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Mapping Time-Dependent Changes in Soil Slip-Debris Flow Probability

by

Russell H. Campbell[1], Richard L. Bernknopf[2]

and David R. Soller[3]

A time-dependent statistical hazard function, derived from site studies, can forecast the probability that a debris flow will be initiated in a specified 100-m cell after a specified duration of heavy rainfall. The function is applied in a Geographic Information System to estimate the probabilities for all the cells in a study area in the Oakland hills and display their map distribution at different times during a rain storm.

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[1] 922 National Center
Reston, VA 22092

[2] 345 Middlefield Road, MS 975
Menlo Park, CA 94025

[3] 926 National Center
Reston, VA 22092

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Russell H. Campbell, Richard L. Bernknopf and David R. Soller
U.S. Geological Survey, Reston, VA

Abstract

Case studies of sites where times of occurrence for rainfall-triggered debris flows have been observed, supply duration data and explanatory variables that can be used to estimate the parameters of a statistical survivor function in which the conditional probability of survival decreases as a function of the duration of storm rainfall (time). The parameters, including coefficients for the explanatory variables, permit calculation of other members of the same parametric family, including the hazard function, which is defined as the probability that a rainfall-triggered soil slip-debris flow event will occur at a given time and place, provided no such event occurred there earlier in the storm. The statistical regression model includes explanatory independent variables representing slope, shear resistance, thickness of colluvium, and a time-dependent independent variable representing the cumulative effect of rainfall duration and rate. The dependent variable is a function of time at known times of debris-flow occurrence during the January 3-5, 1982 storm in the San Francisco Bay region. For a study area in the Oakland hills, the hazard function is used in a GIS environment to reconstruct the spatial distribution of probabilities for selected times during the 1982 storm, which is displayed in a sequence of maps. The method offers a potential for short-term (possibly real-time) revision of hazard assessments during rainstorms and, if linked with spatial and temporal socio-economic variables might be of use in prioritizing emergency response. The procedure also offers a rigorously defined framework for comparing the effects of different models (arrangements of explanatory variables) and of different earth-science variables on the map distributions of predicted probabilities, or for comparing the results yielded by applying the same model to different regions.

Introduction

Landslide risk can be expressed in terms of expected losses (safety and property damage) and applied in a decision framework regarding land use (e.g., mitigation) and hazard response (e.g., warning). The level of economic risk from potential landslide hazards cannot be estimated without first estimating the probability that a potentially damaging event will occur at a locality where a measured or estimated economic value is vulnerable to reduction if a landslide event occurs. This is a progress report on a multidisciplinary study to develop a method to estimate the regional distribution of different levels of risk from rainfall-triggered debris flows. Estimating time-dependent soil slip-debris flow probability for suitable subunits of area (e.g., "cells") in a region is an initial step in characterizing debris-flow risk. We have applied a statistical hazard function to forecast the probability that a debris flow will be initiated in a specified 100-m cell after a specified duration of heavy rainfall. Complete characterization of risk will require additions to the probability model to forecast the probability that a debris flow originating elsewhere will enter a specific cell.

In December, 1991, at the request of the California State Geologist, the U.S. Geological Survey began a study to forecast the risk of rainfall-triggered debris-flow damage in the area affected by the fire disaster of October 20, 1991, in the hills northeast of Oakland, California. Although the request was stimulated by the fire disaster, the intended issue was whether requirements for reconstruction should include mitigation measures to prevent damage from debris flows during the normal expected life of a rebuilt residential structure[1]. Therefore, the procedures reported here do not directly address the special effects of fire on hillside materials. (It has long been recognized that those effects may increase the potential for rainfall to result in debris-flow occurrences immediately following a fire, and during a recovery period, perhaps as long as a few years, while vegetation and other soil conditions return to "normal".) Mitigation measures, such as the engineered structures described by Hollingsworth and Kovacs (1981) and Baldwin and others (1987) have been designed and emplaced in both southern California and the San Francisco Bay region. It was expected that widespread post-fire reconstruction offered an opportunity to add protective structures that might prevent damage from future rainstorms. At present, the probability model addresses only the initiation of debris flows, and that only on natural (not recently burned) hillsides. Although it does not include the potential for hazard to a downslope or downstream area from debris flows originating at higher elevation, it does show time-dependent changes in the expected abundance of debris flows in different, relatively small drainage basins as rainfall persists. Therefore, these preliminary results may be applicable to hazard warning and mitigation issues.

One result of wild chaparral fires is that a burned area produces debris flows earlier in a storm, in greater volume, and, perhaps, from smaller storms having relatively brief and less-intense rainfall than would be expected to initiate debris flows from unburned slopes. Chaparral fires affect hillside materials in ways that increase the potential for rainfall-triggered debris-flow occurrence immediately following a fire and during a recovery period of a few months to a few years. These effects have been described by researchers such as Wells (1987), Morton (1989) and Spittler (1989). Although the differences in mechanisms are not fully understood, it is possible that further research will permit modification of our probability model to accommodate

[1] Another principal issue, the short-term protection of undamaged property adjacent to (especially downstream from) burned areas, from debris flows originating in the burned area, was already being vigorously pursued by other Federal agencies, as well as by State and local disaster response agencies, and by private contractors.

the changed expectations for the immediate post-fire condition. On unburned slopes there is usually some time delay between the start of storm rainfall and initiation of the earliest debris-flows, and those slopes may respond only to storms containing prolonged heavy rainfall. Storms of prolonged heavy rainfall are generally large in area, and burned areas may be only a small proportion of the region that is at risk from prolonged heavy rainfall.

Previous probabilistic analyses of landslide expectations have been generally static, aimed at developing guides to decisions regarding long-term mitigation (e.g., Bernknopf and others, 1988), and might be used to evaluate the expected benefits of adding mitigation measures to requirements for reconstruction in the disaster area. However, dynamic models of the sort developed in this study, which address temporal and spatial changes in degree of hazard, dependent on the specifics of a given storm, have a potential for short-term applications. A reliable forecast of the times and locations of different degrees of potential hazard might provide a rational basis for short-term evacuation warnings as one form of emergency response. Display of the forecast in map form offers a means to clearer communication of potential risk between emergency response managers and the public.

In this study, we generated a time-dependent statistical hazard function to forecast the probability that a debris flow will be initiated in a specified 100-m x 100-m area (a cell) after a specified duration of heavy rainfall. The hazard function is an equation that estimates the probability of initiating a rainfall-triggered debris flow at a hillside site after a specified duration of storm rainfall, conditional on no failure having been initiated at that site earlier in the storm. The equation, derived by regression, is used in a Geographic Information System (GIS) environment to calculate estimates of predicted probability of failure in each 100-m cell of a study area in the hills of Oakland, California. The GIS environment permits rapid input of map information into computerized analytical procedures and rapid display of analytical results in map form. Indeed, if the spatial data were in place at the beginning of a storm, and storm rainfall were monitored by continuously recording gages, hourly changes in predicted probability could be mapped in near real time.

Acknowledgements

Special thanks to S. D. Ellen for providing 1982 storm rain gage records from stations near sites where debris flows were observed at known times, and to G. F. Wieczorek for many leads to useful data in various articles in Professional Paper 1434. In addition, G. F. Wieczorek, S. D. Ellen, R. K. Mark and S. H. Cannon provided many helpful discussions about their studies of debris flows triggered by the 1982 storm, and R. K. Mark provided digital map data on post-storm inventories and elevations in the Oakland hills area. W. Moy assisted with early stages of preparation of a preliminary version of the regression database in LOTUS 1-2-3, installed the LIMDEP software, and ran the first regressions in LIMDEP. S. Price designed ARC/INFO plotting routines that organized the GIS map plots into panels. J. Spears, M. Falkenstein, and G.

Oppenheimer (the latter two served as USGS Volunteers) assisted in preparing data and illustrations. The GIS work was done in the USGS NMD-operated interdivision GIS laboratory in Reston, VA, and we are grateful to L. K. Peng for hardware and software systems administration support. We appreciate reviews by G. F. Wieczorek, D. M. Perkins and R. W. Jibson of a preliminary abbreviated summary of results (Campbell and Bernknopf, 1993). All these colleagues are from the U.S. Geological Survey. This paper has benefited from reviews by G. F. Wieczorek of the U.S. Geological Survey and by A. G. Barrows of the California Division of Mines and Geology. The use of brand names for commercial software is solely to provide an accurate description of procedures, and no endorsement by the U.S. Geological Survey is intended nor implied.

Overview of our approach

Historically, debris flows originating on natural slopes during prolonged heavy rainfall have posed a substantial threat of personal injury and property damage in hillside communities in many parts of the world. Researchers have explored a variety of deterministic physical models of the mechanisms by which these events are initiated and flow to lower elevations (e.g., Johnson, 1970; Campbell, 1975; Ellen, 1988; Wilson, 1989). A premise that underlies all of the physical models is that prolonged heavy rainfall results in an increased tendency for debris flows to occur in the area receiving the rainfall. A probability model for the initiation of debris flows during rainstorms can utilize variables of the sort employed by deterministic physical models, even though the probability model itself has no physical counterpart that is more specific than the premise. Statistical analysis was not used to seek to identify the significant explanatory variables because we felt that the deterministic models identified an appropriate set of variables. Moreover, in reporting observations from specific sites, experienced observers tended to include descriptions of properties that are useful for estimating variables known to be of importance in the deterministic models. Statistical analysis was used, primarily, to evaluate the statistical associations of a variety of explanatory variables to specific outcomes in the context of an established probability model.

Observations recorded during and after the January 3-5, 1982, storm in the San Francisco Bay region (SFBR) provide a data set, consisting of spatially and temporally significant variables, suitable as duration (or "survival") data for hazard function analysis by regression. The 11 sites identified on the index map (Figure 1.) are widely scattered over four SFBR counties. The same spatial variables were observed (or could be reasonably inferred from maps and text descriptions) for each site, and the times-of-occurrence of debris flows were also observed and described, chiefly in USGS Professional Paper 1434 (Ellen and Wieczorek, 1988).

Data from 9 continuously recording rain gages, each located near (within a few kilometers) one or more of the sites (from S. D. Ellen, 1992, written communication) were used to define the beginning and end of storm rainfall, which provides measures of the total duration (in hours) of exposure of cells in the vicinity of each gage, as well as the duration of survival (time-to-failure), *T*, for cells where soil slips occurred. The cumulative rainfall at each gage station, adjusted to show incremental increases only for times that rainfall intensity exceeds threshold minima that depend on the mean annual precipitation at the station (see Cannon and Ellen, 1988), provides a time-varying variable, CRI_T, that can be calculated from records for rain gages near the sites of failure.

The spatial data from the 11 sites and an identifier for a continuously recording rain gage near each site are summarized in Appendix A and in Table 1. The length of time from the beginning of a storm to the time of failure, or to the end of the period of observation, provides the duration of survival, *T*, which is substituted for *t* in a probability function that is the dependent variable in regression analysis. Because each incremental increase in the *CRI* that does not result in failure produces a separate observation of the duration of survival, *T*, the resulting data set attains a size that is the product of the number of sites and each time increment[2] between the beginning of the storm and the time of failure at the observed site. The time of failure is also termed the time that an observed cell "exits" from the set being observed. Cells in the vicinity of a failed site, that have virtually the same properties and essentially the same exposure as a failed site, are termed "censored"; they have survived beyond the end of the period of observation (the end of storm rainfall), and are treated in the regression program as asymptotic to failure at some future, unattained time. Using times-of-failure and times-of-censoring in a Weibull survival function as the dependent variables, regression yields coefficients for the independent variables and parameters appropriate for calculating the related density, distribution, and hazard functions.

FIGURE 1.--NEAR HERE

Hillside attributes for the Oakland hills study area were acquired in a GIS from regional maps of geology, soils, a landslide inventory, and digital line graph (DLG) data for roads, streams, and contours. Rainfall records from a nearby rain gage were used to reconstruct the *CRI* curves for the 1982 storm in the area. The hillside attributes and rainfall characteristics were used to calculate the probability estimates in the GIS environment, and the results are displayed in a panel of maps (Figures 13. A. - 13. J.). A comparison of the distribution of actual failures during that storm (from post-storm inventory mapping reported in Ellen and Wieczorek, 1988) with the distribution of probability categories forecast by the model for hour 36 (approximately the end of the storm rainfall) indicates that the actual failures constitute a representative sample

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[2] Where time is measured in hours, each hour of survival becomes a new observation. Time increments, however, do not need to be equal and, as a practical matter, if a rainfall rate is relatively constant for a period of two or more hours, that multi-hour period can be used as a single observation.

of the population at that hour.

Reading probability maps differs from reading susceptibility maps that show categories of "high", "moderate", or "low" potential for landslide hazard. In a landslide susceptibility map, one expects to find the greatest number of failures in areas designated as having the highest susceptibility, a lesser number in areas designated as moderate, and few or none in those of low susceptibility. The area occupied by each susceptibility category has no bearing on these expectations. In contrast, a landslide probability map is expected to have a number of failures in each probability category that is proportional to the population of cells (area) that fall in that category. The number of expected failures in each category, therefore, is the product of the probability and the number of cells in the category. Consequently, if the highest probability category is found in only a few cells, the expected number of failures may be substantially lower than is expected from a lower probability category that occupies an area of many cells.

Probability model

The probability model under study is an adaptation of statistical procedures for the development of hazard functions from the analysis of time-to-failure (or duration of survival) data, recently summarized by Kiefer (1988). Kiefer attributes the early development of these techniques to industrial engineering, where they have been used to describe the useful lives of various machines, and in the biomedical sciences, to describe events such as the survival times of heart transplant recipients. To paraphrase Kiefer's description, using the probability of a soil slip-debris flow event during a spell of heavy rainfall as an example, the central concept is not the unconditional probability of an event taking place, e.g., the probability that failure will occur at a specific location after exactly 12 hours of storm rainfall, but the conditional probability of failure in the 12th hour of the storm, given that no failure occurred at that location in the preceding 11 hours.

Hazard function analyses commonly utilize a probability model that can be described by a density function, that is, one having a continuous distribution (Cox and Oakes, 1984, p. 13). Kiefer (1988, p. 649) discusses difficulties in the application of normal and lognormal probability distributions, describes how a few of the most commonly used parametric probability distributions have been applied to the analysis of duration (or survival) data, and identifies how the behavior of the functions relates to reasonable natural conditions. For example, the constant hazard rate of an exponential distribution would be inappropriate as applied to rainfall-triggered soil slip-debris flows, because the likelihood of higher frequencies of debris-flow events is expected to increase with time as high rates of rainfall continue.

We specify the conditional probability P that a soil slip-debris flow will occur during a rainstorm at a given time, t, and place, k, on the condition that no landslide occurred there earlier in the storm. This specifies P as a Markov process[3] that has a discrete state space (slide at k, $s=\{0,1\}$)[4] and a continuous parameter space (time, $t=\{0,1,...,T\}$) (Bhat, 1984). In this kind of probability model, the rainfall causes a time-dependent change in the probability that the site will survive successive time increments of the storm. As rain persists at a rate exceeding some threshold minimum, the conditional probability that a soil slip-debris flow will occur is expected to rise, and a change in state (from s=0 to s=1) can be viewed as the consequence of time-dependent reductions in stability at k. The model is used to test the null hypothesis[5], H_0, in equation 1.

$$H_0\text{: } P_s^k(T) = P_s^k(0); \quad \textit{where } t=0,1,...,T; \quad k=1,...,K \tag{1}$$

To prepare an example, we used data available for the exceptional storm of January 3-5, 1982, in the San Francisco Bay region, when times of failure were observed for sites of several debris flows (Ellen and Wieczorek, 1988), and applied the model to an area of the Oakland hills.

The conditional probability of soil slips is derived from a cumulative probability distribution of duration, $F(t)=P_s(T\leq t)$, of the current physical state, s=0, for which the survivor function is $S(t)=1-F(t)=P_s(T>t)$ (Kiefer, 1988; Lancaster, 1990). The model assumes that the probability of survival continues to decrease with time as high-intensity rainfall continues. We chose the Weibull distribution to model duration data from the 1982 storm because it has the assumed property when the shape parameter, p, is greater than 1. In the notation of Greene (1991, p. 724), the model for the Weibull survivor function is equation 2.

$$S(t) = \exp(-(\lambda t)^p) \; ; \quad \textit{with } \lambda = e^{-(\beta_1 x_1 + \beta_2 x_2, ..., \beta_{nx_n})} \tag{2}$$

where x_i are independent variables (Greene, 1991). The coefficients, β, and parameter, p,

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[3]A Markov process is defined as a limited-memory sequence having the property of a one-stage memory. That is, an outcome at the second stage is only dependent on the outcome of the first stage, and not on outcomes at stages prior to the first.

[4] Soil slip-debris flow either occurs at k $(s=1)$, or does not occur at k $(s=0)$.

[5] Simply stated, the null hypothesis, H_0, is that the probability of a soil slip-debris flow occurring in any cell, k, at some future time, when $t=T$, during a rainstorm, is the same as the probability at the beginning of the rainstorm, when t=0. The alternative hypothesis, H_1, is that the probabilities for the same cell, k, are different for $t=0$ and $t=T$.

determined in the regression, also control the scale and shape, respectively, for the related Weibull probability density, probability distribution, and hazard functions (Figure 2).[6]

FIGURE 2.--NEAR HERE

Specifying the variables

The dependent variable is a function of time, which requires defining (1) a time of origin, (2) a scale for measuring time, and (3) a failure time that occurs only once for each site (Cox and Oakes, 1984). Cells in which a failure event occurs at an observed time are said to "exit" from the set of cells that make up the population under study. The functions assume that sites that survive the period of observation have failure times later than the end of the period of observation, and observations of their durations of survival are termed "censored". Clearly, there are several ways to specify the times of origin and ending of a rain storm from rain gage records. In the example reported here, the time of origin of the period of observation is specified as the beginning of a 2-or-more-hour period in which rainfall having an intensity greater than 0.25 mm/h (.01 in/h) is recorded at the nearest rain gage to the site of an observed failure; the end of the observation period is defined by the end of that rainfall rate at the same gage (see rainfall curves). The duration of survival, therefore, extends to either the time of failure (for sites where failure occurred) or beyond the censoring time at the end of storm rainfall (for sites that survived the entire storm).

Unfortunately, none of the SFBR case studies included direct observations of the number of censored cells in the vicinity of a failed cell. To be included with the same set of cells as a failed cell, a censored cell should also have spatial characteristics that are virtually identical (within the range of observation or measurement error) to those of the cell that failed at a known time. In the absence of direct observations, it was necessary to estimate a proportion of censored cells in the vicinity of each observed failed cell by extrapolating from data on overall slope frequency and failure frequencies in different slope categories assembled for San Mateo County by Wieczorek and others (1988). (Details of the procedure are described in Appendix B.)

The independent variables reflect (1) the prestorm stability at each site, as characterized by prestorm hillside characteristics, and (2) the destabilizing effect of rainfall, as characterized by rain gage records. To use hillside characteristics in a probability model, they must be represented by numbers (e.g., slope in degrees or percent). Moreover, the same variables must be observed (or readily estimated from descriptive records) at all the sites contributing to the

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[6] If $p=1$, the hazard function becomes a constant, which is the case for an exponential distribution. If $p<1$, the Weibull hazard function decreases with duration (Kiefer, 1988) and does not have the assumed property.

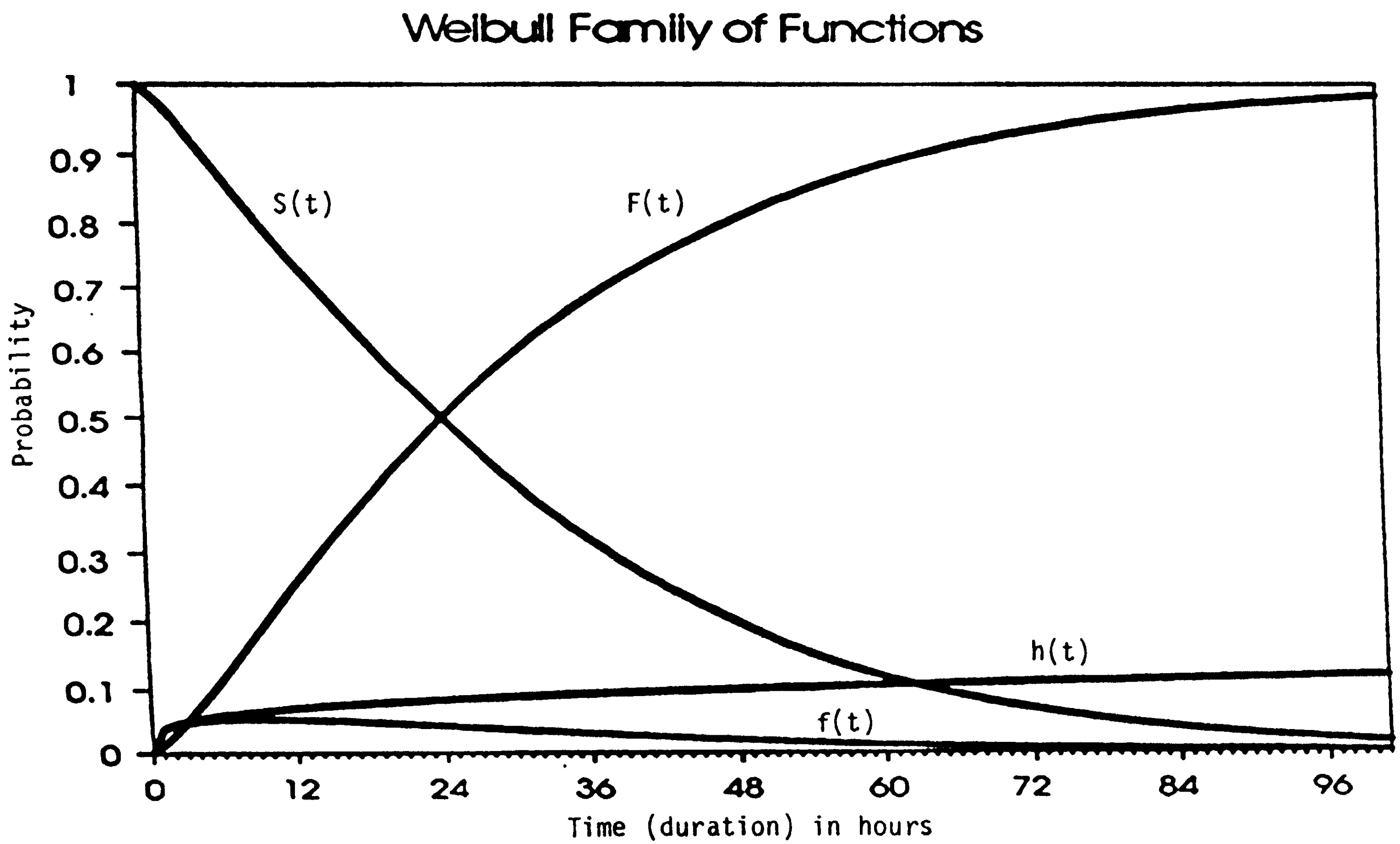


Figure 2. Related Weibull functions, extrapolated to 102 hours using mean values for x_i from the regression data set.
$S(t)$, survivor function;
$F(t)=1-S(t)$, cumulative probability distribution function;
$f(t)=dF(t)/dt,=\lambda p(\lambda t)^{p-1}exp(-(\lambda t)^p)$, probability density function;
$h(t)=f(t)/S(t)=\lambda p(\lambda t)^{p-1}$, hazard function.

regression database, as well as readily inferred from regional map data in areas where the regression equation will be applied. The variables described for failure sites in Appendix A, and summarized in Table 1 meet these criteria. However, it seems clear that greater comprehensiveness and more uniform quantitative results would be achieved if the case-study observations had been made with the specific objective of measuring and recording the variables used in this statistical analysis.

TABLE 1.--NEAR HERE

The spatial independent variables of Table 1 are slope, shear resistance, and thickness of colluvium. These are variables that are commonly significant in geotechnical analyses of slope stability and, although calculations based on properties estimated from descriptions and regional map data are clearly not stability analyses, they provide a systematic model within which information about the variables can be incrementally improved. Other workers, (e.g., Carrara and others, 1978; Mark, 1992) have found some geomorphologic features and vegetation associations to be statistically important factors in statistical assessments of factors affecting slope stability. Some of these factors, such as planar and profile curvature, can be derived from the same digital elevation model that yields data on slope; however, many other identified factors require special mapping (e.g., vegetation type and density, or classification of erosional characteristics). Because the scope of the present study is developmental, and constrained to use available (or very quickly acquired) regional map data, we suggest that these additional factors be considered in a context that relates them to one or another of the variables commonly used in geotechnical analyses.

Geotechnical models of slope stability utilize relatively few variables, and those are subject to uncertainty about how accurately they have been measured and how well measurements of samples represent the materials in areas adjacent to a sample locality. Uncertainty is significantly increased if those variables are estimated from site-specific descriptive narratives, and increased still further if estimated from regional map information rather than by geotechnical analysis of detailed site data, including testing for soil properties at closely spaced sample intervals. Moreover, the areal distribution of rainfall is hardly ever uniform over an area of more than a few square kilometers, and a widely spaced gaging network cannot capture the entire range of rainfall rates nor their local distributions. It is not surprising, therefore, that many rainfall-triggered soil slips occur in settings where adjacent, seemingly identical areas remain unfailed at the end of a storm. Presumably, relatively small differences in properties or rainfall that fall within the range of statistical uncertainty are responsible for a failure event occurring in one area and not in another of equal susceptibility.

Table 1. -- Tabular data for eleven sites of rainfall-triggered debris flows in the San Francisco Bay region during the storm of January 3-5, 1982 (see Fig. 1 for locations of numbered sites); showing observed time of occurrence on January 4, thresholds for rainfall rate, I_0 , which reflects whether mean annual precipitation is greater than or less than 660 mm at the nearest recording raingage; slope reported in case studies or measured from contours; shear resistance estimated from reported observations of soil properties, including geotechnical measurements of strength, where tested; thickness of colluvial soil as reported in case studies, and an estimate of the number of censored sites in the vicinity of each failed site based on statistical relations reported in USGS Professional Paper 1434. The threshold intensities in this example are approximately those of Keefer and others (1987). All failures occurred on January 4, 1982, at the time-of-day (TOD) shown in 24-hour format. "Time to fail (h)" is number of hours from start of continuous storm rainfall at intensity .25 mm/h (.01 in/h) or greater to time of observed debris flow. The procedure for estimating the number of unfailed (or "censored") cells, in the vicinity of and having the same hillside characteristics as the cells in which failures occurred, is discussed in the text (especially Appendix B).

