic conductivity (m/day) of the Grande Ronde
formation in the Pasco Basin.

H.C. of Grande Ronde Basalts in the NE
Density Curve⁷⁸.

Submodel(s) :

Undetected Features

Data From Relative Frequency

No transform on X

-1.00000202 to 50.00010299 error bounds on X
0.00000000 to .00349230 values of X

Point by Point

Density Points :

0.	0.000000000
1.	60.1801223754
2.	5.0500102043
3.	4.3200087547
4.	3.2400066852
5.	2.5200049877
6.	3.9600081443
7.	3.0600061416
8.	2.1600043773
9.	1.4400029182
10.	1.2600024938
11.	1.6200033664
12.	1.4400029182
13.	1.4400029182
14.	1.0800021934
15.	1.4400029182
16.	1.0800021934
17.	.5400011062
18.	.9000018119
19.	1.4400029182
20.	1.6200033664

Units for X meters / day

Source PNL -- Charles Cole & Alan Baldwin

The hydraulic conductivity (m/day) of the Grande Ronde
formation in the northeast recharge area.

SW Discharge Point, Frac. Dist from Basin SW
Density Curve 79.

Submodel(s) :

Undetected Features

Data From Expert Judgement

No transform on X

0.000000000 to .60700125 error bounds on X
.49700102 to .60700125 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X unitless

Source PNL -- Alan Baldwin & Gregg Petrie

Confined aquifer ground water from the southwest recharge area discharges to the unconfined aquifer in the Pasco Basin at one point along the model cross section between the southwest edge of the Pasco Basin and the site (strictly schematic representation for modeling purposes only). Curve 79 is the fractional distance along the MCS (from the southwest edge of the Pasco Basin to the northeast edge of the Pasco Basin) and locates a representative discharge point.

NE Discharge Point, Frac. Dist From Basin SW
Density Curve 80.

Submodel(s) :

Undetected Features

Data From Expert Judgement

No transform on X

.37000074 to 1.00000202 error bounds on X
.60700125 to .63000125 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X unitless

Source PNL -- Alan Baldwin & Gregg Petrie

Confined aquifer ground water from the northeast recharge area discharges to the unconfined aquifer in the Pasco Basin to one point along the model cross section between the north east edge of the Pasco Basin and the site (strictly schematic representation for modeling purposed only). Curve 80 is the fractional distance along the MCS (from the southwest edge of the Pasco Basin to the northeast edge of the Pasco Basin) and locates a representative discharge point.

**Trend of Local Faults in Degrees From North
Density Curve⁸¹.**

Submodel(s) :

Undetected Features

Judgement and Data

No transform on X

-90.00018310 to 90.00018310 error bounds on X

-90.00018310 to 90.00018310 values of X

Point by Point

Density Points :

0. 3.0000061988
1. 6.0000123977
2. 1.0000020265
3. 9.0000181198
4. 1.0000020265
5. 1.0000020265
6. 17.0000343322
7. 8.0000162124
8. 17.0000343322
9. 8.0000162124
10. 17.0000343322
11. 1.0000020265
12. 1.0000020265
13. 6.0000123977
14. 1.0000020265
15. 1.0000020265
16. 5.0000100135
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 3.0000061988

Units for X degrees

Source Robert D. Bentley *

**Trend of the local fault system in the Pasco Basin measured
in degrees from the north.**

*** Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Aug. 1980.**

**Distance Between Local Faults of Pasco Basin
Density Curve⁸².**

Submodel(s) :

Undetected Features

Judgement and Data

No transform on X

1.00000202 to 25.00005149 error bounds on X
3.00000619 to 5.00001001 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X kilometers

Source Robert D. Bentley *

Distance (km) between the local faults of the Pasco Basin.

*** Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.**

**Width of a Local Fault Zone
Density Curve⁸³.**

Submodel(s) :

**Undetected Features
Deformation**

Judgement and Data

Log transform on X

-1.00000202 to 3.00000619 error bounds on X
0.00000000 to 2.00000405 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters

Source Robert D. Bentley *

Width (m) of typical local fault zone in the Pasco Basin.

*** Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.**

**Local Fault Trend Variation
Density Curve⁸⁴.**

Submodel(s) :
Undetected Features
Deformation

Judgement and Data

No transform on X

-40.00008010 to 40.00008010 error bounds on X
-20.00004005 to 20.00004005 values of X

**Normal Curve
Density Points :**

0.	.0044320092
1.	.0104200220
2.	.0223900461
3.	.0439800882
4.	.0789501619
5.	.1295002698
6.	.1942003822
7.	.2661005258
8.	.3332006931
9.	.3814007759
10.	.3989008235
11.	.3814007759
12.	.3332006931
13.	.2661005258
14.	.1942003822
15.	.1295002698
16.	.0789501619
17.	.0439800882
18.	.0223900461
19.	.0104200220
20.	.0044320092

Units for X degrees
Source Robert D. Bentley *

Trend variation (degrees) of local fault zone in the Pasco Basin. This variable is the error or variation of the determined value of density curve number 81.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.

**Time Between Local Faulting Events in Basin
Density Curve⁸⁵.**

Submodel(s) :

**Undetected Features
Deformation**

Judgement and Data

Log transform on X

4.00000810 to 8.00001621 error bounds on X
5.00001001 to 7.00001430 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X years

Source Robert D. Bentley *

The time (yr) between local earthquakes in the Pasco Basin.

*** Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Aug. 1980.**

**Width of a Thrust Fault Zone
Density Curve⁸⁶.**

Submodel(s) :

**Undetected Features
Deformation**

Judgement and Data

Log transform on X

-4.000000810 to 2.000000405 **error bounds on X**
-3.000000619 to 1.000000202 **values of X**

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters

Source Robert D. Bentley *

The width (m) of the typical thrust fault zone in the Pasco Basin.

*** Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.**

**Time Between Thrust Fault Movements
Density Curve⁸⁷.**

Submodel(s) :

Undetected Features
Deformation

Judgement and Data

Log transform on X

3.00000619	to 7.00001430	error bounds on X
4.00000810	to 6.00001239	values of X

Normal Curve

Density Points :

0.	.0044320092
1.	.0104200220
2.	.0223900461
3.	.0439800882
4.	.0789501619
5.	.1295002698
6.	.1942003822
7.	.2661005258
8.	.3332006931
9.	.3814007759
10.	.3989008235
11.	.3814007759
12.	.3332006931
13.	.2661005258
14.	.1942003822
15.	.1295002698
16.	.0789501619
17.	.0439800882
18.	.0223900461
19.	.0104200220
20.	.0044320092

Units for X years

Source Robert D. Bentley *

Time (yr) between thrust fault earthquakes in the Pasco Basin.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.

**Width of New Faults in SW Fault System
Density Curve**

Submodel(s) :

Undetected Features

Judgement and Data

Log transform on X

0.00000000 to 2.00000405 error bounds on X
.48000097 to 1.48000302 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters

Source Robert D. Bentley *

Width (m) of newly created Fault zone in the southwest fault system. The southwest fault system is the area southwest of the Pasco Basin between the Pasco Basin and the model boundary.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.

**Width of New Faults in NE Fault System
Density Curve⁸⁹.**

Submodel(s) :

Undetected Features

Data From Expert Judgement

Log transform on X

-.22000045 to 3.00000619

error bounds on X

.77000155 to 2.78000569

values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters

Source Robert D. Bentley *

Width (m) of newly created fault zone in the northeast fault system. The northeast fault system is the area northeast of the Pasco Basin between the Pasco Basin and the model boundary.

*** Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.**

**Time Between SW Faulting Events
Density Curve⁹⁰.**

Submodel(s) :

**Undetected Features
Deformation**

Judgement and Data

Log transform on X

4.00000810 to 8.00001621 error bounds on X
5.00001001 to 7.00001430 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X years

Source Robert D. Bentley *

Time (yr) between earthquakes in the southwest fault system.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.

**Time Between NE Faulting Events
Density Curve⁹¹.**

Submodel(s) :

**Undetected Features
Deformation**

Judgement and Data

Log transform on X

4.00000810 to 8.00001621 error bounds on X
5.00001001 to 7.00001430 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X years

Source Robert D. Bentley *

Time (yr) between earthquakes in the northeast fault system.

*** Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Aug. 1980.**

Distance of Discharge Arc to Discharge Point
Density Curve 92.

Submodel(s) :

Undetected Features

Judgement and Data

No transform on X

0.000000000 to 180.00036621 error bounds on X

50.00010299 to 110.00022125 values of X

Point by Point

Density Points :

0. .0000010000
1. .0000013000
2. .0000016000
3. .0000019000
4. .0000022000
5. .0000025000
6. .0000028000
7. 30.6000633239
8. 32.4000663757
9. 31.8000640869
10. .0000030000
11. .0000027000
12. .0000024000
13. .0000021000
14. .0000018000
15. .0000015000
16. .0000012000
17. .0000009000
18. .0000006000
19. .0000003000
20. .0000002000

Units for X degrees

Source PNL -- Alan Baldwin & Gregg Petrie

The unconfined aquifer discharges to the Columbia River and the discharge arc are schematic representations of the Columbia River. Curve 92 is the fractional distance along the discharge point (starting at the northwest end and moving along the arc clockwise).

Northern Dip of New Anticline
Density Curve⁹³.

Submodel(s) :
Fold Creation

Judgement and Data
No transform on X

0.00000000 to 90.00018310 error bounds on X
0.00000000 to 90.00018310 values of X

Point by Point
Density Points :

0.	0.0000000000
1.	4.0000081062
2.	8.0000162124
3.	12.0000247955
4.	15.0000305175
5.	20.0000400543
6.	24.0000495910
7.	29.0000591278
8.	34.0000686645
9.	42.0000839233
10.	52.0001068115
11.	62.0001258850
12.	72.0001449584
13.	84.0001678466
14.	95.0001907348
15.	100.0002059936
16.	96.0001983642
17.	80.0001602172
18.	32.0000648498
19.	12.0000247955
20.	0.0000000000

Units for X degrees
Source Robert D. Bentley *

Dip (degrees) of the northern limb of a newly created fold
(anticline).

* Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Sep. 1980.

**Eastern Plunge of New Anticline
Density Curve⁹⁴.**

Submodel(s) :

Fold Creation

Judgement and Data

No transform on X

0.000000000 to 45.00009155 error bounds on X
1.00000202 to 12.00002479 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X degrees

Source Robert D. Bentley *

**Eastern plunge angle (degrees) of the fold axis of a newly
created anticline.**

*** Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Sep. 1980.**

**Southern Dip of New Anticline
Density Curve 95.**

**Submodel(s) :
Fold Creation**

**Judgement and Data
No transform on X**

0.00000000 to 90.00018310 error bounds on X
5.00001001 to 55.00011062 values of X

**Normal Curve
Density Points :**

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X degrees

Source Robert D. Bentley *

**Dip (degrees) of the southern limb of a newly created
anticline.**

*** Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Sep. 1980.**

**Western Plunge of New Anticline
Density Curve⁹⁶.**

Submodel(s) :

Fold Creation

Judgement and Data

No transform on X

0.000000000 to 45.00009155 error bounds on X
1.00000202 to 12.00002479 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X degrees

Source Robert D. Bentley *

**Western plunge angle (degrees) of the fold axis of a newly
created anticline.**

*** Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Sep. 1980.**

**Angle Between New Fold and Local Fault Trend
Density Curve 97.**

Submodel(s) :

Fold Creation

Judgement and Data

No transform on X

0.00000000 to 90.00018310 error bounds on X
0.00000000 to 90.00018310 values of X

Point by Point

Density Points :

0. 5.0000100135
1. 4.8000097274
2. 4.0000081062
3. 2.8000057220
4. 1.7000035285
5. 1.0000020265
6. .6000012397
7. .4000008106
8. .3000006198
9. .2000004053
10. .2000004053
11. .2000004053
12. .3000006198
13. .5000010013
14. .7000014305
15. 1.0000020265
16. 2.2000045776
17. 5.0000100135
18. 7.6000151634
19. 8.5000171661
20. 9.0000181198

Units for X degrees

Source Robert D. Bentley *

Angle (degrees) (in the horizontal plane) between the local fault trend (determined by density curve 81) and a newly created anticline. This logic assumes there is a tectonic relationship between the faults and folds of the Pasco Basin

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.

Fraction of FOLDMX For Fold Position Vector
Density Curve⁹⁸.

Submodel(s) :

Fold Creation

Data From Expert Judgement

No transform on X

0.00000000 to 1.00000202 error bounds on X
0.00000000 to 1.00000202 values of X

Position Vector

Density Points :

0. 0.0000000000
1. 1.0000020265
2. 2.0000040531
3. 3.0000061988
4. 4.0000081062
5. 5.0000100135
6. 6.0000123977
7. 7.0000143051
8. 8.0000162124
9. 9.0000181198
10. 10.0000200271
11. 11.0000219345
12. 12.0000247955
13. 13.0000267028
14. 14.0000286102
15. 15.0000305175
16. 16.0000324249
17. 17.0000343322
18. 18.0000362396
19. 19.0000381469
20. 20.0000400543

Units for X unitless

Source PNL -- Gregg Petrie

The length of the "fold position vector". The length of the vector is a fraction of the scalar variable FOLDMX (which is the maximum distance from the repository site for a new fold). The vector starts at the repository site and ends at the fold center.

Angle From North For Fold Position Vector
Density Curve 99.

Submodel(s) :
Fold Creation

Data From Expert Judgement

No transform on X

0.00000000 to 360.00073242 error bounds on X
0.00000000 to 360.00073242 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X degrees

Source PNL -- Gregg Petrie

The angle (degrees) from the north in the horizontal plane for the trend of the "fold position vector". The vector starts at the repository site and ends at the new fold center.

Fraction of FMAXD For Fault Position Vector
Density Curve 100.

Submodel(s) :

Fault Creation

Data From Expert Judgement

No transform on X

0.00000000 to 1.00000202 error bounds on X
0.00000000 to 1.00000202 values of X

Position Vector

Density Points :

0. 0.0000000000
1. 1.0000020265
2. 2.0000040531
3. 3.0000061988
4. 4.0000081062
5. 5.0000100135
6. 6.0000123977
7. 7.0000143051
8. 8.0000162124
9. 9.0000181198
10. 10.0000200271
11. 11.0000219345
12. 12.0000247955
13. 13.0000267028
14. 14.0000286102
15. 15.0000305175
16. 16.0000324249
17. 17.0000343322
18. 18.0000362396
19. 19.0000381469
20. 20.0000400543

Units for X unitless

Source PNL -- Gregg Petrie

The length of the "sub-basalt basement fault position vector". The length of the vector is a fraction of the values of scalar variable FMAXD (which is the maximum distance from the repository site). It ends at the sub-basalt basement fault and is perpendicular to the sub-basalt basement fault trend.

Angle From North For Fault Position Vector

Density Curve 101.

Submodel(s) :

Fault Creation

Data From Expert Judgement

No transform on X

0.00000000 to 360.00073242 error bounds on X

0.00000000 to 360.00073242 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X degrees

Source PNL -- Gregg Petrie

The angle (degrees) from the north in the horizontal plane for the trend of the "sub-basalt basement fault position vector". The vector starts at the repository site, ends at the sub-basalt fault, and is perpendicular to the sub-basalt basement fault trend.

**Time Between Sub-Basalt Faulting Events
Density Curve 102.**

Submodel(s) :

Sub-Basalt Faulting
Fault Creation

Data From Transformation

No transform on X

0.000000000 to 400.00082397 error bounds on X
.01445402 to 12.00002479 values of X

Exponential Form

Density Points :

0. .0144540286
1. .0116080236
2. .0093221187
3. .0074864153
4. .0060122122
5. .0048283095
6. .0038776078
7. .0031140062
8. .0025008049
9. .0020084037
10. .0016129033
11. .0012953026
12. .0010402021
13. .0008354018
14. .0006709012
15. .0005387911
16. .0004326909
17. .0003474906
18. .0002790605
19. .0002241104
20. .0001799803

Units for X years

Source Lawrence H. Wight *

Time (yr) between sub-basalt basement earthquakes.
(Assuming earthquake acceleration threshold of 5.5 Richter
Magnitude.)

* See Wight, L. H., Appendix B.

Variance of Polynomial Number 15
Density Curve 103.

Submodel(s) :
Fault Creation

Variance - For Future Use
No transform on X

0.000000000 to 0.000000000 error bounds on X
0.000000000 to 0.000000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X unitless
Source PNL -- Gregg Petrie

Variance or error for polynomial number 15.

Magnitude of Sub-Basalt Faulting Event
Density Curve 104.

Submodel(s) :

Sub-Basalt Faulting

Data From Transformation

No transform on X

2.00000405 to 9.00001811 error bounds on X
5.50001096 to 8.00001621 values of X

Point by Point

Density Points :

0. .2995005893
1. .2121004343
2. .1247002601
3. .1018002152
4. .0778781557
5. .0557951116
6. .0328120684
7. .0267660570
8. .0207210421
9. .0146760296
10. .0086301174
11. .0070401148
12. .0054500117
13. .0038600082
14. .0022700047
15. .0018517039
16. .0014335029
17. .0010153021
18. .0005970613
19. .0001788303
20. .0000001000

Units for X Richter Magnitude

Source Lawrence H. Wight *

Richter magnitude of sub-basalt basement earthquake.

*** See Wight, L. H., Appendix B.**

Variance of Function CHHCFT
Density Curve 105.

Submodel(s) :

Sub-Basalt Faulting

Variance - For Future Use

No transform on X

1.00000202 to 1.00000202

error bounds on X

1.00000202 to 1.00000202

values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / day

Source PNL --- Gregg Petrie and Mike Foley

Variance or error (m/day) of Function CHHFCT.

Subsidence Rate of The Pasco Basin

Density Curve 106.

Submodel(s) :

Deformation

Data From The Literature

Log transform on X

-8.00001621 to -3.00000619 error bounds on X

-7.00001430 to -4.00000810 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year

Source Robert D. Bentley *

Subsidence rate (m/yr) of the Pasco Basin.

(Note: This is the absolute value of the subsidence rate. The model subtracts this number from elevation. The value cannot give a negative value as it is log transformed.)

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.

**Uplift Rate of Rattlesnake Ridge
Density Curve 107.**

Submodel(s) :
Deformation

Judgement and Data
Log transform on X

-8.000001621 to -3.000000619 error bounds on X
-7.000001430 to -4.000000810 values of X

Normal Curve
Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year
Source Robert D. Bentley *

**Uplift rate (m/yr) of Rattlesnake and Yakima Ridge
structures.**

* Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Sep. 1980.

**Uplift Rate For Saddle Mountains Structure
Density Curve 108.**

**Submodel(s) :
Deformation**

**Judgement and Data
Log transform on X**

-8.00001621 to -3.00000619 error bounds on X
-7.00001430 to -3.00000619 values of X

**Normal Curve
Density Points :**

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

**Units for X meters / year
Source Robert D. Bentley ***

Uplift rate (m/yr) for Saddle Mountains structure.

*** Unpublished consultant's report to PNL from Robert D.
Bentley of Central Washington University on Sep. 1980.**

**Uplift Rate For Gable Mountain Structure
Density Curve 109.**

Submodel(s) :

Deformation

Judgement and Data

Log transform on X

-8.00001621 to -3.00000619 error bounds on X
-7.00001430 to -4.00000810 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year

Source Robert D. Bentley *

Uplift rate (m/yr) for Gable Mountain and Umtanum Ridge structures.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.

**Uplift Rate For Horse Heaven Hills Structure
Density Curve 110.**

Submodel(s) :

Deformation

Judgement and Data

Log transform on X

-8.000001621 to -3.000000619 error bounds on X
-7.000001430 to -4.000000810 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / year

Source Robert D. Bentley *

Uplift rate (m/yr) for Horse Heaven Hills structure.

* Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.

H.C. Increase From Saddle Mountains Activity
Density Curve 111.

Submodel(s) :

Deformation

Judgement and Data

No transform on X

-10.00002002 to 1.00000202 error bounds on X
-.01000002 to -.00100000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X unitless

Source James W. Crosby *

Increase in hydraulic conductivity (fraction of starting value) of Pasco Basin Basalts due to earthquakes in the Saddle Mountains structure.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

H.C. Increase From Gable Mountain Activity
Density Curve¹¹².

Submodel(s) :

Deformation

Judgement and Data

No transform on X

-10.000002002 to 1.00000202 error bounds on X
-.030000006 to -.00100000 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X unitless

Source James W. Crosby *

Increase in hydraulic conductivity (fraction of starting value) of Pasco Basin Basalts due to earthquakes in the Gable Mountain or Umtanum Ridge structures.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

H.C. Increase From Rattlesnake Mtn. Activity
Density Curve 113.

Submodel(s) :

Deformation

Judgement and Data

No transform on X

-10.000002002 to 1.00000202 error bounds on X
-.020000004 to -.01000002 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / day

Source James W. Crosby *

Increase in hydraulic conductivity (fraction of starting value) of Pasco Basin Basalts due to earthquakes in Rattlesnake or Yakima Ridge structures.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

H.C. Change Due to Local Faulting Event
Density Curve 114.

Submodel(s) :
Deformation

Judgement and Data
No transform on X

-1.000000202 to .001000000 error bounds on X
-.09070018 to -.02200004 values of X

Point by Point
Density Points :

0.	70.0001449584
1.	66.3801345825
2.	62.9601249694
3.	59.7101211547
4.	56.6201133728
5.	53.7001113891
6.	50.9301033020
7.	48.3000984191
8.	45.8100929260
9.	43.4400863647
10.	41.2000846862
11.	39.0700798034
12.	37.0600776672
13.	35.1400718688
14.	33.3300704956
15.	31.6100654602
16.	29.9800605773
17.	28.4300575256
18.	26.9600543975
19.	25.5700511932
20.	24.2500495910

Units for X meters / day
Source James W. Crosby *

Hydraulic conductivity change (m/day) of Pasco Basin Basalts
due to local earthquakes in the Pasco Basin.

* Unpublished consultant's report to PNL from James W.
Crosby III of Washington State University on Aug. 1980.

**H.C. Change Due to Thrust Faulting
Density Curve** 115.

Submodel(s) :
Deformation

Test Data

No transform on X

-.00100000 to .00100000 error bounds on X
-.00010000 to .00010000 values of X

**Normal Curve
Density Points :**

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / day
Source James W. Crosby *

**Change of hydraulic conductivity (m/day) of Pasco Basin
Basalts due to thrust fault earthquakes in the Pasco Basin.**

* Unpublished consultant's report to PNL from James W.
Crosby III of Washington State University on Aug. 1980.

**Displacement Per Thrusting Event
Density Curve 116.**

**Submodel(s) :
Deformation**

Judgement and Data

Log transform on X

-1.50000309 to 2.48000502 error bounds on X
-.52000107 to 1.48000302 values of X

**Normal Curve
Density Points :**

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters

Source Robert D. Bentley *

Fault displacement during a thrusting event.

*** Unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.**

Fold Uplift Rate
Density Curve 117.

Submodel(s) :
Deformation

Data From Expert Judgement
No transform on X

-1.53000307 to 2.48000502 error bounds on X
0.00000000 to .00013400 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters /year

Source PNL -- M. Foley, G. Petrie & R. Bentley *

Anticline uplift rate (m/yr). This rate is for existing anticlines within the Pasco Basin, as well as for newly created folds.

* The new rate came from Mike Foley and Gregg Petrie on February 26, 1981. The original rates came from an unpublished consultant's report to PNL from Robert D. Bentley of Central Washington University on Sep. 1980.

H.C. Increase During Fold Growth
Density Curve 118.

Submodel(s) :

Deformation

Data From Relative Frequency

Log transform on X

-20.000004005 to -1.000000202 error bounds on X
-19.02003860 to -7.50601530 values of X

Point by Point
Density Points :

0. .0050955104
1. .0197450389
2. .0343950724
3. .0490451002
4. .0636941242
5. .0764331579
6. .0891721820
7. .1019002079
8. .1146002292
9. .0987262058
10. .0828031826
11. .0668791294
12. .0509551048
13. .0414010858
14. .0318470621
15. .0222920441
16. .0127390265
17. .0114650237
18. .0101910209
19. .0089172182
20. .0076433153

Units for X meters / day / year

Source James W. Crosby

The annual increase of hydraulic conductivity (m/day/yr)
during active fold growth.

**HC Change In NE Fault With Each Fault Event
Density Curve 119.**

Submodel(s) :

Deformation

Data From Expert Judgement

No transform on X

-.25000050 to 1.25000250 error bounds on X
-.25000050 to 1.25000250 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / day

Source James W. Crosby *

Change in the hydraulic conductivity (m/day) of the representative fault in the northeast fault system for each earthquake. The representative fault is the sum of all the faults in the northeast fault system, and the effects of northeast fault system earthquakes are addressed as if the effects were from one large fault.

*** Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.**

HC Change In SW Fault With Each Fault Event
Density Curve 120.

Submodel(s) :

Deformation

Data From Expert Judgement

No transform on X

-1.75000357 to 1.75000357 error bounds on X
.25000050 to 1.75000357 values of X

Normal Curve

Density Points :

0. .0044320092
1. .0104200220
2. .0223900461
3. .0439800882
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439800882
18. .0223900461
19. .0104200220
20. .0044320092

Units for X meters / day

Source James W. Crosby *

Change in the hydraulic conductivity (m/day) of the representative fault in the southwest fault system for each earthquake. The representative fault is the sum of all the faults in the southwest fault system, and the effects of southwest fault system earthquakes are addressed as if the effect were from one large fault.

* Unpublished consultant's report to PNL from James W. Crosby III of Washington State University on Aug. 1980.

Variance of Polynomial Number 20
Density Curve¹²¹.

Submodel(s) :
Hydrology

Variance - For Future Use
No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

0.000 0.000
centimeters / year

Units for X centimeters / year
Source PNL -- Gregg Petrie

Variance or error (cm/yr) of polynomial 20.

Variance of Polynomials 21 to 24

Density Curve 122.

Submodel(s) :

Hydrology

Variance - For Future Use

No transform on X

0.00000000 to 0.00000000 error bounds on X

0.00000000 to 0.00000000 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters

Source James W. Crosby

Variation or error (m) for polynomial numbers 21 through 24.

Variance of Polynomials 25 to 28
Density Curve 123.

Submodel(s) :
Hydrology

Variance - For Future Use
No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters
Source James W. Crosby

Variation or error (m) for polynomial number 25 through 28.

Speed of Unconfined Ground Water, Climate 1
Density Curve 124.

Submodel(s) :
Hydrology

See Text For Explanation
No transform on X

-4.00000810 to 10000.02050781 error bounds on X
150.00030517 to 300.00061035 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / day

Source PNL -- Andy Reisenaur & Alan Baldwin

Velocity (m/day) of ground water in the unconfined aquifer during an interglacial climate state.

Note: According to Andy Reisenaur, the velocities through the unconfined aquifer can vary widely, depending where the repository is sited. This curve represents the 'worst case' estimate only.

**Speed of Unconfined Ground Water, Climate 2
Density Curve 125.**

Submodel(s) :

Hydrology

See Text For Explanation

No transform on X

-4.00000810 to 10000.02050781 error bounds on X

150.00030517 to 300.00061035 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / day

Source PNL -- Andy Reisenaur & Alan Baldwin

Velocity (m/day) of ground water in the unconfined aquifer during a temperate interstadial climate state.

Note: According to Andy Reisenaur, the velocities through the unconfined aquifer can vary widely, depending where the repository is sited. This curve represents the 'worst case' estimate only.

**Speed of Unconfined Ground Water, Climate 3
Density Curve 126.**

Submodel(s) :

Hydrology

See Text For Explanation

No transform on X

-4.00000810 to 10000.02050781 error bounds on X

150.00030517 to 300.00061035 values of X

Uniform Curve

Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / day

Source PNL -- Andy Reisenaur & Alan Baldwin

Velocity (m/day) of ground water in the unconfined aquifer during an interstadial climate state.

Note: According to Andy Reisenaur, the velocities through the unconfined aquifer can vary widely, depending where the repository is sited. This curve represents the 'worst case' estimate only.

Speed of Unconfined Ground Water, Climate 4
Density Curve 127.

Submodel(s) :
Hydrology

See Text For Explanation
No transform on X

-4.00000810 to 10000.02050781 error bounds on X
150.00030517 to 300.00061035 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X meters / day

Source PNL -- Andy Reisenaur & Alan Baldwin

Velocity (m/day) of ground water in the unconfined aquifer
during a stadial climate state.

Note : According to Andy Reisenaur, the velocities through
the unconfined aquifer can vary widely, depending where the
repository is sited. This curve represents the 'worst case'
estimate only.

Variance of Polynomial Number 31
Density Curve 128.

Submodel(s) :
Hydrology

Variance - For Future Use
No transform on X

0.00000000 to 0.00000000 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X unitless
Source James W. Crosby

Variation or error of polynomial number 29.

Geochemical Gradient
Density Curve 129.

Submodel(s) :
Hydrology

Judgement and Data

No transform on X

0.00000000 to 49.00009918 error bounds on X
.00126000 to .00154000 values of X

Normal Curve
Density Points :

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X ppm / meter

Source PNL -- Bill Deutch & Alan Baldwin

Geochemical concentration difference (ppm) in the direction
of groundwater flow for calcium.

Note : Bill Deutch calculated the value for geochemical
gradient based on data from Wells G99-33-56 and DB1. The
value from these two wells came out to be approximately
1.4 ppm/km. This curve is plus or minus 10 percent of this
value.

Variance of Polynomial Number 19
Density Curve 130.

Submodel(s) :
Hydrology

Variance - For Future Use

No transform on X

-1.00000202 to 1.00000202 error bounds on X
0.00000000 to 0.00000000 values of X

Uniform Curve
Density Points :

0. 1.0000020265
1. 1.0000020265
2. 1.0000020265
3. 1.0000020265
4. 1.0000020265
5. 1.0000020265
6. 1.0000020265
7. 1.0000020265
8. 1.0000020265
9. 1.0000020265
10. 1.0000020265
11. 1.0000020265
12. 1.0000020265
13. 1.0000020265
14. 1.0000020265
15. 1.0000020265
16. 1.0000020265
17. 1.0000020265
18. 1.0000020265
19. 1.0000020265
20. 1.0000020265

Units for X Unitless

Source PNL -- Charles Cole and Gregg Petrie

Variance term for polynomial 32. Polynomial 32 uses H.C. to
get effective porosity.

**Change in Repository HC From Swarm Activity
Density Curve 131.**

Submodel(s) :

Climate

Data From Expert Judgement

No transform on X

0.00000000 to 1.00000202 error bounds on X
.01000002 to .03000006 values of X

**Normal Curve
Density Points :**

0. .0044319090
1. .0104210221
2. .0223950457
3. .0439840888
4. .0789501619
5. .1295002698
6. .1942003822
7. .2661005258
8. .3332006931
9. .3814007759
10. .3989008235
11. .3814007759
12. .3332006931
13. .2661005258
14. .1942003822
15. .1295002698
16. .0789501619
17. .0439840888
18. .0223950457
19. .0104210221
20. .0044319090

Units for X unitless

Source Steve Malone

**Fractional change of hydraulic conductivity when an
earthquake swarm intersects the repository.**

*** Unpublished personal communication between Gregg Petrie of
PNL and Steve Malone of the University of Washington on
May 1981.**

APPENDIX B

ACLIN

APPENDIX B

ACLIN

The Astronomical Climate Index (ACLIN) (Figures B.1 and B.2) was used to derive the climate states (Figures B.3 and B.4) used in the Geologic Simulation Model. ACLIN was derived from longitude of perihelion (Figures B.5 and B.6), obliquity (Figures B.7 and B.8), and eccentricity (Figures B.9 and B.10) behavior of the earth's orbit and calibrated against Pleistocene sea level as described by Petrie, G. M. et al. 1981. Geologic Simulation Model for a Hypothetical Site in the Columbia Plateau, PNL-3542, Pacific Northwest Laboratory, Richland, Washington.

FIGURE B.1. Astronomical Climate Index (ACLIN) for 0 to 20,000 yrs A.P.

FIGURE B.2. Astronomical Climate Index (ACLIN) for 0 to 1,000,000 yrs A.P.

FIGURE B.3. GSM Climate Index for 0 to 20,000 yrs A.P.

FIGURE B.4. GSM Climate Index for 0 to 1,000,000 yrs A.P.

FIGURE B.5. Longitude of Perihelion for 0 to 20,000 yrs A.P.

FIGURE B.6. Longitude of Perihelion for 0 to 1,000,000 yrs A.P.

FIGURE B.7. Obliquity for 0 to 20,000 yrs A.P.

FIGURE B.8. Obliquity for 0 to 1,000,000 yrs A.P.

B.10

FIGURE B.9. Eccentricity for 0 to 20,000 yrs A.P.

FIGURE B.10. Eccentricity for 0 to 1,000,000 yrs A.P.

APPENDIX C

EARTHQUAKE ENGINEERING STUDIES FOR THE GSM

EARTHQUAKE ENGINEERING STUDIES FOR THE GSM

A consulting report submitted by L. H. Wight and TERA Corporation.

**EARTHQUAKE ENGINEERING
AND THE BATTELLE
BASALT REPOSITORY
RELEASE SCENARIO MODEL**

Submitted to:

Mr. Jonathan Lindberg
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November 10, 1980

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1.0 INTRODUCTION

The Battelle Pacific Northwest Laboratories has undertaken a program designed to assess the feasibility of disposing high level radioactive wastes in geologic media. This multi-faceted program has major components addressing important laboratory measurements, significant licensing issues, and a variety of socio-economic issues. One important part of this program involves the safety analysis of the geologic repository performance. In order to quantify a possible risk associated with repository operations, Battelle has undertaken an effort to model the repository over a one million year design life. Because of the variety and complexity of events which could initiate a failure of the repository over this long design life, Battelle has assembled a multi-disciplinary team of experts to assist in the development of the safety analysis model. Since it is intended to explicitly take account of the uncertainty in the events and in the repository response, Battelle is basing the model on a Monte Carlo simulation of the system.

This report will provide the bases for selection of important earthquake engineering and seismological parameters for this simulation. For purposes of simulation testing, this report focuses on parameter evaluation for the Hanford Reservation. Section 2 of this report defines the spatial and temporal levels of earthquake activity in the Pacific Northwest and concludes with seismicity models for the area in which biases associated with population distribution have been removed. The next section of the report presents a newly developed technology for probabilistically predicting earthquake rupture. We believe that this technology has direct application to the Columbia Plateau. Finally, the last section of the report presents an analysis of the effect of earthquakes on hydraulic conductivity. This important parameter will define the interrelationship between earthquakes and transport mechanisms through the repository.

2.0 EARTHQUAKE STATISTICS FOR THE COLUMBIA PLATEAU

In this section, we analyze the seismicity in each of the source zones in Figure 2-1 to estimate the recurrence relationship for earthquakes in each zone. This relationship is one of the keystones to a probabilistic seismic risk assessment and is usually characterized by the two parameters, a and b , in

$$\log N = a - bM$$

where N is the cumulative annual number of earthquakes greater than earthquake magnitude M . Where we require conversion of an epicentral MM intensity to magnitude, we employ the correlation presented by Topozada (1975):

$$M = 1.85 + 0.49I$$

In our analysis of the recurrence relationship, we direct particular attention to the stability of the activity rate, b , of earthquakes. The parameter b , of the two parameters, is the most significant because it logarithmically determines the recurrence of large earthquakes.

Instability in b can arise when the subinterval of time within which earthquakes are considered is either too long, in which case the data are incompletely reported, or is too short, such that the mean activity rate is unstable. The overall approach in this report is to calculate, for each source region, the average annual number of earthquakes in a specified magnitude interval and to then sum these over magnitude to provide an estimate of the cumulative number of earthquakes greater than a given magnitude.

A linear least squares fit of $\log N = a - bM$ results in best estimates of a and b . Within this procedure, it is the estimates of the average annual number of events in a specified magnitude interval that can introduce significant errors in the earthquake parameters. We use the method developed by Stepp (1974) to minimize these errors.

Following Stepp, we first group earthquakes in each source zone into magnitudes intervals of 0.5. For each magnitude interval, we calculate the average annual number of earthquakes, λ for several subintervals of time, T . The standard deviation of σ is given by

$$\sigma = \sqrt{\frac{\lambda}{T}}$$

and therefore σ must behave like $T^{-1/2}$ if, as we have assumed, λ is constant. Plotting the subinterval values of σ allows one to readily determine over what interval σ begins to behave like $T^{-1/2}$. This is, therefore, the subinterval of data that is long enough to give a good estimate of the mean activity rate, but short enough that it does not include intervals with incomplete data.

The results of this analysis are presented in Table 2-1 where we indicate that a and b values that are developed from the regression analysis, as well as the coefficient of determination for the fit.

Because preliminary analysis showed that the seismic risk at the site was dominated by the risk due to local earthquakes in source zone five, we use this zone to illustrate the details of our statistical analysis and to further elaborate on the technique.

It is apparent from Figure 2-1 that zone five is relatively aseismic compared to surrounding source zones. Because of the significance of this zone and its macro-aseismicity, we rely heavily on data from the University of Washington microseismic array centered on the Hanford Reservation.

Applying the stability techniques described above to the historical record of earthquakes in zone five results in the data indicated in Figure 2-2. Figure 2-3 indicates how the annual activity rates for each magnitude interval are defined, and Table 2-2 summarizes these rates and the interval of time appropriate for each magnitude interval.

TABLE 2-1
EARTHQUAKE PARAMETERS FOR EACH SOURCE ZONE

<u>Seismic Zone</u>		<u>$\log N_c = a - bM$</u>		<u>Coefficient of Determination</u>
<u>Site ID (Fig 4-2)</u>	<u>Descriptor</u>	<u>a</u>	<u>b</u>	<u>r^2</u>
1	Puget Sound	4.30	1.05	0.99
2	S. Cascades	3.50	0.93	0.92
3	N. Cascades	3.50	0.93	0.92
4	Milton-Freewater	3.31	1.00	0.87
5	Site Source Zone	4.54	1.16	0.99

TABLE 2-2
RESULTS OF EARTHQUAKE STATISTICS ANALYSIS FOR
ZONE 5 (SITE SOURCE ZONE)

<u>Magnitude Interval</u>	<u>Time Interval</u>		<u>Annual Rate</u>
<u>M</u>	<u>Dates</u>	<u>Duration</u>	
3.5-4.0	1945-1969	25	0.508
4.0-4.5	1910-1969	60	0.204
4.5-5.0	1890-1969	100	0.092

FIGURE 2-2
RECURRENCE RELATION FOR SEISMIC ZONE 5

TERA CORPORATION

FIGURE 2-3
STANDARD DEVIATION OF THE ANNUAL NUMBER
OF HISTORICAL EARTHQUAKES IN ZONE 5

TERA CORPORATION

Because these results are supported by only 48 earthquakes in the magnitude range of 3.5-5.5, we turn to supplementary data from the microseismic network. This network has been operational since 1969 and since then has been reliably reporting earthquakes over a large area that includes much of zone five. Accounting for the coverage area, a parallel analysis of the micro-earthquakes located in zone five results in the remaining indicated data in Figure 2-2. A best fit to the data of the form,

$$\log N = a - bM$$

is obtained by the values $a = 4.54$ and $b = 1.16$.

3.0 FAULT RUPTURE HAZARD

The possible proximity of shears or faults to a repository facility suggests that the risk due to fault rupture should be considered. A rigorous analysis of this risk would require a detailed knowledge of the fault and fracture pattern in the immediate vicinity of the facility, which is beyond the scope of this study. This section, however, sets the general methodology that could be applied to the Columbia Plateau.

Fault rupture hazard is defined as the probability that the maximum surface displacement at a point on the fault exceeds a given value over the time period of interest. The general approach is as follows. The fault system is divided into a series of segments of equal seismicity. Earthquake occurrences within each segment are treated as Poisson-Bernoulli processes. The random occurrence of all events from each fault is combined with a fault rupture model to develop a probability distribution of surface displacement for any point on the fault. The calculation to this point essentially results in an assessment of the rupture hazard on one of the pre-existing shears. The next step in the analysis is to account for the fact that trenches between the shears in the near vicinity of GETR have exposed undisturbed soils of a certain age, thus indicating that the area between the shears has not ruptured in this time.

3.1 EARTHQUAKE OCCURRENCE MODEL

The basic input parameters of the earthquake occurrence model are the magnitude range (upper and lower bound magnitudes) and earthquake recurrence. With respect to earthquake data, the magnitudes are discretized every 1/4 of a magnitude unit as is commonly done in data recording. This representation permits the use of discrete models.

The development of the model involves three steps:

- (1) Assuming that earthquake occurrences form a Poisson process with mean rate of occurrence independent of

magnitude, a distribution is obtained on the number of occurrences for the time period considered.

- (2) Given that an event has occurred, a distribution on the magnitude of events is determined. The process generating model can be assumed to be Bernoulli. The probability of success, p_{M_i} , corresponding to each trial, is defined as the probability that the event that has occurred is of magnitude M_i . Thus, the probability of failure, $q_{M_i} = 1 - p_{M_i}$, at each trial is the probability that the event is not of magnitude M_i . The probability of having r events of magnitude M_i , given that a total of n events have occurred, can therefore be obtained using the binomial distribution.

- (3) The distribution of the number of events of each magnitude, independent of the number of trials, is obtained by combining steps one and two.

Earthquake Occurrence (Poisson Model)

It is assumed, once the seismic sources have been located, that earthquake occurrences on each source form a Poisson process with mean rate of occurrence independent of magnitude. For earthquake events to follow the Poisson model, the following assumptions must be valid:

1. Earthquakes are spatially independent
2. Earthquakes are temporally independent
3. The probability that two seismic events will take place at the same time and at the same location approaches zero.

The first assumption implies that the occurrence or absence of a seismic event at one site does not affect the occurrence or absence of another seismic event at some other site or the same site. The second assumption implies that seismic events do not have memory. The assumptions of spatial and temporal independence have been verified by data when aftershock sequences are removed and are commonly accepted. The degree of dependence between events, due to the dual mechanism of stress accumulation and release, has not yet been determined with any amount of precision, but the earth's "memory" appears to fade quite rapidly with time (Garner and Knopoff, 1974). The third assumption implies that, for a small time-interval, more than one seismic event cannot occur on one source.

Thus, considering all the events of magnitude greater than an arbitrary lower bound, a distribution is obtained for the number of occurrences in a given period of time, t . The lower bound is chosen so that earthquakes of magnitude smaller than the one specified, which have a negligible damage potential, can thus be disregarded. This distribution is obtained for each seismic source.

In its general form, the Poisson law can be written as

$$P_N(n/\lambda) = \frac{e^{-\lambda t} (\lambda t)^n}{n!}, \quad t \geq 0; n \text{ integer } \geq 0, \quad (3-1)$$

where

$P_N(n/\lambda)$ = probability of having n events in time period t , given

n = number of events

λ = mean rate of occurrence per unit of time

Thus, if the mean rate of occurrence λ is known, the probability distribution function can be defined completely.

The parameter λ is obtained from the data and can be modified subjectively. In the present case, it is expressed as the mean rate of occurrence, per year, of earthquakes larger than magnitude 3.5.

Estimate of λ

If one assumes that the number of seismic events for a future time t follows a Poisson probability law, there is still uncertainty about the parameter λ , the mean rate of occurrence (Equation 3-1). Therefore, λ is treated as a random variable. The probabilistic information on λ can be obtained through historical data or from the subjective knowledge of the analyst. The subjective probability distribution on λ is called the "prior distribution."

The concept of conjugate prior is used for analytical simplicity (Raiffa and Schlaifer, 1961). Therefore, the prior distribution for the random variable λ is chosen as the gamma distribution with parameters λ' and ν' . Since the gamma distribution can fit a large variety of shapes, this choice does not introduce any major limitations in the model.

Using the historical information, one can obtain the sample likelihood function for λ . The posterior distribution for λ can be obtained by combining the prior distribution and the sample likelihood function by means of Bayes' theorem.

Let $f'_{\Lambda}(\lambda)$ be the prior probability distribution function for λ , and $L(\lambda)$ be the sample likelihood function for λ (given by the Poisson law for n observations), then the posterior distribution $f''_{\Lambda}(\lambda)$ is obtained as

$$f''_{\Lambda}(\lambda) = N_1 L(\lambda) f'_{\Lambda}(\lambda), \quad (3-2)$$

where N_1 is a normalizing constant. The posterior distribution of λ is also gamma type with parameters λ'' and ν'' .

In Equation 3-1, the conditional probability on the number of events n is based on λ . The unconditional or the marginal distribution on n can be obtained by using Equation 3-1 together with Equation 3-2 and integrating over all λ 's. Thus,

$$P_N(n) = \int_0^{\infty} P_N(n/\lambda) f''_{\Lambda}(\lambda) d\lambda \quad (3-3)$$

which leads to

$$P_N(n) = \frac{\Gamma(n + \nu'')}{n! (\nu'')} \cdot \frac{t^n \lambda'' \nu''}{(t + \lambda'')^{n + \nu''}} \quad (3-4)$$

for n integer ≥ 0 , $\nu'' > 0$, $\lambda'' > 0$, $t > 0$.

Equation 3-4 is called the "marginal Bayesian distribution of n ." This distribution, after the uncertainties on the mean rate of occurrence are considered, gives the probability of the number of events above a predetermined lower bound M_0 , in time period t .

