REPLACEMENT

Erosion, Sediment, and Water Quality in the High Winter Rainfall Zone of the Northwestern United States

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Oregon State University, Corvallis

EROSION, SEDIMENT, AND WATER QUALITY IN THE HIGH WINTER RAINFALL ZONE OF THE NORTHWESTERN UNITED STATES

SUMMARY AND RECOMMENDATIONS

Erosion and Sediments

Measured erosion rates at all sites in western Oregon over the past 4 years were within the range of 0.1 to 4 T/acre/yr. Long-term erosion rates estimated from analysis of radioactive fallout were within the range of 1 to 12 T/acre/yr. The highest amounts of erosion and runoff occurred during storms which followed periods of high soil moisture, frozen ground, or extensive crusting. Combinations of these conditions occurred only infrequently, but, when present, resulted in runoff from the entire watershed. Most storms, however, produced runoff only from limited areas. These critical landscapes included soils in lower slope positions and around the margins of waterways.

Soil moisture content and perched water tables are major factors which influence erosion. Immediately following fall planting, the soil surface is loose and porous. Early rains infiltrate the soil and increase the moisture content, particularly above restrictive layers which impeded percolation through the soil. As the winter season progresses, increases in soil moisture cause perched water tables to develop even on hill slopes. At this time, the water moves downslope by subsurface flow and tends to surface in the lower slope positions. The impact of perched water tables is reduced by installation of drainlines which reduce soil moisture content.

Fall and early winter rains break down the soil aggregates and result in a surface crust, thus limiting infiltration and causing runoff to occur. However, the effect of crusting is short lived because cracking of the crust occurs during intervening dry periods. Due to the combined effects of surface cracking and increased plant cover, the amounts of runoff and particularly soil losses are lower in the spring than in the winter.

Although freezing is not common in the Willamette Valley, frozen soil was encountered in 2 of the 4 years of observations. The highest rates of erosion occurred during rainstorms following frozen ground.

Water Quality

Nitrate concentrations in the runoff were generally low at one location except for a runoff period immediately following fertilization. Nitrate levels in the runoff were higher at two other locations, and high levels persisted through much of the winter. Concentrations of dissolved phosphorus in the runoff generally were less than 0.1 ppm. Annual losses of total phosphorus ranged up to 20 lb/acre and were correlated with sediment loss. Approximately 1 percent of an applied herbicide (diuron) was lost during the winter season. Maximum concentration of diuron in the runoff was low and did not exceed 90 ppb.

Recommendations

Erosion rates measured to date are low relative to other regions in the United States. Due to the variability of weather patterns, however, we may not have yet sampled a major runoff event. Nevertheless, erosion rates have been great enough to warrant erosion control practices. Because of the importance of perched watertables on runoff and erosion, critical lower slope positions should receive particular attention. Installation of drainage systems will reduce the impact of saturated soil conditions. Margins around drainageways should be planted to permanent cover. If the land must be used for annual cropping, seeding rates should be increased by cross-seeding.

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Oregon Fine Fescue Commission

Oregon Highland Bentgrass Commission

METRIC CONVERSION FACTORS

1 kilometer = 0.621 miles

1 meter = 0.094 yards

1 centimeter = 0.394 inches

1 $kilometer^2$ = 0.386 $miles^2$

1 $kilometer^2$ = 247.1 acres

1 hectare = 2.47 acres

1 $meter^3$ = 35.32 ft^3

1 metric ton (mTon) = 1.102 tons - US (T)

1 metric Ton (mTon)/ha = 0.446 T/acre

1 kg/ha = 0.892 lbs/acre

1 $foot^3$ = 28.32 liters

CONTENTS

CHAPTER 1. INTRODUCTION

M. E. Harward

Background

A few decades ago there was considerable interest in agricultural practices in relation to wind and water erosion where emphasis was on conservation of the resource. Recently, implementation of PL92-500 and Section 208, dealing with non-point sources of pollution (NPSP), is evidence of a renewed interest in erosion. Present concern, however, is on water quality and erosion studies per se are insufficient. Research must relate soil detachment and sediment transport in order to obtain methods of reducing soil loss and degradation of water quality.

Most research on erosion has been in the midwest and eastern U.S. Much less has been done on agricultural lands in the northwest. There has been some work in the Palouse region of Washington (McCool et al., 1976). West of the Cascades, however, most studies of soil erosion have taken the form of surveys with little or no attention to erosion processes within agricultural fields (U.S. Soil Conservation Service, 1949; Anderson, 1954; Baum and Kaiser, 1965; Willamette Basin Task Force, 1969; Rickert et al., 1976; Young, 1976; Hedlund, 1977; Tillamook Bay Task Force, 1978).

Until recently, agricultural erosion in this region was not recognized as a major or priority problem. However, argument about the magnitude of problems here relative to other areas is a mute question. All states are concerned with Section 208, PL92-500 dealing with NPSP. There is ample evidence that we do have erosion problems in this region. It is also possible that there may be increased rates of erosion as a result of changes in land use and management practices. Regulation of grass field burning has resulted in some shift from perennial grass to grain on the hill soils surrounding the valley.

The agricultural industry is conscious of environmental problems. Questions most often posed by agricultural producers, commodity groups, and resource based organizations are generally specific. They want to know the degree to which given management practices result in degradation of soil productivity and water quality. Society recognizes that imposition of some controls is necessary. However, the agricultural industry wants those controls to be based on sound research information.

STEEP: A Regional Research Effort

Increased awareness and concern by farmers working through commodity groups and resource organizations, such as the Wheat League, Wheat Commission, and Soil and Water Conservation Districts, resulted in a regional research effort on erosion. They provided the stimulus and, importantly, were successful in securing federal funds to develop the program. The total program known as STEEP (Solutions to Environmental and Economic Problems) is broad and includes all factors which affect erosion. The five major areas include: 1) tillage and management, 2) plant design, 3) erosion and runoff prediction, 4) pest management, and 5) economics. STEEP is a regional research project involving cooperative work by the Agricultural Experiment Stations in Idaho, Oregon, and Washington, and the USDA, SEA-AR. Each of the State Experiment Stations focuses on different specific problems.

The major effort by the Oregon Agricultural Experiment Stations contributes to Objective 3 of the regional STEEP program. This regional objective is:

Erosion and Runoff Prediction

For short range needs adapt the existing Universal Soil Loss Equation for application to Pacific Northwest conditions of climate, topography, and cropping systems.

- Reduce and replace empiricism in the equation with physically based descriptions of the erosion process.
- Improve prediction capability by using measurements of soil loss over a range of slope lengths and steepnesses.
- Develop a physically based hydrologic-erosion model to describe water runoff and soil loss from watersheds.
- Study fundamental relationships between upland erosion, sediment load, chemical content, and water flow dynamics.

The specific objectives of the Oregon project are:

- To determine the major factors which influence the erosion and transport of soil materials in the winter rainfall climatic zone.
- To apply the knowledge to soil management practices for minimizing yield of sediments while maintaining profitable agricultural enterprises.
- To provide physically based predictive models for soil erosion hazard, soil loss and sediments.

Research is directed specifically to the high winter rainfall zone west of the Cascades. Because of the potential for erosion, emphasis is placed on soils of the foothills which surround the Willamette Valley and systems of farming which involve annual cropping such as fall planted cereals and/or annual grass seed crops. An agricultural watershed in southern Polk County was selected. The hill soils and agricultural systems of the watershed are typical of the western margin of the Willamette Valley. The intent of the research is to relate processes of erosion to physically based parameters and then to use soil properties to extend the research information to other areas with the aid of soil survey reports.

When the regional STEEP research program was initiated about four years ago, the Oregon Agricultural Experiment Station did not have an active research project on erosion. Consequently, it was necessary to organize and develop a completely new program. The philosophy of the Experiment Station was to assemble a group with sufficient number of personnel and funds for equipment to make significant progress in the shortest time possible. It must be recognized, however, that erosion and sediment transport involve important relationships with weather patterns which vary considerably from one year to the next. Results of research of this type will be meaningful only when enough storm events are measured to reasonably encompass the range in weather patterns and to relate these events to erosion processes.

The Oregon project placed primary emphasis on quantifying the amount of erosion and sediments being transported during the winter rainfall season. Concern about other factors relating to water quality resulted in an expansion of the research to include herbicides and the plant nutrients, particularly nitrates and phosphates. A major motivation for the expanded research was the integration of studies involving chemicals in the runoff with the on-going research dealing with erosion and sediments. Equipment for measurement of volume of runoff and for sampling was in operation. Other detailed data were being obtained to provide a measure of both sub-surface and overland flow in response to soil properties and weather. By implementing the studies of chemical constituents and integrating it with the on-going erosion project, a more thorough evaluation of the total system was possible. This approach has advantages from the standpoint of time, manpower and costs which would be much less than if done separately. Funds for the expanded research on water quality came from sources other than STEEP. These include the Agricultural Experiment Station, USDA, SEA-AR, the Oregon State University Water Resources Research Institute, and the Office of Water Research and Technology. Thus, the total erosion and water quality research effort in western Oregon includes other related investigations and is not limited to the STEEP project.

Organization of the Reports

The purpose of this publication is to make obtained data available for information and use by others. Other reports, in the form of supplements or additions, will be published as other data become available and as different phases of research are completed. Some of the data included in this report involve phases of study which are still in progress. In such cases, data are presented with little or no discussion since interpretations now would be premature. The actual data, however, may be of interest and of use by others and this publication is a mechanism for making them available.

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CHAPTER 2. INITIAL HYPOTHESES AND EVIDENCE OF MAJOR FACTORS INFLUENCING EROSION IN THE PACIFIC NORTHWEST

G. F. Kling

Summary

The Universal Soil Loss Equation (USLE) has not been calibrated for the high winter rainfall zone of the northwestern United States. The limitations which have been recognized for this equation are those which are common to this region. This makes extrapolation of the equation to this area difficult and teneous. Factors not included in the equation but which are important to the zone include the influence of prior storm patterns and soil moisture (antecedant moisture), layers in the soil sample which restrict the penetration and movement of water, and landscape position. Information is needed on the influence of soil properties and weather patterns in relation to perched water tables in order to obtain a satisfactory equation for predicting erosion and runoff.

Introduction

The Universal Soil Loss Equation (USLE) is often taken as a starting or focal point in erosion studies (Wischmeier et al., 1971). The equation has the form

$$A = RKLSCP$$

where: A is predicted soil loss (T/A),
R is a rainfall factor,
K is a soil erodibility factor,
L is slope length,
S is steepness,
C is the cover or cropping factor, and
P is the erosion control practice factor.

The equation was derived and calibrated largely on data from the midwest and eastern United States. The USLE provides a means for evaluating the effect of cultural practices on erosion. Accordingly, it is a tool used by the U.S. Soil Conservation Service to aid in decisions on the need and design for specific management practices (USSCS, 1976). Properly calibrated and used, it serves a useful purpose. Unfortunately, its limitations are not always understood and it is sometimes misused (Wischmeier, 1976).

Some of the limitations recognized by Wischmeier (1976) and others relate directly to the different climatic patterns prevalent in the Pacific Northwest. Specifically, the USLE was not developed or calibrated for the long duration, low intensity storm systems which characterize our winter rainfall season.

Major Factors Influencing Erosion

The USLE implies that any storm will produce runoff and erosion; the magnitude will be modified by ground cover and erosion control practices. Initial research by our group, however, indicates that antecedent moisture is also critically important in any model attempting to predict the occurrence of overland flow. Many of our soils contain lithologic discontinuities (Chapter 4). These discontinuities create zones of reduced permeability within the soil profile which tend to perch the water table. It appears that many of the storms that occur in the early fall after the prolonged dry period characteristic of our summer, infiltrate completely and produce little or no overland flow. As the winter season progresses and the duration of the storms increases, perched water tables are formed even on gently sloping hillsides. As the water tables approach the soil surface saturation occurs and infiltration rates decrease. This phenomenon implies that two storms with the same intensity and duration of rainfall could produce quite different amounts of overland flow depending on the antecedent moisture conditions in the soil (Dunne, 1978). Therefore, we hypothesize that any model which attempts to predict erosion in the Pacific Northwest must include antecedent moisture as a controlling factor.

If the presence of water tables do influence overland flow, then topographic position on the slope also will be important because water tables tend to be closer to the surface in the lower slope positions. A second hypothesis would be that an adequately calibrated model would need to account for slope position and runoff contributing area.

The third aspect of the USLE that is being investigated involves the K, or soil, factor. Some data suggest that the inherent erodibility of the soil surface changes throughout the winter season. This could be related to aggregate stability which in turn might be related to management practices. It appears that as the winter season progresses, there is an additional cycle in the infiltration rate, not directly related to water table fluctuations. Infiltration rates decrease from initially high values in the early fall to a minimum in January and then return to relatively high values in March or April. These changes are related to changes in the character of the soil surface including porosity and aggregate stability. Superimposed on this phenomenon is the potentially drastic influence of rainfall occurring on frozen ground. This occurs in the Pacific Northwest and potentially is the most serious of our erosion events. Any erosion model would need to evaluate the frequency of these multiple events.

Our fourth major area of erosion research addresses the fate of entrained sediment on the watershed. The USLE only addresses the initial detachment of eroded particles. Much of the initially detached material is redeposited in the same or adjacent fields and does not enter the permanent streams and waterways. Because of a growing concern about the impact of our current agricultural practices on water quality, we are devoting a major research effort towards elucidating and quantifying the transport processes involved in moving the initially detached particles.

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SECTION I. THE ELKINS ROAD EXPERIMENTAL WATERSHED

CHAPTER 3. GENERAL METHODS AND DESIGN OF EXPERIMENTS

G. F. Kling and B. Lowery

Introduction

This study is being conducted in the western foothills of the Willamette Valley. The Willamette Valley is bordered on the west by the Coast Range and on the east by the Cascade Range. The valley is drained by the Willamette River which flows northward to the Columbia River.

The study area is a 285 ha watershed in southern Polk County, Oregon (T.9S., R.5W.). This watershed is within the Luckiamute River drainage basin. The Luckiamute is a major tributary of the Willamette River (Fig. 3-1).

This particular watershed was selected as representative of the soil landscapes and cropping practices common to much of the western margin of the Willamette Valley. The watershed contains several definable sub-watersheds, ranging in size from 0.46 ha to 6.0 ha (Fig. 3-1). These nested sub-watersheds provide the framework for developing and testing a sediment transport model.

The privately-owned land is planted to small grains and grasses. All agronomic operations are carried out by the farmers prior to equipment installation in the fall; all equipment is removed before harvest. In this manner we are monitoring erosion and runoff under actual agricultural practices as they are used in the Willamette Valley.

Surface Flow

This research project has been directed towards an understanding of subsurface moisture conditions at the time overland flow occurs. Overland flow is being measured on a watershed basis as well as within a given watershed. Surface runoff from 0.46, 1.4 and 6.0 ha sub-watersheds within the 285 ha main watershed are monitored using H-flumes. Runoff and erosion within the sub-watersheds is determined by erosion plots.

Erosion Plots

Runoff and sediment yield from a selected site within a sub-watershed are measured using standard and mini-erosion plots. The standard plots are 2.03 by 25.4 m and the mini-plots 2.08 by 5.08 m. The plot walls and ends are constructed of discrete 111.8 cm sections of 18 gage sheet metal (Fig. 3-2), with a folded top along a 101.6 cm section, part of which overlaps the remaining 10.2 cm unfolded extension of the adjacent section. Sediment troughs, constructed from the same material, are 233.7 by 61.0 cm for the standard and 233.7 by 10.2 cm for the mini-plots. The troughs are placed parallel to the slope contour in a trench against a clean vertical cut 3 to 4 cm below the soil surface. A trough lip is then inserted perpendicular to the trough into the cut face (Fig. 3-2). This is followed by lid supports and plot sides which extend approximately 5 cm into the ground. Plot sides are aligned using strings as boundary guides. Runoff water is channeled from the sediment troughs to tubs through 15.2 cm diameter pipes. Lids were constructed for plot troughs and tubs to prevent precipitation interception (Fig. 3-2). The plots are equipped with splitters[1] which divert a known fraction (approximately a tenth) into tubs, from which the total runoff can be calculated. During the 1977-78 rainfall season an attempt was made to sample plots after a given storm interval, but storm intervals were very difficult to define. Therefore, sampling was conducted on a weekly basis in subsequent years. The volume of water in the tub is measured and a representative sample is taken for sediment determination. The troughs are sampled at the same time as the tubs. The total sediment in the troughs is collected, dried to 100°C and weighed for sediment yield calculations.

Flumes

Overland flow from each sub-watershed is monitored with H-flumes; a 22.9 cm H-flume for the 0.46 ha sub-watershed and 45.7 cm H-flumes for the 1.4 and 6.0 ha sub-watersheds. The flumes were designed as described by the Agricultural Research Services field manual (U.S. Agricultural Research Service, 1962). The flumes are installed at each sub-watershed outlet, with two 1.22 by 2.44 m pieces of exterior plywood (flume wings) placed to a depth of approximately 60 cm to channel flow through the flume.

Depth of flow in the flumes is measured using Instrumentation Specialties Co. ISCO Model 1700 flow meters. This measurement is converted (an internal process of the instrument) to volume of flow per unit time and printed on tape using ISCO Model 1710 printers.

ISCO Model 1680 wastewater samplers are used in periodic sampling of runoff in the flumes. In most cases the samples are taken on a flow proportional basis. The automatic sampling program is augmented by manual "grab" samples.

Precipitation

Precipitation amounts and intensities are measured using Meteorology Research Inc. Model 304 tipping bucket raingage. This instrument has a resolution of .25 mm.

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[1]Splitter design courtesy of D. K. McCool, Pullman, Washington.

Total precipitation is also measured with Tru-Check wedge-shaped non-recording raingages. These raingages serve as a back-up in case of problems with the recording gages.

Subsurface Moisture

This study has been conducted over a wide range in soil moisture conditions from very dry to saturated. Wells, piezometers and tensiometers are used to measure these changes in soil moisture status.

Wells

Depth to perched water tables is measured using wells placed at selected sites in and near the sub-watersheds. Daily measurements consist of a maximum water table height (minimum depth from soil surface to perched water table) since the last reading and a present water table height. This is achieved by an acrylic styrofoam float type stage recorder (Fig. 3-3). The styrofoam floats on the water surface and adheres to the acrylic tube when the water table recedes. Well casings were constructed from 5.1 cm diameter polyvinyl chloride (PVC) pipe with 5.0 mm randomly drilled holes from top to bottom. The wells were plugged at bottom with a rubber stopper (Fig. 3-3).

The wells are installed to a depth of approximately 150.0 cm. Installation consists of drilling a 5.1 cm diameter hole using a barrel soil auger and inserting the casing and stage recorder (no backfilling is necessary).

Piezometers

Positive pore water pressure (piezometric head) is measured with piezometers. The piezometers were designed after Yee (1975). Piezometers were constructed from 1.9 cm diameter PVC pipe with 4.5 mm holes drilled randomly along a length of 10 cm at the bottom of the pipe (Fig. 3-4). The holes were covered with a woven nylon screen to prevent the entrance of backfill material. The screen was secured by taping its ends to the pipe. The lower ends of the piezometers were sealed with rubber stoppers. A styrofoam stage-recorder is used to measure the maximum and present piezometric heads.

The piezometers are installed such that the perforated section corresponds with the center of the soil horizon. In most cases the piezometers are placed in batteries of four, in the Ap, B1, IIB2tb, and IIC horizons. The piezometers placed in the IIC horizons are in all cases 150.0 cm below the ground surface.

Piezometers are installed using a 3.8 cm diameter bucket auger. they are backfilled with about 500 ml of dry coarse silt followed by alternating layers of bentonite and silt (Fig. 3-4).

Tensiometers

Pore water pressures were also measured with tensiometers. The tensiometers used in this study were described by Harr (1976). They consist of a 1.3 cm PVC pipe with a porous ceramic cup epoxyed to the end. The cup is sealed with a rubber stopper with two 3.5 mm holes for the connecting tubes (Fig. 3-5).

The manometers are filled with methylene bromide (density 2.5 g/cm^3). Methylene bromide is colorless, thus sudan IV (a dye insoluble in water) was used to discern the water-methylene bromide interface. The manometer stands were constructed using a 5.1 x 5.1 cm board with two meter sticks used as a scale.

A 3.8 cm diameter hole is drilled using a soil auger to install the tensiometers at selected sites in the sub-watersheds. Tensiometers are placed at depths corresponding to those of piezometers. They are installed in a similar fashion as piezometers except the initial backfill material consisted of soil taken from that horizon during augering.

V-notch Weir

In August, 1979, drainlines were installed in the 1.4 ha sub-watershed to determine the effect of soil drainage on reducing overland flow.[1] Flow from the drainline, at a point corresponding to the watershed outlet, was monitored with a V-notch weir. This weir was designed to handle a maximum flow capacity of 28.3 liters per second. Flow was measured using an ISCO flow meter similar to that described for flumes. The weir was placed at a 45 cm elevation drop in the drainline. It was housed in a 1.22 m diameter, aluminum culvert. This culvert extended vertically lengthwise 2.05 m below the soil surface with 7.6 cm extending into a concrete slab. Subsurface drainage water flowed into the culvert through a 30.5 cm diameter pipe, which extended over the collection box of the weir. After passing over the weir, water drained out of the culvert via a 15.2 cm pipe into the drainline.

Nomenclature

A system of numbers and letters was established to identify study areas, sub-watersheds and instrument stations within the Elkins Road watershed. This system is presented here:

Study areas

The 285 ha watershed was divided into four study areas, E1, E2, E3, and E4 (Fig. 3-6).

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[1]The assistance of Mr. Lester Gahler and Advanced Drainage Systems Inc. in bearing a portion of the material and installation costs of the drainage system is gratefully acknowledged.

Sub-watersheds

Sub-watersheds are identified by study area and size:

E1F1	0.46 ha sub-watershed in study area E1
E4F1	1.4 ha sub-watershed in study area E4
E4F2	6.0 ha sub-watershed in study area E4

Instrument Stations

Flumes

E1F1	flume at outlet of 0.46 ha sub-watershed
E4F1	flume at outlet of 1.4 ha sub-watershed
E4F2	flume at outlet of 6.0 ha sub-watershed
E3C1	culvert at outlet of 285 ha watershed
E4V1	V-notch wier at drainline outlet, study area E4F1

Erosion Plots (examples)

E4S1	Standard erosion plot number 1 within study area E4
E1M2	Mini erosion plot number 2 within study area E1

Wells (example)

E4W1	Well number 1 within study area E4

Piezometers (example)

E1Z3	piezometer number 3 within study area E1

Tensiometers (example)

E4T2	tensiometer number 2 within study area E4

Raingages (examples)

E4R1	tipping-bucket type recording raingage number 1 within study area E4
E4P2	wedge-type raingage number 2 within study area E4

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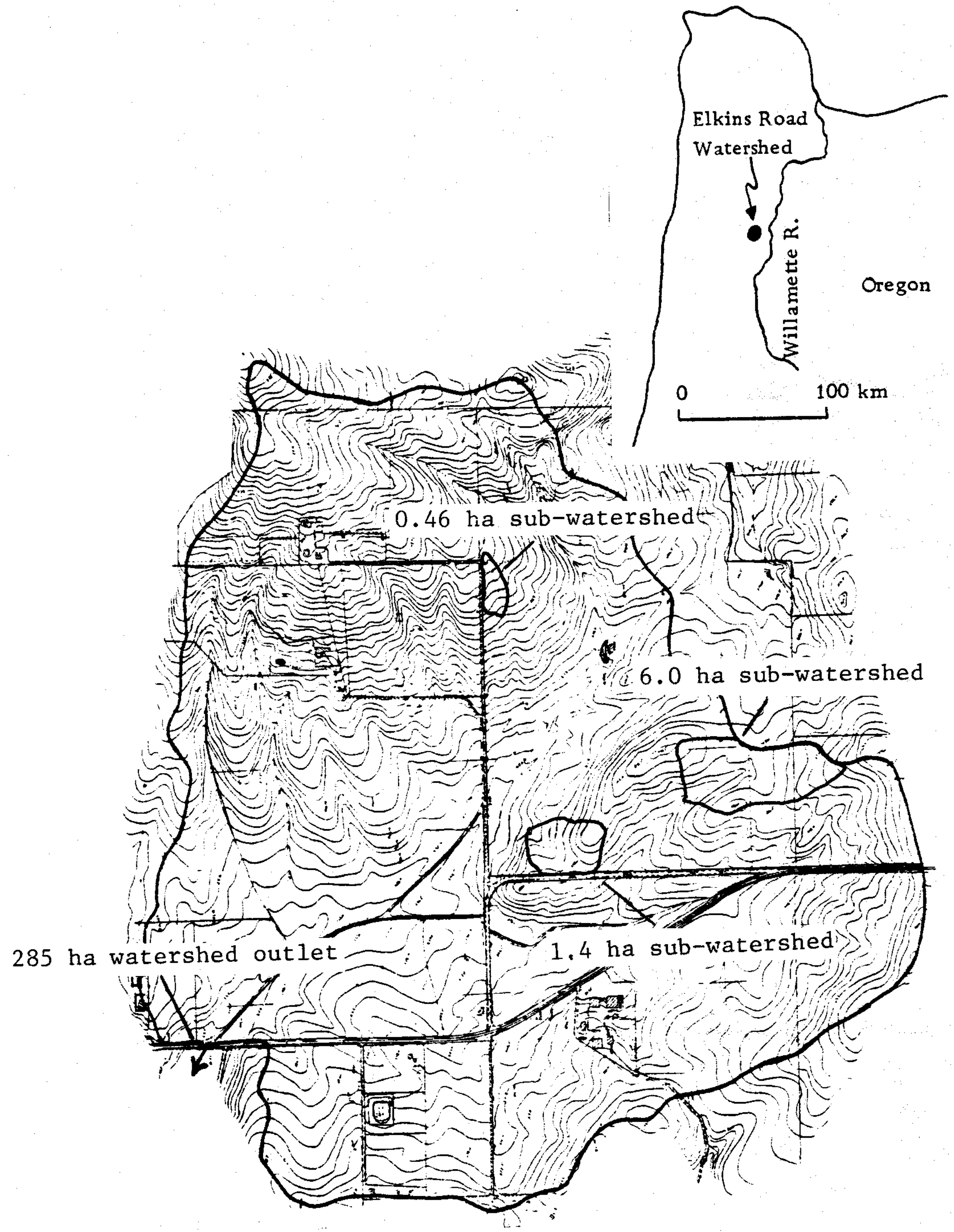

Fig. 3-1--Location of Elkins Road Watershed.

