Statistical Analysis of Hydrological Data from Five Small Watersheds in Western Oregon Volume I: Analysis

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STATISTICAL ANALYSIS OF HYDROLOGICAL DATA FROM FIVE SMALL WATERSHEDS IN WESTERN OREGON

VOLUME I: ANALYSIS

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ABSTRACT

This report presents an analysis of field data obtained during the Elkins Road Experimental Watershed Study, a research project designed to quantify relationships between precipitation characteristics and watershed runoff and sediment yield for conditions representative of portions of the Willamette Valley, Oregon. The data included hourly measurements of precipitation and watershed runoff and periodic measurements of suspended sediment concentrations for five small agricultural watersheds from November 1977 to April 1981. The complete data base used in this study is in Volume II.

The watersheds were fall-planted to wheat during each year of the experiment. Measurements for each field season began immediately after planting in October or November and ended in April or May. Total precipitation for each of the four field seasons ranged between 20 and 30 inches. Seasonal watershed runoff ranged between 1 and 41% of seasonal precipitation; the lowest amounts of runoff were measured on watersheds which had been tile-drained or which had deep, well-drained variants of the Willakenzie silt loam. Seasonal sediment yield ranged from 81 to 4,038 lbs/acre-yr; the highest annual rates of sediment yield were from watersheds with the highest rates of runoff except for one large watershed that contained a high proportion of woodlot and pasture. Runoff from this watershed ranged between 19 and 32% of precipitation, and sediment yield ranged between 276 and 768 lbs/acre-yr.

The data were described and analyzed using concepts of precipitation "events" and "event characteristics." For each precipitation event, characteristics for the runoff and sediment yield were computed for each watershed. Between 25 and 50% of the precipitation events did not result in measurable runoff. Discriminant analysis showed that the occurrence of runoff was associated with high levels of antecedent precipitation. Both the occurrence and the amount of runoff resulting from an event were determined to a greater extent by the amount of precipitation in the 168 and 48 hours before the event than by either precipitation amount or intensity during the event.

A few events were responsible for most of the seasonal sediment yield. On one of the watersheds, a single precipitation event caused a sediment yield of 3,920 lbs/acre, which accounted for 83% of the total soil loss from this watershed over the four-year study. Similar values, for different events, for the other watersheds were 9, 10, 13, and 31%. The highest rates of sediment yield occurred during events with high precipitation amount and intensity falling on either a saturated soil profile or a frozen soil surface. For most events, however, low rates of runoff and small suspended sediment concentrations combined to result in low sediment yields.

The results of these analyses provide quantitative information regarding the characteristics of precipitation important for predicting long-term rates of erosion in this region.

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1. INTRODUCTION

Measurements made during the last two decades have shown that erosion losses from agricultural land in portions of the Pacific Northwest can be very high (USDA, 1981). However, predicting the rate of this erosion has been difficult (McCool et al., 1982). This is so, in part, because of the unique climatic characteristics of the region. In most of the Eastern United States, the highest rates of runoff and erosion result from periods of high-intensity rainfall (Wischmeier and Smith, 1978). In the modified marine climate of the Northwestern United States, however, rainfall intensities are lower than in many other parts of the United States, seldom exceeding 5 mm/hr. Under these conditions, the highest rates of runoff and erosion result from periods of long-duration, low-intensity rainfall that can saturate the soil profile (Istok and Kling, 1983). Also important are rainfall on a frozen or thawing soil surface and combined rainfall and snowmelt (Zuzel et al., 1982).

Research, primarily on non-agricultural lands, has shown that runoff production is often a function of degree of saturation of the soil (Kirkby and Chorley, 1967; Harr, 1977). However, classical concepts of erosion on agricultural lands suggest that runoff and erosion are primarily a result of the high rainfall intensity that occurs during storm periods. For example, the most widely used erosion prediction tool is the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The only climatic variables included in the USLE are precipitation amount and intensity. No allowance for antecedent soil water content is made (McCool et al., 1976). Another technique, the curve-number method of predicting watershed runoff (SCS, 1972), recognizes the increase in runoff potential when antecedent soil water content is high. However, the field data used to develop the curve numbers come primarily from regions that have much higher rainfall intensities than the Northwestern United States. Additional field data are needed to determine the effects of antecedent soil water content on runoff and erosion under conditions of long duration, low-intensity rainfall.

The objective of this study was to determine the relative significance of several precipitation characteristics on the occurrence and amount of ensuing runoff and sediment yield resulting from individual storms. The precipitation characteristics that were studied included the amount, intensity, and duration of precipitation during the storm as well as four characteristics of the amount of precipitation preceding the storm. The latter characteristics were used as indirect indicators of the soil water content before a storm. The runoff characteristics that were studied were the magnitude, maximum, and average rate of runoff resulting from the storm. The sediment yield characteristics were the magnitude and maximum rate of sediment yield occurring during each runoff hydrograph.

The analysis utilized hydrologic data collected during the Elkins Road Experimental Watershed Study (Harward et al., 1980). For each hour during four winter rainfall seasons, measurements of precipitation, runoff, and suspended sediment concentrations were made for five small agricultural watersheds in western Oregon. A computer-accessible data base containing the data was prepared and is presented in Volume 2 of this report.

The first step in the analysis was to prepare summaries of the data for storm periods using the concept of "precipitation events". Precipitation events are defined in Section 2. Monthly and seasonal summaries of the data were also prepared and are described in Section 3. Next, marginal frequency distributions for characteristics of precipitation, watershed runoff, and sediment yield during precipitation events were computed. These distributions are discussed in Section 4. Then, using the runoff data, precipitation events were separated into several categories based on the occurrence and amount of runoff during the event. Discriminant analysis was used to identify the precipitation event characteristics that were significant in determining the occurrence and amount of runoff. The analysis is in Section 5. A summary of the results is in Section 6.

2. METHODS

2.1 Precipitation Events and Event Characteristics

The data base used in this study consisted of hourly measurements of precipitation, watershed runoff, and suspended sediment concentrations. These measurements were made at five small agricultural watersheds from November 1977 to April 1981. A summary of the characteristics of these watersheds and a complete listing of the hydrologic data base are in Volume 2 of this report. All data have been stored on magnetic tape and procedures for retrieving them from the tapes are in an Appendix to Volume 2. A summary of the topographic and soils data for the watersheds is also in Volume 2.

Monthly totals for precipitation were calculated by summing the hourly data in a given month. The precipitation data were then analyzed in terms of "precipitation events". The hourly precipitation data were divided into precipitation events using an event definition based on the sequence of hourly precipitation amounts. According to the definition, events consisted of sequences of hours with measurable precipitation ("wet" hours) separated from each other by at least six consecutive hours with no measurable precipitation ("dry" hours). That is, two wet hours that were separated by less than six dry hours were considered to be part of the same event. An example of the implementation of this definition is presented in Figure 1. The top line in Figure 1 illustrates the grouping of wet and dry hours into precipitation events. In this example, five sequences of measured precipitation satisfied the definition of a precipitation event. These are indicated by the five stippled areas.