Distribution of Magnitudes (Bernoulli Model)

A Bernoulli trial is used to model information on magnitudes. Given that an event has occurred, the probability that it is of any given Richter magnitude can be represented in terms of a Bernoulli trial. If the seismic event that has occurred is of the M_i under consideration, then the outcome of the Bernoulli trial is a success. Conversely, failure at each trial implies that the seismic event that has occurred is of some other magnitude.

If p_{M_i} = probability of success at each trial corresponding to M_i

and $q_{M_i} = 1 - p_{M_i}$

= probability of failure at each trial,

then using the binomial law,

$$P_R(r_{M_i}/n, p_{M_i}) = C_n^{r_{M_i}} p_{M_i}^{r_{M_i}} (1 - p_{M_i})^{n - r_{M_i}} \quad (3-5)$$

for an integer $n > 0$, r_{M_i} integer; $0 \leq r_{M_i} \leq n$, and $0 \leq p_{M_i} \leq 1$.

where $P_R(r_{M_i}/n, p_{M_i})$ is read as the probability that r_{M_i} events of magnitude M_i will occur out of a total of n events, given that the probability of occurrence of M_i is p_{M_i} at each trial, and

$$C_n^{r_{M_i}} = \frac{n!}{r_{M_i}!(n - r_{M_i})!}$$

A different probability p_{M_i} is obtained for each M_i considered in the model. A similar equation is thus obtained for each of the other magnitudes. The probabilities p_{M_i} are mutually exclusive within the range of selected magnitudes, hence,

$$\sum_{\text{all } M_i} p_{M_i} = 1.0.$$

As an example, for $M_i = 6$ and $n = 5$,

$$P(0 \text{ events of } M = 6 \text{ given } 5 \text{ earthquakes}) = (1 - p_6)^5$$

$$P(1 \text{ events of } M = 6 \text{ given } 5 \text{ earthquakes}) = 5 \times p_6 \times (1 - p_6)^4$$

$$P(5 \text{ events of } M = 6 \text{ given } 5 \text{ earthquakes}) = p_6^5.$$

It should be noted that

$$\sum_{r=0}^n p(r/n) = 1.0.$$

To be consistent with the Gutenberg-Richter earthquake recurrence relationship the probability p_{M_i} should be consistent with an exponential distribution of magnitudes. Cornell (1971) has proposed such a distribution which incorporates both lower and upper bound limits on magnitude:

$$P(M \leq m) = K \left\{ 1 - \text{Exp} \left[-\beta (m - M_l) \right] \right\} \quad (3-6)$$

where,

$$P(M \leq m) = \text{probability of } M \leq m$$

$$K = \left\{ 1 - \text{Exp} \left[-\beta (M_u - M_l) \right] \right\}^{-1}$$

$$\beta = 2.3b$$

M_u = upper bound magnitude

M_l = lower bound magnitude

The probability that an earthquake has a magnitude within the range $m_i \pm \Delta m/2$, equivalent to the Bernoulli parameter p_{M_i} , then becomes

$$p_{M_i} = P(M \leq m_i + \Delta m/2) - P(M \leq m_i - \Delta m/2) \quad (3-7)$$

Equation 3-5 represents the generating process for the number of events M_i . However, this information is conditional on the knowledge about p_{M_i} , the probability of success corresponding to M_i .

Estimate of p_{M_i}

The conjugate prior distribution on p_{M_i} , $f'_P(p_{M_i})$, is assumed to be beta type with parameters η' and ξ' . Since the normalized beta distribution is bounded between 0 and 1, and fits a large variety of shapes, this choice does not introduce any major limitations in the model. A prior distribution of a similar form has to be assumed for each of the magnitudes considered.

The usual format of the available data indicates that, among the n earthquakes observed for a given source, r_{M_i} were of M_i . This information is used in the construction of the sample likelihood function. The sample likelihood function on p_{M_i} , $L(p_{M_i}/n, r_{M_i})$, may be obtained from the generating process (Equation 3-5).

The posterior distribution $f''_P(p_{M_i})$ is given by

$$f''_P(p_{M_i}) = N_l L(p_{M_i}/n, r_{M_i}) f'_P(p_{M_i}) \quad (3-8)$$

where N_i is a normalizing constant. The posterior distribution on p_{M_i} is also beta type with parameters η'' and ξ'' .

In Equation 3-5, the conditional probability on the number of successes, r_{M_i} , is based on p_{M_i} and n . The condition on p_{M_i} can be removed using Equation 3-8 and integrating over all the values of p_{M_i} as follows:

$$P_R(r_{M_i}/n) = \int_0^1 P_R(r_{M_i}/p_{M_i}, n) f_P(p_{M_i}) dp_{M_i} \quad (3-9)$$

$$= C_n^{r_{M_i}} \left[\frac{\Gamma(\eta''_{M_i})}{(\xi''_{M_i}) (\eta''_{M_i} - \xi''_{M_i})} \cdot \frac{(a_{M_i}) (\beta_{M_i} - a_{M_i})}{\Gamma(\beta_{M_i})} \right]$$

for n integer > 0 , r_{M_i} integer; $0 \leq r_{M_i} \leq n$,

$$\text{and } \xi''_{M_i} = \xi'_{M_i} + r_{M_i}$$

$$\eta''_{M_i} = \eta'_{M_i} + n$$

$$r_{M_i} + \xi''_{M_i} = a_{M_i}$$

$$n + \eta''_{M_i} = \beta_{M_i}$$

The above expression is the distribution on the number of earthquakes of magnitude M_i given that n earthquakes have occurred. There is a similar distribution for each M_i considered.

Marginal Distribution on the Number of Magnitudes

The distribution of the number of events of each magnitude independent of the number of trials, is obtained from Equations 3-4 and 3-9, thus

$$P_R(r_{M_i}) = \sum_{n=0}^{\infty} P_R(r_{M_i}/n) p_N(n) \quad (3-10)$$

$$= \sum_{n=0}^{\infty} C_n^{r_{M_i}} \frac{\Gamma(\eta''_{M_i})}{\Gamma(\xi''_{M_i}) \Gamma(\eta''_{M_i} - \xi''_{M_i})} \cdot \frac{\Gamma(r_{M_i} + \xi''_{M_i}) \Gamma(n + \eta''_{M_i} - r_{M_i} - \xi''_{M_i})}{(n + \eta''_{M_i})} \cdot \frac{\Gamma(n + \nu'') t^n}{n! \Gamma(\nu'') (t + \lambda'')^{n + \nu''}}$$

This distribution describes totally the seismicity of the source considered in terms of the two parameters magnitude (M_i) and number of occurrences (n).

The Bernoulli model has the advantage that the probability of occurrence of an earthquake of any given magnitude (p_{M_i}) can be established and updated independently of other magnitudes. It also offers greater flexibility in the use of historical seismicity data and in combining it with subjective information through a Bayesian approach.

3.2 FAULT RUPTURE PARAMETERS

The three fault rupture parameters required in the development of the hazard model are fault rupture length (L), fault rupture displacement (D), and fault rupture radius (R). Models used to estimate these parameters from earthquake magnitude (M) were developed from regression analyses using the method of least squares. A statistical summary of these analyses is presented in Table 3-1, and tabulated values of the parameters are provided in Table 3-2.

TABLE 3-1

SUMMARY OF REGRESSION ANALYSES FOR FAULT LENGTH,
FAULT DISPLACEMENT AND SOURCE RADIUS

$$\ln Y = A_Y + B_Y M$$

<u>Parameter</u>	<u>Coefficients</u>		<u>Standard Error</u>	<u>Correlation Coefficient</u>	<u>N</u>
	<u>A_Y</u>	<u>B_Y</u>			
Fault Length, L(km)	-4.670	1.185	0.83	0.76	73
Fault Displacement, D(cm)	-3.797	1.273	0.84	0.76	73
Source Radius, R(km)	-3.391	0.843	0.63	0.73	163

TABLE 3-2

TABULATED VALUES OF FAULT LENGTH,
FAULT DISPLACEMENT, AND SOURCE RADIUS

Magnitude (M_L)	Fault Length L(km)	Source Radius R(km)	Fault Displacement D(cm)
3.5	0.6	0.6	1.9
4.0	1.1	1.0	3.7
4.5	2.0	1.5	6.9
5.0	3.6	2.3	13.0
5.5	6.3	3.5	25.0
6.0	12.0	5.3	47.0
6.5	21.0	8.0	88.0
7.0	38.0	12.0	166.0

Fault Length (L)

Slemmons (1977) has recently tabulated fault length and displacement data for 87 worldwide earthquakes occurring since 1819. He used these data to develop relationships between magnitude and fault length, where fault length was the independent variable. His equations are thus valid for estimating magnitude from fault length.

In our model, what is required is an estimate of length when magnitude is known. Therefore, the regression analyses were repeated using M as the independent variable. The limited amount of data available on normal-oblique slip faults precluded their exclusive use in the analysis. Therefore, it was decided to use data from all fault types in the regression.

Based on the 73 observations for $4.0 \leq M \leq 8.7$ in Slemmons (1977), the log-linear relationship between L and M was found to be

$$\ln L(M) = -4.67 + 1.19 M \quad (3-11)$$

for fault length in kilometers.

Fault Displacement (D)

A similar analysis was run for maximum fault displacement. Again using the Slemmons (1977) data for all fault types, the log-linear relationship between D and M was determined as

$$\ln D(M) = -3.80 + 1.27 M \quad (3-12)$$

for displacement in centimeters.

Source Radius (R)

Source radius is a measure of the true rupture dimensions, not just those observed on the surface after the earthquake. It requires that theoretical source spectrum shapes be fitted to observed spectra, and that the source parameters be estimated from theoretical dislocation models. Source radius thus represents the radius of a circular rupture surface whose area is equivalent to that of the actual rupture surface.

From Brune's (1970) dislocation model, source radius may be computed from the relationship

$$R = \frac{2.34}{2 \pi f_0} \quad (3-13)$$

where β is the shear-wave velocity of the medium, and f_0 is corner frequency (the point where the high frequency decay begins on the source displacement spectrum).

Using this model, Thatcher and Hanks (1973) estimated the source radius of many Southern California earthquakes. Campbell (1977) expanded this set to include 163 earthquakes of $3.0 \leq M_L \leq 6.8$. Using these data, the following log-linear relationship between R (in kilometers) and M was established:

$$\ln R(M) = -3.39 + 0.84 M \quad (3-14)$$

3.3 FAULT RUPTURE HAZARD MODEL

For an earthquake of given magnitude and location, the probability of observing a displacement greater than a particular level at a point on the fault located at a distance, x_i , is comprised of a joint probability of three events. The first is the probability that surface rupture occurs, which we will designate as "event E_s ." The second is the probability that surface rupture extends at least as far as the point of interest (designated as "event E_ℓ "). The last is the probability that the displacement exceeds the specified value (designated as "event E_d ").

Mathematically, this joint probability may be expressed as

$$P(D > d \mid M_j, x_i) = P(E_d \cap E_\ell \cap E_s)$$

where M_j is the magnitude under consideration and x_i is the distance along the fault from segment i (the location of the earthquake) to the point in question (Figure 3-1).

Simplifying, by means of conditional probability theory,

$$\begin{aligned} P(D > d \mid M_j, x_i) &= P(E_d \mid E_\ell \cap E_s) \cdot P(E_\ell \cap E_s) \\ &= P(E_d \mid E_\ell \cap E_s) \cdot P(E_\ell \mid E_s) \cdot P(E_s) \end{aligned} \quad (3-15)$$

with all events being contingent upon the occurrence of a given earthquake. After developing models for the above probabilities and unconditionalizing with respect to M_j and x_i , Equation 3-15 may then represent the hazard from all possible earthquakes on the fault.

$P(E_s)$

Surface rupture during a given earthquake is assumed to occur if the source radius (R) is greater than the distance along the fault plane from the center of the rupture to the ground surface, designated as " w_i " (Figure 3-1). Since, for a given earthquake, the horizontal extent of faulting tends to be greater than the vertical extent, this definition of surface rupture is considered conservative.

For a given magnitude M_j , we may compute source radius from Equation (3-14)

$$\ln R_j = A_R + B_R M_j \quad (3-16)$$

Because of uncertainty in this expression, R_j may be considered a random variable. Let us assume R_j to be lognormally distributed with a median of $\ln R_j$ and a standard deviation σ_R (on $\ln R$) equal to the standard error of estimate,

FIGURE 3-1
SCHEMATIC OF THE FAULT RUPTURE
HAZARD MODEL

Table 3-1. Then, the probability that R_j is greater than w_i (the event E_s) is given by

$$\begin{aligned}
 P(E_s) &= P(R_j > w_i) \\
 &= 1 - P(R_j \leq w_i) \\
 &= 1 - \frac{1}{\sigma_R \sqrt{2\pi}} \int_{-\infty}^{\ln w_i} \text{Exp} \left[-1/2 \left(\frac{y - \ln R_j}{\sigma_R} \right)^2 \right] dy \\
 &= 1 - \Phi \left(\frac{\ln w_i - \ln R_j}{\sigma_R} \right) \tag{3-17}
 \end{aligned}$$

where $\Phi (*)$ represents the standard-normal cumulative distribution function.

$P(E_l | E_s)$

Given that a surface rupture occurs, let it be assumed that its length is equally distributed in both directions along the fault trace (i.e., bilateral rupture). The midpoint of this rupture is directly above the assumed point of initiation (Figure 3-1). For rupture to occur at the site of interest, it must proceed at least as far as that distance from the midpoint of the surface expression to the site, x_i . Therefore, rupture occurs at the site if $L_j/2 > x_i$, where L_j is the surface rupture length associated with a magnitude M_j event.

L_j is computed from the data in Table 3-2, thus

$$\ln L_j = A_L + B_L M_j \tag{3-18}$$

To account for uncertainty in the regression, L_j may be considered lognormally distributed, with median $\ln L_j$ and standard deviation (on $\ln L$) of σ_L .

The probability of the event E_ℓ occurring (given E_r), becomes

$$\begin{aligned}
 P(E_\ell | E_r) &= P(L_j/2 > x_i) \\
 &= P(L_j > 2x_i) \\
 &= 1 - P(L_j \leq 2x_i) \\
 &= 1 - \Phi\left(\frac{\ln L_j - 2x_i}{\sigma_L}\right)
 \end{aligned} \tag{3-19}$$

$$P(E_d | E_\ell \cap E_s)$$

Given that surface rupture occurs and that it proceeds at least as far as the site, the surface displacement associated with the earthquake M_j may be estimated from Equation 3-12 as follows:

$$\ln D_j = A_D + B_D M_j \tag{3-20}$$

Accounting for uncertainty in this estimate, D_j is considered lognormally distributed, with median $\ln D_j$ and standard deviation (on $\ln D$) of σ_D . The probability that the displacement exceeds some specified value d then becomes

$$\begin{aligned}
 P(E_d | E_\ell \cap E_s) &= P(D_j > d) \\
 &= 1 - P(D_j \leq d) \\
 &= 1 - \Phi\left(\frac{\ln D_j - \ln d}{\sigma_D}\right)
 \end{aligned} \tag{3-21}$$

Displacement Hazard

The surface displacement hazard for a point on a fault associated with an earthquake on segment i of magnitude M_j is obtained by substituting Equations 3-17, 3-19 and 3-21 into Equation 3-15.

$$P(D > d_i | M_j, x_i) = \left[1 - \phi \left(\frac{\ln D_i - \ln d_i}{j_D} \right) \right] \cdot \left[1 - \phi \left(\frac{\ln L_i - \ln x_i}{L} \right) \right] \cdot \left[1 - \phi \left(\frac{\ln R_i - \ln w_i}{R} \right) \right]$$

The total hazard at the point in question requires combining the hazards associated with all possible earthquakes hypothesized to occur on the fault. For this purpose, the two-dimensional fault plane of area A_0 is divided into an equal number of segments of equal seismicity.

Contribution of One Segment

The contribution to displacement greater than or equal to d_i of all events M_j occurring on the same segment is computed as:

$$P(D > d_i) = pP(M_j) + [1 - (1 - p)^2] P(2M_j) + \dots + [1 - (1 - p)^n] P(nM_j) \quad (3-22)$$

where

$P(D > d_i)$ = probability of obtaining displacement greater than or equal to d_i at least once

$P(kM_j)$ = probability of k occurrences of event M_j with $k = 1, 2 \dots n$

p = $P(D \geq d_i / M_j)$, probability of obtaining a displacement greater or equal to d_i given an event M_j .

Setting $q = 1 - p$, the above expression can be rewritten:

$$P(D \leq d_i) = P(\text{no } M_j) + \sum_{k=1}^n q^k P(kM_j) \quad (3-23)$$

with n chosen so that $q^k P(nM_j)$ can be neglected.

The above discussion assumes independence among events. Hence, the contribution of all possible events can be combined as follows:

$$P(D \geq d_i) \Big|_{\text{one segment}} = 1 - \prod_{\text{all } M_j} \left[1 - P(D > d_i)_{M_j} \right] \quad (3-24)$$

The whole range of magnitudes is included, from the largest one down to the smallest one that generates a noticeable effect at the site ($M_j \geq M_{\min}$ as a function of distance). This eliminates the consideration of a large number of events.

Contribution of One or Several Sources

Because the events are assumed to be independent from segment to segment, the contribution of each segment of a source is combined as in Equation 3-24.

$$P(D > d_i)_{\text{one source}} = 1 - \prod_{\text{all segments}} \left[1 - P(D > d_i)_{\text{one segment}} \right] \quad (3-25)$$

When several sources are considered, the same principle is applied for each source. Thus,

$$P(D > d_i) = 1 - \prod_{\text{all sources}} \left[1 - P(D > d_i)_{\text{one source}} \right] \quad (3-25)$$

This expression gives the probability that, at least once during the period of interest, d_i will be exceeded.

4.0 DEVELOPMENT OF A POLYNOMIAL TO CALCULATE CHANGE IN HYDRAULIC CONDUCTIVITY OF BASALT FOR BASALT REPOSITORY RELEASE SCENARIO MODEL

4.1 SUMMARY

Dynamic loading during earthquakes may conceivably induce permeability changes in basalt by one or more of the following three mechanisms: 1) Increase of matrix permeability by creation and extension of microcracks, 2) Extension of large pre-existing cracks in the basalt, 3) Differential relative displacement of adjacent blocks so as to increase fracture permeability. Little work has been done previously in either the laboratory or the field to evaluate these mechanisms, but measurements of matrix permeability changes after underground nuclear explosions suggest that the first mechanism will be insignificant during earthquakes. This conclusion is supported by theoretical considerations given herein. No reliable field data ^{are} (13) available with which to evaluate the roles of mechanisms 2) and 3) during earthquakes. Two empirical considerations suggest that they should have minor, if any, effect on hydraulic conductivity: a) The basalts have already sustained numerous earthquakes during their history with magnitudes as great as any expected in the future. We would not expect future earthquakes to produce states of hydraulic conductivity not already achieved as the result of past events. b) In situ confining pressures will close fractures that open or lengthen during earthquakes, so that an increased fracture density after an earthquake need not be accompanied by increased hydraulic conductivity.

Our analysis of mechanisms of dynamic hydraulic-conductivity enhancement indicates that no changes will occur at depths greater than about 950 meters. Thus, potential leakage resulting from this problem can be avoided altogether by locating the repository at a depth greater than this. At lesser depths we feel that significant hydraulic-conductivity changes due to earthquakes are unlikely, but the possibility of conductivity increases becomes greater with decreasing depth and confining pressure. We submit that the following expressions, which are based on the limited data available and on theoretical considerations, are

reasonable estimates of hydraulic conductivity in basalt after occurrence of a nearby earthquake:

$$K = K_i \left[1 + .10 \left\{ \frac{91.3 A_g - 0.086d - 17.3}{82.7} \right\} \right], d < 950m \quad (A)$$

$K = K_i$, when $d > 950m$ or when term in inner brackets in (A) is negative

Where K is hydraulic conductivity following the earthquake, K_i the initial permeability, A_g peak acceleration in units of g , and d the depth of the repository. Hydraulic-conductivity change at depths shallower than 950 meters is given by equation (IA9) after substituting 0 for the coefficient 1 after the left bracket. Hydraulic-conductivity change at depths greater than 950 meters is zero.

4.2 INTRODUCTION

The subject of dynamically induced permeability changes in rock under true in situ conditions, i.e. conditions to which the rock is subject during earthquakes, is one that has been scarcely addressed in the geophysical and hydrological literature. Direct observations of evidence of changes are few and have been made at the earth's surface. For example, people have observed increases in the flow from springs after earthquakes. Conversely, springs have also been observed to dry up following earthquakes. Such behavior need not indicate hydraulic-conductivity changes; however, it could, for example, result from tectonic ground uplift or subsidence and attendant raising or lowering of the water table. It should also be recalled that commonly there is amplification of particle motion and seismic loads near the ground surface. Thus, surficial changes are probably different than those at depths where confining pressures also work against physical deformation and change.

Laboratory and theoretical studies concerned with permeability and hydraulic conductivity have concentrated on measurement and prediction of these parameters under a variety of flow boundary conditions, but under static loading

conditions on the rock matrix itself. The only field studies that we have found that have direct application to the subject of seismically induced permeability changes are those dealing with the effects of underground nuclear explosions on rock properties. Although these studies are qualitatively helpful, by themselves they do not supply sufficient information for quantifying seismic effects on hydraulic conductivity.

Because of the lack of information on the subject, we have chosen to formulate a relationship between earthquake acceleration and hydraulic-conductivity changes by considering the fundamental properties that produce hydraulic conductivity and the ways in which seismic loadings are likely to alter them. After first estimating amplitudes of dynamic earthquake loads, we then evaluate the likelihood of these loads affecting hydraulic conductivity by different mechanisms. Using results from this analysis and reported data from underground nuclear tests, we conclude by formulating a relationship between earthquake acceleration and hydraulic conductivity.

4.3 HYDRAULIC CONDUCTIVITY AND PERMEABILITY: DEFINITIONS AND ORIGIN

The realization that ground water flow is proportional to permeability or hydraulic conductivity was first made by Darcy (1856) and Dupuit (1863). Darcy's well-known law of ground water flow can be written

$$Q = K I A \quad (1)$$

where K is hydraulic conductivity, I is hydraulic gradient, A the cross-sectional area across which flow takes place, and Q the flow rate in dimensions of volume per unit time.

Hydraulic conductivity is a function of the physical characteristics of the conducting material and of the fluid. For granular materials these characteristics include packing, porosity, stratification, arrangement of grains, grain size,

and size and distribution of connections between pores (pore throats). Davis and DeWiest (1966) define hydraulic conductivity as

$$K = C d^2 \frac{\gamma}{\mu} \quad (2)$$

where γ is the weight of the fluid, μ its dynamic viscosity, d a characteristic length, and C a dimensionless constant which takes into account the physical characteristics of the material. The intrinsic permeability is defined as

$$K = C d^2 \quad (3)$$

and is considered as characteristic of the conducting medium alone. Thus, we observe that for seismic loadings to change hydraulic conductivity, they must have an effect on the properties that define C . The most conceivable such effects in porous rock would likely be cracking and alteration of sizes and configuration of pore throats. One cannot predict a priori, however, whether this response would increase or decrease hydraulic conductivity. Generation of new pore throats suggests a conductivity increase, but related processes, such as pulverization of small amounts of material along the new crack faces, might lead to plugging of pores and an actual decrease of conductivity.

A second type of hydraulic conductivity in rock, more important than porous flow in dense jointed rocks such as basalt, is fracture conductivity. If the fractures are narrow enough so that laminar flow predominates, Darcy's law can be used to describe the flow if a large cross-sectional area is considered that contains a statistically representative number of fractures. If earthquake-induced dynamic loading of such rock produces conductivity increases, the mechanism should be creation of new fractures, opening of old fractures, or both. Conversely, however, dynamic loading could result in compaction of the jointed blocks into a denser arrangement, reducing fracture volume and conductivity.

One might suspect that transient stress waves are of sufficient magnitude in some earthquakes to fracture or otherwise affect basalts in the repository area, changing their hydraulic conductivity. However, because the basalts are of

Miocene age, they must already have been subject to numerous shocks equal to or greater than those that can be expected during the life of the repository. Thus, unless time-dependent processes have served to reduce hydraulic conductivity subsequent to previous earthquake-induced increases, it intuitively seems unlikely that future shocks would result in increases above current in situ values. Time-dependent chemical precipitation or particle deposition in fractures come to mind as permeability-reducing processes, but we have no direct knowledge of them in the context of the repository site.

4.4 ESTIMATION OF EARTHQUAKE-INDUCED STRESSES IN BASALT

To evaluate whether earthquake accelerations may produce fracturing in rock, we shall first estimate the magnitude of compressional, tensional, and shear stresses that seismic waves produce. Let us first assume propagation of a plane wave through an isotropic, homogeneous solid with perfect lateral constraint, so that displacement occurs in the $\underline{x}$ -direction only. The displacement, $\underline{u}$, is related to stresses in the $\underline{x}$ -direction by the equation of motion.

$$\rho \frac{\partial^2 \underline{u}}{\partial t^2} = \frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{xy}}{\partial y} + \frac{\partial \sigma_{xz}}{\partial z} \quad (4)$$

where ρ is density.

Since the $\underline{x}$ -direction is normal to a principal plane, the shear stresses are zero and (4) reduces to

$$\rho \frac{\partial^2 \underline{u}}{\partial t^2} = \frac{\partial \sigma_{xx}}{\partial x} \quad (5)$$

From the isotropic stress-strain equations of linear elasticity, it can be shown that for these conditions

$$\sigma_{xx} = \left(\lambda + 2\mu \right) \frac{\partial \underline{u}}{\partial x} \quad (6)$$

where λ and μ are Lamé's constants of the material. Substituting (6) in (5) gives

$$\frac{\partial^2 u}{\partial t^2} = \frac{\partial^2 u}{\partial x^2} (\lambda + 2\mu) \quad (7)$$

Solving for u , differentiating u with respect to x and t , and equating the to derivatives leads to the following expression for the normal stress (Kolsky, 1963, pp. 42-43).

$$\sigma_{xx} = \rho C \frac{\partial u}{\partial t} \quad (8)$$

where $C = \sqrt{(\lambda + 2\mu)/\rho}$ and is the dilatational wave velocity and the partial derivative is the particle velocity.

Before evaluating normal stresses using measured values of density, wave velocity and particle velocity, let us follow the same procedure as above to evaluate stresses associated with a wave that produces pure shear in the x-y plane. If the σ_{xy} and σ_{yx} components are the maximum shear stresses, the normal stress components σ_{xx} and σ_{yy} vanish. Furthermore, we are assuming plane propagation so that all derivatives with respect to the z -direction vanish. Equation (4) becomes

$$\rho \frac{\partial^2 u}{\partial t^2} = \frac{\partial \sigma_{xy}}{\partial y} \quad (9)$$

From the isotropic stress-strain equations we get

$$\sigma_{xy} = \frac{1}{2} \mu \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right) \quad (10)$$

but for conditions for pure shear $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$, so that we can write

$$\rho \frac{\partial^2 u}{\partial t^2} = \mu \frac{\partial^2 u}{\partial x^2} \quad (11)$$

the same procedures used to derive (8) from (7) gives the shear stress as

$$\sigma_{xy} = \rho C' \frac{\partial u}{\partial t} \quad (12)$$

where C' is now the shear wave velocity in the medium, $C' = \sqrt{(\mu / \rho)}$. From a two-dimensional Mohr's circle of stress it is possible to determine the magnitudes of the principal normal stresses associated with the pure shear (12). As seen in Figure 4-1, one principal stress component in the x-y plane is tensile, the other is compressive. Both have magnitudes equal to the maximum shear stress in the plane.

From equations (8) and (12) we see that the peak magnitudes of normal and shear stresses for a rock of a given density are governed by the P-wave and S-wave velocities, respectively, and by peak particle velocities. Based on measured densities, wave velocities, and particle velocities, we can now calculate theoretical values of these stresses. Table 4-1 gives measured values of these properties and the sources from which they were derived for use in calculation of peak earthquake-induced stresses.

Because of P-wave velocities, V_p , are greater than S-wave velocities, V_s , the greatest induced stress changes are likely to be those associated with passage of the pressure wave through the rock. Using $V_p = 5.62$ km/sec and the maximum measured particle velocity in Table 4-1 yields a magnitude for the stress pulse of

$$\begin{aligned} \sigma_{xx} &= (2.9 \text{ g/cm}^3) (5.62 \times 10^5 \text{ cm/sec}) (34 \text{ cm/sec}) \\ &= 5.54 \times 10^7 \text{ dynes/cm}^2 \\ &= 5.54 \times 10^6 \text{ N/m}^2 \\ &= 55.4 \text{ bars} \\ &= 803 \text{ psi} \end{aligned}$$

Figure 1. (a) Mohr's circle for pure shear, $\sigma_{xy} = \sigma_{yx}$ on planes normal to x- and y- directions. No normal stresses act on these planes, as can be seen from the Mohr's circle for $2\theta = 90^\circ$ and $2\theta = 270^\circ$. Also, the shear stresses σ_{xy} and σ_{yx} , and the principal stresses σ_1 and σ_3 are all of equal magnitude.

(b) Stresses on the faces of a small cubic element under the stress state in (a).

TABLE 4-1
DENSITY AND VELOCITY DATA

		<u>Source</u>
Density	2.9 g/cm ³	Stacey (1977, p. 333), typical density given for basalt.
Wave velocity		Averages of values for basalts by Press (1966, Table 9-1).
P-wave	5.62 km/sec	
S-wave	3.04 km/sec	
Particle velocities		
horizontal motion	26.0 cm/sec	Peak velocity given by Ambraseys (1978) in tabulation of European strong-motion data.
	34 cm/sec	Peak velocity on rock at 15 km from source for earthquakes of about magnitude 6.5 (Seed et al., 1976)
	30 cm/sec	Greatest recorded velocity reported by Boore et al. (1980). Value is for instrument site on rock about 20 km from source of magnitude 6.4.
horizontal or vertical motion	greater than 100 cm/sec	Theoretical estimate by Brune (1976, p. 173) of maximum near-source ground motion on solid rock.
	125 cm/sec	Estimated peak velocity at epicentral distance of 2 km for magnitude 8.6 earthquake (higher value) and magnitude 7.6 earthquake (lower value) (Perkins, 1980).
	90 cm/sec	
Ratio of horizontal particle velocity to horizontal acceleration	79 cm/sec/g	Seed et al., (1976), average value on rock for earthquakes of about magnitude 6.5.
	32	Average value computed from peak accelerations and velocities from European strong-motion data (Ambraseys, 1978, Table 3).
	56	Average value on rock from Hall et al. (1975).

Using the highest estimated value of particle velocity from Table 4-1, 125 cm/sec, yields a transient stress change of

$$\begin{aligned}
 \sigma_{xx} &= (2.9 \text{ g/cm}^3) (5.62 \times 10^5 \text{ cm/sec}) (125 \text{ cm/sec}) \\
 &= 2.04 \times 10^8 \text{ dynes/cm}^2 \\
 &= 2.04 \times 10^7 \text{ N/m}^2 \\
 &= 204 \text{ bars} \\
 &= 2950 \text{ psi}
 \end{aligned}$$

It is now possible to address the question of stress magnitude as a function of earthquake acceleration using ratios of particle velocity to acceleration from Table 4-1. Brune (1976, p. 173) theoretically estimates maximum possible accelerations in large earthquakes at between 1g and 2g. The velocity-to-acceleration ratio given by Seed et al. (1976) for measurements on rock, 79 cm/sec/g, therefore corresponds to maximum theoretical particle velocity of 158 cm/sec. It should be pointed out that this ratio was found by Seed et al. (1976) to be uniform at epicentral distances ranging from 60km to 15km and would therefore appear reasonable as a predictor of velocities from accelerations even closer to the source region. Using the theoretically extreme particle velocity of 158 cm/sec and values of ρ and V_p as before, the maximum instantaneous normal stress value is $2.5 \times 10^7 \text{ N/m}^2 = 258 \text{ bars} = 3734 \text{ psi}$.

The transient stress component of 258 bars, calculated above, should be considered as the absolute upper limit of the magnitude of stress pulses that may be generated by earthquakes near the basalt repository site. Several mitigating effects should result in lower actual values of transient stresses near underground repository even in very large earthquakes. First, the horizontal particle motions in Table 4-1 are generally considered to result from shear waves. Substitution of S-wave velocities for P-wave velocities in the equations for stress would reduce stress values in the equations for stress by a factor of about 1.85. The second consideration is that all of the particle velocities were measured at the earth's surface where topographic amplification can occur. According to Brune (1976, p. 170), topographic amplifications of about 2 are possible. If we divide the extreme stress of 258 bars by 1.85, the resulting value

of peak instantaneous stress is 140 bars. Dividing again by 2 gives 70 bars, perhaps a more reasonable value of the peak stress change at an underground repository site.

An additional consideration in the estimation of magnitudes of stress transients is the possibility of wave superposition and attendant stress amplification. Although wave reflection and some amount of superposition will occur in any layered, fractured medium like basalt, reflected pulses are typically attenuated and travel slower than the primary waves that produced them. Similarly, superposition of primary P- and S-waves with Rayleigh and Love waves is of small concern because of the relatively slow speed of propagation of the last two wave varieties (Kolsky, 1963, p. 22). Dr. M. Niazi (personal communication) estimates that stress wave amplitudes in the solid earth are unlikely to undergo enhancement by superposition of more than a factor of two and that this amount of amplification would itself be rare.

4.5 LIKELIHOOD OF FRACTURE OF BASALT BY PEAK STRESS TRANSIENTS

The foregoing discussion indicates that the instantaneous stress changes induced by passage of seismic waves through rock are extremely unlikely to exceed about 200 bars in even the largest of earthquakes. Transient stress changes at depth in large earthquakes are probably 100 bars or less. We now examine the ability of these stress transients to produce fracturing of basalt in the three dominant modes of rock failure, i.e. compressive, tensile, and shear failure.

Compression and Shear

Rock in the earth is naturally subjected to compressive and shear stresses by lithostatic loading. At depths greater than about 300 meters the greatest compression is typically in the vertical direction and is given by the equation

$$\sigma_v = \rho g d \quad (13)$$

where ρ is density, g is gravitational acceleration, and d is depth. For a typical overburden density of 2.6 g/cm^3 , the vertical stress increase with depth is

$$\Delta\sigma_v = 0.26 \text{ bar/meter}$$

According to the hydrogeologic column of Atlantic Richfield (1976), the Columbia River basalt group extends to a depth of at least 1500 meters in the Pasco Basin. At this depth the overburden exerts a vertical stress of about 390 bars. Adding this value to 100 bars of transient earthquake-induced compression results in a maximum compressive stress of about one-half kilobar, significantly below the uniaxial compressive strengths of most rocks. Jaeger and Cook (1969, p. 39), for example, give the compressive strength of Frederick Diabase, a basalt-like rock, as over 4.8 kilobars (Table 4-2). In situ the Columbia basalts are under triaxial rather than uniaxial compression and will have an even greater strength than in uniaxial tests (Jaeger & Cook, 1969, Ch. 6). For these reasons, we conclude that compressive failure in situ will not be induced by seismic waves, and that this mechanism will not alter the hydraulic conductivity of the rock.

Shear failure in rock is closely related to compressive failure. Typically, specimens loaded in compression fail in shear on planes inclined to the directions of the principal stresses. The value of shear stress on these failure planes is normally within a factor of three of the differential compressive stress at failure ($\sigma_1 - \sigma_3$), and for intact specimens this differential stress is of the order of kilobars. Thus, shear failure cannot be seriously considered as a mechanism that changes hydraulic conductivity because of the considerably lower magnitudes of seismically induced shear stresses.

4.5.1 Tensile Failure

To evaluate the likelihood of tensile failure of basalt in response to seismic loading, we first compute the magnitudes of tensile stresses likely to occur as high-amplitude seismic waves pass through the rock. The vertical lithostatic

TABLE 4-2

The uniaxial compressive strength, C_0 , loading Young's modulus, E , and Poisson's ratio, ν , for a number of rocks.

Rock	C_0 (kpsi)	E (10^6 psi)	ν
Granite, Westerly	33.2	8.1	0.11
Quartzite, Cheshire	66.7	11.4	
Diabase, Frederick	70.6	14.4	
Marble, Tennessee	22.1	6.9	
Granite, Charcoal	25.1	6.4	
Shale, Witwatersrand	24.9	9.8	0.23
Granite Aplite (Chert)	85.2	12.0	0.20
Quartzite, Witwatersrand	29.0	11.3	
Dolerite, Karroo	48.0	12.1	
Marble, Wombeyan	11.2	9.4	
Sandstone, Gosford	5.36	1.4	
Limestone, Solenhofen	32.5	7.7	

Source: Jaeger and Cook (1969, p. 139)

compression was given by (13). Assuming that there is perfect horizontal constraint so that the vertical stress produces no lateral displacement, and further assuming elastic isotropy and homogeneity, the lithostatic horizontal compression is

$$\sigma_h = \frac{\nu \Delta \sigma_v d}{1 - \nu} \quad ? \quad (14)$$

where ν is Poisson's ratio. Thus, the lithostatic component of in situ horizontal compression can never exceed the vertical stress because the maximum possible value of Poisson's ratio is 0.5. For most rocks Poisson's ratio is under 0.3.

Taking $\nu = 0.25$ for the basalt and using $\gamma = 0.26$ bar/meter as given earlier, we can easily compute the depth above which tensile dilatational waves will yield a net tensile stress in the rock. Using the relatively extreme value of 100 bars for the magnitude of the tensile pulse, this depth is

$$d = \frac{(1 - \nu)(100 \text{ bars})}{(0.26 \text{ bar/meter})} = 1154 \text{m.}$$

Thus, below about 1150 meters no net tension should be produced, even during strong nearby earthquakes. This would appear to rule out tensile fracturing as a source of hydraulic-conductivity enhancement below this depth. At shallower depths we must compare the earthquake-induced loads to loads required to fracture the rock in tension. Brace (1964) gives tensile strengths of intact specimens of quartzite, granite, and diabase as between 280 and 400 bars. These values are so much greater than the predicted tension peaks of 100 bars that fracturing of solid basalt by tensional seismic waves would appear to be practically impossible.

A second, more feasible form of tensile fracturing is by extension of pre-existing cracks in the basalt. It is well known that cracks and sharp corners concentrate stresses in elastic materials subjected to applied tensions (Inglis, 1913; Lawn and Wilshaw, 1975). In linear elastic fracture mechanics, this stress concentration is expressed through a quantity called the stress intensity factor, K_I . For each

material there is a characteristic value of this quantity, known as the fracture toughness, at which a crack in the material will grow. For brittle rocks like basalt, fracture toughness is typically about 11 bar-meter^{1/2} (Holzhausen and Johnson, 1979).

To predict whether fractures will extend in a deeply buried basalt as a result of earthquake loading, it is necessary to estimate the values of the stress intensity factor that the loading will produce at tips of fractures in the rock and then compare them to the fracture toughness. Because of the complexity of basalt in situ, exact prediction of stress intensity factors is impossible, but we can perhaps put an upper bound on them by some elementary considerations. For static tensile loading in a direction normal to a penny-shaped crack in an infinite isotropic and homogeneous medium, the stress intensity factor at the crack tip is (Lawn and Wilshaw, 1975).

$$K_I = \frac{2}{\pi} T (a)^{1/2} \quad (15)$$

where T is the magnitude of the applied tensile stress. This expression probably overestimates stress intensity factors that can be realized in basalts in response to tensile stress pulses. This is so because numerous pre-existing fractures in situ cause elastic interactions that tend to reduce crack-tip stress intensity factors below values for an isolated crack under the same load (Delameter et al., 1977). In addition, if the direction of the tensile pulse is not perpendicular to the fracture plane, the stress intensity factor is also reduced below the value in equation (15).

We shall make the nonconservative assumption that (15) gives the stress intensity factor at the tips of certain pre-existing cracks in the basalt. Thus, for crack extension to occur, the value of K_I must exceed the fracture toughness of 11 bar-meter^{1/2}. If we further assume that the largest planar isolated cracks in the basalt have radii of one meter, the value of net tension, T , necessary to cause their extension is: $T = (\pi/2) (11 \text{ bar-meter}^{1/2}) / (1 \text{ meter}^{1/2}) = 17.3 \text{ bars}$. It should be noted that we feel this value of tension to be a very low estimate because the

assumptions made in using equation (15) are probably rarely valid. Actual values of tension necessary for crack extension are likely to be greater because of the structural complexity of the basalt and of the arriving stress waves.

If the tensile pulse has a magnitude of 100 bars, the lithostatic in situ compression cannot exceed 82.7 bars for there to be net tension of 17.3 bars. This value of net tension occurs at the depth:

$$d = \frac{(1 - \nu)(82.7 \text{ bars})}{\nu(0.26 \text{ bar/meter})} = 954 \text{ m.}$$

Thus, earthquake-induced extension of some isolated fractures with radii greater than 1 meter is theoretically possible at depths less than about 950 meters according to this analysis.

4.6 PERMEABILITY CHANGES AFTER STIMULATION OF SANDSTONE RESERVOIRS WITH NUCLEAR EXPLOSIVES

The closest large-scale analogy to dynamic earthquake-induced loading of rocks is the dynamic loading produced by underground explosions. The Gasbuggy project, in which a 29-kiloton device was exploded at a depth of 2570 meters in the San Juan Basin of New Mexico, has probably provided most of the data currently available about shock-wave induced permeability changes. This explosion and the Rulison explosion near Grand Junction, Colorado were in tight gas-bearing sandstones and were conducted for the purpose of increasing permeability and gas production by fracturing the rock.

One of the more significant results of the Gasbuggy and Rulison experiments was the discovery that matrix permeability of the sandstones was nearly unaffected outside of the zone of cavity formation surrounding the well. Borg (1970) states that "microfracturing in the shocked rock" surrounding the Gasbuggy detonation point "has been examined microscopically in core samples. The amount of fracturing observed is small and shows little correlation with distance from the shot point." This observation is significant because the rocks were subjected to transient loads (compressions) as high as 6 to 8 kilobars. Borg (1970) also observed that there was fracturing and separation (from 1 to 50 microns) along

bedding planes in the finer-grained sediments but speculated that these partings would be closed under in situ conditions and would not lead to permeability changes.

Quong and LaGuardia (1970) measured matrix permeabilities in sandstones sampled up to 116 m from the detonation point in the Gasbuggy test. They found "comparatively little change in permeability of specimens recovered 72m to 116 meters from the explosion point". Since shock wave amplitudes decrease with increasing distance from the source, we conclude that permeability changes at distances greater than 116m were probably negligible. Quong and LaGuardia (1970) made no attempt to evaluate hydraulic-conductivity changes related to the possible formation or extension of large fractures in the rock.

4.7 DISCUSSION

The foregoing analysis has shown that for one-dimensional wave propagation in an isotropic and homogeneous earth the instantaneous value of stress at a point is equal to the product of rock density, wave velocity, and particle velocity. Stress can be related to particle accelerations through the ratios of particle velocities to particle accelerations given in Table 4-1. Measurements and theoretical predictions of maximum achievable particle velocity and acceleration indicate that propagating seismic waves are unlikely to induce compressional, tensional, or shear stress components in excess of 100 bars in basalts at depths greater than a few hundred meters.

We have ruled out matrix permeability increases from seismic loading on the basis of theoretical considerations and comparisons with effects of underground nuclear explosions. However, seismic waves can conceivably increase hydraulic conductivity in two other ways: 1) by fracturing the basalt, and thereby opening new flow paths, 2) by shifting blocks along pre-existing joints and fractures so as to result in greater separation and fracture conductivity after the earthquake (this could be the result of propping on asperities along the joint surfaces). The second source of hydraulic-conductivity enhancement would appear possible only at relatively shallow depths (less than 950 meters) for which net tensions can propagate through the rock and momentary separation and shear displacement along joint surfaces can occur. Still, no direct measurements of this process

have ever been made, and it can be neither confirmed nor disproven with any certainty. We do feel, however, that block displacement must be ruled out as a conceivable mechanism of permeability enhancement at depths below about 950 meters.

The results of the Rulison and Gasbuggy tests strongly suggest that earthquake-induced loading cannot change hydraulic conductivity by producing new microfractures in the matrix of the rock. The only remaining possibility for hydraulic-conductivity enhancement is extension of relatively large (centimeters to meters), pre-existing fractures in the basalt. Because of high lithostatic compressions at depth, this mechanism should be inoperative below about 950 meters. At these depths hydraulic-conductivity change is independent of depth and is equal to zero:

$$\Delta K = 0, \text{ when } d > 950\text{m} \quad (16)$$

At shallower depths some growth of pre-existing fractures might occur during earthquakes, but it is debatable whether this will lead to hydraulic-conductivity changes because the newly developed fracture segments should close up again after passage of the seismic waves through the rock. Closure occurs in response to the lithostatic compression that the rock is naturally subjected to.

If hydraulic-conductivity changes occur above 950 meters because of block movement or fracture extension, the small smount of available evidence suggests that the changes are small, i.e., within a few percent of the initial hydraulic conductivity. We shall here engage in intelligent speculation as to what the relationship between acceleration and conductivity change might be, as there ~~is~~ are insufficient data to formulate an iron-clad expression. We make the assumption that the ratio of particle velocity to acceleration is 56 cm/sec/g, the average of the three values in Table 4-1. We further assume that the hydraulic-conductivity increase associated with an earthquake that produces peak transient values of tension of 100 bars* is 10 percent and results from the combined

*This is a net tension of 100 bars. If the static in situ compression is 50 bars, the tensile wave must have an amplitude of 150 bars to produce net tension of 100 bars.

effects of fracture lengthening and block movement. Furthermore, we assume that both of these processes of conductivity enhancement become operative when the net amplitude of the tensional pulse (after subtracting lithostatic compression) is 17.3 bars (see page 4-13) and that there is a linear increase of conductivity from 0 to 10 percent in the stress range from 17.3 to 100 bars.