Site Num.	$I_{(0)}$ (mm/h)	TOD fail.	Time to fail (h)	Slope (deg)	Shear resistance (deg)	Thickness (m)	Number censored
1	6.86	1930	25	30°	30°	4.5	13
2	6.86	1310	18	38°	35°	4.3	9
3	6.86	2115	28	30°	40°	1.8	13
4	4.57	2310	29	26°	40°	3.9	8
5	6.86	1900	25	31°	40°	7.7	8
6	4.57	2100	28	26°	40°	1.0	9
7	4.57	1200	25	20°	40°	2.0	3
8	6.86	1400	20	26°	40°	2.0	5
9	6.86	1030	23	23°	40°	2.0	4
10	4.57	1234	20	26°	40°	0.5	11
11	4.57	2000	28	17°	30°	1.5	16

Most site descriptions include either a direct observation of the slope angle or a detailed topographic map from which it can be measured for the locations where failures began. At a few sites, however, slopes could only be measured from the contours of the 7.5' quadrangle maps. Within the Oakland hills study area, a digital line graph of the topographic contours was available, and provided the basis for a good quality digital elevation model(DEM) at 30-meter spacing. From the DEM, slope angles were derived for each 100-meter cell in the area.

An angle of shear resistance was estimated for the colluvium at each of the 11 failure sites. Geotechnical measurements of samples were available only for Site 4, where direct shear test results are reported to have internal friction angles ranging from 26° to 39°. Because of the sparseness of test measurements, we adopted a systematic procedure to estimate an angle of shear resistance from descriptions of the colluvium and underlying parent material that could also be applied to regional map data in the Oakland hills. A shear resistance of 40° was assigned for colluvium derived from metamorphic rocks, unaltered igneous rocks, or very well indurated sedimentary rocks; 35° was assigned for colluvium derived from moderately indurated sedimentary rocks, including shales; and 30° was assigned for colluvium derived from unconsolidated surficial deposits, including preexisting landslide deposits. These three categories also represent the expectation that the stronger bedrock materials give rise to colluvium that contains larger and more abundant clasts in the gravel and boulder size range and, therefore, stronger colluvium. The categories fall within the range of angles of shearing resistance reported by Terzaghi and Peck (1967, p. 107) as representative for sands and silts. The selection of shear-resistance categories was aided by G. F. Wieczorek (written communication, 1992) who earlier led development of the categorization of shear strengths used (Wieczorek and others, 1985) for analyzing regional slope instability during earthquakes. In the Oakland hills area, categorization of shear resistance was assisted by the observations of Radbruch (1957), Radbruch and Case (1967) and Nilsen (1975), and by descriptions of hillside materials units provided by S. D. Ellen and C. M. Wentworth (written communication, 1992) from a manuscript they are preparing on hillside materials and slopes of the San Francisco Bay region, California. Although our estimation procedure may not be suitable for some applications, for methods development purposes it does provide consistent preliminary estimates of broad categories of shear resistance in slope materials.

Thickness of colluvium was observed and reported for many of the sites of failure summarized in Appendix A; for the remainder, thickness could be reliably estimated from published photographs and maps, tabulated descriptions of sample locations, or regional associations. Within the Oakland hills study area, thickness was estimated based on the descriptions of soils series map units in reports prepared by the U.S. Soil Conservation Service (Welch, 1977; Welch, 1981).

Functional combinations of some variables were also prepared and tested in the regression analysis. An example of a functional combination is the *stability index (SI)*, defined as the ratio of the tangent of the slope angle to the tangent of an angle of shear resistance of the hillside material. This ratio has the form of a dry factor-of-safety, to which it is analogous; but it is clearly not the result of, nor a substitute for, a geotechnical analysis of slope stability.

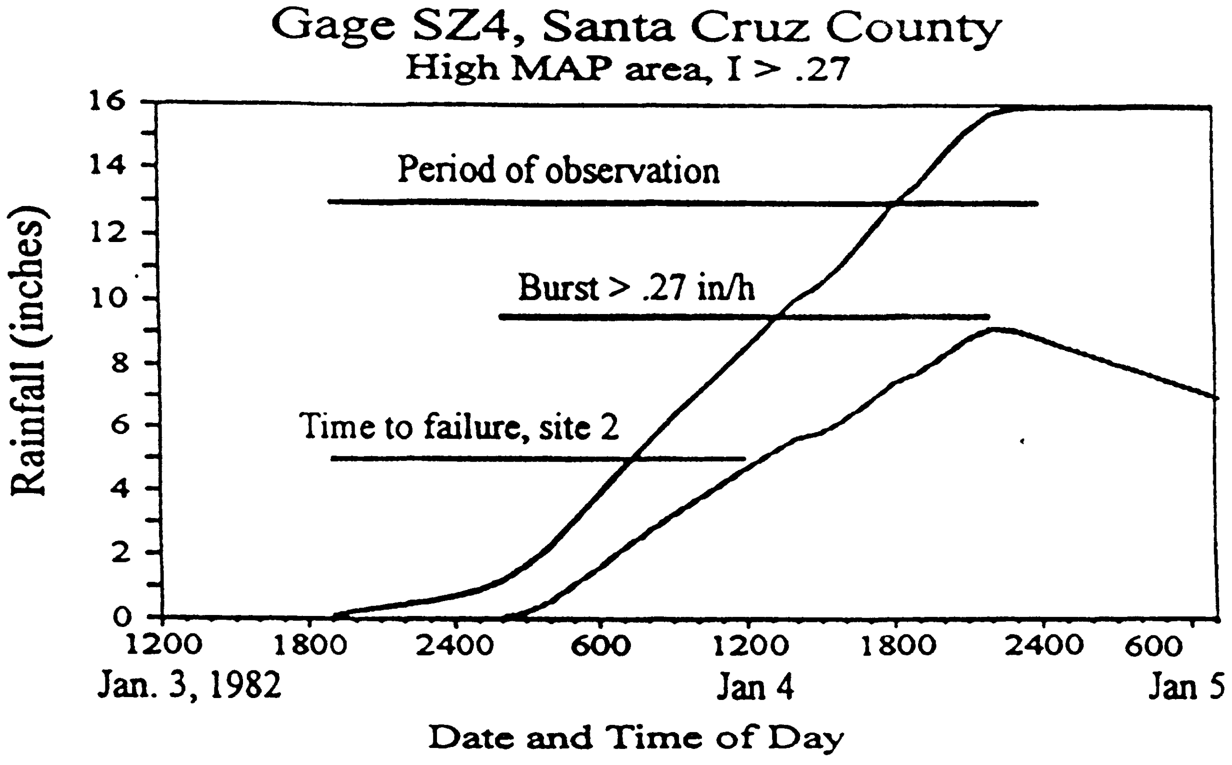
A separate independent variable represents the cumulative effect of rainfall at time, *T*, as a function of rainfall intensity and duration. Several workers have suggested that debris flows are triggered only after minimum conditions of rainfall intensity and duration have been achieved (e.g., Campbell, 1975) and some have suggested functional forms for limiting minimum combinations of intensity and duration (e.g., Caine, 1980; Wieczorek and Sarmiento, 1988; Cannon and Ellen, 1988). Keefer and others (1987) have applied empirically derived thresholds to procedures for monitoring a network of telemetered rain gages to provide regional warnings about the potential of an ongoing storm to trigger debris flows in the SFBR. The empirical thresholds are thought to represent a dynamic balance between rates of rainfall input to slope-surface materials and output from those materials by deep percolation, lateral drainage or surface runoff. Where input rates exceed output rates, water can accumulate in the pores and, in sufficient amounts, cause increases in pore pressure and a consequent reduction in shear resistance at a potential slip surface, commonly at or near the base of the colluvium. Wilson (1989) has developed a theoretical deterministic model that describes these physical relationships.

Our probability model incorporates the notion of an empirical threshold (or thresholds) in a time-varying variable that is derived from recording rain gage records using a simple difference equation. The equation permits selecting any threshold intensity, I_0, between 0 and the maximum rate recorded at a site. Although we have used constant I_0's in the present study, the difference equation could, if desired, apply a time-dependent function such as that of Caine (1980) or Cannon and Ellen (1988) to determine a threshold intensity for a selected time. The *cumulative rainfall index* (CRI_T) is a convenient way to characterize a cumulative effect at time (T) for bursts of rainfall rates (I) in time interval (t) that exceed selected minimum rates (I_0) (Figure 3). It is calculated as:

$$CRI_T = CRI_{T-1} + (I_t - I_0)t; \quad Subject\ to\text{: } CRI_T \geq 0 \tag{3}$$

FIGURE 3.--NEAR HERE

The I_0's used in preparing the regression database of Appendix B are 6.9 mm/h (.27 in/h)



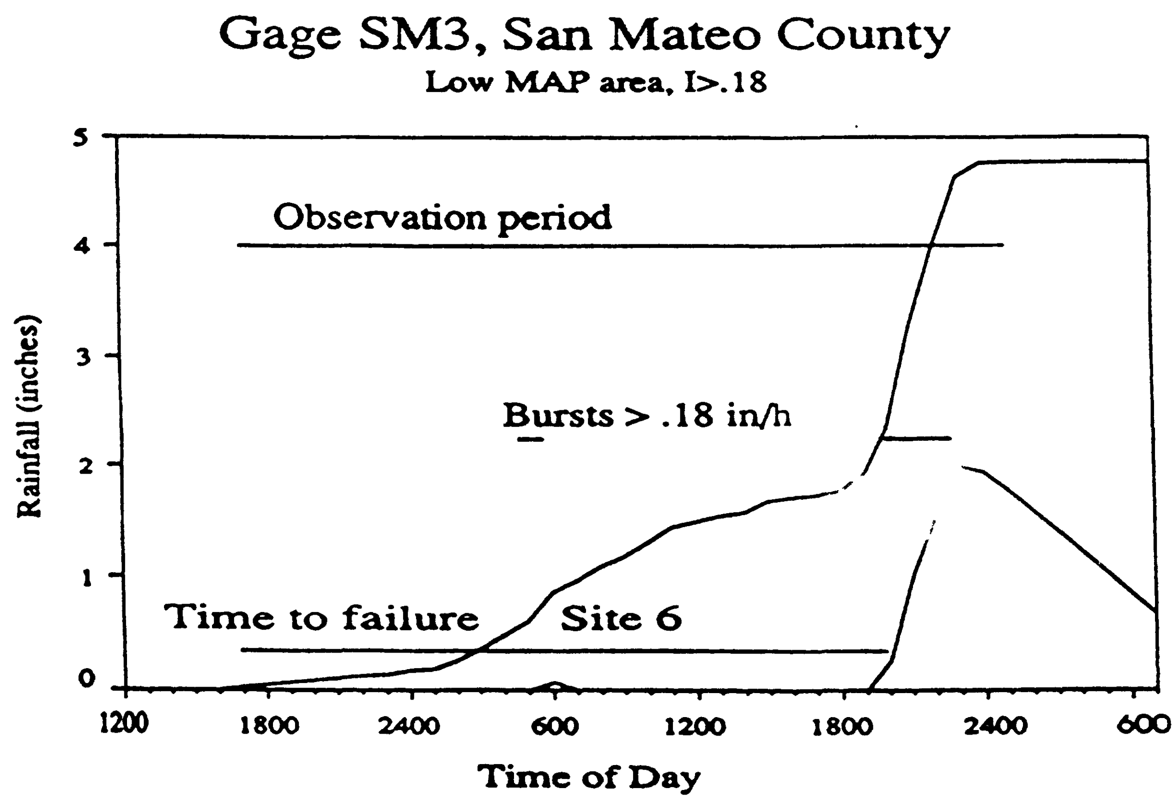


Figure 3. Rainfall curves illustrating *CRI* at two different gages: SZ-4 - A gage in Santa Cruz County in an area having a high (greater than 660 mm) mean annual precipitation (MAP); and SM-3 - a gage in San Mateo County in an area having low (less than 660 mm) mean annual precipitation. At both gages, upper curves are total cumulative rainfall; lower curves are cumultive (*CRI*) rainfall from equation 3, using an I_0 of 6.8 mm/h (.27 in/h) for SZ-4, a high MAP gage, and an I_0 of 4.6 mm/h (.18 in/h) for SM-3, a low MAP gage.

and 4.6 mm/h (.18 in/h), where gages are in areas having mean annual precipitation (MAP) greater or less than 660 mm (26 in), respectively. The use of two thresholds follows the work of Cannon and Ellen (1988) which shows that, in the San Francisco Bay region, areas receiving MAP greater than 660 mm have higher threshold intensities than areas receiving MAP less than 660 mm.. In the present study, the specific minima were chosen because, at the observed times of failure, they were exceeded by the rainfall rates at all gages near the failure sites. The CRI_T may be combined with spatially variable hillside characteristics if the independence of the variables is not compromised. For regression and computation in the present example, the (CRI_T) can be used alone or in combination with the thickness of colluvium (estimated from case studies and soils maps) in a ratio M so that the product, MSI, is a time-varying fraction of SI.

The foregoing variables were selected for specification because they had been observed and reported at case study sites, or could be easily estimated from maps and descriptive reports that included the case studies; in addition, the same variables could be estimated from regional data available for selected areas where a probability equation using them might be applied. Although some combined forms, such as the *stability index*, may be analogous to some simple deterministic geotechnical models, it would be misleading to regard them as physical models. The probability model treats them simply as convenient combinations of individual variables. The probability model would accept more variables (and more complex combinations of variables) if the relevant data were available for both regression and map area application.

Regression

The table of data from 11 sites, in widely scattered parts of the San Francisco Bay region, lists debris flows that occurred during the storm of January 3-5, 1982 (Fig. 1), their observed time of occurrence on January 4, thresholds for rainfall rate, I_0, at the nearest recording rain gages, the hillside characteristics at those sites, and an estimate of the number of unfailed (censored) sites in the vicinity of each site of failure. The spatial variables were examined by regression in combination with each of two time-varying variables, cumulative rainfall (CUMR) and CRI, both individually and in combination with other spatial variables. Table 2 shows results of regressions on 20 different sets of variables, including some functional combinations.

TABLE 2.--NEAR HERE

Regression on equation 2, the survival function, yields the kinds of coefficients and other statistics tabulated in Table 3 for the last model listed in Table 2. Regressions were run using the commercial econometric software package LIMDEP, Version 6.0 (Greene, 1991). (Appendix C

Table 2. Table comparing different regression models. Explanatory variables include: CUMR, cumultive rainfall from start of period of observation; CRI, indexed cumulative rainfall (from equation 3); SLOPE, tangent of the slope angle at site of initiation; SS, tangent of the angle of shear resistance; CT, thickness of colluvium; SI, stability index, SS/SLOPE; Mm, ratio CUMR/CT; Mi, ratio CRI/CT. In addition to parameters and coefficients, regression yields t-ratios for each variable, a quartile survivor distribution, and model log-likelihood. All models have high model log-likelihood. For 111 degrees of freedom, the critical limit for 90% acceptance is 1.28 or higher, so nearly all the variables are significant at or above that level in all but 5 of the models (6, 9, 10, 11, 12). Five models (1, 2, 3, 7, 8) yield parameters, *p*, less than 1, and are, therefore, incompatable with the underlying premise of increasing probability with duration of intense rainfall. Four of those models (1, 2, 7, 8) show unrealistically short durations for survival of 50% of cells (the average time to failure at the 11 sites of Table 1 is 24.5 hours). Of the 10 models remaining, all appear to be statistically acceptable. For the maps displayed in this report we selected model 20, for which regression results are listed in Table 3 and Appendix E.

MODEL	T-RATIOS FOR THE VARIABLES									*P*	SURVIVAL DISTRIBUTION (HOURS)			
	CUMR	CRI	SLOPE	SS	CT	SI	Mm	Mi	MSI		95%	75%	50%	25%
1. CUMR	-3.159	NA	NA	NA	NA	NA	NA	NA	NA	0.127	0.00	0.00	0.00	0.01
2. CRI	NA	-3.750	NA	NA	NA	NA	NA	NA	NA	0.169	0.00	0.00	0.01	0.53
3. SLOPE, CUMR	-7.503	NA	16.611	NA	NA	NA	NA	NA	NA	0.845	0.85	6.54	18.5	42.1
4. SLOPE, CRI	NA	-7.611	25.605	NA	NA	NA	NA	NA	NA	1.023	2.12	11.5	27.1	53.30
5. SS, CUMR	-2.494	NA	NA	30.674	NA	NA	NA	NA	NA	1.592	6.25	18.5	32.1	49.61
6. SS, CRI	NA	-0.624	NA	42.349	NA	NA	NA	NA	NA	1.656	6.87	19.4	33.1	50.24
7. CT, CUMR	-4.457	NA	NA	NA	5.321	NA	NA	NA	NA	0.149	0.00	0.00	0.00	0.01
8 CT CRI	NA	-8.488	NA	NA	11.653	NA	NA	NA	NA	0.328	0.00	0.16	2.27	18.77
9. SLOPE, SS, CT, CUMR	-3.422	NA	.810	11.517	4.239	NA	NA	NA	NA	1.330	3.88	14.2	27.5	46.28
10. SLOPE, SS, CT, CRI	NA	-0.287	-1.365	12.773	1.722	NA	NA	NA	NA	1.697	7.19	19.8	33.3	50.15
11. SLOPE, SS, CUMR	-2.52	NA	1.271	12.563	NA	NA	NA	NA	NA	1.493	5.37	17.0	30.7	48.89
12. SLOPE, SS, CRI	NA	0.532	-1.198	14.556	NA	NA	NA	NA	NA	1.728	7.46	20.2	33.7	50.28
13. SI, CUMR	21.093	NA	NA	NA	NA	21.093	NA	NA	NA	2.936	15.3 2	27.6	37.2	47.10
14. SI, CRI	NA	31.847	NA	NA	NA	104.76	NA	NA	NA	3.870	17.9 7	28.0	35.2	42.11
15. SI, CT, CUMR	4.355	NA	NA	NA	5.442	57.203	NA	NA	NA	3.107	15.6 3	27.2	36.1	45.15
16. SI, CT, CRI	NA	14.005	NA	NA	4.386	95.666	NA	NA	NA	4.114	18.7 9	28.6	35.4	41.87
17. SI, Mm (Mm=CUMR/CT)	NA	NA	NA	NA	NA	40.553	-6.55	NA	NA	1.186	3.07	13.1	27.5	49.37
18. SI, Mi (Mi=CRI/CT)	NA	NA	NA	NA	NA	38.982	NA	-5.16	NA	1.129	2.74	12.6	27.5	50.86
19. SI, MSI=Mm*SI	NA	NA	NA	NA	NA	42.515	NA	NA	-7.47	1.233	3.37	13.6	27.8	48.83
20. SI, MSI=Mi*SI	NA	NA	NA	NA	NA	41.269	NA	NA	-6.49	1.175	3.03	13.1	27.8	50.21

is an example of a LIMDEP regression command file. Appendix D is the data file used in the regressions reported here; and Appendix E is an example of a LIMDEP report on regression results.) Regression was repeated for the combinations of variables listed in Table 2. Five of the models (6,9,10,11,12) include one or more variables for which t-ratios are below the critical limit (1.28) for 90% acceptance. Five models (1, 2, 3, 7, 8) yield shape parameters, p, that are less than 1.0 and produce grossly inappropriate percentile distributions for survival; these models, therefore, yield probabilities that decrease with duration of high-intensity rainfall from an instantaneous high at hour 1, which is not compatable with the premise that higher frequencies of debris-flow events are expected to occur with greater duration of high-intensity rainfall. The survival functions for five of the models are shown in Figure 4, of which four appear to be appropriate for further application (the curve for *CRI* alone has parameter $p = .169$, which is incompatable with the assumed property that the probability of survival decreases with time while high-intensity rain continues). The curve for *SI, CRI* has $p = 3.87$, which provides for a slow increase in failure probability during the early hours of the storm, but the probability of survival drops to 0 after only about 64 hours, the shortest survival time among the four models. The curve showing the highest frequency of survival at long durations is the model using *SI* and *MSI* (where $M=CRI_T/39CT$). For this model, the variables are conveniently expressed in the same physical units, their correlation coefficient is low, and their signs relate them in a manner analogous to a physical model in which initial stability, *SI*, is incrementally reduced by a fraction, *MSI*, that is a function of rainfall rate and duration. Therefore, we selected this model for use in calculating the time-dependent spatial distribution of probabilities in the area chosen for mapping.

TABLE 3.--NEAR HERE

FIGURE 4.--NEAR HERE

Mapping soil slip-debris flow probability

The coefficients and parameters determined by the regression are then used to calculate hazard function probability estimates for each cell *(k)* in the Oakland hills study area for each hour of the storm. For the selected model, the hazard function, *h(t)*, is:

$$h = p t^{p-1} \lambda^p = 1.17 t^{.17} (e^{-(2.51 SI - 2.54 MSI)})^{1.17} \quad (4)$$

The maps, as plotted in Figures 13.A.-13.J., were prepared digitally as a cover in ARC/INFO, version 5.1, for the northwest quarter of the Oakland East 7.5 minute topographic quadrangle. Rain gage data from gage station A-5 were used to reconstruct the *CRI* and *CUMR* curves

Table 3. Regression results for the model SI, MSI, where MSI = (CRI/(39 x CT)) x SI. Both variables are significant, and the coefficients have the expected signs. These coefficients and parameter, p, are used to calculate the conditional (hazard function) probabilities shown in Figures 13A-13J.

Variable	Coefficient(β)	t-ratio	Mean of x	Std. Dev. of x
SI	2.51	41.3	1.57	0.33
MSI	-2.54	-6.5	0.12	0.20

Log-Likelihood -468.9; p=1.17; λ=.03; Median time to failure=28 h
Correlation coefficient for SI, MSI = 0.04

Percentiles of individuals surviving to time t

SURVIVAL	0.25	0.50	0.75	0.95
TIME	50.2	27.8	13.2	3.0

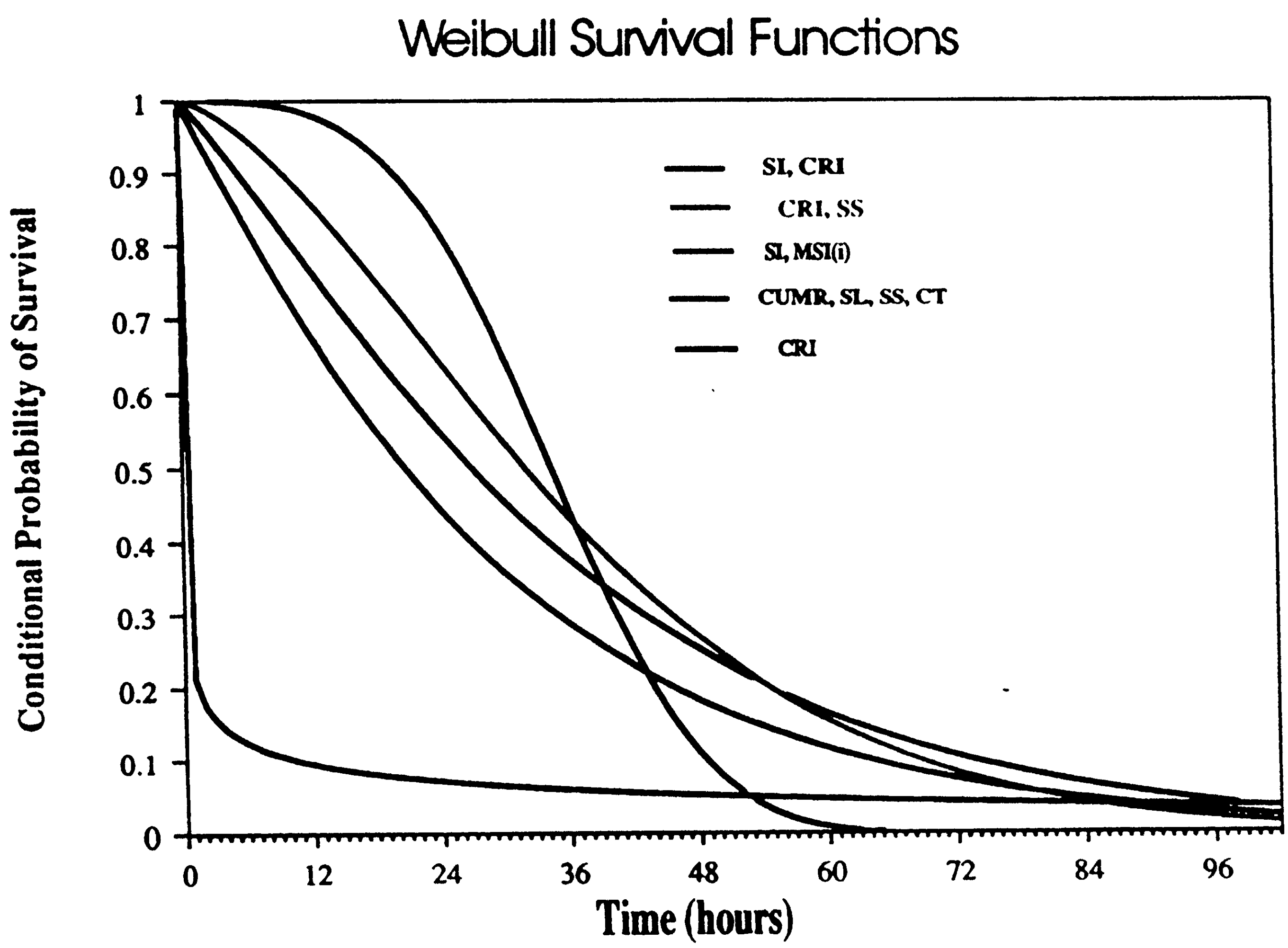


Figure 4. Weibull survival functions for averages of the variables in the regression data set, showing regression results for several combinations of the variables. Except for the regression on *CRI* alone (magenta) these curves have acceptably high log-likelihood, and the T-ratios for the variables are significant. Of these, we selected the model using *SI* and *MSI* for use in calculating the probabilities shown on the maps.