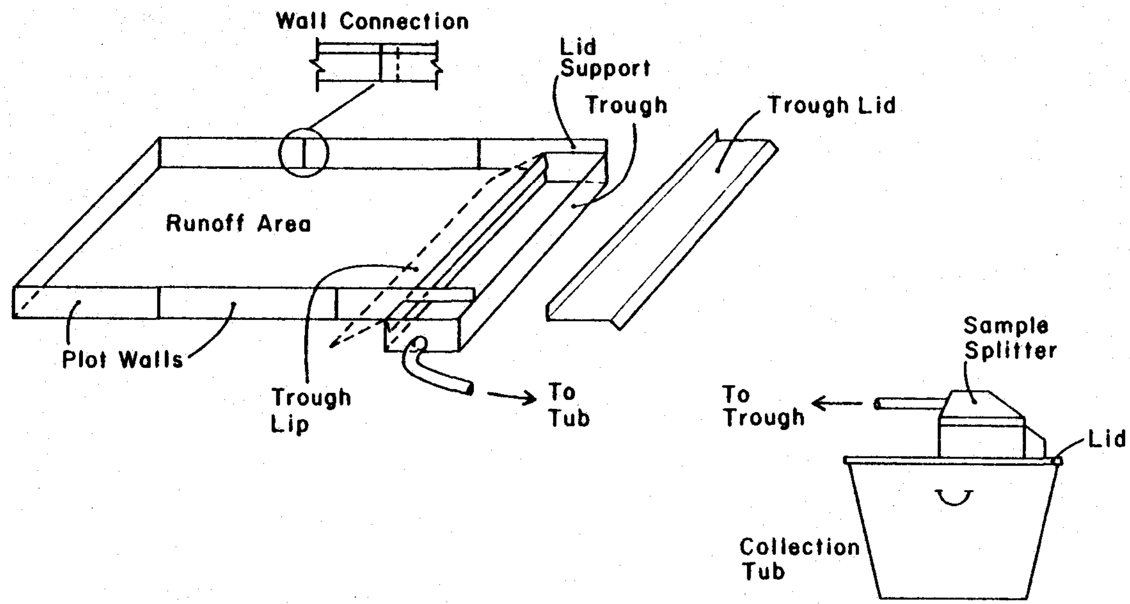

Figure 3-2--Erosion plot design.

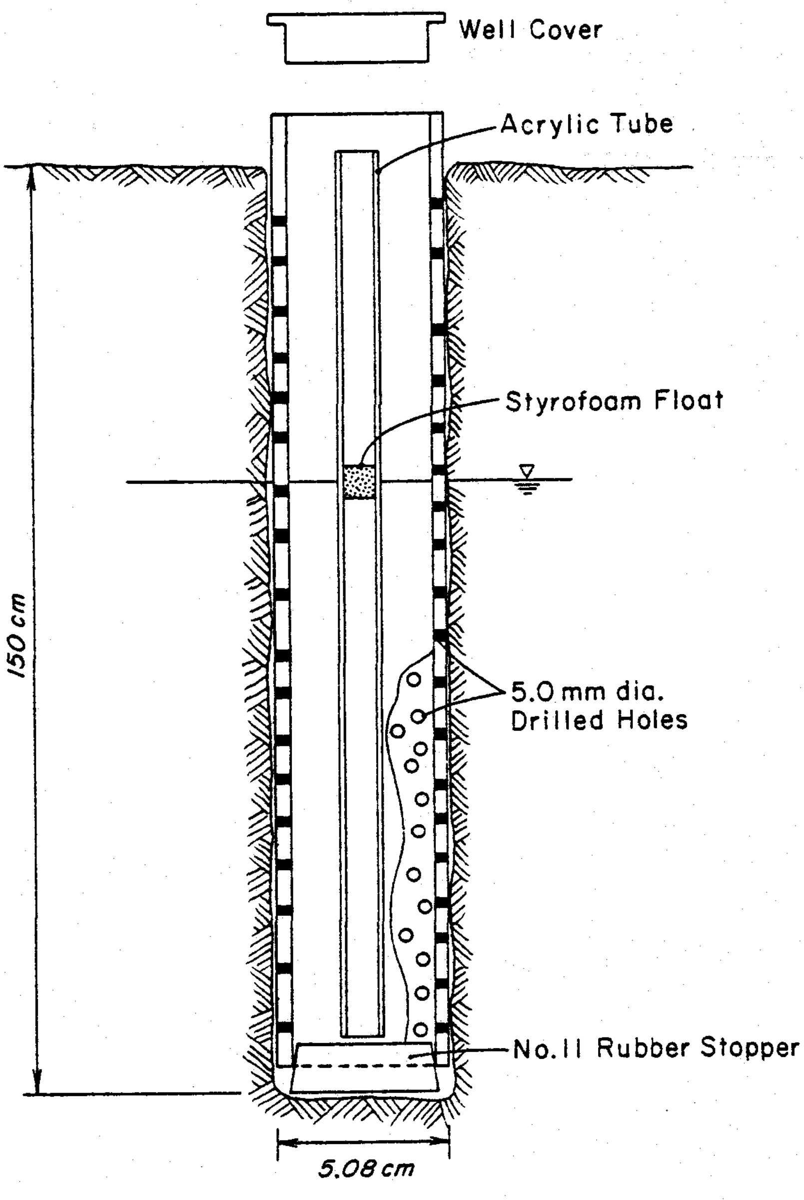

Fig. 3-3--Design and installation of wells.

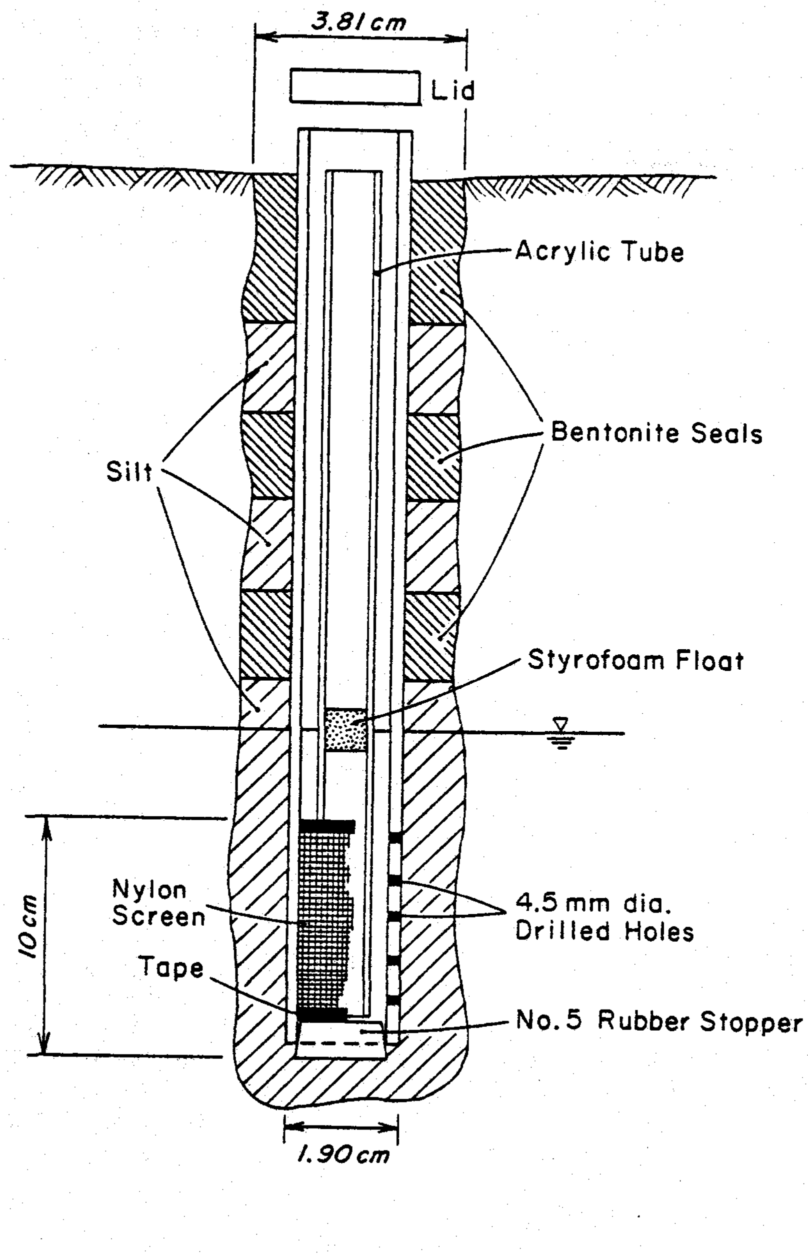

Fig. 3-4--Design and installation of piezometers.

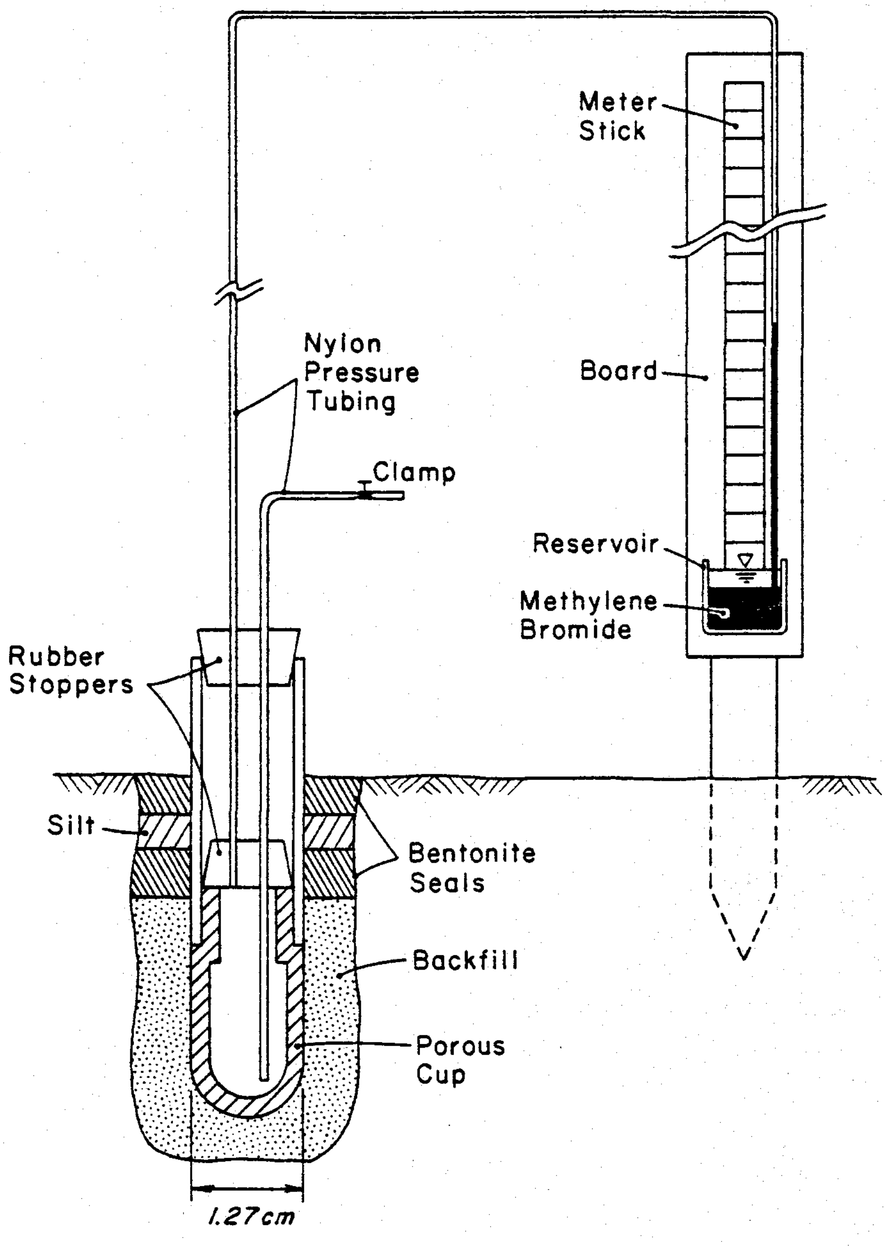

Fig. 3-5--Design and installation of tensiometers.

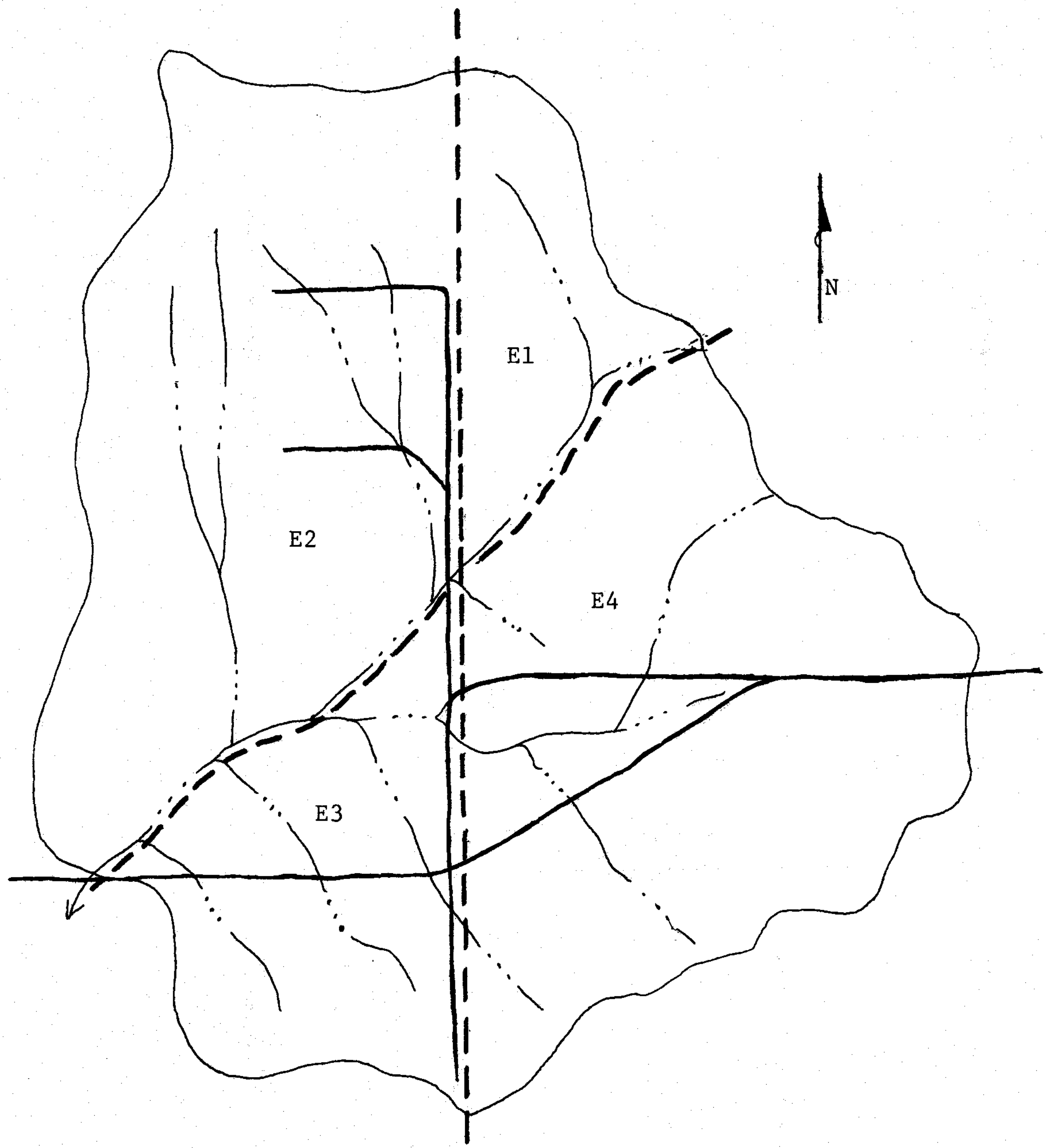

Fig. 3-6--Location of study areas within Elkins Road Watershed. Study area boundaries are shown by broad dashed line.

CHAPTER 4. SOILS AND GEOMORPHIC RELATIONSHIPS ON THE WATERSHED

R. B. Brown, J. R. Glasmann, B. Lowery, and G. F. Kling[1]

Summary

The Willamette Valley consists of a series of depositional landscape surfaces. The soils have developed on two parent materials. A younger silty material overlies either a buried soil or weathered sedimentary rock. The depth and permeability of these underlying layers vary over the watershed. The underlying layers may restrict the percolation of water and result in perched water tables and greater susceptibility to erosion. These soil properties are expected to be useful in assessing erosion hazard.

Introduction

Soils and geomorphology of the Elkins Road study site were investiated in 1977 and 1978. Much of the work has been reported by Glasmann and others (Glasmann, 1979; Glasmann and Kling, 1980; Glasmann et al., 1980). Material in this chapter is taken largely from these previous reports, with appropriate background support from the reports of other researchers, including Baldwin (1964), Balster and Parsons (1968, 1969), Gelderman and Parsons (1972), and Hoover (1963).

The soil map and legend that appear in this chapter have appeared previously only in a condensed, generalized form (Glasmann et al., 1980).

Materials and Methods

Geomorphic surfaces were mapped by field observation, using aerial photos and a 1:2400 topographic map having 1.5 m contours. Stratigraphy was described in 18 soil pits excavated well into bedrock, in 21 undisturbed soil cores collected using a trailer-mounted hydraulic probe, and in 58 hand-augured holes ranging to 4 m in depth.

Laboratory analyses were performed to characterize the different sedimentary units on the watershed. These analyses included particle size distribution, clay and sand mineralogy, major and trace element chemistry, and SEM studies of quartz grain morphology. Detailed descriptions, results, and discussions of these analyses are given elsewhere (Glasmann, 1979; Glasmann and Kling, 1980).

Soils were mapped at a 1:7920 (8"=1 mile) scale using standard soil survey techniques. Due to the nature of this study and the needs of

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[1] P. B. Thornburg was associated with the erosion project as a Research Technician during the period September, 1976 to February, 1978. His contributions are gratefully acknowledged.

parallel studies of perched water tables and erosion on the watershed, particular attention was given to thickness of surface silts. Presence of a buried, exhumed, or relict paleosol, and depth to saprolite also were emphasized in mapping and in development of the map legend. The legend was restricted as much as possible to established soil series. Variants were included in the legend as needed. The legend initially was established based on morphological descriptions of 30 pedons, and observations of soil from numerous additional auger holes. The legend then was modified and augmented appropriately as mapping progressed.

Four soil pedons, designated E2T1, E2T2, E4T1, and E4T2 based on their proximity to tensiometer sites for the 1976-77 field season, were characterized using standard laboratory procedures. Particle size analysis was performed by a modified pipette method (Kilmer and Alexander, 1949; Chu and Davidson, 1953). Total weight of silt plus clay was determined for each sample by drawing a representative aliquot from the settling cylinder immediately after shaking the full 1130 ml suspension of water plus silt and clay. The value thus determined was combined with total sand determined from previous wet-sieving to give total sample weight. Subsequent pipettings after appropriate settling times, together with sand and total sample weights, yielded sand, silt, and clay contents in weight percent.

Chemical analyses on the soil pedons were performed at the OSU Soil Testing Laboratory. Soil pH was determined using a glass electrode pH meter with a 1:2 soil to solution ratio (Berg and Gardner, 1978). Soil organic matter was determined by Walkley-Black titration (Walkley and Black, 1934). Exchangeable potassium, sodium, calcium, and magnesium were extracted by ammonium acetate at pH 7 (Peech et al., 1947) and determined on an atomic absorption spectrophotometer (Berg and Gardner, 1978). Exchangeable hydrogen was determined by the triethanolamine method (Peech, 1965). Cation exchange capacity was determined using ammonium acetate at pH 7 (Schollenberger and Simon, 1945).

Results and Discussion

Soil and geomorphic maps are given in Figures 4-1 and 4-2. General and detailed cross-sections of the Elkins Road landscape are given in Figures 4-3 and 4-4. Soil and geomorphic map legends are shown in Tables 4-1 and 4-2. Brief descriptions of the major characteristics of stratigraphic units are given in Table 4-3. Selected soil profile descriptions and corresponding characterization data are shown in Tables 4-4 through 4-6.

The soils on the Elkins Road watershed reflect the geomorphic history of the area. Most soils have a surface cap of younger silty material derived from valley flooding at the close of the Wisconsin ice age. These silty materials are deposited on a more highly weathered, previous soil profile developed in a mixed sedimentary, weathered bedrock of the Spencer formation. This buried profile is generally more clayey and, where present, tends to perch water tables and strongly influence overland flow and erosion.

Detailed discussions of soils, stratigraphy, and geomorphology are found in Glasmann et al. (1980). An important finding of these studies is that the soils associated with the Brateng and Dolph geomorphic surfaces are highly variable as a function of variations in (1) thickness of overlying silts, (2) degree of expression of the buried paleosol, and (3) texture of the underlying soft bedrock.

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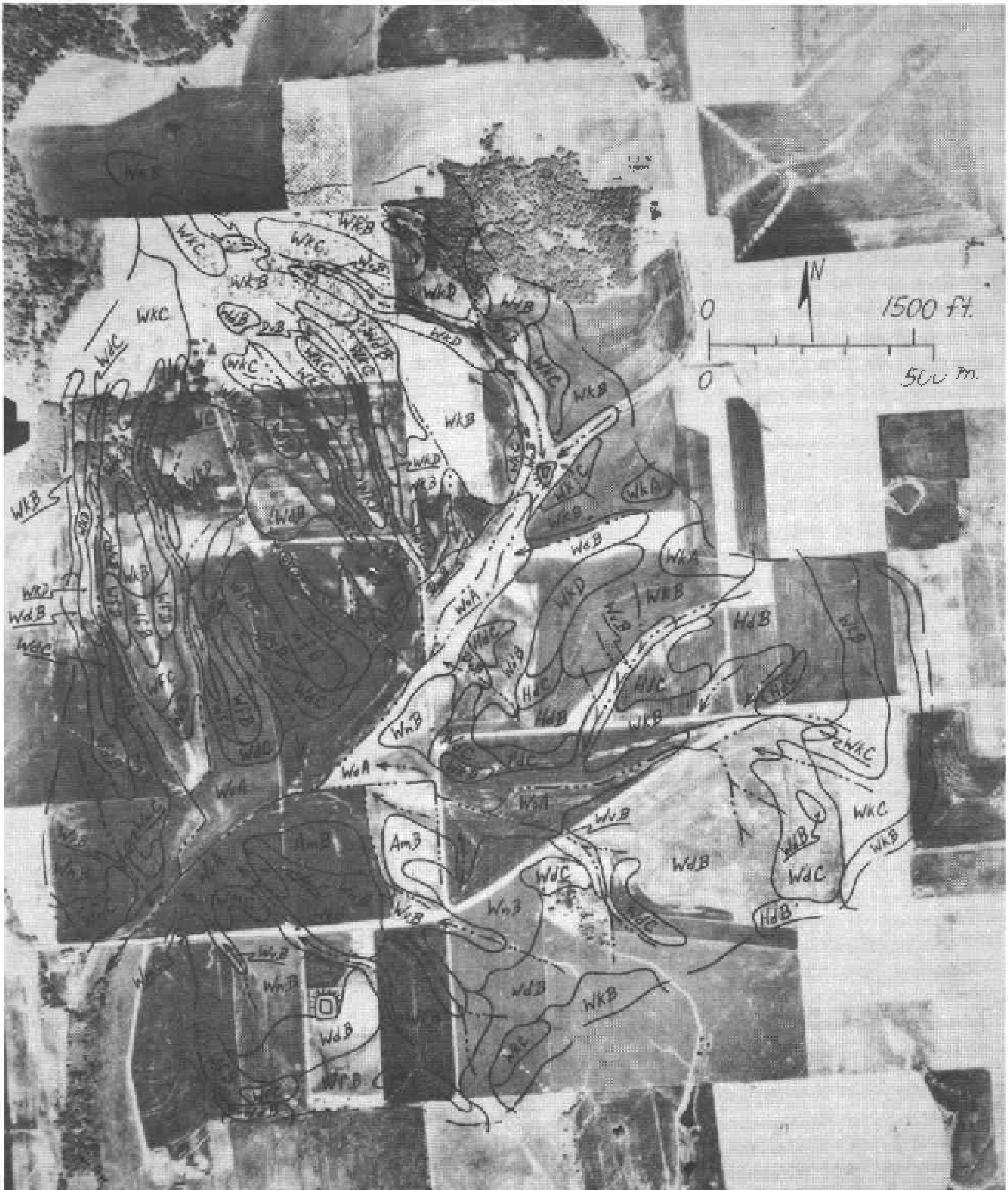


Fig. 4-1--Soil map, Elkins Road Watershed. Map legend is given in Table 4-1.

Table 4-1--Soil map legend, Elkins Road Watershed.

Map symbol	Soil[+]	Slope (%)	Range in characteristics	Inclusions[≠]	Proportion of 285 hectare mapping area (%)
AmB	Amity (Argiaquic Xeric Argialbolls, fine-silty, mixed, mesic)	3-7	Somewhat poorly drained; greater than 150 cm over bedrock.	Occasional WnB, WoA, WvB; small areas of unnamed, moderately well or somewhat poorly drained alluvial terrace soil.	1.6
DvB	Dupee Variant, Fine-silty[++] (Aquultic Haploxeralfs, fine-silty, mixed, mesic)	3-7	Somewhat poorly drained, except moderately well drained in higher elevations of some delineations; greater than 100 cm over bedrock; 50 to about 95 cm of surface silts over paleosol, although usually 70 to about 95 cm; this soil found in wide swales along ephemeral drainageways, in fan-like positions, and in footslopes; moderate to severe flood hazard.	Occasional WvB; paleosol weakly expressed in places.	2.8
HdB	Helmick Variant, Moderately Deep[##] (Aquic Xerochrepts, very-fine, mixed, mesic)	3-7	Somewhat poorly or moderately well drained; 50 to 100 cm over clayey bedrock; this unit difficult to map because occurrence of fine-textured layers in bedrock is difficult to predict; these clayey layers usually 4 m or more thick with 35 to 50% clay, but occasionally thinner, and occasionally having 50 to 70% clay.	Percentage of inclusions is high in and near delineations of Hd; common Wk; occasional Wd; occasionally deeper than 100 cm over bedrock; surface silts occasionally less than 50 cm thick, especially in convex shoulder areas or in steeper areas of the unit; presence of a paleosol just above or in the clayey bedrock is hard to distinguish due to the fineness of the bedrock.	3.8
HdC	Helmick Variant, Moderately Deep[##] (Aquic Xerochrepts, very-fine, mixed, mesic)	7-12	Same as for HdB.	Same as for HdB.	1.1

Table 4-1--continued.

Map symbol	Soil[+]	Slope (%)	Range in characteristics	Inclusions[‡]	Proportion of 285 hectare mapping area (%)
WdB	Willakenzie Variant, Deep[#] (Ultic Haploxeralfs, fine-silty, mixed, mesic)	3-7	Well or moderately well drained; 100 to 150 cm over bedrock; 25 to 90 cm of surface silts over paleosol.	Sometimes deeper than 100 cm over paleosol; occasionally fine textured as function of well-developed paleosol or of clayey bedrock; occasionally fine-loamy as function of gravelly/sandy bedrock; surface silts less than 25 cm thick in places, especially convex shoulder areas and steeper parts of the unit; occasional inclusions of WnB, especially at lower elevations where WdB is gradational between moderately deep upland soils and deep silty soils of lower elevations.	13.0
WdC	Willakenzie Variant, Deep[#] (Ultic Haploxeralfs, fine-silty, mixed, mesic)	7-12	Well or moderately well drained; 100 to 150 cm over bedrock; 50 to 90 cm of surface silts over paleosol; silts commonly reworked and in some cases overthickened by slope wash, the latter particularly apparent in footslope positions.	Sometimes deeper than 100 cm over paleosol; occasionally fine-loamy as function of gravelly/sandy bedrock; occasional WkC; occasional deep analogues of Wf and Hd; inclusions of WnB, WoA, WvB, and DvB along lower edges of delineations where WdC is gradational between moderately deep upland soils and deep silty soils of lower elevations.	4.3
WfB	Willakenzie Variant, Fine[##] (Ultic Haploxeralfs, fine, mixed, mesic)	3-7	Well or moderately well drained; 50 to 100 cm over bedrock; 25 to about 90 cm of surface silts over a strongly developed paleosol.	Sometimes deeper than 100 cm over bedrock; less frequently, deeper than 100 cm over paleosol; surface silts occasionally less than 25 cm thick over paleosol, especially in convex shoulder areas or in steeper parts of the unit; occasional Wk and Hd.	6.2
WfC	Willakenzie Variant, Fine[##] (Ultic Haploxeralfs, fine, mixed, mesic)	7-12	Same as for WfB.	Same as for WfB.	3.5

Table 4-1--continued.