In its most general form, the equation we have derived for hydraulic conductivity is:

$$K = K_i \left[1 + .10 \left\{ \frac{(\rho c) (56 A_g) (10^{-6}) - \frac{\nu \Delta \sigma_v d}{1-\nu} - \left(\frac{\pi}{2}\right) (K_{IC}) (a^{1/2})}{100 \text{ bars} - \left(\frac{\pi}{2}\right) (K_{IC}) (a^{1/2})} \right\} \right] \quad (17)$$

where K_i is the initial hydraulic conductivity in meters/day, ρ basalt density in g/cm^3 , c wave velocity in cm/sec, A_g peak particle acceleration expressed in units of g , ν Poisson's ratio, $\Delta \sigma_v$ the gradient of vertical lithostatic stress with depth d , K_{IC} the fracture toughness of the basalt, and a the characteristic radius of pre-existing fractures in the basalt. Substituting the values for these parameters that have been used previously* (Table 4-1) gives

$$K = K_i \left[1 + .10 \left\{ \frac{91.3 A_g - 0.086 d - 17.3}{82.7} \right\} \right] \quad (18)$$

If the term in the inner brackets is negative, we assume no change and equation (18) becomes $K = K_i$.

* a is taken as 1 meter, K_{IC} as 11 bar-meter^{1/2}, and ν as 0.25.

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APPENDIX D

AS-RUN GSM CODE

APPENDIX D

AS-RUN GSM CODE

The code presented in Volume 1 of this report was modified several times prior to running the simulations reported herein. The version of the GSM code used in the simulations is contained in this appendix.

```
-----
00001 C ***** AEGIS MAIN ROUTINE *****
00002 C
00003 C
00004 C PROGRAM DESCRIPTION :
00005 C THIS IS THE MONTE CARLO SIMULATION OF LONG-TERM GEOLOGIC
00006 C FAR-FIELD PROCESSES ON THE STORAGE OF NUCLEAR WASTE IN THE
00007 C PASCO BASIN.
00008 C
00009 C
00010 C AUTHORS :
00011 C GREGG M. PETRIE BATTELLE PACIFIC NORTHWEST LABS
00012 C ALAN J. BALDWIN BATTELLE PACIFIC NORTHWEST LABS
00013 C
00014 C
00015 C HOST COMPUTER : PDP 11/55
00016 C
00017 C LOGICAL UNIT ASSIGNMENTS :
00018 C LUNINP=1 INPUT DATA FILES
00019 C LUNHIS=2 HISTORY DATA FILES
00020 C LUNOUT=3 OUTPUT FILES
00021 C LUNSUM=4 SUMMARY FILE
00022 C LUNVS =5 IVS 60 SCOPE (IF USED)
00023 C LUNTTY=6 USER TERMINAL
00024 C LUNCLM=7 CLIMATE FILE
00025 C
00026 C DEVICE ASSIGNMENTS:
00027 C DI1: >>>> ALL INPUT
00028 C DI2: >>>> HISTORY OUTPUT
00029 C DI2: >>>> M.C.B. OUTPUT
00030 C DI3: >>>> SUMMARY FILE INFORMATION
00031 C
00032 C
00033 C
00034 C
00035 C THE SENSE SWITCH MEANINGS ARE:
00036 C SENSE SWITCH 0 = DUMP OUT CLIMATE INFORMATION TO TERMINAL
00037 C SENSE SWITCH 1 = DUMP LEVEL 'H' HISTORY MESSAGES
00038 C SENSE SWITCH 2 = DUMP LEVEL 'O' HISTORY MESSAGES
00039 C SENSE SWITCH 3 = DUMP RUN * COMPLETED, ETC., TO TERMINAL
00040 C SENSE SWITCH 4 = HALT MODEL AT THE END OF A RUN, WRITE DUMP
00041 C SENSE SWITCH 5 = RESTART MODEL FROM WHERE IT WAS HALTED
00042 C SENSE SWITCH 6 = START MODEL WITH A RANDOM SEED
00043 C
00044 C (NOTE: SWITCHES 4 AND 5 ALLOW THE MODEL TO RESTART EVEN IF THE
00045 C SYSTEM CRASHES BECAUSE THE MODEL CONSTANTLY SAVES THE
00046 C PRESENT STATE AND THE PRESENT RANDOM NUMBER SEED.)
00047 C
00048 C PRESENT SUBMODELS :
00049 C UNDETECTED FEATURES (UNFEAT)
00050 C - THIS SUBMODEL ALLOWS FOR FEATURES SUCH AS FOLDS, FAULTS,
00051 C DIKES, ETC. THAT MAY HAVE BEEN MISSED IN THE ORIGINAL
00052 C SURVEY.
00053 C CLIMATE (CLIM)
```



```
00054 C      - THIS SUBMODEL READS THE CLIMATE FILE, THEN ALLOWS FOR
00055 C      CERTAIN RANDOM EVENTS TO AFFECT THE CLIMATE STATE.
00056 C      SEA LEVEL FLUCTUATIONS (SLEVEL)
00057 C      - THIS SUBMODEL FINDS THE CURRENT SEA LEVEL AND ASSOCIATED
00058 C      EFFECTS.
00059 C      MAGMATIC EVENTS (MAGMAT)
00060 C      - THIS SUBMODEL CALCULATES THE PROBABILITY AND EFFECTS OF
00061 C      A MAGMATIC EVENT IN THE PASCO BASIN.
00062 C      DEFORMATION (DEFORM)
00063 C      - THIS SUBMODEL ALLOWS FOR CHANGES
00064 C      DUE TO FOLDING OR FAULTING.
00065 C      GLACIAL EVENTS (GLACER)
00066 C      - THIS SUBMODEL UPDATES THE GLACIER POSITION AND ALLOWS
00067 C      FOR THE EFFECTS OF GLACIATION ON THE GEOSYSTEM.
00068 C      GEOMORPHIC EVENTS (GEOMOR)
00069 C      - THIS SUBMODEL ACCOUNTS FOR CHANGES IN THE PATH LENGTH
00070 C      OF THE UNCONFINED GROUND WATER SYSTEM AND EROSION(OR DEPOSITION
00071 C      SUBBASALT FAULTING (SUBFLT)
00072 C      - THIS SUBMODEL ACCOUNTS FOR THE EFFECTS OF SUB BASALT
00073 C      FAULTING.
00074 C      METEORITE IMPACT (METRIT)
00075 C      - THIS SUBMODEL ACCOUNTS FOR THE EFFECTS OF A
00076 C      METEORITE IMPACT IN THE PASCO BASIN.
00077 C      HYDROLOGY (HYDRO)
00078 C      - THIS SUBMODEL ACCOUNTS FOR THE STATE OF THE HYDROLOGIC
00079 C      SYSTEM.
00080 C
00081 C
00082 C      INTEGER IGO(15)
00083 C      LOGICAL LDUMP,LMORE
00084 C      COMMON /MORDMP/ LDUMP , LMORE
00085 C
00086 C      COMMON /IJRAN/ IRAN,JRAN
00087 C
00088 C      INCLUDE 'D111(226,226)COMMON,FLX1'
00089 C
00090 C      OPEN-FILES-READ-IN-DATA-INITALIZE-CHECK-FOR-RESTART
00091 C      RUN-SIMULATION
00092 C      CLOSE-FILES
00093 C
00094 C
00095 C
00096 C
00097 C      *****
```

```
-----
00098 C      TO OPEN-FILES-READ-IN-DATA-INITALIZE-CHECK-FOR-RESTART
00099 C      .
00100 C      .
00101 C      . CALL READS
00102 C      .
00103 C      .
00104 C      ...FIN
00105 C
00106 C
```

```

00107 C *****
-----

00108      TO RUN=SIMULATION
00109 C *****RUN SIMULATION*****
00110 C .
00111 C .
00112      DO (IRUN = ISTRN , NRUNS)
00113      . . WRITE (6,100)IRUN,ISTRN,NRUNS
00114      100 . . FORMAT(//,1X,7('*****'),//,T25,'START OF TIME STEP ',I4,
00115      1. . . //,T10,'START ',I4,T50,'END',I4,//,1X,7('*****'),//)
00116      . . WHEN (IRUN .GT. 0) IRUN1=IRUN
00117      . . ELSE IRUN1=1
00118      . . CALL OPINT(IRUN1)  IOPEN OUTPUT FILES
00119      . . CALL UNFEAT      IUNDETECTED FEATURES SUBMODEL
00120 C .
00121 C .
00122 C .
00123 C .
00124 C . . MONTE CARLO RUN 1
00125      . . UNTIL (LEND(7))
00126 C . . . *****START OF A TIME STEP *****
00127      . . . CALL CLIM      ICLIMATE
00128      . . . CALL MIX(IGO) ISELECT SUBMODEL ORDERING
00129      . . . DO (ISUB = 1,7)
00130      . . . . SELECT (IGO(ISUB))
00131      . . . . . (1) CALL SLEVEL      ISEA LEVEL
00132      . . . . . (2) CALL MAGMAT      IMAGMATIC EVENTS
00133      . . . . . (3) CALL DEFORM      IDEFORMATION
00134      . . . . . (4) CALL GLACER      ICONT. GLACIER
00135      . . . . . (5) CALL GEOMOR      IGEOMORPHIC EVENT
00136      . . . . . (6) CALL SUBFLT      ISUB-BASALT FAULTING
00137      . . . . . (7) CALL METRIT      IMETEORITE IMPACT
00138      . . . . . FIN
00139      . . . FIN
00140      . . . CALL HYDRO      IHYDROLOGY SUBMODEL
00141      . . . CALL OUTALL(IRUN1) IOUTPUT TO M,C,S, SCALAR FILE AND CHECKS SWITCHS
00142 C . . . *****END OF A TIME STEP *****
00143 C .
00144 C .
00145 C . . . FIN
00146      . . . CALL CLOUT(IRUN1) IWRITES TO SUMMARY FILE,CLOSES FILES AND REMINDS CLIM
00147      . . . FIN
00148      . . . FIN
00149 C .
00150 C .
00151 C .
00152 C *****
-----

00153      TO CLOSE=FILES
00154 C *****CLOSE FILES*****
00155 C .
00156      . CALL CLOSIT ICLOSE THE LAST OF THE FILES

```

```
00157 C      .      I.E. THE SUMMARY AND
00158 C      .      CLIMATE FILES
00159 C      .
00160      ...FIN
00161 C
00162 C
00163 C      *****
00164      END
```

PROCEDURE CROSS-REFERENCE TABLE

```
00098 OPEN-FILES-READ-IN-DATA-INITALIZE-CHECK-FOR-RESTART
00090

00153 CLOSE-FILES
00092

00108 RUN-SIMULATION
00091
```

(FLECS VERSION 22.46)

```
00165 C      ***** SUBTINE,FLX *****
00166 C      ROOT NAME=SUBTINE,FLX
00167 C
00168 C      THIS SUBROUTINE PACKAGE HOLDS THE FOLLOWING SUBROUTINES:
00169 C
00170 C      SHAFT  ■ ROUTINE TO SHAFT THE SEAL
00171 C      LTEST  ■ LOGICAL FUNCTION FOR BINOMIAL TEST WITH TIME
00172 C      LTESTW ■ LOGICAL FUNCTION FOR BINOMIAL TEST
00173 C      GLSEAR ■ ROUTINE TO DO SOMETHING
00174 C      GETFLD ■ ROUTINE TO GET FOLD CHARACTERISTICS
00175 C      SETFLT ■ ROUTINE TO SET UP A FAULT IN THE SUBBASALT BASEMENT
00176 C      POLY   ■ ROUTINE TO EVALUATE A POLYNOMIAL
00177 C      ANGBTN ■ FUNCTION TO FIND SMALLEST ANGLE IN THE LINEAMENT
00178 C      PROB   ■ FUNCTION TO CHECK PROBABILITY CURVE
00179 C      RANDOM ■ FUNCTION TO GIVE A RANDOM NUMBER
00180 C      INUMBR ■ ROUTINE TO COMPARE THE VALUES OF AN INTEGER NUMBER
00181 C      RNUMBR ■ ROUTINE TO TYPE A REAL NUMBER
00182 C      NOTE   ■ ROUTINE TO TYPE A NOTE
00183 C      CHANGX ■ ROUTINE TO CHANGE A LAYER
00184 C      POISON ■ ROUTINE FOR POISSON DISTRIBUTION
00185 C      HISTXX ■ ROUTINE FOR HISTORY MESSAGES
00186 C
00187 C      ***** SHAFT,FLX *****
00188 C
00189 C
00190 C      ACCOUNTS FOR CHANGES IN THE HYDRAULIC CONDUCTIVITY IN THE SHAFT
00191 C      SEAL IN THE FOLLOWING WAY:
00192 C
00193 C
```



```
00194 C
00195 SUBROUTINE SHAFT(ACCELT,TIMEIN)
00196 C
00197 INCLUDE 'DI:[226,226]COMMON,FLX'
00198 C
00199 CALL NOTE(12,'ENTER SHAFT')
00200 IF (ACCELT .GE. ACLCRT)
00201 . PSHAFT=POLY(S,TIMEIN)
00202 . IF(L TEST(PSHAFT) )
00203 . . CSHAFT=CSHAFT+PROB(27) IDRAW FOR CHANGE IN HYDRAULIC CONDUCTIVITY
00204 . . CALL RNUMBR(12,'SITE SHAFTED',CSHAFT)
00205 . ...FIN
00206 ...FIN
00207 C
00208 C THIS SUBROUTINE MAY WELL CHANGE WHEN THE EXACT NATURE OF THE
00209 C REPOSITORY IS WELL DEFINED
00210 C
00211 RETURN
00212 END
```

(FLECS VERSION 22,46)

```
-----
00213 C ***** LTEST *****
00214 C
00215 C PROGRAM DESCRIPTION :
00216 C
00217 C BINOMIAL TEST WHERE PROBABILITY IS INFLUENCED BY TIME
00218 C
00219 C LOGICAL FUNCTION LTEST(PROBIN)
00220 C
00221 INCLUDE 'DI:[226,226]COMMON,FLX'
00222 C
00223 COMMON /IJRAN/ IRAN,JRAN
00224 C
00225 WHEN(DTIME,EQ,100,0) PROB=PROBIN
00226 ELSE
00227 . NT=DTIME/100,0+0.5
00228 . PROB=1.0-(1.0-PROBIN)**NT
00229 ...FIN
00230 C
00231 WHEN(RANDOM(IRAN,JRAN),LE,PROB)LTEST=.TRUE.
00232 ELSE LTEST=.FALSE.
00233 C
00234 RETURN
00235 END
```

(FLECS VERSION 22,46)

```
-----
00236 C ***** LTESTN *****
00237 C
00238 C PROGRAM DESCRIPTION :
00239 C BINOMIAL TEST
```

```
00240 C
00241 C
00242 LOGICAL FUNCTION LTESTM(PROB)
00243 C
00244 COMMON /IJRAN/ IRAN,JRAN
00245 C
00246 WHEN(RANDOM(IRAN,JRAN).LE. PROB)LTESTM=.TRUE,
00247 ELSE LTESTM=.FALSE,
00248 RETURN
00249 END
```

(FLECS VERSION 22,46)

```
-----
00250 C ***** GLSEAR *****
00251 C
00252 C PROGRAM DESCRIPTION :
00253 C TO FIND THE RATIO BETWEEN THE CALCULATED ICE VOLUME AT ITS FURTHEST
00254 C EXTENT, AND THE 'CORRECT' VALUE
00255 C
00256 SUBROUTINE GLSEAR(SOURCE,RATIO)
00257 RAD=ABS(SOURCE-47.5)
00258 C DISTANCE BETWEEN THE CURRENT SOURCE AREA AND
00259 C THE MAXIMUM EXTENT OF THE GLACIER (HERE A PRELIMINARY VALUE OF
00260 C 47.5 DEGREES LATITUDE IS USED)
00261 STEP2=RAD*RAD*80RT(RAD)
00262 RATIO=37.88/STEP2 ;RATIO BETWEEN CALCULATED AND 'REAL' VALUE
00263 CALL RNUMBR(14,'SEA-ICE RATIO',RATIO)
00264 RETURN
00265 END
```

(FLECS VERSION 22,46)

```
-----
00266 C ***** GETFLD *****
00267 C
00268 C PROGRAM DESCRIPTION :
00269 C DEFINE THE CHARACTERISTICS OF A NEW FOLD
00270 C
00271 SUBROUTINE GETFLD
00272 C
00273 INCLUDE 'DI:(226,226)COMMON,FLX'
00274 C
00275 REAL FANGLE(4) ;REMOVE THIS LATER
00276 C # 12
00277 DO(I=1,4)
00278 C ***** DENSITY CURVE *****
00279 . FANGLE(I)=90.0-PROB(92+I);CURVES 93 - 96
00280 C *****
00281 C . ANGLE 1 = NORTHERN ANGLE
00282 C . ANGLE 2 = EASTERN ANGLE
00283 C . ANGLE 3 = SOUTHERN ANGLE
00284 C . ANGLE 4 = WESTERN ANGLE
00285 . CALL RNUMBR(12,'ANGLE VALUE',FANGLE(I))
```

```

00286      . FANGLE(I)=FANGLE(I)/57.2958
00287      ...FIN
00288      POST=0.0
00289 C ***** DENSITY CURVE *****
00290      AXISAN=WTREND+PROB(97);TREND AWAY FROM THE LOCAL FAULTING SYSTEM
00291      DISTFD=PROB(98)*FOLDMX;RADIAL DISTANCE
00292      FOLDAN=PROB(99) ;ANGLE FROM NORTH
00293 C *****
00294      IF(AXISAN.GE.180)AXISAN=180.0-AXISAN ;I.E. A LINEAMENT,NOT A VECTOR
00295      AVAXIS=90.0-ANGBTN(AXISAN,FOLDAN)
00296      CALL RNUMBR(15,'AN BTN VEC-AXIS',AVAXIS)
00297      AVAXIS=AVAXIS/57.2958
00298      COSAN2=COS(AVAXIS)
00299      SINAN=SIN(AVAXIS)
00300      CALL RNUMBR(15,'FOLD AXIS TREND',AXISAN)
00301      CALL RNUMBR(15,'RADIAL DISTANCE',DISTFD)
00302      CALL RNUMBR(19,'FOLD POSITION ANGLE',FOLDAN)
00303      RETURN
00304      END

```

(FLECS VERSION 22,46)

```

-----
00305 C ***** SETFLT *****
00306 C
00307 C PROGRAM DESCRIPTION :
00308 C ROUTINE TO SET UP A FAULT IN THE SUBBASALT BASEMENT
00309 C
00310 C SUBROUTINE SETFLT
00311 C
00312 C REAL RADIST(1,1),DELX(1,1) ;REMOVE THIS LATER
00313 C
00314 C INCLUDE 'DI:(226,226)COMMON,FLX'
00315 C
00316 C # 13
00317 CALL NOTE (17,'SUBBASEMENT FAULT')
00318 LFBASE=,TRUE, ;FAULT IN SUB-BASEMENT
00319 C *****DENSITY CURVE*****
00320 FDIST=PROB(100)*FHAXD;DRAW FOR THE RADIAL DISTANCE
00321 FANG=PROB(101) ;DRAW FOR FAULT ANGLE
00322 TSUBFT=PROB(102) ;DRAW FOR THE TIME OF THE NEXT FAULT
00323 C *****
00324 CALL RNUMBR(14,'ANGLE OF FAULT',FANG)
00325 CALL RNUMBR(17,'DISTANCE TO FAULT',FDIST)
00326 CALL RNUMBR(17,'NEXT FAULT ACTIVE',TSUBFT)
00327 RDFTDT=SQRT((DEPHAS/1000.0)**2+FDIST**2) ;GET RADIAL DISTANCE
00328 C
00329 C
00330 C FIND THE ANGLE OF THE FAULT POSITION VECTOR RELATIVE
00331 C TO THE CROSS SECTION
00332 F AND C=ANGBTN(FANG,ANCROSS)
00333 ANGLE=FANDC/57.2958
00334 CALL RNUMBR(19,'FAULT AND CROSS AN.',FANDC)
00335 XF=FDIST*COS(ANGLE)
00336 YF=FDIST*SIN(ANGLE)

```

```

00337 C
00338 C FIND THE Z COORDINATE FOR THE LAYER ON THE BOTTOM
00339 DO(ISYSTH=1,3)
00340 . RADIST(NLAYER,ISYSTH)=DBASE+DELX(NLAYER,ISYSTH)/2.0
00341 ...FIN
00342 NBOTOM=NLAYER-1
00343 C FIND THE Z COORDINATE FOR EACH LAYER OF EACH SUBSYSTEM
00344 DO(ISYSTH=1,3)
00345 . DO(LAYER=NBOTOM,1,-1)
00346 . . CALL INUMBR(7,'LAYER=',LAYER)
00347 . . CALL INUMBR(8,'SYSTEM=',ISYSTH)
00348 . . EXTRA=DELX(LAYER+1,ISYSTH)/2.0+DELX(LAYER,ISYSTH)/2.0
00349 . . RADIST(LAYER,ISYSTH)=RADIST(LAYER+1,ISYSTH)+EXTRA
00350 . . CALL RNUMBR(11,'Z DISTANCE',RADIST(LAYER,ISYSTH))
00351 . ...FIN
00352 ...FIN
00353 C
00354 C FIND THE DISTANCE FOR EACH LAYER(IN EACH SUBSYSTEM) AND
00355 C THE FAULT
00356 YY=YF*YF
00357 DO(LAYER=1,NLAYER)
00358 . DO(ISYSTH=1,3)
00359 . . CALL INUMBR(7,'LAYER=',LAYER)
00360 . . CALL INUMBR(8,'SYSTEM=',ISYSTH)
00361 . . ZZ=(RADIST(LAYER,ISYSTH)/1000.0)**2 ! IN KM
00362 . . XX=(REPOST(LAYER,ISYSTH)-XF)**2
00363 . . RADIST(LAYER,ISYSTH)=SQRT(ZZ+XX+YY)
00364 . . CALL RNUMBR(15,'TOTAL DISTANCE',RADIST(LAYER,ISYSTH)) KM
00365 . ...FIN
00366 ...FIN
00367 C
00368 C
00369 C
00370 C FIND THE ANGLE BETWEEN THE CROSS SECTION AND THE FAULT LINE
00371 ANGLE=90.0- F AND C
00372 CALL RNUMBR(19,'FAULT LINE AND SECT',ANGLE)
00373 ANGLE=ANGLE/57.2958
00374 C #####DENSITY CURVE#####
00375 ANFACT=POLY(15,ANGLE)+PROB(103)!FIND THE CORRECTION FOR THE ANGLE
00376 C #####
00377 C
00378 C
00379 C FIND THE DISTANCE FROM THE SURFACE TO EACH COMPONENT
00380 DO(ISYSTH=1,3) DEPTHZ(1,ISYSTH)=DELX(1,ISYSTH)/2.0
00381 DO(LAYER=2,NLAYER)
00382 . DO(ISYSTH=1,3)
00383 . . DEPTHZ(LAYER,ISYSTH)=DEPTHZ(LAYER-1,ISYSTH)+DELX(LAYER-1,ISYSTH)
00384 +. . /2.0 + DELX(LAYER,ISYSTH)/2.0
00385 . . CALL RNUMBR(5,'DEPTHZ',DEPTHZ(LAYER,ISYSTH))
00386 . ...FIN
00387 ...FIN
00388 RETURN
00389 END

```


D.11

```
00444      . (3)HORNER=EXP(P)
00445      . (4)HORNER=10.0**P
00446      ...FIN
00447      CALL RNUMBR(7,'#Y OUT=',HORNER)
00448      POLY=HORNER
00449      C
00450      C
00451      C
00452      RETURN
00453      END
```

(FLECS VERSION 22,46)

```
-----
00454      C ***** ANGBTN *****
00455      C
00456      C PROGRAM DESCRIPTION :
00457      C FIND THE SMALLEST ANGLE BETWEEN THE CROSS SECTION AND A
00458      C LINEAMENT
00459      C
00460      C FUNCTION ANGBTN(ANGLNA,ANCROS)
00461      C FIND THE SMALLEST ANGLE BETWEEN THE CROSS SECTION AND THE
00462      C LINEAMENT
00463      C ANGLNA: ANGLE (FROM NORTH) OF THE LINEAMENT
00464      C ANCROS ANGLE (FROM NORTH) OF THE MODEL CROSS SECTION
00465      C
00466      C CALL RNUMBR(16,'@LINEAMENT ANGLE',ANGLNA)
00467      C ANGLE=ANGLNA-ANCROS
00468      C IF (ANGLE,LT,0.0) ANGLE =360.0+ANGLE
00469      C ANGBT=ANGLE
00470      C IF (ANGLE,GT,90.0,AND, ANGLE ,LT,180.0) ANGBT=180.0-ANGLE
00471      C IF (ANGLE,GE,180.0,AND,ANGLE ,LE, 270.) ANGBT=ANGLE-180.0
00472      C IF (ANGLE,GT,270.0) ANGBT=360.0-ANGLE
00473      C CALL RNUMBR(11,'@ANGLE OUT=',ANGBT)
00474      C IF (ANGBT,GT,90.0 ,OR, ANGBT ,LE, 0.0 )
00475      C . CALL NOTE (11,'ANGLE ERROR')
00476      C . ANGBT=45.0
00477      C ...FIN
00478      C ANGBTN=ANGBT
00479      C RETURN
00480      C END
```

(FLECS VERSION 22,46)

```
-----
00481      C ***** PROB *****
00482      C
00483      C PROGRAM DESCRIPTION :
00484      C SAMPLE FROM DENSITY CURVES
00485      C
00486      C FUNCTION PROB (ID)
00487      C
00488      C COMMON /IJRAN/ IRAN , JRAN
00489      C
```

```

00490      INCLUDE 'DI:[226,226]COMMON,FLX'
00491      C
00492      CALL INUMBR(15,'#DENSITY CURVE',ID)
00493      C
00494      C
00495      WHEN(ID.LT.1.OR.ID.GT.NDEN)
00496      . TYPE 604 ,ID;WRITE OUT ERROR MESSAGE RIGHT NOW!
00497      604 . FORMAT(19, 'ERROR IN DENSITY FUNCTION')
00498      . PROB=0.0 IDUMMY VALUE BACK
00499      ...FIN
00500      ELSE
00501      . PROB=1,E20 ITO MARK A POSSIBLE ERROR CONDITION
00502      . TESTS=RANDOM(19AN,JRAN)
00503      . WHEN(IOPON(ID).LT.0.AND. DTIME.GT.100.0)
00504      . . SD=DTIME/100.0
00505      . . SD=(XHIGH(ID)-XLOW(ID))/80;NEW RANGE
00506      . . AVE=(XHIGH(ID)+XLOW(ID))/2.0
00507      . . XLOWS=AVE-SD/2.0
00508      . . XHIGHS=AVE+SD/2.0
00509      . ...FIN
00510      . ELSE
00511      . . XLOWS=XLOW(ID)
00512      . . XHIGHS=XHIGH(ID)
00513      . ...FIN
00514      . SELECT(ABS(IOPON(ID)))
00515      . . (1)
00516      C . . . UNIFORM
00517      . . . PROB=X*TESTS*(XHIGHS-XLOWS)+XLOWS
00518      . . . ...FIN
00519      . . (2)
00520      C . . . NORMAL
00521      . . . TEST2=RANDOM(19AN,JRAN)
00522      . . . CALL RNUMBR(11,'#2ND RANDOM',TEST2)
00523      . . . SD=SQRT(-2.0*LOG(TESTS))*COS(6.2831853*TEST2)
00524      . . . AVE=(XHIGHS+XLOWS)/2.0
00525      . . . SDD=(XHIGHS-XLOWS)/6.0
00526      . . . PROB=X*AVE+SDD*SD
00527      . . . IF(PROB.LT.XLOWS) PROB=XLOWS
00528      . . . IF(PROB.GT.XHIGHS) PROB=XHIGHS
00529      . . . ...FIN
00530      . . (3)
00531      C . . . EMPIRICAL
00532      . . . DX=(XHIGHS-XLOWS)/20.0
00533      . . . PROB=XHIGHS
00534      . . . DO(I=0,19)
00535      . . . . IF(TESTS.GE.CURVE(ID,I).AND.TESTS.LT.CURVE(ID,I+1) )
00536      . . . . . WHEN(ABS(CURVE(ID,I)-CURVE(ID,I+1)).GT.0.00001)
00537      . . . . . RATIOS=(TESTS-CURVE(ID,I))/(CURVE(ID,I+1)-CURVE(ID,I))
00538      . . . . . PROB=XRATIOS*DX+DX*FLOAT(I)+XLOWS
00539      . . . . . ...FIN
00540      . . . . ELSE PROB=DX*FLOAT(I)+DX/2.0+ XLOWS
00541      . . . . ...FIN
00542      . . . ...FIN
00543      . . ...FIN
00544      . . (4)
00545      C . . . RADIUS OF A POSITION VECTOR OF UNIT LENGTH

```

```
00546      . . . PROB=SQRT(TESTS)
00547      . . . FIN
00548      . . . (5)
00549      C      . . . EXPONENTIAL
00550      C      . . . LAMDA IS SORTED IN XLOW
00551      . . . PROB=-LOG(TESTS)/XLOW(ID)
00552      . . . FIN
00553      . . . FIN
00554      C      .
00555      C      .
00556      . IF(PROB, EQ, 1.0E20)
00557      . . TYPE 100, ID, PROB, DX, TESTS IWRITE OUT ERROR MESSAGE RIGHT NOW
00558      100 . . FORMAT (' DRAW ERROR = ', I6, Ix, 3G20.4)
00559      . . PROB=(XLOW(ID)+XHIGH(ID))/2.0
00560      . . . FIN
00561      . WHEN(LOGTR(ID), EQ, 0) PROB=PROB*IND TRANSFORM
00562      . ELSE PROB=10.0**PROB
00563      . . . FIN
00564      CALL RNUMBR(11, 'VALUE OUT=', PROB)
00565      CALL RNUMBR(15, 'RANDOM NUMBER=', TESTS)
00566      RETURN
00567      END
```

(FLECS VERSION 22,46)

```
00568      C ***** RANDOM *****
00569      C
00570      C PROGRAM DESCRIPTION :
00571      C THIS FUNCTION GIVES A RANDOM NUMBER. LATER, WE MAY WANT TO
00572      C CHANGE TO A DIFFERENT PSEUDO-RANDOM NUMBER GENERATOR.
00573      C
00574      C FUNCTION RANDOM(IRAN, JRAV)
00575      C RANDOM=RAV(IRAN, JRAV)
00576      C RETURN
00577      C END
```

(FLECS VERSION 22,46)

```
00578      C ***** INUMBR *****
00579      C
00580      C PROGRAM DESCRIPTION :
00581      C FORMATS A HISTORY MESSAGE
00582      C
00583      C SUBROUTINE INUMBR(NUM, TEXT1, IVALUE)
00584      C
00585      C BYTE TEXT1(NUM)
00586      C
00587      C LOGICAL LMORE, LDUMP
00588      C COMMON /HORDMP/ LMORE, LDUMP
00589      C
00590      C INCLUDE 'OI:1226,226'COMMON, FLX'
00591      C
```

```
00592 C
00593 IF(.NOT.LMORE.AND. TEXT1(1).EQ.'#') RETURN
00594 IF(.NOT.LDUMP.AND. TEXT1(1).EQ.'#') RETURN
00595 VALUE=IVALUE
00596 CALL RNUMBR(NUM,TEXT1,VALUE)
00597 RETURN
00598 END
```

(FLECS VERSION 22,46)

```
-----
00599 C ***** RNUMBR *****
00600 C
00601 C PROGRAM DESCRIPTION :
00602 C FORMATS A MESSAGE, AND A CORRESPONDING VALUE, TO THE HISTORY FILE
00603 C
00604 C SUBROUTINE RNUMBR(NUM,TEXT1,VALUE)
00605 C
00606 C LOGICAL LMORE,LDUMP
00607 C COMMON /MURDMP/ LMORE,LDUMP
00608 C
00609 C BYTE TEXT1(NUM),NOTES(20)
00610 C DIMENSION RNOTES(5)
00611 C EQUIVALENCE (RNOTES(1),NOTES(1))
00612 C
00613 C INCLUDE 'DI:1226,226)COMMON.FLX'
00614 C
00615 C
00616 C IF(.NOT.LMORE.AND. TEXT1(1).EQ.'#') RETURN
00617 C IF(.NOT.LDUMP.AND. TEXT1(1).EQ.'#') RETURN
00618 C
00619 C NOTES(1) = ' '
00620 C DO (I=1,20)
00621 C . WHEN (I.LE. NUM) NOTES(I)= TEXT1(I)
00622 C . ELSE NOTES(I) = ' '
00623 C ...FIN
00624 C CALL HISTXX(RNOTES,TIMEH,VALUE)
00625 C
00626 C
00627 C
00628 C RETURN
00629 C END
```

(FLECS VERSION 22,46)

```
-----
00630 C ***** NOTE *****
00631 C
00632 C PROGRAM DESCRIPTION :
00633 C FORMATS A MESSAGE FOR THE HISTORY FILE
00634 C
00635 C SUBROUTINE NOTE(NUM,TEXT1)
00636 C
00637 C LOGICAL LMORE,LDUMP
```

```
00638      COMMON /MORDMP/ LMORE , LDUMP
00639      C
00640      INCLUDE 'DI:[226,226]COMMON,FLX'
00641      C
00642      BYTE TEXT1(NUM),NOTES(20)
00643      DIMENSION RNOTES(5)
00644      EQUIVALENCE (RNOTES(1),NOTES(1))
00645      C
00646      C
00647      IF(.NOT.LMORE.AND. TEXT1(1).EQ.'#') RETURN
00648      IF(.NOT.LDUMP.AND. TEXT1(1).EQ.'#') RETURN
00649      DO(I=1,20)
00650      . WHEN(I.LE.NUM)NOTES(I)=TEXT1(I)
00651      . ELSE NOTES(I)=' '
00652      ...FIN
00653      C
00654      C
00655      C      ADD NEW NOTE TO LIST
00656      CALL HISTXX(RNOTES,TIMEN,TIMEN)
00657      C
00658      C
00659      C
00660      RETURN
00661      END
```

(FLECS VERSION 22,46)

```
-----
00662      C      ***** CHANGX *****
00663      C
00664      C      PROGRAM DESCRIPTION :
00665      C      UPDATES THE PASCO BASIN FOR EROSION(OR DEPOSITION) OF THE RIVER
00666      C      CHANNEL
00667      C      SUBROUTINE CHANGX(DIFFIN)
00668      C
00669      C
00670      C      INCLUDE 'DI:[226,226]COMMON,FLX'
00671      C
00672      C      DIFF=DIFFIN
00673      C      CALL RNUMBR(7,'#CHANGE',DIFFIN)
00674      C      CALL RNUMBR(12,'#START REPOS',RDEPTH)
00675      C      RDEPTH=RDEPTH+DIFF  IDEPTH TO THE REPOSITORY
00676      C      SELEV=SELEV+DIFF  ISITE ELEVATION
00677      C      HEADBS=HEADBS+DIFF  IHEAD VALUE IN THE BASIN
00678      C      ESENT=ESENT+DIFF  ISENTINEL GAP ELEVATION
00679      C      EWALL=EWALL+DIFF  IVILLUA GAP ELEVATION
00680      C
00681      C      DO(LAYER=ITOP,NLAYER)
00682      C      . DO(ISYSTH=1,3)
00683      C      . . DEPTHZ(LAYER,ISYSTH)=DEPTHZ(LAYER,ISYSTH)+DIFF
00684      C      . ...FIN
00685      C      ...FIN
00686      C
00687      C
00688      C      IF(RDEPTH.LE. 0.0 .AND. .NOT. LBRECH)
```

```

00689      . CALL NOTE(17,'EROSION TO REPOS,')
00690      . KEY=2
00691      . LBRECH=,TRUE.
00692      . BTIME=TIMEH
00693      ...FIN
00694 C
00695 C
00696      WHEN(DIFF .GT. 0,0)
00697 C      . FIRST CHECK FOR SEDIMENTATION
00698 C      .
00699      . IF(ITYPE(ITOP).NE.1 .AND. ITOP.GT.1)
00700      . . ITOP=ITOP+1
00701      . . CALL INUMBR(9,'NEW LAYER',ITOP)
00702      . . DELX(ITOP,2)=0,0
00703      . . ITYPE(ITOP)=1
00704      . . ...FIN
00705      . DELX(ITOP,2)=DELX(ITOP,2)+DIFF
00706      ...FIN
00707      ELSE
00708 C      . NOW CHECK FOR EROSION
00709      . WHILE(ABS(DIFF).GT.DELX(ITOP,2).AND.ABS(DIFF).GT.1E-11)
00710      . . CALL INUMBR(10,'LAYER GONE',ITOP)
00711      . . CALL RNUMBR(13,'LAST EROSION=',DIFF)
00712      . . DIFF=DIFF+DELX(ITOP,2) !NOTE DIFF < 0,0
00713      . . ITOP=ITOP+1
00714      . . IF (ITOP.GT.NLAYER)
00715      . . . CALL NOTE(9,'NO M.C.S.')
```

(FLECS VERSION 22,46)

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00728 C ***** POISSON *****
00729 C
00730 C PROGRAM DESCRIPTION : GENERATES POISSON RANDOM DEVIATE
00731 C
00732 C FUNCTION POISSON(AVE)
00733 C INCLUDE 'DI1:(226,226)COMMON,PLX'
00734 C COMMON /IJRAN/ IRAN,JRAN
00735 C
00736 C CALL RNUMBR(16,'#AVE POISSON IN1',AVE)
00737 C WHEN(DTIME.EQ.100,0)AVER=AVE
00738 C ELSE
00739 C . AVER=AVE+(DTIME/100,0)
```

```

00740      . CALL RNUMBR(16,'#AVE POISSON IN2',AVER)
00741      ...FIN
00742  C
00743  C
00744      WHEN(AVER,GT,50)
00745  C      . USE A NORMAL APPORX.
00746      . SD = SQRT(-2.0 * LOG(RANDOM(IRAN,JRAN)))
00747      . *COS(6.2831853*RANDOM(IRAN,JRAN))
00748  1.      SD=SQRT(-2.0*LOG(RANDOM(IRAN,JRAN)))*COS(6.2831853*RANDOM(IRAN,JRAN))
00749  C      . SD=SQRT(-2.0*LOG(RANDOM(IRAN,JRAN)))*COS(6.2831853*RANDOM(IRAN,JRAN))
00749      . N=AVER+SD*SQRT(AVER)+0.5
00750      ...FIN
00751      ELSE
00752      . EAVE=EXP(-AVER)
00753      . N=1
00754      . S=1.0
00755      . REPEAT UNTIL(S,LT,EAVE)
00756      . . S=S*RANDOM(IRAN,JRAN)
00757      . . N=N+1
00758      . ...FIN
00759      ...FIN
00760  C
00761      POISON=N
00762      CALL INUMBR(13,'#POISSON OUT#',N)
00763      RETURN
00764      END

```

(FLECS VERSION 22.46)

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-----
00765  C ***** HISTXX *****
00766  C
00767  C      PROGRAM DESCRIPTION :
00768  C      THIS SUBROUTINE POSTS MESSAGES TO THE HISTORY FILE AND/OR
00769  C      THE USER TERMINAL.
00770  C
00771      SUBROUTINE HISTXX(RNOTIN,TIMEIN,VALUE)
00772      REAL RNOTIN(5),RNOTE
00773      BYTE BNOTIN(4),BNOTE
00774      EQUIVALENCE (RNOTE,BNOTIN(1)),(BNOTE,BNOTIN(1))
00775  C
00776  C
00777      WRITE(2) RNOTIN,TIMEIN,VALUE
00778      RNOTE = RNOTIN(1)
00779      CALL SSWTCH(7,ISW7)
00780      IF(.NOT.(ISW7.EQ.1.OR,BNOTE.EQ.'#'))
00781      . WHEN(TIMEIN,NE,VALUE) WRITE(6,100) RNOTIN,TIMEIN,VALUE
00782      . ELSE WRITE(6,100) RNOTIN,TIMEIN
00783      ...FIN
00784  100 FORMAT (1X,5A4,F9.0,2X,G20.4)
00785  C
00786  C
00787  C
00788      RETURN
00789      END

```


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C
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FILE NAME = COMMON.FLX

C
C

LOGICAL LASHFL,LBEDRK,LBRECH,LCASTR,LEXPOS,LFBASE,LFBASH,LFDOCT,
1 LFLOOD,LFOLD,LFTINT,LICEON,LHAGRV,LNEWCL,LNWSBF,LRVON,LROCTR,
2 LRVCHG,LRVFXD,LSEACH,LSLIDE,LSSFIN,LTHRST,LXICEN

COMMON /AEGIS/ ACCEL,ACFTMN,ACELCT,ACLCRT,ACPAVE,ACPMAX,ACRPOS,
1 ANCRS,ANCRUN,ANFACT,ANISAN,ARCRAD,ATH,AVEFLD,AVEGAB,
2 AVEMAG,AVENAS,AVRAT,AVESAD,AVESWM,AVETPP,AVQABF,AVHCNE,AVHCON,
3 AVLAND,AVNEHC,AVRAT,AVRATF,AVSADF,AVSWHC,AXISAN,BMULTP,
4 RTIME,CASELV,CGLSTR,CGLSTT,CHCSNE,CHCSSW,
5 CHRKNE,CHRKSW,CONVN,CONVS,CORBED,COSAN,
6 COSBNE,COSBSW,COSNE,COSSW,CRPHFS,CSHAFT,CUNERC,CUSMRC,
7 DBASE,DCORBS,DCORNE,DCORSW,DEADZ,DEP,DEPHIN,
8 DEPBAS,DEPTNE,DEPTSW,DISTFD,DPNTNE,DPNTSW,DSMTMX,
9 DTIME,DURFT,DVRCH,DVRPNE,DVRPOS,DVRPSW,EDGESE,
+ EDGESW,EGAB,ERATTL,ESENT,EWALL,EXTRNE,EXTRSW,FANG,
1 FAREA,FDIST,FLHCNE,FLUXNE,FLUXSW,FLHCON,FLTNE,FLTSW,FLWDNE,
2 FLWDSW,FMAXD,FOLDAN,FOLDHC,FOLDHX,FREFNE,FREFSW,FREQFT,FRESFT,
3 FRESTR,FRINT,FTHCSS,GATNE,GLTNEL,GLNNE,GRSWLN,
4 GLMIN,GLMAX,GLACIN,
5 HARDFC,HCNEGR,HCSWGR,HCNEWS,HCSWWS,HONEGR,HDSWGR,
6 HDNEWS,HDSWWS,HEADBS,HIPATH,HMNEGR,HMNEWS,HMSWGR,HMSWWS,
7 HRIVER,HRVDIS,HT,
8 PASHFL,PCABUP,PFAULT,PFLAT,PFLATF,PFOLD,PFTNEH,
9 PGLCH,PHAGS,PHETRT,PMISFT,PNEEXF,PNWFD,PNWDF,
+ PNWFT,PNWTF,PNWTR,PNWTRF,POST,PRKUP,PRYMAG,PSEAEX,
1 PSSEXF,PSSTFB,PSWEXF,PTREXF,PUNTHS,Q,QDAM,RAD,RADCRT,
+ RAINNE,RAINSW,RATIO,RCANE,RCARNE,RCARSW,RCHNE,RCHSW,RDEPTH,
2 RDTDT,REDU,REBET,REBNE,RESFSW,RESCON,RESPN1,RESPN2,
3 RIVCAP,RKMSIT,RLAT,RLATHI,RLATLW,RHID,ROCKEL,
4 RPGLNE,RPGOST,RPOSHC,RPOSTH,RPSAVE,RTREND,
5 REA,SEACUR,SEAMAX,SEPAGE(3),SELEV,SEICELT,SEICENE,SEITIS0,
6 SITLAT,SITRAD,SLOPE,SLOPHI,SLOPLW,SNLAST,SOURCE,
7 SPEDUN,STATNE,STFLT, TOTLK,TIMEXX,TOTHC(5,3),
8 STGART,STRADT,STSADT,SUMFTN,SURMAT,TEND,TFLER,THABOV,
9 THICKG,THICNE,THRCH,THRWD,TTIME,TIMEH,
+ TLSTNE,TMSULA,TOTRHC,TMOVE,TRSTHC,TRSTRT,TRUSTT,
1 TSUBFT,TTTIME,WGLAT,WBNELN,WBSWLN,XHORNE,XHORSW,XSTART,YSTART,
2 CHHC(2,4,3),CHRS(3),COEFF(11,32),DATA1(200),DELX(4,3),DEPTHZ(4,3),
3 FANGLE(4),FAULT(200),FDR(200),FWIDTH(200),GABHC(4),FRAC(50),
4 HYDCN(4,3),SSFTHC(200),SSFTT(200),
5 ICURVE(32),IFSIT(50),IOPTON(135),IORDER(32),IPOLY(32),
6 ICLIM,ICLING,IFORCE,IRLAYR,ISTRN,ITOP,TMOBF,
7 NCASE,NDEN,NEXTFT,NLAYER,NPOLY,NRUNS,NSSFT,VHRCOR,
8 LASHFL,LAYRGR,LAYRWS,LBEURK,LBRECH,LCASTR,LCLIM,LEXPOS,
9 LFBASE,LFBASH,LFDOCT,LFLOOD,LFOLD,LFTINT,LICEON,LHAGRV,
+ LNEWCL,LNWSBF,LRVON,LROCTR,LRVCHG,LRVFXD,LSEACH,LSLIDE,
1 LSSFIN,LTHRST,LTRUST,LXICEN
1 ,CURVE(135,0:20),
2 ITYPE(8),HYDCN1(4,3),PATHLN(3),AVAXIS,SINAN,EFOLDE,COSAN2,
3 RADHC(4),RADIST(4,3),REPDS(4,3),RESET(100),RKM(3),RKML(3),
4 SADHC(4),
5 TIMES(3),UNPATH(3),VEL(3),XHIGH(135),XLOW(135),
6 LOGTR(135),LOGTRX(32),LOGTRY(32),DELX1(4,3),ITYPE1(8)