(Figure 5) for the January 3-5, 1982 storm as representative of the study area. Base map data are from USGS digital line graphs (DLG's) for roads, streams, and contours, in the quadrangle (Figure 6). The contour DLG was used to prepare a digital elevation model from which a shaded relief map (Figure 6) and a slope map (Figure 7) were derived. Geologic map units (Figure 8) were digitized from the map of Radbruch (1969), and additional landslides and surficial features, such as quarry areas, (Figure 9) were digitized from the landslide inventory of Nilsen (1975). Angles of shearing resistance were then assigned to each of the map units, following the procedure described above (p. ?), and calculated into the polygon attribute tables (.PAT's) of the map covers. Soils map units for Alameda and Contra Costa Counties (Welch, 1977; Welch, 1981) were digitized, joined, and reprojected (Figure 10). From the descriptions of the soils units, average thicknesses were assigned to the map units and calculated into the .PAT of the map cover.

FIGURE 5.--NEAR HERE

FIGURE 6.--NEAR HERE

FIGURE 7.--NEAR HERE

FIGURE 8.--NEAR HERE

FIGURE 9.--NEAR HERE

FIGURE 10.--NEAR HERE

All maps were prepared (reprojected where necessary) in the UTM projection. A cover consisting of an empty mesh of 100-meter cells was generated for the area, and successively intersected with the slope, geologic, landslide, and soils maps. Slope, shear resistance, and thickness of colluvium were then calculated from the intersected covers into the related .PAT of the empty mesh of cells; where intersected cells contained two or more subdivisions of the cell, each containing different values, an area-weighted averaged was calculated and transferred to the appropriate mesh cell. Calculations of probability for each selected hour of the 1982 storm were carried out in INFO and placed into the .PAT of the mesh cover. (Appendix F lists the macro command files used to compute the probabilities in INFO.) Maps of the distribution of the predicted conditional probabilities for 10 selected hours are shown in the panel of maps reconstructing the effects of the 1982 storm (Figure 13 A-J).

FIGURE 13.--NEAR HERE

Discussion

The resulting maps show the distribution and abundance of cells having conditional probabilities that fall within the specified probability categories. In reading and interpreting the probability maps, it may be useful to bear in mind that the definition of the probability of an event can be stated (Weaver, 1963) as follows: "The probability of an event E is defined by the equation:

$$P(E) = \frac{n}{N} \quad (5)$$

where N is the total number of equally probable outcomes, and n is the number of outcomes which constitute the event E." Therefore, in the universe of hillside cells, there is a subset, $N_{T,k}$, having predicted probabilities at time T within the range that defines the category, for which the number of expected failures is $n_{T,k}$. Note that, unless a probability category is 1.0 or 0.0, all categories are expected to have a number of failures at time T that is a function of the number of cells in the category ($N_{T,k}$) and their predicted probability, that is:

$$n_{T,k} = N_{T,k} * P_{T,k}(E) \quad (6)$$

It follows that, in reading and interpreting a landslide probability map, the expectations are somewhat different than those for a landslide susceptibility map, in which the greatest number of failures are generally expected to occur in the highest category of susceptibility. In a landslide probability map, by contrast, the number of expected failures depends on both the probability category <u>and</u> the number of cells in that category. This is the basis on which a Kolmogorov-Smirnov test[7] (Figure 12) can be applied to compare the distribution of predicted probabilities with the distribution of failures as inventoried after the end of the 1982 storm. Figure 12 compares the cumulative relative frequency distribution of *expected* failures in hour 32 (the hour for which hazard function probability is highest) with the cumulative relative frequency distribution of failures identified in a post-storm inventory.

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[7] For a discussions of applications of the Kolmogorov-Smirnov test see standard texts such as Lindgren and McElrath (1967, p. 151-153), Davis (1986, p. 99-101), or Soong (1981, p. 322-325).

A couple of simple examples may help illustrate the contrast in expectations from the two types of maps. In a landslide probability map, suppose a population of 1,100 cells were composed of two unequal subsets, one subset of 100 cells having 10 percent probability of failure in the hour ending at *T*, and another subset of 1,000 cells having 1 percent probability of failure in the same hour. Clearly, the expected number of failures in the first subset (10) is the same as the expected number of failures in the second subset. Landslide probability map performance is judged by how well the *expected distribution* of failed cells is matched by a post-storm inventory. In contrast, consider a landslide susceptibility map showing categories of "high", "moderate", and "low" susceptibility to landsliding. One rational way to judge the performance of the map would be to establish two criteria. The first criterion might be that areas designated as "low" susceptibility should not include more than 5 percent of the failed cells after a maximum triggering event. The second criterion might be that a majority (51 percent or greater) of the failed cells should occur within areas labeled "high" in susceptibility, permitting as many as 44 percent of the failed cells to occur in areas labeled "moderate" in susceptibility. If we apply these criteria to the curve for percentage of the cumulative frequency in the study area from the post 1982 storm inventory (see Fig. 12.), we would assign a probability of about 0.001 (0.1 percent) to the break between "low" and "moderate" susceptibility, and a probability of about .02 (2.0 percent) as the minimum probability in the "high susceptibility" category. In other words, a landslide susceptibility map derived from Figure 11 using the postulated criteria would have a "low susceptibility" map unit that included all cells having slopes less than 14 degrees and all hillside cells having probabilities less than 0.001; it would have a "high susceptibility" map unit that includes all hillside cells having probabilities of 0.020 and greater, and a "moderate susceptibility" map unit that includes all hillside cells having probabilities between 0.001 and 0.020. These breaks suggest the scale used to categorize probability on the maps (Figs. 11, 13A-13J), which indicates that probabilistic procedures can successfully subdivide broad categories of landslide susceptibility.

FIGURE 11.--NEAR HERE

FIGURE 12.--NEAR HERE

The procedure we have developed yields the conditional probability that a soil slip will occur in a map cell at a time *T* during a storm if (1) no failure has occurred in that cell before *T* and (2) rainfall continues to *T*. As relative probability levels they indicate that the null hypothesis of equation 1 should be rejected. Clearly, the predicted probabilities are not equivalent to a deterministic prediction that specific sites will fail or will not fail. However, the Kolmogorov-Smirnov test indicates that the probabilities predicted by a simple time-dependent model accurately portray the frequency distribution of observed failures. The procedure also presents a rigorously defined framework for comparing the results achieved by adding new variables or combinations of explanatory variables, or for comparing the results yielded by applying the same equation in different regions.

Because the equation for estimating time-dependent probabilities as displayed on the maps (Figs. 13 A-J) was built by regression on rainfall and landslide data for the 1982 storm in the SFBR, it may be less valid as a forecast tool for soil slip-debris flow events where applied to other storms and other regions, which should be tested individually. However, because the rainfall at each case study site is characterized from a separate gage record (except for two instances where two sites are associated with one gage), the function is theoretically independent of a particular storm or region, and statistical bias could be reduced by adding to the regression database information from case studies from other regions and other storms. The accuracy of the results could probably be improved by adding some specific observations to those commonly recorded in case studies (e.g., direct observation of the proportion of unfailed slope areas in the vicinity of a studied failure site).

The results reported here are preliminary, and may be improved by further study. For example, some other probability distribution (e.g., a gamma function) might perform incrementally better than the Weibull distribution, additional spatial variables (e.g., permeability, void ratio, etc.) might be acquired and included to develop a more complex model or set of models, more case studies (including representatives of other regions and other storms) could be added to the regression database, or more accurate ways to estimate regional variations in slope, shear resistance, and colluvium thickness may be devised. The shape and scale of the functions are sensitive to (1) variations in the proportion of censored (unfailed) to exited (failed) cells having the same attributes, (2) the specification of the observation period, (3) the geomorphic and geologic properties selected for regression, and (4) the I_0 selected for minimum rate of rainfall. Clearly, better observational input should improve the model. However, the present results encourage further exploration of this and similar models, and their potential, if linked with spatial and temporal socio-economic variables, to identify and delineate rainfall-induced short-term increases in debris-flow risk.

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Appendix A. Regression Data Sites and Sources

Summary information on selected sites having well-established times of failure from case studies or other descriptive observations noted in USGS Professional Paper 1434 (Ellen and Wieczorek, 1988):

1. Alba Road, Ben Lomond, Santa Cruz County, Felton 7.5' quadrangle (Wieczorek and others, 1988, p. 153-155, and Table 8.5 p. 146)
   - Failure time, 19:30, 1/4/82: initial slump, 15:00; mobilized to debris flow from slow slide between 19:30 and 20:00.
   - Rain gage: sz-1[1] (Brackney?), HIMAP[2], MAP ~1180 mm (46 in) use CRI for I_0 = 6.9 mm/h (.27 in/h)
   - Duration of storm rainfall prior to failure: 21 hrs to initial slump, 25 hrs to debris flow
   - Prestorm seasonal rainfall: 800 mm (31.5 inches)[3]
   - Slope: 0.577350 (30 deg)
   - Shear resistance (est.): 0.700208 (35 deg)
   - Thickness of colluvium: 4.5 meters
   - Debris-flow frequency[4]: 5/km^2
   - Estimate approximately 13 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 1

2. Creekwood Dr., Lompico, Santa Cruz County, Felton 7.5' quadrangle (Wieczorek and others, 1988, p. 155-156, Table 8.5 p. 146)
   - Failure time, 13:10, 1/4/82
   - Rain gage: sz-4[1] (Loch Lomond?), HIMAP[2], MAP ~1180 mm (46 in) use CRI for I_0 = 6.9 mm/h (.27 in/h)
   - Duration of storm rainfall prior to failure: 18 hrs
   - Prestorm seasonal rainfall: 800 mm (31.5 in)
   - Slope: 0.781286 (38 deg)
   - Shear resistance (est.): 0.700208 (35 deg)
   - Thickness of colluvium: 4.3 meters
   - Debris-flow frequency[4]: 10/km^2
   - Estimate approximately 9 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 2

3. Madrone Park Cir., Mill Valley, Marin County, San Rafael 7.5' quadrangle (PP-1434 Case Study 3, p.68-69, Fig. 6.2 p. 67, Table 6.1 p. 72)
   - Failure time, 21:15, 1/4/82
   - Rain gage: m-4[1] (Mill Valley?), HIMAP[2], MAP ~900 mm (35 in), use CRI for I_0 = 6.9 mm/h (.27 in/h)
   - Duration of storm rainfall prior to failure: 28 hrs

Prestorm seasonal rainfall: 700 mm (27.5 in)
Slope: 0.577350 (29 deg)
Shear resistance (est.): 0.839100 (40 deg)
Thickness of colluvium: 1.8 meters (estimated from photos, p. 70, 71, in Ellen and others, 1988)
Debris-flow frequency[5]: 3-5/km^2
Estimate approximately 13 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 3.

4. Oddstad Blvd., Pacifica San Mateo County, Montara Mountain 7.5' quadrangle (Howard and others, 1988, p. 171-175 and Table 9.1, p. 180)
   Failure time: 23:10, 1/4/82
   Rain gage: sm-5 (Princeton), LOMAP, MAP ~500 mm (20 in), use CRI for I_0 = 4.6 mm/h (.18 in/h)
   Duration of storm rainfall prior to failure: 29 hrs
   Prestorm seasonal rainfall: 580 mm (22.8 in)
   Slope: 0.487733 (26 deg) (Wieczorek and others, 1988, Table 8.4, p. 145)
   Shear resistance (est.): 0.839100[6] (40 deg)
   Thickness of colluvium: 3.9 meters
   Debris-flow frequency[4]: 3-5/km^2
   Estimate approximately 8 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 4.

5. Canham Road, Scotts Valley, Santa Cruz County, Laurel 7.5' quadrangle (Wieczorek and others, 1988, p. 152-153 and Table 8.5, p. 146)
   Failure time: 19:00 1/4/82
   Rain gage: sz-1[1] (Brackney?), HIMAP[2], MAP ~1175 mm (46 in), use CRI for I_0 = 6.9 mm/h (.27 in/h)
   Duration of storm rainfall prior to failure: 25 hrs
   Prestorm seasonal rainfall: 725 mm (28.6 in)
   Slope: 0.600861 (31 deg)
   Shear resistance (est.): 0.839100 (40 deg)
   Thickness of colluvium: 7.7 meters
   Debris-flow frequency[4]: 8/km^2
   Estimate approximately 8 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 5.

6. Shoal Drive, Colma, San Mateo County, San Francisco South 7.5' quadrangle[7]
   Failure time: 21:00, 1/4/82
   Rain gage: sm-3[1] (Colma?), LOMAP[2], MAP ~600 mm (24 in), use CRI for I_0 = 4.6 mm (.18 in/h)
   Duration of storm rainfall prior to failure: 28 hrs

Prestorm seasonal rainfall: 400 mm (15.7 in)
Slope: 0.487733 (26 deg)
Shear resistance (est.): 0.839100 (40 deg)
Thickness of colluvium (estimated from regional geologic setting): >0.1 meter
Debris-flow frequency[4]: 5/km^2
Estimate approximately 9 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 6.

7. Three Peaks, Nicasio, Marin County, Point Reyes NE 7.5' quadrangle (Ellen and others, 1988, Case Study 1, p. 66 and Fig. 6.2, Fig. 6.3)
   Failure time: 12:00, 1/4/82
   Rain gage: m-10[1] (Nicasio Dam), HIMAP[2], MAP ~800 mm (31 in), use CRI for I_0 = 4.6 mm/h (.18 in/h)
   Duration of storm rainfall prior to failure: 25 hrs
   Prestorm seasonal rainfall: 675 mm (26.6 in)
   Slope: 0.363970 (20 deg)
   Shear resistance (est.): 0.839100 (40 deg)
   Thickness of colluvium: 1.0 meter (Ellen and others, 1988, p. 66)
   Debris-flow frequency[5]: ~5/km^2
   Estimate approximately 3 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 7.

8. Tiburon Ridge, Corte Madera, Marin County, San Quentin 7.5' quadrangle (Ellen and others, 1988, Case Study 4, p.69-70 and Plate 5)
   Failure time: 14:00, 1/4/82
   Rain gage: m-4[1] (Mill Valley?, HIMAP[2], MAP ~700 mm (27 in), use CRI for I_0 = 6.9 mm/h (.27 in/hr)
   Duration of storm rainfall prior to failure: 20 hours
   Prestorm seasonal rainfall: 14.8 inches
   Slope: 0.487733 (26 deg)
   Shear resistance (est.): 0.839100 (40 deg)
   Thickness of colluvium: 2.0 meters
   Debris-flow frequency[5]: ~3-5/km^2
   Estimate approximately 5 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 8.

9. First Valley, Inverness, Marin County, Inverness 7.5' quadrangle (Reneau, 1988, Case Study 5, p. 70-76; and Ellen and Wieczorek, 1988, Plate 5)
   Failure time: 10:30 1/4/82
   Rain gage: m-10[1] (Nicasio Dam), HIMAP[2], MAP ~800 mm (31 in), use CRI for I_0 = 6.9 mm/h (.27 in/hr)
   Duration of storm rainfall prior to failure: 23 hrs

Prestorm seasonal rainfall: 710 mm (28.0 in)
Slope: 0.424475 (23 deg)
Shear resistance (est.): 0.839100 (40 deg)
Thickness of colluvium: 2.0 meters
Debris-flow frequency[5]: ~1-5/km^2
Estimate approximately 4 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 9.

10. Klamath St, Oakland[8], Alameda County, Oakland East 7.5' quadrangle
Failure time: 12:34 1/4/82
Rain gage: a-4[1] (Oak Knoll?), LOMAP[2], MAP ~550 mm (22 in), use CRI for I_0 = 4.6 mm/h (.18 in/hr)
Duration of storm rainfall prior to failure: 19 hrs
Prestorm seasonal rainfall: 550 mm (21.6 in)
Slope: 0.487733 (26 deg)
Shear resistance (est.): 0.839100 (40 deg)
Thickness of colluvium: 0.5 meter
Debris-flow frequency[4]: ~1-10/km^2
Estimate approximately 11 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 10.

11. Sunnyhill Rd., Oakland[7], Alameda County, Oakland East 7.5' quadrangle
Time of failure: 20:00 1/4/82
Rain gage: a-5[1] (Piedmont?), LOMAP[2], MAP ~500 mm (20 in), use CRI for I_0 = 4.6 mm/h (.18 in/hr)
Duration of storm rainfall prior to failure: 28 hrs
Prestorm seasonal rainfall: 400 mm (15.7 in)
Slope: 0.307692 (17 deg)
Shear resistance (est.): 0.577350 (30 deg)
Thickness of colluvium: 1.5 meters
Debris-flow frequency[4]: ~1-10/km^2
Estimate approximately 16 unfailed cells (or "right-censored spells") in the vicinity of, and having equal or greater susceptibility than failed cell at Site 11.

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1. Rain gage records supplied by Cannon and Ellen, identified by their code id.

2. *Cf* Rantz, 1971, SFBR Envir. & Resources Planning Study, Basic Data Contrib 25, map (scale approx. 1:750,000); high and low MAP split based on 26-in. MAP criterion suggested by Cannon and Ellen, 1985, Chap. 3 in USGS Prof. Paper 1434

3. Mark and Newman, 1985, Plate 1. in USGS Prof. Paper 1434

4. Debris-flow frequencies from Wieczorek and others (1988. Plates 8, 9, 10, 11)

5. Debris-flow frequencies from Ellen and others (1988, Fig. 7.1 p. 115, and Plates 5, 7, 14).

6. See especially Table 9.1, p. 180, in Howard and others, 1985

7. Time and location based on notes by Cannon and Ellen (Ellen, 1992, written communication); shear resistance and thickness of colluvium inferred from maps of Wieczorek and others, 1985 (Map I-1257-E), Brabb and Pampeyan, 1983 (USGS Map I-1257-A), and Wieczorek and others, 1988 (Pl. 8., USGS Prof Paper 1434)

8. Time and location from notes of Ellen and Cannon (Ellen, 1992, written communication), slope from topographic map, shear resistance estimated using descriptions from soils maps (Welch, 1981), geologic map (Radbruch, 1969), and landslide inventory (Nilson, 1975).

Appendix B. Estimating Censored Data

Although regional summary maps in Professional Paper 1434 (Ellen and Wieczorek, 1988), such as Plates 8-12 and Figure 7.1 (p. 115), show the areal frequency of debris flows, as inventoried after the storm, the case studies used to develop the SFBR regression data did not include direct observations reporting the proportion of unfailed slopes having the same properties as the failed slopes at observed times of failure. Therefore, it was necessary to estimate a proportional number of censored sites by extrapolating from other observational data assembled by Wieczorek and others (1988) for San Mateo County. The estimates in Table 1 were made using the following procedure:

1. A 2-km x 2-km square was drawn around each failure case study on a 1:24,000-scale topographic quadrangle. (Each square contains 400 cells of 100-m x100-m size.)

2. The relative proportion of hillside to lowland areas was estimated from contour spacing to remove areas having slopes less than 14 degrees from the total to determine the number of hillside cells (cells having slopes of 14 degrees and greater). (Wieczorek and others, 1988, report that 14 degrees is the minimum slope on which a failure was observed.)

3. The histograms of Wieczorek and others (1988), showing distributions of slopes in San Mateo County (Figure B-1), and distributions of failures with respect to slope angles, were normalized to those slopes of 14 degrees and steeper, producing a table (Table B-1) for relative frequency of failure at various hillside slope angles in San Mateo County. The range of slopes in the hillside areas of San Mateo County is used to represent the general distribution of slopes in hillside areas in the SFBR. Both high MAP (mean annual precipitation; usage of Cannon and Ellen, 1988) and low MAP areas are represented by the hillsides of San Mateo County.

FIGURE B-1.--NEAR HERE

TABLE B-1.--NEAR HERE

4. In the hillside areas of a 2x2 km vicinity of a case study, the proportion of areas with slopes equal to or exceeding that at an observed failure site was estimated by multiplying the percent of the 2x2-km vicinity made up of hillside cells (from step 2) by the percentage (from Table B-1, column 3) of hillside cells having slopes equal to or greater than the slope at the observed failure site. The expected proportion (in percent) of failed to unfailed cells was then estimated by summing the frequency percentages for all intervals as steep or steeper than the observed failed site (from column 4, Table B-1). For example, if a 2x2-km vicinity is 80 percent hillside cells, and an observed failure occurred in slope interval 60-65 (an interval minimum of about 31 degrees), then of 400 cells in the vicinity, 320 are in slopes => 14 degrees and 8.2 percent of those (about 26) have slopes => than the observed failure. The sum of the interval percents from

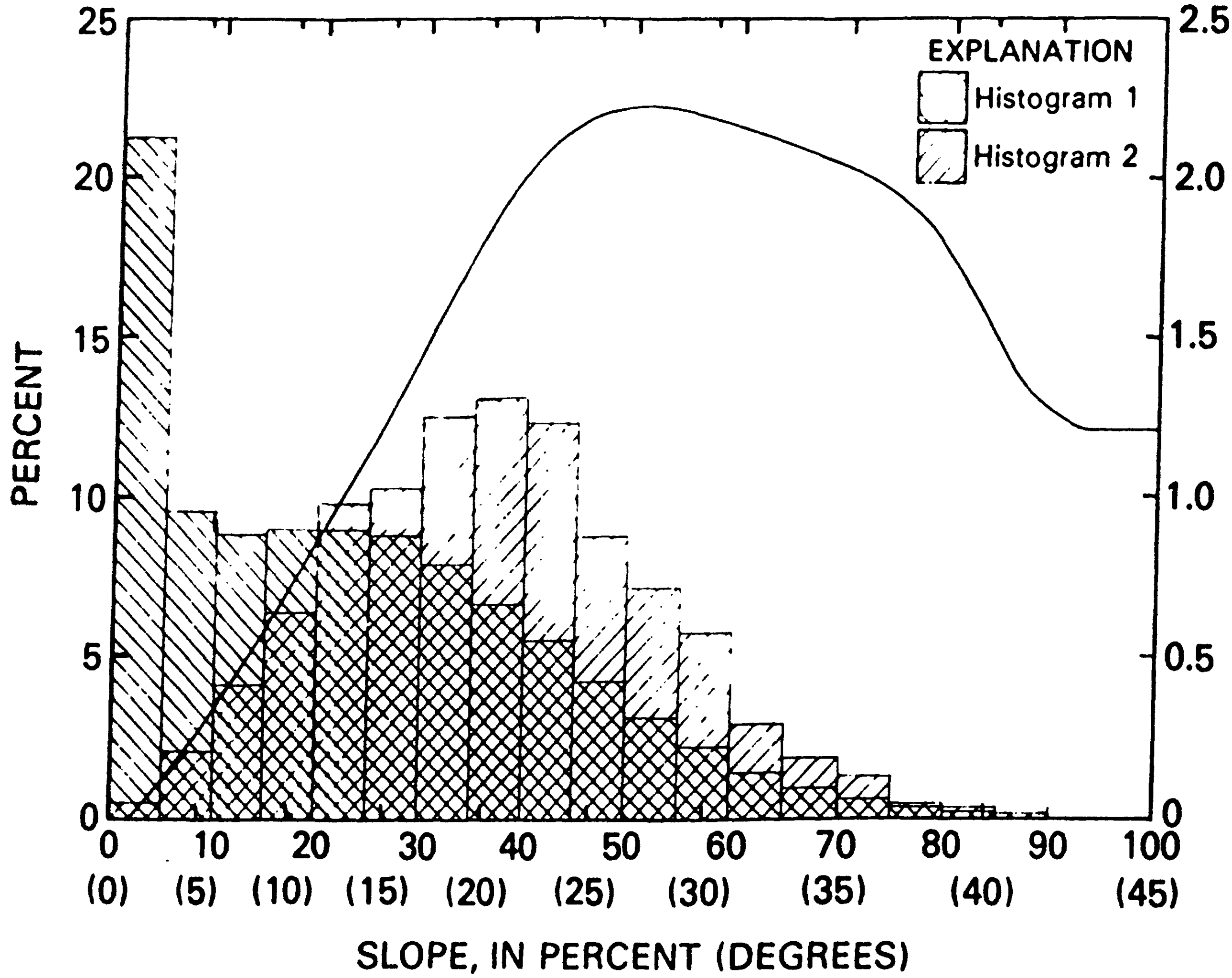

Figure B-1. Slope steepness at debris-flow sources in San Mateo County, California, derived from digital elevation model (after Wieczorek and others, 1988, Figure 8.3, p. 141). Histogram 1 shows steepness of all slopes; histogram 2 shows steepness at debris-flow source areas; curve, ratio of histogram 2 to histogram 1 is normalized steepness distribution of debris flows. To create Table B-1, the histograms were truncated to remove slopes less than 25 percent (about 14 degrees) and renormalized.

Table B-1. Table of proportional distribution of slopes in the hillside areas of the San Francisco Bay region, normalized to include only slopes greater than 25 percent (14 degrees), showing percent of hillside area in slopes greater than the interval minimum.

SLOPE INTERVAL (PERCENT)	INTERVAL MINIMUM, (DEGREES)	HILLSIDE AREAS WITH SLOPES => INTERVAL MIN (PERCENT)	DEBRIS-FLOW FRE-QUENCY (PERCENT) IN SLOPE INTERVAL
25-30	14.04	100.0	13.0
30-35	16.70	78.8	15.5
35-40	19.29	59.5	16.7
40-45	21.80	43.9	15.5
45-50	24.23	30.6	10.7
50-55	26.57	20.7	8.3
55-60	28.81	13.3	7.1
60-65	30.96	8.2	4.8
65-70	33.02	5.1	3.6
70-75	34.99	2.7	2.4
75-80	36.87	1.2	1.2
80-85	38.66	0.5	0.6
85-90	40.36	0.2	0.6

column 4, Table B-1, for slopes greater than 60 percent (about 31 degrees) is 13.2 percent, indicating that 13.2 percent x 26 cells = 3.4 (or about 3 cells) would be expected to fail, and the remaining 23 would not be expected to fail. This yields a ratio of one failed cell to 7 or 8 unfailed (or censored) cells.

5. In the absence of uniform geologic and soils map coverage, the shear resistance and soil thicknesses within these limited vicinities were estimated to be the same as those at the site of recorded failure.

Another approach serves as a partly independent check. Post-storm inventories included in Wieczorek and Ellen (1988, Plates 8-11), adjusted for the proportion of hillside area in a region, yield a frequency distribution useful for comparison. However, both methods are crude approximations that are appropriate only in considering methods development. They could be much improved by direct field observation of conditions in the vicinities of the failed sites.