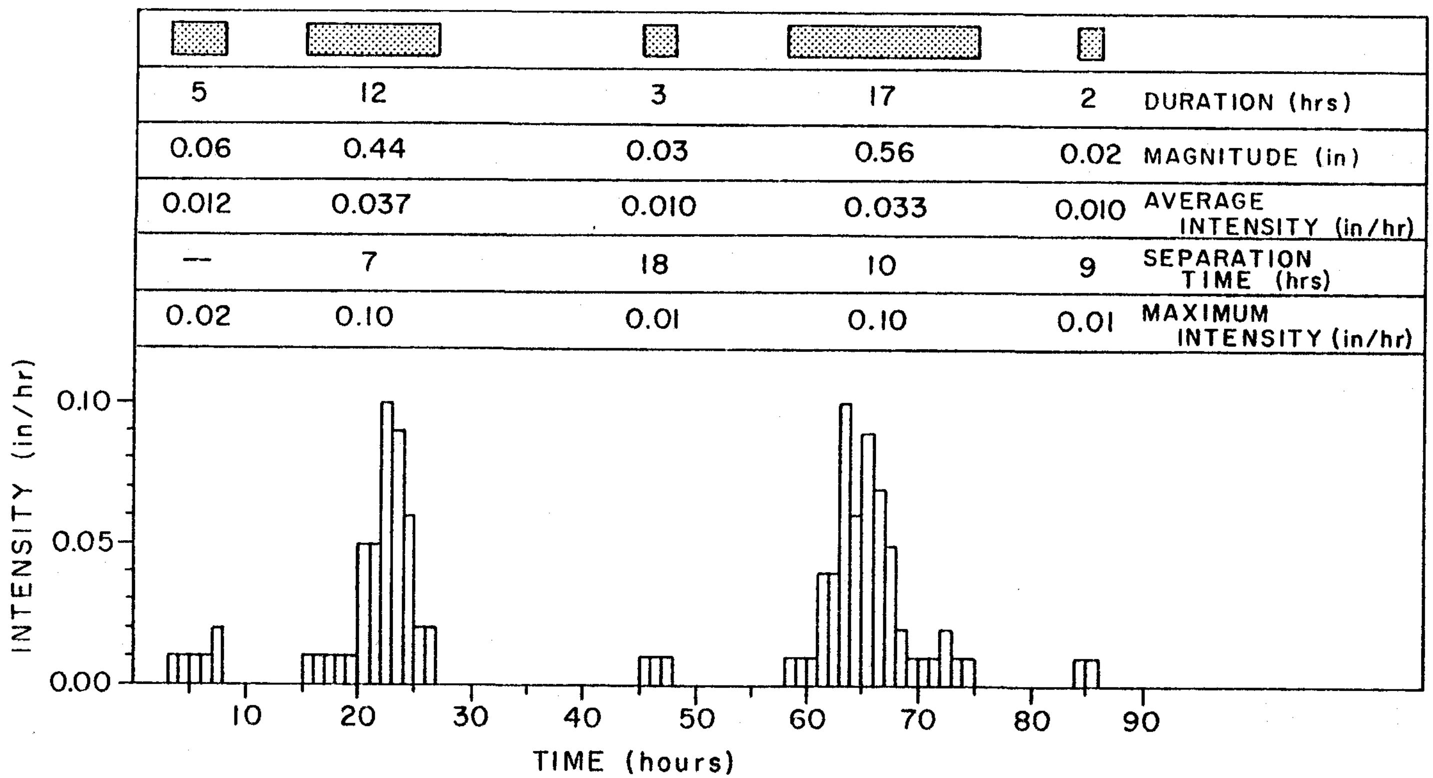

Figure 1. Example of precipitation event definition and calculation of event characteristics for hourly precipitation data. Horizontal stippled bars show the duration of an event.

Precipitation event characteristics were defined using the hourly precipitation measurements during events. These characteristics included the event duration, magnitude, average intensity, maximum intensity, separation, the amount of precipitation that occurred during the 12, 48, and 168 hours before the start of the event, and the amount of precipitation that had occurred between October 1 of the current year and the start of the event (Table 1). Calculated values for five of the event characteristics are shown in Figure 1.

2.2 Characteristics of Watershed Runoff

Monthly totals of watershed runoff were computed by summing the hourly runoff data for each month. The runoff data were then analyzed in terms of "runoff events." The hourly runoff data were divided into runoff events using an event definition based on the starting and ending times of precipitation events. An analysis of runoff hydrographs indicated that surface runoff from the watersheds ended between two and six hours after the end of a precipitation event. For this reason, the hours between the first hourly measurement of a precipitation event and six hours after the last hourly measurement of a precipitation event were used to define the starting and ending times of runoff events (Figure 2). This definition provided a simple method for computing the duration of runoff resulting from the occurrence of precipitation events.

The runoff event characteristics defined were the magnitude of runoff during the event, the average and maximum rate of runoff, and the time-to-peak rate of runoff (Table 2).

Table 1. Definitions of characteristics of precipitation events

Characteristic	Definition	Units	Formula†
Duration	Length of event from first to last hourly measurement.	hrs	$D_k = (L_k - F_k) + 1$
Magnitude	Total amount of precipitation during the event.	in	$M_k = \sum_{i=F_k}^{L_k} p_i$
Average Intensity	Average precipitation intensity during the event.	in/hr	$I_k = \frac{M_k}{D_k}$
Separation	Number of hours separating the event from the previous event.	hrs	$SB_k = (F_k - L_{k-1}) + 1$
Maximum Intensity	Maximum hourly precipitation intensity during the event	in/hr	$IMAX_k = \max_{F_k \leq i \leq L_k} \{p_i\}$
Magnitude for Previous 12 Hours	Total amount of precipitation during the 12 hours preceding the event.	in	$M12_k = \sum_{i=F_{k-12}}^{F_{k-1}} P_i$
Magnitude for Previous 48 Hours	Total amount of precipitation during the 48 hours preceding the event.	in	$M48_k = \sum_{i=F_{k-48}}^{F_{k-1}} P_i$
Magnitude for Previous 168 Hours	Total amount of precipitation during the 168 hours preceding the event.	in	$M168_k = \sum_{i=F_{k-168}}^{F_{k-1}} P_i$
Magnitude for Year Preceding the Event	Total amount of precipitation between 1 October and start of this event.	in	$MYR_k = \sum_{i=1}^{k-1} M_i$

†F_k = first hour of precipitation event k in a given year
L_k = last hour of precipitation event k in a given year
P_i = precipitation recorded during hour i. In a given year, i = 1 for 1:00 am, October 1.

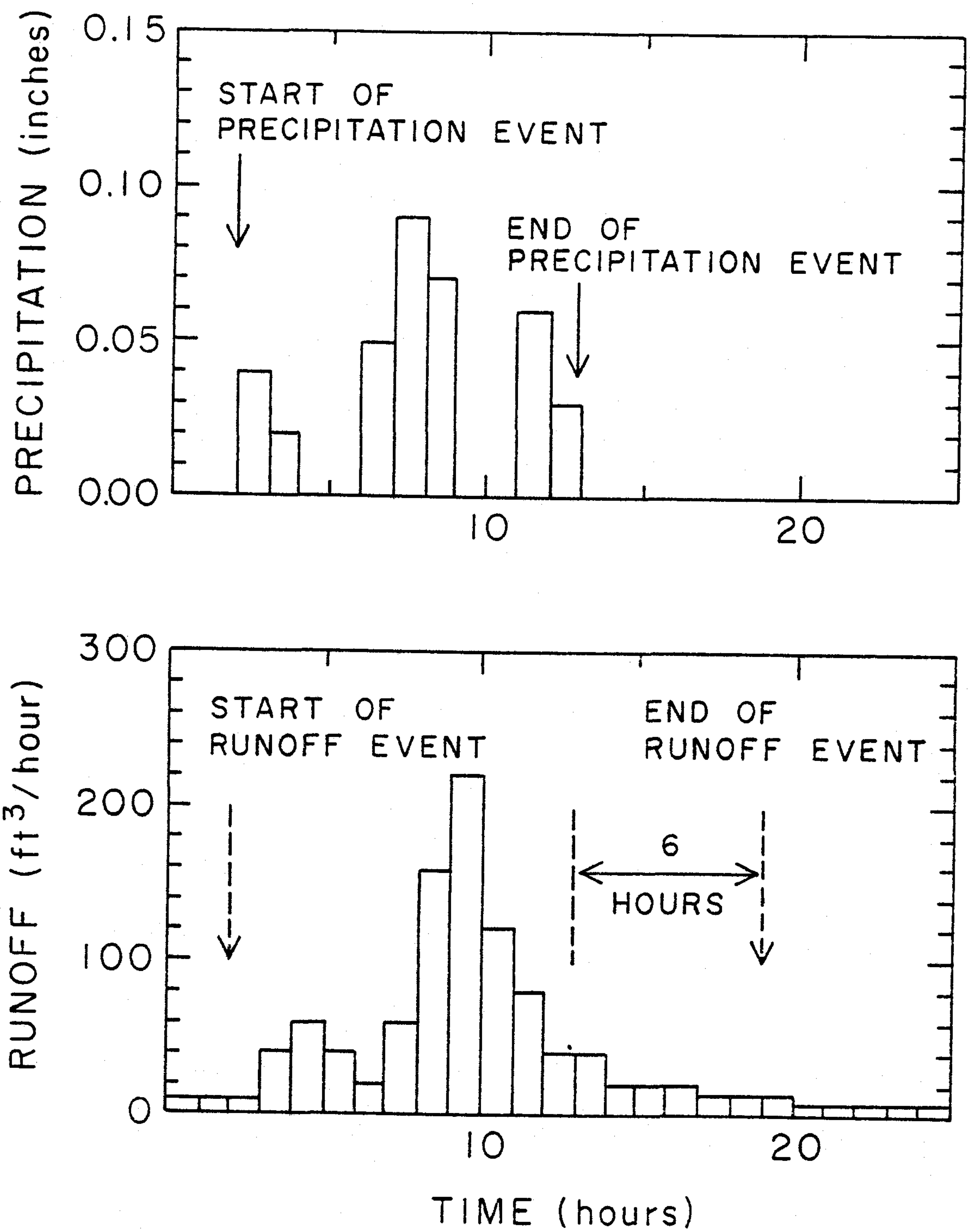

Figure 2. Example of how starting and ending times of a precipitation event are used to define runoff event.