C
C
C
C

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ACELCT  = DATA1( 1)  | Sub-Basalt Quake Critical Acceleration
CALL RNUMBR(9,'#ACELCT  ',DATA1( 1))
ACFTMN  = DATA1( 2)  | Sub-Basalt Quake Critical Acceleration
CALL RNUMBR(9,'#ACFTMN  ',DATA1( 2))
ACLCRT  = DATA1( 3)  | Critical Acceleration For Shaft Seal
CALL RNUMBR(9,'#ACLCRT  ',DATA1( 3))
ANCROS  = DATA1( 4)  | Angle From North of Model Cross Section(MCS)
CALL RNUMBR(9,'#ANCROS  ',DATA1( 4))
ANCRUN  = DATA1( 5)  | Critical Angle For Faults Parallel To M.C.S.
CALL RNUMBR(9,'#ANCRUN  ',DATA1( 5))
ARCRAD  = DATA1( 6)  | Radius of Unconfined Aquifer Discharge Arc
CALL RNUMBR(9,'#ARCRAD  ',DATA1( 6))
AVEFLD  = DATA1( 7)  | Average Number of Missoula Floods Per 100 Yr
CALL RNUMBR(9,'#AVEFLD  ',DATA1( 7))
AVEGAB  = DATA1( 8)  | Average No Gable Mtn Events (STGABT)/100 Yrs
CALL RNUMBR(9,'#AVEGAB  ',DATA1( 8))
AVEMAG  = DATA1( 9)  | Av. No Mag Events/100 Yrs In The Pasco Basin
CALL RNUMBR(9,'#AVEMAG  ',DATA1( 9))
AVENAS  = DATA1( 10) | Aftershocks Per Sub-basalt Earthquake
CALL RNUMBR(9,'#AVENAS  ',DATA1( 10))
AVESWM  = DATA1( 11) | Average No. of Swarm Events In Repository
CALL RNUMBR(9,'#AVESWM  ',DATA1( 11))
AVGABF  = DATA1( 12) | Av. No Gable Mtn Events (FAULT and STGABT)
CALL RNUMBR(9,'#AVGABF  ',DATA1( 12))
AVLAND  = DATA1( 13) | Average Number Of Landslides Per 100 Years
CALL RNUMBR(9,'#AVLAND  ',DATA1( 13))
BMULTF  = DATA1( 14) | Breach Multiplication Factor
CALL RNUMBR(9,'#BMULTF  ',DATA1( 14))
CGLSTR  = DATA1( 15) | Radial Stress For Rock Fracturing
CALL RNUMBR(9,'#CGLSTR  ',DATA1( 15))
CGLSTT  = DATA1( 16) | Tangential Stress For Rock Fracturing
CALL RNUMBR(9,'#CGLSTT  ',DATA1( 16))
CONVN  = DATA1( 17) | Conversion Factor For Old Fracture Healing
CALL RNUMBR(9,'#CONVN  ',DATA1( 17))
CONVS  = DATA1( 18) | Conversion Factor For New Fracture Healing
CALL RNUMBR(9,'#CONVS  ',DATA1( 18))
CORBED  = DATA1( 19) | River Slope Correction For Bedrock
CALL RNUMBR(9,'#CORBED  ',DATA1( 19))
COSBNE  = DATA1( 20) | Angle From Repository To Grande Ronde N.E.
CALL RNUMBR(9,'#COSBNE  ',DATA1( 20))
COSBSW  = DATA1( 21) | Angle From Repository To Grande Ronde S.W.
CALL RNUMBR(9,'#COSBSW  ',DATA1( 21))
CRPMFS  = DATA1( 22) | Critical Distance To Glacier For Permafrost
CALL RNUMBR(9,'#CRPMFS  ',DATA1( 22))
CUNERC  = DATA1( 23) | Current Starting Northeast Recharge
CALL RNUMBR(9,'#CUNERC  ',DATA1( 23))
CUSWRC  = DATA1( 24) | Current Starting Southwest Recharge
CALL RNUMBR(9,'#CUSWRC  ',DATA1( 24))
DBASE  = DATA1( 25) | Basement To Grande Ronde Fm Thickness
CALL RNUMBR(9,'#DBASE  ',DATA1( 25))
DCORRS  = DATA1( 26) | Fault Width Depth Correction For Pasco Basin
CALL RNUMBR(9,'#DCORRS  ',DATA1( 26))
DCORNE  = DATA1( 27) | Fault Width Depth Correction For The N.E.
CALL RNUMBR(9,'#DCORNE  ',DATA1( 27))
DCORSW  = DATA1( 28) | Fault Width Depth Correction For The S.W.
CALL RNUMBR(9,'#DCORSW  ',DATA1( 28))
DEADZ  = DATA1( 29) | Minimum Sea Depth For Sediment Deposition
CALL RNUMBR(9,'#DEADZ  ',DATA1( 29))
DEPBAS  = DATA1( 30) | Vertical Distance Of Repository To Basement
CALL RNUMBR(9,'#DEPBAS  ',DATA1( 30))
DEPMIN  = DATA1( 31) | Sub-Basalt Minimum Depth For H.C. Change
CALL RNUMBR(9,'#DEPMIN  ',DATA1( 31))
DEPTNE  = DATA1( 32) | Half Wan-Sed Thickness at N.E. Basin Edge
CALL RNUMBR(9,'#DEPTNE  ',DATA1( 32))
DEPTSW  = DATA1( 33) | Half Wan-Sed Thickness at S.W. Basin Edge
CALL RNUMBR(9,'#DEPTSW  ',DATA1( 33))

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DEPTNE  = DATA1( 32)  | Half Wan-Sad Thickness at N.E. Basin Edge
CALL RNUMBR(9,'#DEPTNE  ',DATA1( 32))
DEPTSW  = DATA1( 33)  | Half Wan-Sad Thickness at S.W. Basin Edge
CALL RNUMBR(9,'#DEPTSW  ',DATA1( 33))
DSMTMX  = DATA1( 34)  | Max. Radius From Site For Meteorite Impact
CALL RNUMBR(9,'#DSMTMX  ',DATA1( 34))
EDGE NE  = DATA1( 35)  | Distance From Site To Basin Edge N.E.
CALL RNUMBR(9,'#EDGE NE ',DATA1( 35))
EDGE SW  = DATA1( 36)  | Distance From Site To Basin Edge S.W.
CALL RNUMBR(9,'#EDGE SW ',DATA1( 36))
EGAB     = DATA1( 37)  | Elevation Of Gable Mountain
CALL RNUMBR(9,'#EGAB    ',DATA1( 37))
ERATTL   = DATA1( 38)  | Elevation of Rattlesnake Mountain
CALL RNUMBR(9,'#ERATTL ',DATA1( 38))
ESENT    = DATA1( 39)  | Elevation Of Sentinel Gap At Old River Level
CALL RNUMBR(9,'#ESENT   ',DATA1( 39))
EWALL    = DATA1( 40)  | Elevation Wallula Gap At Old River Level
CALL RNUMBR(9,'#EWALL   ',DATA1( 40))
EFOLDE   = DATA1( 41)  | Erosion Factor For Folds Due To Miocene Flt
CALL RNUMBR(9,'#EFOLDE ',DATA1( 41))
EXTRNE   = DATA1( 42)  | Distance From Site To N.E. Recharge Point
CALL RNUMBR(9,'#EXTRNE ',DATA1( 42))
EXTRSW   = DATA1( 43)  | Distance North Of Site to SW Recharge Point
CALL RNUMBR(9,'#EXTRSW ',DATA1( 43))
FMAXD    = DATA1( 44)  | PNL
CALL RNUMBR(9,'#FMAXD   ',DATA1( 44))
FOLDMX   = DATA1( 45)  | Max. Distance From Site For New Fold
CALL RNUMBR(9,'#FOLDMX ',DATA1( 45))
FRAC(1)  = DATA1( 46)  | Ratio Sheft Area To Repository Area
CALL RNUMBR(9,'#FRAC(1) ',DATA1( 46))
FREFNE   = DATA1( 47)  | Time Reset Fraction For N.E. Fault System
CALL RNUMBR(9,'#FREFNE ',DATA1( 47))
FREFSW   = DATA1( 48)  | Time Reset Fraction For S.W. Fault System
CALL RNUMBR(9,'#FREFSW ',DATA1( 48))
FRESFT   = DATA1( 49)  | Time Reset Fraction For Local Faults
CALL RNUMBR(9,'#FRESFT ',DATA1( 49))
FRESTR   = DATA1( 50)  | Time Reset Fraction For Thrust Faults
CALL RNUMBR(9,'#FRESTR ',DATA1( 50))
FTHCSS   = DATA1( 51)  | H.C. Change Factor When Local Fault Is New
CALL RNUMBR(9,'#FTHCSS ',DATA1( 51))
GLATNE   = DATA1( 52)  | Upper Latitude Of N.E. Recharge Area
CALL RNUMBR(9,'#GLATNE ',DATA1( 52))
GLTNE L  = DATA1( 53)  | Lower Latitude Of N.E. Recharge Area
CALL RNUMBR(9,'#GLTNE L ',DATA1( 53))
GRLNNE   = DATA1( 54)  | Site To NE Recharge Area Distance In 8 Ronde
CALL RNUMBR(9,'#GRLNNE ',DATA1( 54))
GRSWLN   = DATA1( 55)  | Site To SW Recharge Area Distance In 8 Ronde
CALL RNUMBR(9,'#GRSWLN ',DATA1( 55))
HARDFC   = DATA1( 56)  | Erosion Rate Fraction For Bedrock in M Flood
CALL RNUMBR(9,'#HARDFC ',DATA1( 56))
HDNEGR   = DATA1( 57)  | Avg. Head Elevation For N.E. Grande Ronde FM
CALL RNUMBR(9,'#HDNEGR ',DATA1( 57))
HDNEWS   = DATA1( 58)  | Avg. Head Elevation For N.E. Wan-Sad FM
CALL RNUMBR(9,'#HDNEWS ',DATA1( 58))
HDSWGR   = DATA1( 59)  | Avg. Head Elevation For S.W. Grande Ronde FM
CALL RNUMBR(9,'#HDSWGR ',DATA1( 59))
HDSWWS   = DATA1( 60)  | Avg. Head Elevation For S.W. Wan-Sad FMS
CALL RNUMBR(9,'#HDSWWS ',DATA1( 60))
HEADBS   = DATA1( 61)  | Avg. Head Elev. For Basin Unconfined Aquifer
CALL RNUMBR(9,'#HEADBS ',DATA1( 61))
HIPATH   = DATA1( 62)  | Maximum Unconfined Aquifer Path Length
CALL RNUMBR(9,'#HIPATH ',DATA1( 62))
HMNEGR   = DATA1( 63)  | Maximum Head of N.E. Grande Ronde
CALL RNUMBR(9,'#HMNEGR ',DATA1( 63))
HMNEWS   = DATA1( 64)  | Maximum Head of N.E. Wennepum Saddle Mtn.
CALL RNUMBR(9,'#HMNEWS ',DATA1( 64))
HMSWGR   = DATA1( 65)  | Maximum Head of S.W. Grande Ronde
CALL RNUMBR(9,'#HMSWGR ',DATA1( 65))
HMSWWS   = DATA1( 66)  | Maximum Head of S.W. Wennepum Saddle Mtn.
CALL RNUMBR(9,'#HMSWWS ',DATA1( 66))

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HMSWGR	= DATA1(65)	1 Maximum Head of S.W. Grande Ronde
CALL RNUMBR(9,'#HMSWGR		1,DATA1(65))
HMSWWS	= DATA1(66)	1 Maximum Head of S.W. Wannapum Saddle Mtn.
CALL RNUMBR(9,'#HMSWWS		1,DATA1(66))
LAYRGR	= DATA1(67)	1 Grande Ronde FM Layer Number
CALL RNUMBR(9,'#LAYRGR		1,DATA1(67))
LAYRWS	= DATA1(68)	1 Wannapum-Saddle FMS Layer Number
CALL RNUMBR(9,'#LAYRWS		1,DATA1(68))
NLAYER	= DATA1(69)	1 Number of Layers in the Model
CALL RNUMBR(9,'#NLAYER		1,DATA1(69))
PASHFL	= DATA1(70)	1 Prob. of Large Ashfall Changing Climate
CALL RNUMBR(9,'#PASHFL		1,DATA1(70))
PCASUP	= DATA1(71)	1 Prob. of Cascade Mountains Uplift
CALL RNUMBR(9,'#PCASUP		1,DATA1(71))
PFAULT	= DATA1(72)	1 Prob of Sub-basalt Fault Exists at Run Start
CALL RNUMBR(9,'#PFAULT		1,DATA1(72))
PFLAT	= DATA1(73)	1 Prob. of Fold Growth Without Faulting
CALL RNUMBR(9,'#PFLAT		1,DATA1(73))
PFLATF	= DATA1(74)	1 Prob. of Fold Growth With Faulting
CALL RNUMBR(9,'#PFLATF		1,DATA1(74))
PFOLD	= DATA1(75)	1 Prob. of Undetected Fold in Pease Basin
CALL RNUMBR(9,'#PFOLD		1,DATA1(75))
PFTNEW	= DATA1(76)	1 Prob. For New Sub-basalt Fault
CALL RNUMBR(9,'#PFTNEW		1,DATA1(76))
PGLCH	= DATA1(77)	1 Prob. of Recharge When Glaciers Cover N.E.
CALL RNUMBR(9,'#PGLCH		1,DATA1(77))
PMAGST	= DATA1(78)	1 Prob. of Mag. Ev. on Site When One in Basin
CALL RNUMBR(9,'#PMAGST		1,DATA1(78))
PMETRT	= DATA1(79)	1 Prob. of Meteorite Impacting Site
CALL RNUMBR(9,'#PMETRT		1,DATA1(79))
PMISFT	= DATA1(80)	1 Prob. of Undetected Fault in Repository Host
CALL RNUMBR(9,'#PMISFT		1,DATA1(80))
PNEEXF	= DATA1(81)	1 Prob of Renewed NE Faulting With Major Fault
CALL RNUMBR(9,'#PNEEXF		1,DATA1(81))
PNWFD	= DATA1(82)	1 Prob. of New Fold Growth Without Faulting
CALL RNUMBR(9,'#PNWFD		1,DATA1(82))
PNWFDF	= DATA1(83)	1 Prob. of New Fold Growth With Faulting
CALL RNUMBR(9,'#PNWFDF		1,DATA1(83))
PNWFT	= DATA1(84)	1 Prob. of New Fault Without Major Faulting
CALL RNUMBR(9,'#PNWFT		1,DATA1(84))
PNWFTF	= DATA1(85)	1 Prob of New Basalt Fault With Major Faulting
CALL RNUMBR(9,'#PNWFTF		1,DATA1(85))
PNWTR	= DATA1(86)	1 Prob. of New Thrust Without Major Faulting
CALL RNUMBR(9,'#PNWTR		1,DATA1(86))
PNWTRF	= DATA1(87)	1 Prob. of New Thrust With Major Faulting
CALL RNUMBR(9,'#PNWTRF		1,DATA1(87))
PRKUP	= DATA1(88)	1 Prob. of E Uplift Affecting Climate /100 Yrs
CALL RNUMBR(9,'#PRKUP		1,DATA1(88))
PRVMAG	= DATA1(89)	1 Prob. of Mag. Event Affecting River Gradient
CALL RNUMBR(9,'#PRVMAG		1,DATA1(89))
PSEAX	= DATA1(90)	1 Prob. of Sea Level Rise in Climate 1
CALL RNUMBR(9,'#PSEAX		1,DATA1(90))
PSSEXF	= DATA1(91)	1 Prob of Renewed Local Faulting With SE Fault
CALL RNUMBR(9,'#PSSEXF		1,DATA1(91))
PSSFTB	= DATA1(92)	1 Prob. of Local Fault System in Pease Basin
CALL RNUMBR(9,'#PSSFTB		1,DATA1(92))
PSWEXF	= DATA1(93)	1 Prob of Renewed SW Faulting With Major Fault
CALL RNUMBR(9,'#PSWEXF		1,DATA1(93))
PTREXF	= DATA1(94)	1 Prob. of Renewed Thrusting With Major Fault
CALL RNUMBR(9,'#PTREXF		1,DATA1(94))
PUNTHS	= DATA1(95)	1 Prob. of Undetected Thrust in Repos. Host
CALL RNUMBR(9,'#PUNTHS		1,DATA1(95))
QDAM	= DATA1(96)	1 Min. Flow For Hydraulic Dam at Wallula Gap
CALL RNUMBR(9,'#QDAM		1,DATA1(96))
RADCRT	= DATA1(97)	1 Sphere Radius Separates Big & Little Craters
CALL RNUMBR(9,'#RADCRT		1,DATA1(97))
RCARNE	= DATA1(98)	1 Starting Area of N.E. Recharge Area
CALL RNUMBR(9,'#RCARNE		1,DATA1(98))
RCARSW	= DATA1(99)	1 Starting Area of S.W. Recharge Area
CALL RNUMBR(9,'#RCARSW		1,DATA1(99))

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RCARNE  # DATA1( 98)  | Starting Area of N.E. Recharge Area
CALL RNUMBR(9,'#RCARNE  ',DATA1( 98))
RCARSW  # DATA1( 99)  | Starting Area of S.W. Recharge Area
CALL RNUMBR(9,'#RCARSW  ',DATA1( 99))
RDEPTH  # DATA1(100)  | Depth To The Repository From Ground Surface
CALL RNUMBR(9,'#RDEPTH  ',DATA1(100))
RESCON  # DATA1(101)  | Response Constant for Climate Change
CALL RNUMBR(9,'#RESCON  ',DATA1(101))
RESPN1  # DATA1(102)  | Distance Response Constant For Glacier Adv.
CALL RNUMBR(9,'#RESPN1  ',DATA1(102))
RESPN2  # DATA1(103)  | Time Response Constant For Glacier Advance
CALL RNUMBR(9,'#RESPN2  ',DATA1(103))
RIVCAP  # DATA1(104)  | Max. Radius From Site For River Capture
CALL RNUMBR(9,'#RIVCAP  ',DATA1(104))
RKMNE   # DATA1(105)  | Distance N of Site For All N.E. Area Covered
CALL RNUMBR(9,'#RKMNE   ',DATA1(105))
RLATHI  # DATA1(106)  | Upper Lat. of Glacier For Missoula Flooding
CALL RNUMBR(9,'#RLATHI  ',DATA1(106))
RLATLW  # DATA1(107)  | Lower Lat. of Glacier For Missoula Flooding
CALL RNUMBR(9,'#RLATLW  ',DATA1(107))
RNELF   # DATA1(108)  | Amount of N.E. recharge area still covered
CALL RNUMBR(9,'#RNELF   ',DATA1(108))
RNERED  # DATA1(109)  | Fraction of reduction in N.E. cover/flood
CALL RNUMBR(9,'#RNERED  ',DATA1(109))
RPGLNE  # DATA1(110)  | Average N.E. Glacier Recharge Point
CALL RNUMBR(9,'#RPGLNE  ',DATA1(110))
RPOSHC  # DATA1(111)  | H.C. of Repository Host-Rock
CALL RNUMBR(9,'#RPOSHC  ',DATA1(111))
RPOSTH  # DATA1(112)  | Repository Thickness
CALL RNUMBR(9,'#RPOSTH  ',DATA1(112))
SEAMAX  # DATA1(113)  | Max. Elevation of Seal Level Rise
CALL RNUMBR(9,'#SEAMAX  ',DATA1(113))
SELEV   # DATA1(114)  | Site Elevation at Ground Surface
CALL RNUMBR(9,'#SELEV   ',DATA1(114))
SITLAT  # DATA1(115)  | Site Latitude
CALL RNUMBR(9,'#SITLAT  ',DATA1(115))
SITRAD  # DATA1(116)  | Radius of Site
CALL RNUMBR(9,'#SITRAD  ',DATA1(116))
SLOPHI  # DATA1(117)  | Highest Possible River Gradient
CALL RNUMBR(9,'#SLOPHI  ',DATA1(117))
SLOPLW  # DATA1(118)  | Lowest Possible River Gradient
CALL RNUMBR(9,'#SLOPLW  ',DATA1(118))
SOURCE  # DATA1(119)  | Latitude of Glacier's Source
CALL RNUMBR(9,'#SOURCE  ',DATA1(119))
STFLT   # DATA1(120)  | First Fault West of Basin Approx. on MCS
CALL RNUMBR(9,'#STFLT   ',DATA1(120))
STGABT  # DATA1(121)  | Uplift Rate on Gable Mtn (For Check MC)
CALL RNUMBR(9,'#STGABT  ',DATA1(121))
THABOV  # DATA1(122)  | Grande Ronde Thickness Above Repository
CALL RNUMBR(9,'#THABOV  ',DATA1(122))
TRSTRT  # DATA1(123)  | Conversion Factor For New Thrusting MC
CALL RNUMBR(9,'#TRSTRT  ',DATA1(123))
VHRCOR  # DATA1(124)  | Horizontal to Vertical H.C. Ratio
CALL RNUMBR(9,'#VHRCOR  ',DATA1(124))
WGLAT   # DATA1(125)  | Latitude of Hellule Gap
CALL RNUMBR(9,'#WGLAT   ',DATA1(125))
WSNELN  # DATA1(126)  | Wanapum-Saddle Path Length For The N.E.
CALL RNUMBR(9,'#WSNELN  ',DATA1(126))
WSSLN   # DATA1(127)  | Wanapum-Saddle Path Length For The S.W.
CALL RNUMBR(9,'#WSSLN   ',DATA1(127))
XSTART  # DATA1(128)  | X Coordinate of Discharge Arc Center
CALL RNUMBR(9,'#XSTART  ',DATA1(128))
YSTART  # DATA1(129)  | Y Coordinate of Discharge Arc Center
CALL RNUMBR(9,'#YSTART  ',DATA1(129))

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FILE NAME = LOGICALS.DAT

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ANFACT= 0.0      IANGLE FACTOR
ATM = 0.0        IFRACTIONAL WASTE TO THE AIR
AVAXIS= 0.0      IANGLE BETWEEN FOLD AND NORMAL TO POSITION VECTOR
AXISAN= 0.0      IANGLE OF FOLD LINE
RTIME = 0.0      ITIME OF BREACH
CASELV= 0.0      ICHANGE IN THE CASCADES ELEVATION (METERS)
>>>>CHMC()= 0.0  ICHANGES IN H.C. FOR EACH LAYER(TYPE,LAYER,SYSTEM)
DO 111 I13 = 1,3
DO 111 I12 = 1,4
DO 111 I11 = 1,2
111 CHMC(I11,I12,I13) = 0.0
>>>>CHRS()= 0.0  ICHANGES IN H.C. FOR REPOSITORY (TYPE)
DO 222,I11 = 1,3
222 CHRS(I11) = 0.0
COSAN = 0.0      ICOS(AVAXIS)
CSHAFT= 0.0      ICHANGE IN SHAFT SEAL H.C.
DEP = 0.0        IAMOUNT OF SEDIMENT DEPOSITED (METERS)
DISTFD= 0.0      ILENGTH OF POSITION VECTOR
DTIME = 100.0    ILENGTH OF TIME INTERVALS IN YEARS
FANG = 0.0       IANGLE OF SUB-BASALT POSITION VECTOR
>>>>FANGLE()=0.0 IANGLE OF EACH FOLD 'LIMB'
DO 333,I11=1,4
333 FANGLE(I11) = 0.0
>>>>FDR() = 0.0  ILOCAL FAULT DIRECTION
DO 444,I11=1,200
444 FDR(I11)=0.0
FLHCNE= 0.0      ICHANGE IN H.C. FOR THE N.E. FAULT SYSTEM
FLHCNW= 0.0      ICHANGE IN H.C. FOR THE S.W. FAULT SYSTEM
FLTNE = 1.0E7    ITIME FOR THE NEXT N.E. SUB-SYSTEM FAULTING EVENT
FLTSW = 1.0E7    ITIME FOR THE NEXT S.W. SUB-SYSTEM FAULTING EVENT
FOLDAN= 0.0      IANGLE OF POSITION VECTOR
FOLDHC= 0.0      ICHANGE IN H.C. FOR FOLD
FPRINT= 0.0      IFRACTION OF REPOSITORY INTERSECTED
>>>>GABHC()=0.0  ICHANGE IN H.C. WITH AN ACTIVE GABBLE MT.
DO 555,I11=1,4
555 GABHC(I11) = 0.0
MT = 0.0         IFRACTION OF WASTE REMAINING IN THE GROUND
ICLIM = 1        ISTARTING CLIMATE
ICLING= 1        ISTARTING CLIMATE FOR GLACIAL SUBMODEL
IRLAY=4 REPOSITORY LAYER NUMBER
ITOP=11 SURFACE LAYER NUMBER AT THE START OF THE RUN
KEY = 5          IBREACH KEY
LCLIM =-1 ILAST CLIMATE INDEX
LASHFL= .FALSE. ILOGIC FLAG SET TRUE IF ASHFALL EFFECT IS ACTIVE
LBEDRK= .FALSE. ILOGIC FLAG SET TRUE IF RIVER IS IN BEDROCK
LBRECH= .FALSE. ILOGIC FLAG SET TRUE IF BREACH
LCASTR= .FALSE. ILOGIC FLAG SET TRUE IF CASCADES AFFECT CLIMATE BY UPLIFT
LEXPOS= .FALSE. ILOGIC FLAG SET TRUE IF A FOLD IS EXPOSED
LPHASE= .FALSE. ILOGIC FLAG SET TRUE IF SUB-BASALT FAULT
LFRASH= .FALSE. ILOGIC FLAG SET TRUE IF A 'MAJOR' SUB-BASALT FAULT
LFDACT= .FALSE. ILOGIC FLAG SET TRUE IF THE NEW FOLD IS ACTIVE
LFLOOD= .FALSE. ILOGIC FLAG SET TRUE IF THE SITE IS FLOODED
LFOLD = .FALSE. ILOGIC FLAG SET TRUE IF A FOLD IS 'FOUND'
LFTINT= .FALSE. ILOGIC FLAG SET TRUE IF FOLD INTERSECTS THE SITE
LICEON= .FALSE. ILOGIC FLAG SET TRUE IF THE SITE IS COVERED BY ICE
LMAGRV= .FALSE. ILOGIC FLAG SET TRUE IF POSSIBLE CHANGE FROM MAG. EVENT
LNEWCL= .FALSE. ILOGIC FLAG SET TRUE IF SYSTEM ENTERS NEW CLIMATE STATE
LNEWSSF= .FALSE. ILOGIC FLAG SET TRUE IF NEW LOCAL FAULT WAS CREATED
LRIVON= .FALSE. ILOGIC FLAG SET TRUE IF THE RIVER IS ON THE SITE
LROCTR= .FALSE. ILOGIC FLAG SET TRUE IF EASTERN UPLIFT
LRVCHG= .FALSE. ILOGIC FLAG SET TRUE IF POSSIBLE CHANGE FROM A GLACIER
LRVFXD= .FALSE. ILOGIC FLAG SET TRUE IF RIVER IS FIXED ON THE SITE
LSEACH= .FALSE. ILOGIC FLAG SET TRUE IF POSSIBLE RIVER COURSE(SEA RETREAT)
LSLIDE= .FALSE. ILOGIC FLAG SET TRUE IF POSSIBLE CHANGE FROM SLIDE

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LRVCHG=,FALSE, ILOGIC FLAG SET TRUE IF POSSIBLE CHANGE FROM A GLACIER
LRVFXD=,FALSE, ILOGIC FLAG SET TRUE IF RIVER IS FIXED ON THE SITE
LSEACH=,FALSE, ILOGIC FLAG SET TRUE IF POSSIBLE RIVER COURSE(SEA RETREAT)
LSLIDE=,FALSE, ILOGIC FLAG SET TRUE IF POSSIBLE CHANGE FROM SLIDE
LSSFIN=,FALSE, ILOGIC FLAG SET TRUE IF LOCAL FAULTS ARE POSSIBLE
LYHRST=,FALSE, ILOGIC FLAG SET TRUE IF A THRUST FAULT IS 'FOUND'
LXICE=,FALSE, IGLACIER ICE HAS NOT YET REACHED WALLUA GAP
NCASE = 2          INUMBER OF EVENTS THAT CAN CAUSE PERVASIVE CHANGE TO H.C.
POST = 0.0         IELEVATION OF A NEW FOLD
>>>>RADHC( )=0.0    ICHANGE IN H.C. DUE TO MOVEMENT ON RATTLESNAKE
RAD=0.0 IDISTANCE OF GLACIER FROM SOURCE AREA
DN 666,III=1,4
666 RADHC(III)= 0.0
RDFDT= 0.0         IDISTANCE FROM REPOSITORY TO THE SUB-BASALT FAULT
REDU = 0.0         IREDUCTION IN GROUND WATER
RKML(1)=1000.0
RKML(2)=1000.0
RKML(3)=1000.0
ROCKEL= 0.0        ICHANGE IN ROCKY MTN. ELEVATION FROM TIME 0
RPGDST=100.0       IVARIABLE TO STORE TOTAL CHANGE AT THE REPOSITORY DUE TO HEALING
SEA = 0.0          ISEA LEVEL WITHOUT ANY ICE TAKEUP
SICELY= 0.0        ICE THICKNESS FROM THE LAST TIME STEP
SICENE= 0.0        ILAST ICE THICKNESS OF THE N.E. SITE
SITISO= 0.0        ICURRENT ISOSTATIC ADJUSTMENT
SLOPE = 0.000390 ISLOPE OF THE RIVER IN THE BASIN
SNLAST=1.0E7 ITIME OF LAST ISOSTATIC EFFECTS
STATNE= 0.0        IISOSTATIC EFFECT FOR THE N.E. AREA
SUBFTN=0.0 ICMULATIVE NUMBER OF FAULTS
SUMFTN=0.0 ICMULATIVE NUMBER OF LOCAL FAULTING EVENTS
SURWAT= 0.0        IFRACTION OF WASTE GOING INTO THE GROUND WATER
IFLER = 0.0        ITOTAL AMOUNT OF FOLD EROSION
THICKG= 0.0        ICE THICKNESS ON THE SITE
THICNE= 0.0        ICE THICKNESS ON THE N.E. RECHARGE POINT
THRCH = 0.0        ITHRUST FAULT H.C.
THRHC = 0.0        ITHRUST FAULT H.C.
THRWD = 0.0        ITHRUST FAULT WIDTH
TIMEH = 0.0        ITIME
TLSTNE= 1.0E7 ITIME OF LAST N.E. ISOSTATIC EFFECT
TMSULA= 0.0        ITOTAL AMOUNT OF MISSOULA FLOOD FLOW
TOTRHC= 0.0        ITOTAL REPOSITORY H.C.
TRMOVE= 0.0        ITOTAL THRUST MOVEMENT
TTIME = 0.0        ITIME
TTTIME= 0.0        ITIME
THOSF=0.0          ITOTAL FLOOD EROSION/DEPOSITION

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00001 C ***** CLIM,FLX *****
00002 C
00003 C THIS SUBMODEL PROVIDES FOR :
00004 C THE CLIMATIC STATE
00005 C NET PRECIPITATION
00006 C RECHARGE
00007 C "ASH FALL" TRIGGERING
00008 C UPLIFT OF THE CASCADES AND CORRESPONDING OROGRAPHIC EFFECTS
00009 C UPLIFT OF THE MOUNTAINS TO THE EAST AND CORRESPONDING OROGRAPHIC
00010 C EFFECTS
00011 C
00012 C IN THE FOLLOWING WAY:
00013 C THE CLIMATE INPUT FILE HAS BEEN READ IN TO PROVIDE FOR:
00014 C CLIMATE INDEX (INTERGLACIER TO STADIAL)
00015 C THE SYSTEM TIME
00016 C A CONTROL VARIABLE USED TO "FORCE" EVENTS DURING A
00017 C MODEL RUN
00018 C
00019 C ALLOW FOR ASH FALL EFFECTING THE CLIMATE
00020 C
00021 C DRAW FOR NET PRECIPITATION AT BOTH THE NORTH EAST AND
00022 C SOUTH WEST RECHARGE AREAS
00023 C
00024 C ALLOW FOR NET UPLIFT OF MOUNTAINS TO BOTH THE EAST AND WEST OF
00025 C THE BASIN
00026 C
00027 C DRAW FOR RECHARGE AT BOTH THE NORTH EAST AND SOUTH WEST RECHARGE
00028 C POINTS
00029 C
00030 C
00031 C ALLOW FOR OROGRAPHIC EFFECTS
00032 C
00033 C SUBROUTINE CLIM
00034 C
00035 C INCLUDE 'DI:(226,226)COMMON,FLX'
00036 C
00037 C CALL NOTE(8,'#CLIMATE')
00038 C
00039 C
00040 C WHEN (LCLIM .NE. ICLIM)
00041 C . LNEWCL=.TRUE.
00042 C . SELECT(ICLIM)
00043 C . . (1) CALL NOTE(13,'INTER GLACIAL')
00044 C . . (2) CALL NOTE(13,'TEMPERATE CL. ')
00045 C . . (3) CALL NOTE(12,'INTERSTADIAL')
00046 C . . (4) CALL NOTE(7,'STADIAL')
00047 C . ...FIN
00048 C . LASHFL = .FALSE.
00049 C . LCLIM=ICLIM
00050 C . ...FIN
00051 C ELSE LNEWCL = .FALSE.
00052 C
00053 C

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00054 C
00055 C
00056 C
00057 C      ALLOW FOR TRIGGER EFFECT HERE
00058 C      IF(.NOT.LASHFL)
00059 C      IF(LTEST(PASHFL))
00060 C      CALL NOTE(8,'ASH FALL') IWRITE TO HISTORY FILE
00061 CC     IF ASH LOAD .GT. CRITICAL AMOUNT
00062 C      IF(ICLIM.EQ. 3)
00063 C      CALL NOTE(14,'FORCED STADIAL')
00064 C      CALL NOTE(19,'FORCED GLAC. GROWTH')
00065 C      LASHFL = .TRUE.
00066 C      LNEWCL = .TRUE.
00067 C      FIN
00068 C      IF(ICLIM.LT. 3)
00069 C      ICLIM=ICLIM+1      IFOR THIS STEP ONLY
00070 C      CALL NOTE(16,'CLIMATE INCREASE')
00071 C      FIN
00072 C      FIN
00073 C      FIN
00074 C
00075 C      IF (LASHFL) ICLIM=4
00076 C      THE ABOVE WILL BE RESET WHEN A NEW(NOT 3) CLIMATIC CODE IS TAKEN
00077 C      FROM FILE # 7
00078 C
00079 C
00080 C
00081 C
00082 C
00083 C
00084 C
00085 C      -----DENSITY-----
00086 C      RAINNE=PROB(ICLIM) IDRAW FOR TOTAL NET PRECIPITATION FOR THE N.E.
00087 C      RAINSH=PROB(ICLIM+4) IDRAW FOR TOTAL NET PRECIP. FOR THE S.W.
00088 C      -----DENSITY-----
00089 C
00090 C
00091 C
00092 C
00093 C
00094 C      S.D. FOR GREATER RAINFALL AT HANFORD BECAUSE
00095 C      THE CASCADES ARE UPLIFTED
00096 C      IF(.NOT. LCASTR)
00097 C      . IF THE CASCADES HAVE NOT ALREADY BEEN UPLIFTED
00098 C      . IF(LTEST(PCASUP).OR.IFORCE.EQ.4)
00099 C      . . CALL NOTE(14,'CASCADE UPLIFT')
00100 C      . . LCASTR=.TRUE.
00101 C      . ...FIN
00102 C      ...FIN
00103 C      WHEN(LCASTR)
00104 C      -----DENSITY-----
00105 C      . CASLV=CASLV+PROB(9)*DIME ICASCADE UPLIFT
00106 C      -----DENSITY-----
00107 C      ...FIN
00108 C      ELSE
00109 C      -----DENSITY-----

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00110      . CASELV=CASELV-PROB(10)*DTIMEIEROSION
00111 C -----DENSITY-----
00112      ...FIN
00113 C -----DENSITY-----
00114      CHCSNE=POLY(1,CASELV)+PROB(11)ICHANGE(NE) DUE TO CASCADE UPLIFT/SUBSIDE
00115      CHCSSW=POLY(2,CASELV)+PROB(12)ICHANGE(SW) DUE TO CASCADE UPLIFT/SUBSIDE
00116 C -----DENSITY-----
00117 C
00118 C
00119 C
00120 C      TEST FOR INCREASED RAIN FALL AT HANFORD BECAUSE OF
00121 C      UPLIFT TO THE EAST
00122
00123      IF(.NOT. LROCTR)
00124 C      . IF THE MOUNTAINS TO THE EAST HAVE NOT ALREADY BEEN UPLIFTED ENOUGH
00125 C      . TO EFFECT THE CLIMATE AT THE SITE
00126      . IF(L TEST(PRKUP) ,OR. IFORCE,EQ.5)
00127      . . CALL NOTE(14,'EASTERN UPLIFT')
00128      . . LROCTR=TRUE.
00129      . ...FIN
00130      ...FIN
00131      WHEN(LROCTR)
00132 C -----DENSITY-----
00133      . ROCKEL=ROCKEL+PROB(13)*DTIME IEASTERN UPLIFT
00134 C -----DENSITY-----
00135      ...FIN
00136      ELSE
00137 C -----DENSITY-----
00138      . ROCKEL=ROCKEL-PROB(14)*DTIME IEASTERN EROSION
00139 C -----DENSITY-----
00140      ...FIN
00141 C
00142 C      NEXT ALLOW FOR OROGRAPHIC EFFECTS, FROM EASTERN UPLIFT, IN THE N.E. AND
00143 C      S.W.
00144 C -----DENSITY-----
00145      CHRKNE=POLY(3,ROCKEL)+PROB(15)
00146      CHRKSW=POLY(4,ROCKEL)+PROB(16)
00147 C -----DENSITY-----
00148 C
00149 C
00150 C
00151 C
00152 C
00153 C
00154 C      ADD IN ANY ELEVATION CORRECTIONS
00155      RAINNE=RAINNE+(RAINNE*CHCSNE)+(RAINNE*CHRKNE)
00156      IF(RAIN NE .LT. 0.0 )
00157      . CALL RNUMBR(13,'ZERO RAIN(NE)',RAINNE)
00158      . RAINNE=1.0E-5
00159 C      . THIS SHOULD NOT HAPPEN, BUT TO AVOID FATAL COMPUTATION ERRORS
00160 C      . THIS BIT OF CODE WILL SET THE RESULT TO 1.0E-5 AND WARN THE USER
00161 C      . OF A POSSIBLE ERROR
00162      ...FIN
00163      RAINSW=RAINSW+(RAINSW*CHCSSW)+(RAINSW*CHRKSW)
00164      IF(RAIN SW .LT. 0.0)
00165 C      . THIS SHOULD NOT HAPPEN, BUT TO AVOID FATAL COMPUTATIONAL ERRORS

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```
00166 C . THIS BIT OF CODE WILL SET ATHE RESULT TO 1.0E-5 AND WARN THE USER
00167 C . OF A POSSIBLE ERROR
00168 C . CALL RNUMBR(13,'ZERO RAIN(SW)',RAINSW)
00169 C . RAINSW=1.0E-5
00170 C ...FIN
00171 C
00172 C
00173 C
00174 C
00175 C
00176 C
00177 C
00178 C
00179 C
00180 C
00181 C
00182 C
00183 C
00184 C GET THE DRAW FOR THE FRACTION OF NET RAINFALL THAT GOES INTO RECHARGE
00185 C -----DENSITY-----
00186 C RCHNE=RAINNE*PROB(ICLIM+16)
00187 C RCHSW=RAINSW*PROB(ICLIM+20)
00188 C -----DENSITY-----
00189 C
00190 C
00191 C
00192 C
00193 C
00194 C
00195 C RETURN
00196 C END
```

(FLECS VERSION 22,46)

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-----
00001 C ***** DEFORM.FLX *****
00002 C
00003 C DEFORMATION SUBMODEL ACCOUNTS FOR :
00004 C FOLDING
00005 C CHANGES IN H.C.
00006 C LOCAL FAULTING IN THE H.C.S.
00007 C
00008 C
00009 C SUBROUTINE DEFORM
00010 C
00011 C
00012 C INCLUDE 'DI:1226,226)COMMON,FLX'
00013 C
00014 C CALL NOTE(12,'#DEFORMATION')
00015 C
00016 C SET-PROBABILITY
00017 C ALLOW-FOR-UPLIFT-SUBSIDENCE-AND-SEISMIC-EVENTS
00018 C CREATE-A-NEW-FAULT
00019 C CHECK-FOR-ANY-ACTIVE-LOCAL-FAULTS
00020 C CHECK-FOR-THRUST-FAULTS
00021 C CHECK-FOR-FOLD-ACTIVITY
00022 C CHECK-FOR-NE-FAULTING
00023 C CHECK-FOR-SW-FAULTING
00024 C CHECK-FOR-EXPLICIT-SWARMS-AT-THE-SITE
00025 C RETURN
00026 C
00027 C
00028 C *****

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```

-----
00029 C TO SET-PROBABILITY
00030 C *****SET-PROBABILITY*****
00031 C
00032 C
00033 C IF A SUBBASEMENT FAULT OCCURED CHANGE THE PROB. NUMBERS
00034 C WHEN(L FBASH)
00035 C . PNEWFT=PNWFTF ICHANCE OF 'CREATING' A NEW FAULT
00036 C . PNEWFD=PNWPDF ICHANCE OF 'CREATING' A NEW FOLD
00037 C . PNEPTR=PNWTRF ICHANCE OF 'CREATING' A NEW THRUST
00038 C . PFACT=PFLATF ICHANCE OF FOLD GROWTH THIS TIME STEP
00039 C . PSSEX=PSSEXF ICHANCE OF AN 'EXTRA' LOCAL EVENT
00040 C . PTREX=PTREXF ICHANCE OF AN 'EXTRA' THRUST FAULT EVENT
00041 C . PNE EX=PNE EXF ICHANCE OF AN 'EXTRA' N.E. FAULT EVENT
00042 C . PSWEX=PSWEXF ICHANCE OF AN 'EXTRA' S.W. FAULT EVENT
00043 C . AVRAT=AVRATF I AVERAGE NUMBER OF EVENTS ON RATTLESNAKE
00044 C . AVGAB=AVGABF I AVERAGE NUMBER OF EVENTS ON GABLE MT.
00045 C . AVSAD=AVSADF I AVERAGE NUMBER OF EVENTS ON SADDLE MT.
00046 C . ...FIN
00047 C . ELSE
00048 C . ELSE USE STANDARD VALUES
00049 C . PNEWFT=PNWFT ICHANCE OF 'CREATING' A NEW FAULT
00050 C . PNEWFD=PNWFD ICHANCE OF 'CREATING' A NEW FOLD

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00051      . . PNEWTR=PNWTR  ICHANCE OF 'CREATING' A NEW THRUST
00052      . . PFACT=PFLAT  ICHANCE OF FOLD GROWTH THIS TIME STEP
00053      . . PSSEX=0.0     ICHANCE OF AN 'EXTRA' LOCAL EVENT
00054      . . PTREX=0.0     ICHANCE OF AN 'EXTRA' THRUST FAULT EVENT
00055      . . PNE EX=0.0    ICHANCE OF AN 'EXTRA' N.E. FAULT EVENT
00056      . . PSWEX =0.0    ICHANCE OF AN 'EXTRA' S.W. FAULT EVENT
00057      C . . AVRAT=AVERAT I AVERAGE NUMBER OF EVENTS ON RATTLESNAKE
00058      . . AVGAB=AVEGAB  I AVERAGE NUMBER OF EVENTS ON GABLE MT.
00059      C . . AVSAD=AVESAD I AVERAGE NUMBER OF EVENTS ON SADDLE MT.
00060      . . .FIN
00061      . . .FIN
00062      C
00063      C
00064      C *****