Appendix C. LIMDEP Command File, Example

The following command file serves as an example of the regressions in LIMDEP that were run to evaluate several probability mode

```
open ; output=lim7cna25.out $
read ; nvar=10 ; file=lim7cna.nhd
   ; names = TIME,NP,CEN,SITE,CUM  RI  PE,SS,SI,CT $
create ; LT=log(TIME)  ; MSI=(CRI/(CT*3.
surv ; lhs=LT,CEN,NP ; rhs=SI,MSI ; model=w                $
close
```

The first line, "open", opens and names an output file to which the regression results will be written.

The second and third lines, "read", instructs LIMDEP to expect to deal with 10 variables, to read the data table, lim7cna.nhd (Appendix B.), as input, and lists the names of the columns of variables in order from left to right. The variables are:

TIME -- Duration, in hours, from beginning of "period of observation". In the database lim7cna.nhd, the beginning of the period of observation is the beginning of storm rainfall specified as the beginning of a period of two or more consecutive hours in which the hourly rainfall rate is equal to or greater than 0.01 in/h (0.25 mm/h). The end of the period of observation is the end of storm rainfall, specified as the first of two or more hours in which the hourly rainfall rate is less than 0.01 in/h. Other databases, in which storm rainfall is specified by higher hourly rates, yield results in which the percentile distribution of survivors with time is significantly shorter than that observed for the 1982 storm. TIME is used as the dependent variable on the left-hand side (LHS) of the regression.

NP -- Number of periods in which the time-varying covariate, CRI, remains constant, increases or decreases. In Appendix B, instead of listing a new period for every hourly change in CRI, new periods were identified with significant changes in the rate of increase (or decrease) in the CRI. As a variable on the left-hand side of the regression, it instructs LIMDEP as to how many rows in the data table are identified with a specific event, whether the event is a failure that occurred in a cell at an observed time before the end or the storm (an "exit"), or a cell having otherwise identical variables, in which no failure occurred during the storm (a "censored" event).

CEN -- A dummy variable indicating whether a failure was observed prior to the end of the period of observation (censored=0), or no failure occurred during the period of observation (censored=1).

SITE -- Numbers without decimal extensions identify sites where soil slip-debris flows occurred at an observed time (see index map). Decimal extensions indicate censored cells, with the highest decimal extension indicating the total estimated number of cells in the vicinity of the failed cell that, although having otherwise identical variables, were not sites of failure.

CUMR -- Cumulative storm rainfall at time TIME.

CRI -- Cumulative storm rainfall in excess of selected threshold for rain gage associated with SITE number (see Appendix D. to identify gage nearest failure site).

SLOPE -- Hillside slope at site of failure, as the tangent of an angle, as observed and reported or mapped in case study, or measured from contours.

SS -- Shear resistance at site of failure, as the tangent of an angle, estimated based on measurements or descriptions in case studies.

SI -- The ratio, SS/SLOPE, sometimes referred to as the "stability index".

CT -- Thickness of colluvium on hillside, in meters, as reported or estimated from descriptions in case studies.

The fourth line, "create", instructs LIMDEP to calculate derivative or compound variables from those listed above, which can then be used in the regression.

The fifth line instructs LIMDEP as to the functional form to be used in the regression, the variables to be included in the left-hand side (lhs) and the right-hand side (rhs) of the regression, the probability model to regress, and requests a list of the regression results. In this example, "surv" identifies the survivor function for the Weibull (model=weibull) probability distribution.

The sixth (and last) line simply instructs limdep to close the output file.

Appendix D., Regression database lim7cna

Number of observations = 523; Number of variables = 10

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
1	10	4	0	10	0.91	0.00	0.487733	0.839100	1.720408	0.5
2	14	4	0	10	1.80	0.17	0.487733	0.839100	1.720408	0.5
3	16	4	0	10	2.07	0.08	0.487733	0.839100	1.720408	0.5
4	20	4	0	10	3.02	0.31	0.487733	0.839100	1.720408	0.5
5	10	5	1	10.1	0.91	0.00	0.487733	0.839100	1.720408	0.5
6	14	5	1	10.1	1.80	0.17	0.487733	0.839100	1.720408	0.5
7	16	5	1	10.1	2.07	0.08	0.487733	0.839100	1.720408	0.5
8	24	5	1	10.1	4.05	0.62	0.487733	0.839100	1.720408	0.5
9	32	5	1	10.1	6.86	1.99	0.487733	0.839100	1.720408	0.5
10	10	5	1	10.2	0.91	0.00	0.487733	0.839100	1.720408	0.5
11	14	5	1	10.2	1.80	0.17	0.487733	0.839100	1.720408	0.5
12	16	5	1	10.2	2.07	0.08	0.487733	0.839100	1.720408	0.5
13	24	5	1	10.2	4.05	0.62	0.487733	0.839100	1.720408	0.5
14	32	5	1	10.2	6.86	1.99	0.487733	0.839100	1.720408	0.5
15	10	5	1	10.3	0.91	0.00	0.487733	0.839100	1.720408	0.5
16	14	5	1	10.3	1.80	0.17	0.487733	0.839100	1.720408	0.5
17	16	5	1	10.3	2.07	0.08	0.487733	0.839100	1.720408	0.5
18	24	5	1	10.3	4.05	0.62	0.487733	0.839100	1.720408	0.5
19	32	5	1	10.3	6.86	1.99	0.487733	0.839100	1.720408	0.5
20	10	5	1	10.4	0.91	0.00	0.487733	0.839100	1.720408	0.5
21	14	5	1	10.4	1.80	0.17	0.487733	0.839100	1.720408	0.5
22	16	5	1	10.4	2.07	0.08	0.487733	0.839100	1.720408	0.5
23	24	5	1	10.4	4.05	0.62	0.487733	0.839100	1.720408	0.5
24	32	5	1	10.4	6.86	1.99	0.487733	0.839100	1.720408	0.5
25	10	5	1	10.5	0.91	0.00	0.487733	0.839100	1.720408	0.5
26	14	5	1	10.5	1.80	0.17	0.487733	0.839100	1.720408	0.5
27	16	5	1	10.5	2.07	0.08	0.487733	0.839100	1.720408	0.5
28	24	5	1	10.5	4.05	0.62	0.487733	0.839100	1.720408	0.5
29	32	5	1	10.5	6.86	1.99	0.487733	0.839100	1.720408	0.5
30	10	5	1	10.6	0.91	0.00	0.487733	0.839100	1.720408	0.5
31	14	5	1	10.6	1.80	0.17	0.487733	0.839100	1.720408	0.5
32	16	5	1	10.6	2.07	0.08	0.487733	0.839100	1.720408	0.5
33	24	5	1	10.6	4.05	0.62	0.487733	0.839100	1.720408	0.5
34	32	5	1	10.6	6.86	1.99	0.487733	0.839100	1.720408	0.5
35	10	5	1	10.7	0.91	0.00	0.487733	0.839100	1.720408	0.5
36	14	5	1	10.7	1.80	0.17	0.487733	0.839100	1.720408	0.5
37	16	5	1	10.7	2.07	0.08	0.487733	0.839100	1.720408	0.5
38	24	5	1	10.7	4.05	0.62	0.487733	0.839100	1.720408	0.5
39	32	5	1	10.7	6.86	1.99	0.487733	0.839100	1.720408	0.5
40	10	5	1	10.8	0.91	0.00	0.487733	0.839100	1.720408	0.5

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
41	14	5	1	10.8	1.80	0.17	0.487733	0.839100	1.720408	0.5
42	16	5	1	10.8	2.07	0.08	0.487733	0.839100	1.720408	0.5
43	24	5	1	10.8	4.05	0.62	0.487733	0.839100	1.720408	0.5
44	32	5	1	10.8	6.86	1.99	0.487733	0.839100	1.720408	0.5
45	10	5	1	10.9	0.91	0.00	0.487733	0.839100	1.720408	0.5
46	14	5	1	10.9	1.80	0.17	0.487733	0.839100	1.720408	0.5
47	16	5	1	10.9	2.07	0.08	0.487733	0.839100	1.720408	0.5
48	24	5	1	10.9	4.05	0.62	0.487733	0.839100	1.720408	0.5
49	32	5	1	10.9	6.86	1.99	0.487733	0.839100	1.720408	0.5
50	10	5	1	10.10	0.91	0.00	0.487733	0.839100	1.720408	0.5
51	14	5	1	10.10	1.80	0.17	0.487733	0.839100	1.720408	0.5
52	16	5	1	10.10	2.07	0.08	0.487733	0.839100	1.720408	0.5
53	24	5	1	10.10	4.05	0.62	0.487733	0.839100	1.720408	0.5
54	32	5	1	10.10	6.86	1.99	0.487733	0.839100	1.720408	0.5
55	10	5	1	10.11	0.91	0.00	0.487733	0.839100	1.720408	0.5
56	14	5	1	10.11	1.80	0.17	0.487733	0.839100	1.720408	0.5
57	16	5	1	10.11	2.07	0.08	0.487733	0.839100	1.720408	0.5
58	24	5	1	10.11	4.05	0.62	0.487733	0.839100	1.720408	0.5
59	32	5	1	10.11	6.86	1.99	0.487733	0.839100	1.720408	0.5
60	11	4	0	11	1.05	0.00	0.307692	0.577350	1.876389	1.5
61	25	4	0	11	5.10	1.53	0.307692	0.577350	1.876389	1.5
62	27	4	0	11	5.35	1.42	0.307692	0.577350	1.876389	1.5
63	28	4	0	11	5.70	1.59	0.307692	0.577350	1.876389	1.5
64	11	5	1	11.1	1.05	0.00	0.307692	0.577350	1.876389	1.5
65	25	5	1	11.1	5.10	1.53	0.307692	0.577350	1.876389	1.5
66	27	5	1	11.1	5.35	1.42	0.307692	0.577350	1.876389	1.5
67	32	5	1	11.1	7.25	2.42	0.307692	0.577350	1.876389	1.5
68	37	5	1	11.1	7.41	1.68	0.307692	0.577350	1.876389	1.5
69	11	5	1	11.2	1.05	0.00	0.307692	0.577350	1.876389	1.5
70	25	5	1	11.2	5.10	1.53	0.307692	0.577350	1.876389	1.5
71	27	5	1	11.2	5.35	1.42	0.307692	0.577350	1.876389	1.5
72	32	5	1	11.2	7.25	2.42	0.307692	0.577350	1.876389	1.5
73	37	5	1	11.2	7.41	1.68	0.307692	0.577350	1.876389	1.5
74	11	5	1	11.3	1.05	0.00	0.307692	0.577350	1.876389	1.5
75	25	5	1	11.3	5.10	1.53	0.307692	0.577350	1.876389	1.5
76	27	5	1	11.3	5.35	1.42	0.307692	0.577350	1.876389	1.5
77	32	5	1	11.3	7.25	2.42	0.307692	0.577350	1.876389	1.5
78	37	5	1	11.3	7.41	1.68	0.307692	0.577350	1.876389	1.5
79	11	5	1	11.4	1.05	0.00	0.307692	0.577350	1.876389	1.5
80	25	5	1	11.4	5.10	1.53	0.307692	0.577350	1.876389	1.5
81	27	5	1	11.4	5.35	1.42	0.307692	0.577350	1.876389	1.5
82	32	5	1	11.4	7.25	2.42	0.307692	0.577350	1.876389	1.5
83	37	5	1	11.4	7.41	1.68	0.307692	0.577350	1.876389	1.5
84	11	5	1	11.5	1.05	0.00	0.307692	0.577350	1.876389	1.5

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
85	25	5	1	11.5	5.10	1.53	0.307692	0.577350	1.876389	1.5
86	27	5	1	11.5	5.35	1.42	0.307692	0.577350	1.876389	1.5
87	32	5	1	11.5	7.25	2.42	0.307692	0.577350	1.876389	1.5
88	37	5	1	11.5	7.41	1.68	0.307692	0.577350	1.876389	1.5
89	11	5	1	11.6	1.05	0.00	0.307692	0.577350	1.876389	1.5
90	25	5	1	11.6	5.10	1.53	0.307692	0.577350	1.876389	1.5
91	27	5	1	11.6	5.35	1.42	0.307692	0.577350	1.876389	1.5
92	32	5	1	11.6	7.25	2.42	0.307692	0.577350	1.876389	1.5
93	37	5	1	11.6	7.41	1.68	0.307692	0.577350	1.876389	1.5
94	11	5	1	11.7	1.05	0.00	0.307692	0.577350	1.876389	1.5
95	25	5	1	11.7	5.10	1.53	0.307692	0.577350	1.876389	1.5
96	27	5	1	11.7	5.35	1.42	0.307692	0.577350	1.876389	1.5
97	32	5	1	11.7	7.25	2.42	0.307692	0.577350	1.876389	1.5
98	37	5	1	11.7	7.41	1.68	0.307692	0.577350	1.876389	1.5
99	11	5	1	11.8	1.05	0.00	0.307692	0.577350	1.876389	1.5
100	25	5	1	11.8	5.10	1.53	0.307692	0.577350	1.876389	1.5
101	27	5	1	11.8	5.35	1.42	0.307692	0.577350	1.876389	1.5
102	32	5	1	11.8	7.25	2.42	0.307692	0.577350	1.876389	1.5
103	37	5	1	11.8	7.41	1.68	0.307692	0.577350	1.876389	1.5
104	11	5	1	11.9	1.05	0.00	0.307692	0.577350	1.876389	1.5
105	25	5	1	11.9	5.10	1.53	0.307692	0.577350	1.876389	1.5
106	27	5	1	11.9	5.35	1.42	0.307692	0.577350	1.876389	1.5
107	32	5	1	11.9	7.25	2.42	0.307692	0.577350	1.876389	1.5
108	37	5	1	11.9	7.41	1.68	0.307692	0.577350	1.876389	1.5
109	11	5	1	11.10	1.05	0.00	0.307692	0.577350	1.876389	1.5
110	25	5	1	11.10	5.10	1.53	0.307692	0.577350	1.876389	1.5
111	27	5	1	11.10	5.35	1.42	0.307692	0.577350	1.876389	1.5
112	32	5	1	11.10	7.25	2.42	0.307692	0.577350	1.876389	1.5
113	37	5	1	11.10	7.41	1.68	0.307692	0.577350	1.876389	1.5
114	11	5	1	11.11	1.05	0.00	0.307692	0.577350	1.876389	1.5
115	25	5	1	11.11	5.10	1.53	0.307692	0.577350	1.876389	1.5
116	27	5	1	11.11	5.35	1.42	0.307692	0.577350	1.876389	1.5
117	32	5	1	11.11	7.25	2.42	0.307692	0.577350	1.876389	1.5
118	37	5	1	11.11	7.41	1.68	0.307692	0.577350	1.876389	1.5
119	11	5	1	11.12	1.05	0.00	0.307692	0.577350	1.876389	1.5
120	25	5	1	11.12	5.10	1.53	0.307692	0.577350	1.876389	1.5
121	27	5	1	11.12	5.35	1.42	0.307692	0.577350	1.876389	1.5
122	32	5	1	11.12	7.25	2.42	0.307692	0.577350	1.876389	1.5
123	37	5	1	11.12	7.41	1.68	0.307692	0.577350	1.876389	1.5
124	11	5	1	11.13	1.05	0.00	0.307692	0.577350	1.876389	1.5
125	25	5	1	11.13	5.10	1.53	0.307692	0.577350	1.876389	1.5
126	27	5	1	11.13	5.35	1.42	0.307692	0.577350	1.876389	1.5
127	32	5	1	11.13	7.25	2.42	0.307692	0.577350	1.876389	1.5
128	37	5	1	11.13	7.41	1.68	0.307692	0.577350	1.876389	1.5

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
129	11	5	1	11.14	1.05	0.00	0.307692	0.577350	1.876389	1.5
130	25	5	1	11.14	5.10	1.53	0.307692	0.577350	1.876389	1.5
131	27	5	1	11.14	5.35	1.42	0.307692	0.577350	1.876389	1.5
132	32	5	1	11.14	7.25	2.42	0.307692	0.577350	1.876389	1.5
133	37	5	1	11.14	7.41	1.68	0.307692	0.577350	1.876389	1.5
134	11	5	1	11.15	1.05	0.00	0.307692	0.577350	1.876389	1.5
135	25	5	1	11.15	5.10	1.53	0.307692	0.577350	1.876389	1.5
136	27	5	1	11.15	5.35	1.42	0.307692	0.577350	1.876389	1.5
137	32	5	1	11.15	7.25	2.42	0.307692	0.577350	1.876389	1.5
138	37	5	1	11.15	7.41	1.68	0.307692	0.577350	1.876389	1.5
139	11	5	1	11.16	1.05	0.00	0.307692	0.577350	1.876389	1.5
140	25	5	1	11.16	5.10	1.53	0.307692	0.577350	1.876389	1.5
141	27	5	1	11.16	5.35	1.42	0.307692	0.577350	1.876389	1.5
142	32	5	1	11.16	7.25	2.42	0.307692	0.577350	1.876389	1.5
143	37	5	1	11.16	7.41	1.68	0.307692	0.577350	1.876389	1.5
144	5	4	0	8	0.55	0.00	0.487733	0.839100	1.720408	2.0
145	7	4	0	8	1.15	0.06	0.487733	0.839100	1.720408	2.0
146	11	4	0	8	2.00	0.00	0.487733	0.839100	1.720408	2.0
147	20	4	0	8	6.15	1.72	0.487733	0.839100	1.720408	2.0
148	5	5	1	8.1	0.55	0.00	0.487733	0.839100	1.720408	2.0
149	7	5	1	8.1	1.15	0.06	0.487733	0.839100	1.720408	2.0
150	11	5	1	8.1	2.00	0.00	0.487733	0.839100	1.720408	2.0
151	29	5	1	8.1	9.90	3.04	0.487733	0.839100	1.720408	2.0
152	32	5	1	8.1	10.45	2.78	0.487733	0.839100	1.720408	2.0
153	5	5	1	8.2	0.55	0.00	0.487733	0.839100	1.720408	2.0
154	7	5	1	8.2	1.15	0.06	0.487733	0.839100	1.720408	2.0
155	11	5	1	8.2	2.00	0.00	0.487733	0.839100	1.720408	2.0
156	29	5	1	8.2	9.90	3.04	0.487733	0.839100	1.720408	2.0
157	32	5	1	8.2	10.45	2.78	0.487733	0.839100	1.720408	2.0
158	5	5	1	8.3	0.55	0.00	0.487733	0.839100	1.720408	2.0
159	7	5	1	8.3	1.15	0.06	0.487733	0.839100	1.720408	2.0
160	11	5	1	8.3	2.00	0.00	0.487733	0.839100	1.720408	2.0
161	29	5	1	8.3	9.90	3.04	0.487733	0.839100	1.720408	2.0
162	32	5	1	8.3	10.45	2.78	0.487733	0.839100	1.720408	2.0
163	5	5	1	8.4	0.55	0.00	0.487733	0.839100	1.720408	2.0
164	7	5	1	8.4	1.15	0.06	0.487733	0.839100	1.720408	2.0
165	11	5	1	8.4	2.00	0.00	0.487733	0.839100	1.720408	2.0
166	29	5	1	8.4	9.90	3.04	0.487733	0.839100	1.720408	2.0
167	32	5	1	8.4	10.45	2.78	0.487733	0.839100	1.720408	2.0
168	5	5	1	8.5	0.55	0.00	0.487733	0.839100	1.720408	2.0
169	7	5	1	8.5	1.15	0.06	0.487733	0.839100	1.720408	2.0
170	11	5	1	8.5	2.00	0.00	0.487733	0.839100	1.720408	2.0
171	29	5	1	8.5	9.90	3.04	0.487733	0.839100	1.720408	2.0
172	32	5	1	8.5	10.45	2.78	0.487733	0.839100	1.720408	2.0

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
173	5	4	0	3	0.55	0.00	0.577350	0.839100	1.453364	1.8
174	7	4	0	3	1.15	0.06	0.577350	0.839100	1.453364	1.8
175	11	4	0	3	2.00	0.00	0.577350	0.839100	1.453364	1.8
176	28	4	0	3	9.50	2.83	0.577350	0.839100	1.453364	1.8
177	5	5	1	3.1	0.55	0.00	0.577350	0.839100	1.453364	1.8
178	7	5	1	3.1	1.15	0.06	0.577350	0.839100	1.453364	1.8
179	11	5	1	3.1	2.00	0.00	0.577350	0.839100	1.453364	1.8
180	29	5	1	3.1	9.90	3.04	0.577350	0.839100	1.453364	1.8
181	31	5	1	3.1	10.45	2.78	0.577350	0.839100	1.453364	1.8
182	5	5	1	3.2	0.55	0.00	0.577350	0.839100	1.453364	1.8
183	7	5	1	3.2	1.15	0.06	0.577350	0.839100	1.453364	1.8
184	11	5	1	3.2	2.00	0.00	0.577350	0.839100	1.453364	1.8
185	29	5	1	3.2	9.90	3.04	0.577350	0.839100	1.453364	1.8
186	31	5	1	3.2	10.45	2.78	0.577350	0.839100	1.453364	1.8
187	5	5	1	3.3	0.55	0.00	0.577350	0.839100	1.453364	1.8
188	7	5	1	3.3	1.15	0.06	0.577350	0.839100	1.453364	1.8
189	11	5	1	3.3	2.00	0.00	0.577350	0.839100	1.453364	1.8
190	29	5	1	3.3	9.90	3.04	0.577350	0.839100	1.453364	1.8
191	31	5	1	3.3	10.45	2.78	0.577350	0.839100	1.453364	1.8
192	5	5	1	3.4	0.55	0.00	0.577350	0.839100	1.453364	1.8
193	7	5	1	3.4	1.15	0.06	0.577350	0.839100	1.453364	1.8
194	11	5	1	3.4	2.00	0.00	0.577350	0.839100	1.453364	1.8
195	29	5	1	3.4	9.90	3.04	0.577350	0.839100	1.453364	1.8
196	31	5	1	3.4	10.45	2.78	0.577350	0.839100	1.453364	1.8
197	5	5	1	3.5	0.55	0.00	0.577350	0.839100	1.453364	1.8
198	7	5	1	3.5	1.15	0.06	0.577350	0.839100	1.453364	1.8
199	11	5	1	3.5	2.00	0.00	0.577350	0.839100	1.453364	1.8
200	29	5	1	3.5	9.90	3.04	0.577350	0.839100	1.453364	1.8
201	31	5	1	3.5	10.45	2.78	0.577350	0.839100	1.453364	1.8
202	5	5	1	3.6	0.55	0.00	0.577350	0.839100	1.453364	1.8
203	7	5	1	3.6	1.15	0.06	0.577350	0.839100	1.453364	1.8
204	11	5	1	3.6	2.00	0.00	0.577350	0.839100	1.453364	1.8
205	29	5	1	3.6	9.90	3.04	0.577350	0.839100	1.453364	1.8
206	31	5	1	3.6	10.45	2.78	0.577350	0.839100	1.453364	1.8
207	5	5	1	3.7	0.55	0.00	0.577350	0.839100	1.453364	1.8
208	7	5	1	3.7	1.15	0.06	0.577350	0.839100	1.453364	1.8
209	11	5	1	3.7	2.00	0.00	0.577350	0.839100	1.453364	1.8
210	29	5	1	3.7	9.90	3.04	0.577350	0.839100	1.453364	1.8
211	31	5	1	3.7	10.45	2.78	0.577350	0.839100	1.453364	1.8
212	5	5	1	3.8	0.55	0.00	0.577350	0.839100	1.453364	1.8
213	7	5	1	3.8	1.15	0.06	0.577350	0.839100	1.453364	1.8
214	11	5	1	3.8	2.00	0.00	0.577350	0.839100	1.453364	1.8
215	29	5	1	3.8	9.90	3.04	0.577350	0.839100	1.453364	1.8
216	31	5	1	3.8	10.45	2.78	0.577350	0.839100	1.453364	1.8

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
217	5	5	1	3.9	0.55	0.00	0.577350	0.839100	1.453364	1.8
218	7	5	1	3.9	1.15	0.06	0.577350	0.839100	1.453364	1.8
219	11	5	1	3.9	2.00	0.00	0.577350	0.839100	1.453364	1.8
220	29	5	1	3.9	9.90	3.04	0.577350	0.839100	1.453364	1.8
221	31	5	1	3.9	10.45	2.78	0.577350	0.839100	1.453364	1.8
222	5	5	1	3.10	0.55	0.00	0.577350	0.839100	1.453364	1.8
223	7	5	1	3.10	1.15	0.06	0.577350	0.839100	1.453364	1.8
224	11	5	1	3.10	2.00	0.00	0.577350	0.839100	1.453364	1.8
225	29	5	1	3.10	9.90	3.04	0.577350	0.839100	1.453364	1.8
226	31	5	1	3.10	10.45	2.78	0.577350	0.839100	1.453364	1.8
227	5	5	1	3.11	0.55	0.00	0.577350	0.839100	1.453364	1.8
228	7	5	1	3.11	1.15	0.06	0.577350	0.839100	1.453364	1.8
229	11	5	1	3.11	2.00	0.00	0.577350	0.839100	1.453364	1.8
230	29	5	1	3.11	9.90	3.04	0.577350	0.839100	1.453364	1.8
231	31	5	1	3.11	10.45	2.78	0.577350	0.839100	1.453364	1.8
232	5	5	1	3.12	0.55	0.00	0.577350	0.839100	1.453364	1.8
233	7	5	1	3.12	1.15	0.06	0.577350	0.839100	1.453364	1.8
234	11	5	1	3.12	2.00	0.00	0.577350	0.839100	1.453364	1.8
235	29	5	1	3.12	9.90	3.04	0.577350	0.839100	1.453364	1.8
236	31	5	1	3.12	10.45	2.78	0.577350	0.839100	1.453364	1.8
237	5	5	1	3.13	0.55	0.00	0.577350	0.839100	1.453364	1.8
238	7	5	1	3.13	1.15	0.06	0.577350	0.839100	1.453364	1.8
239	11	5	1	3.13	2.00	0.00	0.577350	0.839100	1.453364	1.8
240	29	5	1	3.13	9.90	3.04	0.577350	0.839100	1.453364	1.8
241	31	5	1	3.13	10.45	2.78	0.577350	0.839100	1.453364	1.8
242	14	4	0	9	2.10	0.00	0.424475	0.839100	1.976795	2.0
243	16	4	0	9	2.70	0.06	0.424475	0.839100	1.976795	2.0
244	18	4	0	9	3.10	0.00	0.424475	0.839100	1.976795	2.0
245	23	4	0	9	5.90	1.45	0.424475	0.839100	1.976795	2.0
246	14	5	1	9.1	2.10	0.00	0.424475	0.839100	1.976795	2.0
247	16	5	1	9.1	2.70	0.06	0.424475	0.839100	1.976795	2.0
248	18	5	1	9.1	3.10	0.00	0.424475	0.839100	1.976795	2.0
249	25	5	1	9.1	8.00	2.74	0.424475	0.839100	1.976795	2.0
250	36	5	1	9.1	8.80	0.84	0.424475	0.839100	1.976795	2.0
251	14	5	1	9.2	2.10	0.00	0.424475	0.839100	1.976795	2.0
252	16	5	1	9.2	2.70	0.06	0.424475	0.839100	1.976795	2.0
253	18	5	1	9.2	3.10	0.00	0.424475	0.839100	1.976795	2.0
254	25	5	1	9.2	8.00	2.74	0.424475	0.839100	1.976795	2.0
255	36	5	1	9.2	8.80	0.84	0.424475	0.839100	1.976795	2.0
256	14	5	1	9.3	2.10	0.00	0.424475	0.839100	1.976795	2.0
257	16	5	1	9.3	2.70	0.06	0.424475	0.839100	1.976795	2.0
258	18	5	1	9.3	3.10	0.00	0.424475	0.839100	1.976795	2.0
259	25	5	1	9.3	8.00	2.74	0.424475	0.839100	1.976795	2.0
260	36	5	1	9.3	8.80	0.84	0.424475	0.839100	1.976795	2.0