2.3 Sediment Concentrations and Sediment Yield

Values for hourly time series of sediment discharge (e.g., pounds of sediment per hour) were obtained for each watershed by multiplying the rate of watershed runoff for each hour by the corresponding sediment concentration. For those hours when no sediment samples were taken, linear, piece-wise interpolation was used to estimate the concentrations of the sediment during that time period.

Monthly totals of sediment yield were calculated by summing the hourly values of sediment discharge for each hour in a given month. Then, characteristics of sediment discharge were defined for runoff events using the computed hourly rates of sediment discharge for the individual watersheds. These characteristics were the magnitude of sediment yield, the average and maximum rates of sediment discharge, and the maximum suspended sediment concentration that occurred during the event (Table 3).

Table 2. Definitions of characteristics of runoff events

Characteristic	Definition	Units	Formula†
Magnitude	Total amount of runoff during the event	ft^3	$MR_k = \sum_{i=F_k}^{L_k} R_i$
Average Flow	Average rate of runoff during the event	$\frac{ft^3}{hr}$	$AR_k = \frac{M_k}{(L_k - F_k) + 1}$
Maximum Flow	Maximum rate of runoff during the event	$\frac{ft^3}{hr}$	$MMR_k = \max_{F_k \leq i \leq L_k} \{R_i\}$
Time-to-Peak	Number of hours from start of event to hour containing maximum flow rate.	hr	$TR_k = (L_k - M_k) + 1$

†F_k = first hour of runoff event k
L_k = last hour of runoff event k
M_k = hour containing maximum rate of runoff during event k
R_i = runoff during hour i

Table 3. Definitions of suspended sediment characteristics

Characteristic	Definition	Units	Formula†
Magnitude	Total sediment yield during the event	lbs	$MS_k = \sum_{i=F_k}^{L_k} S_i$
Average Discharge	Average rate of sediment discharge during the event	$\frac{lbs}{hr}$	$AS_k = \frac{MS_k}{(L_k - F_k) + 1}$
Maximum Discharge	Maximum rate of sediment discharge during the event	$\frac{lbs}{hr}$	$MMS_k = \max_{F_k \leq i \leq L_k} \{S_i\}$
Maximum Concentration	Maximum suspended sediment concentration during the event	$\frac{mg}{L}$	$MC_k = \max_{F_k \leq i \leq L_k} \{C_i\}$

†S_i = sediment discharge during hour i
C_i = suspended sediment concentration during hour i

3. SUMMARIES OF HYDROLOGIC DATA

The objective of this section is to provide an overview of the hydrologic data that were collected during the four-year study. Specifically, the monthly totals for precipitation, runoff, and sediment yield will be discussed. During periods when data were not recorded, e.g., because of equipment failures, a missing data code was entered into the data base for each hour during the period (see Volume 2). These periods were ignored in all of the calculations described in this report. Thus, computed monthly totals of runoff and sediment yield were smaller than would be expected if no data were missing. However, because most of the missing runoff data occurred in the early fall and late spring when the potential for runoff was small, the monthly and seasonal totals described in this section are approximately correct. As a guide to the interpretation of the data contained in this report, a tabulation of the percentage of missing data contained within the data base is presented in Table 4. Each entry in the table is the percentage of data missing from the total number of hours of data for the field season. For example, seven percent of the hourly runoff measurements for watershed E4F1 were not recorded during the 1979/80 field season. There were no missing precipitation data. Fewer than 12% of the hourly runoff measurements were missing, except for watershed E1F1 during 1977/78 and for watershed E3C1 during 1980/81.

Monthly totals of precipitation, runoff, and sediment yield for each of the watersheds are presented in Tables 5 through 9. Total precipitation for the four field seasons ranged between 20 and 30 inches. Monthly precipitation totals were lowest during March, April, and May and highest in December, January, and February. The largest monthly precipitation total (11.65 inches) occurred in December 1981.

Table 4. Percentage of missing data contained in hydrologic data base

Field season	Percentage of Missing Data					
		Watershed Runoff				
	Precipitation	E1F1	E4F1	E4F2	E4F3	E3C1
	%					
1977/78	0	41	3	9	--†	5
1978/79	0	0	6	8	--	0
1979/80	0	2	7	12	--	1
1980/81	0	7	8	4	11	54

†Measurements on this watershed began in 1980/81.

Table 5. Monthly totals of precipitation, watershed runoff, and sediment yield for watershed E1F1

Field season	Month	Precipitation	Watershed runoff		Sediment yield
		in	in	%	lbs/acre
1977/78	Nov	5.42	0	0	–†
	Dec	8.50	0	0	–
	Jan	4.73	0	0	–
	Feb	2.76	0.19	7	–
	Mar	1.10	0	0	–
	Apr	3.10	0	0	–
	May	2.80	0	0	–
	June	0.54	0	0	–
	TOTALS	28.95	0.19	1	–
1978/79	Oct	0.33	0	0	0
	Nov	3.17	0	0	0
	Dec	1.81	0.03	2	19
	Jan	2.58	0.21	8	83
	Feb	6.33	1.79	28	305
	Mar	2.29	0.11	5	11
	Apr	1.46	0	0	0
	May	2.04	0	0	0
	TOTALS	20.01	2.14	11	418
1979/80	Oct	5.63	0	0	0
	Nov	2.99	0	0	0
	Dec	5.74	0.04	1	3
	Jan	5.33	2.21	42	78
	Feb	3.26	0	0	0
	Mar	3.19	0	0	0
	Apr	3.39	0	0	0
	TOTALS	29.53	2.25	7	81
1980/81	Oct	0.97	0	0	0
	Nov	5.23	0.01	0	1
	Dec	11.65	8.55	73	4,156
	Jan	2.25	0.06	3	23
	Feb	3.87	0.28	7	59
	Mar	3.45	0	0	0
	Apr	0.66	0	0	0
	TOTALS	28.08	8.90	32	4,239

† Suspended sediment concentrations were not measured on this watershed during 1977/78.

Table 6. Monthly totals of precipitation, watershed runoff, and sediment yield for watershed E4F1

Field season	Month	Precipitation	Watershed runoff		Sediment yield
		in	in	%	lbs/acre
1977/78	Nov	5.42	1.73	32	743
	Dec	8.50	6.02	71	2,732
	Jan	4.73	3.01	64	530
	Feb	2.76	0.81	30	32
	Mar	1.10	0	0	0
	Apr	3.10	0.05	2	1
	May	2.80	0.03	1	0
	June	0.54	0	0	0
	TOTALS	28.95	11.64	40	4,038
1978/79	Oct	0.33	0	0	0
	Nov	2.17	0	0	0
	Dec	1.81	0.79	44	13
	Jan	2.58	3.42	132	1,009
	Feb	6.33	3.75	59	2,381
	Mar	2.29	0.76	33	194
	Apr	1.46	0	0	0
	May	2.04	0	0	0
	TOTALS	20.01	5.58	28	3,597
1979/80	Oct	5.63	0.03	1	21
	Nov	2.99	0	0	0
	Dec	5.74	0.10	2	69
	Jan	5.33	1.33	25	1,102
	Feb	3.26	0.02	1	2
	Mar	3.19	0	0	0
	Apr	3.39	0.01	0	1
	TOTALS	29.53	1.49	5	1,195
1980/81	Oct	0.97	0	0	0
	Nov	5.23	0.19	4	103
	Dec	11.65	1.85	16	1,025
	Jan	2.25	0.18	8	43
	Feb	3.87	0.07	2	111
	Mar	3.45	0	0	0
	Apr	0.66	0	0	0
	TOTALS	28.08	2.29	8	1,282