```

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-----
00065      TO ALLOW-FOR-UPLIFT-SUBSIDENCE-AND-SEISMIC-EVENTS
00066      C *****ALLOW-FOR-UPLIFT-SUBSIDENCE-AND-SEISMIC-EVENTS*****
00067      C *****ALLOW FOR UPLIFT AND SUBSIDENCE*****
00068      C .
00069      C .
00070      C . DRAW FOR SUBSIDENCE IN THE BASIN
00071      C . RELATIVE TO THE THE N.E. AREA(I.E.'ZERO' VERTICAL MOVEMENT IN THE N.E
00072      C ***** DENSITY CURVE *****
00073      . CHBAS=PROB(106)*DTIME I SUBSIDENCE(OR UPLIFT) IN THE BASIN
00074      C . NOTE THAT THE ABOVE HAS A MINUS SIGN
00075      C *****
00076      . SELEV=SELEV+CHBAS
00077      . HEADBS=HEADBS+CHBAS
00078      C . THEN DRAW FOR THE RELATIVE CHANGES AT THE FOLLOWING AREAS:
00079      C ***** DENSITY CURVE *****
00080      . STRAT=PROB(107) I STRAIN RATE FOR RATTLESNAKE
00081      C *****
00082      . HDSWWS=HDSWWS+STRAT*DTIME
00083      . HDSWGR=HDSWGR+STRAT*DTIME
00084      . ERATTL=ERATTL+STRAT*DTIME I RATTLESNAKE ELEVATION CHANGES
00085      C ***** DENSITY CURVE *****
00086      . STSAD=PROB(108) I STRAIN RATE FOR SADDLE MT.
00087      C *****
00088      . ESSENT=ESSENT+STSAD*DTIME I SENTINEL GAP(SADDLE MT)
00089      C ***** DENSITY CURVE *****
00090      . STGAB=PROB(109) I STRAIN RATE FOR GABLE MT.
00091      C *****
00092      . EGAB=EGAB+STGAB*DTIME I GABLE MT.
00093      C ***** DENSITY CURVE *****
00094      . EWALL=EWALL+PROB(110)*DTIME I WALLULA GAP (HORSE HEAVEN HILLS)
00095      C *****
00096      C *****
00097      . IF(STGAB.GE. STGAB T)
00098      . . NEVENT=POISON(AVGAB)
00099      C . . SUMFTN=SUMFTN+NEVENT
00100      . . IF(NEVENT.GT.0)
00101      . . . DO(I=1,NEVENT)
00102      C . . . LAYER=LAYRWS
00103      C . . . TOTAL=UP+HC

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00104 C ***** DENSITY CURVE *****
00105 . . . . GABHC(LAYRWS)=GABHC(LAYRWS)+PROB(112)*HYDCN1(LAYRWS,2)
00106 C . . . . LAYER=LAYRGR
00107 C . . . . TOTAL=UP=HC
00108 . . . . GABHC(LAYRGR)=GABHC(LAYRGR)+PROB(112)*HYDCN1(LAYRGR,2)
00109 C *****
00110 . . . . CALL NOTE (17,'GABBLE MT. ACTIVE')
00111 . . . . FIN
00112 . . . . FIN
00113 . . . . FIN
00114 . . . . FIN
00115 C
00116 CC IF(STSAD,GE,STSAD T)
00117 CC NEVENT=POISON(AVSAD) GET THE NUMBER EVENTS THIS TIME STEP
00118 CC IF(NEVENT,GT,0)
00119 CC SUMFTN=SUMFTN+NEVENT
00120 CC DO(I=1,NEVENT)
00121 CC CALL NOTE (18,'SADDLE MT. ACTIVE') NOTE CHANGE IN DOC,
00122 CC LAYER=LAYRWS
00123 CC TOTAL=UP=HC
00124 CC ***** DENSITY CURVE *****
00125 CC SADHC(LAYRWS)=SADHC(LAYRWS)+PROB(111)*TOTAL
00126 CC LAYER=LAYRGR
00127 CC TOTAL=UP=HC
00128 CC SADHC(LAYRGR)=SADHC(LAYRGR)+PROB(111)*TOTAL
00129 CC *****
00130 CC FIN
00131 CC FIN
00132 CC FIN
00133 CC IF(STRAT,GE,STRAT T)
00134 CC NEVENT=POISON(AVRAT)
00135 CC IF(NEVENT,GT,0)
00136 CC SUMFTN=SUMFTN+NEVENT
00137 CC DO(I=1,NEVENT)
00138 CC LAYER=LAYRWS
00139 CC TOTAL=UP=HC
00140 CC ***** DENSITY CURVE *****
00141 CC RADHC(LAYRWS)=RADHC(LAYRWS)+PROB(113)*TOTAL
00142 CC LAYER=LAYRGR
00143 CC TOTAL=UP=HC
00144 CC RADHC(LAYRGR)=RADHC(LAYRGR)+PROB(113)*TOTAL
00145 CC ACTIVITY ON RATTLESNAKE RIDGE
00146 CC *****
00147 CC CALL NOTE (19,'RATTLESNAKE ACTIVE') NOTE CHANGE IN DOC
00148 CC FIN
00149 CC FIN
00150 CC FIN
00151 CC
00152 CC TO TOTAL=UP=HC
00153 CC TOTAL=SADHC(LAYER)+RADHC(LAYER)+GABHC(LAYER)+HYDCN(LAYER,2)
00154 CC 1 +CHHC(1,LAYER,2)+CHHC(2,LAYER,2)
00155 CC IF(TOTAL .LE,0,0)
00156 CC THIS SHOULD NOT HAPPEN, BUT JUST IN CASE CHECK HERE
00157 CC CALL RNUMBR(12,'H.C. TOO LOW',TOTAL) CHANGE DOC
00158 CC CALL RNUMBR(11,'FIRST VALUE',HYDCN(LAYER,2)) CHANGE DOC
00159 CC TOTAL=1.E-10

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00160 CC FIN
00161 CC FIN
00162 C
00163 C
00164 C
00165 C
00166 C *****

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-----
00167 TO CREATE-A-NEW-FAULT
00168 C ****CREATE A NEW FAULT*****
00169 C .
00170 C .
00171 C . SEE ABOUT 'CREATING' A NEW LOCAL FAULT
00172 C . IF(IFORCE, EQ, 8, AND, .NOT, LSSFIN)
00173 C . . CALL NOTE(19, 'NO NEW FAULT FORCED')
00174 C . . IFORCE=0
00175 C . . FIN
00176 C . IF(IFORCE, EQ, 8, AND, LNWSSF)
00177 C . . CALL NOTE(16, 'NEW FAULT FORCED')
00178 C . . LNWSSF=.FALSE, ISET FALSE TO ALLOW THE USER TO FORCE
00179 C . . MORE THAN ONE NEW LOCAL FAULT
00180 C . . FIN
00181 C . IF(.NOT, LNWSSF, AND, LSSFIN)
00182 C . . IF A NEW LOCAL FAULT HAS NOT ALREADY BEEN CREATED AND
00183 C . . LOCAL FAULTS ARE ALLOWED THIS RUN THEN:
00184 C . . IF( L TEST (PNEWFT), OR, IFORCE, EQ, 8)
00185 C . . . IF A S.D. IS TRUE FOR CREATING A NEW LOCAL FAULT THEN:
00186 C . . . WRITE TO THE HISTORY FILE
00187 C . . . FIND THE MAXIMUM DISTANCE BETWEEN FAULTS AND PLACE THE
00188 C . . . NEW FAULT THERE
00189 C . . . THEN DRAW FOR:
00190 C . . . WIDTH
00191 C . . . DIRECTION
00192 C . . . AND STARTING HYDRAULIC CONDUCTIVITY
00193 C . . . SET THE STARTING TIME FOR THE 'NEXT' EVENT TO THE CURRENT TIME
00194 C . . . AND INCREASE THE NUMBER OF LOCAL FAULTS BY 1
00195 C . . . CALL NOTE(15, 'NEW LOCAL FAULT')
00196 C . . . LNWSSF=.TRUE, I MARK THAT A NEW FAULT HAS FORMED
00197 C . . . DISMAX=-1.0E24
00198 C . . . IMAX=1
00199 C . . . FIND THE MAX. DISTANCE BETWEEN FAULTS
00200 C . . . DO(I=1, NSSFT-1)
00201 C . . . . DISCUR=FAULT(I+1)-FAULT(I)
00202 C . . . . IF(DISCUR, GT, DISMAX)
00203 C . . . . . DISMAX=DISCUR
00204 C . . . . . IMAX=I
00205 C . . . . FIN
00206 C . . . FIN
00207 C . . . NOW INSERT THE NEW FAULT
00208 C . . . IF(NSSFT, EQ, 200)
00209 C . . . . CALL NOTE (15, 'LOST LAST FAULT')
00210 C . . . . NSSFT=199
00211 C . . . FIN
00212 C . . . DO(I=NSSFT+1, IMAX+1, =1)

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00213      . . . . SSFTT(IK)=SSFTT(IK-1)ITIME
00214      . . . . FOR(IK)=FOR(IK-1)IDIRECTION
00215      . . . . SSFTHC(IK)=SSFTHC(IK-1)H.C.
00216      . . . . RESET(IK)=RESET(IK-1) IRESET TIME
00217      . . . . FAULT(IK)=FAULT(IK-1)IDISTANCE
00218      . . . . ...FIN
00219      . . . . NSSFT=NSSFT+1
00220      . . . . SSFTT(IMAX) =TTIME ISET THE FAULT TO BE ACTIVE THIS TIME STEP
00221      . . . . RESET(IMAX)=0.0
00222 C ***** DENSITY CURVE *****
00223      . . . . FWIDTH(IMAX)=PROB(83)/COSAN
00224      . . . . FDR(IMAX)=RTREND+PROB(84)
00225      . . . . SSFTHC(IMAX)=PROB(114)*FTHCSS IGET STARTING H.C.
00226      . . . . SUMFTN=SUMFTN+1.0
00227 C *****
00228      . . . . FAULT(IMAX)=FAULT(IMAX)+DISMAX/2.0 ISET NEW DISTANCE
00229      . . . . DO(I=1,NSSFT)
00230      . . . . . CALL RNUMBR(10,'FAULT NEW',FAULT(I))
00231      . . . . . IF(I.EQ.IMAX)CALL RNUMBR(18,'NEW FAULT DISTANCE',FAULT(IMAX))
00232      . . . . ...FIN
00233      . . . . IF(ABS(FAULT(IMAX)),LE, SITRAD)
00234      . . . . . CALL NOTE(12,'SITE FAULTED')
00235      . . . . . NEXTFT=NEXTFT+1
00236      . . . . . IF(NEXTFT.GT.50)
00237      . . . . . . CALL NOTE(18,'LOST FAULT IN REPS')
00238      . . . . . . NEXTFT=50
00239      . . . . ...FIN
00240      . . . . IFBIT(NEXTFT)=IMAX
00241      . . . . ANG=ANGBTN(FDR(IMAX),ANGROS)
00242      . . . . R=ABS(FAULT(IMAX)*SIN(ANG/57.296))I.E. GET THE
00243 C . . . . . NORMAL DISTANCE
00244 C . . . . . TO THE FAULT
00245      . . . . . RLENGTH=SQRT(SITRAD*SITRAD-R*R)*2 ILENGTH OF FAULT SITE
00246 C . . . . . INTERSECTION
00247      . . . . . AREA=RLENGTH*(FWIDTH(IMAX)/1000.0)*COSAN
00248      . . . . . FRAC(NEXTFT)=AREA/(SITRAD*SITRAD*3.14159)
00249      . . . . . CALL RNUMBR(17,'FRACTION OF INTER',FRAC(IMAX))
00250      . . . . ...FIN
00251      . . . . ...FIN
00252      . . . . ...FIN
00253      . . . . ...FIN
00254 C
00255 C
00256 C *****
-----
00257      TO CHECK-FOR-ANY-ACTIVE-LOCAL-FAULTS
00258 C *****CHECK FOR ANY ACTIVE LOCAL FAULTS*****
00259 C
00260 C
00261      . IF(NSSFT.GT. 2)
00262 C . . REMEMBER THAT THE 1ST AND LAST FAULT ARE OUTSIDE THE BASIN
00263 C . . FIRST CHECK FOR ANY EXTRA EVENTS CAUSED BY SUBBASALT FAULTING
00264      . . DO(K=2,NSSFT-1)
00265      . . . IF(LTESTW(P3SEX) )

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00266      . . . . WHEN(RESET(K).LT.TIMEH)
00267 C      . . . . . IF A LOCAL FAULT IS TRIGGERED AHEAD OF TIME THEN:
00268 C      . . . . . WRITE TO THE HISTORY FILE
00269 C      . . . . . RESET THE TIME FOR THIS LOCAL FAULT TO BE ACTIVE TO
00270 C      . . . . . THE CURRENT TIME
00271      . . . . . CALL INUMBR(16,'EXTRA ADJUSTMENT',K)
00272      . . . . . SSFTT(K)=TTIMEI RESET TIME TO EVENT TO OCCURE RIGHT NOW
00273      . . . . . ...FIN
00274      . . . . . ELSE
00275      . . . . . CALL INUMBR(14,'EXTRA EVENT ON',K)
00276 C      ***** DENSITY CURVE *****
00277      . . . . . SSFTHC(K)=SSFTHC(K)+PROB(114) IGET CHANGE IN H,C,
00278      . . . . . SUMFTN=SUMFTN+1.0
00279 C      *****
00280      . . . . . ...FIN
00281      . . . . . ...FIN
00282      . . . . . ...FIN
00283 C      . . .
00284 C      . . .
00285      . . . REPEAT UNTIL(TMIN,GE,TEND)
00286      . . . TMIN=1.0E20
00287      . . . DO(K=2,NSSFT-1)
00288      . . . . IF(SSFTT(K).LT.TEND)
00289 C      . . . . . IF THIS LOCAL FAULT IS ACTIVE THEN:
00290 C      . . . . . WRITE TO THE HISTORY FILE
00291      . . . . . CALL INUMBR(12,'FAULT ACTIVE',K)
00292 C      . . . . . DRAW FOR HYDRAULIC CONDUCTIVITY
00293 C      . . . . . DRAW FOR THE TIME UNTIL THE NEXT EVENT
00294 C      ***** DENSITY CURVE *****
00295      . . . . . TINC=PROB(85) IGET INCREMENT IN TIME
00296      . . . . . SSFTHC(K)=PROB(114)+SSFTHC(K) I ADD TO CHANGES IN K
00297 C      *****
00298      . . . . . SUMFTN=SUMFTN+1.0
00299      . . . . . RESET(K)=SSFTT(K)+TINC+PREFT
00300      . . . . . SSFTT(K)=SSFTT(K)+TINC
00301      . . . . . ...FIN
00302      . . . . . TMIN=MIN(SSFTT(K),TMIN)
00303      . . . . . ...FIN
00304      . . . . . CALL RNUMBR(12,'#MIN. EVENT=',TMIN)
00305      . . . . . ...FIN
00306      . . . . . ...FIN
00307      . . . . . ...FIN
00308 C
00309 C
00310 C      *****

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-----
00311      TO CHECK-FOR-THRUST-FAULTS
00312 C      ****CHECK FOR THRUST FAULTS*****
00313 C      .
00314 C      .
00315 C      . CHECK FOR A THRUST FAULT IN THE REPOSITORY
00316 C      .
00317 C      . IF(.NOT. L TRUST)
00318 C      . . IF THERE IS NOT A THRUST FAULT THEN TRY TO CREATE ONE

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00319      . . IF( L TEST(PNEWTR) .OR. IFORCE.EQ.9)
00320 C      . . . IF THE S.D. IS TRUE FOR A THRUST FAULT IN THE REPOSITORY THEN:
00321 C      . . . DRAW FOR :
00322 C      . . . THICKNESS
00323 C      . . . HYDRAULIC CONDUCTIVITY
00324 C      . . . AND SET THE TIME TO THE 'NEXT', THRUSTING ACTIVITY TO CURRENT TIME
00325 C      . . . SET LOGIC FLAG
00326 C      . . . WRITE TO THE HISTORY FILE
00327 C      ***** DENSITY CURVE *****
00328      . . . THRW=PROB(86) IGET THRUST WIDTH
00329      . . . THRC=PROB(115)*TRSTRT IGET STARTING H.C.
00330 C      *****
00331      . . . IF(THRW.GE.RPOSTH)
00332 C      . . . . IF THIS MESSAGE OCCURS THEN THERE IS AN ERROR IN CURVE 115
00333      . . . . CALL RNUMBR(15,'THRUST TOO WIDE',THRW)
00334      . . . . THRW=RPOSTH/2.0
00335      . . . ...FIN
00336      . . . TRUST=TTIME ISET THRUST TO BE ACTIVE THIS TIME STEP
00337      . . . RESET T=0.0
00338      . . . TRMOVE=0.0
00339      . . . LTRUST=.TRUE.
00340      . . . CALL NOTE(16,'NEW THRUST FAULT')
00341      . . . ...FIN
00342      . . . ...FIN
00343 C      .
00344 C      .
00345 C      .
00346 C      .
00347      . IF(L TRUST)
00348      . . IF(LTESTH(PTRX))
00349 C      . . . THRUST EVENT TIMING EFFECTED BY A SUB-BASALT FAULTING EVENT
00350      . . . WHEN(RESET T.LE.TIMEH)
00351 C      . . . . THE TIMING OF THE SCHEDULED EVENT IS RESET
00352      . . . . CALL NOTE(15,'THRUST ADJUSTED')
00353      . . . . TRUST T=TTIME ISET TIME TO ALLOW FOR THE EVENT TO OCCUR THIS STEP
00354      . . . . ...FIN
00355      . . . . ELSE
00356 C      . . . . AN EXTRA FAULTING EVENT OCCURS WHICH DOES NOT EFFECT THE TIMING
00357 C      . . . . OF THE CURRENTLY SCHEDULED EVENT
00358      . . . . CALL NOTE(18,'EXTRA THRUST EVENT')
00359 C      ***** DENSITY CURVE *****
00360      . . . . THRC=THRC+PROB(115) IGET CHANGE IN H.C.
00361      . . . . TRMOVE=TRMOVE+PROB(116) IGET CHANGE IN TOTAL MOVEMENT
00362      . . . . SUMFTN=SUMFTN+1.0
00363 C      *****
00364      . . . . ...FIN
00365      . . . . ...FIN
00366      . . . WHILE (TRUST T .LT. TEND)
00367 C      . . . . IF THE THRUST FAULT IS ACTIVE THIS TIME STEP THEN
00368 C      . . . . DRAW FOR A CHANGE IN HYDRAULIC CONDUCTIVITY
00369 C      . . . . AND DRAW FOR THE TIME UNTIL THE NEXT EVENT
00370      . . . . CALL NOTE(13,'THRUST ACTIVE')
00371 C      ***** DENSITY CURVE *****
00372      . . . . THRC=THRC+PROB(115) IADD TO CHANGE IN H.C.
00373      . . . . TRMOVE=TRMOVE+PROB(116) IADD TO TOTAL MOVEMENT
00374      . . . . TINC=PROB(87) IINCREMENT IN TIME UNTIL THE NEXT EVENT

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00375 C *****
00376 . . . SUMFTN=SUMFTN+1.0
00377 . . . RESET T=TRUST T+TINC*FRESTR
00378 . . . TRUST T=TRUST T+TINC
00379 . . . FIN
00380 . . . FIN
00381 . . . FIN
00382 C
00383 C
00384 C
00385 C *****

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00386 TO CHECK-FOR-FOLD-ACTIVITY
00387 C ****CHECK FOR FOLD ACTIVITY*****
00388 C .
00389 C .
00390 . IF( .NOT. L FOLD)
00391 C . . IF THERE IS NO FOLD PRESENT SEE ABOUT CREATING ONE
00392 . . IF(L TEST(PNEWFD) .OR. IFORCE.EQ.2)
00393 C . . . IF A NEW FOLD IS CREATED THEN(WITH A CALL TO GETFOLD) :
00394 C . . . DRAW FOR A STARTING K VALUE
00395 C . . . DRAW FOR A LOCATION (RELATIVE TO THE REGIONAL TREND)(SEE FIG 3.6
00396 C . . . DRAW FOR THE ANGLES(SEE FIG 3.7)
00397 C . . . SET THE STARTING ELEVATION TO ZERO
00398 C . . . WRITE TO THE HISTORY FILE
00399 . . . CALL NOTE(16,'NEW FOLD CREATED')
00400 . . . CALL GETFLD
00401 . . . FOLDHC=0.0
00402 . . . FIN
00403 . . . FIN
00404 C .
00405 . LFACT=.FALSE.
00406 . IF(L FOLD)
00407 . . IF(L TEST(PFACT) .OR. IFORCE .EQ.2)
00408 C . . . IF THE FOLD IS ACTIVE FOR THE REST OF THE TIME STEP THEN:
00409 C . . . DRAW FOR AN INCREASE IN HEIGHT
00410 C ***** DENSITY CURVE *****
00411 . . . RNUM=PROB(117)*OTIME /FOLD GROWTH
00412 . . . FOLDHC=FOLDHC+PROB(118)*OTIME /AVERAGE INCREASE IN H.C. IN THE FOLD
00413 C *****
00414 . . . CALL RNUMBR(11,'FOLD GROWTH',RNUM)
00415 . . . POST=POST+RNUM
00416 . . . LFACT=.TRUE.
00417 . . . FIN
00418 . . . FIN
00419 . . . FIN
00420 C
00421 C
00422 C *****

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00423 TO CHECK-FOR-NE-FAULTING
00424 C ****CHECK FOR NE FAULTING*****

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00425 C .
00426 C .
00427 C . CHECK TO SEE IF N.E. FAULTING IS ACTIVE
00428 C . IF(LTESTW(PNEEX))
00429 C 'EXTRA' FAULTING EVENT OCCURED DUE TO SUB-BASALT FAULTING EVENT
00430 C . . WHEN(RESFNE,LE,TIMEH)
00431 C . . . CALL NOTE(13,'N.E. ADJUSTED')
00432 C . . . FLTNE=TTIME
00433 C . . ...FIN
00434 C . . ELSE
00435 C . . . CALL NOTE(17,'N.E. EXTRA ACTIVE')
00436 C ***** DENSITY CURVE *****
00437 C . . . FLHCNE=FLHCNE+PROB(119) !CHANGE IN H,C.
00438 C *****
00439 C . . ...FIN
00440 C . . ...FIN
00441 C . NOW DO 'NORMAL' N.E. FAULTING
00442 C . WHILE(FLTNE,LT,TEND)
00443 C . . IF THERE IS A FAULTING EVENT THIS TIME STEP THEN
00444 C . . . DRAW FOR CHANGE IN HYDRAULIC CONDUCTIVITY
00445 C . . . DRAW FOR THE TIME UNTIL THE NEXT TIME STEP
00446 C . . . CALL NOTE(17,'N.E. FAULT ACTIVE')
00447 C ***** DENSITY CURVE *****
00448 C . . . FLHCNE=FLHCNE+PROB(119) !CHANGE IN H,C.
00449 C . . . TINC=PROB(91) !INCREMENT OF TIME UNTIL THE NEXT EVENT
00450 C *****
00451 C . . RESFNE=FLTNE+TINC*PREFNE
00452 C . . FLTNE=FLTNE+TINC
00453 C . . ...FIN
00454 C . . ...FIN
00455 C
00456 C
00457 C
00458 C *****

```

```

00459 TO CHECK-FOR-SW-FAULTING
00460 C ****CHECK FOR SW FAULTING*****
00461 C .
00462 C .
00463 C . NOW LOOK AT THE S.W. FAULT ZONE
00464 C . IF(LTESTW(PSWEX))
00465 C 'EXTRA' EVENT IN THE S.W. FAULT ZONE DUE TO SUB-BASALT FAULTING
00466 C . . WHEN(RESFSW,LE,TIMEH)
00467 C . . . SCHEDULED EVENT RESET TO CURRENT TIME STEP
00468 C . . . CALL NOTE (13,'S.W. ADJUSTED')
00469 C . . . FLT3W=TTIME
00470 C . . ...FIN
00471 C . . ELSE
00472 C 'EXTRA' EVENT WITHOUT EFFECTING THE SCHEDULED EVENT
00473 C . . . CALL NOTE(17,'S.W. EXTRA ACTIVE')
00474 C ***** DENSITY CURVE *****
00475 C . . . FLHC3W=FLHC3W+PROB(120) !CHANGE IN H,C.
00476 C *****
00477 C . . ...FIN

```

```
00478      . ...FIN
00479      C      . NOW DO THE 'NORMAL' CASE
00480      .      . WHILE(FLTSW,LT,TEND)
00481      C      .      . IF THERE IS A FAULTING EVENT THIS TIME STEP THEN;
00482      C      .      .      . DRAW FOR THE CHANGE IN HYDRAULIC CONDUCTIVITY
00483      C      .      .      . DRAW FOR THE TIME UNTIL THE NEXT TIME STEP
00484      .      .      . CALL NOTE(17,'S.W. FAULT ACTIVE')
00485      C      . ***** DENSITY CURVE *****
00486      .      . FLHCSW=FLHCSW+PROB(120) !CHANGE IN H,C.
00487      .      . TINC=PROB(90) !INCREMENT IN TIME UNTIL THE NEXT EVENT
00488      C      . *****
00489      .      . RESFSW=FLTSW+TINC*FREPSW
00490      .      . FLTSW=FLTSW+TINC
00491      .      . ...FIN
00492      . ...FIN
```

```
-----
00493      TO CHECK-FOR-EXPLICIT-SWARMS-AT-THE-SITE
00494      C      ***** CHECK-FOR-EXPLICIT-SWARMS-AT-THE-SITE*****
00495      C      .
00496      C      .
00497      C      . AVESWM= AVERAGE NUMBER OF SWARM EVENTS/100.0 YEARS(I)
00498      C      . NSWARM = NUMBER OF SWARM EVENTS(T)
00499      C      . CHRS(3)= TOTAL CHANGE IN H,C. DUE TO SWARM EVENTS(A)
00500      C      . TEMP = TEMP. VARIABLE (T)
00501      C      .
00502      C      .
00503      .      . NSWARM=POISON(AVESWM)
00504      .      . IF(NSWARM,GT,0)
00505      .      .      . DO(I=1,NSWARM)
00506      .      .      .      . TEMP=PROB(131)*RPOSHC
00507      .      .      .      . CALL RNUMBR(11,'NEW CHANGE',TEMP)
00508      .      .      .      . CHRS(3)=TEMP+CHRS(3)
00509      .      .      . ...FIN
00510      .      . ...FIN
00511      . ...FIN
00512      C
00513      C
00514      C
00515      END
```

PROCEDURE CROSS-REFERENCE TABLE

```
00311 CHECK-FOR-THRUST-FAULTS
00020

00029 SET-PROBABILITY
00016

00386 CHECK-FOR-FOLD-ACTIVITY
00021

00459 CHECK-FOR-SW-FAULTING
```

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00023

00167 CREATE-A-NEW-FAULT
00018

00423 CHECK-FOR-NE-FAULTING
00022

00257 CHECK-FOR-ANY-ACTIVE-LOCAL-FAULTS
00019

00065 ALLOW-FOR-UPLIFT-SUBSIDENCE-AND-SEISMIC-EVENTS
00017

00493 CHECK-FOR-EXPLICIT-SWARMS-AT-THE-SITE
00024

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```
-----
00001 C ***** GEOMOR,FLX *****
00002 C
00003 C THIS SUBMODEL ACCOUNTS FOR :
00004 C CHANGES IN PATH LENGHT OF THE UNCONFINED AQUIFER(BY RIVER
00005 C MOVEMENT) CAUSED OR PREVENTED BY:
00006 C GLACIER ICE
00007 C FLOODING BY THE SEA
00008 C MAGMATIC EVENT
00009 C LANDSILDE(S)
00010 C CHANGES IN RIVER SLOPE(ALSO EFFECTED BY A NUMBER OF EVENTS)
00011 C RIVER EROSION OR DEPOSITION
00012 C CATABSTROPHIC(MISSOULA) FLOODING
00013 C
00014 C
00015 C
00016 C
00017 SUBROUTINE GEOMOR
00018 C
00019 C
00020 C
00021 INCLUDE 'DI:[226,226]COMMON,FLX'
00022 C
00023 CALL NOTE(10,'#GEOMORPHIC')
00024 C
00025 C
00026 WHEN(.NOT. LICEON .AND. .NOT. LFLOOD)
00027 . CHECK-FOR-FOLD-SITE-INTERSECTION
00028 . ALLOW-FOR-RIVER-MOVEMENT
00029 . GET-DISCHARGE-SLOPE-AND-EROSION
00030 . CHECK-FOR-MISSOULA-FLOODS
00031 . . .FIN
00032 ELSE CALL NOTE(13,'#SITE COVERED')
00033 C
00034 RETURN
```

```
-----
00035 TO CHECK-FOR-FOLD-SITE-INTERSECTION
00036 C *****CHECK FOR FOLD SITE INTERSECTION*****
00037 C .
00038 C .
00039 C . LEXPOS=.FALSE. ; FOLD NOT EXPOSED AT THE SURFACE
00040 C . LFTINT=.FALSE. ; FOLD DOES NOT INTEREST THE SITE
00041 C .
00042 C .
00043 C .
00044 C . CHECK FOR A NEW FOLD
00045 C . IF (LFOLD)
00046 C . . IF A FOLD IS PRESENT THEN SEE IF IT IS EXPOSED
00047 C . . FOREF=POST-TFLER
00048 C . . CALL RNUMBR(12,'#FOLD RELIEF',FOREF)
00049 C . . IF(FDREF.GT.0.0)
00050 C . . . CALL RNUMBR(12,'FOLD EXPOSED',FDREF)
```



```

00051      . . . LEXPOS=.TRUE.
00052      . . .FIN
00053      . ...FIN
00054      C      .
00055      C      .
00056      C      .
00057      C      .
00058      C      . FINDS IF AN INTERSECTION OCCURS AND HOW MUCH
00059      . WHEN(UNPATH(2).LE,SITRAD)
00060      . . IF(.NOT,LRIVON)CALL NOTE(8,'RIVER ON')
00061      . . LRIVON=.TRUE.
00062      . ...FIN
00063      . ELSE
00064      . . IF(LRIVON)CALL NOTE(9,'RIVER OFF')
00065      . . LRIVON=.FALSE.
00066      . ...FIN
00067      . IF(LEXPOS .AND. .NOT, LRVFXD)
00068      C      . . THE FOLD IS EXPOSED AT THE SURFACE AND THE RIVER IS NOT ALREADY
00069      C      . . FIXED IN PLACE THEN CHECK TO SEE IF IT IS NOW CAPTURED BY THE RIVER
00070      . . FWASTE=-1.0      ! SET FLAG TO CHECK IF THE FOLD IS CLOSE BY
00071      . . LRVFXD=LINTER(RIVCAP,FANGLE,POST,COSAN2,SINAN,AVAXIS,DISTFD
00072      +. . . ,FWASTE)
00073      . ...FIN
00074      . IF(LPD ACT)
00075      C      . . IF THE FOLD IS ACTIVE SEE IF IT INTERSECTS THE REPOSITORY AND
00076      C      . . IF SO THE FRACTIONAL AMOUNT THAT IT INTERSECTS
00077      . . LFTINT =
00078      +. . LINTER(SITRAD,FANGLE,POST,COSAN2,SINAN,AVAXIS,DISTFD,FRAC(2))
00079      . ...FIN
00080      . ...FIN
00081      C
00082      C
00083      C *****

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-----
00084      TO ALLOW-FOR-RIVER-MOVEMENT
00085      C *****ALLOW FOR RIVER MOVEMENT*****
00086      C      .
00087      C      .
00088      C      . ----DENSITY----
00089      . CH=PROB(46)*UTIME      ! NORMAL CHANGE IN RIVER SLOPE
00090      C      . -----
00091      . CHANGE=SLOPE
00092      C      .
00093      C      .
00094      C      .
00095      C      . CHECK FOR LANDSLIDES
00096      . NSLIDE=POISON(AVLAND) ! GET THE NUMBER OF LANDSLIDES
00097      . IF(NSLIDE.EQ.0 .AND. IFORCE.EQ.3)
00098      . . CALL NOTE(12,'FORCED SLIDE')
00099      . . NSLIDE=1
00100      . ...FIN
00101      . IF(NSLIDE.GT.0)LSLIDE=.TRUE.
00102      . IF(LRVCHG)
00103      C      . . IF A MAJOR CHANGE IN RIVER SLOPE DUE TO GLACIER ACTIVITY

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00104 C . . ----DENSITY-----
00105 . . CH=PROB(47) !CHANGE IN SLOPE DUE TO GLACIERS
00106 C . . ----DENSITY-----
00107 . . CHANGE=SLOPE
00108 . . CALL RNUMBR(18,'SLOPE FROM GLACIER',CH)
00109 . . ...FIN
00110 . . IF(LSEACH)
00111 C . . IF A MAJOR CHANGE IN RIVER SLOPE DUE TO FLOODING BY THE SEA
00112 C . . ----DENSITY-----
00113 . . CH=PROB(48) !CHANGE IN SLOPE DUE TO FLOODING
00114 C . . ----DENSITY-----
00115 . . CALL RNUMBR(19,'SLOPE FROM FLOODING',CH)
00116 . . CHANGE=SLOPE
00117 . . ...FIN
00118 . . IF(LMAGRV)
00119 C . . MAJOR CHANGE IN RIVER SLOPE DUE TO MAGMATIC EFFECTS
00120 C . . ----DENSITY-----
00121 . . CH=PROB(49) !CHANGE WITH MAG. EVENTS
00122 C . . ----DENSITY-----
00123 . . CALL RNUMBR(17,'SLOPE FROM MAGMA',CH) !CHANGE DOC
00124 . . CHANGE=SLOPE
00125 . . ...FIN
00126 . . IF(LSLIDE)
00127 . . DO(I=1,N8SLIDE)
00128 C . . . CHANGE IN RIVER SLOPE DUE TO LANDSLIDING
00129 C . . . ----DENSITY-----
00130 . . . CH=PROB(50) !CHANGE IN RIVER SLOPE DUE TO LANDSLIDING
00131 C . . . ----DENSITY-----
00132 . . . CALL RNUMBR(17,'SLOPE FROM SLIDE',CH) !CHANGE DOC
00133 . . . CHANGE=SLOPE
00134 . . . ...FIN
00135 . . ...FIN
00136 C . .
00137 C . .
00138 C . .
00139 . . IF(.NOT. LHEDRK)
00140 C . . IF THE RIVER IS NOT IN BEDROCK
00141 . . IF(.NOT. LRVFXD)
00142 C . . IF THE RIVER IS NOT FIXED ON THE SITE BY A FOLD
00143 . . DO(IPATH=1,3)
00144 C . . . ----DENSITY-----
00145 . . . CH=PROB(51)*DTIME !NORMAL CHANGE IN THE UNCONFINED GROUND WATER
00146 C . . . ----DENSITY-----
00147 C . . . . . PATH LENGTH
00148 . . . CHANGE=PATH=LENGTH
00149 . . . IF(LRVCHG)
00150 C . . . MAJOR CHANGE FROM A GLACIER
00151 C . . . ----DENSITY-----
00152 . . . CH=PROB(52) !CHANGE IN UNCONFINED PATH LENGTH DUE TO A GLACIER
00153 C . . . ----DENSITY-----
00154 . . . CALL RNUMBR(17,'CH, PATH(GLACIER)',CH)
00155 . . . CHANGE=PATH=LENGTH
00156 . . . ...FIN
00157 . . . IF(LSEACH)
00158 C . . . MAJOR CHANGE FROM THE SEA NO LONGER FLOODING THE SITE
00159 C . . . ----DENSITY-----

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00160      . . . . . CH=PROB(53) !CHANGE IN UNCONFINED PATH LENGTH DUE TO THE SEA
00161      C      . . . . . -----
00162      . . . . . CHANGE-PATH-LENGTH
00163      . . . . . CALL RNUMBR(13,'CH, PATH(SEA)',CH)
00164      . . . . . ...FIN
00165      . . . . . IF(LMAGRV)
00166      C      . . . . . MAJOR CHANGE IN PATH LENGTH DUE TO A MAGMATIC EVENT
00167      C      . . . . . -----DENSITY-----
00168      . . . . . CH=PROB(54) !CHANGE DUE TO A MAGMATIC EVENT
00169      C      . . . . . -----
00170      . . . . . CALL RNUMBR(14,'CH, PATH(MAGMATIC)',CH)
00171      . . . . . CHANGE-PATH-LENGTH
00172      . . . . . ...FIN
00173      . . . . . IF(LSLIDE)
00174      . . . . . DO(I=1,NBLSIDE)
00175      C      . . . . . MAJOR CHANGE IN PATH LENGTH DUE TO A LANDSLIDE
00176      C      . . . . . -----DENSITY-----
00177      . . . . . CH=PROB(55) !UNCONFINED PATH LENGTH CHANGE DUE TO A LANDSLIDE
00178      C      . . . . . -----
00179      . . . . . SELECT(IPATH)
00180      . . . . . . (1) CALL NOTE (13,'FOR THE S.W.')

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00213      . IF(LBEDRK)
00214      . . CH=CH*CORBED
00215      . . CALL RNUMBR(20,'BEBROCK CORRECTION=1,CH)
00216      . . .FIN
00217      . SLOPE=SLOPE+CH
00218      . IF(SLOPE,LT,SLOPLW)
00219      . . CALL RNUMBR(20,'RIVER SLOPE RESET=L',SLOPE)
00220      . . SLOPE=SLOPLW
00221      . . .FIN
00222      . IF(SLOPE,GE,SLOPHI)
00223      . . CALL RNUMBR(20,'RIVER SLOPE RESET=H',SLOPE)
00224      . . SLOPE=SLOPHI
00225      . . .FIN
00226      . . .FIN
00227      C
00228      C
00229      C *****
-----

00230      TO CHANGE=PATH=LENGTH
00231      C *****CHANGE PATH LENGTH*****
00232      C
00233      C
00234      . UNPATH(IPATH)=ABS(UNPATH(IPATH)+CH)
00235      . IF(UNPATH(IPATH).GT, HIPATH)
00236      . . CALL INUMBR(18,'RESET PATH LENGTH',IPATH)ICHANGE DOC
00237      . . CALL RNUMBR(12,'OLD LENGTH=1,UNPATH(IPATH)) ICHANGE DOC
00238      . . UNPATH(IPATH)=HIPATH
00239      . . .FIN
00240      . IF(ITYPE(ITOP).EQ,1)
00241      . . IF(UNPATH(IPATH).LE,DELX(ITOP,2)/1000,0 )
00242      . . . CALL INUMBR(18,'RESET PATH LENGTH',IPATH)ICHANGE DOC
00243      . . . CALL RNUMBR(12,'OLD LENGTH=1,UNPATH(IPATH)) ICHANGE DOC.
00244      . . . UNPATH(IPATH)=DELX(ITOP,2)/1000,0
00245      . . . CALL RNUMBR(11,'NEW VALUE =1,UNPATH(IPATH))ICHANGE DOC,
00246      . . . .FIN
00247      . . .FIN
00248      . . .FIN
00249      C
00250      C
00251      C *****
-----

00252      TO GET=DISCHARGE=SLOPE=AND=EROSION
00253      C *****GET DISCHARGE SLOPE AND EROSION*****
00254      C
00255      C
00256      C
00257      C . -----DENSITY-----
00258      C . Q=PROB(S5+ICLIM) IDRAW FOR DISCHARGE
00259      C . -----
00260      C . POWER=SLOPE*Q
00261      C
00262      C

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00263 C . -----DENSITY-----
00264 . TEMP=SLOPE**1.5
00265 . RATE=POLY(13,TEMP)+PROB(59+ICLIM)
00266 . CALL RNUMBR(6,'RATE',RATE)
00267 . CALL RNUMBR(6,'SLOPE',SLOPE)
00268 C . -----
00269 . IF(ITYPE(ITOP).NE.1 .AND. RATE.LT.0.0)RATE=RATE*HARDPC
00270 . CALL CHANGX(RATE*DTIME)
00271 . ...FIN
00272 C
00273 C
00274 C *****

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-----
00275 TO CHECK-FOR-MISSOULA-FLOODS
00276 C *****CHECK FOR MISSOULA FLOODS*****
00277 C .
00278 C .
00279 . IF(GLACIN.GT.0.0)
00280 C . . FIRST CORRECT FOR TIME STEP
00281 . . NFLOD=POISON(AVEFLO) IDRAW FOR THE NUMBER OF 'MISSOULA' FLOODS
00282 . . IF(NFLOD.GT. 0)
00283 . . . DO(IFLOD=1,NFLOD)
00284 C . . . . -----DENSITY-----
00285 . . . . QFLOOD=PROB(64) IGET THE AMOUNT OF FLOODING
00286 C . . . . -----
00287 . . . . TMSULA=TMSULA+1.0 IADD TO THE COUNTER FOR TOTAL FLOOD VOLUME
00288 . . . . POWER=QFLOOD*SLOPE I STREAM 'POWER'
00289 C . . . . -----DENSITY-----
00290 . . . . EROS=POLY(14,POWER)+PROB(65)ITOTAL AMOUNT OF FLOOD EROSION
00291 C . . . . -----
00292 . . . . CALL RNUMBR(11,'FLOOD WATER',QFLOOD)
00293 . . . . CALL RNUMBR(12,'FLOOD EROSION',EROS)
00294 . . . . EROSB=EROS
00295 . . . . IF(LBEDRK)EROSB=EROS*HARDPC I CORRECT EROSION IF THE RIVER IS IN BEDROCK
00296 . . . . CALL CHANGX(EROSB) I UPDATE THE SYSTEM FOR THE FLOOD EROSION
00297 . . . . THOSF=THOSF+EROSB
00298 C . . . .
00299 C . . . .
00300 . . . . CHECK-FOR-EROSION-ON-A-FOLD
00301 C . . . .
00302 C . . . .
00303 C . . . . UPDATE THE EFFECTIVE N.E. RECHARGE AREA
00304 . . . . TEMP=RNRED*RNELF
00305 . . . . RNELF=RNELF-TEMP
00306 . . . . RCARNE=RCARNE+TEMP
00307 C . . . .
00308 C . . . .
00309 C . . . .
00310 C . . . .
00311 C . . . . -----DENSITY-----
00312 . . . . CH=PROB(66) IDRAW FOR CHANGE IN RIVER SLOPE
00313 C . . . . -----
00314 . . . . CALL RNUMBR(16,'SLOPE FROM FLOOD',CH)
00315 . . . . CHANGE-SLOPE

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00316      . . . . IF(.NOT.LRVFXD,AND. .NOT. LBEDRK)
00317      . . . . . DO(IPATH=1,3)
00318      C      . . . . . -----DENSITY-----
00319      . . . . . CH=PROB(67) !CHANGE IN PATH LENGTH
00320      C      . . . . . -----
00321      . . . . . CALL RNUMBR(15,'PATH CH,(FLOOD)',CH)
00322      . . . . . CHANGE=PATH-LENGTH
00323      . . . . . ...FIN
00324      . . . . . ...FIN
00325      C      . . . . .
00326      C      . . . . .
00327      C      . . . . .
00328      C      . . . . .
00329      C      . . . . .
00330      . . . . . IF(QFLOOD.GT. QDAH,AND. .NOT.LXICEW)
00331      C      . . . . . -----DENSITY-----
00332      . . . . . DZ=PROB(68) !GET DEPOSITION
00333      . . . . . TMOSE=TMOSE+DZ
00334      C      . . . . . -----
00335      . . . . . CALL CHANGX(DZ)
00336      . . . . . CALL RNUMBR(16,'FLOOD DEPOSITION',DZ)
00337      . . . . . ...FIN
00338      C      . . . . .
00339      C      . . . . .
00340      . . . . . ...FIN
00341      . . . . . ...FIN
00342      C      . . . . .
00343      . . . . . ...FIN
00344      . . . . . ...FIN

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-----
00345      TO CHECK-FOR-EROSION-ON-A-FOLD
00346      . IF(LEXPOS)
00347      . . EROS=EROS*EFOLDE !ALLOW FOR EXTRA EROSION DUE TO TOPO. EFFECTS
00348      C      . . IF THE FOLD IS EXPOSED
00349      . . OTHER=POST-TFLER !DIFFERENCE BETWEEN THEORETICAL HEIGHT AND TOTAL
00350      C      . . EROSION TO DATE
00351      C      . . (I.E. CURRENT FOLD HEIGHT)
00352      . . WHEN(ITYPE(ITOP).LE. 2)
00353      C      . . . I.E. SOFT ROCK
00354      . . . RLEFT=DELX(2,ITOP)-TFLER !AMOUNT OF EXPOSED SOFT ROCK LEFT
00355      C      . . . ON THE FOLD
00356      . . . WHEN(RLEFT.LT.0.0)
00357      C      . . . . WHEN NO SOFT ROCK IS LEFT
00358      . . . . ERFOLD=EROS*HARDFC !CORRECT FOR HARD ROCK
00359      . . . . ERFOLD=MIN(ERFOLD,OTHER) !CANNOT ERODE MORE OF THE FOLD THAN IS LEFT
00360      . . . . ...FIN
00361      . . . . ELSE
00362      C      . . . . AT LEAST SOME SOFT ROCK LEFT
00363      . . . . . ERFOLD=EROS
00364      . . . . . ERFOLD=MIN(OTHER,ERFOLD) !DO NOT ERODE AWAY MORE THAN THE FOLD
00365      . . . . . IF(RLEFT.LT.ERFOLD)
00366      C      . . . . . WIPE OUT THE LAST OF THE SOFT ROCK
00367      . . . . . TFLER=TFLER+RLEFT
00368      . . . . . ERFOLD=(EROS-RLEFT)*HARDFC !THE REST OF THE EROSION OCCURS IN HARD ROCK

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00369      . . . . .FIN
00370      C      . . . . .ELSE IT WILL WIPE OUT ONLY SOFT ROCK ON THE FOLD
00371      . . . . .FIN
00372      . . . . .FIN
00373      . . . . .ELSE
00374      C      . . . . .ONLY HARD ROCK LEFT
00375      . . . . .ERFOLD=EROS*HARDPC
00376      . . . . .ERFOLD=MIN(OTHER,ERFOLD) !CAN NOT ERODE MORE FOLD THAN IS THERE
00377      . . . . .FIN
00378      . . . . .TFLER=TFLER+ERFOLD !HAVING CALCULATED TOTAL EROSION ADD TO THE TOTAL
00379      C      . . . . .
00380      C      . . . . .
00381      C      . . . . .
00382      C      . . . . .
00383      C      . . . . .
00384      . . . . .IF(TFLER.LE.POST)
00385      . . . . .LEXPOS=.FALSE,
00386      . . . . .TFLER=POST
00387      . . . . .CALL NOTE(16,'FOLD ERODED AWAY')
00388      . . . . .IF(LRVFXD)
00389      . . . . .CALL NOTE(10,'RIVER FREE')
00390      . . . . .LRVFXD=.FALSE,
00391      . . . . .FIN
00392      . . . . .FIN
00393      C      . . . . .FIN
00394      . . . . .FIN
00395      . . . . .FIN
00396      END

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PROCEDURE CROSS-REFERENCE TABLE

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00084 ALLOW-FOR-RIVER-MOVEMENT
00028

00209 CHANGE-SLOPE
00091 00107 00116 00124 00133 00315

00230 CHANGE-PATH-LENGTH
00148 00155 00162 00171 00185 00322

00252 GET-DISCHARGE-SLOPE-AND-EROSION
00029

00035 CHECK-FOR-FOLD-SITE-INTERSECTION
00027

00345 CHECK-FOR-EROSION-ON-A-FOLD
00300

00275 CHECK-FOR-MISSOULA-FLOODS
00030

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-----
00397 LOGICAL FUNCTION LINTER(RAD,FANGLE,POST,COSAN2,SINAN,AVAXIS,
00398 + DISTFD,FRAC)
00399 DIMENSION FANGLE(4),RLEG(4),LEGID(4)
00400 DATA LEGID/2,1,4,3/
00401 C
00402 C
00403 C FUNCTION FINDS THE AMOUNT OF INTERSECTION BETWEEN A FOLD AND A
00404 C CIRCLE
00405 C
00406 RADIUS=RAD*1000.0 ;CHANGE TO METERS
00407 YFOLD=DISTFD*1000.0
00408 DO(I=1,4)
00409 . RLEG(I)=POST*TAN(FANGLE(I))
00410 . CALL RNUMBR(15,'LENGTH OF LOG=',RLEG(I))
00411 . IF(RLEG(I),LT,0.0)
00412 . . CALL RNUMBR(14,'ERROR IN ANGLE',RLEG(I))
00413 . . RLEG(I)=0.99999
00414 . . .FIN
00415 . . .FIN
00416 C
00417 C ANGLE=AVAXIS
00418 ICOUNT=0
00419 DO(I=1,4)
00420 . Y=SIN(ANGLE)*RLEG(LEGID(I)) +YFOLD
00421 . IF(Y,LT, RADIUS)ICOUNT=ICOUNT+1
00422 . ANGLE=ANGLE+1.5708 ;ADD 90 DEGREES
00423 . . .FIN
00424 C
00425 IF(ICOUNT.EQ.0)
00426 . FRAC=0.0
00427 . LINTER=.FALSE.
00428 . RETURN
00429 . . .FIN
00430 C
00431 IF(FRAC,LT,0.0)
00432 C . I.E. FLAG TO BE SET TRUE IF THERE IS EVEN A POSSIBLE INTERSECTION
00433 . LINTER=.TRUE.
00434 . RETURN
00435 . . .FIN
00436 C
00437 C
00438 C
00439 C FIND THE AMOUNT OF INTERSECTION BY DIVIDING UP THE FOLD INTO
00440 C UNIT SQUARES AND THEN COUNTING UP THE NUMBER OF SQUARES WHOSE
00441 C CENTER FALLS WITHIN THE CIRCLE, TO MAKE THE DIVIDING UP THE FOLD
00442 C THE FOLD INTO UNIT SQUARES EASY TRANSFORM THE COORDINATE SYSTEM
00443 C SO THAT THE X AXIS IS PARALLEL TO THE FOLD
00444 C
00445 XCEN=YFOLD*SINAN
00446 YCEN=YFOLD*COSAN2
00447 C
00448 C
00449 C