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
261	14	5	1	9.4	2.10	0.00	0.424475	0.839100	1.976795	2.0
262	16	5	1	9.4	2.70	0.06	0.424475	0.839100	1.976795	2.0
263	18	5	1	9.4	3.10	0.00	0.424475	0.839100	1.976795	2.0
264	25	5	1	9.4	8.00	2.74	0.424475	0.839100	1.976795	2.0
265	36	5	1	9.4	8.80	0.84	0.424475	0.839100	1.976795	2.0
266	14	4	0	7	2.10	0.00	0.363970	0.839100	2.305409	1.0
267	16	4	0	7	2.70	0.06	0.363970	0.839100	2.305409	1.0
268	18	4	0	7	3.10	0.00	0.363970	0.839100	2.305409	1.0
269	24	4	0	7	6.20	1.48	0.363970	0.839100	2.305409	1.0
270	14	5	1	7.1	2.10	0.00	0.363970	0.839100	2.305409	1.0
271	16	5	1	7.1	2.70	0.06	0.363970	0.839100	2.305409	1.0
272	18	5	1	7.1	3.10	0.00	0.363970	0.839100	2.305409	1.0
273	26	5	1	7.1	8.00	2.74	0.363970	0.839100	2.305409	1.0
274	36	5	1	7.1	8.80	0.84	0.363970	0.839100	2.305409	1.0
275	14	5	1	7.2	2.10	0.00	0.363970	0.839100	2.305409	1.0
276	16	5	1	7.2	2.70	0.06	0.363970	0.839100	2.305409	1.0
277	18	5	1	7.2	3.10	0.00	0.363970	0.839100	2.305409	1.0
278	26	5	1	7.2	8.00	2.74	0.363970	0.839100	2.305409	1.0
279	36	5	1	7.2	8.80	0.84	0.363970	0.839100	2.305409	1.0
280	14	5	1	7.3	2.10	0.00	0.363970	0.839100	2.305409	1.0
281	16	5	1	7.3	2.70	0.06	0.363970	0.839100	2.305409	1.0
282	18	5	1	7.3	3.10	0.00	0.363970	0.839100	2.305409	1.0
283	26	5	1	7.3	8.00	2.74	0.363970	0.839100	2.305409	1.0
284	36	5	1	7.3	8.80	0.84	0.363970	0.839100	2.305409	1.0
285	13	5	0	6	0.62	0.00	0.487733	0.839100	1.720408	0.1
286	14	5	0	6	0.87	0.07	0.487733	0.839100	1.720408	0.1
287	15	5	0	6	0.97	0.00	0.487733	0.839100	1.720408	0.1
288	27	5	0	6	1.92	0.00	0.487733	0.839100	1.720408	0.1
289	28	5	0	6	2.36	0.26	0.487733	0.839100	1.720408	0.1
290	13	5	1	6.1	0.62	0.00	0.487733	0.839100	1.720408	0.1
291	14	5	1	6.1	0.87	0.07	0.487733	0.839100	1.720408	0.1
292	27	5	1	6.1	1.92	0.00	0.487733	0.839100	1.720408	0.1
293	31	5	1	6.1	4.63	1.99	0.487733	0.839100	1.720408	0.1
294	33	5	1	6.1	4.77	1.77	0.487733	0.839100	1.720408	0.1
295	13	5	1	6.2	0.62	0.00	0.487733	0.839100	1.720408	0.1
296	14	5	1	6.2	0.87	0.07	0.487733	0.839100	1.720408	0.1
297	27	5	1	6.2	1.92	0.00	0.487733	0.839100	1.720408	0.1
298	31	5	1	6.2	4.63	1.99	0.487733	0.839100	1.720408	0.1
299	33	5	1	6.2	4.77	1.77	0.487733	0.839100	1.720408	0.1
300	13	5	1	6.3	0.62	0.00	0.487733	0.839100	1.720408	0.1
301	14	5	1	6.3	0.87	0.07	0.487733	0.839100	1.720408	0.1
302	27	5	1	6.3	1.92	0.00	0.487733	0.839100	1.720408	0.1
303	31	5	1	6.3	4.63	1.99	0.487733	0.839100	1.720408	0.1
304	33	5	1	6.3	4.77	1.77	0.487733	0.839100	1.720408	0.1

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
305	13	5	1	6.4	0.62	0.00	0.487733	0.839100	1.720408	0.1
306	14	5	1	6.4	0.87	0.07	0.487733	0.839100	1.720408	0.1
307	27	5	1	6.4	1.92	0.00	0.487733	0.839100	1.720408	0.1
308	31	5	1	6.4	4.63	1.99	0.487733	0.839100	1.720408	0.1
309	33	5	1	6.4	4.77	1.77	0.487733	0.839100	1.720408	0.1
310	13	5	1	6.5	0.62	0.00	0.487733	0.839100	1.720408	0.1
311	14	5	1	6.5	0.87	0.07	0.487733	0.839100	1.720408	0.1
312	27	5	1	6.5	1.92	0.00	0.487733	0.839100	1.720408	0.1
313	31	5	1	6.5	4.63	1.99	0.487733	0.839100	1.720408	0.1
314	33	5	1	6.5	4.77	1.77	0.487733	0.839100	1.720408	0.1
315	13	5	1	6.6	0.62	0.00	0.487733	0.839100	1.720408	0.1
316	14	5	1	6.6	0.87	0.07	0.487733	0.839100	1.720408	0.1
317	27	5	1	6.6	1.92	0.00	0.487733	0.839100	1.720408	0.1
318	31	5	1	6.6	4.63	1.99	0.487733	0.839100	1.720408	0.1
319	33	5	1	6.6	4.77	1.77	0.487733	0.839100	1.720408	0.1
320	13	5	1	6.7	0.62	0.00	0.487733	0.839100	1.720408	0.1
321	14	5	1	6.7	0.87	0.07	0.487733	0.839100	1.720408	0.1
322	27	5	1	6.7	1.92	0.00	0.487733	0.839100	1.720408	0.1
323	31	5	1	6.7	4.63	1.99	0.487733	0.839100	1.720408	0.1
324	33	5	1	6.7	4.77	1.77	0.487733	0.839100	1.720408	0.1
325	13	5	1	6.8	0.62	0.00	0.487733	0.839100	1.720408	0.1
326	14	5	1	6.8	0.87	0.07	0.487733	0.839100	1.720408	0.1
327	27	5	1	6.8	1.92	0.00	0.487733	0.839100	1.720408	0.1
328	31	5	1	6.8	4.63	1.99	0.487733	0.839100	1.720408	0.1
329	33	5	1	6.8	4.77	1.77	0.487733	0.839100	1.720408	0.1
330	13	5	1	6.9	0.62	0.00	0.487733	0.839100	1.720408	0.1
331	14	5	1	6.9	0.87	0.07	0.487733	0.839100	1.720408	0.1
332	27	5	1	6.9	1.92	0.00	0.487733	0.839100	1.720408	0.1
333	31	5	1	6.9	4.63	1.99	0.487733	0.839100	1.720408	0.1
334	33	5	1	6.9	4.77	1.77	0.487733	0.839100	1.720408	0.1
335	4	10	0	4	0.30	0.00	0.487733	0.839100	1.720408	3.9
336	5	10	0	4	0.50	0.02	0.487733	0.839100	1.720408	3.9
337	10	10	0	4	0.80	0.00	0.487733	0.839100	1.720408	3.9
338	13	10	0	4	1.40	0.06	0.487733	0.839100	1.720408	3.9
339	14	10	0	4	1.50	0.00	0.487733	0.839100	1.720408	3.9
340	18	10	0	4	2.50	0.28	0.487733	0.839100	1.720408	3.9
341	19	10	0	4	2.60	0.20	0.487733	0.839100	1.720408	3.9
342	23	10	0	4	4.00	0.88	0.487733	0.839100	1.720408	3.9
343	24	10	0	4	4.10	0.80	0.487733	0.839100	1.720408	3.9
344	28	10	0	4	5.70	1.68	0.487733	0.839100	1.720408	3.9
345	4	10	1	4.1	0.30	0.00	0.487733	0.839100	1.720408	3.9
346	5	10	1	4.1	0.50	0.02	0.487733	0.839100	1.720408	3.9
347	10	10	1	4.1	0.80	0.00	0.487733	0.839100	1.720408	3.9
348	13	10	1	4.1	1.40	0.06	0.487733	0.839100	1.720408	3.9

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
349	14	10	1	4.1	1.50	0.00	0.487733	0.839100	1.720408	3.9
350	18	10	1	4.1	2.50	0.28	0.487733	0.839100	1.720408	3.9
351	19	10	1	4.1	2.60	0.20	0.487733	0.839100	1.720408	3.9
352	23	10	1	4.1	4.00	0.88	0.487733	0.839100	1.720408	3.9
353	24	10	1	4.1	4.10	0.80	0.487733	0.839100	1.720408	3.9
354	28	10	1	4.1	5.70	1.68	0.487733	0.839100	1.720408	3.9
355	4	10	1	4.2	0.30	0.00	0.487733	0.839100	1.720408	3.9
356	5	10	1	4.2	0.50	0.02	0.487733	0.839100	1.720408	3.9
357	10	10	1	4.2	0.80	0.00	0.487733	0.839100	1.720408	3.9
358	13	10	1	4.2	1.40	0.06	0.487733	0.839100	1.720408	3.9
359	14	10	1	4.2	1.50	0.00	0.487733	0.839100	1.720408	3.9
360	18	10	1	4.2	2.50	0.28	0.487733	0.839100	1.720408	3.9
361	19	10	1	4.2	2.60	0.20	0.487733	0.839100	1.720408	3.9
362	23	10	1	4.2	4.00	0.88	0.487733	0.839100	1.720408	3.9
363	24	10	1	4.2	4.10	0.80	0.487733	0.839100	1.720408	3.9
364	28	10	1	4.2	5.70	1.68	0.487733	0.839100	1.720408	3.9
365	4	10	1	4.3	0.30	0.00	0.487733	0.839100	1.720408	3.9
366	5	10	1	4.3	0.50	0.02	0.487733	0.839100	1.720408	3.9
367	10	10	1	4.3	0.80	0.00	0.487733	0.839100	1.720408	3.9
368	13	10	1	4.3	1.40	0.06	0.487733	0.839100	1.720408	3.9
369	14	10	1	4.3	1.50	0.00	0.487733	0.839100	1.720408	3.9
370	18	10	1	4.3	2.50	0.28	0.487733	0.839100	1.720408	3.9
371	19	10	1	4.3	2.60	0.20	0.487733	0.839100	1.720408	3.9
372	23	10	1	4.3	4.00	0.88	0.487733	0.839100	1.720408	3.9
373	24	10	1	4.3	4.10	0.80	0.487733	0.839100	1.720408	3.9
374	28	10	1	4.3	5.70	1.68	0.487733	0.839100	1.720408	3.9
375	4	10	1	4.4	0.30	0.00	0.487733	0.839100	1.720408	3.9
376	5	10	1	4.4	0.50	0.02	0.487733	0.839100	1.720408	3.9
377	10	10	1	4.4	0.80	0.00	0.487733	0.839100	1.720408	3.9
378	13	10	1	4.4	1.40	0.06	0.487733	0.839100	1.720408	3.9
379	14	10	1	4.4	1.50	0.00	0.487733	0.839100	1.720408	3.9
380	18	10	1	4.4	2.50	0.28	0.487733	0.839100	1.720408	3.9
381	19	10	1	4.4	2.60	0.20	0.487733	0.839100	1.720408	3.9
382	23	10	1	4.4	4.00	0.88	0.487733	0.839100	1.720408	3.9
383	24	10	1	4.4	4.10	0.80	0.487733	0.839100	1.720408	3.9
384	28	10	1	4.4	5.70	1.68	0.487733	0.839100	1.720408	3.9
385	4	10	1	4.5	0.30	0.00	0.487733	0.839100	1.720408	3.9
386	5	10	1	4.5	0.50	0.02	0.487733	0.839100	1.720408	3.9
387	10	10	1	4.5	0.80	0.00	0.487733	0.839100	1.720408	3.9
388	13	10	1	4.5	1.40	0.06	0.487733	0.839100	1.720408	3.9
389	14	10	1	4.5	1.50	0.00	0.487733	0.839100	1.720408	3.9
390	18	10	1	4.5	2.50	0.28	0.487733	0.839100	1.720408	3.9
391	19	10	1	4.5	2.60	0.20	0.487733	0.839100	1.720408	3.9
392	23	10	1	4.5	4.00	0.88	0.487733	0.839100	1.720408	3.9

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
393	24	10	1	4.5	4.10	0.80	0.487733	0.839100	1.720408	3.9
394	28	10	1	4.5	5.70	1.68	0.487733	0.839100	1.720408	3.9
395	4	10	1	4.6	0.30	0.00	0.487733	0.839100	1.720408	3.9
396	5	10	1	4.6	0.50	0.02	0.487733	0.839100	1.720408	3.9
397	10	10	1	4.6	0.80	0.00	0.487733	0.839100	1.720408	3.9
398	13	10	1	4.6	1.40	0.06	0.487733	0.839100	1.720408	3.9
399	14	10	1	4.6	1.50	0.00	0.487733	0.839100	1.720408	3.9
400	18	10	1	4.6	2.50	0.28	0.487733	0.839100	1.720408	3.9
401	19	10	1	4.6	2.60	0.20	0.487733	0.839100	1.720408	3.9
402	23	10	1	4.6	4.00	0.88	0.487733	0.839100	1.720408	3.9
403	24	10	1	4.6	4.10	0.80	0.487733	0.839100	1.720408	3.9
404	28	10	1	4.6	5.70	1.68	0.487733	0.839100	1.720408	3.9
405	4	10	1	4.7	0.30	0.00	0.487733	0.839100	1.720408	3.9
406	5	10	1	4.7	0.50	0.02	0.487733	0.839100	1.720408	3.9
407	10	10	1	4.7	0.80	0.00	0.487733	0.839100	1.720408	3.9
408	13	10	1	4.7	1.40	0.06	0.487733	0.839100	1.720408	3.9
409	14	10	1	4.7	1.50	0.00	0.487733	0.839100	1.720408	3.9
410	18	10	1	4.7	2.50	0.28	0.487733	0.839100	1.720408	3.9
411	19	10	1	4.7	2.60	0.20	0.487733	0.839100	1.720408	3.9
412	23	10	1	4.7	4.00	0.88	0.487733	0.839100	1.720408	3.9
413	24	10	1	4.7	4.10	0.80	0.487733	0.839100	1.720408	3.9
414	28	10	1	4.7	5.70	1.68	0.487733	0.839100	1.720408	3.9
415	4	10	1	4.8	0.30	0.00	0.487733	0.839100	1.720408	3.9
416	5	10	1	4.8	0.50	0.02	0.487733	0.839100	1.720408	3.9
417	10	10	1	4.8	0.80	0.00	0.487733	0.839100	1.720408	3.9
418	13	10	1	4.8	1.40	0.06	0.487733	0.839100	1.720408	3.9
419	14	10	1	4.8	1.50	0.00	0.487733	0.839100	1.720408	3.9
420	18	10	1	4.8	2.50	0.28	0.487733	0.839100	1.720408	3.9
421	19	10	1	4.8	2.60	0.20	0.487733	0.839100	1.720408	3.9
422	23	10	1	4.8	4.00	0.88	0.487733	0.839100	1.720408	3.9
423	24	10	1	4.8	4.10	0.80	0.487733	0.839100	1.720408	3.9
424	28	10	1	4.8	5.70	1.68	0.487733	0.839100	1.720408	3.9
425	7	2	0	2	0.90	0.00	0.781286	0.700208	0.896225	4.3
426	18	2	0	2	8.55	4.68	0.781286	0.700208	0.896225	4.3
427	7	3	1	2.1	0.90	0.00	0.781286	0.700208	0.896225	4.3
428	28	3	1	2.1	15.70	9.13	0.781286	0.700208	0.896225	4.3
429	30	3	1	2.1	15.95	8.84	0.781286	0.700208	0.896225	4.3
430	7	3	1	2.2	0.90	0.00	0.781286	0.700208	0.896225	4.3
431	28	3	1	2.2	15.70	9.13	0.781286	0.700208	0.896225	4.3
432	30	3	1	2.2	15.95	8.84	0.781286	0.700208	0.896225	4.3
433	7	3	1	2.3	0.90	0.00	0.781286	0.700208	0.896225	4.3
434	28	3	1	2.3	15.70	9.13	0.781286	0.700208	0.896225	4.3
435	30	3	1	2.3	15.95	8.84	0.781286	0.700208	0.896225	4.3
436	7	3	1	2.4	0.90	0.00	0.781286	0.700208	0.896225	4.3

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
437	28	3	1	2.4	15.70	9.13	0.781286	0.700208	0.896225	4.3
438	30	3	1	2.4	15.95	8.84	0.781286	0.700208	0.896225	4.3
439	7	3	1	2.5	0.90	0.00	0.781286	0.700208	0.896225	4.3
440	28	3	1	2.5	15.70	9.13	0.781286	0.700208	0.896225	4.3
441	30	3	1	2.5	15.95	8.84	0.781286	0.700208	0.896225	4.3
442	7	3	1	2.6	0.90	0.00	0.781286	0.700208	0.896225	4.3
443	28	3	1	2.6	15.70	9.13	0.781286	0.700208	0.896225	4.3
444	30	3	1	2.6	15.95	8.84	0.781286	0.700208	0.896225	4.3
445	7	3	1	2.7	0.90	0.00	0.781286	0.700208	0.896225	4.3
446	28	3	1	2.7	15.70	9.13	0.781286	0.700208	0.896225	4.3
447	30	3	1	2.7	15.95	8.84	0.781286	0.700208	0.896225	4.3
448	7	3	1	2.8	0.90	0.00	0.781286	0.700208	0.896225	4.3
449	28	3	1	2.8	15.70	9.13	0.781286	0.700208	0.896225	4.3
450	30	3	1	2.8	15.95	8.84	0.781286	0.700208	0.896225	4.3
451	7	3	1	2.9	0.90	0.00	0.781286	0.700208	0.896225	4.3
452	28	3	1	2.9	15.70	9.13	0.781286	0.700208	0.896225	4.3
453	30	3	1	2.9	15.95	8.84	0.781286	0.700208	0.896225	4.3
454	7	2	0	5	1.01	0.00	0.600861	0.839100	1.396496	7.7
455	24	2	0	5	13.16	7.57	0.600861	0.839100	1.396496	7.7
456	7	3	1	5.1	1.01	0.00	0.600861	0.839100	1.396496	7.7
457	28	3	1	5.1	16.39	9.72	0.600861	0.839100	1.396496	7.7
458	33	3	1	5.1	16.59	8.57	0.600861	0.839100	1.396496	7.7
459	7	3	1	5.2	1.01	0.00	0.600861	0.839100	1.396496	7.7
460	28	3	1	5.2	16.39	9.72	0.600861	0.839100	1.396496	7.7
461	33	3	1	5.2	16.59	8.57	0.600861	0.839100	1.396496	7.7
462	7	3	1	5.3	1.01	0.00	0.600861	0.839100	1.396496	7.7
463	28	3	1	5.3	16.39	9.72	0.600861	0.839100	1.396496	7.7
464	33	3	1	5.3	16.59	8.57	0.600861	0.839100	1.396496	7.7
465	7	3	1	5.4	1.01	0.00	0.600861	0.839100	1.396496	7.7
466	28	3	1	5.4	16.39	9.72	0.600861	0.839100	1.396496	7.7
467	33	3	1	5.4	16.59	8.57	0.600861	0.839100	1.396496	7.7
468	7	3	1	5.5	1.01	0.00	0.600861	0.839100	1.396496	7.7
469	28	3	1	5.5	16.39	9.72	0.600861	0.839100	1.396496	7.7
470	33	3	1	5.5	16.59	8.57	0.600861	0.839100	1.396496	7.7
471	7	3	1	5.6	1.01	0.00	0.600861	0.839100	1.396496	7.7
472	28	3	1	5.6	16.39	9.72	0.600861	0.839100	1.396496	7.7
473	33	3	1	5.6	16.59	8.57	0.600861	0.839100	1.396496	7.7
474	7	3	1	5.7	1.01	0.00	0.600861	0.839100	1.396496	7.7
475	28	3	1	5.7	16.39	9.72	0.600861	0.839100	1.396496	7.7
476	33	3	1	5.7	16.59	8.57	0.600861	0.839100	1.396496	7.7
477	7	3	1	5.8	1.01	0.00	0.600861	0.839100	1.396496	7.7
478	28	3	1	5.8	16.39	9.72	0.600861	0.839100	1.396496	7.7
479	33	3	1	5.8	16.59	8.57	0.600861	0.839100	1.396496	7.7
480	7	2	0	1	1.01	0.00	0.577350	0.700208	1.212796	4.5

Obs	*T*	*NP*	*CEN*	*SITE*	*CUMR*	*CRI*	*SLOPE*	*SS*	*SI*	*CT*
481	25	2	0	1	13.94	8.08	0.577350	0.700208	1.212796	4.5
482	7	3	1	1.1	1.01	0.00	0.577350	0.700208	1.212796	4.5
483	28	3	1	1.1	16.39	9.72	0.577350	0.700208	1.212796	4.5
484	33	3	1	1.1	16.59	8.57	0.577350	0.700208	1.212796	4.5
485	7	3	1	1.2	1.01	0.00	0.577350	0.700208	1.212796	4.5
486	28	3	1	1.2	16.39	9.72	0.577350	0.700208	1.212796	4.5
487	33	3	1	1.2	16.59	8.57	0.577350	0.700208	1.212796	4.5
488	7	3	1	1.2	1.01	0.00	0.577350	0.700208	1.212796	4.5
489	28	3	1	1.2	16.39	9.72	0.577350	0.700208	1.212796	4.5
490	33	3	1	1.2	16.59	8.57	0.577350	0.700208	1.212796	4.5
491	7	3	1	1.3	1.01	0.00	0.577350	0.700208	1.212796	4.5
492	28	3	1	1.3	16.39	9.72	0.577350	0.700208	1.212796	4.5
493	33	3	1	1.3	16.59	8.57	0.577350	0.700208	1.212796	4.5
494	7	3	1	1.4	1.01	0.00	0.577350	0.700208	1.212796	4.5
495	28	3	1	1.4	16.39	9.72	0.577350	0.700208	1.212796	4.5
496	33	3	1	1.4	16.59	8.57	0.577350	0.700208	1.212796	4.5
497	7	3	1	1.5	1.01	0.00	0.577350	0.700208	1.212796	4.5
498	28	3	1	1.5	16.39	9.72	0.577350	0.700208	1.212796	4.5
499	33	3	1	1.5	16.59	8.57	0.577350	0.700208	1.212796	4.5
500	7	3	1	1.6	1.01	0.00	0.577350	0.700208	1.212796	4.5
501	28	3	1	1.6	16.39	9.72	0.577350	0.700208	1.212796	4.5
502	33	3	1	1.6	16.59	8.57	0.577350	0.700208	1.212796	4.5
503	7	3	1	1.7	1.01	0.00	0.577350	0.700208	1.212796	4.5
504	28	3	1	1.7	16.39	9.72	0.577350	0.700208	1.212796	4.5
505	33	3	1	1.7	16.59	8.57	0.577350	0.700208	1.212796	4.5
506	7	3	1	1.8	1.01	0.00	0.577350	0.700208	1.212796	4.5
507	28	3	1	1.8	16.39	9.72	0.577350	0.700208	1.212796	4.5
508	33	3	1	1.8	16.59	8.57	0.577350	0.700208	1.212796	4.5
509	7	3	1	1.9	1.01	0.00	0.577350	0.700208	1.212796	4.5
510	28	3	1	1.9	16.39	9.72	0.577350	0.700208	1.212796	4.5
511	33	3	1	1.9	16.59	8.57	0.577350	0.700208	1.212796	4.5
512	7	3	1	1.10	1.01	0.00	0.577350	0.700208	1.212796	4.5
513	28	3	1	1.10	16.39	9.72	0.577350	0.700208	1.212796	4.5
514	33	3	1	1.10	16.59	8.57	0.577350	0.700208	1.212796	4.5
515	7	3	1	1.11	1.01	0.00	0.577350	0.700208	1.212796	4.5
516	28	3	1	1.11	16.39	9.72	0.577350	0.700208	1.212796	4.5
517	33	3	1	1.11	16.59	8.57	0.577350	0.700208	1.212796	4.5
518	7	3	1	1.12	1.01	0.00	0.577350	0.700208	1.212796	4.5
519	28	3	1	1.12	16.39	9.72	0.577350	0.700208	1.212796	4.5
520	33	3	1	1.12	16.59	8.57	0.577350	0.700208	1.212796	4.5
521	7	3	1	1.13	1.01	0.00	0.577350	0.700208	1.212796	4.5
522	28	3	1	1.13	16.39	9.72	0.577350	0.700208	1.212796	4.5
523	33	3	1	1.13	16.59	8.57	0.577350	0.700208	1.212796	4.5