Table 7. Monthly totals of precipitation, watershed runoff, and sediment yield for watershed E4F2

Field season	Month	Precipitation	Watershed runoff		Sediment yield
		in	in	%	lbs/acre
1977/78	Nov	5.42	0	0	0
	Dec	8.50	6.15	72	1,746
	Jan	4.73	4.11	87	126
	Feb	2.76	1.68	61	66
	Mar	1.10	0	0	0
	Apr	3.10	0	0	0
	May	2.80	0	0	0
	June	0.54	0	0	0
	TOTALS	28.95	11.94	41	1,938
1978/79	Oct	0.33	0	0	0
	Nov	3.17	0	0	0
	Dec	1.81	0.49	27	31
	Jan	2.58	0.99	38	148
	Feb	6.33	4.04	64	1,222
	Mar	2.29	1.12	49	135
	Apr	1.46	0	0	0
	May	2.04	0.08	4	3
	TOTALS	20.01	6.72	34	1,539
1979/80	Oct	5.63	0.14	2	95
	Nov	2.99	0.73	24	142
	Dec	5.74	3.00	52	386
	Jan	5.33	3.88	73	821
	Feb	3.26	1.18	36	85
	Mar	3.19	0.60	19	22
	Apr	3.39	0.17	5	5
	TOTALS	29.53	9.70	33	1,556
1980/81	Oct	0.97	0.01	1	7
	Nov	5.23	0.41	8	204
	Dec	11.65	5.09	44	2,421
	Jan	2.25	0.56	25	118
	Feb	3.87	1.21	31	800
	Mar	3.45	0.20	6	24
	Apr	0.66	0	0	0
	TOTALS	28.08	7.48	27	3,574

Table 8. Monthly totals of precipitation, watershed runoff, and sediment yield for watershed E4F3

Field season	Month	Precipitation	Watershed runoff		Sediment yield
		in	in	%	lbs/acre
1980/81	Oct	0.97	0.01	1	2
	Nov	5.23	0.31	6	188
	Dec	11.65	6.24	54	1,935
	Jan	2.25	0.31	14	39
	Feb	3.87	0.99	26	186
	Mar	3.45	0.11	3	44
	Apr	0.66	0.07	10	1
	TOTALS	28.08	8.04	29	2,395

Table 9. Monthly totals of precipitation, watershed runoff, and sediment yield for watershed E3C1

Field season	Month	Precipitation	Watershed runoff		Sediment yield
		in	in	%	lbs/acre
1977/78	Nov	5.42	0.49	9	126
	Dec	8.50	3.72	44	396
	Jan	4.73	1.89	40	193
	Feb	2.76	0.96	35	18
	Mar	1.10	0.25	23	2
	Apr	3.10	0.72	23	10
	May	2.80	1.01	36	22
	June	0.54	0.12	22	1
	TOTALS	28.95	9.16	32	768
1978/79	Oct	0.33	0	0	0
	Nov	3.17	0.01	0	1
	Dec	1.81	0.23	13	7
	Jan	2.58	0.47	18	29
	Feb	6.33	2.87	45	198
	Mar	2.29	1.12	49	34
	Apr	1.46	0.13	9	6
	May	2.04	0.23	12	23
	TOTALS	20.01	5.07	25	298
1979/80	Oct	5.63	0.02	0	1
	Nov	2.99	0.28	9	9
	Dec	5.74	1.37	24	55
	Jan	5.33	2.24	42	150
	Feb	3.26	0.85	26	17
	Mar	3.19	0.46	15	22
	Apr	3.39	0.44	13	23
	TOTALS	29.53	5.66	19	276
1980/81	Oct	0.97	0	0	0
	Nov	5.23	0.04	1	1
	Dec	11.65	4.61	40	336
	Jan	2.25	0.37	17	19
	Feb	3.87	0.25	6	11
	Mar	3.45	0.15	4	7
	Apr	0.66	0	0	0
	TOTALS	28.08	5.42	19	374

Seasonal runoff from all of the watersheds and for all four field seasons ranged between 1 and 41% of precipitation. The lowest amounts of runoff were from watershed E1F1 and from watershed E4F1 after the installation of tile drainage between the 1978/79 and 1979/80 field seasons (Volume 2). Runoff from watershed E1F1 was less than 12% of precipitation for three of the four field seasons (Table 5). After the installation of tile drainage, runoff from watershed E4F1 did not exceed 8% of precipitation (Table 6). Runoff from watersheds E4F1 before tile drainage, and watersheds E4F2, E4F3, and E3C1 ranged from 19 to 41% of precipitation (Tables 6 to 9). During any individual month, watershed runoff often exceeded 50% of monthly precipitation. Runoff from watershed E4F1 was greater than precipitation during January 1979 (Table 6) because of the melting of snow not recorded by the precipitation gauge (Harward et al., 1980).

Trends in sediment yield followed trends in watershed runoff (Tables 5 to 9). The months with the highest sediment yields were December, January, and February. This reflects the higher runoff during these months as well as the occurrence of frozen soil, high water tables, and low plant cover (Harward et al., 1980; Istok and Kling, 1983). The highest sediment yields for any month of the year occurred when watershed runoff exceeded 20 to 30% of monthly precipitation. Generally most of the soil loss for a watershed occurred during a single month of the field season. For example, more than 98% of the sediment yield from watershed E1F1 during 1980/81 occurred during December (Table 5).

Seasonal sediment yields from the individual watersheds ranged from 81 to 4,038 lbs/acre. These values are fairly low and in most cases were below "soil loss tolerance" values of from 2,000 to 10,000 lbs/acre for these soils published by the Soil Conservation Service. The variability in measured rates of soil erosion should be apparent from the monthly summaries. This variability is caused by many factors but primarily is the result of variability in weather conditions from one field season to another. For this reason, it is important not to consider the data in Tables 5 to 9 as "average" or long-term rates of soil loss. Rather they represent a portion of the range in possible values of sediment yield that can be expected from these soils under these management practices. A more detailed understanding of the effects of different climatic variables on runoff and erosion from these soils can be obtained by studying the response of these watersheds to individual precipitation events.

4. PRECIPITATION, RUNOFF, AND SEDIMENT YIELD FOR EVENTS

4.1 Precipitation Events and Event Characteristics

This section presents a description of the precipitation events that occurred during the Elkins Road study in terms of frequency distributions of event characteristics. A total of 355 precipitation events were found in the data base using the definition given in Section 2.1. The monthly relative frequency distribution for number of precipitation events shows the seasonal distribution of event occurrence for the Elkins Road study area (Figure 3). The highest number of events occurred from November through March. This seasonal distribution is characteristic of western Oregon as can be seen in a similar plot based on the long-term precipitation data for the weather station at Salem, Oregon (also shown in Figure 3).

Marginal distributions for the characteristics of the precipitation events recorded at Elkins Road shows that the majority of the events had small magnitudes, short durations, and low rainfall intensities (Table 10). For example, 75% of the precipitation events had a maximum intensity of 0.01 in/hr or less. By comparing the two columns containing the 0.75-th quantile and the maximum value, the importance of the few events which had large values of characteristics should be apparent. For example, 75% of the events had a magnitude of 0.35 in or less, but the remaining 25% of the events had a magnitude from 0.35 to 4.45 in.