Map symbol	Soil[+]	Slope (%)	Range in characteristics	Inclusions[≠]	Proportion of 285 hectare mapping area (%)
WfD	Willakenzie Variant, Fine[##] (Ultic Haploxeral[illegible], fine, mixed, mesic)	12-20	Same as for WfB.	Same as for WfB.	0.4
WkA	Willakenzie (Ultic Haploxeralfs, fine-silty, mixed, mesic)	0-3	Moderately well or well drained; 50 to 100 cm over mainly silty bedrock; 50 to 75 cm of surface silts over paleosol.		0.7
WkB	Willakenzie (Ultic Haploxeralfs, fine-silty, mixed, mesic)	3-7	Well or moderately well drained; 50 to 100 cm over mainly silty bedrock; 25 to 90 cm of surface silts over paleosol.	Paleosol occasionally absent; occasional WdB, WfB, and HdB; occasionally fine-loamy as function of gravelly/sandy bedrock; surface silts occasionally less than 25 cm thick, especially in convex shoulder areas and in steeper parts of the unit, and in high elevations (more than 120 m above sea level).	19.0
WkC	Willakenzie (Ultic Haploxeralfs, fine-silty, mixed, mesic)	7-12	Same as for WkB.	Paleosol occasionally absent; surface silts occasionally less than 25 cm thick over paleosol, especially in convex shoulder areas or in steeper parts of the unit; occasional Wd; occasionally fine-loamy as function of gravelly/sandy bedrock.	10.7
WkD	Willakenzie (Ultic Haploxeralfs, fine-silty, mixed, mesic)	12-20	Same as for WkB.	Same as for WkC.	4.3
WmC	Willamette Variant, Non-Pachic* (Ultic Argixerolls, fine-silty, mixed, mesic)	7-12	Well drained; greater than 150 cm over bedrock.	Occasional Wn.	1.0

Table 4-1--continued.

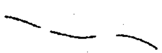
Map symbol	Soil[+]	Slope (%)	Range in characteristics	Inclusions[≠]	Proportion of 285 hectare mapping area (%)
WnB	Woodburn (Aquultic Argixerolls, fine-silty, mixed, mesic)	3-7	Moderately well drained; greater than 150 cm over bedrock.	Occasional Wm, AmB; in places the upper boundary of the argillic horizon is below 100 cm.	9.3
WoA	Waldo (Fluventic Haplaquolls fine, mixed, mesic)	0-3	Poorly drained; greater than 150 cm over bedrock; greater than 100 cm of alluvium over an argillic horizon, with silt coatings common on prism faces above this depth; stratified; texture variable within fine-silty textural family; channel scars apparent in least disturbed parts of landscape; severe flood hazard.	Poorly to well expressed argillic horizon below about 70 cm in places, especially around edges of delineations, where alluvium is thin; occasional Am on A and B slopes; stratification may cause some pedons to be fine-silty, coarse-silty, or fine, and similar textural variations are possible below the 100 cm depth.	10.9
WvB	Waldo Variant, Gently Sloping[**] (Fluventic Haplaquolls, fine, mixed, mesic)	3-7	Somewhat poorly or poorly drained; greater than 150 cm over bedrock; greater than 100 cm of alluvium over an argillic horizon; this unit similar to WoA but found on higher, gently sloping areas along ephemeral drainage-ways; severe flood hazard.	Occasional WoA and AmB; moderately well drained in higher parts of some delineations; stratification may cause some pedons to be fine-silty, coarse-silty, or fine; an argillic horizon may be found above the 100 cm depth; bedrock may be found above the 150 cm depth in higher elevations.	7.2
	Water (farm ponds)				0.2
	Dike				
	Stream (crossable with tillage implements)				
	Stream (not crossable with tillage implements)				
	Watershed Boundary				

Table 4-1--continued.

[+]All surface textures are silty clay loam except those of Amity, Willamette, and Woodburn soils, which have silt loam surfaces.

[≠]The most common inclusions in each map unit are indicated here.

[++]True Dupee soils are in a fine family and have loam or silt loam surface texture.

[≠≠]The Helmick series consists of deep soils that formed in "mixed alluvium and colluvium over residuum weathered from sandstone and siltstone" (Official Series Description, National Cooperative Soil Survey, USDA, 1/77). This variant differs in that it is moderately deep to clayey bedrock. Also the depth of solum in this variant is often greater than the 50 cm allowed for Helmick soils.

[#]True Willakenzie soils are moderately deep (50 to 100 cm) to bedrock.

[##]True Willakenzie soils are fine-silty.

[*]True Willamette soils have a thicker mollic epipedon than this variant. This variant was first recognized by Gelderman and Parsons (Gelderman, F. W., and R. B. Parsons. 1972. Argixerolls on late Pleistocene surfaces in northwestern Oregon. Soil Sci. Soc. Am. Proc. 36:335-341).

[**]True Waldo soils are nearly level and poorly drained. This variant is gently sloping and often somewhat poorly drained.

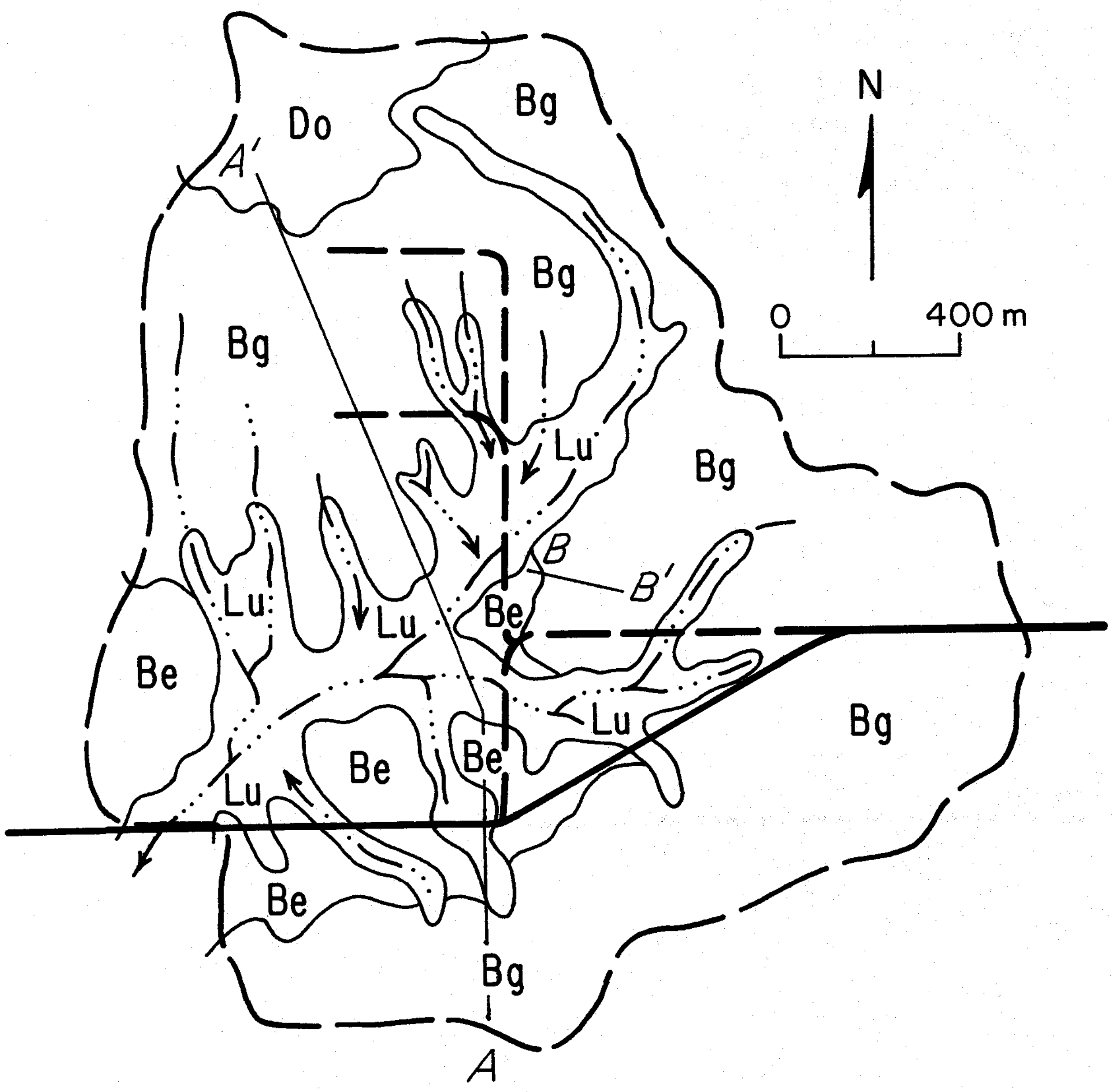


Fig. 4-2--Geomorphic map, Elkins Road Watershed (after Glasmann et al., 1980). Map legend is given in Table 4-2. Transects A-A' and B-B' are locations of cross-sections (Figs. 4-3, 4-4).

Table 4-2--Geomorphic map legend, Elkins Road Watershed (After Glasmann et al., 1980).

Map symbol	Geomorphic surface	Age
Do	Dolph	Middle Pleistocene
Bg	Brateng	Late Pleistocene
Be	Bethel	Late Pleistocene
Lu	Luckiamute	Holocene

Table 4-3--Stratigraphic units, Elkins Road Watershed (after Glasmann and Kling, 1980, and Glasmann et al., 1980).

Name	Age	Characteristics
Modern Alluvium	Holocene	Clayey/silty
Willamette Formation		
Greenback Member	Late Pleistocene	Silty
Irish Bend Member	Middle to Late Pleistocene	Silty
Paleosol	Early to Middle Pleistocene	Partially truncated, highly variable in texture
Spencer Formation	Eocene	Highly variable in texture

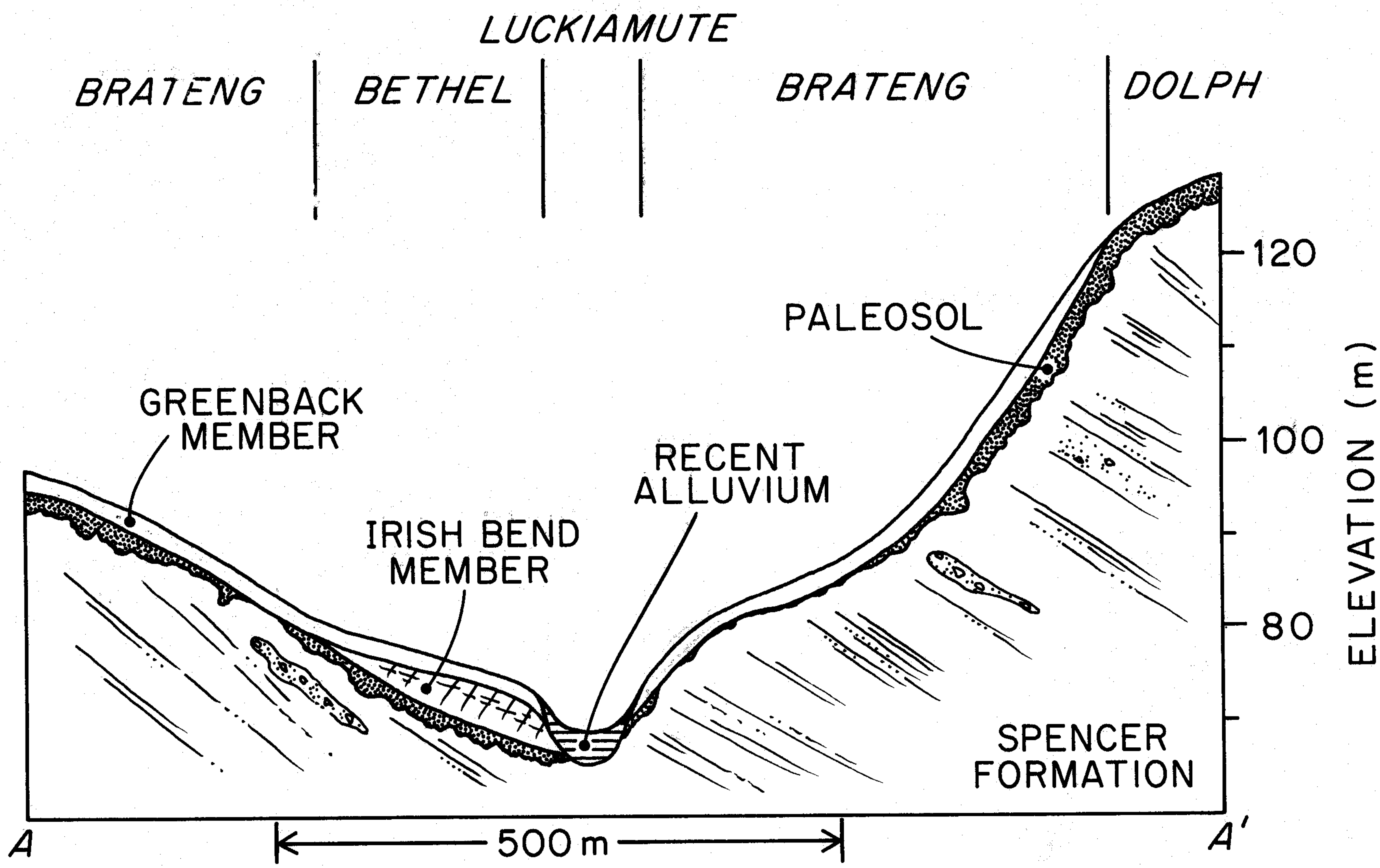


Fig. 4-3. Idealized cross-section of transect A-A' (Fig. 4-1), Elkins Road Watershed, showing geomorphic surfaces and stratigraphic units. Cross-section is based on profile information collected from 7 soil pits, 2 road cuts, and 20 auger holes. Thickness of stratigraphic units is exaggerated.

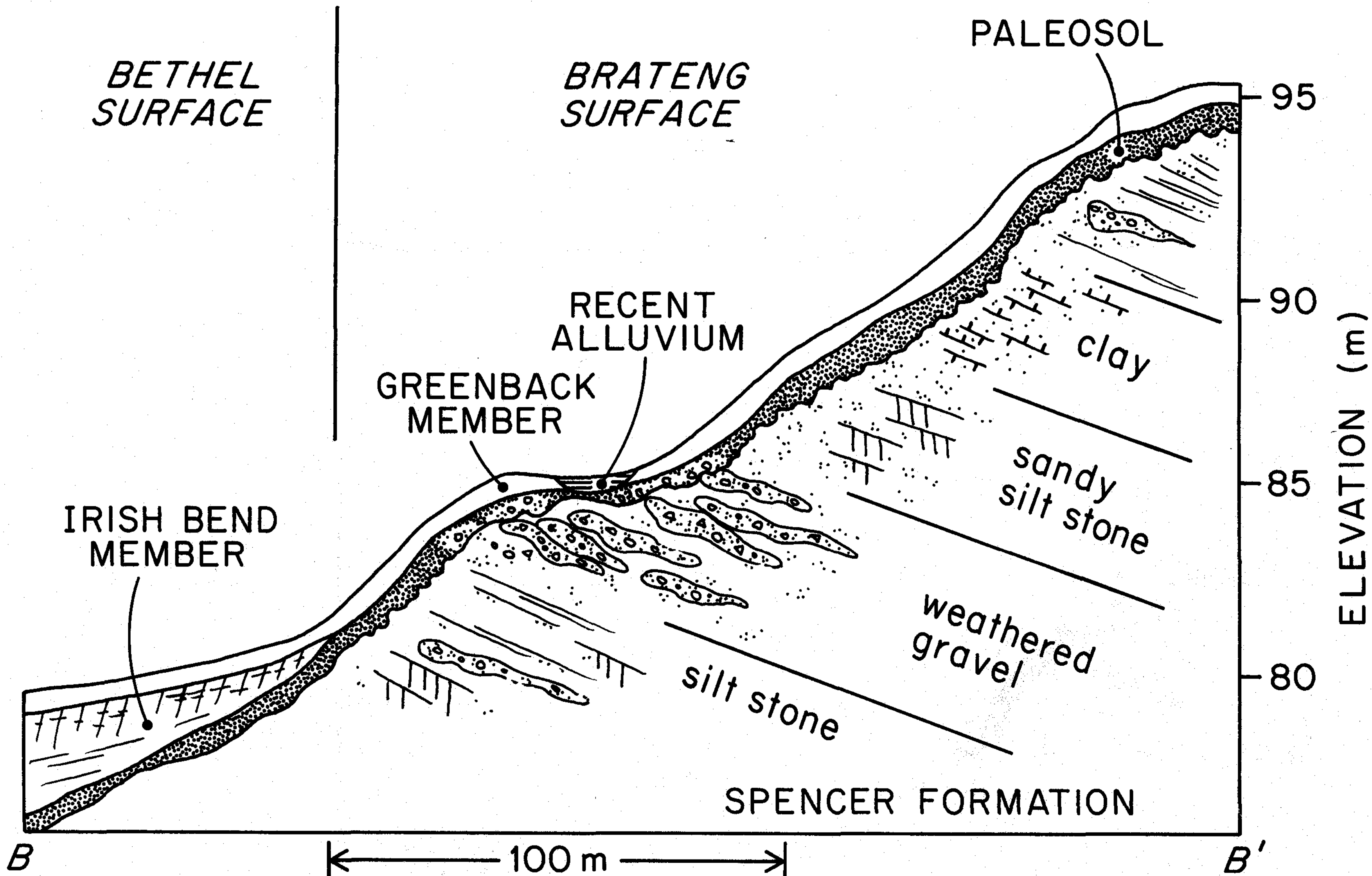


Fig. 4-4. Detailed cross-section of transect B-B' (Fig. 4-1), Elkins Road Watershed, showing stratigraphic units and the extreme lithologic/textural variability of the Spencer Formation. Cross-section is based on profile information collected from 2 soil pits and 17 undisturbed soil cores. Thickness of stratigraphic units is exaggerated.

Table 4-4--Soil profile descriptions of sites E2T1, E2T2, E4T1, and E4T2, Elkins Road Watershed (After Glasmann, 1979).

Horizon	Depth (cm)	Description (dry colors, unless indicated otherwise)
Pedon designation: E2T1 Location: Upslope, near watershed E2F1		Described by: J. R. Glasmann and B. Lowery Date: April 1977
Ap	0-20	Pale brown (10YR 6/3) silt loam, dark brown (10YR 3/3) moist; weak fine granular structure; hard, friable, slightly sticky, slightly plastic; many fine roots; many fine and medium interstitial pores; straw distributed through the horizon; strongly acid (pH 5.4); abrupt smooth boundary.
A12	20-28	Pale brown (10YR 6/3) silt loam, dark brown (10YR 3/3) moist; massive (plow pan); very hard, sticky, plastic; few very fine and fine roots, concentrated along fracture faces and in larger tubular pores; few fine, and common very fine tubular pores; strongly acid (pH 5.4); gradual smooth boundary.
B1	28-42	Yellowish brown (10YR 5/4) silt loam; moderate fine subangular blocky structure; firm, sticky, plastic; common fine roots within peds; few fine and medium tubular pores; common very fine tubular pores within peds; discontinuous silt coatings in medium tubular pores; trace of approx. 6 x 3 cm, angular channers (unweathered gray aphanite); strongly acid (pH 5.4); gradual smooth boundary.
B2	42-62	Yellowish brown (10YR 5/6) and light yellowish brown (10YR 6/4) silt loam, dark yellowish brown (10YR 4/4) moist; weak fine subangular blocky structure; firm, sticky, plastic; common fine, and few medium roots; common medium and fine tubular pores; few distinct black concretions; discontinuous silt coatings in medium tubular pores, increasing toward bottom of horizon; medium acid (pH 5.6); clear smooth boundary.
A'2	62-72	Light gray (10YR 7/2) light silty clay loam with yellowish brown (10YR 5/4) ped interiors; weak fine subangular blocky structure; hard, friable, slightly sticky, slightly plastic; very few fine roots; few fine interstitial pores; few medium, and common fine and very fine tubular pores; peds coated with light gray silt which can be blown off dry peds; many black concretions, 2-5 mm in diameter; very few thin clay films of dark yellowish brown (10YR 4/4) in tubular pores and beneath silt coatings on ped faces; strongly acid (pH 5.5); abrupt wavy boundary.
IIB21tb	72-88	Strong brown (7.5YR 5/8) silty clay loam; strong medium prismatic structure parting to strong medium and fine subangular blocky structure; extremely firm, sticky, slightly plastic; very few very fine roots; very few fine pores; continuous moderately thick clay films of dark brown (7.5YR 4/4) on ped faces and on vertical prism faces; thick clay films of dark brown in pores; common black concretions, 2-5 mm in diameter; black stains on prism faces between peds; medium acid (pH 5.6); clear smooth boundary.

Table 4-4--continued.

Horizon	Depth (cm)	Description (dry colors, unless indicated otherwise)
IIB22tb	88-135	Brownish yellow (10YR 6/6) and light yellowish brown (10YR 6/4) silty clay loam; moderate medium prismatic structure parting to strong medium subangular blocky structure; very hard, sticky, plastic; trace of fine and very fine roots; very few fine and very fine tubular pores, and traces of medium tubular pores; moderately thick clay films of dark brown (7.5YR 4/4) on ped faces and in tubular pores; few dendritic black stains on prism faces; few small black concretions; medium acid (pH 5.8); abrupt irregular (ranging from 117 to 140 cm depths) boundary.
IICr1	135-150	Variegated yellow (2.5Y 7/6) and pinkish gray (7.5YR 7/2) silt loam; parting along horizontal bedrock strata; very firm, slightly sticky, slightly plastic; trace of very fine roots along clayey horizontal partings; very few fine and very fine tubular pores in layers of clayey, gray (chroma = 2) strata; at 150 cm, a 4 mm thick black iron pan is present continuously along the lower boundary; medium acid (pH 5.8); abrupt smooth boundary.
IICr2	150-160	Yellow (2.5Y 7/6) and pinkish gray (7.5YR 7/2) loam; horizontally bedded; very firm, slightly sticky, slightly plastic; horizon is weathered siltstone with pockets of reddish yellow (5YR 6/8) weathered sandstone; sandstone is also laminated, but lacks parting characteristic of siltstones.

Horizon	Depth	Description (moist colors, unless indicated otherwise)
Pedon designation: E2T2 Location: Downslope, near Watershed E2F1		Described by: R. B. Brown, J. R. Glasmann, and P. Thornburg Date: April 1977
Ap	0-19	Dark brown (10YR 3/3) silt loam, pale brown (10YR 6/3) dry; weak medium subangular blocky structure parting to moderate fine granular structure; hard, friable, sticky, plastic; many fine and very fine roots; common fine and very fine tubular and interstitial pores, and few medium tubular pores; very few fine, distinct mottles of strong brown (7.5YR 5/8); strongly acid (pH 5.3); abrupt smooth boundary.
A12	19-26	Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) silt loam, pale brown (10YR 6/3) dry; moderate medium angular blocky structure parting to moderate very fine subangular blocky structure; common very fine and fine roots; few very fine tubular pores; dark brown rubbed; very few fine, distinct mottles of strong brown (10YR 3/3); strongly acid (pH 5.4); clear smooth boundary.
A3	26-47	Dark brown (10YR 3/3) and very dark grayish brown (10YR 3/2) silt loam, pale brown (10YR 6/3) dry; moderate fine subangular blocky structure parting to moderate very fine subangular blocky structure; slightly hard, friable, sticky, plastic; common very fine and fine roots; common fine and very fine, and few medium tubular pores; dark brown rubbed; medium acid (pH 5.6); abrupt smooth boundary.

Table 4-4--continued.

Horizon	Depth (cm)	Description (moist colors, unless indicated otherwise)
IIB1b	47-57	Dark brown (10YR 3/3) and dark yellowish brown (10YR 4/4) heavy silt loam; moderate medium subangular blocky structure; hard, friable, slightly sticky, plastic; common very fine and fine roots; common very fine and fine tubular pores; dark yellowish brown rubbed; few thin coatings of very dark grayish brown (10YR 3/2) in pores and on ped faces; trace of sand-size black concretions or weathered rock fragments; medium acid (pH 5.8); clear wavy boundary.
IIB21tb	57-82	Dark yellowish brown (10YR 4/4) heavy silt loam; moderate medium subangular blocky structure; friable, sticky, plastic; few very fine roots; common very fine and fine tubular pores; few fine distinct black stains; few fine distinct mottles of strong brown (7.5YR 5/8) in lowermost 5 cm of horizon; few thin clay films and silt coatings of dark yellowish brown in pores and on ped faces; trace of coarse sand or pebble-size concretions or weathered rock fragments, mostly black, or black with strong brown interiors; medium acid (pH 5.8); abrupt wavy boundary.
IIIB22tb	82-101	Dark yellowish brown (10YR 4/4) silty clay loam; moderate coarse prismatic structure parting to moderate medium subangular blocky structure; firm, sticky, plastic; few very fine roots; common very fine and fine tubular pores; many moderately thick silt coatings on prism faces; many moderately thick clay films of dark yellowish brown on ped faces and in pores; few fine distinct black and strong brown (7.5YR 5/8) mottles and stains; medium acid (pH 5.8); abrupt wavy boundary.
IIIB23tb	101-145	Dark brown (10YR 4/3) heavy silty clay loam; moderate coarse prismatic structure parting to weak medium angular blocky, structure; firm, sticky, plastic; very few very fine roots; common very fine and fine tubular pores; common fine distinct yellowish brown (10YR 5/6), pale yellow (5Y 7/3), black, and strong brown (7.5YR 5/8) mottles and stains; few moderately thick silt coatings on prism faces; continuous moderately thick clay films of dark brown and dark yellowish brown (10YR 4/4) on ped faces and in pores; dark yellowish brown rubbed; traces of weathered gravel, fine concretions, and gravel and fine gravel-size, subangular and angular, hard pebbles; slightly acid (pH 6.1).

Pedon designation: E4T1
Location: Upslope, Watershed E4F1

Described by: R. B. Brown, P. Thornburg, and J. R. Glasmann
Date: May 1977

Ap	0-25	Dark brown (10YR 3/3) silt loam, pale brown (10YR 6/3) dry; moderate fine and very fine subangular blocky structure; hard, firm, sticky, slightly plastic; common very fine roots; common very fine and fine, and few medium interstitial and tubular pores; medium acid (pH 5.6); abrupt smooth boundary.

Table 4-4--continued.