Appendix E. Example of Regression Results

```
Unexpected END OF FILE at record
524
SAMPLE set to observations 1 to    523
There are  10 variables in the data work area.
Use STATUS for a list.
1


 MODEL COMMAND: SURV ; LHS=LT,CEN,NP ; RHS=SI,MSI ; MODEL=WEIBULL ; LIST $
 Log-linear survival regression model: WEIBULL
 Least squares is used to obtain starting values for MLE.
 Censoring status variable is CEN
 Hazard modelled as a step function
 Numper of records given by   NP
 Found    523 records, and   111 individuals

 Ordinary    least squares regression.    Dep. Variable      = LT
 Observations        =            111       Weights          = ONE
 Mean of LHS         = 0.3455263D+01       Std.Dev of LHS   = 0.1287868D+00
 StdDev of residuals= 0.6998616D+00       Sum of squares   = 0.5338888D+02
 R-squared           = 0.0000000D+00     Adjusted R-squared= -0.9174312D-02
 F[  1,   109]       = 0.0000000D+00
 Log-likelihood      = -0.1168802D+03     Restr.(b=0) Log-l = 0.7050536D+02
Variable     Coefficient      Std. Error      t-ratio     Prob:t:>x      Mean of X    Std.Dev.of X
-------------------------------------------------------------------------------------------------
 SI               2.1075      0.4874E-01     43.242       0.0000         1.5741         0.33489
 MSI        -0.29803E-01      0.3355         -0.089       0.92922        0.1206         0.20114
 Iterations: Method=D/F/P   Maximum interations  50
 Convergence criteria:      Gradient= 0.100D-03    F= 0.100D-03    b= 0.100D-04

 ********************************************************************************

                  Method=D/F/P ; Maximum interations 50
   Convergence criteria: Gradient=    0.1000000E-03
                  Function  =    0.1000000E-03
                  Parameters=    0.1000000E-04
   Starting values:   -2.107       0.2980E-01  0.6999

  ==> Steepest descent iterations

  Iteration:   1 Fn=   508.2203
  PARAM   -2.11      0.298E-01 0.700
  GRADNT   169.      -1.69      -193.

  Iteration:   2 Fn=   483.7682
  PARAM   -2.26      0.313E-01 0.872
  GRADNT   30.8      -6.79      5.80
```

```
Iteration:  3 Fn=  481.7864
PARAM  -2.38    0.577E-01 0.849
GRADNT -3.72    -8.13     10.3

==> D/F/P  ITERATIONS

Iteration:  1 Fn=  481.7864
PARAM  -2.38    0.577E-01 0.849
GRADNT -3.72    -8.13     10.3

Iteration:  2 Fn=  481.4013
PARAM  -2.36    0.899E-01 0.808
GRADNT  4.26    -7.97     -4.88

Iteration:  3 Fn=  476.7174
PARAM  -2.55     1.19     0.722
GRADNT -32.9    -7.81     -33.5

Iteration:  4 Fn=  471.4407
PARAM  -2.55     2.31     0.733
GRADNT -5.57     0.594    -47.8

Iteration:  5 Fn=  469.0427
PARAM  -2.51     2.33     0.839
GRADNT -4.24    -1.54     1.68

Iteration:  6 Fn=  468.8883
PARAM  -2.51     2.54     0.849
GRADNT -0.629E-01 0.350E-01-0.731

Iteration:  7 Fn=  468.8875
PARAM  -2.51     2.54     0.851
GRADNT  0.546E-01-0.735E-02 0.111E-01

Iteration:  8 Fn=  468.8874
PARAM  -2.51     2.54     0.851
GRADNT  0.392E-02 0.757E-03-0.539E-02
** Function has converged.
```

****

Log-linear survival regression model: WEIBULL
Maximum Likelihood Estimates
Log-Likelihood.............. -468.89

Variable	Coefficient	Std. Error	t-ratio	Prob:t:>x	Mean of X	Std.Dev.of X
SI	2.5056	0.6072E-01	41.269	0.00000	1.5741	0.33489
MSI	-2.5386	0.3908	-6.495	0.00000	0.12057	0.20114
Sigma	0.85117	0.5233E-01	16.266	0.00000		

Parameters of underlying density at data means:
(Lambda=exp(bx), P=1/sigma, Median=1/Lambda for Normal and
Logit,((log2)^1/P)/L for W/E,Boxcox(2,theta)^1/P / L if het)

Parameter	Estimate	Std. Error	Confidence Interval
Lambda	0.02630	0.00245	0.0215 to 0.0311
P	1.17485	0.07223	1.0333 to 1.3164
Median	27.83145	2.59470	22.7458 to 32.9171

Percentiles of survival distribution:

SURVIVAL	0.25	0.50	0.75	0.95
TIME	50.21	27.83	13.17	3.03

Predicted Values (* => observation was not in estimating sample.)

Observation	Obsrvd.Time	exp(bx)=prdT	Intg.Hazard	Hazard	Survival
1	10.000	74.494	0.0945	0.0111	0.9098
2	14.000	71.711	0.1467	0.0123	0.8635
3	16.000	73.171	0.1676	0.0123	0.8457
4	20.000	69.498	0.2315	0.0136	0.7934
5	10.000	74.494	0.0945	0.0111	0.9098
6	14.000	71.711	0.1467	0.0123	0.8635
7	16.000	73.171	0.1676	0.0123	0.8457
8	24.000	64.836	0.3111	0.0152	0.7326
9	32.000	47.704	0.6256	0.0230	0.5350
10	10.000	74.494	0.0945	0.0111	0.9098
11	14.000	71.711	0.1467	0.0123	0.8635
12	16.000	73.171	0.1676	0.0123	0.8457
13	24.000	64.836	0.3111	0.0152	0.7326
14	32.000	47.704	0.6256	0.0230	0.5350
15	10.000	74.494	0.0945	0.0111	0.9098
16	14.000	71.711	0.1467	0.0123	0.8635
17	16.000	73.171	0.1676	0.0123	0.8457
18	24.000	64.836	0.3111	0.0152	0.7326

19	32.000	47.704	0.6256	0.0230	0.5350
20	10.000	74.494	0.0945	0.0111	0.9098
21	14.000	71.711	0.1467	0.0123	0.8635
22	16.000	73.171	0.1676	0.0123	0.8457
23	24.000	64.836	0.3111	0.0152	0.7326
24	32.000	47.704	0.6256	0.0230	0.5350
25	10.000	74.494	0.0945	0.0111	0.9098
26	14.000	71.711	0.1467	0.0123	0.8635
27	16.000	73.171	0.1676	0.0123	0.8457
28	24.000	64.836	0.3111	0.0152	0.7326
29	32.000	47.704	0.6256	0.0230	0.5350
30	10.000	74.494	0.0945	0.0111	0.9098
31	14.000	71.711	0.1467	0.0123	0.8635
32	16.000	73.171	0.1676	0.0123	0.8457
33	24.000	64.836	0.3111	0.0152	0.7326
34	32.000	47.704	0.6256	0.0230	0.5350
35	10.000	74.494	0.0945	0.0111	0.9098
36	14.000	71.711	0.1467	0.0123	0.8635
37	16.000	73.171	0.1676	0.0123	0.8457
38	24.000	64.836	0.3111	0.0152	0.7326
39	32.000	47.704	0.6256	0.0230	0.5350
40	10.000	74.494	0.0945	0.0111	0.9098
41	14.000	71.711	0.1467	0.0123	0.8635
42	16.000	73.171	0.1676	0.0123	0.8457
43	24.000	64.836	0.3111	0.0152	0.7326
44	32.000	47.704	0.6256	0.0230	0.5350
45	10.000	74.494	0.0945	0.0111	0.9098
46	14.000	71.711	0.1467	0.0123	0.8635
47	16.000	73.171	0.1676	0.0123	0.8457
48	24.000	64.836	0.3111	0.0152	0.7326
49	32.000	47.704	0.6256	0.0230	0.5350
50	10.000	74.494	0.0945	0.0111	0.9098
51	14.000	71.711	0.1467	0.0123	0.8635
52	16.000	73.171	0.1676	0.0123	0.8457
53	24.000	64.836	0.3111	0.0152	0.7326
54	32.000	47.704	0.6256	0.0230	0.5350
55	10.000	74.494	0.0945	0.0111	0.9098
56	14.000	71.711	0.1467	0.0123	0.8635
57	16.000	73.171	0.1676	0.0123	0.8457
58	24.000	64.836	0.3111	0.0152	0.7326
59	32.000	47.704	0.6256	0.0230	0.5350
60	11.000	110.12	0.0668	0.0071	0.9354
61	25.000	97.220	0.2028	0.0095	0.8164
62	27.000	98.094	0.2197	0.0096	0.8028
63	28.000	96.746	0.2330	0.0098	0.7921
64	11.000	110.12	0.0668	0.0071	0.9354
65	25.000	97.220	0.2028	0.0095	0.8164
66	27.000	98.094	0.2197	0.0096	0.8028
67	32.000	90.424	0.2951	0.0108	0.7444

68	37.000	96.039	0.3261	0.0104	0.7217
69	11.000	110.12	0.0668	0.0071	0.9354
70	25.000	97.220	0.2028	0.0095	0.8164
71	27.000	98.094	0.2197	0.0096	0.8028
72	32.000	90.424	0.2951	0.0108	0.7444
73	37.000	96.039	0.3261	0.0104	0.7217
74	11.000	110.12	0.0668	0.0071	0.9354
75	25.000	97.220	0.2028	0.0095	0.8164
76	27.000	98.094	0.2197	0.0096	0.8028
77	32.000	90.424	0.2951	0.0108	0.7444
78	37.000	96.039	0.3261	0.0104	0.7217
79	11.000	110.12	0.0668	0.0071	0.9354
80	25.000	97.220	0.2028	0.0095	0.8164
81	27.000	98.094	0.2197	0.0096	0.8028
82	32.000	90.424	0.2951	0.0108	0.7444
83	37.000	96.039	0.3261	0.0104	0.7217
84	11.000	110.12	0.0668	0.0071	0.9354
85	25.000	97.220	0.2028	0.0095	0.8164
86	27.000	98.094	0.2197	0.0096	0.8028
87	32.000	90.424	0.2951	0.0108	0.7444
88	37.000	96.039	0.3261	0.0104	0.7217
89	11.000	110.12	0.0668	0.0071	0.9354
90	25.000	97.220	0.2028	0.0095	0.8164
91	27.000	98.094	0.2197	0.0096	0.8028
92	32.000	90.424	0.2951	0.0108	0.7444
93	37.000	96.039	0.3261	0.0104	0.7217
94	11.000	110.12	0.0668	0.0071	0.9354
95	25.000	97.220	0.2028	0.0095	0.8164
96	27.000	98.094	0.2197	0.0096	0.8028
97	32.000	90.424	0.2951	0.0108	0.7444
98	37.000	96.039	0.3261	0.0104	0.7217
99	11.000	110.12	0.0668	0.0071	0.9354
100	25.000	97.220	0.2028	0.0095	0.8164
101	27.000	98.094	0.2197	0.0096	0.8028
102	32.000	90.424	0.2951	0.0108	0.7444
103	37.000	96.039	0.3261	0.0104	0.7217
104	11.000	110.12	0.0668	0.0071	0.9354
105	25.000	97.220	0.2028	0.0095	0.8164
106	27.000	98.094	0.2197	0.0096	0.8028
107	32.000	90.424	0.2951	0.0108	0.7444
108	37.000	96.039	0.3261	0.0104	0.7217
109	11.000	110.12	0.0668	0.0071	0.9354
110	25.000	97.220	0.2028	0.0095	0.8164
111	27.000	98.094	0.2197	0.0096	0.8028
112	32.000	90.424	0.2951	0.0108	0.7444
113	37.000	96.039	0.3261	0.0104	0.7217
114	11.000	110.12	0.0668	0.0071	0.9354
115	25.000	97.220	0.2028	0.0095	0.8164
116	27.000	98.094	0.2197	0.0096	0.8028

117	32.000	90.424	0.2951	0.0108	0.7444
118	37.000	96.039	0.3261	0.0104	0.7217
119	11.000	110.12	0.0668	0.0071	0.9354
120	25.000	97.220	0.2028	0.0095	0.8164
121	27.000	98.094	0.2197	0.0096	0.8028
122	32.000	90.424	0.2951	0.0108	0.7444
123	37.000	96.039	0.3261	0.0104	0.7217
124	11.000	110.12	0.0668	0.0071	0.9354
125	25.000	97.220	0.2028	0.0095	0.8164
126	27.000	98.094	0.2197	0.0096	0.8028
127	32.000	90.424	0.2951	0.0108	0.7444
128	37.000	96.039	0.3261	0.0104	0.7217
129	11.000	110.12	0.0668	0.0071	0.9354
130	25.000	97.220	0.2028	0.0095	0.8164
131	27.000	98.094	0.2197	0.0096	0.8028
132	32.000	90.424	0.2951	0.0108	0.7444
133	37.000	96.039	0.3261	0.0104	0.7217
134	11.000	110.12	0.0668	0.0071	0.9354
135	25.000	97.220	0.2028	0.0095	0.8164
136	27.000	98.094	0.2197	0.0096	0.8028
137	32.000	90.424	0.2951	0.0108	0.7444
138	37.000	96.039	0.3261	0.0104	0.7217
139	11.000	110.12	0.0668	0.0071	0.9354
140	25.000	97.220	0.2028	0.0095	0.8164
141	27.000	98.094	0.2197	0.0096	0.8028
142	32.000	90.424	0.2951	0.0108	0.7444
143	37.000	96.039	0.3261	0.0104	0.7217
144	5.0000	74.494	0.0419	0.0098	0.9590
145	7.0000	74.244	0.0624	0.0105	0.9395
146	11.000	74.494	0.1057	0.0113	0.8997
147	20.000	67.655	0.2389	0.0140	0.7875
148	5.0000	74.494	0.0419	0.0098	0.9590
149	7.0000	74.244	0.0624	0.0105	0.9395
150	11.000	74.494	0.1057	0.0113	0.8997
151	29.000	62.835	0.4032	0.0163	0.6682
152	32.000	63.756	0.4449	0.0163	0.6409
153	5.0000	74.494	0.0419	0.0098	0.9590
154	7.0000	74.244	0.0624	0.0105	0.9395
155	11.000	74.494	0.1057	0.0113	0.8997
156	29.000	62.835	0.4032	0.0163	0.6682
157	32.000	63.756	0.4449	0.0163	0.6409
158	5.0000	74.494	0.0419	0.0098	0.9590
159	7.0000	74.244	0.0624	0.0105	0.9395
160	11.000	74.494	0.1057	0.0113	0.8997
161	29.000	62.835	0.4032	0.0163	0.6682
162	32.000	63.756	0.4449	0.0163	0.6409
163	5.0000	74.494	0.0419	0.0098	0.9590
164	7.0000	74.244	0.0624	0.0105	0.9395
165	11.000	74.494	0.1057	0.0113	0.8997

166	29.000	62.835	0.4032	0.0163	0.6682
167	32.000	63.756	0.4449	0.0163	0.6409
168	5.0000	74.494	0.0419	0.0098	0.9590
169	7.0000	74.244	0.0624	0.0105	0.9395
170	11.000	74.494	0.1057	0.0113	0.8997
171	29.000	62.835	0.4032	0.0163	0.6682
172	32.000	63.756	0.4449	0.0163	0.6409
173	5.0000	38.153	0.0919	0.0216	0.9122
174	7.0000	38.033	0.1369	0.0230	0.8721
175	11.000	38.153	0.2320	0.0248	0.7930
176	28.000	32.880	0.8280	0.0347	0.4369
177	5.0000	38.153	0.0919	0.0216	0.9122
178	7.0000	38.033	0.1369	0.0230	0.8721
179	11.000	38.153	0.2320	0.0248	0.7930
180	29.000	32.519	0.8741	0.0354	0.4172
181	31.000	32.967	0.9303	0.0353	0.3944
182	5.0000	38.153	0.0919	0.0216	0.9122
183	7.0000	38.033	0.1369	0.0230	0.8721
184	11.000	38.153	0.2320	0.0248	0.7930
185	29.000	32.519	0.8741	0.0354	0.4172
186	31.000	32.967	0.9303	0.0353	0.3944
187	5.0000	38.153	0.0919	0.0216	0.9122
188	7.0000	38.033	0.1369	0.0230	0.8721
189	11.000	38.153	0.2320	0.0248	0.7930
190	29.000	32.519	0.8741	0.0354	0.4172
191	31.000	32.967	0.9303	0.0353	0.3944
192	5.0000	38.153	0.0919	0.0216	0.9122
193	7.0000	38.033	0.1369	0.0230	0.8721
194	11.000	38.153	0.2320	0.0248	0.7930
195	29.000	32.519	0.8741	0.0354	0.4172
196	31.000	32.967	0.9303	0.0353	0.3944
197	5.0000	38.153	0.0919	0.0216	0.9122
198	7.0000	38.033	0.1369	0.0230	0.8721
199	11.000	38.153	0.2320	0.0248	0.7930
200	29.000	32.519	0.8741	0.0354	0.4172
201	31.000	32.967	0.9303	0.0353	0.3944
202	5.0000	38.153	0.0919	0.0216	0.9122
203	7.0000	38.033	0.1369	0.0230	0.8721
204	11.000	38.153	0.2320	0.0248	0.7930
205	29.000	32.519	0.8741	0.0354	0.4172
206	31.000	32.967	0.9303	0.0353	0.3944
207	5.0000	38.153	0.0919	0.0216	0.9122
208	7.0000	38.033	0.1369	0.0230	0.8721
209	11.000	38.153	0.2320	0.0248	0.7930
210	29.000	32.519	0.8741	0.0354	0.4172
211	31.000	32.967	0.9303	0.0353	0.3944
212	5.0000	38.153	0.0919	0.0216	0.9122
213	7.0000	38.033	0.1369	0.0230	0.8721
214	11.000	38.153	0.2320	0.0248	0.7930

215	29.000	32.519	0.8741	0.0354	0.4172
216	31.000	32.967	0.9303	0.0353	0.3944
217	5.0000	38.153	0.0919	0.0216	0.9122
218	7.0000	38.033	0.1369	0.0230	0.8721
219	11.000	38.153	0.2320	0.0248	0.7930
220	29.000	32.519	0.8741	0.0354	0.4172
221	31.000	32.967	0.9303	0.0353	0.3944
222	5.0000	38.153	0.0919	0.0216	0.9122
223	7.0000	38.033	0.1369	0.0230	0.8721
224	11.000	38.153	0.2320	0.0248	0.7930
225	29.000	32.519	0.8741	0.0354	0.4172
226	31.000	32.967	0.9303	0.0353	0.3944
227	5.0000	38.153	0.0919	0.0216	0.9122
228	7.0000	38.033	0.1369	0.0230	0.8721
229	11.000	38.153	0.2320	0.0248	0.7930
230	29.000	32.519	0.8741	0.0354	0.4172
231	31.000	32.967	0.9303	0.0353	0.3944
232	5.0000	38.153	0.0919	0.0216	0.9122
233	7.0000	38.033	0.1369	0.0230	0.8721
234	11.000	38.153	0.2320	0.0248	0.7930
235	29.000	32.519	0.8741	0.0354	0.4172
236	31.000	32.967	0.9303	0.0353	0.3944
237	5.0000	38.153	0.0919	0.0216	0.9122
238	7.0000	38.033	0.1369	0.0230	0.8721
239	11.000	38.153	0.2320	0.0248	0.7930
240	29.000	32.519	0.8741	0.0354	0.4172
241	31.000	32.967	0.9303	0.0353	0.3944
242	14.000	141.62	0.0660	0.0055	0.9362
243	16.000	141.07	0.0775	0.0057	0.9254
244	18.000	141.62	0.0886	0.0058	0.9152
245	23.000	129.00	0.1319	0.0067	0.8764
246	14.000	141.62	0.0660	0.0055	0.9362
247	16.000	141.07	0.0775	0.0057	0.9254
248	18.000	141.62	0.0886	0.0058	0.9152
249	25.000	118.73	0.1604	0.0075	0.8518
250	36.000	134.17	0.2132	0.0070	0.8080
251	14.000	141.62	0.0660	0.0055	0.9362
252	16.000	141.07	0.0775	0.0057	0.9254
253	18.000	141.62	0.0886	0.0058	0.9152
254	25.000	118.73	0.1604	0.0075	0.8518
255	36.000	134.17	0.2132	0.0070	0.8080
256	14.000	141.62	0.0660	0.0055	0.9362
257	16.000	141.07	0.0775	0.0057	0.9254
258	18.000	141.62	0.0886	0.0058	0.9152
259	25.000	118.73	0.1604	0.0075	0.8518
260	36.000	134.17	0.2132	0.0070	0.8080
261	14.000	141.62	0.0660	0.0055	0.9362
262	16.000	141.07	0.0775	0.0057	0.9254
263	18.000	141.62	0.0886	0.0058	0.9152

264	25.000	118.73	0.1604	0.0075	0.8518
265	36.000	134.17	0.2132	0.0070	0.8080
266	14.000	322.64	0.0251	0.0021	0.9752
267	16.000	319.74	0.0296	0.0022	0.9708
268	18.000	322.64	0.0337	0.0022	0.9669
269	24.000	258.38	0.0613	0.0030	0.9405
270	14.000	322.64	0.0251	0.0021	0.9752
271	16.000	319.74	0.0296	0.0022	0.9708
272	18.000	322.64	0.0337	0.0022	0.9669
273	26.000	213.87	0.0841	0.0038	0.9193
274	36.000	284.42	0.0882	0.0029	0.9156
275	14.000	322.64	0.0251	0.0021	0.9752
276	16.000	319.74	0.0296	0.0022	0.9708
277	18.000	322.64	0.0337	0.0022	0.9669
278	26.000	213.87	0.0841	0.0038	0.9193
279	36.000	284.42	0.0882	0.0029	0.9156
280	14.000	322.64	0.0251	0.0021	0.9752
281	16.000	319.74	0.0296	0.0022	0.9708
282	18.000	322.64	0.0337	0.0022	0.9669
283	26.000	213.87	0.0841	0.0038	0.9193
284	36.000	284.42	0.0882	0.0029	0.9156
285	13.000	74.494	0.1286	0.0116	0.8793
286	14.000	68.878	0.1538	0.0129	0.8574
287	15.000	74.494	0.1521	0.0119	0.8589
288	27.000	74.494	0.3035	0.0132	0.7382
289	28.000	55.677	0.4460	0.0187	0.6402
290	13.000	74.494	0.1286	0.0116	0.8793
291	14.000	68.878	0.1538	0.0129	0.8574
292	27.000	74.494	0.3035	0.0132	0.7382
293	31.000	8.0224	4.8945	0.1855	0.0075
294	33.000	10.264	3.9437	0.1404	0.0194
295	13.000	74.494	0.1286	0.0116	0.8793
296	14.000	68.878	0.1538	0.0129	0.8574
297	27.000	74.494	0.3035	0.0132	0.7382
298	31.000	8.0224	4.8945	0.1855	0.0075
299	33.000	10.264	3.9437	0.1404	0.0194
300	13.000	74.494	0.1286	0.0116	0.8793
301	14.000	68.878	0.1538	0.0129	0.8574
302	27.000	74.494	0.3035	0.0132	0.7382
303	31.000	8.0224	4.8945	0.1855	0.0075
304	33.000	10.264	3.9437	0.1404	0.0194
305	13.000	74.494	0.1286	0.0116	0.8793
306	14.000	68.878	0.1538	0.0129	0.8574
307	27.000	74.494	0.3035	0.0132	0.7382
308	31.000	8.0224	4.8945	0.1855	0.0075
309	33.000	10.264	3.9437	0.1404	0.0194
310	13.000	74.494	0.1286	0.0116	0.8793
311	14.000	68.878	0.1538	0.0129	0.8574
312	27.000	74.494	0.3035	0.0132	0.7382

313	31.000	8.0224	4.8945	0.1855	0.0075
314	33.000	10.264	3.9437	0.1404	0.0194
315	13.000	74.494	0.1286	0.0116	0.8793
316	14.000	68.878	0.1538	0.0129	0.8574
317	27.000	74.494	0.3035	0.0132	0.7382
318	31.000	8.0224	4.8945	0.1855	0.0075
319	33.000	10.264	3.9437	0.1404	0.0194
320	13.000	74.494	0.1286	0.0116	0.8793
321	14.000	68.878	0.1538	0.0129	0.8574
322	27.000	74.494	0.3035	0.0132	0.7382
323	31.000	8.0224	4.8945	0.1855	0.0075
324	33.000	10.264	3.9437	0.1404	0.0194
325	13.000	74.494	0.1286	0.0116	0.8793
326	14.000	68.878	0.1538	0.0129	0.8574
327	27.000	74.494	0.3035	0.0132	0.7382
328	31.000	8.0224	4.8945	0.1855	0.0075
329	33.000	10.264	3.9437	0.1404	0.0194
330	13.000	74.494	0.1286	0.0116	0.8793
331	14.000	68.878	0.1538	0.0129	0.8574
332	27.000	74.494	0.3035	0.0132	0.7382
333	31.000	8.0224	4.8945	0.1855	0.0075
334	33.000	10.264	3.9437	0.1404	0.0194
335	4.0000	74.494	0.0322	0.0095	0.9683
336	5.0000	74.451	0.0419	0.0098	0.9590
337	10.000	74.494	0.0945	0.0111	0.9098
338	13.000	74.366	0.1289	0.0116	0.8791
339	14.000	74.494	0.1403	0.0118	0.8691
340	18.000	73.898	0.1903	0.0124	0.8267
341	19.000	74.068	0.2022	0.0125	0.8169
342	23.000	72.635	0.2590	0.0132	0.7718
343	24.000	72.802	0.2715	0.0133	0.7622
344	28.000	70.986	0.3352	0.0141	0.7152
345	4.0000	74.494	0.0322	0.0095	0.9683
346	5.0000	74.451	0.0419	0.0098	0.9590
347	10.000	74.494	0.0945	0.0111	0.9098
348	13.000	74.366	0.1289	0.0116	0.8791
349	14.000	74.494	0.1403	0.0118	0.8691
350	18.000	73.898	0.1903	0.0124	0.8267
351	19.000	74.068	0.2022	0.0125	0.8169
352	23.000	72.635	0.2590	0.0132	0.7718
353	24.000	72.802	0.2715	0.0133	0.7622
354	28.000	70.986	0.3352	0.0141	0.7152
355	4.0000	74.494	0.0322	0.0095	0.9683
356	5.0000	74.451	0.0419	0.0098	0.9590
357	10.000	74.494	0.0945	0.0111	0.9098
358	13.000	74.366	0.1289	0.0116	0.8791
359	14.000	74.494	0.1403	0.0118	0.8691
360	18.000	73.898	0.1903	0.0124	0.8267
361	19.000	74.068	0.2022	0.0125	0.8169