The marginal distribution for event separation shows that 75% of the events occurred within 46 hours of at least one other precipitation event (Table 10). This is important because precipitation during closely spaced sequences of precipitation events decreases the infiltration

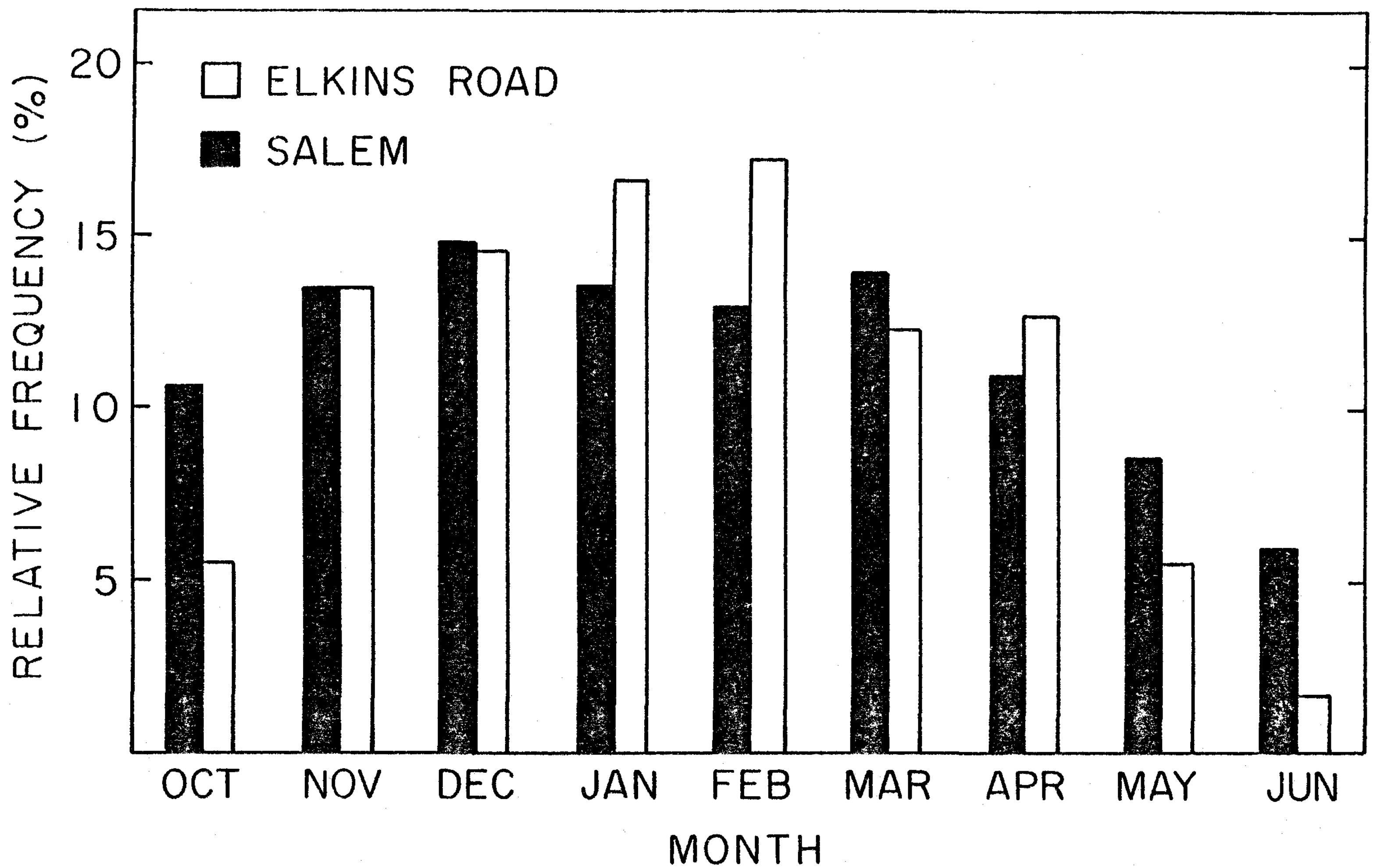

Figure 3. Monthly relative frequency distribution for precipitation events for the Elkins Road Study area and for the weather station at Salem, Oregon.

Table 10. Marginal distributions for precipitation event characteristics at Elkins Road (n=355)

Characteristic	min	Quantiles 0.25	0.50	0.75	max	Units
Duration	1	2	7	16	71	hours
Magnitude	0.01	0.03	0.12	0.35	4.45	inches
Average Intensity	0.003	0.010	0.013	0.032	0.122	in/hr
Separation	6	9	17	46	428	hours
Maximum Intensity	0.01	0.02	0.04	0.10	0.50	in/hr
Magnitude for Previous 12 Hours	0.0	0.0	0.0	0.01	0.91	inches
Magnitude for Previous 48 Hours	0.00	0.00	0.14	0.38	3.42	inches
Magnitude for Previous 168 Hours	0.0	0.22	0.69	1.38	6.10	inches
Magnitude for Year Preceding the Event	0.0	7.33	16.98	22.43	28.90	inches

capacity of the soil profile and increases the potential for runoff. The characteristics M12, M48, M168, and MYR are measures of the amount of precipitation that preceded an event. Twenty-five percent of the events had 0.01 inches or more in the 12 hours before the event (Table 10). Twenty-five percent of the events had 1.38 inches or more during the 168 hours, or one week, before the event. The maximum values of these two characteristics were 0.91 and 6.10 inches. As will be shown in Section 5, events that had large values of these characteristics were much more likely to produce runoff than events that had small values of these characteristics.

4.2 Runoff Events and Event Characteristics

This section presents a statistical description of the runoff that resulted from individual precipitation events. Specifically, the marginal distributions of runoff event characteristics will be discussed. In Section 2.2, a runoff event was defined as the portion of the hourly runoff data from the first hour of a precipitation event until six hours after the end of the precipitation event. For each runoff event, four characteristics were calculated: the magnitude of runoff, average and maximum flow rate, and the time-to-peak. Runoff events and event characteristics are introduced to develop a quantitative description of the runoff hydrograph that results from a precipitation event. They also make a comparison possible between patterns of occurrence and amount of runoff from the different watersheds.

Many precipitation events did not produce measurable runoff. For example, the 0.25, 0.50, and 0.75 quantiles for "magnitude of runoff" are all zero at watershed E1F1 (Table 11). This means that no measurable

Table 11. Marginal distributions for runoff characteristics for watersheds E1F1 and E4F1

Charac- teristic	min	Quantile 0.25	0.50	0.75	0.85	0.95	0.99	max	units
E1F1:									
Magnitude	0	0	0	0	200	400	1,600	21,000	ft^3
					0.05	0.10	0.39	5.09	in
Average Flow	0	0	0	0	6	14	70	380	ft^3/hr
					–†	–	0.02	0.09	in/hr
Maximum Flow	0	0	0	0	15	50	240	1,400	ft^3/hr
					–	0.01	0.06	0.34	in/hr
Time-to-peak	0	0	0	0	1	7	22	42	hrs
E4F1:									
Magnitude	0	0	0	77	600	3,200	10,000	21,000	ft^3
				–	0.05	0.25	0.80	1.67	in
Average Flow	0	0	0	4	46	130	370	580	ft^3/hr
				–	–	0.01	0.03	0.05	in/hr
Maximum Flow	0	0	0	34	100	500	1,900	5,000	ft^3/hr
				–	–	0.04	0.15	0.40	in/hr
Time-to-peak	0	0	0	2	6	15	25	39	hrs

†Depths of runoff of less than 0.01 inch are not listed.

runoff was produced by at least 75% of the precipitation events that occurred at watershed E1F1. Similarly, 50% of the precipitation events at watersheds E4F1 and E4F2 did not produce measurable runoff (Tables 11 and 12). Less than 15% of all precipitation events produced more than 0.25 inches of runoff on any of the watersheds (Tables 11-13). Runoff from only a few events produced a large portion of the total recorded runoff. For example, 99% of the runoff events on watershed E1F1 had a magnitude of 0.39 inches or less while the maximum value was 5.09 inches, more than 13 times larger.

Rates of runoff were small. Average flows never exceeded 0.06 inches/hour. Maximum flow rates were often quite large, however. For example, maximum flow rate from watershed E4F1 was 0.40 inches/hour (Table 11) which is close to the maximum recorded rainfall intensity of 0.50 inches/hour (Table 10). The maximum flow rate usually occurred concurrently with the maximum rainfall intensity. This can be seen in the marginal distributions of the runoff characteristic "time-to-peak." This characteristic is the number of hours that elapsed between the occurrences of maximum rainfall intensity and maximum flow rate. Fifty percent of the runoff events had a "time-to-peak" of one hour or less (Tables 11-13). This is primarily because of the small size of these watersheds, and in general, the values of this characteristic increased with increasing watershed size.