Horizon	Depth (cm)	Description (moist colors, unless indicated otherwise)
A12	25-34	Very dark grayish brown (10YR 3/2) and dark yellowish brown (10YR 4/4) silt loam; pale brown (10YR 6/3) and very pale brown (10YR 7/4) dry; moderate medium subangular blocky structure; very hard, firm, sticky, slightly plastic; common very fine roots; common very fine and few fine and medium tubular pores; dark brown (10YR 3/3) rubbed; medium acid (pH 5.8); clear smooth boundary.
A3	34-57	Very dark grayish brown (10YR 3/2) and dark yellowish brown (10YR 4/4) heavy silt loam, pale brown (10YR 5/3) and very pale brown (10YR 7/4) dry; moderate medium subangular blocky structure; very hard, firm, sticky, plastic; common very fine roots; common very fine and fine, and few medium tubular pores; very dark grayish brown rubbed; trace of ∿1 cm-in-diameter, subrounded pebbles of chert/agate; medium acid (pH 5.8); clear wavy boundary.
B11	57-70	Dark brown (10YR 3/3) and dark yellowish brown (10YR 4/4) heavy silt loam, very pale brown (10YR 7/4) and pale brown (10YR 6/3) dry; moderate medium and find subangular blocky structure; hard, firm, sticky, plastic; few very fine roots; common very fine and fine tubular pores; dark yellowish brown rubbed; medium acid (pH 5.8); clear wavy boundary.
IIB12	70-81	Yellowish brown (10YR 5/6) clay loam; moderate medium subangular blocky structure; hard, firm, sticky, plastic; few very fine roots; common very fine and fine tubular pores; sand grains subangular to moderately well rounded, mostly light colored, but some dark; few fine distinct variegations of strong brown (7.4YR 5/8); yellowish brown rubbed; very few thin clav films of strong brown (7.5YR 5/6) in pores and on ped faces; medium acid (pH 5.8); clear wavy boundary.
IIB21tb	81-92	Yellowish brown (10YR 5/6) clay loam; moderate medium subangular blocky structure; hard firm, sticky, plastic, few very fine roots and tubular pores; sand grains subangular to moderately well rounded mostly light colored, but some dark; common fine faint variegations of strong brown (7.5YR 5/6); yellowish brown rubbed; few moderately thick clay films of strong brown on ped faces and in pores; medium acid (pH 5/8); clear wavy boundary.
IIB22tb	92-102	Yellowish brown (10YR 5/4) heavy clay loam; moderate medium angular blocky structure; hard, friable, sticky, plastic; very few very fine roots and tubular pores; trace of well-rounded, moderately spherical, moderately weathered fine pebbles; sand grains similar to pebbles in shape and lithology; trace of irregularly-shaped, pebble-size concretions of black (7.5YR 2/0) and strong brown (7.5YR 5/8); common medium distinct variegations of strong brown; yellowish brown rubbed; many moderately thick clay films of brown (7.5YR 4.4); medium acid (pH 5.8); abrupt smooth boundary.
IIIB3tb	102-108	Olive brown (2.5YR 4/4) and yellowish brown (10YR 5/6) clay; massive with occasional nearly vertical fracture faces; firm, sticky, very plastic; very few very fine roots and tubular pores; common medium distinct mottles of strong brown (7.5YR 5/8) and few medium distinct mottles of light olive gray (2.5YR 6/2); yellowish brown rubbed; many moderately thick clay films of yellowish brown (10YR 5/4) on fracture faces; medium acid (pH 5.8); clear smooth boundary.

Table 4-4--continued.

Horizon	Depth (cm)	Description (moist colors, unless indicated otherwise)
IIICr	108-151	Grayish brown (2.5Y 5/2) clay; massive; firm, sticky, very plastic; very few very fine tubular pores; common bands of strong brown (7.5YR 5/8) in a roughly horizontal arrangement, 0.5-2 cm thick and 3-15 cm apart; common medium faint mottles of light olive gray (5Y 6/2), common coarse distinct mottles of yellowish brown (10YR 5/6), and common medium distinct mottles of strong brown; light olive brown (2.5YR 5/4) rubbed; few thin clay films of light olive gray on fracture faces; medium acid (pH 5.8).

Pedon designation: E4T2
Location: Downslope, Watershed E4E1

Described by: R. B. Brown, P. Thornburg, and J. R. Glasmann
Date: April 1977

Ap	0-18	Very dark grayish brown (10YR 3/2) silt loam, pale brown (10YR 6/3) dry; moderate fine subangular blocky structure; hard slightly sticky, slightly plastic; common very fine roots and interstitial and tubular pores; strongly acid (pH 5.3); abrupt smooth boundary.
A12	18-25	Dark brown (10YR 3/3) heavy silt loam; weak medium subangular blocky structure; very hard, sticky; plastic; common very fine roots and medium, fine, and very fine tubular pores; plowpan; larger pores commonly having accumulations of coprogenous material (dark, and bridged together by coatings of very dark grayish brown (10YR 3/2)); strongly acid (pH 5.5); clear wavy boundary.
A3	25-50	Dark brown (10YR 3/3) heavy silt loam; moderate medium and fine subangular blocky structure; very hard, firm, sticky, plastic; common very fine roots and medium, fine, and very fine tubular pores; larger pores commonly having accumulations of coprogenous material (dark and bridged together by coatings of very dark grayish brown (10YR 3/2)); very dark grayish brown coatings in tubular pores and on ∿50% of ped faces; strongly acid (pH 5.5); clear wavy boundary.
IIB1tb	50-66	Yellowish brown (10YR 5/4) silty clay loam; moderate medium subangular blocky structure; firm, sticky, plastic; few very fine roots; common fine and very fine and few medium tubular pores; common fine distinct mottles of strong brown (7.5YR 5/8); many moderately thick clay films of dark brown (10YR 3/3) on ped faces and in pores; few thick coatings of very dark grayish brown (10YR 3/2) in tubular pores and on ped faces; trace of 1-10 mm, rounded and subrounded, moderately spherical gravel and very coarse sand; strongly acid (pH 5.4); clear wavy boundary.

Table 4-4--continued.

Horizon	Depth (cm)	Description (moist colors, unless indicated otherwise)
IIB2tb	66-95	Yellowish brown (10YR 5/6) light silty clay; weak coarse prismatic structure parting to moderate medium subangular blocky structure; firm, slightly sticky, plastic; few very fine roots; common very fine tubular pores; many fine and medium distinct mottles of strong brown (7.5YR 5/8), and few fine distinct mottles of light brownish gray (2.5Y 6/2); continuous thick clay films of dark yellowish brown (10YR 4/4) on ped faces and in pores; few fine coatings of black (10YR 2/0); trace of sand and fine gravel-size tuffaceous material, of coarse gravel and cobblestone-size variegated fragments resembling IIIB3tb horizon material, and of hard, buff colored gravel of low sphericity; strongly acid (pH 5.4); gradual wavy boundary.
IIB3tb	95-117	Variegated yellowish red (5YR 4/6) and strong brown (7.5YR 5/8) heavy clay loam; weak coarse and medium subangular blocky structure; firm, sticky, plastic; very few very fine roots and tubular pores; few fine distinct mottles of 2.5Y 7/2; many thick clay films of dark yellowish brown (10YR 4/4) on ped faces and common thick clay films of very dark grayish brown (10YR 3/2) in pores; $\sim$5% weathered fine gravel, well rounded to subangular, moderately spherical, some tuffaceous, the rest weathered beyond recognition; strongly acid (pH 5.4); clear wavy boundary.
IICr1	117-143	Variegated yellowish brown (10YR 5/6), yellowish red (5YR 5/8), and pale yellow (2.5Y 7/4) loam; massive; firm, sticky, plastic; yellowish brown rubbed; few fine coatings of black (10YR 2/0); highly weathered fine gravel to medium sand-size particles, moderately well rounded, moderately spherical, well graded, lithology including a large proportion of tuffaceous material; $\sim$5% hard fine gravel; medium acid (pH 5.6); abrupt smooth boundary.
IICr2	143-150	Variegated strong brown (7.5YR 5/6) and light yellowish brown (10YR 6/4) weathered rock; massive; firm, sticky, slightly plastic; yellowish brown (10YR 5/6) rubbed; few fine coatings of black (10YR 2/0); well graded sandstone with a large proportion of tuffaceous material; strongly acid (pH 5.5).

Table 4-5--**Soil chemical properties at sites E2T1, E2T2, E4T1, and E4T2, Elkins Road Watershed.**

Pedon designation	Horizon	Depth	Sample designation	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	H^{+}	CEC	Base saturation NH_4OAC	Base saturation Sum	Organic matter	pH
		----cm----		-------------------	------	meq/100 g	------	------	-------------------	------------	%	------------	
E2T1	Ap	0-20	ERO-2, 38	3.7	1.1	0.48	0.14	9.0	10.09	54.0	37.6	2.57	5.2
	A12	20-28	ERO-25	3.2	1.3	0.32	0.21	17.9	10.60	47.5	21.9	2.27	5.3
	B1	28-42	ERO-18, 40	4.9	2.0	0.26	0.11	6.5	12.14	61.0	52.8	2.64	5.6
	B2	42-65	ERO-1	4.8	2.2	0.22	0.42	5.5	9.82	77.8	58.1	0.96	5.8
	A'2	65-72	ERO-29	4.8	4.6	0.24	0.23	4.7	12.99	76.0	67.7	0.50	5.4
	IIB21tb	72-88	ERO-5	7.7	7.3	0.26	0.26	6.8	18.13	85.6	69.5	0.45	5.8
	IIB22tb	88-120	ERO-11	8.6	7.4	0.14	0.28	7.7	16.11	101.9	68.1	0.45	5.9
		120-150 (soil)	ERO-8	11.0	8.2	0.11	0.39	7.0	19.29	102.1	73.8	0.50	6.1
	IICr1	120-150 (saprolite)	ERO-31	11.8	9.9	0.12	0.49	3.7	22.41	97.4	85.5	0.10	5.9
	IICr2	150-160	ERO-17	14.7	11.0	0.15	0.45	3.7	20.25	129.9	87.7	0.30	6.2
E2T2	Ap	0-19	ERO-23	4.5	1.0	0.30	0.09	10.9	9.17	64.1	35.0	3.22	5.2
	A12	19-26	ERO-21	5.3	1.4	0.19	0.09	10.3	10.07	69.3	40.4	2.67	5.5
	A3	26-47	ERO-14, 35	4.2	1.6	0.16	0.13	8.3	9.78	63.2	42.7	1.81	5.5
	IIB1b	47-57	ERO-4	4.2	1.8	0.11	0.10	5.9	7.73	80.3	51.3	1.21	5.7
	IIB21tb	57-82	ERO-9, 34	3.6	2.4	0.08	0.14	5.2	8.44	73.1	55.6	0.66	5.6
	IIIB22tb	82-101	ERO-30	3.7	4.2	0.04	0.37	4.6	10.62	78.2	64.4	0.45	6.0
	IIIB23tb	101-145	ERO-16	8.4	6.9	0.07	0.53	2.6	14.10	112.8	85.9	0.65	6.9

Table 4-5--continued.

Pedon designation	Horizon	Depth	Sample designation	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	H^{+}	CEC	Base saturation NH_4OAC	Base saturation Sum	Organic matter	pH
		----cm-----		------------------	------------------	--meq/100 g--	------------------	------------------	------------------	-------------	------%------	-------------	
E4T1	Ap	0-25	ERO-19	5.8	1.5	0.39	0.09	14.2	13.73	56.7	35.4	3.53	5.3
	A12	25-34	ERO-3	7.2	2.5	0.27	0.10	10.2	14.48	69.5	49.7	2.77	5.8
	A3	34-57	ERO-24, 39	6.2	3.2	0.20	0.12	9.5	13.66	71.2	50.6	2.06	5.6
	B11	57-70	ERO-12	5.9	3.8	0.09	0.10	8.6	12.88	76.8	53.5	0.96	5.8
	IIB12	70-81	ERO-27	5.8	5.0	0.12	0.26	7.2	15.00	74.5	60.8	0.86	5.6
	IIB21tb	81-92	ERO-10	8.3	7.2	0.09	0.17	11.0	18.66	84.5	58.9	0.10	5.7
	IIB22tb	92-102	ERO-7	8.1	7.3	0.11	0.19	10.9	19.72	79.6	59.0	0.76	5.7
	IIIB3tb	102-108	ERO-32	12.5	12.0	0.29	0.43	7.1	34.20	73.7	78.0	0.81	5.3
	IIICr	108-151	ERO-15	15.3	13.0	0.35	0.39	11.1	32.22	90.1	72.3	0.60	5.4
E4T2	Ap	0-18	ERO-13, 36	4.6	1.4	0.36	0.14	11.2	12.92	51.4	37.2	3.27	5.2
	A12	18-25	ERO-20	6.9	2.7	0.32	0.09	10.3	12.99	77.1	49.3	2.77	5.7
	A3	25-50	ERO-6	6.6	3.3	0.18	0.10	6.3	12.39	82.2	61.8	1.66	5.9
	IIB1tb	50-66	ERO-33	7.4	6.0	0.11	0.19	4.0	15.93	86.0	77.4	0.60	5.8
	IIB2tb	66-95	ERO-22, 37	11.8	7.2	0.18	0.17	7.0	21.60	91.2	73.6	0.55	5.8
	IIB3tb	95-117	ERO-26	13.7	8.9	0.19	0.28	5.9	23.11	99.8	79.6	0.55	5.6
	IICr1	117-148	ERO-28	12.2	7.6	0.22	0.30	6.0	21.31	95.4	77.2	0.10	5.8

Table 4-6--Soil particle size distribution at sites E2T1, E2T2, E4T1, and E4T2, Elkins Road Watershed (after Glasmann, 1979).

Pedon designation	Horizon	Depth	Sample designation	vcs	cs	ms	fs	vfs	Total sand	csi	fsi	Total silt	Total clay
		----cm-----		----------					%			----------	-------
E2T1	Ap	5-15	STP-36	0.4	1.3	1.0	5.1	10.5	18.5	22.4	37.8	60.3	21.3
	A12	20-28	STP-35, 90	0.7	1.2	1.0	4.8	9.7	17.5	23.0	38.6	61.6	21.0
	B1	28-35	STP-43	0.7	1.2	1.0	4.6	9.2	16.7	24.2	36.7	61.0	22.4
		35-42	STP-31, 93	0.5	1.1	1.0	4.6	9.2	16.4	22.2	38.3	60.5	23.1
	B2	42-52	STP-42, 103	0.6	1.2	1.0	4.4	9.2	16.4	22.1	38.4	60.6	23.0
		52-62	STP-27, 109	0.5	1.7	0.9	4.3	9.8	17.1	20.9	37.5	58.4	24.5
	A'2	62-72	STP-53	0.9	1.2	0.9	5.3	11.4	19.7	22.6	34.3	56.9	23.4
	IIB21tb	72-81	STP-56	0.5	0.8	0.5	4.0	10.7	16.6	19.7	25.8	45.4	38.0
		81-89	STP-51, 91	0.4	0.8	0.6	4.2	11.0	16.9	19.9	26.4	47.0	36.8
	IIB22tb	89-99	STP-50, 107	0.8	0.8	0.5	3.9	11.0	17.0	21.5	26.8	48.3	34.7
		99-109	STP-21, 92	1.2	1.1	0.6	4.1	10.2	17.2	21.6	25.0	46.6	36.2
		109-119	STP-60, 98	0.4	0.4	0.3	2.9	10.2	14.1	23.1	28.9	52.0	33.9
		119-130	STP-49	0.4	0.6	0.5	3.3	9.1	13.8	23.7	28.2	51.9	34.3
		130-140 (soil)	STP-19	0.5	0.4	0.4	3.1	10.6	15.0	21.4	24.1	45.5	39.5
	IICr1	130-140 (saprolite)	STP-15, 96	0.2	0.2	0.2	1.5	9.4	11.5	23.3	33.7	57.0	31.5
		140-150	STP-59	0.6	0.5	0.3	2.4	9.4	13.3	17.6	30.3	48.0	38.8
	IICr2	150-160	STP-47	0.7	1.1	0.6	1.5	4.4	8.3	25.5	37.5	63.0	28.7
		160-170	STP-28	0.0	0.2	0.2	1.1	5.4	6.9	26.4	41.6	68.0	25.1
E2T2	Ap	5-15	STP-37	0.5	1.4	1.1	5.2	10.8	19.0	26.9	32.6	59.5	21.5
	A12	19-26	STP-38	0.4	0.7	0.9	6.2	13.6	21.8	23.6	32.7	56.3	21.9

Table 4-6--continued.

Pedon desig-nation	Horizon	Depth	Sample designation	vcs	cs	ms	fs	vfs	Total sand	csi	fsi	Total silt	Total clay
		----cm-----		-------------------					---%---				-------------------
E2T2	A3	26-36	STP-41	0.2	0.8	0.9	5.8	13.1	20.8	22.5	32.9	55.4	23.8
		36-47	STP-34	0.3	0.8	0.8	5.5	13.6	21.0	23.9	32.6	56.5	22.5
	IIB1b	47-57	STP-52	0.5	1.1	1.1	6.1	13.6	22.5	22.5	34.4	56.8	20.7
	IIB21tb	57-67	STP-68	0.3	0.7	0.7	5.4	13.6	20.7	24.7	34.8	59.5	19.7
		67-77	STP-64	0.4	0.8	0.8	5.7	13.6	21.2	23.5	35.8	59.3	19.5
		77-82	STP-2	0.8	1.2	1.0	5.6	12.4	20.9	25.0	30.1	55.1	24.0
	IIIB22tb	82-92	STP-63, 87	0.4	0.9	0.8	5.5	12.5	20.2	23.3	36.2	59.5	20.4
		92-101	STP-70, 101	0.2	0.7	0.6	4.4	10.6	16.5	21.0	34.8	55.8	27.8
	IIIB23tb	101-111	STP-67	0.4	0.8	0.7	4.3	10.0	16.2	20.6	36.0	56.6	27.1
		111-121	STP-69, 86	0.5	1.0	0.9	5.0	9.8	17.2	18.5	36.0	54.5	28.3
		121-130	STP-65	0.5	1.1	0.8	4.4	10.0	16.9	19.9	34.6	54.4	28.7
		130-140	STP-66, 95	0.5	1.1	0.8	4.4	10.4	17.2	19.6	33.3	53.0	29.8
		140-150	STP-1	0.5	0.6	0.6	3.8	10.1	15.6	22.0	26.9	48.8	35.6
E4T1	Ap	10-20	STP-32	0.8	2.7	3.1	8.4	6.0	21.1	17.6	37.8	55.4	23.5
	A12	25-34	STP-33, 108	0.8	2.9	3.0	7.7	5.3	19.6	15.0	35.0	50.0	30.4
	A3	34-47	STP-39, 104	0.8	2.9	3.2	7.8	5.4	20.3	14.6	35.1	49.6	30.0
		47-57	STP-10, 97	0.8	3.0	3.3	8.1	5.5	20.7	15.4	34.2	49.6	29.6
	B11	57-63	STP-7	0.8	3.6	3.6	8.6	5.8	22.4	17.0	31.9	48.9	28.7
		63-70	STP-46	1.1	3.8	3.9	9.1	6.2	24.1	15.8	35.1	50.9	25.1
	IIB12	70-81	STP-26	0.7	3.1	3.6	8.6	5.9	21.9	13.1	33.6	46.7	31.4
	IIB21tb	81-92	STP-22	0.4	3.5	4.4	8.9	5.7	22.8	8.5	23.2	31.8	45.4
	IIB22tb	92-102	STP-5	1.2	5.7	5.3	9.3	5.8	27.4	9.9	21.2	30.0	42.6

Table 4-6--continued.

Pedon designation	Horizon	Depth	Sample designation	vcs	cs	ms	fs	vfs	Total sand	csi	fsi	Total silt	Total clay
		----cm----		%									
E4T1	IIIB3tb	102-108	STP-8	0.8	2.9	2.7	5.5	3.6	15.6	8.0	14.7	22.8	61.6
	IIICr	108-118	STP-57, 110	0.2	1.0	0.9	1.8	1.1	5.0	4.5	21.0	25.4	69.6
		118-128	STP-55	0.0	0.1	0.1	0.3	0.5	1.0	3.2	32.5	35.6	63.3
		128-138	STP-61, 106	0.2	0.4	0.2	0.4	0.8	1.9	5.2	29.3	34.0	64.1
		138-148	STP-62	0.0	0.0	0.0	0.1	0.8	1.0	5.0	29.2	34.1	64.8
		148-158	STP-11	0.0	0.0	0.0	0.2	1.2	1.5	7.0	27.4	34.4	64.1
E4T2	Ap	4-14	STP-30, 112	0.4	1.5	2.0	7.9	6.9	18.6	19.8	39.6	59.4	22.0
	A12	18-25	STP-29	0.2	1.2	1.7	7.7	7.4	18.2	16.5	40.9	57.4	24.4
	A3	25-30	STP-40, 89	1.0	1.5	1.8	8.4	7.8	20.0	17.1	37.5	54.6	25.4
		30-40	STP-44	0.5	1.3	1.8	8.3	7.9	19.9	17.8	37.5	55.3	24.8
		40-50	STP-45, 88	0.6	1.7	2.2	9.9	8.6	23.0	17.6	36.8	54.2	22.8
	IIB1tb	50-60	STP-17	0.9	1.9	2.2	11.0	10.6	26.7	16.5	27.0	43.5	29.8
		60-66	STP-58	2.0	2.4	2.7	11.9	10.3	29.3	14.7	25.8	40.5	30.2
	IIB2tb	66-76	STP-6, 111	2.9	2.8	2.6	10.9	9.3	28.5	12.4	21.2	33.6	38.0
		76-86	STP-14, 100	1.0	1.3	2.4	13.0	9.4	27.0	12.8	22.7	35.6	37.4
		86-95	STP-54, 94	0.9	2.2	3.1	14.5	10.3	31.0	11.0	23.3	34.3	34.7
	IIB3tb	95-105	STP-3, 99	0.3	1.1	4.2	15.6	9.6	30.8	10.9	22.0	32.9	36.3
		105-117	STP-13	1.2	4.5	4.8	14.5	9.2	34.3	11.6	21.3	32.9	32.8
	IICr1	117-127	STP-25	5.4	11.0	6.3	11.8	8.8	43.3	5.4	24.2	29.7	27.0
		127-137	STP-48, 102	5.1	10.0	6.9	13.5	9.7	45.2	11.8	23.2	35.0	19.8
		137-143	STP-20	3.7	8.1	6.2	13.5	10.4	42.0	13.5	21.1	34.6	23.4
	IICr2	143-150	STP-24, 105	1.8	12.3	10.4	15.1	9.3	49.1	11.9	21.4	33.4	17.6

SECTION II. EROSION AND RUNOFF

CHAPTER 5. GROSS EROSION

J. D. Istok and B. Lowery

Summary

For three years of data, measured annual amounts of gross erosion from all sites ranged between 0.2 and 4 tons per acre. Total losses varied with the soil, the landscape position, and the amount and intensity of rainfall. Soils which are less well-drained, with restrictive layers near the surface, or in lower landscape positions, had higher amounts of runoff and erosion. Some of the largest amounts of erosion occurred with storms following a period of freezing.

Introduction

The Universal Soil Loss Equation (USLE) is used in making decisions on the need and design of conservation practices. To be useful, the equation must be properly calibrated (Chapter 2). Measurements of gross erosion made with standard erosion plots can be used to calibrate the USLE for the long duration, low intensity storm systems which characterize our winter rainfall season. Plot data also can be used to evaluate the relationship of erosion to physical parameters such as slope position, profile morphology, etc.

Materials and Methods

Gross erosion and runoff were measured with erosion plots as described in Chapter 3. These plots were established in the various sub-watersheds and on different landscape positions. Mini-erosion plots were installed when the slope was irregular or of insufficient length to permit the installation of a standard plot. They also were used to evaluate their usefulness in making gross erosion measurements.

Two study areas, E1 and E4, which differed in drainage characteristics were selected for gross erosion measurements (Fig. 5-1). The locations of the erosion plots for the 1977-78, 1978-79, and 1979-80 rainfall seasons are given in Figures 5-2 through 5-7. In each case, plots were in fall-planted small grains and/or grass seed fields. Drain-lines were installed on sub-watershed E4F1 (within study area E4) in August, 1979, to test the effect of lowering the perched water table on reducing amounts of runoff and gross erosion.

Results and Discussion

The amount of erosion per unit area varied with the soil, the landscape position and the amount and intensity of rainfall. Greater amounts of gross erosion were measured in study area E4 compared with study area E1 (Tables 5-1--5-19). The Helmick soil on parts of study area E4 is less well-drained than the Willakenzie soil found at study area E1 (Chapter 4). Greater depths to restrictive layers for soils in E1 result in higher infiltration rates (Chapter 9) and reduced amounts of runoff and erosion.

For each study area in 1977-78, the total runoff and gross erosion from plots in lower landscape positions were greater than that from upper landscape positions (Tables 5-1--5-7). There is a significant amount of lateral, downslope subsurface flow at both E1 and E4 (Chapter 8). This water tends to surface in lower landscape positions. Greater amounts of runoff and erosion in toe slope positions are attributed to decreases in infiltration rates and plant cover due to seasonal perched water tables (Chapter 9).

For three years of data, measured amounts of gross erosion from all sites were within the range of 0.2 to 4 T/acre/yr (0.5 to 9 mTon/ha/hr) with average values of less than 2 T/acre/yr (4.5 mTon/ha/yr) (Tables 5-1--5-19).

For the first year following installation of drainlines (1979-80 season), greater amounts of gross erosion were measured in upper landscape positions than in lower ones (Tables 5-12--5-19). This is opposite to observations on this watershed in 1977-78, prior to installation of drainlines. The relative changes in amounts of gross erosion in lower landscape positions may be attributed to the effectiveness of drainage systems in reducing seepage areas. More data must be collected however before drainage systems can be recommended as an alternate management practice to reduce gross erosion. Settling of the soil surface over the drainlines has been observed to alter patterns of overland flow. In addition, the inherent variability in erosion plot measurements and differences in weather patterns from one year to the next make final interpretations premature.