362	23.000	72.635	0.2590	0.0132	0.7718
363	24.000	72.802	0.2715	0.0133	0.7622
364	28.000	70.986	0.3352	0.0141	0.7152
365	4.0000	74.494	0.0322	0.0095	0.9683
366	5.0000	74.451	0.0419	0.0098	0.9590
367	10.000	74.494	0.0945	0.0111	0.9098
368	13.000	74.366	0.1289	0.0116	0.8791
369	14.000	74.494	0.1403	0.0118	0.8691
370	18.000	73.898	0.1903	0.0124	0.8267
371	19.000	74.068	0.2022	0.0125	0.8169
372	23.000	72.635	0.2590	0.0132	0.7718
373	24.000	72.802	0.2715	0.0133	0.7622
374	28.000	70.986	0.3352	0.0141	0.7152
375	4.0000	74.494	0.0322	0.0095	0.9683
376	5.0000	74.451	0.0419	0.0098	0.9590
377	10.000	74.494	0.0945	0.0111	0.9098
378	13.000	74.366	0.1289	0.0116	0.8791
379	14.000	74.494	0.1403	0.0118	0.8691
380	18.000	73.898	0.1903	0.0124	0.8267
381	19.000	74.068	0.2022	0.0125	0.8169
382	23.000	72.635	0.2590	0.0132	0.7718
383	24.000	72.802	0.2715	0.0133	0.7622
384	28.000	70.986	0.3352	0.0141	0.7152
385	4.0000	74.494	0.0322	0.0095	0.9683
386	5.0000	74.451	0.0419	0.0098	0.9590
387	10.000	74.494	0.0945	0.0111	0.9098
388	13.000	74.366	0.1289	0.0116	0.8791
389	14.000	74.494	0.1403	0.0118	0.8691
390	18.000	73.898	0.1903	0.0124	0.8267
391	19.000	74.068	0.2022	0.0125	0.8169
392	23.000	72.635	0.2590	0.0132	0.7718
393	24.000	72.802	0.2715	0.0133	0.7622
394	28.000	70.986	0.3352	0.0141	0.7152
395	4.0000	74.494	0.0322	0.0095	0.9683
396	5.0000	74.451	0.0419	0.0098	0.9590
397	10.000	74.494	0.0945	0.0111	0.9098
398	13.000	74.366	0.1289	0.0116	0.8791
399	14.000	74.494	0.1403	0.0118	0.8691
400	18.000	73.898	0.1903	0.0124	0.8267
401	19.000	74.068	0.2022	0.0125	0.8169
402	23.000	72.635	0.2590	0.0132	0.7718
403	24.000	72.802	0.2715	0.0133	0.7622
404	28.000	70.986	0.3352	0.0141	0.7152
405	4.0000	74.494	0.0322	0.0095	0.9683
406	5.0000	74.451	0.0419	0.0098	0.9590
407	10.000	74.494	0.0945	0.0111	0.9098
408	13.000	74.366	0.1289	0.0116	0.8791
409	14.000	74.494	0.1403	0.0118	0.8691
410	18.000	73.898	0.1903	0.0124	0.8267

411	19.000	74.068	0.2022	0.0125	0.8169
412	23.000	72.635	0.2590	0.0132	0.7718
413	24.000	72.802	0.2715	0.0133	0.7622
414	28.000	70.986	0.3352	0.0141	0.7152
415	4.0000	74.494	0.0322	0.0095	0.9683
416	5.0000	74.451	0.0419	0.0098	0.9590
417	10.000	74.494	0.0945	0.0111	0.9098
418	13.000	74.366	0.1289	0.0116	0.8791
419	14.000	74.494	0.1403	0.0118	0.8691
420	18.000	73.898	0.1903	0.0124	0.8267
421	19.000	74.068	0.2022	0.0125	0.8169
422	23.000	72.635	0.2590	0.0132	0.7718
423	24.000	72.802	0.2715	0.0133	0.7622
424	28.000	70.986	0.3352	0.0141	0.7152
425	7.0000	9.4462	0.7032	0.1180	0.4950
426	18.000	8.8651	2.2981	0.1500	0.1004
427	7.0000	9.4462	0.7032	0.1180	0.4950
428	28.000	8.3457	4.1458	0.1740	0.0158
429	30.000	8.3786	4.4751	0.1753	0.0114
430	7.0000	9.4462	0.7032	0.1180	0.4950
431	28.000	8.3457	4.1458	0.1740	0.0158
432	30.000	8.3786	4.4751	0.1753	0.0114
433	7.0000	9.4462	0.7032	0.1180	0.4950
434	28.000	8.3457	4.1458	0.1740	0.0158
435	30.000	8.3786	4.4751	0.1753	0.0114
436	7.0000	9.4462	0.7032	0.1180	0.4950
437	28.000	8.3457	4.1458	0.1740	0.0158
438	30.000	8.3786	4.4751	0.1753	0.0114
439	7.0000	9.4462	0.7032	0.1180	0.4950
440	28.000	8.3457	4.1458	0.1740	0.0158
441	30.000	8.3786	4.4751	0.1753	0.0114
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449	28.000	8.3457	4.1458	0.1740	0.0158
450	30.000	8.3786	4.4751	0.1753	0.0114
451	7.0000	9.4462	0.7032	0.1180	0.4950
452	28.000	8.3457	4.1458	0.1740	0.0158
453	30.000	8.3786	4.4751	0.1753	0.0114
454	7.0000	33.086	0.1613	0.0271	0.8511
455	24.000	30.258	0.7617	0.0373	0.4669
456	7.0000	33.086	0.1613	0.0271	0.8511
457	28.000	29.499	0.9406	0.0395	0.3904
458	33.000	29.903	1.1228	0.0400	0.3254
459	7.0000	33.086	0.1613	0.0271	0.8511

460	28.000	29.499	0.9406	0.0395	0.3904
461	33.000	29.903	1.1228	0.0400	0.3254
462	7.0000	33.086	0.1613	0.0271	0.8511
463	28.000	29.499	0.9406	0.0395	0.3904
464	33.000	29.903	1.1228	0.0400	0.3254
465	7.0000	33.086	0.1613	0.0271	0.8511
466	28.000	29.499	0.9406	0.0395	0.3904
467	33.000	29.903	1.1228	0.0400	0.3254
468	7.0000	33.086	0.1613	0.0271	0.8511
469	28.000	29.499	0.9406	0.0395	0.3904
470	33.000	29.903	1.1228	0.0400	0.3254
471	7.0000	33.086	0.1613	0.0271	0.8511
472	28.000	29.499	0.9406	0.0395	0.3904
473	33.000	29.903	1.1228	0.0400	0.3254
474	7.0000	33.086	0.1613	0.0271	0.8511
475	28.000	29.499	0.9406	0.0395	0.3904
476	33.000	29.903	1.1228	0.0400	0.3254
477	7.0000	33.086	0.1613	0.0271	0.8511
478	28.000	29.499	0.9406	0.0395	0.3904
479	33.000	29.903	1.1228	0.0400	0.3254
480	7.0000	20.881	0.2769	0.0465	0.7581
481	25.000	18.121	1.4594	0.0686	0.2324
482	7.0000	20.881	0.2769	0.0465	0.7581
483	28.000	17.607	1.7246	0.0724	0.1782
484	33.000	17.966	2.0428	0.0727	0.1297
485	7.0000	20.881	0.2769	0.0465	0.7581
486	28.000	17.607	1.7246	0.0724	0.1782
487	33.000	17.966	2.0428	0.0727	0.1297
488	7.0000	20.881	0.2769	0.0465	0.7581
489	28.000	17.607	1.7246	0.0724	0.1782
490	33.000	17.966	2.0428	0.0727	0.1297
491	7.0000	20.881	0.2769	0.0465	0.7581
492	28.000	17.607	1.7246	0.0724	0.1782
493	33.000	17.966	2.0428	0.0727	0.1297
494	7.0000	20.881	0.2769	0.0465	0.7581
495	28.000	17.607	1.7246	0.0724	0.1782
496	33.000	17.966	2.0428	0.0727	0.1297
497	7.0000	20.881	0.2769	0.0465	0.7581
498	28.000	17.607	1.7246	0.0724	0.1782
499	33.000	17.966	2.0428	0.0727	0.1297
500	7.0000	20.881	0.2769	0.0465	0.7581
501	28.000	17.607	1.7246	0.0724	0.1782
502	33.000	17.966	2.0428	0.0727	0.1297
503	7.0000	20.881	0.2769	0.0465	0.7581
504	28.000	17.607	1.7246	0.0724	0.1782
505	33.000	17.966	2.0428	0.0727	0.1297
506	7.0000	20.881	0.2769	0.0465	0.7581
507	28.000	17.607	1.7246	0.0724	0.1782
508	33.000	17.966	2.0428	0.0727	0.1297

509	7.0000	20.881	0.2769	0.0465	0.7581
510	28.000	17.607	1.7246	0.0724	0.1782
511	33.000	17.966	2.0428	0.0727	0.1297
512	7.0000	20.881	0.2769	0.0465	0.7581
513	28.000	17.607	1.7246	0.0724	0.1782
514	33.000	17.966	2.0428	0.0727	0.1297
515	7.0000	20.881	0.2769	0.0465	0.7581
516	28.000	17.607	1.7246	0.0724	0.1782
517	33.000	17.966	2.0428	0.0727	0.1297
518	7.0000	20.881	0.2769	0.0465	0.7581
519	28.000	17.607	1.7246	0.0724	0.1782
520	33.000	17.966	2.0428	0.0727	0.1297
521	7.0000	20.881	0.2769	0.0465	0.7581
522	28.000	17.607	1.7246	0.0724	0.1782
523	33.000	17.966	2.0428	0.0727	0.1297

Appendix F. Macro's for Calculating Probabilities in ARC/INFO

The following are two ARC/INFO aml's (batch commands written in ARC Macro Language) originally written by D.R. Soller in 1992 to call for repeat calculation of distribution function probabilities for each hour of duration using input CRI from gage A-5 in Oakland, CA, for the selected hour. The aml's were modified in 1993 and 1994 by R. H. Campbell for use with other probability functions (the present version calculates the hazard function). Masterhf.aml calls hfcalc.aml to calculate probabilities at user-defined times (as frequently as each hour; presently set to calculate for 4-hour intervals). It can also be modified to input storm rain-gage data from other gages in other areas.

This aml sequence (masterhf.aml-hfcalc.aml) was created for use with a single ARC/INFO (version 5.0) cover consisting of cellular polygons, and was designed to place the calculated probabilities for each hour in a separate item in the <cover>.PAT. The calculations by hfcalc.aml are, therefore, performed in INFO. Masterhf.aml is run at the ARC prompt as "&r masterhf.aml <covername>". If hfcalc.aml is run alone, it is called at the ARC prompt as "&r hfcalc.aml <covername> <hour> <CRI>". The macro, hfcalc.aml, contains several special steps to trap illegal divide-by-0 operations and to convert negative exponents to inverse positive exponents for calculation in INFO. (Note: Since the installation of ARC/INFO version 6.1 for general use in the USGS Eastern Region GIS Laboratory, this calculation is done in the GRID subroutine.)

1. masterhf.aml

```
&ARGS cover
&IF [NULL %cover%] &THEN &S cover := [RESPONSE 'cover']
&IF [NULL %cover%] &THEN &GOTO QUIT
/*
&r hfcalc %cover% 1 .000000
/* &r hfcalc %cover% 2 .000000
/* &r hfcalc %cover% 3  .000000
&r hfcalc %cover% 4 .000000
/* &r hfcalc %cover% 5  .000000
/* &r hfcalc %cover% 6  .000000
/* &r hfcalc %cover% 7  .000000
&r hfcalc %cover% 8 .000000
/* &r hfcalc %cover% 9  .000000
/* &r hfcalc %cover% 10  .000000
/* &r hfcalc %cover% 11  .000000
&r hfcalc %cover% 12 .0200000
/* &r hfcalc %cover% 13  .030000
```

```
/* &r hfcalc %cover% 14  .150000
/* &r hfcalc %cover% 15  .280000
&r hfcalc %cover% 16 .400000
/* &r hfcalc %cover% 17 .580000
/* &r hfcalc %cover% 18 .690000
/* &r hfcalc %cover% 19 .860000
&r hfcalc %cover% 20 1.030000
/* &r hfcalc %cover% 21 1.100000
/* &r hfcalc %cover% 22 1.320000
/* &r hfcalc %cover% 23 1.390000
&r hfcalc %cover% 24 1.510000
/* &r hfcalc %cover% 25 .1.530000
/* &r hfcalc %cover% 26 1.470000
/* &r hfcalc %cover% 27 1.420000.
&r hfcalc %cover% 28 1.590000
/* &r hfcalc %cover% 29 1.860000
/* &r hfcalc %cover% 30 2.130000
/* &r hfcalc %cover% 31 2.350000
&r hfcalc %cover% 32  2.420000
/* &r hfcalc %cover% 33 2.340000
/* &r hfcalc %cover% 34 2.170000
/* &r hfcalc %cover% 35 2.010000
&r hfcalc %cover% 36 1.840000
/* &r hfcalc %cover% 37 1.680000
&return
```

2. hfcalc.aml

```
/*
&ARGS cover hour cri
&IF [NULL %cover%] &THEN &S cover := [RESPONSE 'cover']
&IF [NULL %cover%] &THEN &GOTO QUIT
&IF [NULL %hour%] &THEN &S hour := [RESPONSE 'hour']
&IF [NULL %hour%] &THEN &GOTO QUIT
&IF [NULL %cri%] &THEN &S cri := [RESPONSE 'cri']
&IF [NULL %cri%] &THEN &GOTO QUIT
/*
ADDITEM %cover%.PAT %cover%.PAT HF%hour% 4 8 F 6
/*
&data arc info
ARC
```

```
SEL %cover%.PAT
CALC HF%hour% = 0
CALC BETA = 0
CALC LAMBDA = 0
CALC SIH = 0
CALC M = 0
CALC MSIH = 0
CALC SYMB = 0
RES TRIM NE 1              | Selects only cells without boundary effects.
RES CZ LT .2               | Identifies cells where soil too thin for soil slips to form
CALC HF%hour% = 0
N
CALC SYMB = 1              | Identifier for no further calculation
N
ASEL
RES TRIM NE 1              | Selects for no boundary effects and
RES SYMB NE 1              |  no further calculation of probability
RES TANASLOPE = 0          | To avoid illegal divide by 0
CALC HF%hour% = 0          | Pre set probability to 0
N
CALC SYMB = 2              | Identifier for divide by 0
N
ASEL
RES TRIM NE 1              | No boundary effects
RES SYMB NE 1              | No further calculation of probability
RES SYMB NE 2              | No divide by 0
CALC M = %cri% / ( CZ * 39 )
N
CALC SIH = SI
N
RES TANASLOPE LE .01    | No divide by near 0
CALC SIH = 57.735  | Pre set SIH to large number
N
ASEL
RES TRIM NE 1
RES SYMB NE 1
RES SYMB NE 2
CALC MSIH = M * SIH
N
CALC BETA = 2.5056 * SIH - 2.5386 * MSIH
N
RES BETA GE 0              | INFO requires transformation for negative exponents
```

```
CALC LAMBDA = 1 / ( 2.71828 ** BETA )
N
ASEL
RES TRIM NE 1
RES SYMB NE 1
RES SYMB NE 2
RES BETA LT 0
CALC LAMBDA = 2.71828 ** ( - BETA )
N
ASEL
RES TRIM NE 1
RES SYMB NE 1
RES SYMB NE 2
CALC HF%hour% = ( 1.17485 ) * ( LAMBDA  ** 1.17485 ) * ( %hour% ** .17485 )
N
ASEL
Q STOP
&END
&return
```

Figure Captions

Figure 1. Index map showing San Francisco Bay region, numbers 1-11 identify sites of 1982 rainstorm-triggered debris flows having known times of failure. Leaders from adjacent map identify location of the northwest part of the Oakland East 7.5' quadrangle.

Figure 2. Related Weibull functions, extrapolated to 102 hours using mean values for x_i from the regression data set.
$S(t)$, survivor function;
$F(t)=1-S(t)$, cumulative probability distribution function;
$f(t)=dF(t)/dt, =\lambda p(\lambda t)^{p-1}exp(-(\lambda t)^p)$, probability density function;
$h(t)=f(t)/S(t)=\lambda p(\lambda t)^{p-1}$, hazard function.

Figure 3. Rainfall curves illustrating *CRI* at two different gages: SZ-4 - A gage in Santa Cruz County in an area having a high (greater than 660 mm) mean annual precipitation (MAP); and SM-3 - a gage in San Mateo County in an area having low (less than 660 mm) mean annual precipitation. At both gages, upper curves are total cumulative rainfall; lower curves are cumultive (*CRI*) rainfall from equation 3, using an I_0 of 6.8 mm/h (.27 in/h) for SZ-4, a high MAP gage, and an I_0 of 4.6 mm/h (.18 in/h) for SM-3, a low MAP gage.

Figure 4. Weibull survival functions for averages of the variables in the regression data set, showing regression results for several combinations of the variables. Except for the regression on *CRI* alone (magenta) these curves have acceptably high log-likelihood, and the T-ratios for the variables are significant. Of these, we selected the model using *SI* and *MSI* for use in calculating the probabilities shown on the maps.

Figure 5. Gage record A-5, a gage in Alameda County near in the southwestern quarter of the Oakland East quadrangle, showing (1) cumulative storm rainfall curve (red) and period of observation specified by it, and (2) cumulative rainfall index curve (blue), which provides a CRI_T at the end of each time increment used to calculate probability from the hazard function. (Also shows time to failure at nearby site number 11.) Used in calculating probabilities for maps of the northwest quarter of the Oakland East 7.5' quadrangle.

Figure 6. Shaded relief base map for the northwest quarter of the Oakland East 7.5' quadrangle from USGS digital line graph (DLG) data, showing post-storm (1982) debris-flow scar inventory (red dots) from R. K. Mark (electronic communication, 1992).

D. Hour 12

E. Hour 16

F. Hour 20

G. Hour 24

H. Hour 28

I. Hour 32

J. Hour 36

Figure B-1. Slope steepness at debris-flow sources in San Mateo County, California, derived from digital elevation model (after Wieczorek and others. 1988, Figure 8.3, p. 141). Histogram 1 shows steepness of all slopes; histogram 2 shows steepness at debris-flow source areas; curve, ratio of histogram 2 to histogram 1 is normalized steepness distribution of debris flows. To create Table B-1, the histograms were truncated to remove slopes less than 25 percent (about 14 degrees) and renormalized.

Table Captions

Table 1. -- Tabular data for eleven sites of rainfall-triggered debris flows in the San Francisco Bay region during the storm of January 3-5, 1982 (see Fig. 1 for locations of numbered sites); showing observed time of occurrence on January 4, thresholds for rainfall rate, I_0, which reflects whether mean annual precipitation is greater than or less than 660 mm at the nearest recording raingage; slope reported in case studies or measured from contours; shear resistance estimated from reported observations of soil properties, including geotechnical measurements of strength, where tested; thickness of colluvial soil as reported in case studies, and an estimate of the number of censored sites in the vicinity of each failed site based on statistical relations reported in USGS Professional Paper 1434. The threshold intensities in this example are approximately those of Keefer and others (1987). All failures occurred on January 4, 1982, at the time-of-day (TOD) shown in 24-hour format. "Time to fail (h)" is number of hours from start of continuous storm rainfall at intensity .25 mm/h (.01 in/h) or greater to time of observed debris flow. The procedure for estimating the number of unfailed (or "censored") cells, in the vicinity of and having the same hillside characteristics as the cells in which failures occurred, is discussed in the text (especially Appendix B).

Table 2. Table comparing different regression models. Explanatory variables include: CUMR, cumultive rainfall from start of period of observation; CRI, indexed cumulative rainfall (from equation 3); SLOPE, tangent of the slope angle at site of initiation; SS, tangent of the angle of shear resistance; CT, thickness of colluvium; SI, stability index, SS/SLOPE; Mm, ratio CUMR/CT; Mi, ratio CRI/CT. In addition to parameters and coefficients, regression yields t-ratios for each variable, a quartile survivor distribution, and model log-likelihood. All models have high model log-likelihood. For 111 degrees of freedom, the critical limit for 90% acceptance is 1.28 or higher, so nearly all the variables are significant at or above that level in all but 5 of the models (6, 9, 10, 11, 12). Five models (1, 2, 3, 7, 8) yield parameters, p, less than 1, and are, therefore, incompatable with the underlying premise of increasing probability with duration of intense rainfall. Four of those models (1, 2, 7, 8) show unrealistically short durations for survival of 50% of cells (the average time to failure at the 11 sites of Table 1 is 24.5 hours). Of the 10 models remaining, all appear to be statistically acceptable. For the maps displayed in this report we selected model 20, for which regression results are listed in Table 3 and Appendix E.

Table 3. Regression results for the model SI, MSI, where MSI=(CRI/(39 x CT)) x SI. Both variables are significant, and the coefficients have the expected signs. These coefficients and parameter p are those used to calculate the conditional (hazard function) probabilities shown in Figures 13A-13J.

Table B-1. Table of proportional distribution of slopes in the hillside areas of the San Francisco Bay region, normalized to include only slopes greater than 25 percent (14 degrees), showing percent of hillside area in slopes greater than the interval minimum.

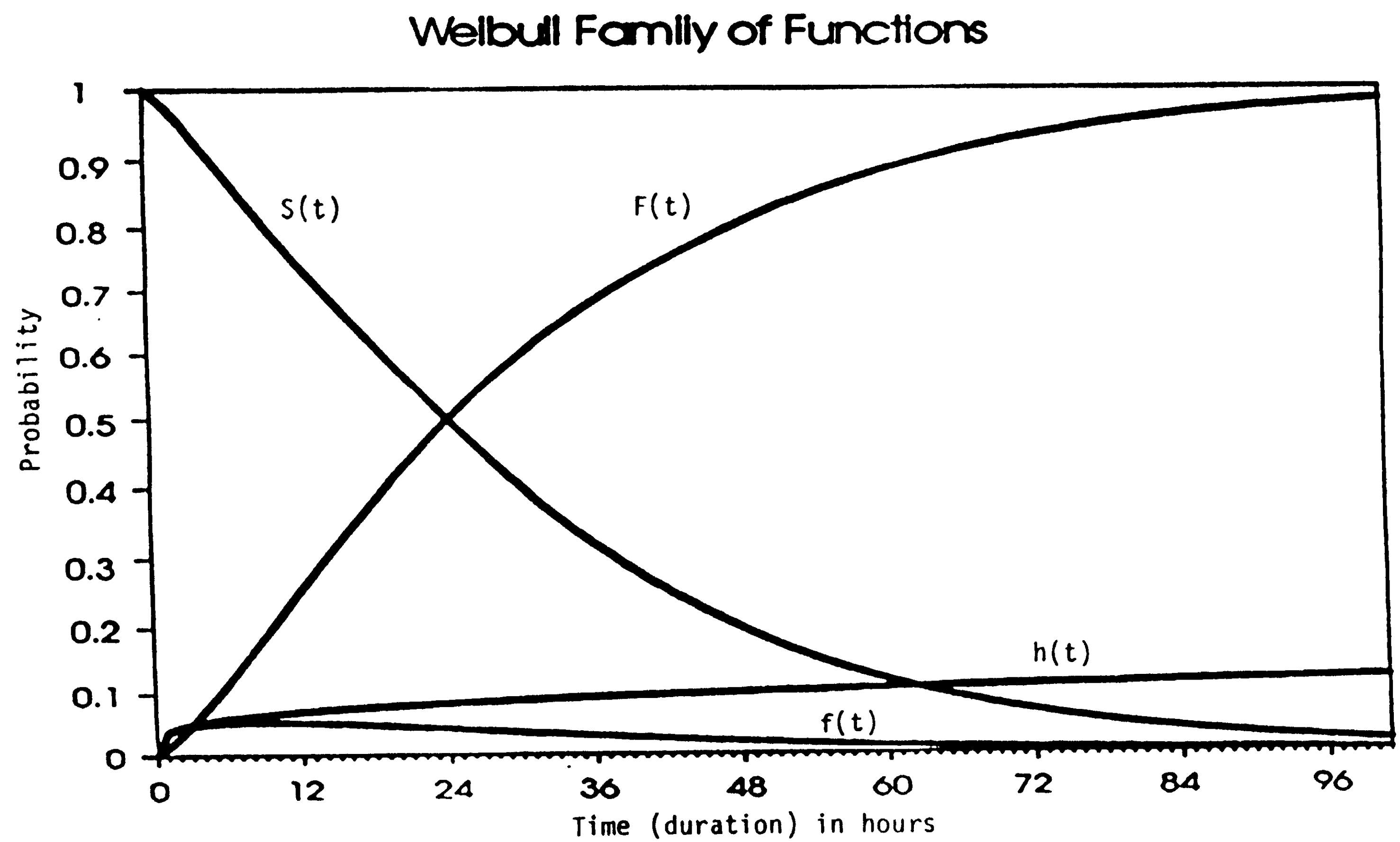


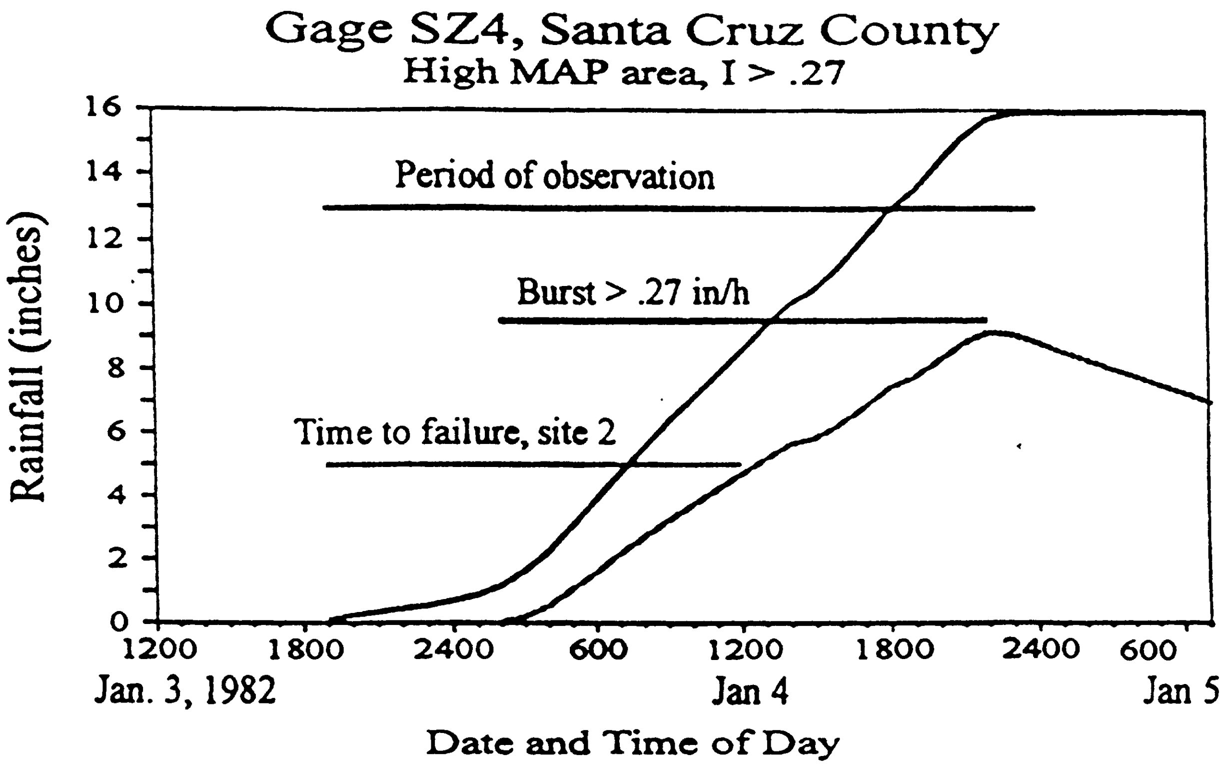
Figure 2. Related Weibull functions, extrapolated to 102 hours using mean values for x_i from the regression data set.