```



```

00450 C
00451 C
00452 C
00453 AMOUNT=0.0
00454 C NEXT DIVIDE THE 'TOP' HALF INTO UNIT (METER**2) SQUARES
00455 IF(RLEG(1).GE.1.0)
00456 C . IGNORE ANYTHING LESS THAN 1 METER
00457 . TANLF=RLEG(4)/RLEG(1)
00458 . TANRT=RLEG(2)/RLEG(1)
00459 C .
00460 . N=RLEG(1)+0.5
00461 . YCUR=.5 ;DISTANCE FROM THE 'TOP'
00462 . DO(I=1,N)
00463 . . X=YCUR*TANLF
00464 . . XWIDE=(X+YCUR*TANRT)
00465 . . X=-X
00466 . . IF(XWIDE.GE.1.0)
00467 C . . . IGNORE BOX LESS THAN 1.0 METER WIDE
00468 . . . JN=XWIDE+0.5
00469 . . . Y=(RLEG(1)-YCUR) +YCEN
00470 . . . DO(J=1,JN)
00471 . . . . DIST=SQRT((X+XCEN)**2 + Y*Y) ;GET TO FROM THE CENTER OF THE CIRCLE
00472 C . . . . TO THE CENTER OF THE UNIT SQUARE
00473 . . . . IF(DIST.LE,RADIUS)AMOUNT=AMOUNT+1.0
00474 . . . . X=X+1.0
00475 . . . . ...FIN
00476 . . . . ...FIN
00477 . . YCUR=YCUR+1.0
00478 . . ...FIN
00479 . ...FIN
00480 C NOW CHECK THE BOTTOM
00481 IF(RLEG(3).GE.1.0)
00482 C . IGNORE ANY THING LESS THAN 1 METER
00483 . TANLF=RLEG(4)/RLEG(3)
00484 . TANRT=RLEG(2)/RLEG(3)
00485 C .
00486 . N=RLEG(3)+0.5
00487 . YCUR=.5 ;DISTANCE FROM THE 'BOTTOM'
00488 . DO(I=1,N)
00489 . . X=YCUR*TANLF
00490 . . XWIDE=(X+YCUR*TANRT)
00491 . . X=-X
00492 . . IF(XWIDE.GE.1.0)
00493 C . . . IGNORE BOX LESS THAN 1.0 METER WIDE
00494 . . . JN=XWIDE+0.5
00495 . . . Y=YCEN-(RLEG(3)-YCUR)
00496 . . . DO(J=1,JN)
00497 . . . . DIST=SQRT((X+XCEN)**2 + Y*Y) ;GET TO FROM THE CENTER OF THE CIRCLE
00498 C . . . . TO THE CENTER OF THE UNIT SQUARE
00499 . . . . IF(DIST.LE,RADIUS)AMOUNT=AMOUNT+1.0
00500 . . . . X=X+1.0
00501 . . . . ...FIN
00502 . . . . ...FIN
00503 . . YCUR=YCUR+1.0
00504 . . ...FIN
00505 . ...FIN

```

```
00506  C
00507      WHEN(AMOUNT,GT,0.0)
00508      .  FRAC=AMOUNT/(3.1416*RADIUS*RADIUS)
00509      .  IF(FRAC,GT,1.0)
00510      .  .  CALL RNUMBR(19,'ERROR IN FOLD COUNT',AMOUNT)
00511      .  .  FRAC=1.0
00512      .  ...FIN
00513      .  CALL RNUMBR(17,'FRACTION OF FOLD',FRAC)
00514      .  LINTER=,TRUE.
00515      ..FIN
00516      ELSE
00517      .  FRAC=0.0
00518      .  LINTER=,FALSE.
00519      ..FIN
00520      RETURN
00521      END
```

(FLECS VERSION 22.46)

```
-----
00001 C ***** GLACER,FLX *****
00002 C
00003 C
00004 C PROGRAM DESCRIPTION :
00005 C THIS ROUTINE MODELS THE EFFECTS OF CONTINENTAL GLACIATION
00006 C ON THE REPOSITORY.
00007 C THE EVENTS ACCOUNTED FOR ARE :
00008 C - GLACIAL ADVANCE AND RETREAT
00009 C - ISOSTATIC ADJUSTMENTS
00010 C - DISPLACEMENT OF THE SEA
00011 C - GLACIAL EROSION AND DEPOSITION
00012 C - CONDITIONS FOR A POSSIBLE RIVER COURSE CHANGE
00013 C - GLACIER-INDUCED FRACTURING OF THE BASALT
00014 C
00015 C
00016 C SUBROUTINE GLACER
00017 C
00018 C LOGICAL LTEMPG(3)
00019 C
00020 C INCLUDE 'DI;(226,226)COMMON,FLX'
00021 C
00022 C CALL NOTE(14,'#GLACIER START')
00023 C
00024 C
00025 C FIND-GLACIER-EDGE-POSITION
00026 C SEE-IF-THE-GLACIER-IS-ON-THE-SITE
00027 C TRY-TO-GLACIALLY-FRACTURE-THE-SYSTEM
00028 C RETURN
00029 C
00030 C
00031 C *****
-----

00032 C TO FIND-GLACIER-EDGE-POSITION
00033 C *****FIND GLACIER EDGE POSITION*****
00034 C .
00035 C .
00036 C . GIVE CURRENT POSITION OF THE GLACIER EDGE IN
00037 C . RAD : DEGREES FROM SOURCE POINT
00038 C . RLAT : LATITUDE
00039 C . RKMSIT: KILOMETERS TO SITE
00040 C .
00041 C . RLAT=RKMSIT/111.0+SITLAT
00042 C . RAD=SOURCE-RLAT
00043 C . RKM(1)=RKMSIT+EXTRSW
00044 C . RKM(2)=RKMSIT
00045 C . RKM(3)=RKMSIT+EXTRNE
00046 C ...FIN
00047 C
00048 C
00049 C *****
```

```

-----
00050      TO SEE-IF-THE-GLACIER-IS-ON-THE-SITE
00051 C      ***SEE IF THE GLACIER IS ON THE SITE*****
00052 C      .
00053 C      .
00054      . WHEN(RKMSIT .LE. 0.0)
00055      . . IF(.NOT. LICEON)
00056 C      . . . I.E. FIRST TIME ON THE SITE
00057      . . . IF(LFLOOD)
00058 C      . . . . THIS SHOULD NOT HAPPEN SINCE THE GLACIER GROWTH REDUCES SEA LEVEL
00059      . . . . CALL NOTE(8,'SEA GONE')
00060      . . . . LFLOOD=.FALSE.
00061      . . . . ...FIN
00062      . . . LICEON=.TRUE.
00063      . . . CALL NOTE(20,'CON. GLACIER ON SITE')
00064      . . . ...FIN
00065 C      . . I.E. GLACIER ON SITE
00066 C      . .
00067      . . THICKG=RHIGHT(RKMSIT) !GLACIER THICKNESS ON THE SITE
00068      . .
00069 C      . .
00070 C      -----DENSITY-----
00071      . . CALL CHANGX(PROB(41)*DIME) !ICE EROSION OR DEPOSITION
00072 C      . .
00073 C      . . CHECK FOR THE GLACIER A WALLUA GAP
00074      . . IF(.NOT. LXICEW)
00075      . . . IF(RLAT.LE. WGLAT)
00076      . . . . CALL NOTE(14,'NO HYDRO, DAMS')
00077      . . . . LXICEW=.TRUE.
00078      . . . . ...FIN
00079      . . . ...FIN
00080 C      -----
00081      . . ...FIN
00082      . . ELSE
00083      . . . IF(LICEON)
00084 C      . . . . GLACIER JUST LEFT SITE
00085      . . . . LICEON=.FALSE.
00086      . . . . THICKG=0.0
00087      . . . . LRVCHG=.TRUE. !POSSIBLE MAJOR CHANGE IN THE RIVER COURSE
00088      . . . . CALL NOTE(19,'GLACIER LEAVES SITE')
00089      . . . . CALL RNUMBR(11,'#SUBSIDENCE',SITISO)!CHANGE DOC
00090      . . . . ...FIN
00091      . . . ...FIN
00092 C      .
00093 C      . ALSO CHECK ON THE N.E. AREA
00094      . WHEN(RKMSIT.LT. RKHNE) THICNE=RHIGHT(RPGLNE-RKMSIT)
00095      . ELSE THICNE=0.0
00096      . ...FIN
00097 C      .
00098 C      .
00099 C      *****
-----

```

```

00100      TO TRY-TO-GLACIALLY-FRACTURE-THE-SYSTEM

```

```

00101 C ****TRY TO GLACIALLY FRACTURE THE SYSTEM*****
00102 C .
00103 . DO(ISYSTH=1,3)
00104 . . LTEMPG(ISYSTH)=(RKM(ISYSTH).GT.0.0.AND.RKM(ISYSTH).LE.200.0)
00105 +. . .OR.(RKML(ISYSTH).GT.200.0.AND.RKM(ISYSTH).LE.0.0)
00106 . . ...FIN
00107 C .
00108 . DO(ISYSTH=1,3)
00109 . . TOP=0.0
00110 . . IF(LTEMPG(ISYSTH) )
00111 . . . DO(LAYER=ITOP,NLAYER)
00112 C . . . .
00113 . . . . DEPTH=TOP +DELX(LAYER,ISYSTH)/2.0
00114 . . . . IF(ITYPE(LAYER).GT.2)
00115 . . . . . CALL GSTRES(RKM(ISYSTH),DEPTH,RADSTR,TANSTR)
00116 . . . . . CALL RNUMBR(14,'RADIAL STRESS',RADSTR)
00117 . . . . . CALL RNUMBR(13,'TANG. STRESS',TANSTR)
00118 . . . . . PFR=PROB2(RADSTR,TANSTR,CGLSTR,CGLSTT)
00119 . . . . . IF(LTESTH(PFR).AND.CHMC(2,LAYER,ISYSTH).LE.0.0 )
00120 . . . . . CALL INUMBR(18,'ICE FRACTURES ROCK',LAYER)
00121 . . . . . CALL INUMBR(16,'SYSTEM FRACTURED',ISYSTH)
00122 . . . . . CALL PERM(RADSTR,TANSTR,DEPTH,HYDCN(LAYER,ISYSTH),
00123 +. . . . . CHMC(2,LAYER,ISYSTH),CGLSTR,CGLSTT)
00124 . . . . . ...FIN
00125 C . . . .
00126 . . . . ...FIN
00127 C . . . .
00128 . . . . TOP=TOP+DELX(LAYER,ISYSTH)
00129 . . . . ...FIN
00130 C . . . .
00131 . . . . ...FIN
00132 . . . . ...FIN
00133 C .
00134 C .
00135 C . NOW CHECK ON THE REPOSITORY
00136 . IF(LTEMPG(2) )
00137 . . CALL GSTRES(RKMSIT,RDEPTH,RADSTR,TANSTR)
00138 . . PFR=PROB2(RADSTR,TANSTR,CGLSTR,CGLSTT)
00139 . . IF(LTESTH(PFR).AND. CHR8(2).LE.0.0)
00140 . . . CALL PERM(RADSTR,TANSTR,RDEPTH,RPOSHC,CHR8(2),CGLSTR,CGLSTT)
00141 . . . CALL RNUMBR(20,'REPOSITORY HIT BY GL',CHR8(2))
00142 . . . ...FIN
00143 . . . ...FIN
00144 C .
00145 C .
00146 . DO(ISYSTH=1,3)
00147 . . RKML(ISYSTH)=RKM(ISYSTH)
00148 . . ...FIN
00149 C .
00150 . ...FIN
00151 END

```

PROCEDURE CROSS-REFERENCE TABLE

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00050 SEE-IF-THE-GLACIER-IS-ON-THE-SITE
00026

00032 FIND-GLACIER-EDGE-POSITION
00025

00100 TRY-TO-GLACIALLY-FRACTURE-THE-SYSTEM
00027

(FLECS VERSION 22,46)

```
00152      FUNCTION RHIGHT(RKMSIT)
00153 C      FIND THICKNESS OF THE CONT. GLACIER RKM KM, BACK 'UP' THE
00154 C      GLACIER
00155      D=ABS(RKMSIT*1000.0 )!CHANGE TO METERS
00156      RHIGHT=4.7*SQRT(D)
00157 C      FROM ANDREWS(1975)
00158      RETURN
00159      END
```

(FLECS VERSION 22,46)

```
00160      SUBROUTINE GSTRES(RKMSIT,RMID,RADSTR,TANSTR)
00161 C
00162 C
00163      WHEN (RKMSIT.LE.200.0 .AND. RKMSIT.GE.0.0)
00164      .   TANSTR=POLY(9,RKMSIT)
00165      .   RADSTR=POLY(10,RKMSIT)
00166      ...FIN
00167      ELSE
00168      .   TANSTR=0.0
00169      .   RADSTR=0.0
00170      ...FIN
00171 C
00172 C
00173 C
00174 C
00175 C      IGNORE DEPTH EFFECTS FOR NOW
00176      RETURN
00177      END
```

(FLECS VERSION 22,46)

```
00178      SUBROUTINE PERM(RADSTR,TANSTR,DEPTH,STARTK,HC,CGLSTR,CGLSTT)
00179      IF(ABS(RADSTR).GE.CGLSTR)HC=POLY(11,ABS(RADSTR))+HC
00180      IF(ABS(TANSTR).GE.CGLSTT)HC=POLY(12,ABS(TANSTR))+HC
00181 C      -----DENSITY-----
00182      IF(HC.GT.0.0) HC=HC+PROB(45)
00183 C      -----DENSITY-----
```

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```
00184      CALL RNUMBR(9,'GL. H.C.',MC)
00185      RETURN
00186      END
```

(FLECS VERSION 22.46)

```
00187      FUNCTION PROB2(RADSTR,TANSTR,CGLSTR,CGLST T)
00188      C      CHANCE OF FRACTURE DUE TO CONT, ICE
00189      LOGICAL LTEMP
00190      LTEMP=ABS(RADSTR).GT.CGLSTR .OR. ABS(TANSTR).GT.CGLST T
00191      WHEN(LTEMP) PROB2=1.0
00192      ELSE PROB2=0.0
00193      RETURN
00194      END
```

(FLECS VERSION 22.46)

```
-----
00001 C ***** HYDRO,FLX *****
00002 C
00003 C
00004 C PROGRAM DESCRIPTION :
00005 C THIS ROUTINE MODELS THE DEEP GROUND WATER FLOW AROUND THE
00006 C REPOSITORY
00007 C IT ACCOUNTS FOR :
00008 C - MODIFICATION OF PATH LENGTHS
00009 C - MODIFICATION IN NORTHEAST RECHARGE AREA
00010 C - PRESSURIZED RECHARGE BY A CONTINENTAL GLACIER
00011 C - MODIFICATION OF HEAD VALUES DUE TO CLIMATE
00012 C - CALCULATION OF DARCY VELOCITIES
00013 C - CALCULATION OF TRAVEL TIME
00014 C - CHECKING FOR A BREACH CONDITION
00015 C - PERMAFROST EFFECTS
00016 C
00017 C
00018 C
00019 C SUBROUTINE HYDRO
00020 C NOTE THAT SOME OF THE DEBUG CHECKS HAVE BEEN LEFT IN THE CODE
00021 C HOWEVER, THEY WILL BE REMOVED AND ARE THUS NOT CALLED OUT IN THE
00022 C DOCUMENTATION
00023 C
00024 C
00025 C REAL TUBEND(12),TUBEHC(12),WEIGHT(3),HC(60)
00026 C + ,FTEMP(61),DIST(4,3),VELC(4,3)
00027 C
00028 C INCLUDE 'DI:(226,226)COMMON,FLX'
00029 C
00030 C CALL NOTE(5,'#HYDRO')
00031 C
00032 C
00033 C CALCULATE THE DISTANCE FROM SITE/LAYER1 INTERFACE TO RIVER
00034 C
00035 C DO(IPATH=1,3)PATHLN(IPATH)=UNPATH(IPATH)*1000.0
00036 C IF(LICEON)
00037 C . CALL NOTE(18,'*CHECK HY, FOR ICE')
00038 C . PATHT=ABS(RKM(2))*1000.0
00039 C . DO(IPATH=1,3)
00040 C . . IF(PATHT.GT. PATHLN(IPATH))
00041 C . . . CALL INUMBR(16,'*ICE DRIVEN PATH',IPATH);CHANGE DOC
00042 C . . . PATHLN(IPATH)=PATHT
00043 C . . ...FIN
00044 C . ...FIN
00045 C ...FIN
00046 C
00047 C CALCULATE FLOOD EFFECTS
00048 C
00049 C IF(LFLOOD)
00050 C . WHEN(ITYPE(ITOP).EQ.1)
00051 C . . DO(I=1,3)PATHLN(I)=DELX(ITOP,2)
00052 C . ...FIN
00053 C . ELSE
```



```

00054      . . DO(I=1,3)PATHLN(I)=.0001 IASSUME VERY THIN LAYER
00055      . ...FIN
00056      ...FIN
00057 C *****
00058 C
00059 C
00060 C      CALCULATE N,E. RECHARGE AREA *****
00061 C
00062 C      REDUCTION OF RECHARGE AREA BECAUSE OF ICE COVER
00063      RCANE=RCARNE
00064      IF(RLAT,LT,GLATNE,AND,RLAT,GT,GLTNEL)RCANE=RCANE*POLY(30,RLAT)
00065 C *****
00066 C
00067 C
00068 C
00069 C      CALCULATE EFFECT FOR TOTAL COVERAGE OF N,E. RECHARGE AREA BY GLACIER
00070 C      ICE
00071 C
00072      IF(THICNE,GT, 0.0)
00073 C      . I,E. GLACIER ICE ON THE N,E. RECHARGE AREA
00074      . WHEN(LTEST(PGLCH))
00075      . . CALL NOTE(20,'FAR GLACIER RECHARGE')
00076 C      . . -----DENSITY CURVE-----
00077      . . RCHNE=POLY(20,THICNE)+PROB(121)
00078 C      . . -----
00079      . . CALL RNUMBR(14,'GLACIER EFFECT',RCHNE)
00080      . ...FIN
00081      . ELSE
00082      . . CALL NOTE(19,'NO FAR GL RECHARGE')
00083      . . RCANE=1.E-05 IREDUCE THE EFFECTIVE RECHARGE TO NEAR ZERO
00084      . ...FIN
00085      ...FIN
00086 C *****
00087 C
00088 C      CALCULATE HEAD VALUES AT THE FAR RECHARGE AREAS*****
00089 C      -----DENSITY CURVE-----
00090      TEMP=POLY(20+ICLIM,RCHSW)+PROB(122)
00091      IF(TEMP,GT,HMSWWS)
00092      . CALL RNUMBR(19,'MAX N.E. G.R. HEAD',RCHSW)
00093      . TEMP=HMSWWS
00094      ...FIN
00095      HCSWWS=HDSWWS+TEMP+8ITISO
00096      TEMP=POLY(20+ICLIM,RCHSW)+PROB(122)
00097      IF(TEMP,GT, HMSWGR)
00098      . CALL RNUMBR(19,'MAX S.W. G.R. HEAD',RCHSW)
00099      . TEMP=HMSWGR
00100      ...FIN
00101      HCSWGR=TEMP+HDSWGR+8STATNE
00102 C -----
00103 C      ALSO CALCULATE THE HEAD VALUE IN THE BASIN
00104      WHEN(LFLOOD) HRIVER=SEACUR
00105      ELSE HRIVER=HEAD88
00106      HRIVER=HRIVER+8ITISO IADD IN ANY ISOSTATIC EFFECTS
00107      WHEN(RCHNE,GT,0.0)
00108 C      . -----DENSITY CURVE-----
00109      . TEMP=POLY(24+ICLIM,RCHNE)+PROB(123)

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```

00110      . IF(TEMP.GT.HMNEWS)
00111      . . CALL RNUMBR(18,'MAX N.E. W.B. HEAD',RCHNE)
00112      . . TEMP=HMNEWS
00113      . ...FIN
00114      . HCNEWS=TEMP+HDNEWS+8IT180
00115      . TEMP=POLY(24+ICLIN,RCHNE)+PROB(123)
00116      . IF(TEMP.GT.HMNEGR)
00117      . . CALL RNUMBR(19,'MAX N.E. G.R. HEAD',RCHNE)
00118      . . TEMP=HMNEGR
00119      . ...FIN
00120      . HCNEGR=TEMP+HDNEGR+8TATNE
00121 C      . -----
00122      . ...FIN
00123      ELSE
00124      . HCNEWS=HRIVER
00125      . HCNEGR=HRIVER
00126      . CALL RNUMBR( 14,'N.E. FLOW STOP',RCHNE)
00127      . ...FIN
00128 C      *****
00129 C
00130      DO(LAYER=1,NLAYER)
00131      . DO(ISYSTH=1,3) TOTHC(LAYER,ISYSTH)=0.0
00132      . ...FIN
00133 C
00134 C
00135 C      ADD UP ANY CHANGES TO CONDUCTIVITY *****
00136      CALL SSWTCH(11,ISW11)
00137      DO(LAYER=1TOP,NLAYER)
00138      . DO(ISYSTH=1,3)
00139      . . WHEN(ITYPE(LAYER).GT.2)
00140      . . . WHEN((LAYER.EQ.LAYRWS.OR.LAYER.EQ.LAYRGR).AND.ISYSTH.EQ.2)
00141      . . . . ADDHC=GABHC(LAYER)
00142      . . . . ...FIN
00143      . . . ELSE ADDHC=0.0
00144      . . . TOTHC(LAYER,ISYSTH)=HYDCN(LAYER,ISYSTH)+ADDHC
00145      . . . DO(ICASE=1,NCASE)
00146      . . . . TOTHC(LAYER,ISYSTH)=TOTHC(LAYER,ISYSTH)+
00147      . . . . CH HC(ICASE,LAYER,ISYSTH)
00148      . . . . ...FIN
00149      . . . ...FIN
00150      . . ELSE TOTHC(LAYER,ISYSTH)=HYDCN(LAYER,ISYSTH)
00151      . . IF(ISW11.EQ.1) WRITE(6,130) LAYER,ISYSTH,TOTHC(LAYER,ISYSTH)
00152      . . . 130      FORMAT(' TOTHC=',I2,I2,G20.6)
00153      . . IF(TOTHC(LAYER,ISYSTH).LE.0.0)
00154      . . . SHOULD NOT HAPPEN BUT FOR G.A. INCLUDE THIS INTERNAL CHECK
00155      . . . CALL INUMBR(11,'TOTHC LAYER',LAYER)
00156      . . . CALL INUMBR(12,'TOTHC SYSTEM',ISYSTH)
00157      . . . CALL RNUMBR(10,'H.C. VALUE',TOTHC(LAYER,ISYSTH))
00158      . . . TOTHC(LAYER,ISYSTH)=1.0E-20
00159      . . . ...FIN
00160      . . ...FIN
00161      . ...FIN
00162 C      *****
00163 C
00164 C
00165 C      CALCULATE SPEED IN LAYER 1*****

```

```

00166 C -----DENSITY CURVE-----
00167 SPEDUN=PROB(123+ICLIM) !SPEED IN THE UNCONFINED LAYER
00168 REDU=1.0
00169 C -----
00170 IF(RKM(2).LT. CHPMFS)
00171 . TEMP=ABS(RKM(2))
00172 . IF(RKM(2).LT.0.0) TEMP=0.0
00173 C . -----DENSITY CURVE-----
00174 . REDUPOLY(29,TEMP)+PROB(128)
00175 C . -----
00176 . IF(REDU.LE.0.0.OR. REDU .GT.1.0)
00177 . . CALL RNUMBR(15,'BAD PERMA REDUC',REDU)
00178 . . WHEN(REDU.LE.0.00)REDU=1.0E-6
00179 . . ELSE REDU=1.0
00180 . ...FIN
00181 . CALL RNUMBR(18,'PERMAFROST REDUCE',REDU)
00182 . SPEDUN=SPEDUN*REDU
00183 . ...FIN
00184 C *****
00185 C
00186 C
00187 C
00188 C FIND THE AVERAGE VALUE OF THE REPOSITORY*****
00189 TOTRHC=RPOSHC+CHRS(1)+CHRS(2)+CHRS(3)
00190 IF(TOTRHC.LT.0.0)
00191 C . INTERNAL Q,A. CHECK
00192 . CALL NOTE(12,'H.C. TOO LOW')
00193 . TOTRHC=1.0E-10
00194 . ...FIN
00195 C 1 : SHAFT SEAL
00196 C 2 : FOLD
00197 C 3-50 STARTING LOCAL FAULTS
00198 C
00199 C
00200 C ***** FIND THE FRACTION OF ANY FOLD/FAULT INTERSECTION
00201 WHEN(LFTINT)
00202 . HC(2)=FOLDHC+RPOSHC
00203 . IF(HC(2).LT.0.0)
00204 C . . INTERNAL Q,A. CHECK
00205 . . CALL RNUMBR(17,'FOLD H.C. TOO LOW',HC(2) )
00206 . . HC(2)=1.0E-10
00207 . . ...FIN
00208 . ...FIN
00209 ELSE
00210 . FRAC(2)=0.0
00211 . HC(2)=0.0
00212 . ...FIN
00213 IF(NEXTFT.GT.2)
00214 . DO(L=3,NEXTFT)
00215 . . HC(L)=SSPTHG(IFSIT(L))+RPOSHC
00216 . . IF(HC(L).LT.0.0)
00217 C . . . INTERNAL Q,A. CHECK
00218 . . . CALL INUMBR(14,'FAULT H.C. LOW',L)
00219 . . . HC(L)=1.0E-10
00220 . . ...FIN
00221 . ...FIN

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```

00222      ...FIN
00223      TFRAC=0.0
00224      DO(L=2,NEXTFT) TFRAC=TFRAC+FRAC(L);ADD UP TOTAL FRACTION OF
00225      C                               INTERSECTION
00226      WHEN(TFRAC.GT.1)
00227      . CALL RNUMBR(20,'TOT, REPOS FRACTION',TFRAC)
00228      C .
00229      C . SINCE THE TOTAL FRACTION MAY BE GREATER THAN 1 DUE TO SOME
00230      C . INTERSECTION
00231      C . OF EVENTS
00232      C .
00233      . DO(I=1,NEXTFT) FTEMP(I)=FRAC(I)/TFRAC
00234      ...FIN
00235      ELSE
00236      . DO(I=1,NEXTFT) FTEMP(I)=FRAC(I)
00237      ...FIN
00238      FRINT=0.0 ;SET TOTAL AMOUNT OF REPOSITORY INTERSECTION
00239      DO(I=2,NEXTFT) FRINT=FRINT+FTEMP(I);NOTE THE SHAFT SEAL IS IGNORED HERE
00240      C *****
00241      C
00242      C
00243      RPSAVE=(1.0-FRINT)*TOTRHC ;NEXT FIND THE REPOSITORY AVERAGE
00244      DO(I=2,NEXTFT) RPSAVE=RPSAVE+HC(I)*FTEMP(I)
00245      CALL RNUMBR(17,'REPOSITORY H.C.',RPSAVE)
00246      IF(L TRUST .AND. TRSTHC.GT. 0.0 )
00247      . AL=RPOSTH-THRWD
00248      . RPSAVE=RPOSTH/(AL/RPSAVE+THRWD/TRSTHC)
00249      . CALL RNUMBR(16,'REPOS AVE RESET',RPSAVE)
00250      ...FIN
00251      C *****
00252      C
00253      C
00254      C
00255      C FIND THE AVERAGE H.C. ABOVE THE REPOSITORY*****
00256      HC(1)=CSHAFT+HYDCN1(2,2);CURRENT H.C. VALUE OF SHAFT SEAL
00257      ISYSTH=2
00258      TFRAC=0.0
00259      DO(I=1,NEXTFT) TFRAC=TFRAC+FRAC(I)
00260      WHEN(TFRAC.GT.1.0)
00261      . DO(I=1,NEXTFT) FTEMP(I)=FRAC(I)/TFRAC
00262      ...FIN
00263      ELSE
00264      . DO(I=1,NEXTFT) FTEMP(I)=FRAC(I)
00265      ...FIN
00266      FTEMP(NEXTFT+1)=1.0-TFRAC
00267      C
00268      ITOP1=IRLAYR-1
00269      WHILE(ITOP1.NE.ITOP-1.AND.ITYPE(ITOP1).NE.1)
00270      . TUBEHC(ITOP1)=TOTHC(ITOP1,2)
00271      . TUBEWD(ITOP1)=DELX (ITOP1,2)
00272      . ITOP1=ITOP1-1
00273      ...FIN
00274      ITOP1=ITOP1+1
00275      TUBEHC(IRLAYR)=TOTHC(IRLAYR,ISYSTH)
00276      TUBEWD(IRLAYR)=THABOV ;THICKNESS ABOVE THE REPOSITORY
00277      TUBEHC(IRLAYR+1)=RPS AVE ;REPOSITORY H.C.

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00278      TUBEND(IRLAYR+1)=RPOSTH  IREPOSITORY THICKNESS(METERS)
00279  C
00280      IF(ISW11.EQ.1)
00281      . DO(LAYER=ITOP1,IRLAYR+1)
00282      . . WRITE(6,131) LAYER,TUBEHC(LAYER),TUBEND(LAYER)
00283      . . . FORMAT(1X,I2,2G20.8)
00284      . . . FIN
00285      . . . FIN
00286      TOTL=0.0
00287      TOTLK=0.0
00288      DO(LAYER=ITOP1,IRLAYR+1)
00289      . IF(ITYPE(LAYER).GT.2.AND.LAYER.NE.IRLAYR+1)
00290      . . HC(NEXTFT+1)=TUBEHC(LAYER)
00291      . . AVETOT=0.0
00292      . . HC(1)=CSHAFT+HYDCN1(LAYER,2)
00293      . . HC(2)=FOLDHC+HYDCN1(LAYER,2)
00294      . . IF(NEXTFT.GT.2)
00295      . . . DO(K=3,NEXTFT)HC(K)=SSFTHC(K)+HYDCN1(LAYER,2)
00296      . . . FIN
00297      . . DO(J=1,NEXTFT+1)AVETOT=AVETOT+HC(J)*FTEMP(J)
00298      . . IF(ISW11.EQ.1)
00299      . . . DO(J=1,NEXTFT+1) WRITE(6,132) J,LAYER,HC(J),FTEMP(J)
00300      . . . . FORMAT(' FRAC=',I2,I2,2G20.8)
00301      . . . FIN
00302      . . TUBEHC(LAYER)=AVETOT
00303      . . . FIN
00304      . . WHEN(TUBEHC(LAYER).GT.0.0)
00305      . . . TOTL=TOTL+TUBEND(LAYER)
00306      . . . TOTLK=TOTLK+TUBEND(LAYER)/TUBEHC(LAYER)
00307      . . IF(ISW11.EQ.1)
00308      . . . WRITE(6,136) LAYER,TUBEND(LAYER),TUBEHC(LAYER),TOTL,TOTLK
00309      . . . . FORMAT(1X,I2,4G20.8)
00310      . . . FIN
00311      . . . FIN
00312      . ELSE CALL INUMBR(15,'LOST H.C. LAYER',LAYER)
00313      . . . FIN
00314  C *****
00315  C
00316  C
00317  C
00318  C WORK IN VALUES FROM THE G.R. *****
00319  C
00320      TOT=0.0
00321      AVETPP=TOTL/TOTLK IAVEAGE H.C. ABOVE THE REPOSITORY
00322      WHEN(RCHSW.GT.0.0)
00323      . TOTLSW=TOTL
00324      . TLK SW=TOTLK
00325      . ADD-IN-THE-SW
00326      . DVRPSW=AVHCSW*((HCSWGR-HRIVER)/TOTLSW)
00327      . TOT=AVHCSW
00328      . . FIN
00329      ELSE DVRPSW=0.0 I Darcy VELOCITY =0.0
00330      WHEN(RCHNE.GT.0.0)
00331      . TOTLNE=TOTL
00332      . TLKNE=TOTLK
00333      . ADD-IN-THE-NE

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00334      .   DVRPNE=AVHCNE*((HCNEGR=HRIVER)/TOTLNE)
00335      .   WHEN (TOT,EQ,0,0) TOT=AVHCNE
00336      .   ELSE TOT=(TOT+AVHCNE)/2,0
00337      ...FIN
00338      ELSE DVRPNE=0,0 !DARCY VELOCITY =0,0
00339  C
00340  C
00341  C
00342  C
00343  C
00344  C
00345  C
00346      DVRPOS=DVRPNE+DVRPSW
00347      IF(DVRPOS,LE,0,0)CALL RNUMBR(9,'NEG, VEL, ',DVRPOS)ICHANGE DDC,
00348      WHEN(DVRPOS,EQ,0,0) SEPAGE(2)=1,0E-28 !EFFECTIVELY ZERO
00349      ELSE SEPAGE(2)=DVRPOS/(POLY(19,TOT)+PROB(130)) !SEEPAGE VEL.
00350  C *****
00351  C
00352  C
00353  C
00354  C
00355  C
00356  C      CALCULATE THE TRAVEL TIME 8.W.
00357      FIND=THE-AVE-HC-FOR-WAN-SAD-SW
00358  C      NOTE THAT SOME OF THE DEBUG CHECKS HAVE BEEN LEFT IN
00359      WHEN (TOTLSW,NE, 0,0)
00360      .   VEL(1)=AVSWHC*((HCSWWS=HRIVER)/TOTLSW)
00361      .   SEPAGE(1)=VEL(1)/(POLY(19,AVSWHC)+PROB(130)) !SEEPAGE VEL.
00362      ...FIN
00363      ELSE
00364      .   WRITE (6,100) 1,'T','O','T','L','S','W'
100 .   FORMAT(//,' **** ERROR IN HYDRO AT ',12,' - FLOATING POINT'
00365      1.   ' DIVIDE BY ZERO WITH ',6A1,//)
00366      .   VEL(1) = 1,0E-28
00367      .   SEPAGE(1)=1,0E-28
00368      ...FIN
00369      WHEN(VEL(1),LT,0,0)
00370      .   CALL RNUMBR(17,'8.W. SAD-WAN LE 0',VEL(1))
00371  D      .   CALL RNUMBR(12,' ---- AVSWHC',AVSWHC)
00372  D      .   CALL RNUMBR(12,' ---- HCSWWS',HCSWWS)
00373  D      .   CALL RNUMBR(12,' ---- HRIVER',HRIVER)
00374  D      .   CALL RNUMBR(12,' ---- TOTLSW',TOTLSW)
00375  U      .   TIMES(1)=0,0
00376      ...FIN
00377      ELSE
00378      .   TIMES(1)=TOTL/SEPAGE(1)+PATHLN(1)/SPEDUN
00379      ...FIN
00380  C      CALCULATE TRAVEL TIME FOR THE N.E.
00381      FIND=THE-AVE-HC-FOR-WAN-SAD-NE
00382      WHEN (TOTLNE,NE, 0,0)
00383      .   VEL(3)=AVNEHC*((HCNEWS=HRIVER)/TOTLNE)
00384      .   SEPAGE(3)=VEL(3)/(POLY(19,AVNEHC)+PROB(130))
00385      ...FIN
00386      ELSE
00387      .   WRITE (6,100) 2,'T','O','T','L','N','E'
00388      .   VEL(3) = 1,0E-28
00389

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00390      . SEPAGE(3)=1.0E-28
00391      ...FIN
00392      WHEN(VEL(3).LT.0.0)
00393      . CALL RNUMBR(18,'VEL N,E, G,R, LE 0',VEL(3))
00394      D      . CALL RNUMBR(12,' ---- AVNEHC',AVNEHC)
00395      D      . CALL RNUMBR(12,' ---- HCNEWS',HCNEWS)
00396      D      . CALL RNUMBR(12,' ---- HRIVER',HRIVER)
00397      D      . CALL RNUMBR(12,' ---- TOTLNE',TOTLNE)
00398      . TIMES(3)=0.0
00399      ...FIN
00400      ELSE
00401      . WHEN(SEPAGE(3).NE.0.0)
00402      C      . . I.E. THE N,E. FLOW PATH MAY BE STOPED BY A GLACIER AT THE RECHARGE POI
00403      . . TIMES(3)=TOTL/SEPAGE(3)+PATHLN(3)/SPEDUN
00404      . ...FIN
00405      . ELSE TIMES(3)=9999.0 !SET TO AN ARBITRARY NUMBER
00406      . ...FIN
00407      C      COMBINE THE TWO
00408      IF(ISM11.EQ.1) WRITE(6,160) AVHCSN,AVHCNE,AVSMHC,AVNEHC
00409      160  FORMAT(1X,4G20.8)
00410      WEIGHT(1)=RCHSW*RCARSW!TOTAL S,W. FLUX
00411      WEIGHT(3)=RCHNE*RCANE!TOTAL N,E. FLUX
00412      FLUXNE=WEIGHT(3)
00413      FLUXSW=WEIGHT(1)
00414      TOT=WEIGHT(1)+WEIGHT(3)
00415      VEL(2)=OVRPOS
00416      IF(TOT.GT.0.0)
00417      C      . ASSUME THAT THE WANAPUM SADDLE MT. DOMINATES THE FLOW
00418      . SEPAGE(2)=SEPAGE(1)*WEIGHT(1)/TOT+WEIGHT(3)/TOT*SEPAGE(3)
00419      . VEL(2)=VEL(1)*WEIGHT(1)/TOT+VEL(3)*WEIGHT(3)/TOT
00420      . ...FIN
00421      C
00422      C      NOW FIND THE TOTAL WEIGHTED TRAVEL TIME
00423      TRIME=0.0
00424      IF(SEPAGE(2).GT.0.0)
00425      . TRIME=(VHRCOR*RDEPTH/SEPAGE(2)+PATHLN(2)/SPEDUN)/365.25 !YEARS
00426      . ...FIN
00427      CALL RNUMBR(12,'*TRAVEL TIME',TRIME)
00428      TIMES(2)=TRIME
00429      TIMES(1)=TIMES(1)/365.25 !CHANGE TO YEARS
00430      TIMES(3)=TIMES(3)/365.25 !CHANGE TO YEARS
00431      C      *****
00432      C
00433      C      CHECK FOR BREACH CONDITION
00434      IF(ABS(OVRPOS).GT.DVBRCH.AND..NOT.LBRECH)
00435      . LRRECH=.TRUE.
00436      . KEY=3
00437      . BTIME=TIMEH
00438      . CALL RNUMBR (14,'BREACH BY FLUX',OVRPOS)
00439      . ...FIN
00440      C
00441      C
00442      GET-THE-GEOCHEM-EFFECTS
00443      C
00444      RETURN
00445      C

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00446 C
00447 C *****
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00448 TO GET-THE-GEOCHEM-EFFECTS
00449 C *****GET THE GEOCHEM EFFECTS*****
00450 . DIST(2,1)=WSSHLN*1000,0 IMETERS
00451 . DIST(3,1)=(WSSHLN+GRSHLN)/2,0*1000,0 IMETERS
00452 . DIST(4,1)=GRSHLN*1000,0 IMETERS
00453 . DIST(2,2)=DELX(2,2)
00454 . DIST(3,2)=DELX(3,2)
00455 . DIST(4,2)=DELX(4,2)
00456 . DIST(2,3)=WHEELN* 1000,0
00457 . DIST(3,3)=(WHEELN+GRLNNE)/2,0* 1000,0
00458 . DIST(4,3)=GRLNNE* 1000,0
00459 . VELC(2,1)=VEL(1)
00460 . VELC(3,1)=(VEL(1)+DVRPSW)/2,0
00461 . VELC(4,1)=DVRPSW
00462 . VELC(2,2)=VEL(2)
00463 . VELC(3,2)=(VEL(2)+DVRPOS)/2,0
00464 . VELC(4,2)=DVRPOS
00465 . VELC(2,3)=VEL(3)
00466 . VELC(3,3)=(VEL(3)+DVRPNE)/2,0
00467 . VELC(4,3)=DVRPNE
00468 . TOPN=ITOP
00469 . IF(ITOP,LT,2) TOPN=2
00470 . DO(ISYSTM=1,3)
00471 . . DO(LAYER=TOPN,NLAYER)
00472 . . . CALL GEOCHS(HYDCN(LAYER,ISYSTM),DIST(LAYER,ISYSTM),
00473 +. . . VELC(LAYER,ISYSTM),DTIME,CONVN)
00474 . . . DO(ICASE=1,2)
00475 . . . . CALL GEOCHS(CHHC(ICASE,LAYER,ISYSTM),DIST(LAYER,ISYSTM),
00476 +. . . . VELC(LAYER,ISYSTM),DTIME,CONVS)
00477 . . . . IF(ISYSTM,EQ,2,AND, LAYER,EQ,IRLAYR)
00478 . . . . . CALL GEOCHS(CHRS(ICASE),DIST(LAYER,ISYSTM),
00479 +. . . . . VELC(LAYER,ISYSTM),DTIME,CONVS)
00480 . . . . .FIN
00481 . . . .FIN
00482 . . . .FIN
00483 . . .FIN
00484 C .
00485 C .
00486 C .
00487 C .
00488 C . THE REST
00489 . CALL GEOCHS(GABHC(LAYRMS),DIST(LAYRMS,2),VELC(LAYRMS,2),
00490 +. DTIME ,CONVS)
00491 . CALL GEOCHS(CHRS(3),DIST(LAYRGR,2),VELC(LAYRGR,2),
00492 +. DTIME ,CONVS)
00493 . CALL GEOCHS(RPOSHC,DIST(LAYRGR,2),VELC(LAYRGR,2),
00494 +. DTIME ,CONVN)
00495 . CALL GEOCHS(RPGOST,DIST(LAYRGR,2),VELC(LAYRGR,2),
00496 +. DTIME ,CONVN)
00497 . CALL GEOCHS(GABHC(LAYRGR),DIST(LAYRGR,2),VELC(LAYRGR,2),
00498 +. DTIME ,CONVS)