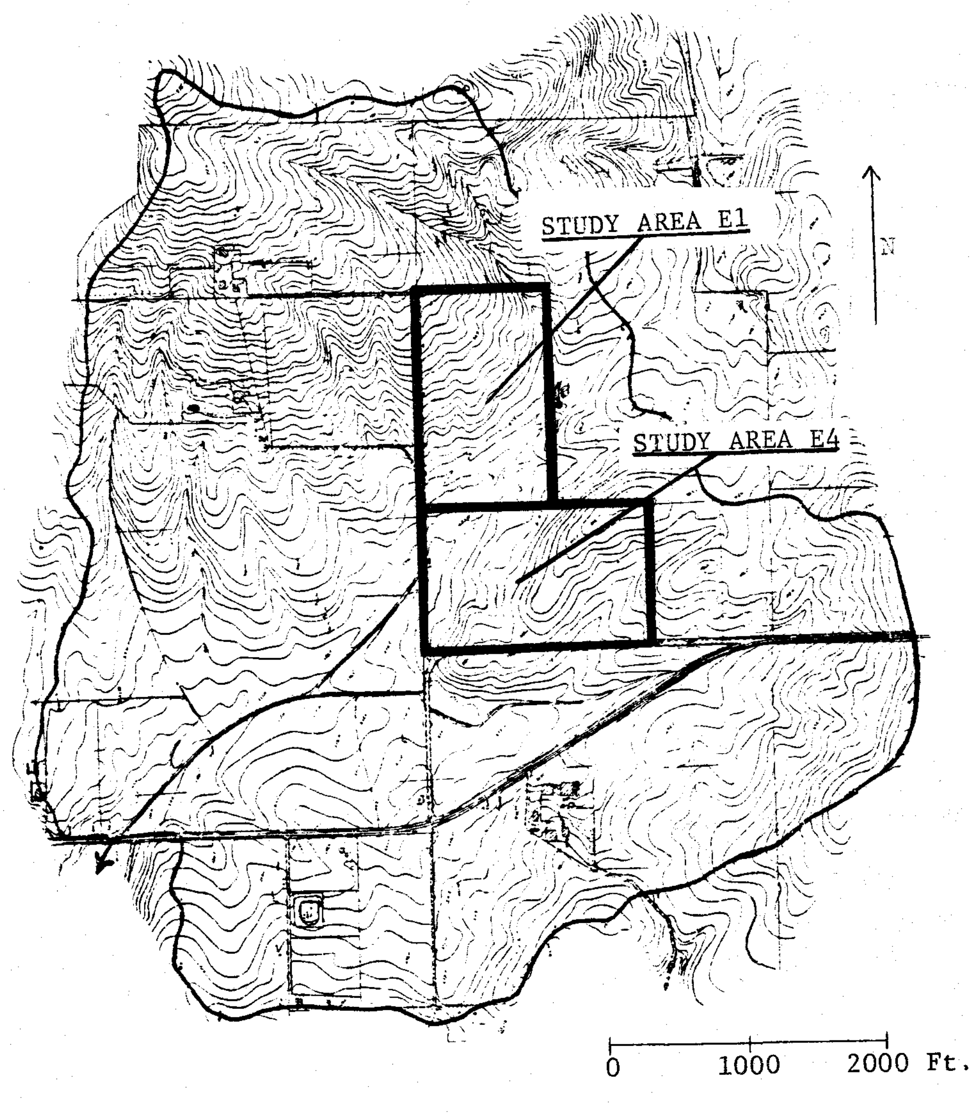


Fig. 5-1--Location of gross erosion study areas within Elkins Road Watershed.

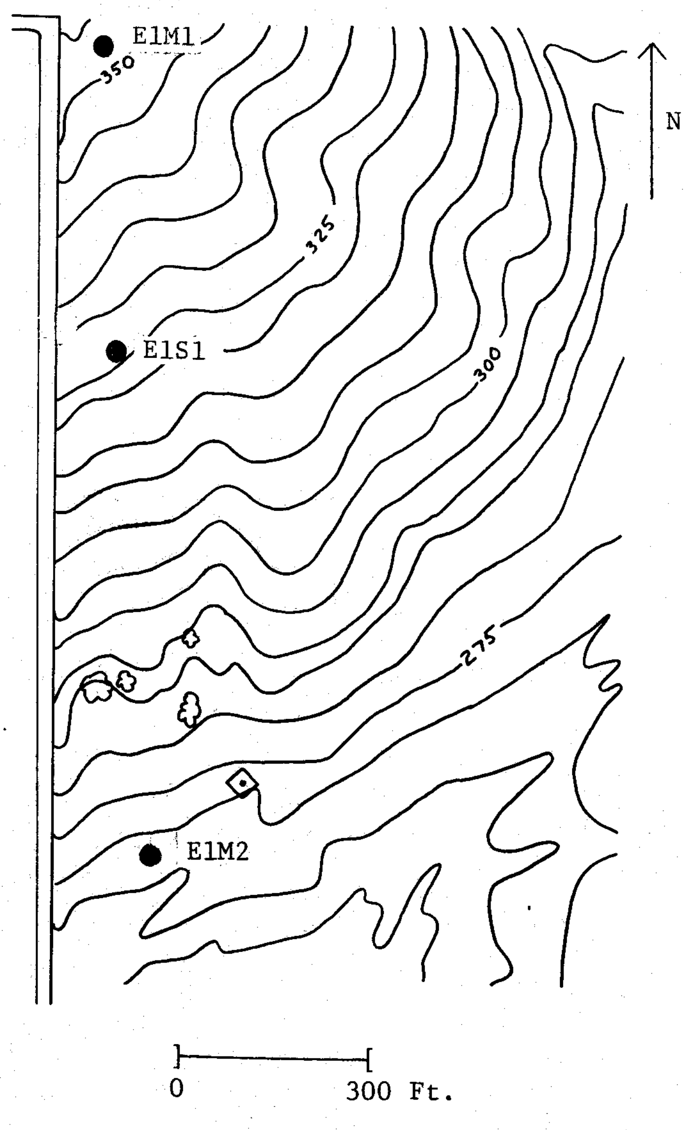


Fig. 5-2--Location of erosion plots in study area E1, 1977-78.

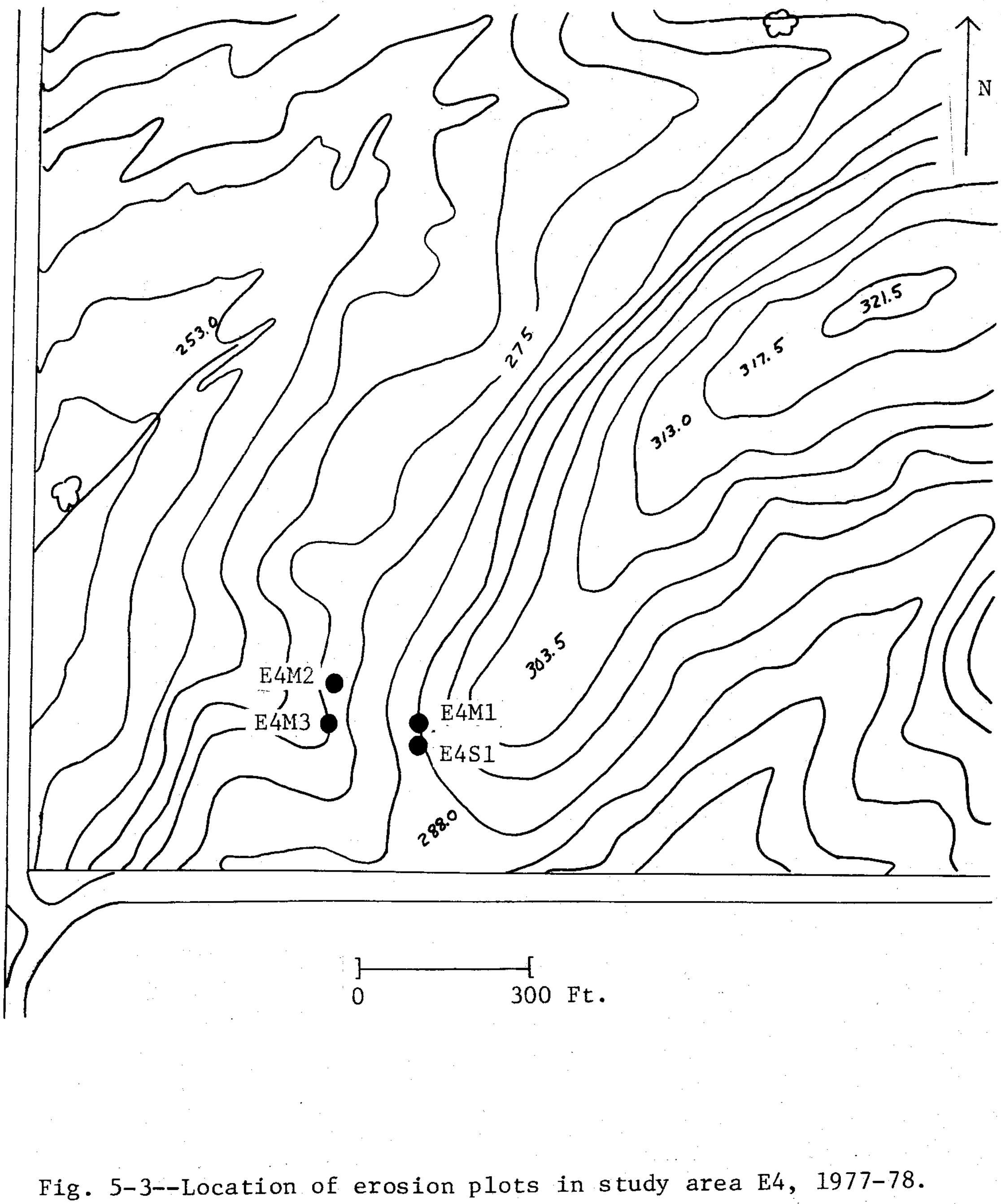


Fig. 5-3--Location of erosion plots in study area E4, 1977-78.

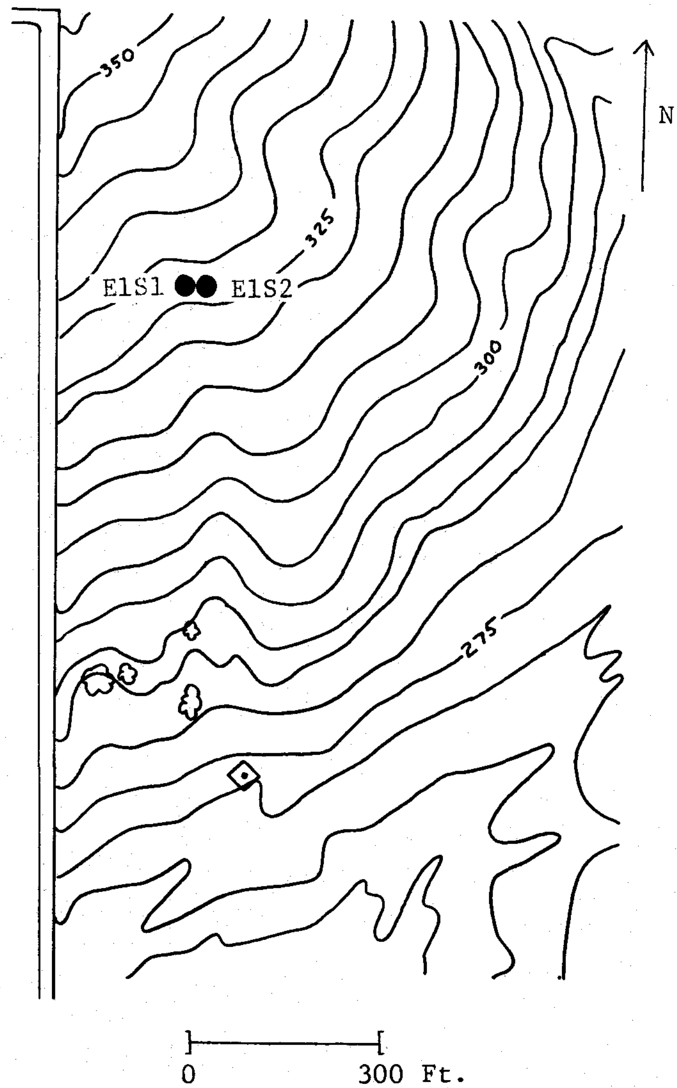


Fig. 5-4--Location of erosion plots in study area E1, 1978-79.

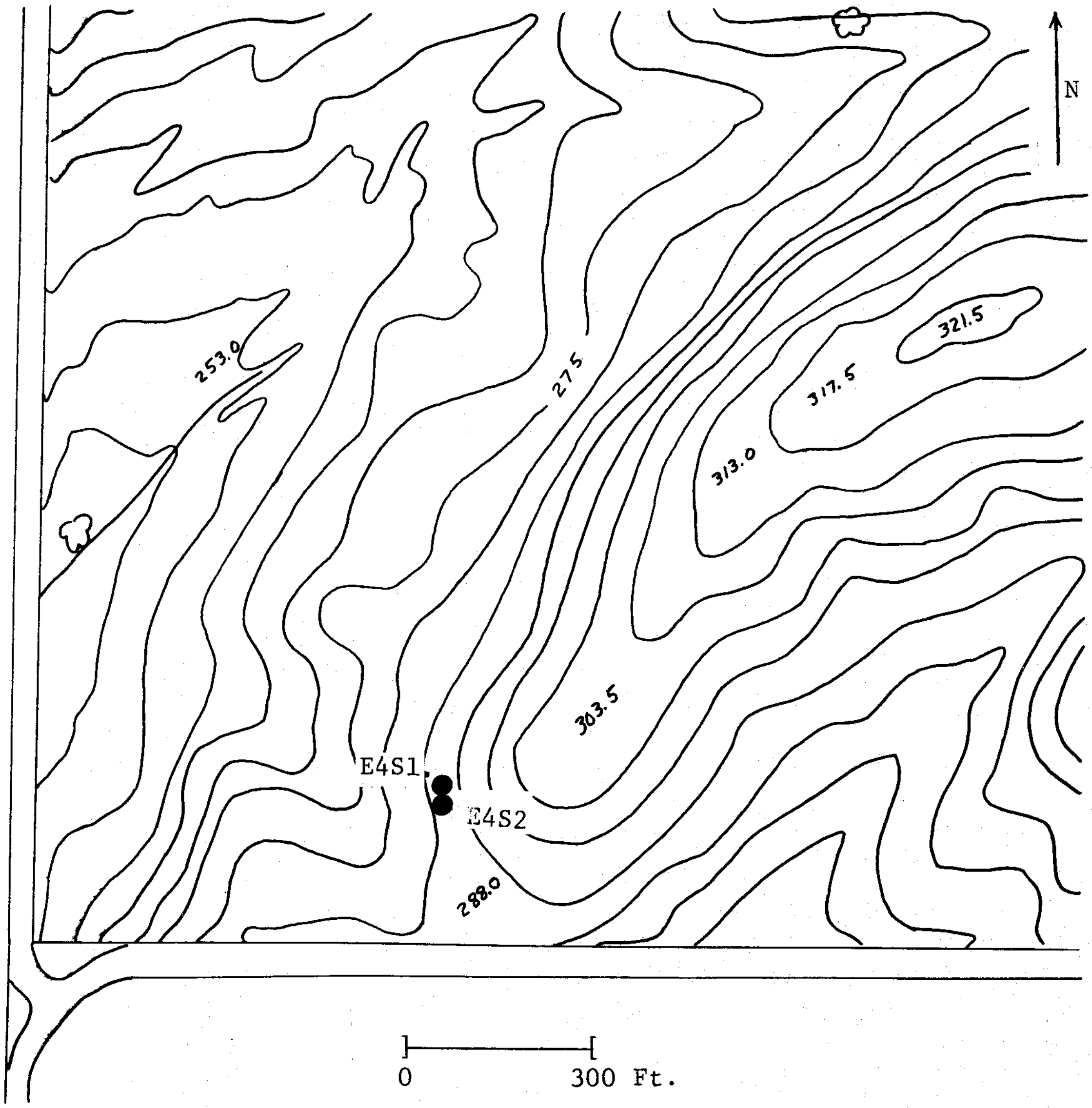


Fig. 5-5--Location of erosion plots in study area E4, 1978-79.

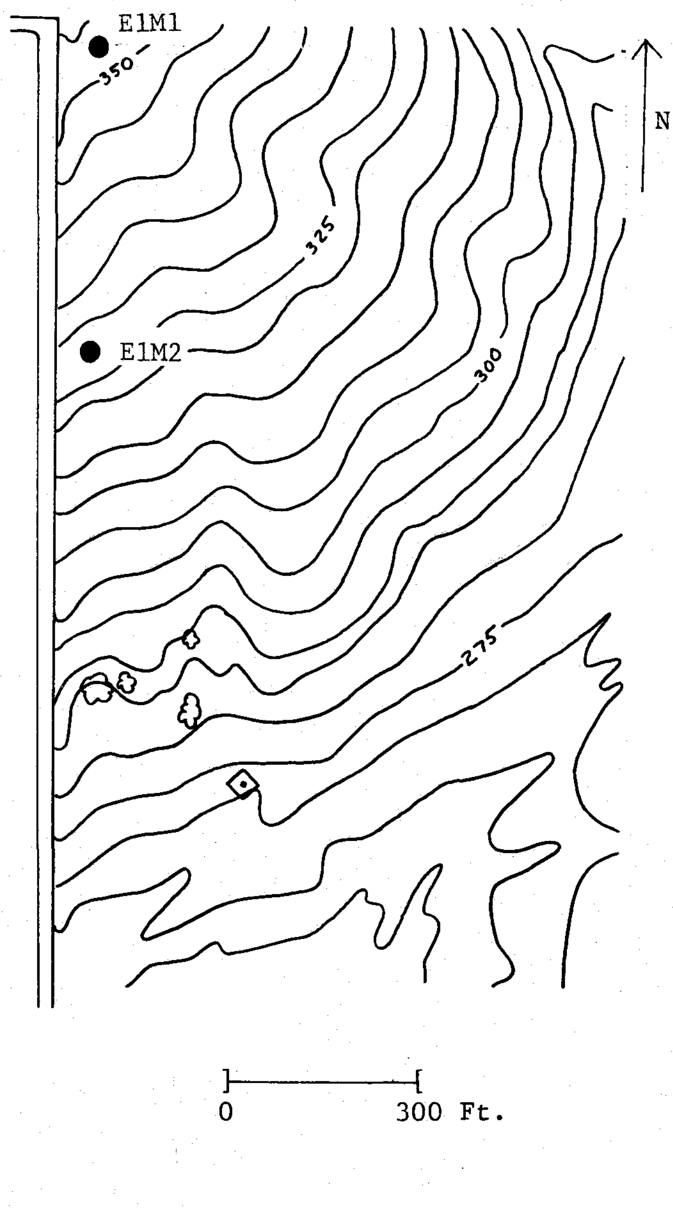


Fig. 5-6--Location of erosion plots in study area E1, 1979-80.

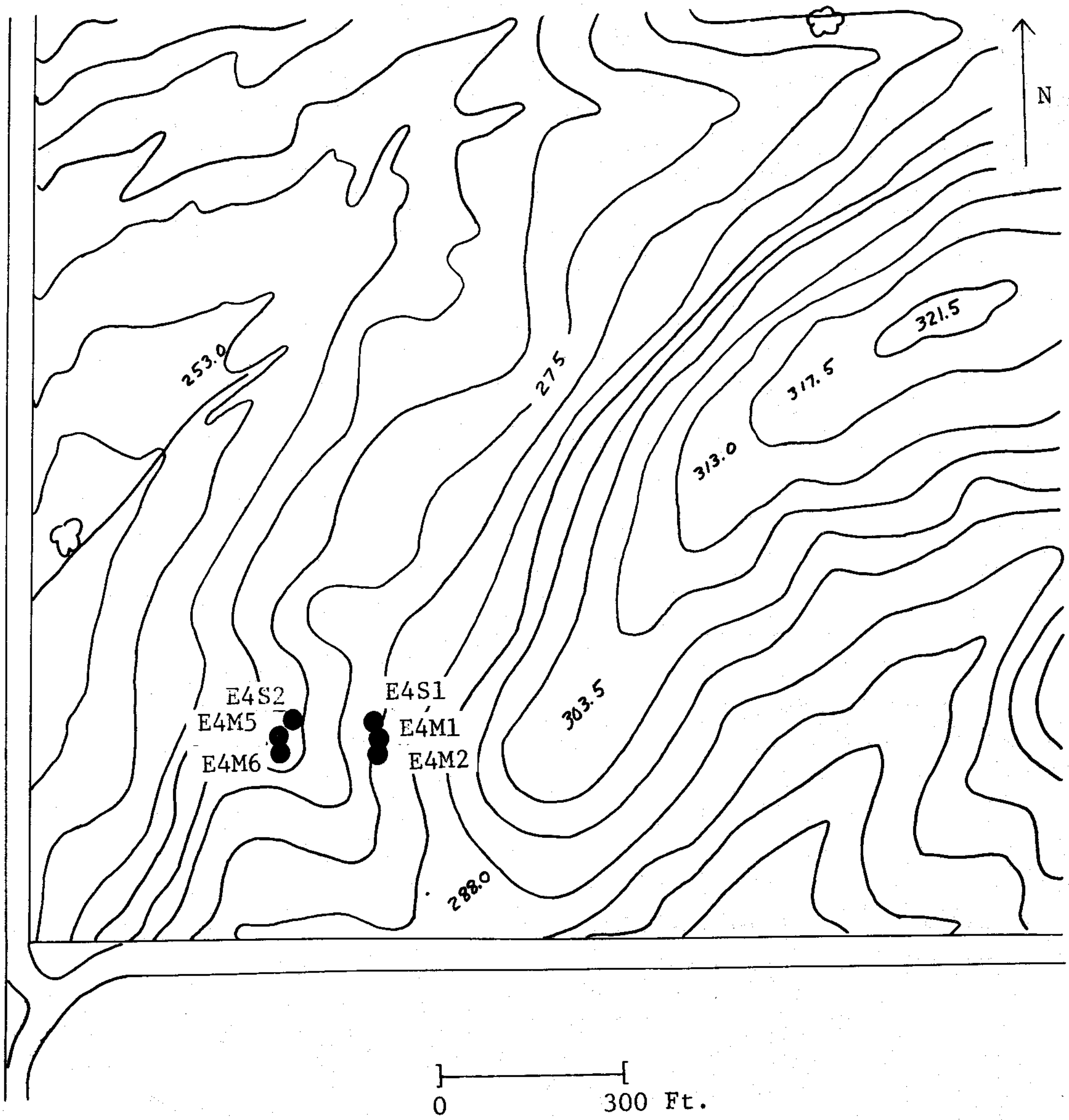


Fig. 5-7--Location of erosion plots in study area E4, 1979-80.

Table 5-1--Runoff and gross erosion from plot E1M1 in 1977-1978; upslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 22-28, 1977	144	4.3	21.5†	15†	600†
Nov. 28-Dec. 5	43	1.5	7.8	18	80
Dec. 5-12	66	2.8	15.2	23	------§
Dec. 12-16	130	5.3	31.3	24	1,240
Dec. 16-Jan. 6, 1978	97	2.0	35.8	37	480
Jan. 6-19	96	1.3	17.4	19	60
Jan. 19-23	18	1.3	1.3	7	70
Jan. 23-Feb. 16	90	1.5	2.2	2	70
Feb. 16-Apr. 12	71	2.0	0.0	0	0
Apr. 12-May 31	170	2.3	0.0	0	0
					2,600

Soil: Willakenzie‡; slope: 6.3%; plot area: $10 m^2$.

†Minimum value, collecting tub was overflowing.
‡See Section 2 for more soils information.
§Missing data.

Table 5-2--Runoff and gross erosion from plot E1M2 in 1977-1978; downslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 22-28, 1977	144	4.3	36.8†	26†	890†
Nov. 28-Dec. 5	43	1.5	26.7	62	270
Dec. 5-12	66	2.8	60.9	92	880
Dec. 12-16	130	5.3	77.2	59	3,000
Dec. 16-Jan. 6, 1978	97	2.0	83.0	86	640
Jan. 6-19	96	1.3	44.6	47	320
Jan. 19-23	18	1.3	10.2	57	290
Jan. 23-Feb. 16	90	1.5	29.0	32	440
Feb. 16-Apr. 12	71	2.0	3.8	5	60
Apr. 12-May 31	170	2.3	16.9	10	0
					6,790

Soil: Dupee variant, fine-silty; slope: 6.5%; plot area: $10m^2$.

†Minimum value, collecting tub was overflowing.

Table 5-3--Runoff and gross erosion from plot E1S1 in 1977-1978; midslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 22-28, 1977	144	4.3	plot not installed		
Nov. 28-Dec. 5	43	1.5	plot not installed		
Dec. 5-12	66	2.8	plot not installed		
Dec. 12-16	130	5.3	plot not installed		
Dec. 16-Jan. 6, 1978	97	2.0	8.0	8	290
Jan. 6-19	96	1.3	4.9	5	90
Jan. 19-23	18	1.3	3.3	18	170
Jan. 23-Feb. 16	90	1.5	4.7	5	130
Feb. 16-Apr. 12	71	2.0	0.3	0	10
Apr. 12-May 31	170	2.3	0.4	0	0

Soil: Willakenzie variant, deep; slope: 7.0%; plot area: $50m^2$.

Table 5-4--Runoff and gross erosion from plot E4M1 in 1977-1978; upslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 22-28, 1977	144	4.3	6.3	4	400
Nov. 28-Dec. 5	43	1.5	----†	--	-----
Dec. 5-12	66	2.8	3.5	5	270
Dec. 12-16	130	5.3	31.3	24	2,460
Dec. 16-Jan. 6, 1978	97	2.0	3.1	3	110
Jan. 6-19	96	1.3	3.3	3	10
Jan. 19-23	18	1.3	2.1	12	90
Jan. 23-Feb. 16	90	1.5	7.3	8	30
Feb. 16-Apr. 12	71	2.0	5.2	7	40
Apr. 12-May 31	170	2.3	0.4	0	0

Soil: Helmick variant, moderately deep; slope: 8.3%; plot area: $10m^2$.

†Missing data.

Table 5-5--Runoff and gross erosion from plot E4M2 in 1977-1978; midslope position.

Storm period	Rainfall		Runoff		Gross erosion
	Total for period	Maximum intensity			
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 22-28, 1977	144	4.3	47.2	33	-----†
Nov. 28-Dec. 5	43	1.5	10.6	25	140
Dec. 5-Dec. 12	66	2.8	5.4	8	510
Dec. 12-Dec.16	130	5.3	50.7	39	6,790
Dec. 16-Jan. 6, 1978	97	2.0	6.2	6	120
Jan. 6-Jan. 19	96	1.3	5.8	6	90
Jan. 19-23	18	1.3	2.1	26	100
Jan. 23-Feb. 16	90	1.5	37.9	42	400
Feb. 16-Apr. 12	71	2.0	10.3	15	60
Apr. 12-May 31	170	2.3	0.0	0	0

Soil: Helmick variant, moderately deep; slope: 7.7%; plot area: $10m^2$.

†Missing data.

Table 5-6--Runoff and gross erosion from plot E4M3 in 1977-1978; downslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 22-28, 1977	144	4.3	----†	---	---
Nov. 28-Dec. 5	43	1.5	----	---	---
Dec. 5-12	66	2.8	3.3	5	150
Dec. 12-16	130	5.3	----	---	---
Dec. 16-Jan. 6, 1978	97	2.0	62.4	64	350
Jan. 6-19	96	1.3	19.7	21	50
Jan. 19-23	18	1.3	38.7	215	100
Jan. 23-Feb. 16	90	1.5	19.3	21	80
Feb. 16-Apr. 12	71	2.0	0.0	0	0
Apr. 12-May 31	170	2.3	0.0	0	0

Soil: Helmick variant, moderately deep and Willakenzie variant, deep; slope: 7.5%; plot area: 10m^2.

†Missing data.

Table 5-7--Runoff and gross erosion from plot E4S1 in 1977-1978; upslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 22-28, 1977	144	4.3	20.3	14	1,920
Nov. 28-Dec. 5	43	1.5	3.0	7	150
Dec. 5-12	66	2.8	6.7	10	680
Dec. 12-16	130	5.3	33.5	26	3,450
Dec. 16-Jan. 6, 1978	97	2.0	5.3	6	290
Jan. 6-19	96	1.3	4.9	5	100
Jan. 19-23	18	1.3	1.2	7	80
Jan. 23-Feb. 16	90	1.5	3.0	3	60
Feb. 16-Apr. 12	71	2.0	1.2	2	20
Apr. 12-May 31	170	2.3	0.5	0	0
					6,750

Soil: Helmick variant, moderately deep; slope: 8.3%; plot area: $50 m^2$.