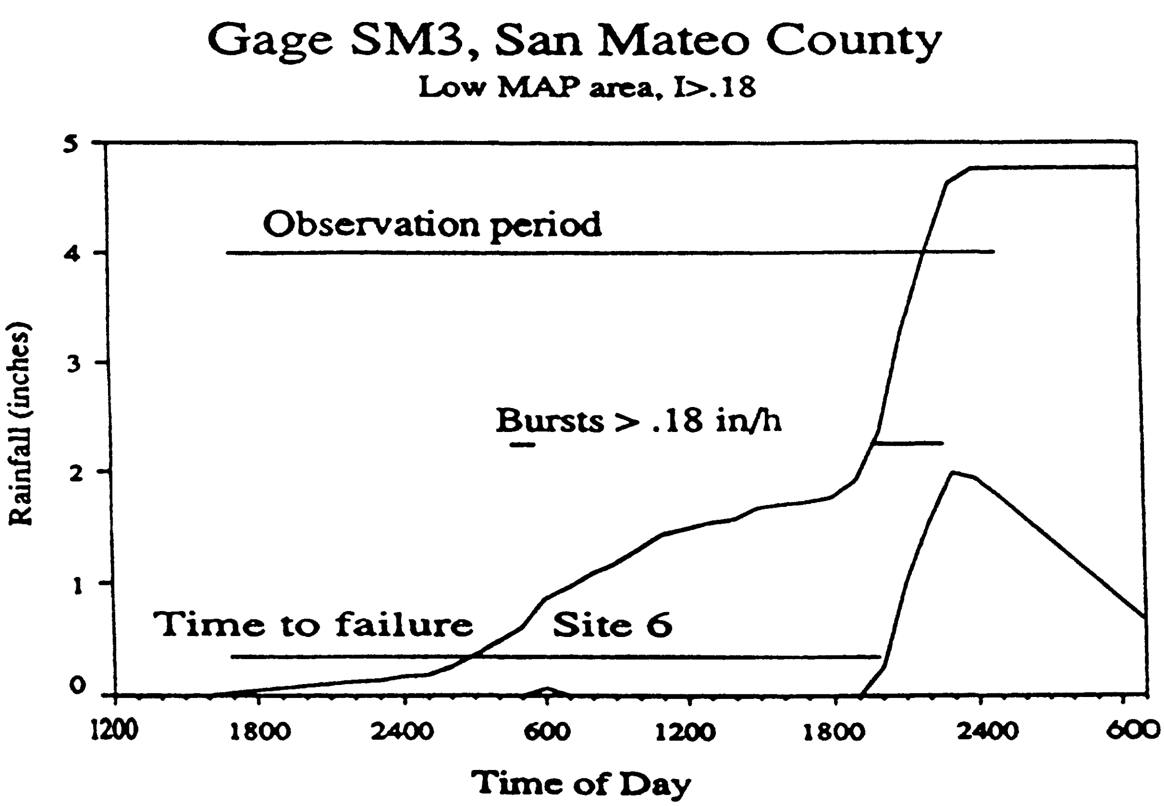
$S(t)$, survivor function;

$F(t)=1-S(t)$, cumulative probability distribution function;

$f(t)=dF(t)/dt, = \lambda p(\lambda t)^{p-1} exp(-(\lambda t)^p)$, probability density function;

$h(t)=f(t)/S(t)=\lambda p(\lambda t)^{p-1}$, hazard function.





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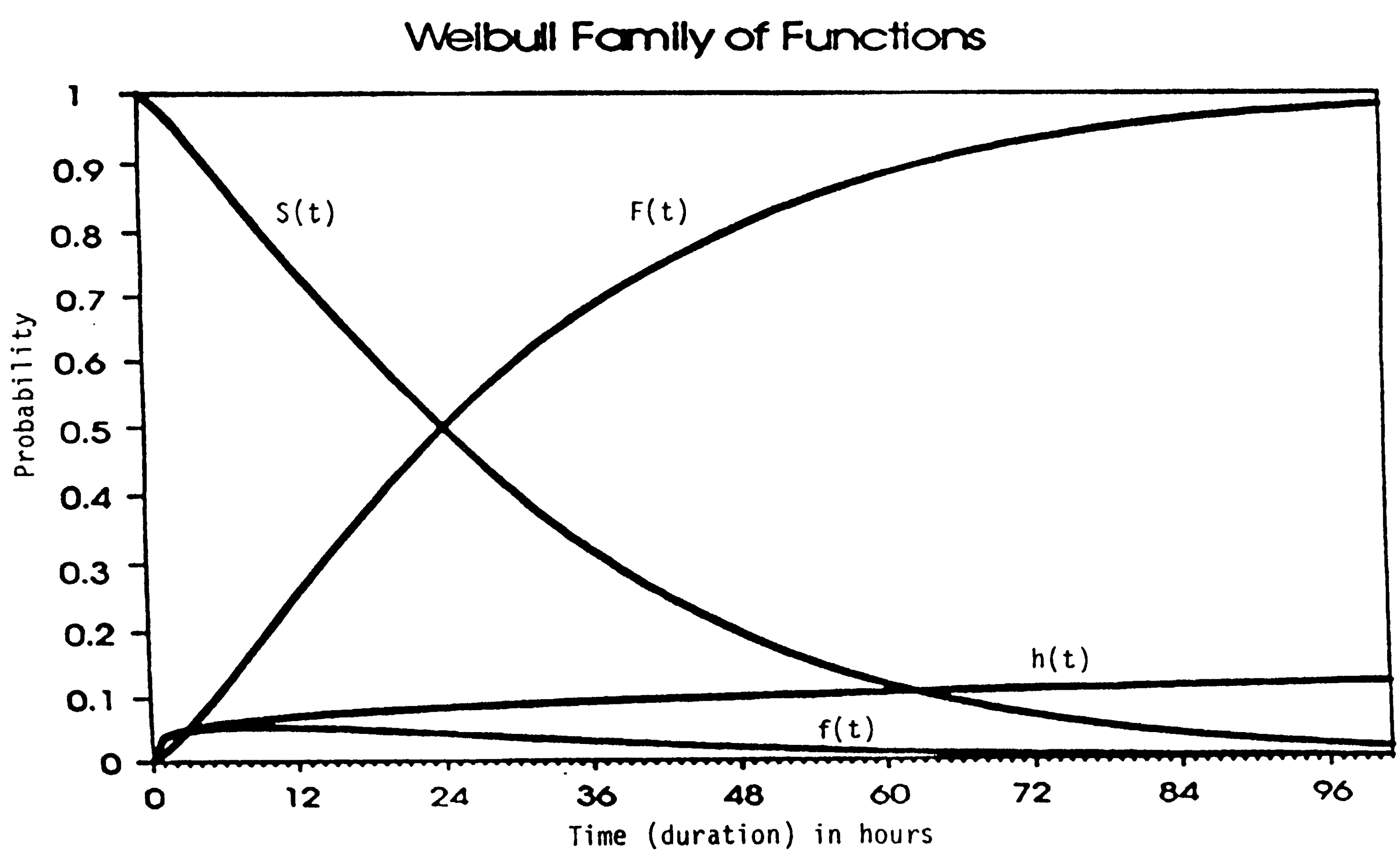

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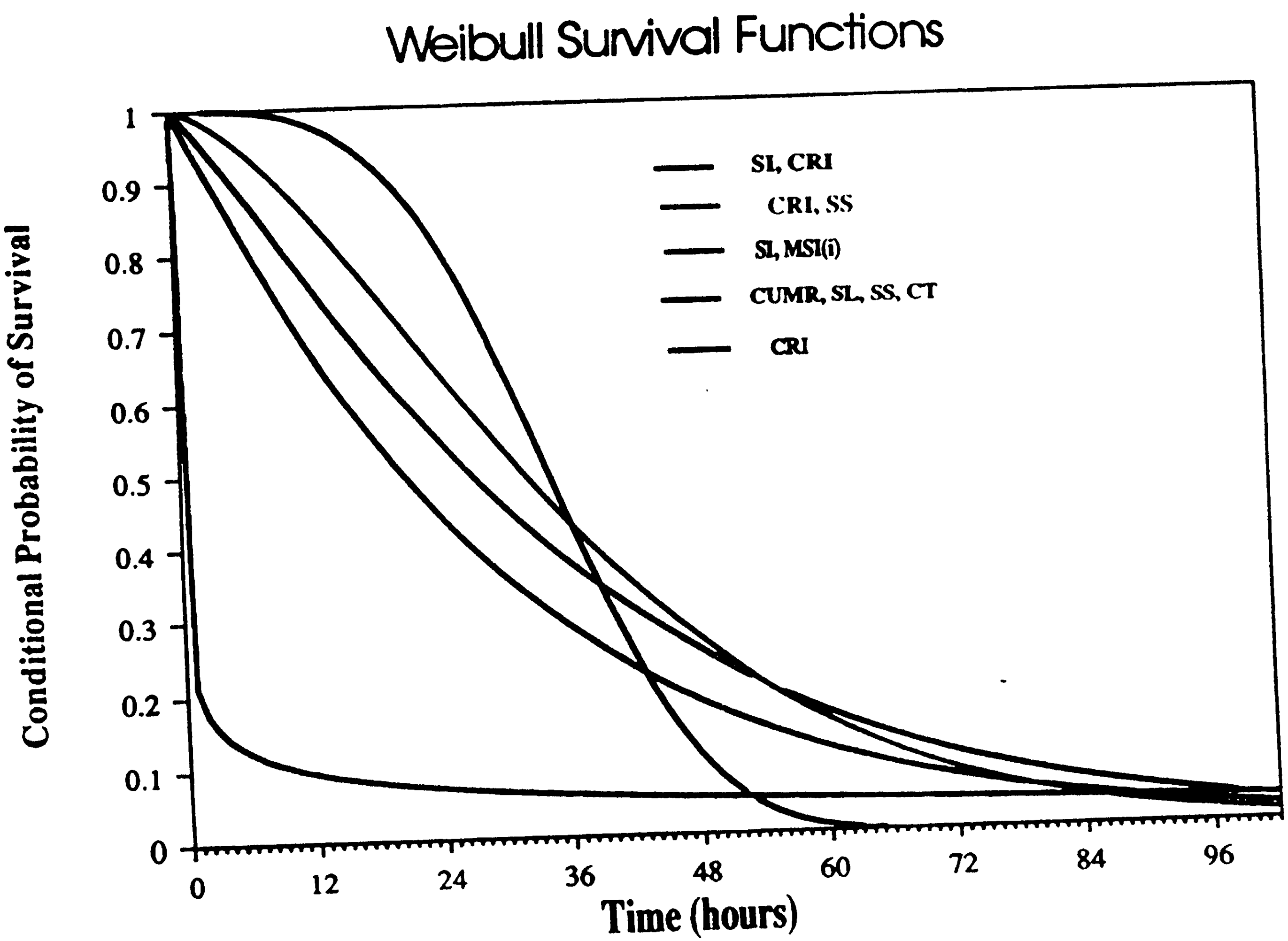
$f(t)=dF(t)/dt,=\lambda p(\lambda t)^{p-1}exp(-(\lambda t)^{p})$, probability density function;
$h(t)=f(t)/S(t)=\lambda p(\lambda t)^{p-1}$, hazard function.



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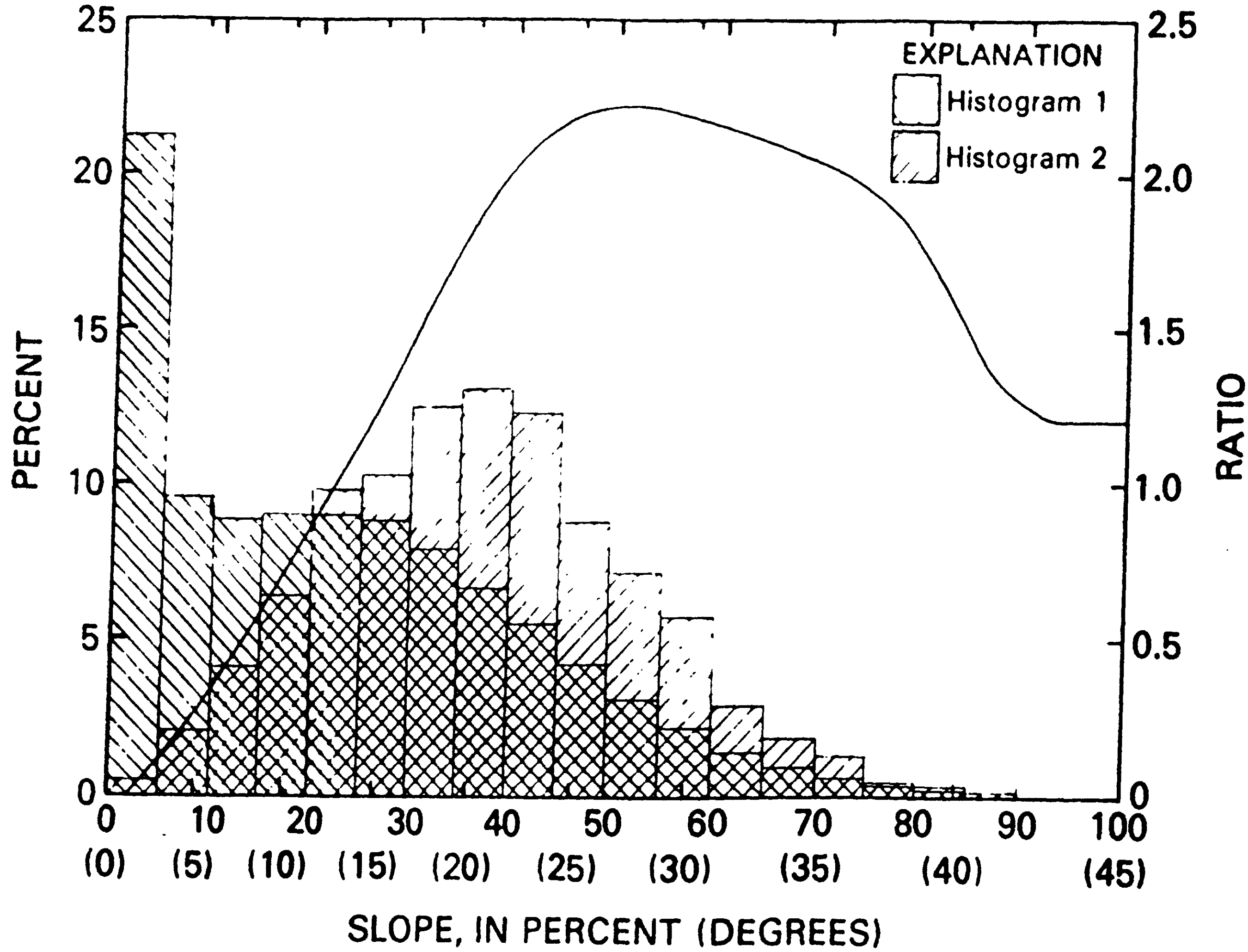

Figure B-1. Slope steepness at debris-flow sources in San Mateo County, California, derived from digital elevation model (after Wieczorek and others, 1988, Figure 8.3, p. 141). Histogram 1 shows steepness of all slopes; histogram 2 shows steepness at debris-flow source areas; curve, ratio of histogram 2 to histogram 1 is normalized steepness distribution of debris flows. To create Table B-1, the histograms were truncated to remove slopes less than 25 percent (about 14 degrees) and renormalized.

Table 1. -- Tabular data for eleven sites of rainfall-triggered debris flows in the San Francisco Bay region during the storm of January 3-5, 1982 (see Fig. 1 for locations of numbered sites); showing observed time of occurrence on January 4, thresholds for rainfall rate, I_0 , which reflects whether mean annual precipitation is greater than or less than 660 mm at the nearest recording raingage; slope reported in case studies or measured from contours: shear resistance estimated from reported observations of soil properties, including geotechnical measurements of strength, where tested; thickness of colluvial soil as reported in case studies, and an estimate of the number of censored sites in the vicinity of each failed site based on statistical relations reported in USGS Professional Paper 1434. The threshold intensities in this example are approximately those of Keefer and others (1987). All failures occurred on January 4, 1982, at the time-of-day (TOD) shown in 24-hour format. "Time to fail (h)" is number of hours from start of continuous storm rainfall at intensity .25 mm/h (.01 in/h) or greater to time of observed debris flow. The procedure for estimating the number of unfailed (or "censored") cells, in the vicinity of and having the same hillside characteristics as the cells in which failures occurred, is discussed in the text (especially Appendix B).

Site Num.	$I_{(0)}$ (mm/h)	TOD fail.	Time to fail (h)	Slope (deg)	Shear resistance (deg)	Thickness (m)	Number censored
1	6.86	1930	25	30°	30°	4.5	13
2	6.86	1310	18	38°	35°	4.3	9
3	6.86	2115	28	30°	40°	1.8	13
4	4.57	2310	29	26°	40°	3.9	8
5	6.86	1900	25	31°	40°	7.7	8
6	4.57	2100	28	26°	40°	1.0	9
7	4.57	1200	25	20°	40°	2.0	3
8	6.86	1400	20	26°	40°	2.0	5
9	6.86	1030	23	23°	40°	2.0	4
10	4.57	1234	20	26°	40°	0.5	11
11	4.57	2000	28	17°	30°	1.5	16

Table 2 Table comparing different regression models. Explanatory variables include CUMR, cumultive rainfall from start of period of observation, CRI, indexed cumulative rainfall (from equation 3), SLOPE, tangent of the slope angle at site of initiation; SS, tangent of the angle of shear resistance; CT, thickness of colluvium; SI, stability index, SS/SLOPE; Mm, ratio CUMR/CT, Mi, ratio CRI/CT. In addition to parameters and coefficients, regression yields t-ratios for each variable, a quartile survivor distribution, and model log-likelihood. All models have high model log-likelihood. For 111 degrees of freedom, the critical limit for 90% acceptance is 1.28 or higher, so nearly all the variables are significant at or above that level in all but 5 of the models (6, 9, 10, 11, 12). Five models (1, 2, 3, 7, 8) yield parameters, *p*, less than 1, and are, therefore, incompatable with the underlying premise of increasing probability with duration of intense rainfall. Four of those models (1, 2, 7, 8) show unrealistically short durations for survival of 50% of cells (the average time to failure at the 11 sites of Table 1 is 24.5 hours). Of the 10 models remaining, all appear to be statistically acceptable. For the maps displayed in this report we selected model 20, for which regression results are listed in Table 3 and Appendix E

MODEL	T-RATIOS FOR THE VARIABLES										SURVIVAL DISTRIBUTION (HOURS)			
	CUMR	CRI	SLOPE	SS	CT	SI	Mm	Mi	MSI	*P*	95%	75%	50%	25%
1. CUMR	-3.159	NA	NA	NA	NA	NA	NA	NA	NA	0.127	0.00	0.00	0.00	0.01
2. CRI	NA	-3.750	NA	NA	NA	NA	NA	NA	NA	0.169	0.00	0.00	0.01	0.53
3. SLOPE, CUMR	-7.503	NA	16.611	NA	NA	NA	NA	NA	NA	0.845	0.85	6.54	18.5	42.1
4. SLOPE, CRI	NA	-7.611	25.605	NA	NA	NA	NA	NA	NA	1.023	2.12	11.5	27.1	53.30
5. SS, CUMR	-2.494	NA	NA	30.674	NA	NA	NA	NA	NA	1.592	6.25	18.5	32.1	49.61
6 SS, CRI	NA	-0.624	NA	42.349	NA	NA	NA	NA	NA	1.656	6.87	19.4	33.1	50.24
7. CT, CUMR	-4.457	NA	NA	NA	5.321	NA	NA	NA	NA	0.149	0.00	0.00	0.00	0.01
8. CT CRI	NA	-8.488	NA	NA	11.653	NA	NA	NA	NA	0.328	0.00	0.16	2.27	18.77
9. SLOPE, SS, CT, CUMR	-3.422	NA	.810	11.517	4.239	NA	NA	NA	NA	1.330	3.88	14.2	27.5	46.28
10. SLOPE, SS, CT, CRI	NA	-0.287	-1.365	12.773	1.722	NA	NA	NA	NA	1.697	7.19	19.8	33.3	50.15
11. SLOPE, SS, CUMR	-2.52	NA	1.271	12.563	NA	NA	NA	NA	NA	1.493	5.37	17.0	30.7	48.89
12. SLOPE, SS, CRI	NA	0.532	-1.198	14.556	NA	NA	NA	NA	NA	1.728	7.46	20.2	33.7	50.28
13. SI, CUMR	21.093	NA	NA	NA	NA	21.093	NA	NA	NA	2.936	15.3 2	27.6	37.2	47.10
14. SI, CRI	NA	31.847	NA	NA	NA	104.76	NA	NA	NA	3.870	17.9 7	28.0	35.2	42.11
15. SI, CT, CUMR	4.355	NA	NA	NA	5.442	57.203	NA	NA	NA	3.107	15.6 3	27.2	36.1	45.15
16. SI, CT, CRI	NA	14.005	NA	NA	4.386	95.666	NA	NA	NA	4.114	18.7 9	28.6	35.4	41.87
17. SI, Mm (Mm=CUMR/CT)	NA	NA	NA	NA	NA	40.553	-6.55	NA	NA	1.186	3.07	13.1	27.5	49.37
18. SI, Mi (Mi=CRI/CT)	NA	NA	NA	NA	NA	38.982	NA	-5.16	NA	1.129	2.74	12.6	27.5	50.86
19. SI, MSI=Mm*SI	NA	NA	NA	NA	NA	42.515	NA	NA	-7.47	1.233	3.37	13.6	27.8	48.83
20. SI, MSI=Mi*SI	NA	NA	NA	NA	NA	41.269	NA	NA	-6.49	1.175	3.03	13.1	27.8	50.21

Table 3. Regression results for the model SI, MSI, where MSI = (CRI/(39 x CT)) x SI. Both variables are significant, and the coefficients have the expected signs. These coefficients and parameter, p, are used to calculate the conditional (hazard function) probabilities shown in Figures 13A-13J.

Variable	Coefficient(β)	t-ratio	Mean of x	Std. Dev. of x
SI	2.51	41.3	1.57	0.33
MSI	-2.54	-6.5	0.12	0.20

Log-Likelihood -468.9; p=1.17; λ=.03; Median time to failure=28 h
Correlation coefficient for SI, MSI = 0.04

Percentiles of individuals surviving to time t

SURVIVAL	0.25	0.50	0.75	0.95
TIME	50.2	27.8	13.2	3.0

Table B-1. Table of proportional distribution of slopes in the hillside areas of the San Francisco Bay region, normalized to include only slopes greater than 25 percent (14 degrees), showing percent of hillside area in slopes greater than the interval minimum.

SLOPE INTERVAL (PERCENT)	INTERVAL MINIMUM. (DEGREES)	HILLSIDE AREAS WITH SLOPES => INTERVAL MIN (PERCENT)	DEBRIS-FLOW FREQUENCY (PERCENT) IN SLOPE INTERVAL
25-30	14.04	100.0	13.0
30-35	16.70	78.8	15.5
35-40	19.29	59.5	16.7
40-45	21.80	43.9	15.5
45-50	24.23	30.6	10.7
50-55	26.57	20.7	8.3
55-60	28.81	13.3	7.1
60-65	30.96	8.2	4.8
65-70	33.02	5.1	3.6
70-75	34.99	2.7	2.4
75-80	36.87	1.2	1.2
80-85	38.66	0.5	0.6
85-90	40.36	0.2	0.6