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00499      ...FIN
00500      C
00501      C
00502      C *****
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00503      TO ADD-IN-THE-SW
00504      C *****ADD IN THE SW*****
00505      C
00506      C
00507      . RFTL=FLWDSW*OCORSW  IS.W. FAULT WIDTH +CORRECTION FOR DEPTH
00508      . WHEN(FLHCSW,NE,0.0)
00509      . . TOTLSW=TOTLSW+RFTL
00510      . . TEMP=FLHCSW+HYDCN(4,1)  IH.C. OF S.W. GENERAL FAULT
00511      . . IF(TEMP,LE,0.0) TEMP=1.0E-10
00512      . . TLKSW=TLKSW+RFTL/TEMP
00513      . . RFTL=GRSWLN*1000.0-RFTL
00514      . ...FIN
00515      . ELSE RFTL=GRSWLN*1000.0  IS.W. GRANDE RONDE LENGTH
00516      . IF(RFTL,LT,0.0)
00517      . . CALL RNUMBR(17,'ERROR IN S.W. LEN',RFTL)
00518      . . CALL RNUMBR(12,' --- GRSWLN',GRSWLN)
00519      . . CALL RNUMBR(12,' --- FLHCSW',FLHCSW)
00520      . . RFTL=0.0
00521      . ...FIN
00522      . IF(TOTHC(4,1),GT,0.0)
00523      . . TOTLSW=TOTLSW+RFTL
00524      . . TLKSW=TLKSW+RFTL/TOTHC(4,1)
00525      . ...FIN
00526      . I=2
00527      . TOT=ABS(EDGESW)*1000.0/COSBSW
00528      . IF(NSSFT,GT,1)
00529      . . WHILE(FAULT(I),LT,0.0 .AND. I ,LT. NSSFT)
00530      . . . IF(SSFTHC(I),NE,0.0 )
00531      . . . . RLENGTH=FWIDTH(I)*OCORBS/COSBSW
00532      . . . . TOTLSW=TOTLSW+RLENGTH
00533      . . . . TEMP=SSFTHC(I)+HYDCN(4,2)
00534      . . . . IF(TEMP,LE,0.0)TEMP=1.0E-10
00535      . . . . TLKSW=TLKSW+RLENGTH/TEMP
00536      . . . . TOT=TOT+RLENGTH
00537      . . . ...FIN
00538      . . . I=I+1
00539      . . ...FIN
00540      . . IF(TOT,LE,0.0) TOT=0.0;SHOULD NOT HAPPEN(I.E. ALL FAULTS)
00541      . ...FIN
00542      . IF(TOTHC(4,2),GT,0.0)
00543      . . TOTLSW=TOTLSW+TOT
00544      . . TLKSW=TLKSW+TOT/TOTHC(4,2)
00545      . ...FIN
00546      . AVHCSW=TOTLSW/TLKSW  AVERAGE VALUE ALONG THE S.W. RIVER PATH
00547      . ...FIN
00548      C
00549      C
00550      C *****

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00551      TO ADD-IN-THE-NE
00552 C      ****ADD IN THE NE*****
00553 C      .
00554 C      .
00555      . RFTL=FLWDNE*DCORNE IN,E. FAULT WIDTH +DEPTH CORRECTION
00556      . WHEN(FLHCNE,NE,0,0)
00557      . . TOTLNE=TOTLNE+RFTL
00558      . . TEMP=FLHCNE+HYDCN(4,3)
00559      . . IF(TEMP,LE,0,0) TEMP=1.0E-10
00560      . . TLKNE=TLKNE+RFTL/(TEMP)
00561      . . RFTL=GRLNNE*1000.0=RFTL
00562      . ...FIN
00563      . ELSE RFTL=GRLNNE*1000.0 !GRANDE RONDE LENGTH N,E.
00564      . IF(RFTL,LT,0,0)
00565      . . CALL RNUMBR(17,'ERROR IN N,E. LEN',RFTL)
00566      . . RFTL=0,0
00567      . ...FIN
00568      . IF(TOTHC(4,3),GT,0,0)
00569      . . TOTLNE=TOTLNE+RFTL
00570      . . TLKNE=TLKNE+RFTL/TOTHC(4,3)
00571      . ...FIN
00572      . TOT=ABS(EDGEENE)*1000.0/COSBNE
00573      . IF (NSSFT ,GT. 200)
00574      . . CALL RNUMBR(19,'ERROR LAST NE FAULT',NSSFT)
00575      . . NSSFT = 200
00576      . ...FIN
00577      . I=NSSFT-1 !LAST FAULT
00578      . IF (I ,GT. 1 .AND. I ,LT. 200)
00579 C      . .
00580 C      . . WHILE (I ,GT. 0 .AND. FAULT(I) ,GT. 0,0)
00581 C      . .
00582      . . WHILE(FAULT(I),GT,0,0)
00583      . . . IF(SSFTHC(I),GT,0,0)
00584      . . . . RLENGTH=FWIDTH(I)*DCORBS/COSBNE
00585      . . . . TOTLNE=TOTLNE+RLENGTH
00586      . . . . TEMP=SSFTHC(I)+HYDCN(4,2)
00587      . . . . IF(TEMP,LE,0,0) TEMP=1.0E-10
00588      . . . . TLKNE=TLKNE+RLENGTH/(TEMP)
00589      . . . . TOT=TOT+RLENGTH
00590      . . . ...FIN
00591      . . . I=I-1
00592      . . . IF (I ,LT. 1) GO TO 11
00593      . . ...FIN
00594      . ...FIN
00595 11 . CONTINUE
00596      . IF(TOT,LE,0,0)TOT=0,0!TOTAL COVERAGE BY FAULTS(SHOULD NOT HAPPEN)
00597      . IF(TOTHC(4,2),GT,0,0)
00598      . . TOTLNE=TOTLNE+TOT
00599      . . TLKNE=TLKNE+TOT/TOTHC(4,2)
00600      . ...FIN
00601      . AVHCNE=TOTLNE/TLKNE !AVERAGE VALUE ALONG THE N,E. RIVER PATH
00602      . ...FIN
00603 C
00604 C

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00605 C *****

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00606      TO FIND-THE-AVE-HC-FOR-WAN-SAD-SW
00607 C      *****FIND THE AVE HC FOR WAN SAD SW*****
00608 C      .
00609 C      .
00610      . TOTLSW=0.0
00611      . TLKSW=0.0
00612      . RFTL=FLWDSW 18.W. FAULTING LENGTH
00613      . WHEN(FLHCSW.NE.0.0)
00614      . . TOTLSW=TOTLSW+RFTL
00615      . . TEMP=FLHCSW+HYDCN(2,1)
00616      . . IF(TEMP.LE.0.0) TEMP=1.0E-10
00617      . . TLKSW=TLKSW+RFTL/(TEMP)
00618      . . RFTL=WSSWLN*1000.0-RFTL
00619      . ...FIN
00620      . ELSE RFTL=WSSWLN*1000.0 I WANAPUM=SADDLE S.W. LENGTH
00621      . IF(RFTL.LT.0.0)
00622      . . CALL RNUMBR(18,'ERROR IN S.W.W LEN',RFTL)
00623      . . CALL RNUMBR(12,'----- WSSWLN',WSSWLN)
00624      . . CALL RNUMBR(12,'----- FLHCSW',FLHCSW)
00625      . . RFTL=0.0
00626      . ...FIN
00627      . IF(TOTHC(2,1).GT.0.0)
00628      . . TOTLSW=TOTLSW+RFTL
00629      . . TLKSW=TLKSW+RFTL/TOTHC(2,1)
00630      . ...FIN
00631      . TOT=XHORSW
00632      . I=2
00633      . WHILE(FAULT(I).LT.DPNTSW .AND. I .LT. NSSFT)
00634      . . IF(SSFTHC(I).NE.0.0)
00635      . . . RLENGTH=FWIDTH(I)/COSSW
00636      . . . TOTLSW=TOTLSW+RLENGTH
00637      . . . TEMP=SSFTHC(I)+HYDCN(2,2)
00638      . . . IF(TEMP.LE.0.0) TEMP=1.0E-10
00639      . . . TLKSW=TLKSW+RLENGTH/(TEMP)
00640      . . . TOT=TOT+RLENGTH
00641      . . ...FIN
00642      . . I=I+1
00643      . ...FIN
00644      . IF(TOT.LE.0.0) TOT=0.0
00645      . IF(TOTHC(2,2).GT.0.0)
00646      . . TOTLSW=TOTLSW+TOT
00647      . . TLKSW=TLKSW+TOT/TOTHC(2,2)
00648      . ...FIN
00649      . WHEN (TLKSW .NE. 0.0)
00650      . . AVSWHC=TOTLSW/TLKSW
00651      . ...FIN
00652      . ELSE
00653      . . WRITE (6,100) 3,'T','L','K','S','W',' '
00654      . . AVSWHC=1.0
00655      . ...FIN
00656      . ...FIN
00657 C

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00658 C
00659 C *****
-----
00660 TO FIND-THE-AVE-HC-FOR-WAN-SAD-NE
00661 C ****FIND THE AVE HC FOR WAN SAC NE*****
00662 C
00663 C
00664 .
00665 . TOTLNE=0.0
00666 . TLKNE=0.0
00667 . RFTL=FLWDNEIN,E, FAULT LENGTH
00668 . WHEN(FLHCNE,NE,0.0)
00669 . . TOTLNE=TOTLNE+RFTL
00670 . . TEMP=FLHCNE+HYDCN(2,3)
00671 . . IF(TEMP,LE,0.0) TEMP=1.0E-10
00672 . . TLKNE=TLKNE+RFTL/(TEMP)
00673 . . RFTL=WSNELN*1000.0-RFTL
00674 . . FIN
00675 . ELSE RFTL=WSNELN*1000.0 (WANAPUM=SADDLE N,E. LENGTH
00676 . IF(RFTL,LT,0.0)
00677 . . CALL RNUMBR(18,'ERROR IN N,E,W LEN',RFTL)
00678 . . RFTL=0.0
00679 . . FIN
00680 . IF(TOTHC(2,3),GT,0.0)
00681 . . TOTLNE=TOTLNE+RFTL
00682 . . TLKNE=TLKNE+RFTL/TOTHC(2,3)
00683 . . FIN
00684 . TOT=XHORNE
00685 . I=2
00686 C WHILE(FAULT(I),LT,DPNTNE)
00687 . WHILE(FAULT(I),LT,DPNTNE ,AND, I .LT. N88FT)
00688 . . IF(88FTHC(I),NE,0.0)
00689 . . . RLENGTH=FWIDTH(I)/COSNE
00690 . . . TOTLNE=TOTLNE+RLENGTH
00691 . . . TEMP=88FTHC(I)+HYDCN(2,2)
00692 . . . IF(TEMP,LE,0.0) TEMP=1.0E-10
00693 . . . TLKNE=TLKNE+RLENGTH/(TEMP)
00694 . . . TOT=TOT+RLENGTH
00695 . . . FIN
00696 . . I=I+1
00697 . . FIN
00698 . IF(TOT,LE,0.0) TOT=0.0
00699 . IF(TOTHC(2,2),GT,0.0)
00700 . . TOTLNE=TOTLNE+TOT
00701 . . TLKNE=TLKNE+TOT/TOTHC(2,2)
00702 . . FIN
00703 . WHEN (TLKNE ,NE, 0.0)
00704 . . AVNEHC=TOTLNE/TLKNE
00705 . . FIN
00706 . ELSE
00707 . . WRITE (6,100) 4,'T','L','K','S','W','I'
00708 . . AVNEHC=1.0
00709 . . FIN
00710 . FIN
END

```

PROCEDURE CROSS-REFERENCE TABLE

00503 ADD-IN-THE-SW
00325

00606 FIND-THE-AVE-HC-FOR-WAN-SAD-SW
00357

00660 FIND-THE-AVE-HC-FOR-WAN-SAD-NE
00382

00551 ADD-IN-THE-NE
00333

00448 GET-THE-GEOCHEM-EFFECTS
00442

(FLECS VERSION 22,46)

00711 SUBROUTINE GEOCHS(HC OLD,DIST,VEL,DTIME,CON)
00712 C CALCULATE REDUCTION IN HYDRAULIC CONDUCTIVITY DUE TO DEPOSITION
00713 C OF CHEMICAL PRECIPITATE
00714 C
00715 C
00716 C
00717 IF(VEL.NE.0.0.AND. HC OLD.GT.1.0E-28)
00718 . FRAC=PROB(129)*VEL*365.25*DTIME* CON
00719 . CALL RNUMBR(8,'#HEALING',FRAC)
00720 . IF(FRAC.GT.1.0)
00721 C . . SHOULD NOT HAPPEN BUT WILL DO AN INTERNAL Q.A. CHECK HERE
00722 . . WRITE(6,100) FRAC,REST,DIST,VEL
00723 100 . . FORMAT(1X,4G20,5)
00724FIN
00725 . HC OLD=HC OLD-FRAC*HC OLD
00726FIN
00727 IF(HC OLD.LT. 0.0)HC OLD =1.E-29 IALLOW FOR ROUND OFF ERROR
00728 RETURN
00729 END

(FLECS VERSION 22,46)

```

-----
00001 C ***** MAGMAT,FLX *****
00002 C
00003 C
00004 C PROGRAM DESCRIPTION :
00005 C THIS ROUTINE MODELS THE EFFECTS OF MAGMATIC EVENTS THAT
00006 C COULD DISRUPT A REPOSITORY.
00007 C THIS SUBMODEL ACCOUNTS FOR :
00008 C - DIRECT BREACHING BY MAGMATIC EVENTS
00009 C - ESTABLISHING CONDITIONS FOR A POSSIBLE RIVER COURSE CHANGE
00010 C
00011 C
00012 C
00013 C SUBROUTINE MAGMAT
00014 C
00015 C INCLUDE 'DI:1226,226'COMMON,FLX'
00016 C
00017 C CALL NOTE (15,'MAGMATIC START')
00018 C LMAGRV= .FALSE. ! MAGMATIC DOES NOT YET INTERSECT THE RIVER
00019 C
00020 C
00021 C
00022 C NMAG=POISSON(AVMAG) !DRAW NUMBER OF EVENTS FROM A POISSON DISTRIBUTION
00023 C IF(NMAG.EQ.0.AND. IFORCE.EQ.7)
00024 C . CALL NOTE (17,'FORCED MAG. EVENT')
00025 C . NMAG=1
00026 C ...FIN
00027 C
00028 C IF(NMAG.GT.0)
00029 C . DO(IMAG=1,NMAG)
00030 C . . I,E. MAGMATIC EVENT IN PASCO BASIN
00031 C . . CALL NOTE(15,'MAGMATIC EVENT')
00032 C . .
00033 C . .
00034 C . . WHEN(LTESTH(PMAGST))
00035 C . . . MAGMA EVENT NOT ONLY IN THE BASIN BUT IN THE SITE
00036 C . . . CALL NOTE(18,'MAG. EVENT ON SITE')
00037 C . . . WHEN(.NOT.LBRECH)
00038 C . . . . BTIME = TIMEH
00039 C . . . . LBRECH = .TRUE.
00040 C . . . . KEY=0
00041 C . . . . ...FIN
00042 C . . . ELSE CALL NOTE(17,'ALLREADY BREACHED')
00043 C . . .
00044 C . . . WHEN(LFLOOD.OR.LICEON.OR.LRIVON)
00045 C . . . . I,E. WATER ON SITE CAUSING PHREATIC TRANSPORT
00046 C . . . . CALL NOTE (18,'PHREATIC TRANSPORT')
00047 C -----DENSITY-----
00048 C . . . . ATM = PROB(28) ! SELECT WASTE TO AIR
00049 C . . . . SURWAT = PROB (29) ! SELECT FRACTION OF WASTE TO WATER
00050 C -----DENSITY-----
00051 C . . . . CALL REMAIN(HT,ATM,SURWAT)
00052 C . . . . ...FIN
00053 C . . . . ELSE

```

```

00054 C      . . . . NORMAL TRANSPORT
00055      . . . . CALL NOTE (16,'NORMAL TRANSPORT')
00056 C      -----DENSITY-----
00057      . . . . ATM = PROB(30)      ! AIR TRANSPORT
00058      . . . . SURWAT = PROB (31)  ! FRACTION OF WASTE  FOR SURFACE WATER
00059 C      -----DENSITY-----
00060      . . . . CALL REMAIN(HT,ATM,SURWAT)
00061      . . . . ...FIN
00062 C      . . . .
00063      . . . . IF(RDEPTH .LT. 500)
00064 C      . . . . CASE 2 BY CRONE
00065      . . . . ATM = ATM*4.0
00066      . . . . SURWAT=SURWAT*4.0
00067      . . . . CALL REMAIN(HT,ATM,SURWAT)
00068      . . . . ...FIN
00069 C      . . . .
00070      . . . . IF(LRIVON)
00071      . . . . LMAGRV=.TRUE.
00072      . . . . CALL NOTE(20,'MAG EVENT HITS RIVER')
00073      . . . . IF(LRVFXD.AND. .NOT. LBEDRK)
00074 C      . . . . I.E. RIVER FIXED IN PLACE BY A FOLD
00075      . . . . LRVFXD=.FALSE.
00076      . . . . CALL NOTE(18,'RIVER FREE BY MAG. ')
00077      . . . . ...FIN
00078      . . . . ...FIN
00079      . . . . CALL RNUMBR(12,'WASTE TO ATM',ATM)
00080      . . . . CALL RNUMBR(14,'WASTE TO WATER',SURWAT)
00081      . . . . ...FIN
00082      . . . . ELSE
00083 C      . . . . EVENT OFF SITE
00084 C      . . . .
00085 C      . . . .
00086      . . . . IF(LTESTW(PRVHAG) )
00087      . . . . CALL NOTE (20,'MAG EVENT HITS RIVER')
00088      . . . . LMAGRV=.TRUE.
00089      . . . . ...FIN
00090      . . . . ...FIN
00091 C      . . . .
00092 C      . . . .
00093      . . . . ...FIN
00094      . . . . ...FIN
00095 C      . . . .
00096 C      . . . .
00097      RETURN
00098      END

```

(FLECS VERSION 22.46)

```

-----
00099 C
00100      SUBROUTINE REMAIN(HT,ATM,SURWAT)
00101 C
00102      TOTAL=ATM+SURWAT
00103      IF(TOTAL.GT.1.0)
00104 C      . THIS SHOULD NOT HAPPEN BUT JUST IN CASE ALLOW FOR A CORRECTION HERE

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```
00105      . CALL NOTE(9,'ROUND OFF')
00106      . ATM=ATM/TOTAL
00107      . SURMAT=SURMAT/TOTAL
00108      ...FIN
00109      HT=1.0-(ATM+SURMAT)
00110      RETURN
00111      END
```

(FLECS VERSION 22.46)

```

-----
00001 C ***** METRIT.FLX *****
00002 C
00003 C THIS ROUTINE ESTIMATES THE EFFECTS OF METEORITE IMPACT IN THE
00004 C PASCO BASIN. IT ACCOUNTS FOR :
00005 C   * THE METEORITE INTERSECTING THE REPOSITORY.
00006 C   * THE SEISMIC EFFECTS TO THE REPOSITORY BY AN IMPACT.
00007 C
00008 C
00009 C
00010 C
00011 C SUBROUTINE METRIT
00012 C
00013 C INCLUDE 'DI:1226,226'COMMON,FLX'
00014 C
00015 C CALL NOTE (7,'METRIT')
00016 C
00017 C
00018 C
00019 C
00020 C IF( LTEST(PMETRT).OR. IFORCE.EQ.6 )
00021 C . CALL NOTE(12,'METERITE HIT')
00022 C . -----DENSITY-----
00023 C . DISTMT=PROB(32)*DSMTMX !GET DISTANCE(KM)
00024 C . ANGMT=PROB(33) !GET ANGLE(0-360)
00025 C . CRSIZE=PROB(34)/2.0 !CRATER RADIUS(KM)
00026 C . -----
00027 C . CALL RNUMBR(13,'METERITE DIST',DISTMT)
00028 C . CALL RNUMBR(12,'METERITE ANG',ANGMT)
00029 C . CALL RNUMBR(11,'CRATER SIZE',CRSIZE)
00030 C . DTOTAL=SQRT( (RDEPTH/1000.0)**2+DISTMT**2)
00031 C .
00032 C .
00033 C . WHEN((RADCRT+CRSIZE).GT.DTOTAL)
00034 C . .
00035 C . . CLASS II - CRATER INTERSECTS REPOSITORY
00036 C . .
00037 C . . CALL NOTE(11,'MAJOR EVENT')
00038 C . . ...FIN
00039 C . . ELSE
00040 C . . CLASS I - POSSIBLE SECONDARY EFFECTS ONLY
00041 C . . SIESLG=(ALOG10(CRSIZE*2.0)+6.115)/0.288 !LOG OF ENERGY(SEE EQUATION 7)
00042 C . . PART1=10.0**((0.28*(SIESLG/1.5))
00043 C . .
00044 C . . NOTE THAT THE ABOVE USES LOG10(ENERGY)=1.5*MAGNITUDE FROM
00045 C . . KANAMORI,H AND O.L. ANDERSON,"THORETICAL BASIS OF SOME
00046 C . . EMPIRICAL RELATIONS IN SEISMOLOGY" 898A,65,1073-1096,1975
00047 C . .
00048 C . . ACC=(472.0*PART1)/((DTOTAL+25.0)**1.3)!(SEE WIGHT,1979)
00049 C . . CALL SHAFT(ACC,TIMEH)
00050 C . . ...FIN
00051 C .
00052 C .
00053 C ...FIN

```

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00054 C
00055 RETURN
00056 END

(FLECS VERSION 22.46)

```

-----
00001 C ***** OPINT *****
00002 C
00003 C
00004 C PROGRAM DESCRIPTION:
00005 C THIS PROGRAM OPENS THE NEEDED FILES FOR A MONTE CARLO RUN
00006 C OPEN A NEW HISTORY FILE (SEE APPENDIX F)
00007 C OPEN A NEW M.C.S FILE (SEE APPENDIX F)
00008 C SAVE THE STARTING SEED VALUE
00009 C REINITIALIZE ANY VARIABLES
00010 C
00011 C CREATED BY : GREGG M. PETRIE ON: AUG. 28, 1980
00012 C UPDATED BY : ALAN J. BALDWIN ON: SEP. 2, 1980
00013 C
00014 C
00015 C SUBROUTINE OPINT(IRUN)
00016 C
00017 C BYTE BRUN(4),BNAME(28)
00018 C REAL RNAME(7)
00019 C EQUIVALENCE (RNAME(1),BNAME(1))
00020 C
00021 C INCLUDE 'DI:(226,226)COMMON,PLX'
00022 C
00023 C DATA RNAME/'DI2:', '(226', ',226', ']' ', ' ', 'AGS', '0/'
00024 C
00025 C CHANGE IRUN TO CHARACTER FORM FOR FILE NAMES
00026 C
00027 C IRUNM1=IABS(IRUN-1)
00028 C DO (ITMP=1,4) BRUN(ITMP) = ' '
00029 C ENCODE (4,100,BRUN,ERR=999) IRUNM1
00030 100 FORMAT(I4)
00031 C GO TO 200
00032 999 WRITE(6,55) IRUNM1
00033 55 FORMAT(' OPENIT CONVERSION ERROR >>>> IRUN:',I6)
00034 C DO (ITMP=1,4) BRUN(ITMP)='0'
00035 200 CONTINUE
00036 C DO (ITMP=1,4)
00037 C . IF (BRUN(ITMP) .LT. '0' .OR. BRUN(ITMP) .GT. '9')BRUN(ITMP)='0'
00038 C ...FIN
00039 C DO (ITMP=1,4) BNAME(ITMP+15) = BRUN(ITMP)
00040 C
00041 C OPEN UP HISTORY FILE
00042 C
00043 C BNAME(14) = 'H'
00044 C BNAME(15) = 'S'
00045 C BNAME(3) = '2'
00046 D WRITE (6,300) BNAME
00047 300 FORMAT(' OPEN HISTORY FILE ',30A1,' ',1)
00048 C OPEN (UNIT=2,NAME=BNAME,TYPE='NEW',FORM='UNFORMATTED',ERR=399)
00049 C
00050 C OPEN UP MASTER OUTPUT FILE
00051 C
00052 399 BNAME(14) = 'H'
00053 BNAME(15) = 'N'

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```
00054      BNAME(3) = '3'
00055 D      WRITE (6,400) BNAME
00056      400 FORMAT(' OPEN MASTER OUTPUT FILE =',30A1,' ',)
00057      OPEN (UNIT=3,NAME=BNAME,TYPE='NEW',FORM='UNFORMATTED',ERR=499)
00058      499 CONTINUE
00059 C
00060 C
00061      BNAME(14)='C'
00062      BNAME(15)='L'
00063      BNAME(3)='1'
00064 D      WRITE(6,401) BNAME
00065      401 FORMAT(' OPEN GLACIER FILE=',30A1)
00066      OPEN(UNIT=7,NAME=BNAME,FORM='UNFORMATTED',READONLY,
00067      + TYPE='OLD')
00068 C
00069 C      INITIALIZE DATA
00070 C
00071      INCLUDE 'DI:(226,226)INITDAT,DAT'
00072 C
00073      CALL GLSEAR(SOURCE,RATIO)
00074 C
00075      INCLUDE 'DI:(226,226)LOGICALS,DAT'
00076      CHRS(3)=0.0
00077 C
00078      DO (II=1,8) ITYPE(II) = 4
00079      DO(LAYER=1,NLAYER)
00080      .   ITYPE(LAYER)=ITYPE1(LAYER)
00081      .   DO(ISYSTH=1,3)
00082      .   .   DELX(LAYER,ISYSTH)=DELX1(LAYER,ISYSTH)
00083      .   .   FIN
00084      .   FIN
00085 C
00086      TIMEXX=SECNDS(0.0) !GET STARING TIME
00087      RETURN
00088      END
```

(FLECS VERSION 22,46)

```
-----
00001 C   OTHER2A,FLX
00002 C   ***** LEND *****
00003 C
00004 C   PROGRAM DESCRIPTION:
00005 C   READ THE CLIMATE FILE. ON AN END-OF-FILE, SET THE LOGIC FLAG
00006 C   LEND TO .TRUE.
00007 C
00008 C   CREATED BY : GREGG M. PETRIE                ON: AUG. 28, 1980
00009 C   UPDATED BY : ALAN J. BALDWIN             ON: SEP. 2, 1980
00010 C
00011 C   LOGICAL FUNCTION LEND(LUCLIM)
00012 C
00013 C   LOGICAL LDUMP,LMORE
00014 C   COMMON /MORDMP/ LDUMP , LMORE
00015 C
00016 C   INCLUDE 'DI:(226,226)COMMON,FLX'
00017 C
00018 C   READ(LUCLIM,END=999)TTIME,DTIME,FCLIM,GLACIN,GLMIN,GLMAX
00019 C   + ,RKMSIT,STATNE,SITISO
00020 C   ICLIM=FCLIM
00021 C   IFORCE=0
00022 C
00023 C   TEND = TTIME +DTIME      IGET TIME AT THE END OF THE TIME STEP
00024 C   TIMEH = TTIME +DTIME/2.0 IGET TIME FOR THE MIDDLE OF TIME STEP
00025 C   IF (IFORCE .GT. 0) CALL NOTE ( 18 , '!! FORCED EVENT !!')
00026 C   IF(ICLIM .LT.1.OR.ICLIM.GT.4) STOP ' *** BAD CLIMATE INDEX ***'
00027 C   LEND = .FALSE.
00028 C
00029 C   GO TO 888
00030 C   999 CONTINUE
00031 C   LEND=.TRUE.
00032 C   888 CONTINUE
00033 C   RETURN
00034 C   END
```

(FLECS VERSION 22,46)

```
-----
00035 C   ***** MIX *****
00036 C
00037 C   PROGRAM DESCRIPTION:
00038 C
00039 C   RANDOMLY ORDER THE SUBMODELS FOR THE MONTE CARLO RUN.
00040 C
00041 C   CREATED BY : ALAN JAMES BALDWIN                ON: AUG. 14, 1980
00042 C
00043 C   SUBROUTINE MIX(IGO)
00044 C
00045 C   DIMENSION IGO(15),RO(15)
00046 C   LOGICAL LORDER
00047 C
00048 C
```

```

00049      COMMON /IJRAN/IRAN,JRAN
00050      C
00051      C
00052      NSUBMD = 7      ! NUMBER OF ACTIVE SUBMODELS
00053      DO (IORDER = 1,NSUBMD)
00054      .   IGO(IORDER) = IORDER
00055      .   GO(IORDER) = RANDOM(IRAN,JRAN)
00056      ...FIN
00057      C
00058      C      BUBBLE SORT IGO ARRAY USING RANDOM NUMBERS
00059      C
00060      REPEAT UNTIL (LORDER)
00061      .   LORDER = .TRUE.
00062      .   DO (IORDER = 1,NSUBMD-1)
00063      .   .   IF (GO(IORDER) .LT. GO(IORDER+1))
00064      .   .   .   LORDER = .FALSE.
00065      .   .   .   GTEMP = GO(IORDER)
00066      .   .   .   IGTMP = IGO(IORDER)
00067      .   .   .   GO (IORDER) = GO(IORDER+1)
00068      .   .   .   IGO(IORDER) = IGO(IORDER+1)
00069      .   .   .   GO (IORDER+1) = GTEMP
00070      .   .   .   IGO(IORDER+1) = IGTMP
00071      .   .   ...FIN
00072      .   ...FIN
00073      ...FIN
00074      RETURN
00075      END

```

(FLECS VERSION 22,46)

```

-----
00076      C      ***** OUTALL *****
00077      C
00078      C      PROGRAM DESCRIPTION:
00079      C      THIS ROUTINE WRITES THE M. C. 8. OUTPUT DATA AND CHECKS THE
00080      C      SENSE SWITCHES TO SEE WHAT MESSAGES TO DUMP AND IF IT SHOULD
00081      C      HALT THE MODEL.
00082      C
00083      C      CREATED BY : ALAN J. BALDWIN                      ON: AUG. 14, 1980
00084      C
00085      C      SUBROUTINE OUTALL(IRUN)
00086      C
00087      C      LOGICAL LMORE,LDUMP
00088      C      COMMON /MORDMP/ LMORE , LDUMP
00089      C
00090      C      INCLUDE 'DI:(226,226)COMMON,FLX'
00091      C
00092      C      CALL SSWTCH(1,ISW1)      ! DUMP '#' GEOLOGIC MESSAGES
00093      C      WHEN (ISW1 .EQ. 1) LDUMP = .TRUE.
00094      C      ELSE LDUMP = .FALSE.
00095      C      CALL SSWTCH(2,ISW2)      ! DUMP '*' HISTORY MESSAGES
00096      C      WHEN (ISW2 .EQ. 1) LMORE = .TRUE.
00097      C      ELSE LMORE = .FALSE.
00098      C
00099      C      WRITE AN OUTPUT RECORD TO THE OUTPUT FILE

```

```

00100 C
00101 FCLIM = ICLIM
00102 FCLIMG = ICLIMG
00103 FTOP = ITOP
00104 T12=TOTHC(1,2)
00105 T22=TOTHC(2,2)
00106 T32=TOTHC(3,2)
00107 T42=TOTHC(4,2)
00108 T21=TOTHC(2,1)
00109 T41=TOTHC(4,1)
00110 T23=TOTHC(2,3)
00111 T43=TOTHC(4,3)
00112 SGADNE=HCNEGR-HRIVER
00113 SRGDSW=HCSWGR-HRIVER
00114 WHEN(SPEDUN,NE,0.0,AND,TIMES(2),NE,0)
00115 . EWAL=(PATHLN(2)/SPEDUN)/TIMES(2)
00116 ...FIN
00117 ELSE EWAL=0.0
00118 WRITE(3)
00119 1 TIMEH,AVHCNE,AVHCSW,AVNEHC,AVSWHC,CASELV,CHCONE,CHCSSW,
00120 3 CHRKNE,CHRKSW,CHRS(1),CHRS(2),CHRS(3),CSHAFT,DELX(ITOP,2),
00121 4 DVRPOS,DVRPNE,DVRPSW,EGAB,ERATTL,ESENT,EWAL,FLHCNE,FLHCOW,
00122 5 FLUXNE,FLUXSW,FRINT,HCNEGR,HCSWGR,
00123 6 HCNEWS,HCSWWS,HRIVER,FCLIM,
00124 7 PATHLN(1),PATHLN(2),PATHLN(3),POST,0,
00125 8 RAINNE,RAINSW,RCANE,RCHNE,RCHSW,RDEPTH,REDU,
00126 9 RKMSIT,ROCKEL,RPGOST,RPSAVE,SEACUR,
00127 +SELEV,SGADNE,SLOPE,SPEDUN,SRGDSW,SUMFTN,TFLER,THICKG,THICNE,
00128 1 THRCH,TIME,TIMES(1),TIMES(2),TIMES(3),TMSULA,TMOSF,
00129 2 TOTRHC,TRMOVE,VEL(1),VEL(3),SEPAGE(1),SEPAGE(2),SEPAGE(3),
00130 2 CHHC(1,2,1),CHHC(1,2,2),CHHC(1,2,3),CHHC(1,4,1),CHHC(1,4,2),
00131 2 CHHC(1,4,3),CHHC(2,2,1),CHHC(2,2,2),CHHC(2,2,3),CHHC(2,4,1),
00132 2 CHHC(2,4,2),CHHC(2,4,3),T12,T22,T32,T42,T21,T41,T23,T43
00133 RETURN
00134 END

```

(FLECS VERSION 22,46)

```

00135 C ***** CLOUT *****
00136 C
00137 C PROGRAM DESCRIPTION :
00138 C THIS ROUTINE ACCOMPLISHES THE FOLLOWING :
00139 C CLOSING THE CURRENT HISTORY FILE (SEE APPENDIX F)
00140 C CLOSING THE CURRENT M.C.S. FILE (SEE APPENDIX F)
00141 C WRITES TO THE SUMMARY FILE
00142 C CLOSING THE CLIMATE FILE
00143 C
00144 C CREATED BY : GREGG M. PETRIE ON: AUG. 28, 1980
00145 C UPDATED BY : ALAN JAMES BALDWIN ON: SEP. 13, 1980
00146 C
00147 C SUBROUTINE CLOUT(IPUN)
00148 C
00149 C LOGICAL LSMEOF
00150 C

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```

00151      INCLUDE 'DI:(226,226)COMMON,FLX'
00152      C
00153      C      REWIND(7)          I REWIND CLIMATE FILE
00154      CLOSE(UNIT=7)          ICLOSE GLACIER AND CLIMATE FILE
00155      CLOSE (UNIT=2)          I CLOSE HISTORY FILE
00156      CLOSE (UNIT=3)          I CLOSE MASTER OUTPUT FILE
00157      C
00158      C      GIVE THE LENGTH OF THE RUN
00159      TIMEXX=8ECNDS(TIMEXX)/60,0
00160      WRITE(6,100) TIMEXX
00161      100  FORMAT(' LENGTH OF RUN=',F8,2)
00162      C
00163      C      WRITE SUMMARY FILE
00164      C
00165      OPEN (UNIT=4,NAME='DI1:SUMMARY,AGB',TYPE='OLD',
00166      + FORM='UNFORMATTED',ACCESS='DIRECT',RECORDSIZE=64,ERR=300)
00167      GO TO 400
00168      300 STOP ' PROBLEMS OPENING SUMMARY TO WRITE OUTPUT RECORD'
00169      400 CONTINUE
00170      D      WRITE (6,*) ' WRITE SUMMARY RECORD (' ,IRUN,')'
00171      LSMEOF = .TRUE.
00172      WRITE(4,IRUN)IRUN,LSMEOF,IRAN,JRAN,KEY,DVBRCH,AXISAN,BTIME,
00173      1 COSNE,COSBW,DISTFD,DPNTNE,DPNTSW,FANG,(FANGLE(I),I=1,4),
00174      2 FOIST,FLWONE,FLWDSW,FOLDAN,HT,RDFTDT,RTREND,SURMAT,THRND,
00175      3 HYDCN(1,2),((HYDCN(I,JJ),I=2,4),JJ=1,3),
00176      4 HYDCN1(1,2),((HYDCN1(I2,J2),I2=2,4),J2=1,3)
00177      LSMEOF=.FALSE.
00178      IF (IRUN,LT,NRUNS) WRITE(4,IRUN+1) IRUN+1,LSMEOF,0,0,0,0,0,0,
00179      1 0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,
00180      2 0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,
00181      3 ,0.
00182      CLOSE (UNIT=4)
00183      C
00184      C      CHECK SENSE SWITCHES
00185      C
00186      CALL SSWTCH(3,ISW3)          I WRITE OUT DEBUG MESSAGES TO TERMINAL
00187      IF (ISW3.EQ. 1)
00188      .   WRITE (6,500) IRUN,NRUNS
00189      500 .   FORMAT(' AEGIS FINISHED ',IS,' OF ',IS,' RUNS. ')
00190      .   ..FIN
00191      CALL SSWTCH(4,ISW4)          I HALT THE MODEL IF SSW 4 IS UP
00192      IF (ISW4.EQ. 1)
00193      .   WRITE (6,600) IRUN,NRUNS
00194      600 .   FORMAT('/', ' 11111 HALTING AEGIS 11111',//,
00195      1.   ' AEGIS STOPPED AFTER RUN ',IS,' OF ',IS,' RUNS.',//)
00196      .   CALL CLOSIT          ICLOSE SUMMARY AND CLIMATE FILES
00197      .   STOP ' AEGIS HALTED WITH SWITCH 4 (RESTART SWITCH = 5)'
00198      .   ..FIN
00199      RETURN
00200      END

```

(FLECS VERSION 22,46)

```

-----
00201      C      ***** CLOSIT *****

```


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```
00202 C
00203 C   PROGRAM DESCRIPTION :
00204 C   THIS ROUTINE CLOSES THE SUMMARY FILE AND THE CLIMATE FILE,
00205 C
00206 C   SUBROUTINE CLOSIT
00207 C
00208 C   CLOSE (UNIT=7)      I CLOSE CLIMATE FILE
00209 C   CLOSE (UNIT=4)      I CLOSE SUMMARY FILE
00210 C   STOP ' FINISHED WITH AEGIS'
00211 C   RETURN
00212 C   END
```

(FLECS VERSION 22.46)

```

-----
00001 C ***** SLEVEL,FLX *****
00002 C
00003 C
00004 C THIS SUBROUTINE ACCOUNTS FOR RISES OR LOWERING OF SEA LEVEL DUE
00005 C TO CHANGES IN GLACIER ICE VOLUME
00006 C
00007 C SUBROUTINE SLEVEL
00008 C
00009 C INCLUDE 'DI:(226,226)COMMON,FLX'
00010 C
00011 C CALL NOTE(4,'#SEA')
00012 C
00013 C
00014 C
00015 C IF(ICLIM,EQ,1)
00016 C . DURING AN INTERGLACIER CHECK FOR A SEA LEVEL RISE DURING
00017 C . TO A PARTIAL OR TOTAL MELTING OF EXISTING ICE SHEETS
00018 C . NOTE THAT THERE IS A MAX. AMOUNT OF SEALEVEL RISE
00019 C . CORRESPONDS TO A MAX. AMOUNT OF ICE THAT CAN MELT
00020 C . IF(SEA,LT,SEAMAX,AND,L TEST(PSEAFX))
00021 C . . HAVING 'GOT' A RISE IN SEA LEVEL FIND THE AMOUNT
00022 C . . *****DENSITY CURVE*****
00023 C . . SRISE=PROB(25) ;DRAW FOR THE AMOUNT OF SEA LEVEL RISE
00024 C . . *****
00025 C . . SE=SEA+SRISE
00026 C . . CALL RNUMBR(14,'SEA LEVEL RISE',SRISE)
00027 C . ...FIN
00028 C ...FIN
00029 C
00030 C
00031 C FIND THE LOWERING OF SEA LEVEL TO THE GLACIER GROWTH (IF ANY) :
00032 C SEACUR=SEA-SEACH(RAD,RATIO)
00033 C
00034 C
00035 C
00036 C WHEN(SEACUR .GT. (SELEV+1.0),AND, .NOT, LICEON)
00037 C . I.E. THE SITES FLOODED BY THE SEA
00038 C . IF(.NOT, LFLOOD)
00039 C . . AND ALSO FLOODED FOR THE FIRST TIME THEN :
00040 C . . CALL NOTE(12,'SITE FLOODED')
00041 C . . LFLOOD= .TRUE.
00042 C . ...FIN
00043 C
00044 C
00045 C . DEPTH=SEACUR-SELEVIDEPTH OF THE SEA ON THE SITE
00046 C . *****DENSITY CURVE*****
00047 C . DEP=PROB(26)*DTIME ;GET AMOUNT OF SEDIMENT DEPOSITED
00048 C . *****
00049 C . IF(DEPTH,LT,DEADZ)DEP=0.0001 ;NEAR DEAD ZONE
00050 C
00051 C
00052 C . WHEN(SEACUR .LE.(SELEV+DEP))
00053 C . . CURRENT ADDITION OF SEDIMENT JUST BRINGS SITE OUT OF THE SEA

```

```
00054      . . DIFF=ABS(SEACUR-SELEV)
00055      . . CALL CHANGX(DIFF)
00056      . . CALL NOTE(20,'SITE JUST OUT OF SEA')
00057      . . LSEACH=.TRUE.  !CHANGE RIVER CHANNEL
00058      . . LFLOOD=.FALSE. !NO LONGER FLOODED
00059      . . ...FIN
00060      . . ELSE
00061 C      . . NORMAL FLOOD ACTION
00062      . . CALL CHANGX(DEP)
00063      . . ...FIN
00064      . . ...FIN
00065      . . ELSE
00066 C      . . NO FLOODING BY THE SEA THIS TIME STEP
00067      . . DEP=0.0
00068      . . IF(LFLOOD)
00069      . . . CALL NOTE(19,'SITE OUT OF SEA')
00070      . . . LSEACH=.TRUE.  !CHANGE RIVER CHANNEL
00071      . . . ...FIN
00072      . . LFLOOD=.FALSE. !NOT FLOODED
00073      . . ...FIN
00074 C
00075 C
00076 C
00077 C
00078      RETURN
00079      END
```

(FLECS VERSION 22,46)

```
00080      FUNCTION SEACH(RAD,RATIO)
00081 C      GIVEN THE DISTANCE OF THE GLACIER EDGE(IN DEGREES) FROM
00082 C      THE SOURCE LATITUDE THE FUNCTION RETURNS
00083 C      THE AMOUNT OF SEA LEVEL DROP IN METERS
00084 C
00085      SEACH=0.0!FIRST ASSUME NO CHANGE IN SEA LEVEL
00086      IF (RAD.GT.0.0)
00087      . RICE=RATIO*RAD*RAD*SQRT(ABS(RAD) )
00088      . SEACH=RICE*2.64
00089      . ...FIN
00090      RETURN
00091      END
```

(FLECS VERSION 22,46)

```

-----
00001 C ***** SUBFLT.FLX *****
00002 C
00003 C PROGRAM DESCRIPTION :
00004 C THIS ROUTINE MODELS SUB-BASALT BASEMENT FAULTING EVENTS.
00005 C IT ACCOUNTS FOR THE FOLLOWING EVENTS:
00006 C - CHANGES IN HYDRAULIC CONDUCTIVITY
00007 C - TIME BETWEEN SUB-BASALT BASEMENT EARTHQUAKES
00008 C - FAULT AREA OF SUB-BASALT BASEMENT EARTHQUAKES
00009 C - FREQUENCY OF SUB-BASALT BASEMENT EARTHQUAKES
00010 C - DURATION OF A SUB-BASALT BASEMENT EARTHQUAKE
00011 C - ACCELERATION
00012 C - POSSIBLE CHANGES IN THE SHAFT SEAL
00013 C
00014 C
00015 C SUBROUTINE SUBFLT
00016 C
00017 C
00018 C INCLUDE 'DI:(226,226)COMMON,FLX'
00019 C
00020 C
00021 C CALL NOTE(10,'#SUB-FAULT')
00022 C
00023 C
00024 C INITIALIZE
00025 C LFRASH=.FALSE.
00026 C
00027 C
00028 C
00029 C IF(.NOT. LFBASE)
00030 C . WHEN(LTEST(PFTNEW) .OR. IFORCE.EQ.1)
00031 C . . CALL SETFLT
00032 C . . TSUBFT=TTIME
00033 C . ...FIN
00034 C . ELSE RETURN
00035 C ...FIN
00036 C
00037 C
00038 C
00039 C IF(IFORCE.EQ.1)
00040 C . CALL NOTE(15,'FORCED FAULTING')
00041 C . TSUBFT=TTIME
00042 C ...FIN
00043 C
00044 C WHILE(TSUBFT.LT. TEND)
00045 C . CALL RNUMBR(20,'SUB BASALT FAULTING',TSUBFT)
00046 C *****
00047 C . TSUBFT=TSUBFT+PROB(102) ; GET TIME UNTIL THE NEXT FAULT
00048 C . RICH=PROB(104) ; GET THE RICHTER MAGNITUDE
00049 C . WHEN(DTIME.GT.100.0) TEMP=AVENAS*100.0/DTIME
00050 C . ELSE TEMP=AVENAS
00051 C . THE ABOVE IS BECAUSE FUNCTION POISON IS TIME STEP ADJUSTED
00052 C . NUMFT=POISON(TEMP)+1 ; AFTER SHOCKS + STARTING EVENT
00053 C *****