Table 5-8--Runoff and gross erosion from plot E1S1 in 1978-1979; midslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 20-24, 1978	58	0.3	0.0	0	0
Nov. 24-Dec. 2	31	1.3	0.0	0	10
Dec. 2-Dec. 7	21	1.3	0.0	0	0
Dec. 7-14	24	1.3	0.1	0	10
Dec. 14-21	10	0.3	0.1	1	10
Dec. 21-Jan. 10, 1979	52	0.8	14.4	28	60
Jan. 10-11	12	0.8	4.8	40	60
Jan. 11-13	0	0.0	1.1	snowmelt	100
Jan. 13-19	9	1.8	1.9	21	30
Jan. 19-26	3	0.3	0.4	13	20
Jan. 26-Feb. 7	52	1.3	0.5	0	0
Feb. 7-10	40	0.8	5.0	13	60
Feb. 10-16	31	1.8	1.1	4	0
Feb. 16-25	45	1.3	1.6	4	30
Feb. 25-Mar. 3	37	1.3	0.7	2	0
Mar. 3-12	19	0.8	0.3	0	20
Mar. 12-Apr. 3	38	1.3	0.1	0	0
Apr. 3-May 12	134	0.8	3.4	3	120
					530

Soil: Willakenzie; slope: 7.5%; plot area: $50m^2$.

Table 5-9--Runoff and gross erosion from plot E1S2 in 1978-1979; midslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 20-24, 1978	58	0.3	4.4	8	40
Nov. 24-Dec. 2	31	1.3	1.4	5	30
Dec. 2-7	21	1.3	1.4	7	10
Dec. 7-14	24	1.3	0.3	1	10
Dec. 14-21	10	0.3	1.1	11	10
Dec. 21-Jan. 10, 1979	52	0.8	52.7	101	420
Jan. 10-11	12	0.8	32.6	272	270
Jan. 11-13	0	0.0	5.1	snowmelt	110
Jan. 13-19	9	1.8	1.6	18	90
Jan. 19-26	3	0.3	0.1	3	20
Jan. 26-Feb. 7	52	1.3	3.7	7	40
Feb. 7-10	40	0.8	6.0	15	40
Feb. 10-16	31	1.8	4.7	15	20
Feb. 16-25	45	1.3	4.1	9	40
Feb. 25-Mar. 3	37	1.3	3.1	8	10
Mar. 3-12	19	0.8	0.4	2	20
Mar. 12-Apr. 3	38	1.3	1.1	3	10
Apr. 3-May 12	134	0.8	3.6	3	10
					1,210

Soil: Willakenzie; slope: 7.3%; plot area: $50 m^2$.

Table 5-10--Runoff and gross erosion from plot E4S1 in 1978-79; midslope position.

Storm period	Rainfall		Runoff		Gross erosion
	Total for period	Maximum intensity			
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 20-24, 1978	58	0.3	0.9	2	30
Nov. 24-Dec. 2	31	1.3	0.0	0	10
Dec. 2-7	21	1.3	0.0	0	0
Dec. 7-14	24	1.3	0.0	0	10
Dec. 14-21	10	0.3	0.0	0	0
Dec. 21-Jan. 10, 1979	52	0.8	29.9	58	190
Jan. 10-11	12	0.8	13.4	112	220
Jan. 11-13	0	0.0	T	snowmelt	280
Jan. 13-19	9	1.8	0.0	0	0
Jan. 19-26	3	0.3	0.3	10	20
Jan. 26-Feb. 7	52	1.3	0.6	1	10
Feb. 7 - 10	40	0.8	7.5	19	60
Feb. 10-16	31	1.8	0.0	0	0
Feb. 16-25	45	1.3	5.8	13	240
Feb. 25-Mar. 3	37	1.3	3.2	9	30
Mar. 3-12	19	0.8	1.1	6	20
Mar. 12-Apr. 3	38	1.3	0.5	1	0
Apr. 3-May 12	134	0.8	2.2	2	10
					1,130

Soil: Helmick variant, moderately deep; slope: 8.3%; plot area: $50 m^2$.

T trace amount.

Table 5-11--Runoff and gross erosion from plot E4S2 in 1978-79; midslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Nov. 20-24, 1978	58	0.3	T	0	20
Nov. 24-Dec. 2	31	1.3	0.1	0	10
Dec. 2-7	21	1.3	0.0	0	0
Dec. 7-14	24	1.3	0.0	0	10
Dec. 14-21	10	0.3	0.0	0	0
Dec. 21-Jan. 10, 1979	52	0.8	12.0†	23†	140†
Jan. 10-11	12	0.8	4.8	40	60
Jan. 11-13	0	0.0	T	snowmelt	670
Jan. 13-19	9	1.8	0.0	0	0
Jan. 19-26	3	0.3	0.5	17	40
Jan. 26-Feb. 7	52	1.3	1.2	2	20
Feb. 7-10	40	0.8	4.2	11	80
Feb. 10-16	31	1.8	0.0	0	0
Feb. 16-25	45	1.3	9.5	21	1,040
Feb. 25-Mar. 3	37	1.3	0.9	2	50
Mar. 3-12	19	0.8	0.3	2	290
Mar. 12-Apr. 3	38	1.3	0.3	0	10
Apr. 3-May 12	134	0.8	0.2	0	0
					2,440

Soil: Helmick variant, moderately deep; slope: 8.4%; plot area: $50 m^2$.

†Minimum value, collecting tub overflowing.

T trace amount.

Table 5-12--Runoff and gross erosion from plot E1M1 in 1979-80; upslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	38	3.0	plot not installed		
Oct. 25-Nov. 2	40	1.3	plot not installed		
Nov. 2-26	93	1.8	4.5	5	80
Nov. 26-Dec. 3	39	3.8	4.0	10	60
Dec. 3-10	22	1.3	3.5	16	10
Dec. 10-17	24	2.5	3.0	13	20
Dec. 17-26	57	2.3	15.6	27	10
Dec. 26-Jan. 1, 1980	23	1.0	5.9	26	30
Jan. 1-8	32	1.0	12.3	38	10
Jan. 8-15	95	2.0	47.0	50	190
Jan. 15-Feb. 5	34	0.8	----†	--	---
Feb. 5-19	32	1.8	1.3	4	0
Feb. 19-26	8	0.5	T	0	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	0.0	0	0
Mar. 18-Apr. 14	70	1.5	0.0	0	0
					390

Soil: Willakenzie; slope: 6%; plot area: $10 m^2$.

T trace.

†Missing data.

Table 5-13--Runoff and gross erosion from plot E1M2 in 1979-80; midslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	38	3.0	plot not installed		
Oct. 25-Nov. 2	40	1.3	plot not installed		
Nov. 2-26	93	1.8	52.0	56	1,080
Nov. 26-Dec. 3	39	3.8	----†	--	-----
Dec. 3-10	22	1.3	2.7	12	150
Dec. 10-17	24	2.5	0.8	3	70
Dec. 17-26	57	2.3	17.5	31	310
Dec. 26-Jan. 1, 1980	23	1.0	1.5	7	330
Jan. 1-8	32	1.0	8.7	27	40
Jan. 8-15	95	2.0	7.0	7	350
Jan. 15-Feb. 5	34	0.8	----	--	-----
Feb. 5-19	32	1.8	6.0	19	20
Feb. 19-26	8	0.5	0.4	5	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	0.4	1	0
Mar. 18-Apr. 14	70	1.5	1.5	2	0

Soil: Willakenzie variant, deep; slope: 7%; plot area: $10m^2$.

†Missing data.

Table 5-14--Runoff and gross erosion from plot E4M1 in 1979-80; upslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	38	3.0	3.9	10	670
Oct. 25-Nov. 2	40	1.3	14.3	36	490
Nov. 2-26	93	1.8	27.4	29	550
Nov. 26-Dec. 3	39	3.8	17.0	44	1,670
Dec. 3-10	22	1.3	5.8	26	110
Dec. 10-17	24	2.5	7.6	32	300
Dec. 17-26	57	2.3	17.7	31	680
Dec. 26-Jan. 1, 1980	23	1.0	14.2	62	410
Jan. 1-8	32	1.0	10.8	34	190
Jan. 8-15	95	2.0	32.0	34	2,000
Jan. 15-Feb. 5	34	0.8	8.5	25	160
Feb. 5-19	32	1.8	10.0	31	20
Feb. 19-26	8	0.5	0.0	0	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	T	0	0
Mar. 18-Apr. 14	70	1.5	0.4	1	0
					7,250

Soil: Helmick variant, moderately deep; slope: 7%; plot area: $10m^2$.

T trace.

Table 5-15--Runoff and gross erosion from plot E4M2 in 1979-80; upslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	38	3.0	16.1	42	560
Oct. 25-Nov. 2	40	1.3	15.4	39	120
Nov. 2-26	93	1.8	22.2	24	210
Nov. 26-Dec. 3	39	3.8	14.0	36	520
Dec. 3-10	22	1.3	8.0	36	80
Dec. 10-17	24	2.5	17.0	71	250
Dec. 17-26	57	2.3	37.0	65	660
Dec. 26-Jan. 1, 1980	23	1.0	6.3	27	150
Jan. 1-8	32	1.0	0.1	0	10
Jan. 8-15	95	2.0	34.5	36	2,530
Jan. 15-Feb. 5	34	0.8	7.0	21	140
Feb. 5-19	32	1.8	7.0	22	90
Feb. 19-26	8	0.5	0.0	0	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	T	0	0
Mar. 18-Apr. 14	70	1.5	0.3	0	0
					5,320

Soil: Helmick variant, moderately deep; slope: 8%; plot area: $10m^2$.

T trace.

Table 5-16--Runoff and gross erosion from plot E4M5 in 1979-80; downslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	38	3.0	10.9	29	700
Oct. 25-Nov. 2	40	1.3	4.8	12	290
Nov. 2-26	93	1.8	0.7	1	71
Nov. 26-Dec. 3	39	3.8	10.0	26	660
Dec. 3-10	22	1.3	0.8	4	60
Dec. 10-17	24	2.5	8.7	36	210
Dec. 17-26	57	2.3	3.6	6	170
Dec. 26-Jan. 1, 1980	23	1.0	2.2	10	140
Jan. 1-8	32	1.0	0.8	3	50
Jan. 8-15	95	2.0	77.5	82	2,820
Jan. 15-Feb. 5	34	0.8	2.0	6	150
Feb. 5-19	32	1.8	3.5	11	70
Feb. 19-26	8	0.5	0.1	0	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	0.0	0	0
Mar. 18-Apr. 14	70	1.5	0.0	0	0
					5,391

Soil: Helmick variant, moderately deep; slope: 8%; plot area: $10m^2$.

Table 5-17--Runoff and gross erosion from plot E4M6 in 1979-80; downslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	39	3.0	32.1	85	1,620
Oct. 25-Nov. 2	40	1.3	2.0	5	210
Nov. 2-26	93	1.8	9.9	11	320
Nov. 26-Dec. 3	39	3.8	3.6	9	400
Dec. 3-10	22	1.3	1.8	8	80
Dec. 10-17	24	2.5	0.5	2	50
Dec. 17-26	57	2.3	1.5	3	100
Dec. 26-Jan. 1, 1980	23	1.0	6.3	27	120
Jan. 1-8	32	1.0	6.9	22	40
Jan. 8-15	95	2.0	26.3	28	970
Jan. 15-Feb. 5	34	0.8	0.5	2	70
Feb. 5-19	32	1.8	0.0	0	20
Feb. 19-26	8	0.5	0.2	3	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	0.0	0	0
Mar. 18-Apr. 14	70	1.5	0.0	0	0
					4,000

Soil: Helmick variant, moderately deep; slope: 6%; plot area: $10 m^2$.

Table 5-18--Runoff and gross erosion from plot E4S1 in 1979-80; upslope position.

Storm period	Rainfall		Runoff		Gross erosion
	Total for period	Maximum intensity			
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	38	3.0	7.8	21	590
Oct. 25-Nov. 2	40	1.3	0.8	2	90
Nov. 2-26	93	1.8	13.4	14	120
Nov. 26-Dec. 3	39	3.8	1.6	4	370
Dec. 3-10	22	1.3	2.4	11	190
Dec. 10-17	24	2.5	3.0	13	200
Dec. 17-26	57	2.3	24.2	43	780
Dec. 26-Jan. 1, 1980	23	1.0	7.8	34	230
Jan. 1-8	23	1.0	2.2	7	70
Jan. 8-15	95	2.0	25.6	27	2,270
Jan. 15-Feb. 5	34	0.8	3.7	11	410
Feb. 5-19	32	1.8	1.5	5	70
Feb. 19-26	8	0.5	0.0	0	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	0.9	2	0
Mar. 18-Apr. 14	70	1.5	1.5	2	0
					5,390

Soil: Helmick variant, moderately deep; slope: 8%; plot area: $50 m^2$.

Table 5-19--Runoff and gross erosion from plot E4S2 in 1979-80; downslope position.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm--	-%-	----kg/ha----
Oct. 22-25, 1979	39	3.0	plot not installed		
Oct. 25-Nov. 2	40	1.3	plot not installed		
Nov. 2-26	93	1.8	0.2	0	30
Nov. 26-Dec. 3	39	3.8	6.2	16	150
Dec. 3-10	22	1.3	0.6	3	30
Dec. 10-17	24	2.5	0.6	3	40
Dec. 17-26	57	2.3	4.4	8	80
Dec. 26-Jan. 1, 1980	23	1.0	1.5	7	30
Jan. 1-8	32	1.0	0.4	1	10
Jan. 8-15	95	2.0	5.3	6	3,260
Jan. 15-Feb. 5	34	0.8	2.8	8	220
Feb. 5-19	32	1.8	1.6	5	30
Feb. 19-26	8	0.5	0.0	0	0
Feb. 26-Mar. 4	20	0.3	0.0	0	0
Mar. 4-18	59	1.3	0.0	0	0
Mar. 18-Apr. 14	70	1.5	0.0	0	0

Soil: Helmick variant, moderately deep; slope: 8%; plot area: $50 m^2$.

CHAPTER 6. STORM RUNOFF AND SEDIMENT TRANSPORT

M. R. Parsons, J. D. Istok, and R. B. Brown

Summary

Prior weather patterns and antecedent moisture, by controlling the degree of soil saturation, have a strong influence on runoff and sediment yield. Storms which followed periods of low soil moisture saturation, generally resulted in small amounts of runoff. With increased soil saturation, runoff and sediment yield also increased. Storm "runoff energy" was a better predictor of sediment yield than rainfall factors (energy-intensity or "EI" values) in common use. An agricultural drain-line has proved successful in limiting "net" erosion (sediments passing through flumes) during all but the largest storms.

Introduction

Overland flow may be generated by two mechanisms. First, it may be "Hortonian" or "infiltration-excess" in which too much rain falls for the soil to absorb immediately. Hortonian overland flow is implicit in the Universal Soil Loss Equation (USLE). In the second case, saturation of the soil prevents further rapid infiltration, the rate of which is limited to the rate of sub-surface drainage, and is termed "Dunne" (Freeze, 1980) or "saturation-excess." This second process is important in areas with low rainfall intensities and high initial infiltration rates, and/or low soil moisture storage capacity. Such generation of overland flow is not accounted for in the USLE, though it has an equal potential for erosion.

On the basis of soil properties and weather patterns, one would expect the "saturation-excess" mechanism to be important in the Willamette Valley. Research by the Oregon Agricultural Experiment Station prior to initiation of the erosion research project had indicated the prevalence of saturated zones and subsurface flow in the region.

Application of the USLE, with its reliance on rainfall energy characteristics to conditions in the Willamette Valley, may give limited accuracy for sediment yield prediction. The theory behind the USLE suggests that, all other factors held constant, gross erosion in a storm should be a function of the storm's "EI" (total storm energy E, multiplied by maximum rainfall intensity I). The R factor of the USLE is derived by summation of storm EI values from weather records to obtain average annual EI, or R, for a given area (Wischmeier and Smith, 1978). Williams (1975), among other researchers, has contended that this theory is faulty because it ignores soil antecedent moisture content as a factor in the occurrence of runoff and erosion.

The erosion project has given major emphasis to runoff and erosion as they relate to soil moisture. This involves prior weather patterns (antecedent moisture), drainage characteristics of the soils, landscape positions, and the condition of the surface at the time of runoff. This chapter deals with the relationship of these factors to runoff and sediments passing through flumes at watershed outlets.

Materials and Methods

The design and installation of equipment used for flow measurement and water sampling are discussed in Chapter 3.

Results and Discussion

The three sub-watersheds respond quickly to changes in rainfall intensity (Figs. 6-1--6-11). Suspended sediment discharges closely parallel changes in storm runoff. Hydrograph peaks at the watershed outlet (E3C1) are broader than those of the sub-watersheds which is a result of their relative sizes. Storms which occur early in the season often do not result in runoff at the sub-watersheds, although flow at the watershed outlet may be considerable (Figs. 6-1, 6-2, 6-7).

Flow at the watershed outlet, in the absence of surface runoff demonstrates the importance of subsurface flow at Elkins Road. Maximum flow at E3C1 occurs when all sub-watersheds contribute runoff (Figs. 6-10, 6-11).

To illustrate relationships between antecedent moisture, rainfall intensity, runoff, and erosion, certain characteristics of the hydrographs are summarized in Table 6-1. The extent of soil saturation has a strong influence on determining runoff and sediment yield. Storms which followed periods of low soil moisture saturation, generally resulted in small amounts of runoff (Figs. 6-4--6-6, 6-9). With increased soil saturation, runoff and sediment yield also increased. This effect was small, however, for E1F1 which contains a greater extent of well-drained soils than sub-watershed E4F1.

Storms which had a maximum rainfall intensity of less than 1 mm/15 min had small to moderate runoff (Table 6-1). Large amounts of runoff and sediment yield generally occurred when rainfall intensity exceeded 2.0 mm/15 min., but this was not always the case. For example, storms on Jan. 5, 1978 and Jan. 11, 1980 each had maximum rainfall intensities of 2 mm/15 min. but had considerably different runoff and sediment yields. In dealing with prediction of sediment yield from small watersheds, Williams (1975) has found that the "runoff energy" (total storm runoff, Q, multiplied by peak storm runoff, q_p, or "$Q \times q_p$") of a storm gives more accurate prediction of watershed sediment yield than does EI. In the present study, a comparison of EI and $Q \times q_p$ for sediment yield prediction was made using storm data from the 1977-78 and 1978-79 rainfall seasons (Table 6-2). Total watershed sediment yield (T) was found to give a better correlation with $Q \times q_p$ than either 6-hour or 30-minute EI.

In the first season of observation, the drainline has proved successful in limiting sediment loss through the flume in all but the largest storm events. Sediment yields from the sub-watershed for similar storms before and after drainage show a marked decline post installation (Figs. 6-1, 6-10). The effect of the drainline on surface hydrographs is to a) lower peak flows, b) increase response time (time to peak) and c) reduce base flow. Drainline hydrographs (E4V1) exhibit a low broad peak and a long recession limb, which indicates continued removal of soil moisture even after rainfall has ceased. When surface runoff and sediment transport did occur, part of the sediment movement can be attributed to erosion of disturbed soil above the main drainline. We expect this effect to be minimal in the future.

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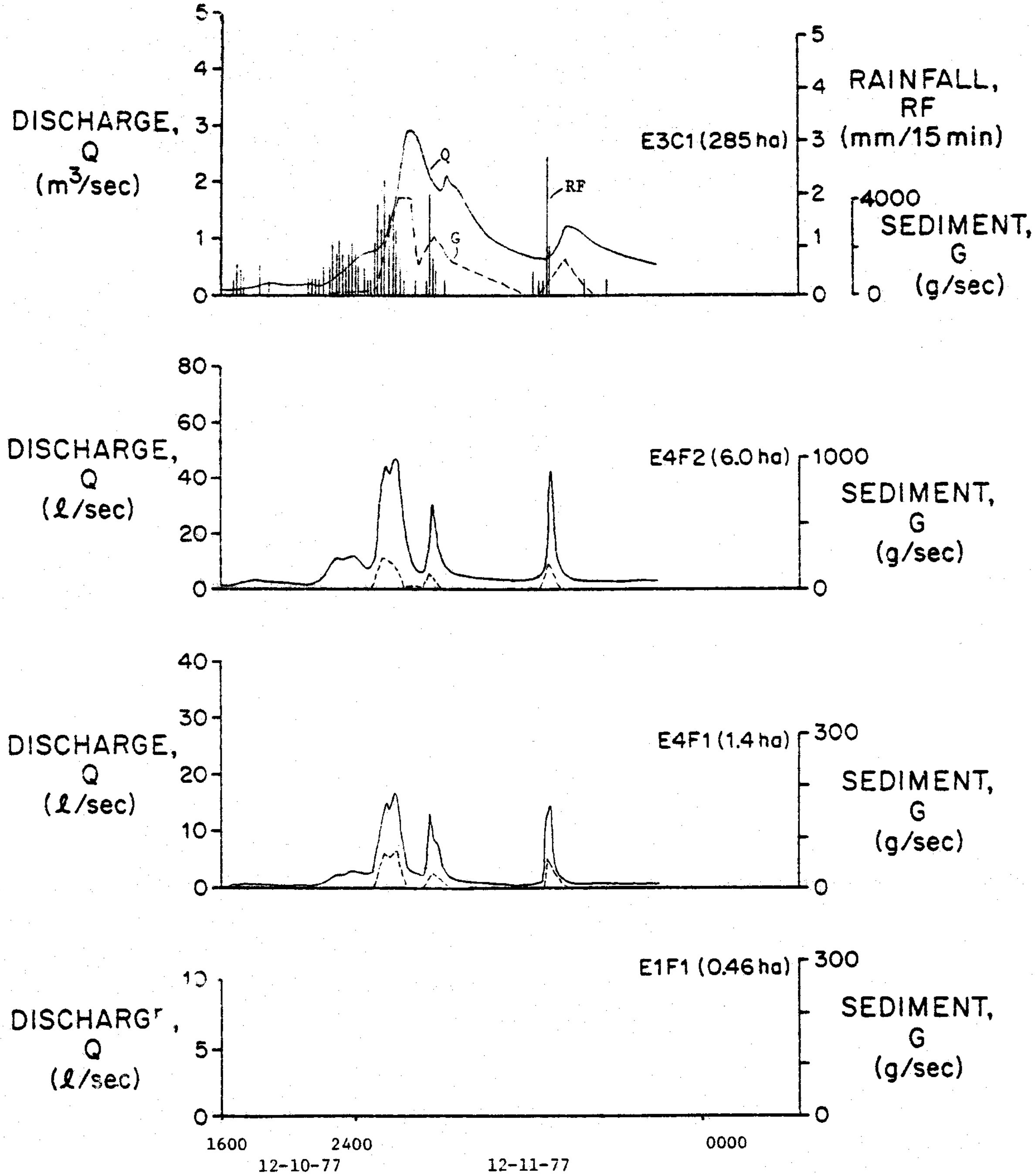

Fig. 6-1. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

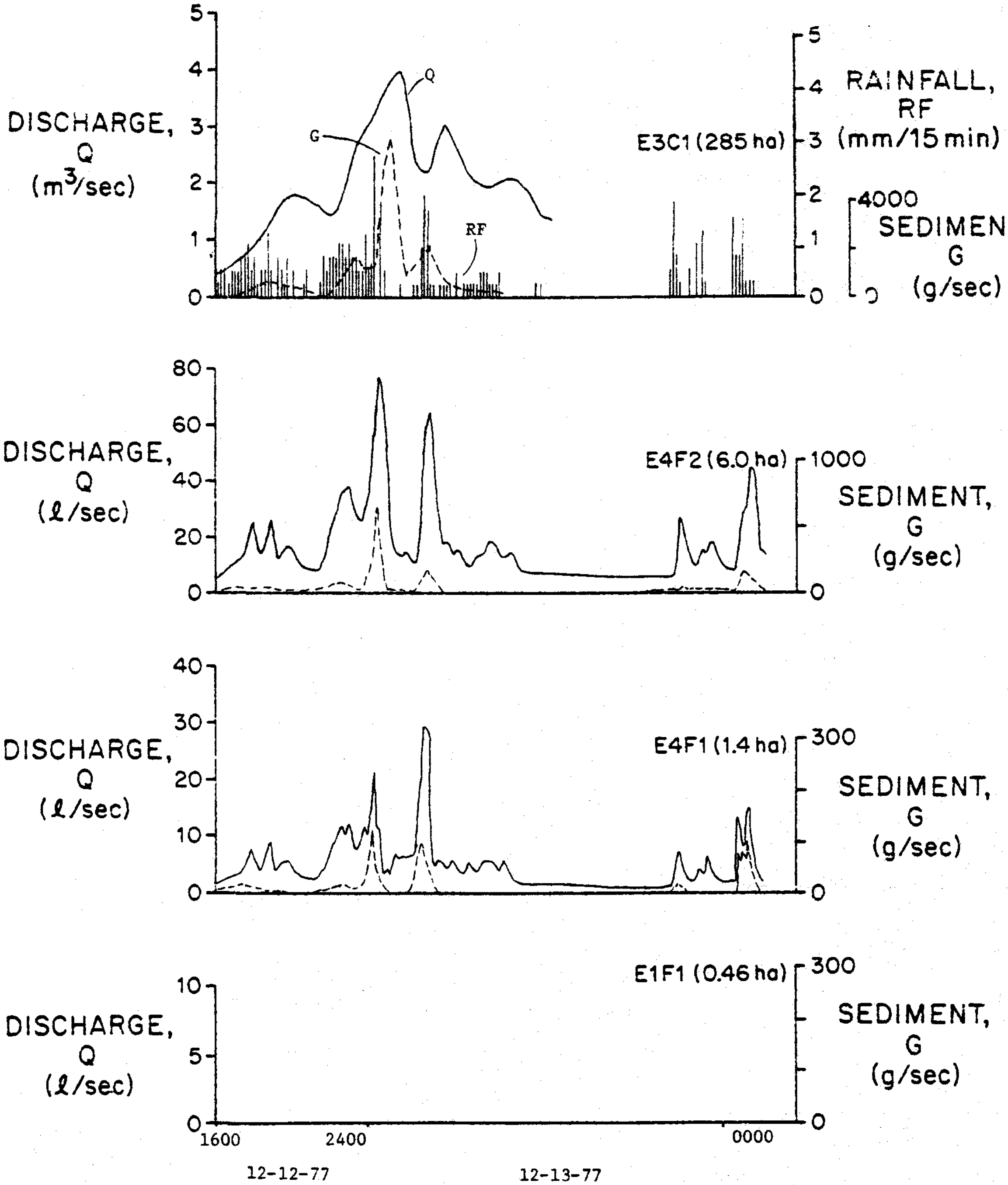

Fig. 6-2. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

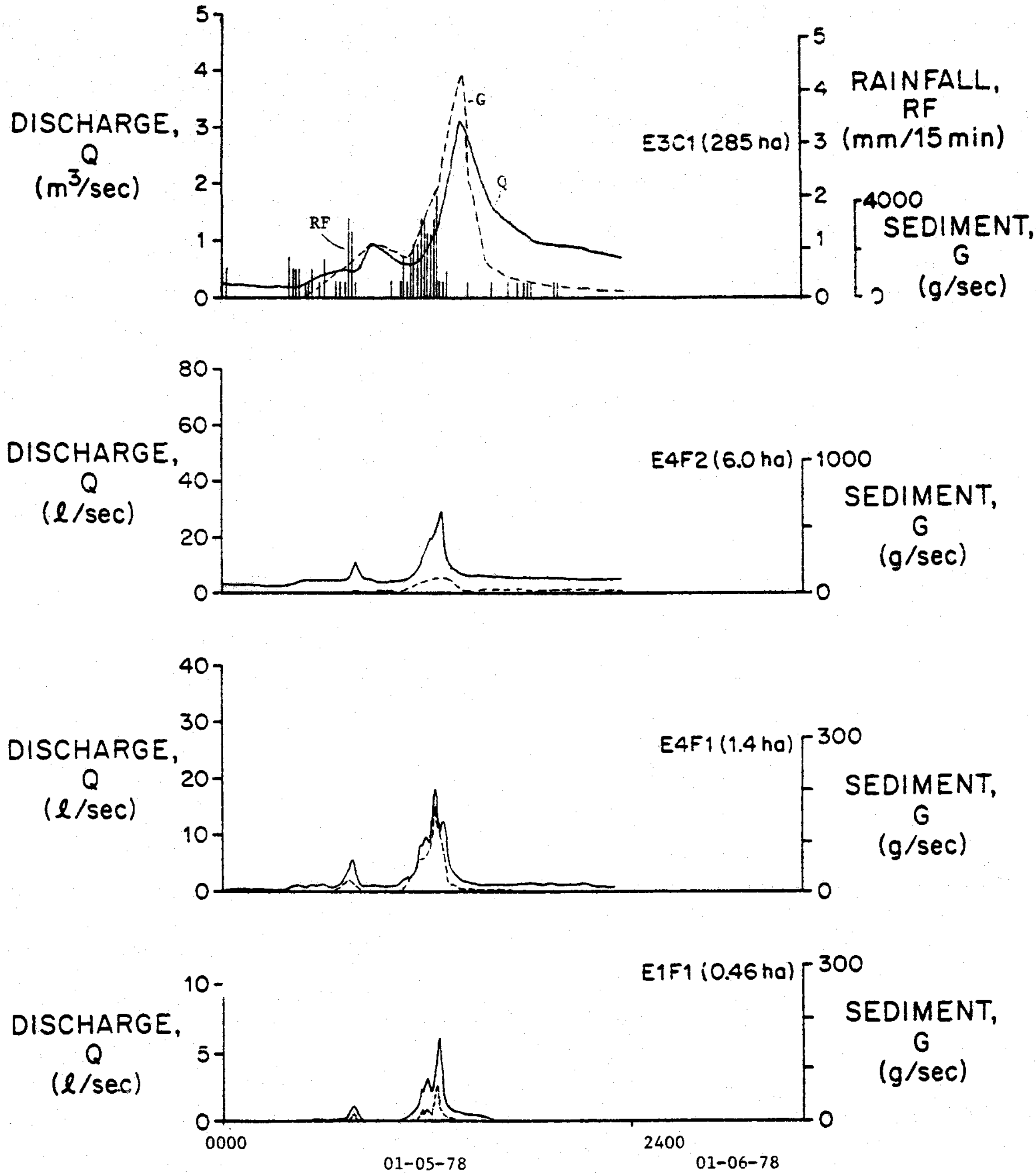

Fig. 6-3. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E1F1, E1F1).