Table 12. Marginal distributions for runoff characteristics for watersheds E4F2 and E4F3

Characteristic	min	Quantile 0.25	0.50	0.75	0.85	0.95	0.99	max	units
E4F2:									
Magnitude	0	0	200	3,000	6,600	19,000	44,000	77,000	ft^3
			-†	-	0.12	0.35	0.82	1.43	in
Average Flow	0	0	21	225	405	720	1,530	2,000	ft^3/hr
			-	-	-	0.01	0.03	0.04	in/hr
Maximum Flow	0	0	68	450	1,100	2,800	8,500	12,000	ft^3/hr
			-	-	0.02	0.05	0.16	0.22	in/hr
Time-to-peak	0	0	1	5	9	18	25	43	hr
E4F3:									
Magnitude	0	0	50	60	340	1,200	13,000	34,000	ft^3
			-	-	-	0.06	0.60	1.58	in
Average Flow	0	0	10	20	40	300	1,100	1,200	ft^3/hr
			-	-	-	0.01	0.05	0.06	in/hr
Maximum Flow	0	0	40	60	75	1,300	3,750	4,300	ft^3/hr
			-	-	-	0.06	0.17	0.20	in/hr
Time-to-peak	0	0	0	1	5	20	21	22	hr

†Depths of runoff of less than 0.01 inch are not listed.

Table 13. Marginal distributions for runoff characteristics for watershed E3C1

Characteristic	min	Quantile 0.25	0.50	0.75	0.85	0.95	0.99	max	units
E4F2:									
Magnitude	0	6,300	21,000	85,000	$15x10^4$	$55x10^4$	$14x10^5$	$42x10^5$	ft^3
		-†	-	0.03	0.06	0.22	0.55	1.64	in
Average Flow	0	650	1,700	5,100	9,000	18,000	45,000	$1.7x10^5$	ft^3/hr
		-	-	-	-	-	0.02	0.07	in/hr
Maximum Flow	0	910	2,300	7,400	24,000	40,000	$24x10^4$	$7.3x10^5$	ft^3/hr
		-	-	-	-	0.02	0.09	0.29	in/hr
Time-to-peak	0	2	6	12	14	27	38	46	hr

†Depths of runoff of less than 0.01 inch are not listed.

4.3 Characteristics of Sediment Yield

The marginal distributions for magnitude of sediment yield show that from 25 to 50% of all precipitation events did not produce measurable sediment yield (Tables 14-16). In most instances, a single event was responsible for a large percentage of the seasonal soil loss from these watersheds. For example, a single precipitation event on watershed E1F1 caused a sediment yield of 4,000 lbs/acre, which represents 84 percent of the total soil loss for this watershed over the four-year study. Equivalent values for watersheds E4F1, E4F2, and E4F3, for different events, are 13, 10, and 31 percent.

More than 95% of the precipitation events had maximum rates of sediment discharge below 40 lbs/acre/hr (Tables 14-16). This is primarily a result of relatively low concentrations of suspended sediment. These never exceeded 300 mg/L. The low rates of runoff described in the previous section and the low levels of sediment concentration combined to result in generally low rates of sediment discharge.

Table 14. Marginal distributions for suspended sediment characteristics for watersheds E1F1 and E4F1

Characteristic	min	Quantiles						max	Units
		0.25	0.50	0.75	0.85	0.95	0.99		
E1F1:									
Magnitude	0	0	0	0	6.0	8.0	77	4,000	lbs/acre
Average Discharge	0	0	0	0	1.0	5.8	70	74	lbs/acre/hr
Maximum Discharge	0	0	0	0	1.9	2.9	7.4	570	lbs/acre/hr
Maximum Concentration	0	0	0	0	3	25	90	250	mg/L
E4F1:									
Magnitude	0	0	0	0.58	6.4	84	220	1,300	lbs/acre
Average Discharge	0	0	0	4.7×10^{-2}	0.70	4.3	28	150	lbs/acre/hr
Maximum Discharge	0	0	0	0.17	7.6	38	170	1,200	lbs/acre/hr
Maximum Concentration	0	0	0	6	18	210	264	276	mg/L

Table 15. Marginal distributions for suspended sediment characteristics for watersheds E4F2 and E4F3

Characteristic	min	Quantiles 0.25	0.50	0.75	0.85	0.95	0.99	max	Units
E4F2:									
Magnitude	0	0	0.22	4.4	51	100	420	830	lbs/acre
Average Discharge	0	0	1.7×10^{-2}	0.28	1.4	4.2	13	20	lbs/acre/hr
Maximum Discharge	0	0	3.0×10^{-2}	0.79	0.89	29	117	410	lbs/acre/hr
Maximum Concentration	0	0	1	20	50	130	190	260	mg/L
E4F3:									
Magnitude	0	0	0	1.9	3.2	3.7	22	750	lbs/acre
Average Discharge	0	0	0	0.56	0.64	0.71	1.5	27	lbs/acre/hr
Maximum Discharge	0	0	0	2.8	3.2	3.6	7.4	171	lbs/acre/hr
Maximum Concentration	0	0	0	2	5	8	57	130	mg/L

Table 16. Marginal distributions for suspended sediment characteristics for watershed E3C1

Characteristic	min	Quantiles 0.25	0.50	0.75	0.85	0.	0.99	max	Units
Magnitude	0	3.5×10^{-2}	0.14	0.63	3.2	11	100	160	lbs/acre
Average Discharge	0	3.9×10^{-3}	1.1×10^{-2}	4.6×10^{-2}	0.13	0.47	2.5	5.8	lbs/acre/hr
Maximum Discharge	0	5.4×10^{-3}	1.7×10^{-2}	8.1×10^{-2}	0.25	2.8	20	40	lbs/acre/hr
Maximum Concentration	0	1	3	6	10	26	44	124	mg/L

5. PRECIPITATION EVENT CHARACTERISTICS AND THE OCCURRENCE AND AMOUNT OF RUNOFF

5.1 Occurrence of Runoff

The previous sections have described some of the general features of the precipitation, runoff, and sediment yield data. The objective of this section is to examine the relationship between precipitation event characteristics and the occurrence of runoff from the various watersheds in greater detail. This information is useful for determining the potential for runoff from these soils and is an important first step in developing techniques for predicting rates of runoff and erosion.

Each precipitation event was assigned to one of two classes using the runoff data for each watershed. Those precipitation events that resulted in measurable runoff were assigned to the "runoff" class for that watershed. All other precipitation events were assigned to the "no-runoff" class. A listing of the mean and standard deviation for precipitation event characteristics for events in each class and for each watershed is in Tables 17 to 21. Events which resulted in runoff had longer durations, higher magnitudes and intensities, and were accompanied by higher levels of antecedent precipitation than those events which did not result in runoff. The mean values of the characteristics for the runoff class for many of the watersheds were often nearly the same. For example, duration of precipitation for events in the runoff class ranged from 15.9 to 15.4 hours for watersheds E1F1, E4F1, and E4F3.

Table 17. Means and standard deviations for precipitation event characteristics grouped by occurrence of runoff on watershed E1F1

Variable	Units	No runoff		Runoff	
		$\bar{X}$	σ	$\bar{X}$	σ
Duration	hrs	9.48	10.7	15.9	12.6
Magnitude	in	0.219	0.315	0.515	0.705
Average Intensity	in/hr	0.021	0.017	0.031	0.021
Maximum Intensity	in/hr	0.055	0.053	0.101	0.074
Separation	hrs	47.1	67.5	23.0	22.0
Magnitude for Previous 12 hours	in	0.021	0.054	0.027	0.069
Magnitude for Previous 48 hours	in	0.228	0.345	0.598	0.564
Magnitude for Previous 168 hours	in	0.660	0.661	1.84	1.16
Magnitude for Year Preceding the Event	in	16.1	9.50	14.8	4.92

Table 18. Means and standard deviations for precipitation event characteristics grouped by occurrence of runoff on watershed E4F1