```

```

00054      .   RICHTR=RICHT*ANFACT      ! CORRECT FOR ANGLE FACTOR
00055      .   CALL INUMBR(11,'MOVEMENTS',NUMFT)
00056      C      .
00057      C      .
00058      C      .
00059      C      .
00060      .   CALCULATE=THE-EFFECTS-OF=THE-FAULTING-ON=HC
00061      C      .
00062      C      .
00063      .   DO(I=1,NUMFT)CALL SHAFT(ACRPOS,TIMEH) !ALLOW FOR SHAFT SEAL EFFECTS
00064      C      .
00065      C      .
00066      C      .
00067      .   IF(ACRPOS,GE, ACELCT)
00068      .   .   LFBASH=.TRUE.
00069      .   .   CALL NOTE(11,'MAJOR FAULT')
00070      .   .   FIN
00071      .   .   FIN
00072      C      .
00073      .   RETURN
00074      C      .
00075      C      .
00076      C      *****

```

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-----
00077      .   TO CALCULATE=THE-EFFECTS-OF=THE-FAULTING-ON=HC
00078      C      *****CALCULATE THE EFFECTS OF THE FAULTING ON HC*****
00079      C      .
00080      C      .
00081      .   ACRPOS=ACLER(RICHTR,RDFTDT)
00082      .   WHEN (ACRPOS,GE, ACFTMN,AND,RDEPTH,LT,DEPMIN)
00083      .   .   FAREA=POLY(16,RICHTR)      ! FAULT AREA
00084      .   .   FREQFT=POLY(17,RICHTR)    ! FREQUENCY
00085      .   .   DURFT =POLY(18,RICHTR)    ! DURATION
00086      .   .   CALL RNUMBR(9,'FREQUENCY',FREQFT) !CHANGE DOC
00087      .   .   CALL RNUMBR(8,'DURATION',DURFT) !CHANGE DOC
00088      .   .   CALL RNUMBR(10,'FAULT AREA',FAREA) !CHANGE DOC
00089      .   .   DO(L=1,NUMFT)
00090      C      *****
00091      .   .   TEMP=CH HC FT(ACRPOS,RDEPTH)*PROB(105)*RPOSHC !CHANGE IN H.C.
00092      C      *****
00093      .   .   CALL RNUMBR(18,'FRACTIONAL CHANGE',TEMP) !ADD TO DOC
00094      .   .   CHRS(1)=TEMP+CHRS(1)
00095      .   .   FIN
00096      .   .   CALL RNUMBR(18,'ACCEL.(REPOSITORY)',ACRPOS)
00097      .   .   FIN
00098      .   .   ELSE CALL NOTE(20,'#FAULT MINOR AT REP,')
00099      C      .
00100      C      .
00101      .   DO(LAYER=ITOP,NLAYER)
00102      .   .   IF(ITYPE(LAYER).GT,2)
00103      .   .   .   DO(ISYSTH=1,3)
00104      .   .   .   .   ACER=ACLER(RICHTR,RADIST(LAYER,ISYSTH) )
00105      .   .   .   .   IF (ACER,GE, ACFTMN,AND, DEPTHZ(LAYER,ISYSTH),LE,DEPMIN)
00106      .   .   .   .   DO(I=1,NUMFT)

```

```
00107 C *****
00108 . . . . . TEMP=CHMCFT(ACER,DEPTHZ(LAYER,ISYSTH))*PROB(105)*
00109 +. . . . . HYDCN1(LAYER,ISYSTH)
00110 C *****
00111 . . . . .FIN
00112 . . . . .FIN
00113 . . . . .FIN
00114 . . . . .FIN
00115 . . . . .FIN
00116 . . . . .FIN
00117 END
```

PROCEDURE CROSS-REFERENCE TABLE

00077 CALCULATE-THE-EFFECTS-OF-THE-FAULTING-ON-HC
00060

(FLECS VERSION 22,46)

```
00118 FUNCTION ACLER(RICHT, DIST)
00119 C NOTE THAT THIS FORMULIZATION IS SEEN TO BE CONSERVATIVE
00120 C WHEN USED AT DEPTH(INSIDE OF THE SURFACE)
00121 TOP=472.0*(10.0**((0.28*RICHT)))
00122 BOTTOM=(DIST+25.0)**1.3
00123 ACLER=TOP/BOTTOM
00124 RETURN
00125 END
```

(FLECS VERSION 22,46)

```
00126 FUNCTION CHMCFT(AG,D)
00127 C THIS FUNCTION IS USED TO CALCULATE THE CHANGES IN H,C, DUE
00128 C TO ACCELERATION A DEPTH, IT IS TAKEN FROM "EARTHQUAKE ENGINEERING AND
00129 C THE BATTELLE REPOSITORY RELEASE SCENARIO MODEL" REPORT SUBMITTED
00130 C BY L.H. WIGHT OF TERA CORP.
00131 C
00132 TEMP=(0.0001126*AG-(D*1.0E-04)-0.020919); EQUATION A PAGE 4-2
00133 IF(TEMP.LT,0,0) TEMP=0,0
00134 CHMCFT=TEMP
00135 RETURN
00136 END
```

(FLECS VERSION 22,46)

```

-----
00001 C ***** UNFEAT,FLX *****
00002 C
00003 C THIS SUBROUTINE ACCOUNTS FOR :
00004 C STARTING H.C. FOR EACH LAYER IN THE SYSTEM
00005 C THE LOCATION OF THE DISCHARGE POINTS OF DEEP GROUND WATER
00006 C SYSTEMS INTO THE SEDIMENT FILL OF THE BASIN
00007 C LOCATION AND STARTING PARAMETERS FOR THE LOCAL FAULTING SYSTEM
00008 C THE POSSIBILITY OF AN UNDETECTED FOLD
00009 C AN UNDETECTED SUB BASALT FAULT
00010 C PARAMETERS FOR THE S.W. SUB-SYSTEM FAULTS
00011 C PARAMETERS FOR THE N.E. SUB-SYSTEM FAULTS
00012 C THE STARTING VALUE FOR THE UNCONFINED PATH LENGTHS
00013 C
00014 C
00015 C SUBROUTINE UNFEAT
00016 C
00017 C
00018 C INCLUDE 'DI;(226,226)COMMON,FLX'
00019 C
00020 C CALL NOTE(11,'#UNDETECTED')
00021 C
00022 C IN THE FOLLOWING WAY:
00023 C
00024 C GET-STARTING=HC
00025 C CALCULATE-THE-DISCHARGE-POINTS
00026 C ACCOUNT-FOR-ANY-LOCAL-FAULTS
00027 C ACCOUNT-FOR-FOLDING-AND-SUB-BASALT-FAULTING
00028 C ACCOUNT-FOR-FAULTING-IN-THE-NE-AND-SW-SUBSYSTEM
00029 C CALCULATE-THE-BASE-CASE
00030 C RETURN
00031 C
00032 C
00033 C *****

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-----
00034 C TO GET-STARTING=HC
00035 C ****GET STARTING HC*****
00036 C .
00037 C .
00038 C . DO (LAYER = ITOP , NLAYER)
00039 C . . NOW LOOK AT EACH SUB-SYSTEM (S.W.,BASIN,N.E.)
00040 C . . DO (ISYSTH = 1 , 3)
00041 C . . . SELECT (ITYPE(LAYER))
00042 C . . . . SELECT BY ROCK TYPE
00043 C . . . . -----DENSITY CURVE-----
00044 C . . . . (1) HC=PROB(69)BASINS SEDIMENTS
00045 C . . . . -----DENSITY CURVE-----
00046 C . . . . (2)
00047 C . . . . . CONSOLIDATED ROCK
00048 C . . . . . SELECT (ISYSTH)
00049 C . . . . . . SELECT BY SUB-SYSTEM
00050 C . . . . . . -----DENSITY CURVE-----

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00051      . . . . . (1) HC=PROB(70) IS,W, SED.
00052      . . . . . (2) HC=PROB(71) IBASIN SED
00053      . . . . . (3) HC=PROB(72) IN,E, SED
00054 C      . . . . . -----
00055      . . . . . ...FIN
00056      . . . . . ...FIN
00057      . . . . . (3)
00058 C      . . . . . BASALT OF THE WANAPUM AND SADDLE MT.
00059      . . . . . SELECT(ISYSTM)
00060 C      . . . . . SELECT BY SUB-SYSTEM
00061 C      . . . . . -----DENSITY CURVE-----
00062      . . . . . (1) HC=PROB(73) IS,W, BASALT OF WANAPUM-SADDLE MT.
00063      . . . . . (2) HC=PROB(74) IBASIN BASALT OF WANAPUM-SADDLE MT.
00064      . . . . . (3) HC=PROB(75) IN,E, BASALT OF WANAPUM-SADDLE MT.
00065 C      . . . . . -----
00066      . . . . . ...FIN
00067      . . . . . ...FIN
00068      . . . . . (4)
00069 C      . . . . . BASALT OF THE GRANDE RONDE
00070      . . . . . SELECT(ISYSTM)
00071 C      . . . . . -----DENSITY CURVE-----
00072      . . . . . (1) HC=PROB(76) IS,W, BASALT OF THE GRANDE RONDE
00073      . . . . . (2) HC=PROB(77) IBASIN BASALT OF THE GRANDE RONDE
00074      . . . . . (3) HC=PROB(78) IN,E, BASALT OF THE GRANDE RONDE
00075 C      . . . . . -----
00076      . . . . . ...FIN
00077      . . . . . ...FIN
00078      . . . . . ...FIN
00079 C      . . . . .
00080      . . . . . IF(LAYER,NE,1)
00081      . . . . . CALL RNUMBR(12,'START H,C,','HC')ICHANGE DOC
00082      . . . . . CALL RNUMBR(10,'THICKNESS',DELX(LAYER,ISYSTM))ICHANGE DOC
00083      . . . . . ...FIN
00084      . . . . . HYDCN(LAYER,ISYSTM)=HC
00085      . . . . . HYDCN1(LAYER,ISYSTM)=HC
00086      . . . . . ...FIN
00087      . . . . . ...FIN
00088      . . . . . ...FIN
00089 C
00090 C
00091 C *****

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-----
00092      TO CALCULATE-THE-DISCHARGE-POINTS
00093 C      ****CALCULATE THE DISCHARGE POINTS*****
00094 C      .
00095 C      .
00096 C      . DRAW FOR THE LOCATION OF THE DISCHARGE POINTS FOR EACH SUB-SYSTEM
00097 C      . -----DENSITY CURVE-----
00098      . DPNTSW=PROB(79)*(EDGESE-EDGESW)+EDGESW IS,W, DISCHARGE POINT
00099      . DPNTNE=PROB(80)*(EDGESE-EDGESW)+EDGESW IN,E, DISCHARGE POINT
00100 C      . -----
00101      . IF (DPNTSW .GT. DPNTNE)
00102      . . CALL NOTE (18,'CHANGING DISCHARGE')
00103      . . TEMP = DPNTSW

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00104      . . DPNTSW=DPNTNE
00105      . . DPNTNE=TEMP
00106      . ...FIN
00107      . CALL RNUMBR(20,'S.W. DISCHARGE POINT',DPNTSW)
00108      . CALL RNUMBR(20,'N.E. DISCHARGE POINT',DPNTNE)
00109 C      . FIND THE ANGLE OF FLOW PATH
00110      . XHORSW=ABS(DPNTSW-EDGESW)*1000.0 !CHANGE TO METERS
00111      . R=SQRT(XHORSW**2+DEPTSW**2)
00112      . COSSW=XHORSW/R
00113      . IF (COS SW .LE. 0.0 .OR. COS SW .GT. 1.0)
00114      . . CALL RNUMBR(15,'ERROR IN COS SW',COSSW)
00115      . . COSSW=1.0
00116      . ...FIN
00117      . XHORSE=R
00118      . CALL RNUMBR(19,'DIST FROM EDGE S.E.',XHORSW)
00119      . XHORNE=ABS(EDGENE-DPNTNE)*1000.0 !CHANGE TO METERS
00120      . R=SQRT(XHORNE**2+DEPTNE**2)
00121      . COSNE=XHORNE/R
00122      . IF (COS NE .LE. 0.0 .OR. COS NE .GT. 1.0)
00123      . . CALL RNUMBR(15,'ERROR IN COS NE',COSNE)
00124      . . COSNE=1.0
00125      . ...FIN
00126 C      .
00127      . XHORNE=R
00128      . CALL RNUMBR(18,'DIST FROM EDGE N.E.',XHORNE)
00129 C      .
00130      . Z=DELX(1,2)/1000.0 !DEPTH TO BASALT/SED INTERFACE(KM)
00131      . DO (IPATH=1,3)
00132      . . SELECT (IPATH)
00133      . . . (1)
00134 C      . . . S.W. DISCHARGE SYSTEM
00135      . . . XOUT = DPNTSW
00136      . . . FIND-DISTANCE-FROM-BASALTSED-DISCHARGE-POINT
00137      . . . ...FIN
00138      . . . (2)
00139 C      . . . IN THE BASIN
00140      . . . XOUT = 0.0
00141      . . . FIND-DISTANCE-FROM-BASALTSED-DISCHARGE-POINT
00142      . . . ...FIN
00143      . . . (3)
00144 C      . . . N.E. DISCHARGE SYSTEM
00145      . . . XOUT = DPNTNE
00146      . . . FIND-DISTANCE-FROM-BASALTSED-DISCHARGE-POINT
00147      . . . ...FIN
00148      . . . ...FIN
00149      . ...FIN
00150      . ...FIN
00151 C
00152 C
00153 C *****

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```

00154      TO FIND-DISTANCE-FROM-BASALTSED-DISCHARGE-POINT
00155 C *****FIND DISTANCE FROM BASALTSED DISCHARGE POINT*****
00156 C .

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00157 C .
00158 C . COORDINATE RELATIVE TO THE CROSS SECTION (Y POSITIVE SOUTH AND
00159 C . X POSITIVE TOWARD THE N.E.
00160 C .
00161 C .
00162 C . -----DENSITY CURVE-----
00163 C . TEMP=(PROB(92))/57.296 !DISTANCE ALONG THE DISCHARGE ARC
00164 C . -----
00165 C .
00166 C . CALL INUMBR(20,'UNCONFINED PATH IS','IPATH)
00167 C . CALL RNUMBR(16,'DISCHARGE ANGLE',TEMP)
00168 C . FIND THE COORDINATES IN A SYSTEM IN LINE WITH NORTH
00169 C . AND TRANSLATE THE ORIGIN BACK OVER THE REPOSITORY
00170 C . YY=COS(TEMP)*ARCRAD + YSTART
00171 C . XX=SIN(TEMP)*ARCRAD + XSTART
00172 C . CALL RNUMBR(07,'X COR1',XX)
00173 C . CALL RNUMBR(07,'Y COR1',YY)
00174 C . TEMP=(90.0-ANGCROS)/57.295
00175 C . ROTATE COORDINATE SYSTEM IN LINE WITH THE M.C.S.
00176 C . X=XX*COS(TEMP)+YY*SIN(TEMP)
00177 C . Y=-XX*SIN(TEMP)+YY*COS(TEMP)
00178 C . CALL RNUMBR(06,'X COR',X)
00179 C . CALL RNUMBR(06,'Y COR',Y)
00180 C . X=X-XOUT
00181 C . DISTUN=SQRT(X*X+Y*Y+Z*Z)
00182 C . CALL RNUMBR(13,'UNPATH DIST',DISTUN)
00183 C . UNPATH(IPATH)=DISTUN
00184 C . ...FIN
00185 C
00186 C
00187 C *****

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-----
00188 TO ACCOUNT-FOR-ANY-LOCAL-FAULTS
00189 C *****ACCOUNT FOR ANY LOCAL FAULTS*****
00190 C .
00191 C .
00192 C . FIND LOCAL FAULT PARAMETERS
00193 C . -----DENSITY CURVE-----
00194 C . RTREND=PROB(81) !GET REGIONAL TREND
00195 C . -----
00196 C .
00197 C . RNDRL=RTREND+90.0
00198 C . ANBTWN=ANGBTN(RNDRL,ANGCROS)
00199 C . IF(ABS(ANBTWN-90.0),LE,ANGCROS UN)
00200 C . . CALL NOTE(15,'FAULTS PARALLEL')
00201 C . . PSSFTS = 0.0 ! NO FAULT ON THE MODEL CROSS SECTION
00202 C . ...FIN
00203 C . COSAN=COS(ANBTWN/57.296)
00204 C . CALL RNUMBR(14,'ANGLE BETWEEN',ANBTWN)
00205 C . IF (COSAN ,LE, 0.0)
00206 C . . CALL NOTE(11,'ERROR ANGLE')
00207 C . . COSAN = 1.0
00208 C . ...FIN
00209 C .

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```

00210 C .
00211 . NEXTFT = 2 I COUNTER FOR FEATURES IN THE REPOSITORY
00212 C . 1 = SHAFT SEAL
00213 C . 2 = FOLD
00214 C . 3-50 = LOCAL FAULTS IN THE REPOSITORY
00215 . WHEN (LTESTW(PSSFTB))
00216 . . LSSFIN = .TRUE. ISET FLAG SHOWING A POSSIBLE FAULT IN THE BASIN
00217 . . CURDIS = STFLT I THE FIRST FAULT IS JUST OUTSIDE THE BASIN
00218 . . REPEAT UNTIL (CURDIS .GT. EDGENW)
00219 . . . SSFTHC(1) = 0.0
00220 C . . -----DENSITY CURVE-----
00221 . . . DISNXT=PROB(82)/COSAN
00222 . . . FWIDTH(1)=PROB(83)/COSAN I EFFECTIVE FAULT WIDTH
00223 C . . -----
00224 . . . SSFTT(1) = 1.0E28 I THIS FAULT IS TO BE OUTSIDE THE BASIN
00225 . . . FAULT(1)=CURDIS
00226 . . . CURDIS = CURDIS+DISNXT
00227 . . . ...FIN
00228 C .
00229 . INEXT=2
00230 . REPEAT UNTIL (CURDIS .GT. EDGENE)
00231 . . FAULT(INEXT) = CURDIS
00232 . . . SSFTHC(INEXT) = 0.0 I STARTING H.C. DIFFERENCE BETWEEN THE FAULT AND THE SURR
00233 C . . . -----DENSITY CURVE-----
00234 . . . DISNXT = PROB(82) / COSAN I DRAW FOR THE NEXT LOCATION
00235 . . . FWIDTH(INEXT) = PROB(83) / COSAN I DRAW FOR THE FAULT WIDTH
00236 . . . FOR(INEXT) = PROB(84) + RTREND I DRAW FOR LOCAL FAULT DIRECTION
00237 . . . SSFTT(INEXT) = PROB(85) I TIME UNTIL THIS FAULT IS ACTIVE
00238 . . . RESET(INEXT) = SSFTT(INEXT)*PRESFT I GET RESET TIME
00239 C . . -----
00240 . . IF (ABS(FAULT(INEXT)) .LT. SITRAD)
00241 C . . . I.E. THIS FAULT GOES THROUGH THE SITE
00242 . . . WHEN (LTESTW(PHISFT))
00243 C . . . AND THE GEOLOGIST MISSED IT
00244 . . . . NEXTFT = NEXTFT + 1
00245 . . . . IF (NEXTFT .GT. 50)
00246 . . . . . CALL NOTE (12, 'MISSED FAULT')
00247 . . . . . NEXTFT = 50
00248 . . . . . ...FIN
00249 . . . . . IFSIT(NEXTFT) = INEXT
00250 . . . . . CALL NOTE(19, 'FAULT IN REPOSITORY')
00251 . . . . . ANG = ANGBTN (FOR(INEXT), ANCR08)
00252 . . . . . R = ABS(FAULT(INEXT)*SIN(ANG/57.296)) I I.E. GET THE NORMAL
00253 C . . . . . DISTANCE TO THE FAULT
00254 . . . . . RLENGTH=SQRT(SITRAD*SITRAD-R*R)*2 I LENGTH OF FAULT SITE
00255 C . . . . . INTERSECTION
00256 . . . . . AREA = RLENGTH*(FWIDTH(INEXT)/1000.0)*COSAN
00257 . . . . . FRAC(NEXTFT)=AREA/(SITRAD*SITRAD*3.14159)
00258 . . . . . CALL RNUMBR(17, 'FRACTION OF INTER', FRAC(NEXTFT))
00259 . . . . . ...FIN
00260 . . . . . ELSE
00261 . . . . . CURDIS = SITRAD
00262 . . . . . FAULT(INEXT) = CURDIS
00263 . . . . . CALL NOTE(18, 'FAULT JUST OUTSIDE')
00264 . . . . . ...FIN
00265 . . . . . ...FIN

```

```

00266      . . . CALL RNUMBR(15,'FAULT LOCATION=',FAULT(INEXT))
00267      . . . INEXT = INEXT + 1
00268      . . . CURDIS = CURDIS + DISNXT
00269      . . . IF (INEXT.GT. 200)
00270      . . . . CALL NOTE (11,'LOST FAULTS')
00271      . . . . INEXT = 200
00272      . . . ...FIN
00273      . . . ...FIN
00274      . . . NSSFT = INEXT
00275      . . . FAULT(INEXT)=CURDIS (REMEMBER THAT THIS FAULT IS OUTSIDE THE BASIN
00276      . . . SSFTT(INEXT)=1,0E28
00277      . . . CALL INUMBR(13,'TOTAL FAULTS',NSSFT)
00278      . . . ...FIN
00279      . . . ELSE
00280      . . . . LSSFIN = .FALSE. (NO FAULTS IN THE BASIN
00281      . . . . CALL NOTE(15,'NO LOCAL FAULTS')
00282      . . . . NSSFT = 0 (NUMBER OF LOCAL FAULTS = 0
00283      . . . ...FIN
00284      C .
00285      C .
00286      C . ALLOW FOR A THRUST FAULT IN THE REPOSITORY
00287      . WHEN (LTESTW(PUNTHS))
00288      C . . -----DENSITY CURVE-----
00289      . . THRWD = PROB(86) (DRAW FOR THRUST WIDTH
00290      . . TRUST = PROB(87) (DRAW FOR TIME OR ACTIVE THRUSTING
00291      . . RESET = TRUST * FRESTR (RESET TIME
00292      C . . -----
00293      . . IF (THRWD.GE. RPOSTH)
00294      . . . CALL RNUMBR(15,'THRUST TOO WIDE',THRWD)
00295      . . . THRWD=RPOSTH/2.0
00296      . . . ...FIN
00297      . . . TRMOVE=0.0 (TOTAL THRUST MOVEMENT SET TO ZERO
00298      . . . CALL NOTE (18,'THRUST FAULT FOUND')
00299      . . . THRCH =0.0 (INITIALIZE H,C. TO ZERO THE DIFFERENCE BETWEEN THE FAULT AND
00300      . . . LTHRST = .TRUE.
00301      . . . ...FIN
00302      . . . ELSE
00303      . . . LTHRST = .FALSE.
00304      . . . CALL NOTE(15,'NO THRUST FOUND')
00305      . . . ...FIN
00306      . . . ...FIN
00307      C .
00308      C .
00309      C *****

```

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-----
00310      TO ACCOUNT-FOR-FOLDING-AND-SUB-BASALT-FAULTING
00311      C *****ACCOUNT FOR FOLDING AND SUB BASALT FAULTING*****
00312      C .
00313      C .
00314      C . CHECK FOR A FOLD
00315      . WHEN (LTESTW(PFOLD))
00316      . . LFOLD = .TRUE.
00317      . . CALL NOTE(10,'FOLD FOUND')
00318      . . CALL GETFLD

```

```

00319      . . FOLDHC=0.0
00320      . ...FIN
00321      . ELSE
00322      . . LFOLD = .FALSE.
00323      . . CALL NOTE (13,'NO FOLD FOUND')
00324      . ...FIN
00325      C
00326      C . CHECK FOR UNKNOWN FAULT IN THE BASEMENT
00327      C
00328      . WHEN (LTESTH(PFAULT)) CALL SETFLT
00329      . ELSE
00330      . . LFBASE = .FALSE.
00331      . . CALL NOTE(18,'NO SUBBASALT FAULT')
00332      . ...FIN
00333      ...FIN
00334      C
00335      C
00336      C *****
      -----

00337      TO ACCOUNT-FOR-FAULTING-IN-THE-NE-AND-SW-SUBSYSTEM
00338      C *****ACCOUNT FOR FAULTING IN THE NE AND SW SUBSYSTEM*****
00339      C
00340      C
00341      C . -----DENSITY CURVE-----
00342      . FLWDSH=PROB(88) !DRAW FOR WIDTH OF REPRESENTATIVE S.W. SUB-SYSTEM
00343      C . FAULT
00344      . FLWONE=PROB(89) !DRAW FOR WIDTH OF REPRESENTATIVE N.E. SUB-SYSTEM
00345      C . FAULT
00346      . FLTSW =PROB(90) !TIME OF NEXT S.W. FAULTING EVENT
00347      . RESFNE=FLTSW*FREFNE !RESET TIME
00348      . FLTNE =PROB(91) !TIME OF NEXT N.E. FAULTING EVENT
00349      . RESFSW=FLTSW*PREFSW
00350      C . -----
00351      . FLHCSW=0.0 !H.C. INITIALIZED TO ZERO
00352      . FLHCNE=0.0 !H.C. INITIALIZED TO ZERO
00353      ...FIN
00354      C
00355      C
00356      C *****
      -----

00357      TO CALCULATE-THE-BASE-CASE
00358      C . TERMS NOT CURRENTLY IN THE DOCUMENTATION INCLUDE:
00359      C . AVHCSW: AVERAGE H.C. ALONG THE S.W. PATH(T)
00360      C . AVHCNE: AVERAGE H.C. ALONG THE N.E. PATH(T)
00361      C . CUNERC: CURRENT N.E. RECHARGE (I)
00362      C . CUSWRC: CURRENT S.W. RECHARGE (I)
00363      C . BMULTF: BREACH MULTIPLICATION FACTOR (I)
00364      C . DVRPNE: DARCY VELOCITY ALONG THE N.E. PATH(T)
00365      C . DVRPSW: DARCY VELOCITY ALONG THE S.W. PATH(T)
00366      C . DVRPOS: TOTAL DARCY VELOCITY THRU THE REPOSITORY(T)
00367      C . GRAONE: N.E. GRADIENT(T)
00368      C . GRADSW: S.W. GRADIENT(T)

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```

00369 C . HCNEGR: CURRENT HEAD VALUE FOR THE N.E. RECHARGE AREA(T)
00370 C . HCSWGR: CURRENT HEAD VALUE FOR THE S.W. RECHARGE AREA(T)
00371 C . TOTL : TOTAL DISTANCE FROM THE BOTTOM OF THE REPOSITORY TO THE RIV
00372 C . TOTLK : SUM OF LENGTH/H.C.(T)
00373 C . TOTNE: TOTAL LENGTH(METERS) ALONG THE N.E. PATH(T)
00374 C . TOTSW: TOTAL LENGTH(METERS) ALONG THE S.W. PATH(T)
00375 C .
00376 . TOTL=DELX(2,2) !WANAPUM-SADDEL
00377 . TOTLK=DELX(2,2)/HYDCN(2,2)
00378 . TOTL=TOTL+DELX(3,2) !'SOFT ROCK' LAYER
00379 . TOTLK=TOTLK+DELX(3,2)/HYDCN(3,2)
00380 . TOTL=TOTL+THABOV !GRANDE RONDE ABOVE THE REPOSITORY
00381 . TOTLK=TOTLK+THABOV/DELX(4,2)
00382 . TOTL=TOTL+RPOSTH !REPOSITORY THICKNESS
00383 . TOTLK=TOTLK+RPOSTH/RPOSHC
00384 C .
00385 C .
00386 . TEMP=ABS(EDGESW)*1000.0/COSBSW
00387 . TOTSW=TOTL+TEMP+GRSWLN*1000.0
00388 . AVHCSW=(TOTSW)/(TOTLK+GRSWLN*1000.0/HYDCN(4,1)+TEMP/HYDCN(4,2))
00389 C .
00390 . TEMP=ABS(EDGESE)*1000.0/COSBSE
00391 . TOTNE=TOTL+TEMP+GRLNNE*1000.0
00392 . AVHCNE=TOTNE/(TOTLK+GRLNNE*1000.0/HYDCN(4,3)+TEMP/HYDCN(4,2))
00393 . CALL RNUMBR(16,'S.W. H.C. START=',AVHCSW);CHANGE DOC
00394 . CALL RNUMBR(16,'N.E. H.C. START=',AVHCNE);CHANGE DOC
00395 . HCSWGR=HDSWGR+POLY(25,CUSWRC)
00396 . GRADSW=(HCSWGR-HEADBS)/TOTSW
00397 . HCNEGR=HDNEGR+POLY(25,CUNERC)
00398 . GRADNE=(HCNEGR-HEADBS)/TOTNE
00399 . CALL RNUMBR(14,'S.W. GRADIENT=',GRADSW);CHAGNE DOC
00400 . CALL RNUMBR(14,'N.E. GRADIENT=',GRADNE);CHANGE DOC
00401 . DVRPSW=AVHCSW*GRADSW
00402 . DVRPNE=AVHCNE*GRADNE
00403 . DVRPOS=DVRPNE+DVRPSW
00404 . DVBRCB=DVRPOS*BMULTF;DEFINATION OF BREACH FLOW
00405 . CALL RNUMBR(19,'STARTING DARCY FLOW',DVRPOS);CHANGE DOC
00406 C .
00407 C .
00408 . TOTL=WSSWLN*1000.0+XHORSW
00409 . TOTLK=WSSWLN*1000.0/HYDCN(2,1)+XHORSW/HYDCN(2,2)
00410 . AVSWHC=TOTL/TOTLK
00411 C .
00412 . TOTL=WSNELN*1000.0+XHORNE
00413 . TOTLK=WSNELN*1000.0/HYDCN(2,3)+XHORNE/HYDCN(2,2)
00414 . AVNEHC=TOTL/TOTLK
00415 . CALL RNUMBR(16,'WAN-SAD S.W. HC=',AVSWHC)
00416 . CALL RNUMBR(16,'WAN-SAD N.E. HC=',AVNEHC)
00417 . ...FIN
00418 . END

```

PROCEDURE CROSS-REFERENCE TABLE

00188 ACCOUNT-FOR-ANY-LOCAL-FAULTS

(FLECS VERSION 22,46) 28-OCT-81 10:17:13 PAGE 00009

00026

00154 FIND-DISTANCE-FROM-BASALTSED-DISCHARGE-POINT
00136 00141 00146

00337 ACCOUNT-FOR-FAULTING-IN-THE-NE-AND-SW-SUBSYSTEM
00028

00357 CALCULATE-THE-BASE-CASE
00029

00034 GET-STARTING-HC
00024

00310 ACCOUNT-FOR-FOLDING-AND-SUB-BASALT-FAULTING
00027

00092 CALCULATE-THE-DISCHARGE-POINTS
00025

(FLECS VERSION 22,46)

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-----
00001 C ***** READS *****
00002 C
00003 C PROGRAM DESCRIPTION:
00004 C THIS ROUTINE CALLS THE ROUTINES TO READ SCALAR, POLYNOMIAL,
00005 C DENSITY AND LAYER DATA, ALONG WITH CHECKING THE POSITIONS OF
00006 C THE SENSE SWITCHES TO SEE IF THE MODEL SHOULD START FROM SCRATCH
00007 C OR RESTART FROM WHERE IT LEFT OFF.
00008 C
00009 C CREATED BY: ALAN J. BALDWIN ON: AUG. 14, 1980
00010 C
00011 C SUBROUTINE READS
00012 C
00013 C LOGICAL LMORE,LDUMP
00014 C COMMON /MORDMP/ LMORE,LDUMP
00015 C
00016 C BYTE BYDATE(10),BYTIME(8)
00017 C LOGICAL LSMEOF
00018 C
00019 C COMMON /IJRAN/ IRAN , JRAN
00020 C
00021 C INCLUDE 'DI:(226,226)COMMON,FLX'
00022 C
00023 C
00024 C READ=SCALAR=DATA
00025 C READ=POLYNOMIAL=DATA
00026 C READ=DENSITY=DATA
00027 C READ=LAYER=DATA
00028 C CHECK=SENSE=SWITCHES
00029 C OPEN=CLIMATE=FILE
00030 C RETURN
00031 C
00032 C
00033 C
-----
00034 C TO OPEN=CLIMATE=FILE
00035 C ****OPEN CLIMATE FILE*****
00036 C .
00037 C .
00038 C . OPEN(UNIT=7,NAME='DI:TABLE,CLM',TYPE='OLD',READONLY
00039 C + ,FORM='UNFORMATTED')
00040 C ...FIN
00041 C
00042 C
-----
00043 C TO CHECK=SENSE=SWITCHES
00044 C ****CHECK=SENSE SWITCHES*****
00045 C .
00046 C .
00047 C . CHECK TO SEE IF RESTART IT FROM WHERE LEFT OFF

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00048 C .
00049 . CALL SSWTCH(5,ISW5) ! RESTART MODEL WHERE IT HALTED
00050 . WHEN (ISW5.EQ. 1)
00051 C . . RESTART MODEL WHERE IT HALTED
00052 . . WRITE (6,100)
00053 100 . . FORMAT(//,40X,'A E G I S',//,
00054 1. . . ' ***** RESTARTING A E G I S FROM WHERE IT LEFT OFF',//)
00055 . . OPEN (UNIT=4,NAME='DI1;SUMMARY.AG8',TYPE='OLD',
00056 +. . . FORM='UNFORMATTED',ACCESS='DIRECT',RECORDSIZE=64,
00057 +. . . ERR=555)
00058 . . GO TO 556
00059 555 . . STOP ! ***** COULD NOT OPEN OLD SUMMARY FILE FOR RESTART!
00060 556 . . CONTINUE
00061 . . READ-SUMMARY-FILE-UNTIL-LAST-RECORD
00062 . . ...FIN
00063 . . ELSE
00064 C . . START MODEL OUT FROM SCRATCH
00065 . . WRITE (6,200)
00066 200 . . FORMAT(//,40X,'A E G I S',//,
00067 1. . . ' $$$$ BEGINNING A E G I S WITH A FRESH START',//)
00068 . . OPEN (UNIT=4,NAME='DI1;SUMMARY.AG8',TYPE='NEW',
00069 +. . . FORM='UNFORMATTED',ACCESS='DIRECT',RECORDSIZE=64,
00070 +. . . INITIALSIZE=30,ERR=557)
00071 . . GO TO 558
00072 557 . . WRITE (6,*) ' ***** PROBLEMS OPENING UP NEW SUMMARY FILE'
00073 558 . . CONTINUE
00074 . . ISTRN = 1
00075 . . ...FIN
00076 . . CLOSE (UNIT=4)
00077 C .
00078 C . RANDOMIZE THE RANDOM NUMBER SEED
00079 C .
00080 . CALL SSWTCH(6,ISW6) ! START MODEL WITH A RANDOM NUMBER SEED
00081 . IF (ISW6.EQ. 1)
00082 . . CALL DATE(BYDATE)
00083 . . CALL TIME(BYTIME)
00084 . . DECODE (9,210,BYDATE,ERR=299) IDAY
00085 210 . . FORMAT(12,7X)
00086 . . DECODE (9,220,BYDATE,ERR=299) IYEAR
00087 220 . . FORMAT(7X,12)
00088 . . DECODE (8,230,BYTIME,ERR=299) IHOUR
00089 230 . . FORMAT(12,6X)
00090 . . DECODE (8,240,BYTIME,ERR=299) IMINUT
00091 240 . . FORMAT(3X,12,3X)
00092 . . DECODE (8,250,BYTIME,ERR=299) ISEC
00093 250 . . FORMAT(6X,12)
00094 . . IRAN = IDAY * IHOUR * ISEC
00095 . . JIRAN = IMINUT * ISEC
00096 D . . WRITE (6,260) IRAN,JIRAN,IYEAR,IDAY,IHOUR,IMINUT,ISEC
00097 260 . . FORMAT(//,' !!!!! THIS RUN USES A RANDOM SEED !!!!!',//,
00098 1. . . ' THE RANDOM SEED IS ',210,/,
00099 2. . . ' YEAR ',13,5X,' DAY ',13,10X,' HOUR ',13,5X,' MINUTE ',
00100 3. . . ' ',13,5X,' SECOND ',13,/,)
00101 299 . . CONTINUE
00102 . . ...FIN
00103 C .

```

```

00104 C . CHECK FOR 'N' LEVEL MESSAGES
00105 C .
00106 . CALL SSWTCH(1,ISW1)
00107 . WHEN (ISW1 .EQ. 1) LDUMP = .TRUE.
00108 . ELSE LDUMP = .FALSE.
00109 C .
00110 C . CHECK FOR 'P' LEVEL MESSAGES
00111 C .
00112 . CALL SSWTCH(2,ISW2)
00113 . WHEN (ISW2 .EQ. 1) LMORE = .TRUE.
00114 . ELSE LMORE = .FALSE.
00115 C .
00116 C . ASK HOW MANY RUNS
00117 C .
00118 470 . WRITE (6,471)
00119 471 . FORMAT(//,' HOW MANY MONTE CARLO RUNS ? ',8)
00120 . READ (6,*,ERR=470) NRUNS
00121 . ...FIN
00122 C
00123 C

```

```

-----
00124 TO READ-SUMMARY-FILE-UNTIL-LAST-RECORD
00125 C ****READ SUMMARY FILE UNTIL LAST RECORD*****
00126 . IREC=0
00127 . LSMEOF = .TRUE.
00128 . REPEAT UNTIL (IREC .NE. IREC .OR. .NOT. LSMEOF)
00129 . . READ(4,IREC+1,ERR=489)IRC,LSMEOF,IRAN,JRAN,KEY,ATM,AXISAN,
00130 1. . BTIME,
00131 1. . COSNE,COSSH,DISTFD,DPNTNE,DPNTSW,PANG,(FANGLE(II),II=1,4),
00132 2. . FDISP,FLWONE,FLWOSH,FOLDAN,HT,RDPTDT,RTREND,SURNAT,THRW,
00133 3. . HYDCN(1,2) , ((HYDCN(II,J1),II=2,4),J1=1,3),
00134 4. . HYDCN1(1,2),((HYDCN1(II,J2),II=2,4),J2=1,3)
00135 . . IF (LSMEOF) IREC = IREC + 1
00136 . . ...FIN
00137 489 . CONTINUE
00138 D . WRITE (6,490) IREC
00139 490 . FORMAT(//,' RESTARTING ON RECORD ',I4)
00140 . WHEN (IREC .LT. 1 ) IBRTN = 1
00141 . ELSE IBRTN = IREC + 1
00142 . ...FIN
00143 C
00144 C

```

```

-----
00145 TO READ-SCALAR-DATA
00146 C ****READ SCALAR DATA*****
00147 C .
00148 C .
00149 C . THIS PROCEDURE READS THE SCALAR FILE DATA.
00150 C .
00151 C .
00152 . OPEN (UNIT=1,NAME='011:SCALAR2.DAT',TYPE='OLD',FORM='UNFORMATTED'
00153 +. ,READONLY)

```

```

00154 D . WRITE (6,*) ' SSSSSS READ SCALAR DATA SSSSSSS'
00155 . INP = 0
00156 . READ(1) NTOTAL
00157 . WHILE (I.EQ.I)
00158 . . READ (1,END=666) DATA1(INP+1)
00159 . . INP = INP + 1
00160 . ...FIN
00161 666 . CONTINUE
00162 . IF (INP.NE.NTOTAL) WRITE(6,15) INP,NTOTAL
00163 15 . FORMAT(' ERROR IN SCALAR ',I6,I5)
00164 . CLOSE (UNIT=1)
00165 . ...FIN
00166 C
00167 C

```

```

-----
00168 TO READ-POLYNOMIAL-DATA
00169 C *****READ POLYNOMIAL DATA*****
00170 C .
00171 C . THIS PROCEDURE READS POLYNOMIAL DATA FROM THE DATA FILE
00172 . OPEN (UNIT=1,NAME='DI1POLY2.CUR',TYPE='OLD',FORM='UNFORMATTED',
00173 + . ,READONLY)
00174 D . WRITE (6,*) ' SSSSSS READ POLYNOMIAL DATA SSSSSSS'
00175 . NPOLY2 = 0
00176 . READ(1) NTOTAL
00177 . WHILE (I.EQ.I)
00178 . . READ(1,END=777) ID
00179 . . NPOLY2 = NPOLY2 + 1
00180 . . IF (ID.LE.0 .OR. ID.GT.32)
00181 D . . . WRITE (6,*) ' ID=,ID, SET TO ,NPOLY2
00182 . . . ID = NPOLY2
00183 . . ...FIN
00184 . . READ(1) LOGTRX(ID),LOGTRY(ID),IORDER(ID),(COEFF(L,ID),L=1,11)
00185 . . ...FIN
00186 777 . CLOSE(UNIT=1)
00187 . IF (NTOTAL.NE.NPOLY2) WRITE(6,10) NPOLY2,NTOTAL
00188 10 . FORMAT(' ERROR IN POLY TOTAL',I5,I5)
00189 . ...FIN
00190 C
00191 C

```

```

-----
00192 TO READ-DENSITY-DATA
00193 C *****READ DENSITY DATA*****
00194 C .
00195 C . THIS PROCEDURE WILL READ IN THE DENSITY CURVE DATA.
00196 C .
00197 . OPEN(UNIT=1,NAME='DI1PROB2.DEN',TYPE='OLD',FORM='UNFORMATTED',
00198 + . ,READONLY)
00199 D . WRITE (6,*) ' SSSSSS READ DENSITY DATA SSSSSSS'
00200 . NDEN = 0
00201 . READ(1) NTOTAL
00202 . WHILE (I.EQ. I)
00203 . . READ(1,ERR=888,END=888) ICURV

```

```

00204      . . NDEN = NDEN + 1
00205      . . IF(ICURV.LE,0,OR, ICURV.GT.135)
00206 D      . . WRITE (6,*) ' ICURV =',ICURV,' SET TO ',NDEN
00207      . . ICURV = NDEN
00208      . . ...FIN
00209      . . READ(1) IOPTON(ICURV),LOGTR(ICURV),XLOW(ICURV),XHIGH(ICURV),
00210      +. . (CURVE(ICURV,K),K=0,20)
00211      . . ...FIN
00212 B88      . . CLOSE(UNIT=1)
00213      . . IF(NTOTAL.NE,NDEN) WRITE(6,11) NDEN,NTOTAL
00214 11      . . FORMAT(' ERROR IN TOTAL DENSITY ',I5,I5)
00215      . . CLOSE (UNIT=1)
00216      . . ...FIN
00217 C
00218 C

```

```

-----
00219      TO READ=LAYER-DATA
00220 C      *****READ LAYER DATA*****
00221 C      .
00222 C      . THIS PROCEDURE READS IN THE DATA FOR EACH LAYER.
00223 C      .
00224 C      .
00225 C      .
00226      . OPEN (UNIT=1,NAME='DI1: LAYER2.DAT',TYPE='OLD',FORM='UNFORMATTED',
00227      +. READONLY)
00228 D      . WRITE (6,*) ' ssssss READ LAYER DATA ssssss'
00229 C      .
00230      . READ(1,END=999)(ITYPE1(K),K=1,4)
00231      . WHILE (I.EQ. 1)
00232      . . READ(1,END=999) DELX1(1,2)
00233      . . DO(LAYER=2,4)
00234      . . . READ(1,END=999)(DELX1(LAYER,ISYSTH),ISYSTH=1,3)
00235      . . . ...FIN
00236      . . READ(1,END=999) REPDST(1,2)
00237      . . DO(LAYER=2,4)
00238      . . . READ(1,END=999)(REPDST(LAYER,ISYSTH),ISYSTH=1,3)
00239      . . . ...FIN
00240      . . ...FIN
00241 C      .
00242 C      .
00243 999      . . CLOSE (UNIT=1)
00244      . . ...FIN
00245 C
00246 C
00247      END

```

PROCEDURE CROSS-REFERENCE TABLE

00145 READ=SCALAR-DATA
00024

00192 READ=DENSITY-DATA

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00026

00124 READ-SUMMARY-FILE-UNTIL-LAST-RECORD
00061

00168 READ-POLYNOMIAL-DATA
00025

00034 OPEN-CLIMATE-FILE
00029

00219 READ-LAYER-DATA
00027

00043 CHECK-SENSE-SWITCHES
00028

(FLECS VERSION 22.46)

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