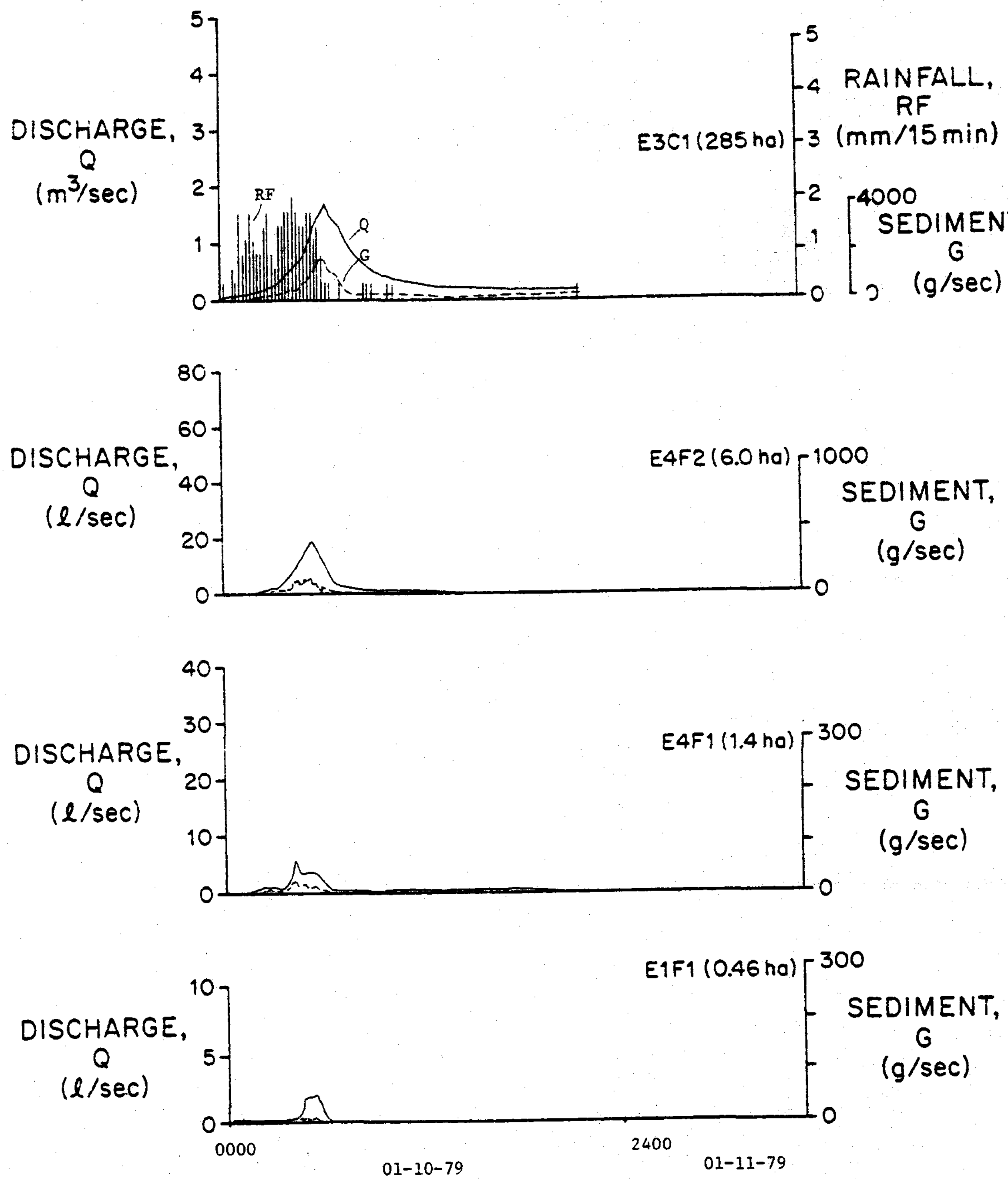

Fig. 6-4. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

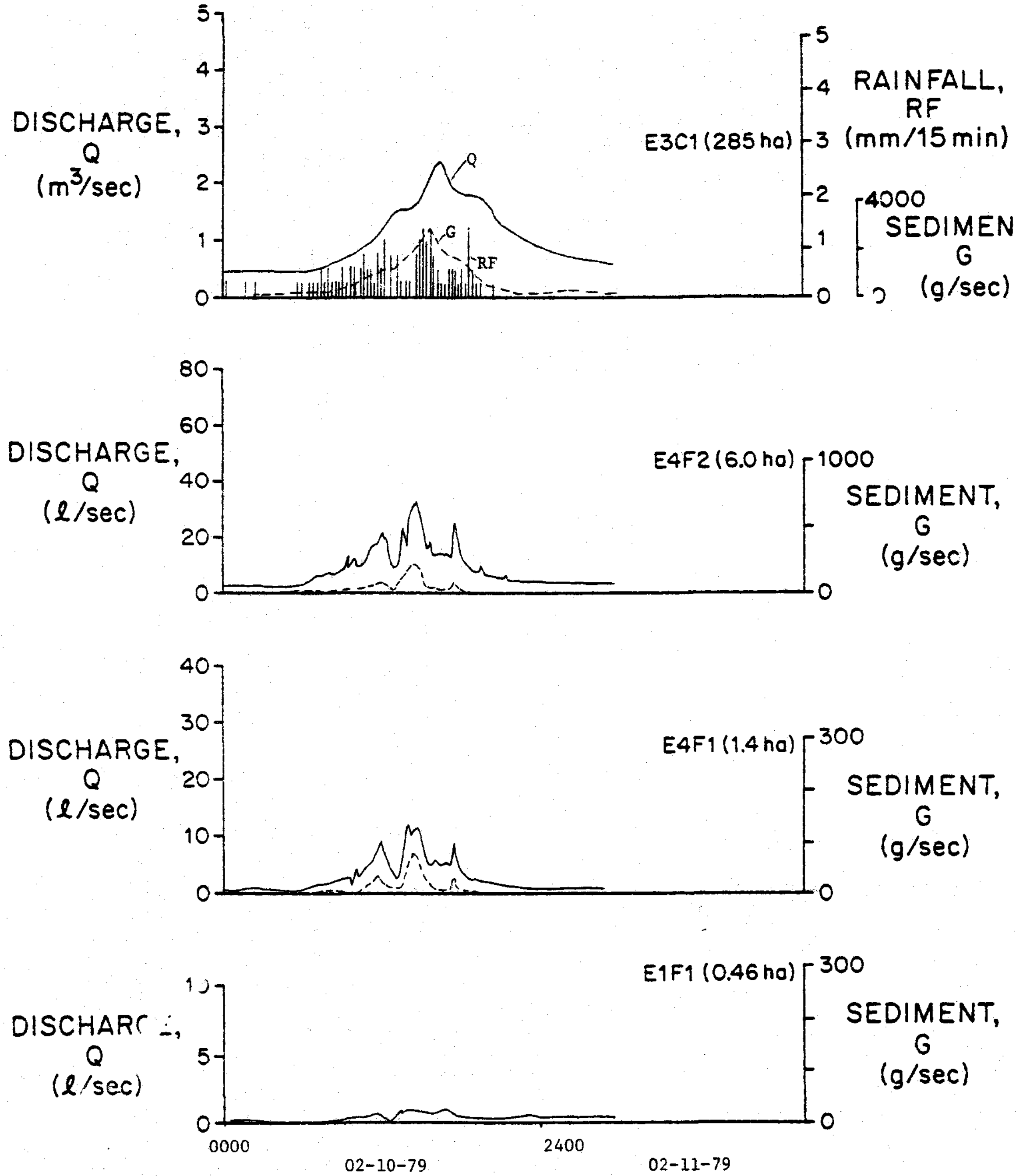

Fig. 6-5. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

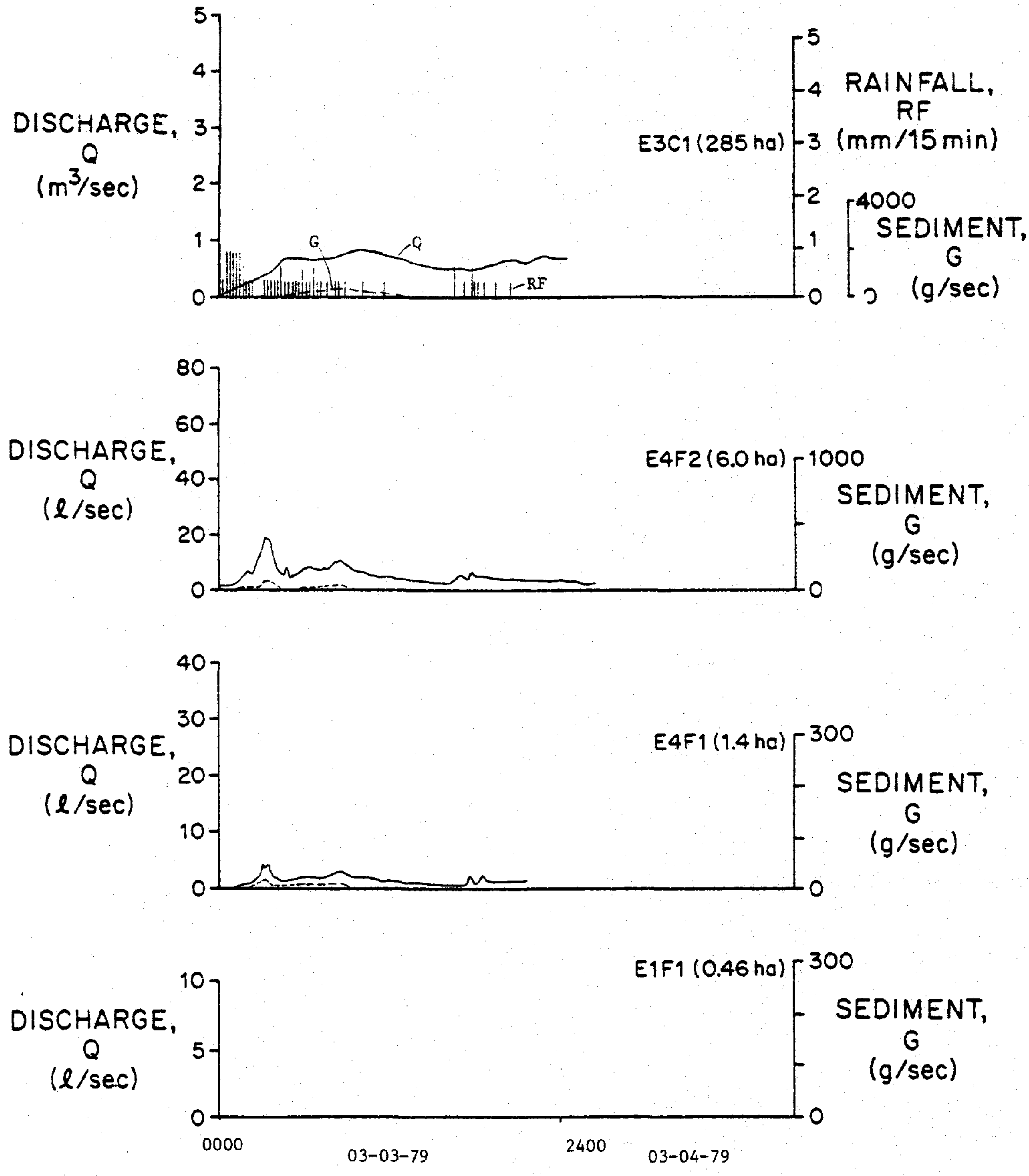

Fig. 6-6. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

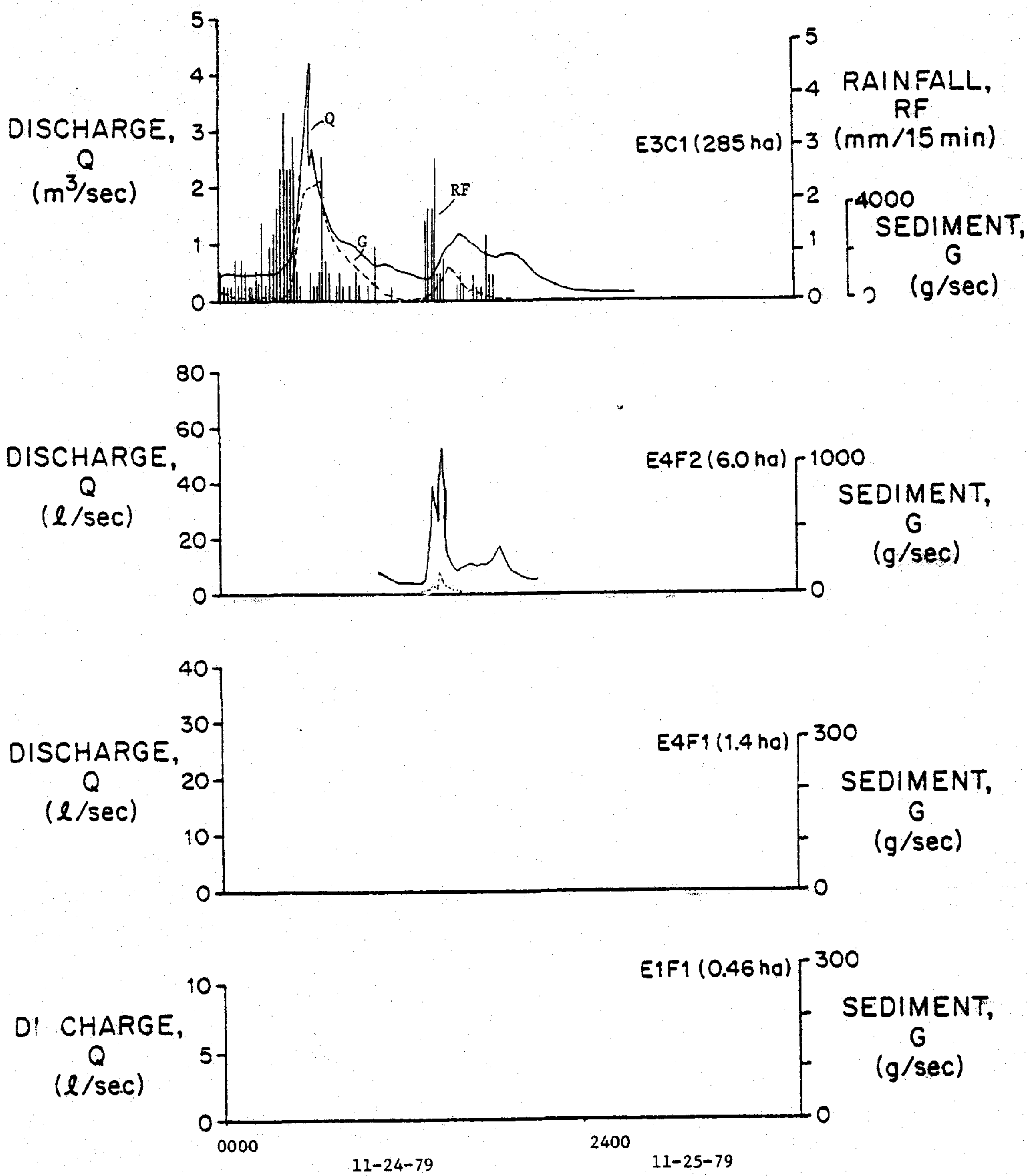

Fig. 6-7. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

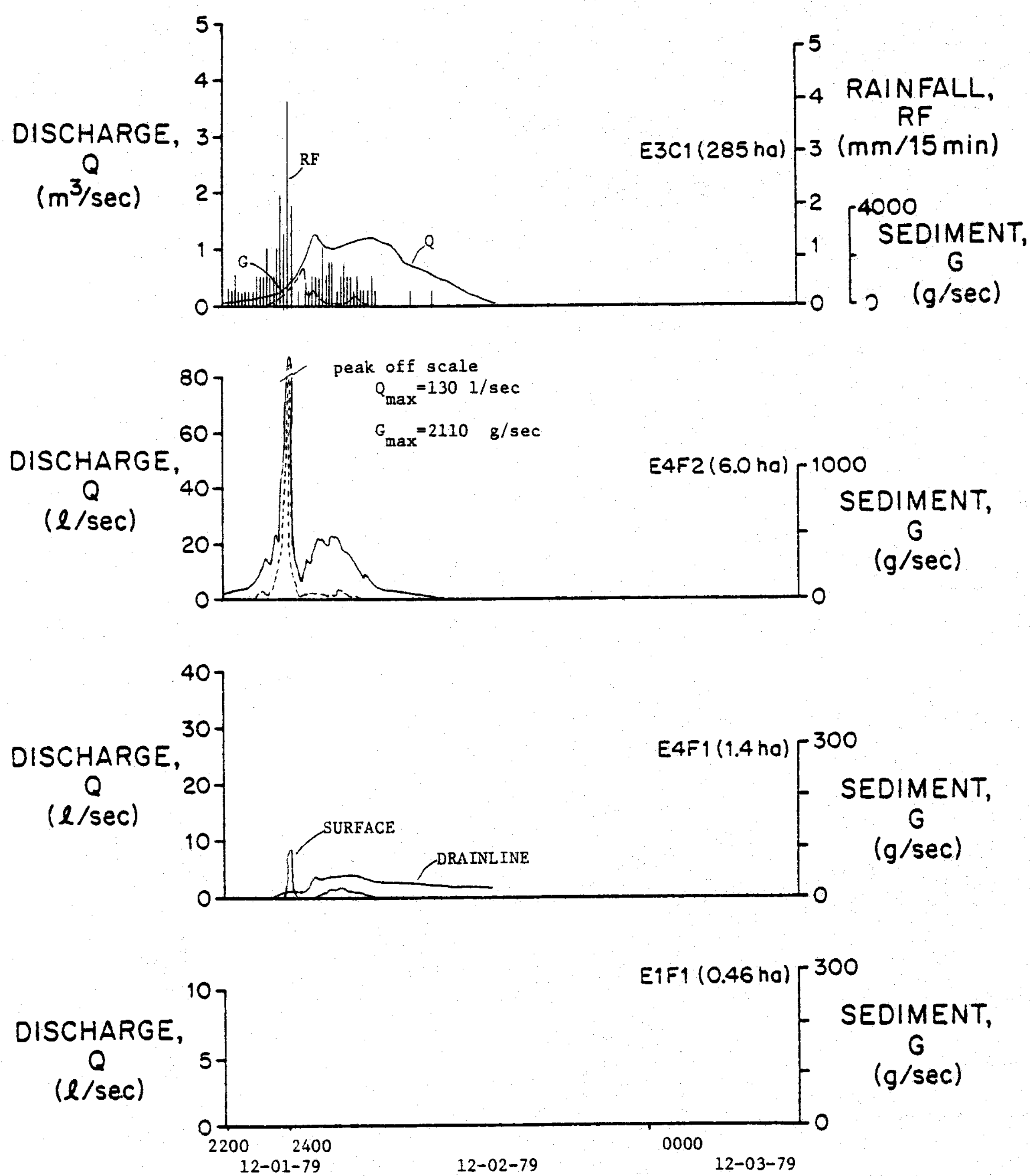

Fig. 6-8. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

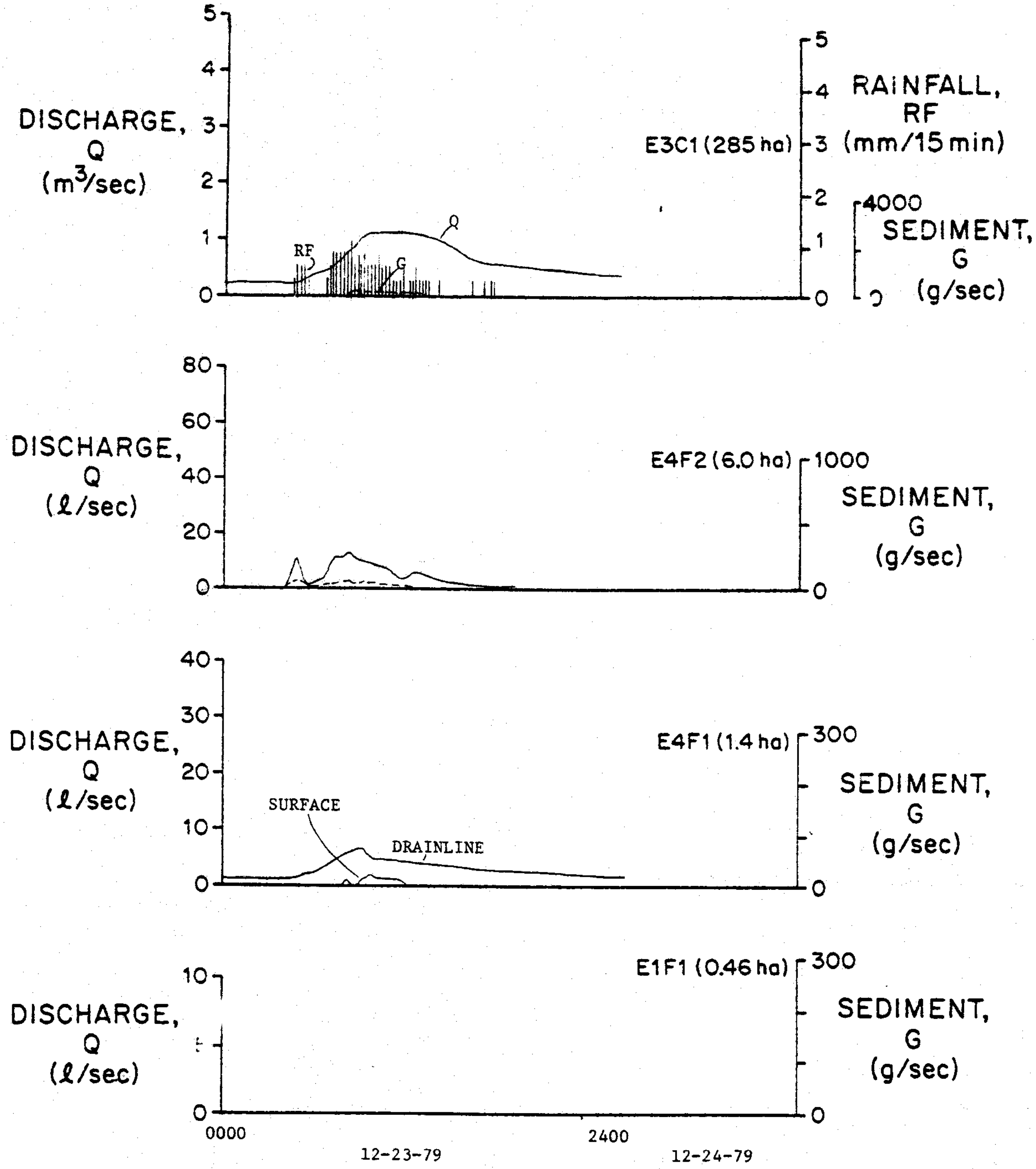

Fig. 6-9. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

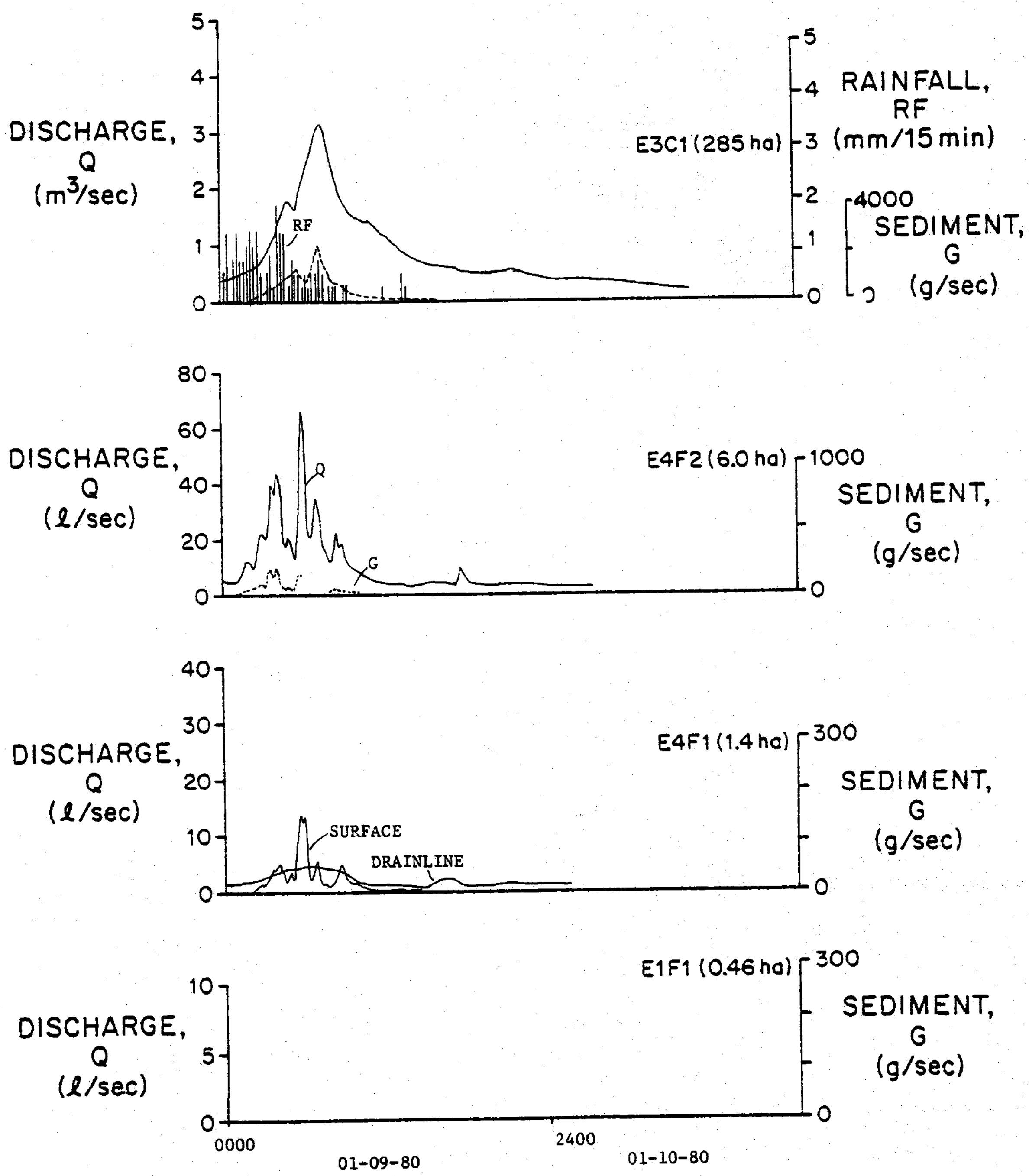

Fig. 6-10. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

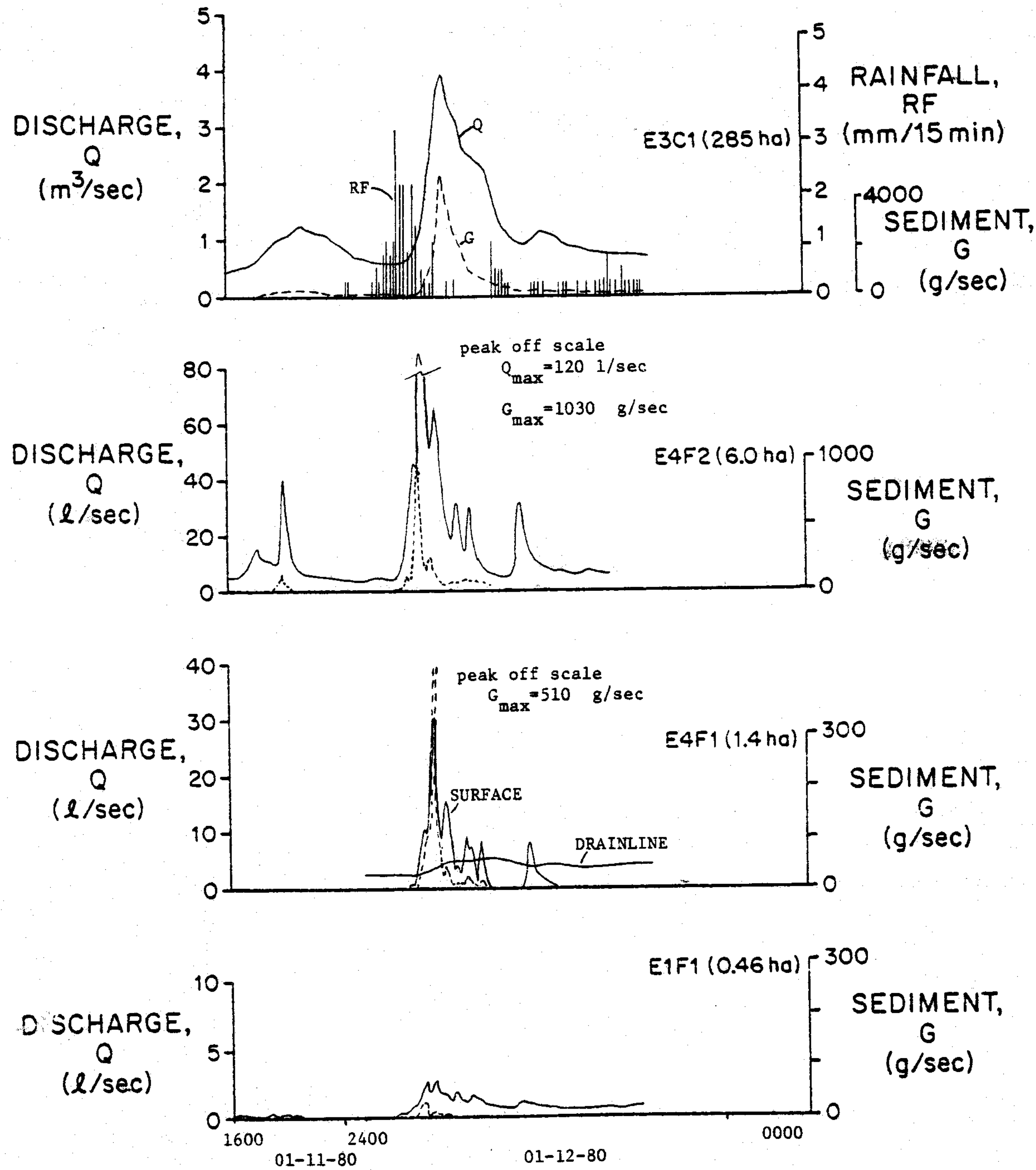

Fig. 6-11. Rainfall, runoff and sediment yield from the main watershed (E3C1) and three sub-watersheds (E4F2, E4F1, E1F1).

Table 6-1--Comparison of storm runoff and sediment yield with soil condition and rainfall intensity.†

		Runoff event size				Maximum rainfall intensity		Sediment yield			
Fig.	Date	E3C1 285 ha	E4F2 6.0 ha	E4F1 1.4 ha	E1F1 0.46 ha	mm/15 min	Soil condition‡	E3C1 285 ha	E4F2 6.0 ha	E4F1 1.5 ha	E1F1 0.46 ha
	1977-78										
6-1	Dec. 10	Moderate	Moderate	Moderate	0	2.8	Partial saturation	Small	Small	Small	0
6-2	Dec. 13	Large	Large	Large	0	2.7	Saturation	Moderate	Moderate	Small	0
6-3	Jan. 5	Moderate	Moderate	Small	Moderate	2.0	Partial saturation	Large	Small	Moderate	Small
6-4	Jan. 10	Small	Small	Small	Small	0.8	Low saturation	Small	Small	Small	Small
	1978-79										
6-5	Feb. 10	Moderate	Moderate	Moderate	Small	0.8	Low saturation	Small	Small	Small	Small
6-6	Mar. 3	Small	Small	Small	0	1.2	Low saturation	Small	Small	Small	N/D
	1979-80										
6-7	Nov. 24	Large	Moderate/ N/D	N/D§	0	3.3	Partial saturation	Moderate	Moderate	N/D	0
6-8	Dec. 1	Small	Large	Small	0	3.8	Partial saturation	Moderate	Very large	Moderate	0
6-9	Dec. 23	Small	Small	Small	0	2.3	Low saturation	Small	Small	0	0
6-10	Jan. 9	Large	Large	Moderate	N/D	2.0	Partial saturation	Moderate	Large	Moderate	Small
6-11	Jan. 11	Large	Large	Large	Moderate	2.0	Saturation	Moderate	Very large	Moderate	Moderate

†"Runoff event size" and "Sediment yield" are based on limited calculations from the hydrographs.

‡"Soil condition" is a general description of the soil moisture status of the watershed prior to the storm. Actual values of the water elevations and pore water pressures are given in Chapter 8.

§"N/D" No data available.

Table 6-2—Regressions of watershed sediment yield on "6-hr EI," "30-min EI," and "runoff energy factor" for three sub-watersheds, Elkins Road Watershed, Oregon.

Watershed	Number of storms (n)	Least Squares Regression Equation†	r^2
E1F1 (0.46 ha)	4	$T = 0.04(EI_6)^{0.01}$	0.00
	4	$T = 0.01 + 0.03(EI_{30})$	0.06
	4	$T = 17.16(Qxq_p)^{0.83}$	0.86
E4F1 (1.4 ha)	17	$T = 0.36(EI_6)^{0.52}$	0.16
	17	$T = 0.40(EI_{30})^{0.67}$	0.34**
	17	$T = 2.78(Qxq_p)^{0.58}$	0.72*
E4F2 (6 ha)	16	$T = 0.24 + 2.14(EI_6)$	0.51*
	16	$T = 0.25 + 0.91(EI_{30})$	0.69*
	16	$T = 2.52(Qxq_p)^{0.73}$	0.78*

†T = total watershed sediment yield per storm.
EI_6 = storm "6-hr EI" (Wischmeier and Smith, 1978).
EI_{30} = storm "30-min EI" (Wischmeier and Smith, 1978).
Qxq_p = storm "runoff energy factor" (Williams, 1975).
**r significant at 5% level.
*r significant at 1% level.

CHAPTER 7. EROSION AND SEDIMENT AS INDICATED BY REDISTRIBUTION OF CESIUM-137[1]

R. B. Brown and G. F. Kling

Summary

Cesium-137, an atmospheric contaminant of nuclear testing, has provided an effective means of assessing long term erosion and redeposition on the Elkins Road watershed. Long term erosion rates fall in the range of 1 to 12 tons/acre/yr. These rates are consistent with short term measurements made with erosion plots. The data also show that toeslopes are active portions of the landscape, serving as both temporary storage sites of eroded sediment and source areas for active erosion. Sideslopes and stable ridgetops, however, show no detectable difference in erosion rates.

Introduction

The main thrust of the erosion research effort at Elkins Road Watershed has involved storm-to-storm, year-to-year monitoring of watershed hydrology, erosion-related soil moisture phenomena, erosion rates, and watershed sediment discharge rates.

In addition to this approach, it was desired from the onset of the project that some technique be found by which erosion/deposition rates could be assessed on the watershed for all or most of the post-World War II period. In the absence of carbon dates, buried artifacts, appropriate stratigraphic markers, and monuments in depositional zones, it was thought that tracing the redistribution of radioactive fallout might be a feasible approach.

Use of fallout radionuclides as indicators of sedimentation rates (McHenry et al., 1973; Ritchie et al., 1975; Pennington et al., 1976) and erosion rates (Menzel, 1960; Ritchie et al., 1974; Ritchie and McHenry, 1975; McHenry and Ritchie, 1977) has become a more and more widely, frequently used practice in the 1960s and 70s.

Liaison was established in 1978 between the OSU erosion project and Dr. N. H. Cutshall of the Environmental Sciences Division at Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. Dr. Cutshall agreed to cooperate in an attempt to evaluate postwar erosion at Elkins Road watershed through an analysis of the redistribution of fallout cesium-137 (^{137}Cs). Dr. Cutshall's principal role in the study was to arrange and oversee the analysis of up to 125 soil samples for ^{137}Cs activity.