Variable	Units	No runoff		Runoff	
		$\bar{X}$	σ	$\bar{X}$	σ
Duration	hrs	8.25	9.64	15.4	12.8
Magnitude	in	0.158	0.219	0.482	0.492
Average Intensity	in/hr	0.0193	0.0152	0.0308	0.0215
Maximum Intensity	in/hr	0.0464	0.0446	0.103	0.0821
Separation	hrs	47.5	65.5	21.9	23.6
Magnitude for Previous 12 hours	in	0.0176	0.0442	0.0350	0.0762
Magnitude for Previous 48 hours	in	0.214	0.315	0.467	0.528
Magnitude for Previous 168 hours	in	0.659	0.664	1.53	1.22
Magnitude for Year Preceding the Event	in	16.5	9.29	13.8	6.13

Table 19. Means and standard deviations for precipitation event characteristics grouped by occurrence of runoff on watershed E4F2

Variable	Units	No runoff		Runoff	
		$\bar{X}$	σ	$\bar{X}$	σ
Duration	hrs	7.07	8.05	12.7	11.7
Magnitude	in	0.124	0.181	0.348	0.412
Average Intensity	in/hr	0.0177	0.0129	0.0263	0.0198
Maximum Intensity	in/hr	0.0418	0.0423	0.0781	0.0706
Separation	hrs	46.4	68.1	32.9	37.7
Magnitude for Previous 12 hours	in	0.0178	0.0388	0.0259	0.0658
Magnitude for Previous 48 hours	in	0.202	0.296	0.359	0.463
Magnitude for Previous 168 hours	in	0.535	0.579	1.26	1.07
Magnitude for Year Preceding the Event	in	17.3	10.1	14.7	6.80

Table 20. Means and standard deviations for precipitation event characteristics grouped by occurrence of runoff on watershed E4F3

Variable	Units	No runoff		Runoff	
		$\bar{X}$	σ	$\bar{X}$	σ
Duration	hrs	10.4	11.3	15.5	14.8
Magnitude	in	0.262	0.394	0.539	0.529
Average Intensity	in/hr	0.0227	0.0178	0.0330	0.0249
Maximum Intensity	in/hr	0.0632	0.0679	0.101	0.0789
Separation	hrs	41.3	61.1	35.9	41.9
Magnitude for Previous 12 hours	in	0.0228	0.0563	0.112	0.267
Magnitude for Previous 48 hours	in	0.287	0.416	0.679	0.964
Magnitude for Previous 168 hours	in	0.870	0.914	1.90	1.84
Magnitude for Year Preceding the Event	in	15.3	8.64	18.6	8.14

Table 21. Means and standard deviations for precipitation event characteristics grouped by occurrence of runoff on watershed E3C1

Variable	Units	No runoff		Runoff	
		$\bar{X}$	σ	$\bar{X}$	σ
Duration	hrs	6.74	7.42	10.9	11.8
Magnitude	in	0.195	0.347	0.276	0.389
Average Intensity	in/hr	0.0254	0.0194	0.0231	0.0189
Maximum Intensity	in/hr	0.0639	0.0649	0.0631	0.0622
Separation	hrs	46.6	49.0	41.4	63.4
Magnitude for Previous 12 hours	in	0.00783	0.0198	0.0239	0.05937
Magnitude for Previous 48 hours	in	0.136	0.356	0.294	0.405
Magnitude for Previous 168 hours	in	0.409	0.840	0.906	0.874
Magnitude for Year Preceding the Event	in	0.827	0.955	15.8	7.80

Stepwise discriminant analysis was used to identify the values and combinations of event characteristics that are most useful in classifying precipitation events into the runoff or no-runoff classes. The results are shown in Table 22, which contains the coefficients of the classification function that were developed for each watershed. Two rows of this table define the classification functions for each watershed. The two classification functions take the form

$$C = \text{constant} + \sum_{i=1}^{n} a_i X_i$$

where n is the number of characteristics determined to be significant in classifying events, a_i is a coefficient, and X_i is an event characteristic. For example, consider the entries for watershed E1F1 (Table 22).

Table 22. Classification functions for precipitation event characteristics grouped by the occurrence of runoff. Units of M, M12, M168, and MYR are inches

Watershed	Group	Constant	M	M12	M168	MYR	Percent correct
E1F1	runoff	-4.867	3.902	-†	3.448	-	76
	no runoff	-1.283	1.624	-	1.247	-	84
E4F1	runoff	-3.627	5.139	-	2.216	-	66
	no runoff	-1.140	1.739	-	0.9386	-	84
E4F2	runoff	-2.217	3.095	-	1.564	-	63
	no runoff	-0.9390	1.097	-	0.6655	-	84
E4F3	runoff	-7.493	4.146	10.98	2.093	0.3317	35
	no runoff	-3.434	2.502	0.3212	1.1796	0.2481	86
E3C1	runoff	-4.748	3.126	-	1.792	0.3551	81
	no runoff	-0.9746	1.444	-	0.5985	0.0439	91

† not significant

In this case, the results of discriminant analysis showed that two event characteristics, magnitude, M, and magnitude in the previous 168 hours, M168, were significant in classifying events into the runoff and no runoff classes. The two classification functions for this watershed can be written using the values of the constants and coefficients listed in the first two rows of Table 22:

$$C \text{ (runoff)}: \; -4.867 + 3.902 \, (M) + 3.448 \, (M168)$$

$$C \text{ (no runoff)}: \; -1.283 + 1.624 \, (M) + 1.247 \, (M168)$$

These equations may be used to predict if runoff would occur from this watershed for an event with specific values of M and M168. This is done by substituting values of the event characteristics into the two classification functions and computing the two C values. The equation which gives the largest value of C corresponds to the predicted class for that event. For example, consider a precipitation event with M168 = 1 in. and M = 0.5 in. Using the classification functions for watershed E1F1 we compute C (runoff) = 0.532 and C (no runoff) = 0.776 and conclude that this event would not result in runoff from this watershed. Using these equations, for this watershed precipitation events that resulted in runoff can be correctly predicted 76% of the time. Events that did not result in runoff can be correctly predicted 84% of the time.

The precipitation event characteristics M and M168 were significant in determining if a precipitation event resulted in runoff or not for all watersheds. For watersheds E4F3 and E3C1 the event characteristics M12 and MYR (see Table 1) were also significant. The classification functions correctly predicted whether an event produced runoff a high percentage of the time. They were most successful in predicting when runoff did not occur. For example, 81% and 91% of the precipitation events could be correctly predicted using the classification functions developed from the runoff data from watershed E3C1. The coefficients assigned to each characteristic were different for each watershed. This results from differences in slope, aspect, and soil type among the different watersheds.

5.2 Amount of Runoff

In Section 5.1, discriminant analysis was used to determine the values and combinations of precipitation event characteristics that were significant in predicting the occurrence of runoff from these watersheds. The significance of precipitation event characteristics M12, M48, and M168 in the classification functions indicated the importance of antecedent precipitation in determining the potential for runoff during winter storms in the Willamette Valley. Additional useful information about the runoff process can be obtained by comparing the amount of runoff resulting from a precipitation event with the associated precipitation event characteristics. By quantifying relationships between precipitation and runoff, simple statistical models for amount of runoff resulting from precipitation events can be developed.

Each precipitation event was assigned to one of five classes using the runoff data for each watershed. This was done by comparing the amount of runoff resulting from a precipitation event, expressed as a depth of water (volume of runoff/area of watershed), with the magnitude of precipitation for the event. The ratio of these two numbers, expressed as a percentage, was referred to as the percent runoff for that event for that watershed. Events that resulted in less than 25% runoff were assigned to Class 1, events with 25 to 50% runoff were assigned to

Class 2, events with 50 to 75% runoff were assigned to Class 3, events with 75 to 100% runoff were assigned to Class 4, and events with 100% or more runoff were assigned to Class 5. For example, a precipitation event with a magnitude of 1.00 inches resulted in 0.3 inches of runoff at watershed E4F1. The percent runoff for this event for this watershed was 30% and the event would be assigned to runoff Class 2.

Most precipitation events resulted in a low percentage of runoff (Table 23). For example, 286 of the 355 precipitation events resulted in less than 25% runoff from watershed E1F1. The number of events in each runoff class was different for each of the watersheds. Watersheds E4F2 and E3C1 had a larger number of events with high values of percent runoff than the other watersheds. Nineteen of the precipitation events resulted in 100% runoff from watershed E4F2 and more than 20% of the events resulted in at least 50% runoff.

Table 23. Classification of runoff events based on percent runoff (magnitude of runoff)/(magnitude of precipitation) x 100%. Entries are the number of events in each class

	Runoff class (lower and upper bounds for percent runoff)				
Watershed	1 (0-25)	2 (25-50)	3 (50-75)	4 (75-100)	5 (100)
E1F1	286 (0.95)†	4 (0.01)	5 (0.02)	2 (0.01)	5 (0.02)
E4F1	275 (0.82)	22 (0.07)	18 (0.05)	6 (0.02)	13 (0.04)
E4F2	204 (0.63)	50 (0.15)	34 (0.10)	17 (0.05)	19 (0.06)
E4F3	54 (0.84)	3 (0.05)	2 (0.03)	3 (0.05)	2 (0.03)
E3C1	223 (0.72)	49 (0.16)	18 (0.06)	4 (0.01)	15 (0.05)

† Percent of total number of runoff events for this watershed.

Stepwise discriminant analysis was used to identify the values and combinations of event characteristics useful for classifying precipitation events into the five runoff classes. This was the same procedure used in the previous section to determine event characteristics useful for classifying events into runoff and no-runoff classes. The coefficients of the classification functions that were developed for each watershed are shown in Table 24. The results for runoff classes with fewer than five events have been deleted. For example, consider the data for watershed E4F1. There are five classification functions shown, one for each runoff class. The precipitation event characteristics that were significant were the precipitation in the 48 and 168 hours before the start of the event, M48 and M168, and the number of dry hours preceding the event (the event separation, S). Using these equations, 69% of the events in runoff Class 1 and 55% of the events in runoff Class 2 could be predicted correctly, and so on. Different precipitation event characteristics were significant and different values of the constants and coefficients in the classification functions were obtained for each watershed. For example, for watershed E1F1, the characteristics M, M48, and M168 were significant while for watershed E3C1, average intensity, I, and M168 were the only significant characteristics.

The number of correct predictions varied from 8 to 81%, with values typically between 30 and 50%. In general, the highest number of correct classifications were determined for events in runoff Class 1, that is, the events with the smallest amounts of runoff. This is caused, in part, by the large number of events in this class (Table 23). The only event characteristic that was significant for all runoff classes and all watersheds was M168. This further illustrates the importance of antecedent precipitation in determining the amount of runoff that will result from a given precipitation event. This was particularly true for watersheds E4F1, E4F3, and E3C1; on these watersheds, the magnitude of precipitation

Table 24. Results of discriminant analysis using precipitation event characteristics to classify runoff events by percent runoff

Watershed	Runoff class	Coefficients of classification function							Percent correct
		Constant	I	M	M48	M168	S	M12	
E1F1	1	-2.41	-†	1.89	0.800	1.26	-	-	81
	3	-11.6	-	2.05	-2.81	6.72	-	-	75
	5	-22.4	-	9.80	5.20	6.02	-	-	50
E4F1	1	-2.39	-	-	0.646	0.768	15.2	-	69
	2	-4.07	-	-	-0.003	1.75	25.8	-	55
	3	-4.95	-	-	1.62	1.54	30.7	-	28
	4	-13.8	-	-	7.96	1.78	47.5	-	50
	5	-4.69	-	-	3.26	1.87	2.40	-	62
E4F2	1	-2.02	-	1.58	-	0.795	-	-	71
	2	-3.20	-	3.40	-	1.47	-	-	34
	3	-3.54	-	2.44	-	2.01	-	-	21
	4	-4.86	-	1.60	-	2.89	-	-	41
	5	-4.00	-	-0.524	-	2.62	-	-	53
E4F3	1	-1.96	-	-	-	1.11	-	-1.80	76
	4	-19.3	-	-	-	2.82	-	48.3	67
E3C1	1	-2.78	68.8	-	-	0.857	-	-	70
	2	-2.91	52.2	-	-	1.44	-	-	8
	3	-4.08	56.0	-	-	2.24	-	-	17
	5	-3.79	15.9	-	-	2.46	-	-	27

† not significant

during an event was not significant in determining the percent of runoff. Instead, characteristics associated with antecedent precipitation, average intensity, and the event separation were significant.

6. SUMMARY AND CONCLUSIONS

This report has presented an analysis of four years of hydrologic data from the Elkins Road Experimental Watershed Study. The analysis consisted of three separate parts. First, monthly totals of the precipitation, runoff, and sediment yield data were used to describe their amount and seasonal distribution. Second, hourly precipitation, watershed runoff, and sediment yield data were analyzed using the concepts of precipitation and runoff events. Frequency distributions for characteristics of these events were used to describe the response of these watersheds to individual events. Third, discriminant analysis was used to identify the value and combinations of the precipitation event characteristics that were associated with the occurrence and amount of runoff. Specific conclusions include the following:

(a) Most of precipitation, runoff, and sediment yield occurred during December and January.

(b) Seasonal runoff from all the watersheds ranged between 1 and 41% of precipitation, with the lowest amounts of runoff occurring on watersheds with deep soil profiles.

(c) Watershed runoff often exceeded 50% of monthly precipitation.

(d) Sediment yield was small, ranging between 81 and 4,239 lbs/acre.

(e) Between 25 and 50% of precipitation events resulted in no runoff.

(f) Average rates of runoff were small, but maximum rates of runoff were close to maximum precipitation intensity.

(g) A few precipitation events were responsible for most seasonal sediment yield. On one watershed a single precipitation event caused 82% of the total soil loss for the four-year study.

(h) The occurrence of runoff during a precipitation event was correlated with the level of antecedent precipitation in the 48 and 168 hours before the event.

(i) The amount of runoff resulting from a precipitation event was determined to a greater extent by the amount of antecedent precipitation than by either precipitation amount or intensity.

This study has contributed to our understanding of the erosion process in western Oregon. We now know that the erosion process is not uniform, because many events cause no measurable runoff or erosion. Instead, a few rainstorms each year are responsible for most of the annual soil loss. These events result from a combination of climatic factors. In this study we demonstrated the importance of antecedent precipitation in determining the amount of runoff that results from a rainstorm.

In shallow soils, with limited infiltration capacity, such as those studied in this report, antecedent precipitation can be more important for predicting rate of runoff and erosion than precipitation amount, duration, or intensity. This means that methods for predicting erosion that rely exclusively on precipitation amount and intensity are not applicable to our region. Instead we must develop new methods that include the interaction between antecedent precipitation and the infiltration capacity of the soil profile in runoff and erosion estimates.

REFERENCES

1. Harr, R. D. 1977. Water flux in soil and subsoil on a steep forested slope. Journal of Hydrology. 33:37-58.

2. Harward, M. E., G. F. Kling, and J. D. Istok (eds.). 1980. Erosion, sediment, and water quality in the high winter rainfall zone of the northwestern United States. Special Report No. 602, Agricultural Experiment Station, Oregon State University, Corvallis.

3. Istok, J. D., and G. F. Kling. 1983. Effect of subsurface drainage on runoff and sediment yield from an agricultural watershed in western Oregon, U.S.A. Journal of Hydrology. 65:279-291.

4. Kirkby, R. D, and R. J. Chorley. 1967. Throughflow, overland flow and erosion. International Assocation of Scientific Hydrologists. 12(3):5-21.

5. McCool, D. K., R. I. Papendick, and F. L. Brooks. 1976. The Universal Soil Loss Equation as adapted to the Pacific Northwest, Chapter 2. p. 135-147. In: Proceedings of 3rd Federal Inter-Agency Sedimentation Conference, Water Resources Council, Washington, DC.

6. McCool, D. K., W. H. Wischmeier, and L. C. Johnson. 1982. Adapting the Universal Soil Loss Equation to the Pacific Northwest. Transactions of the American Society of Agricultural Engineers. 25:928-934.

7. Soil Conservation Service. 1972. National Engineering Handbook Section 4. U.S. Department of Agriculture.

8. U.S. Department of Agriculture. 1981. Program report and environmental impact statement. Soil and Water Resources Conservation Act.

9. Wischmeier, W. H., and D. D. Smith. 1978. Predicting rainfall erosion losses: A guide to conservation planning. United States Department of Agriculture, Agricultural Handbook No. 537.

10. Zuzel, John F., R. R. Allmaras, and R. Greenwalt. 1982. Runoff and soil erosion on frozen soils in northeastern Oregon. Journal of Soil and Water Conservation. 37(6):351-354.