Sediment surveys and reservoirs of known trap efficiency are lacking at Elkins Road watershed. Also, virtually the entire landscape of

[1]All material in this section has been excerpted or condensed from Brown (1980).

interest has been in cultivation for at least part of the period of fallout input and thus has a disturbed surface soil and ^{137}Cs profile. It was expected, therefore, that interpretation of ^{137}Cs measurements would be difficult. This expectation along with the overall limit on number of analyses necessitated the establishment of realistic, modest goals. The following principal objectives were developed: (1) identify, based on areal concentration and depth distribution of ^{137}Cs, parts of the landscape of Elkins Road watershed most severely eroded over the period of input of radioactive fallout, (2) identify, based also on ^{137}Cs signatures, parts of the landscape subject to deposition over the same period, and (3) contingent on the degree of success in meeting one or both of the first two objectives, quantify erosion rates over the period of fallout input.

Materials and Methods

Along each of eight transects representing a variety of elevations, slope aspects, and slope gradients, sample sites were selected in ridgetop, steep sideslope, and concave footslope areas. Also sampled were a single convex ridge shoulder, a high ridgetop, two fencerow-controlled alluvial fans, two sites on a floodplain, and two sites in a farm pond built in 1971 (Fig. 7-1, Table 7-1). Replicate soil cores were collected within a small (<2 m^2) area at each of the 32 sampling sites. Cores were cut into depth increments of 7.5, 10, or 15 cm increments. Corresponding increments from replicates at each site were combined. Samples were analyzed at Oak Ridge National Laboratory for ^{137}Cs activity.

Results and Discussion

Patterns of depth distribution of ^{137}Cs activity suggested strongly that ^{137}Cs had been retained in surface soils on the watershed (Table 7-2). This is consistent with results obtained by other investigators on soils of the eastern United States (McHenry and Ritchies, 1977). Therefore, ^{137}Cs is a good tracer for our erosion and sediment study.

Cesium-137 signatures (depth distributions) of sideslope sites and those of ridgetop sites were, on the average, indistinguishable from each other (Fig. 7-2, Tables 7-3 and 7-4). Depositional sites, in contrast with both sideslopes and ridgetops, tended to have overthickened ^{137}Cs profiles and high total contents of ^{137}Cs. Average total ^{137}Cs activity in depositional sites was about 12 pCi/cm^2. In sideslopes and ridgetops it was about 8 pCi/cm^2.

Concave footslope positions are important zones of sediment storage. Two of eight footslopes sampled (CS16 and CS25) had ^{137}Cs signatures that did not reflect deposition. This suggests that both deposition and re-entrainment occur in footslope positions (Table 7-2).

The two alluvial fans sampled (CS7 and CS19) had strongly depositional ^{137}Cs signatures, but contained much less total sediment than did upstream footslopes. The two floodplain sites (CS20 and CS28) had not experienced net detectable deposition over the fallout period, which was indicative of a diffuse, thin spreading of sediment in the wide floodplain zone. Sites in the eight-year-old pond (CS24 and CS35) were marginally to strongly depositional (Table 7-2).

Two different approaches, "volumetric" and "gravimetric," were used to estimate post-1954 erosion rates in two nested watersheds, designated WCS7 (13 ha) and E4F2 (6 ha) (Fig. 7-3 and 7-4). The "volumetric" approach involved calculation of the volume and mass of sediment currently residing in depositional zones, based on areal extent of the zone and depth of occurrence of ^{137}Cs in the zone. Erosion rate estimates by this technique ranged from 3 to 14 mTon/ha/yr (1 to 6 T/a/yr) (Table 7-5).

The "gravimetric" approach involved algebraic manipulation of measured areal concentrations of ^{137}Cs activity in depositional and non-depositional zones, to obtain estimates of the amount of depletion of fallout ^{137}Cs that had occurred in upland zones. Conversion of the ^{137}Cs loss to sediment loss yielded soil loss estimates ranging from 6 to 27 mTon/ha/yr (3 to 12 T/a/yr) (Table 7-5).

Imprecision in these estimates is great. But the estimates do indicate strongly that modern erosion rates, while not spectacular, warrant the use of appropriate conservation measures in hilly croplands of the region.

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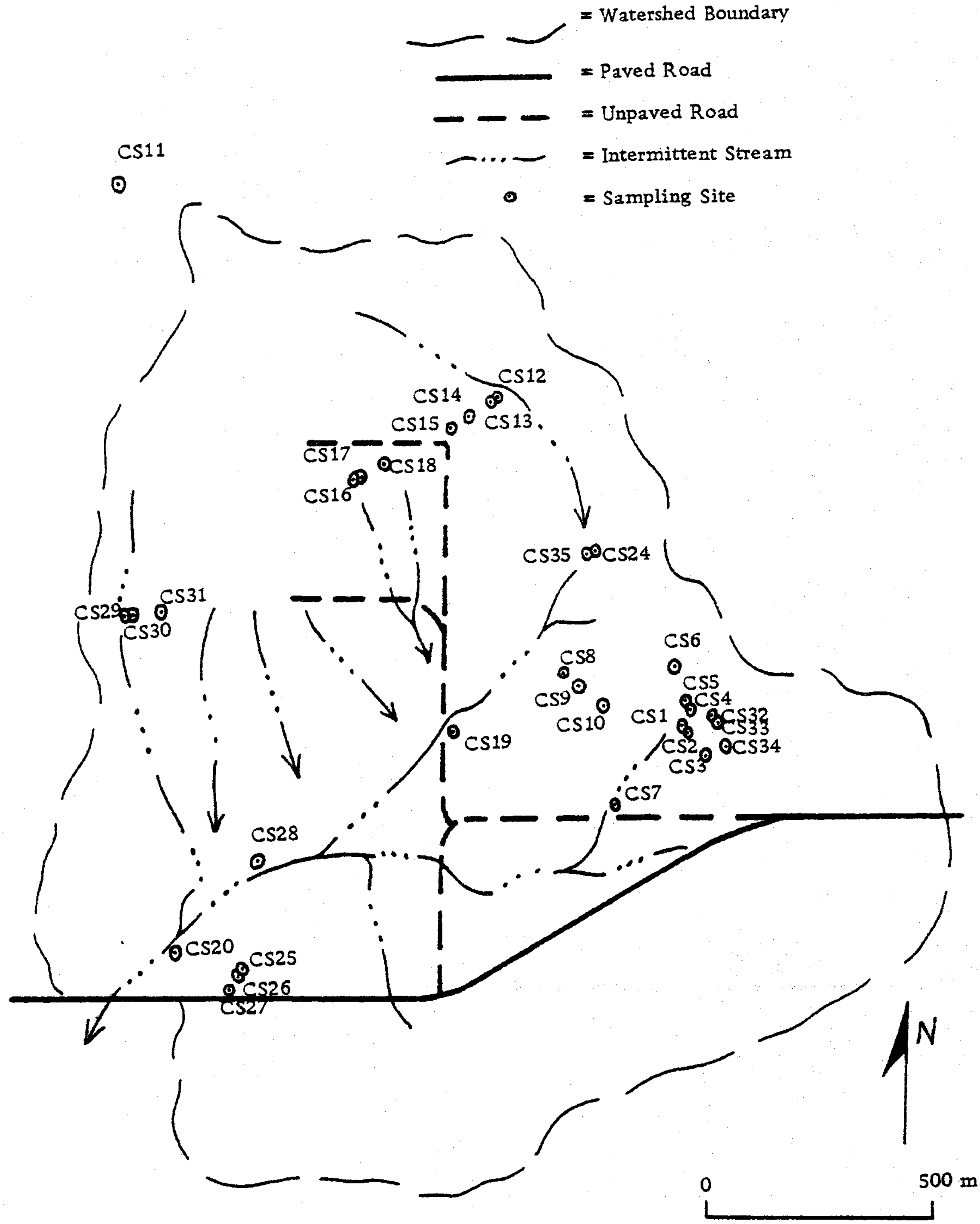

Fig. 7-1--Locations of sampling sites for ^{137}Cs activity, Elkins Road Watershed, Oregon.

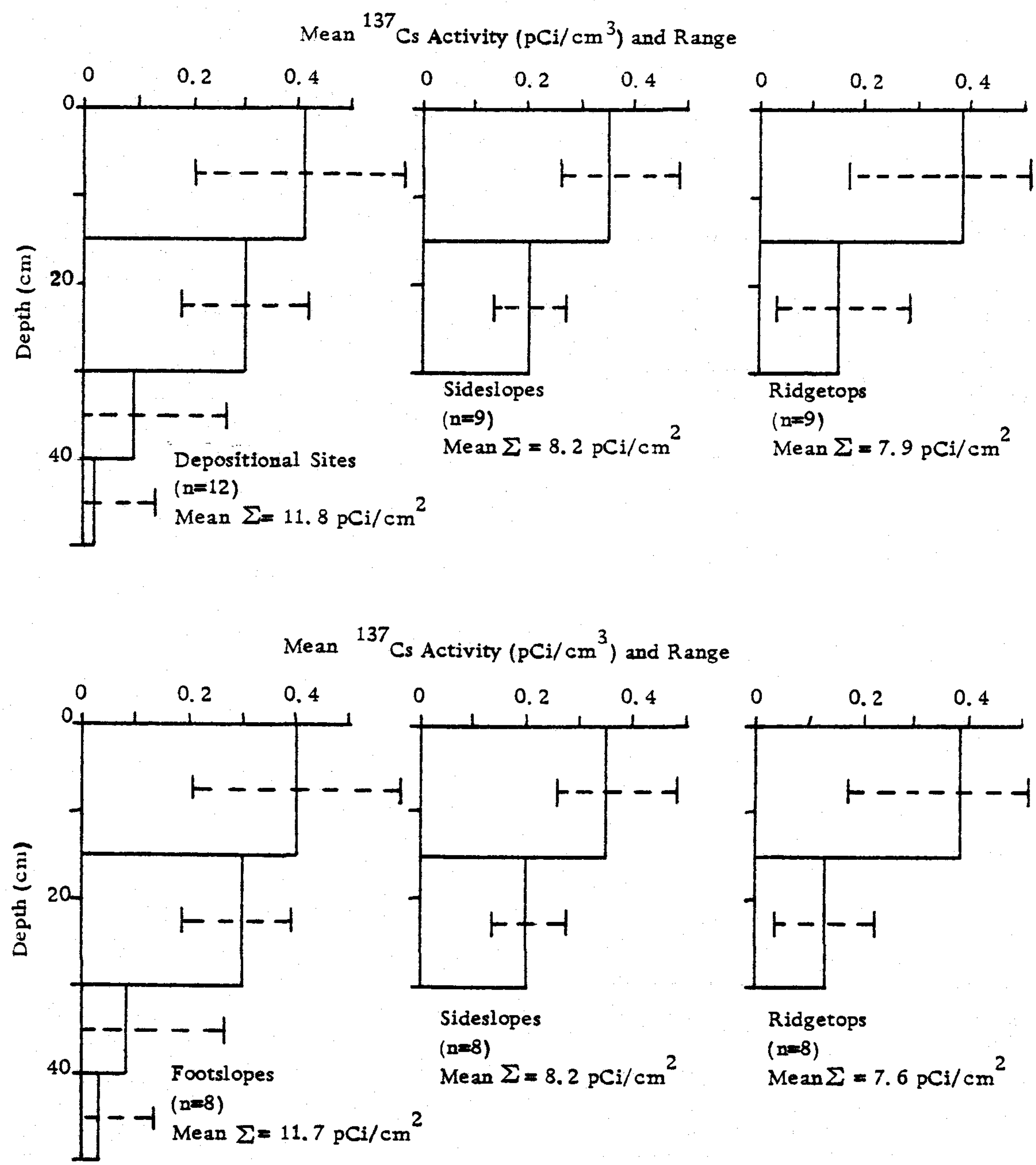

Fig. 7-[illegible]--Depth distributions of mean ^{137}Cs activity for all sites except pond (upper three histograms), and for sites along eight sample transects (lower three histograms) at Elkins Road Watershed, Oregon. For each histogram, the sum of the areas within the bars (cmxpCi/cm^3) equals mean Σ(pCi/cm^2). Dashed lines indicate range of values found.

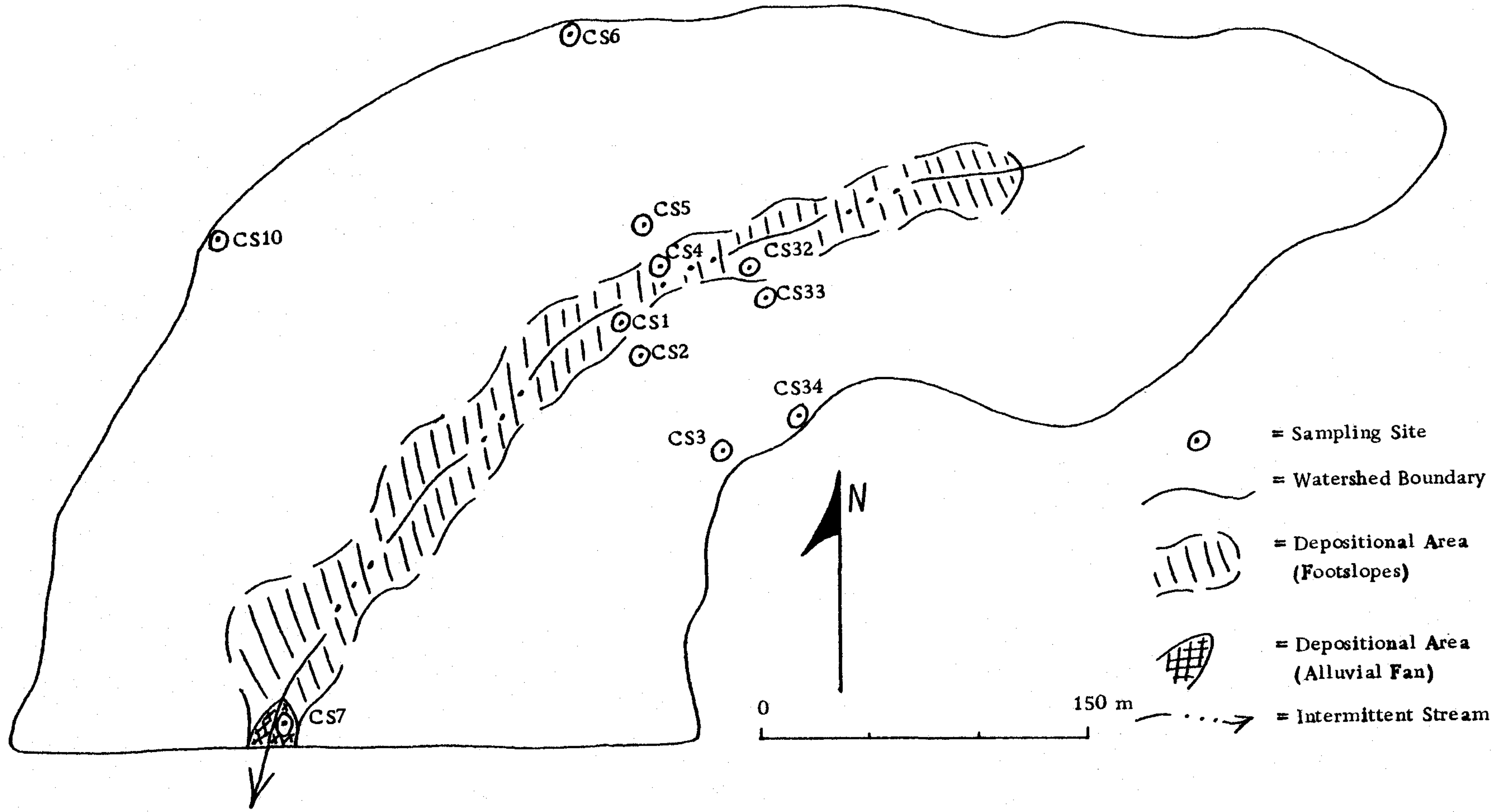

Fig. 7-3--Plan view of watershed WCS7, Elkins Road Watershed, Oregon, showing sampling sites and boundaries of depositional areas. Watershed WCS7 includes watershed E4F2.

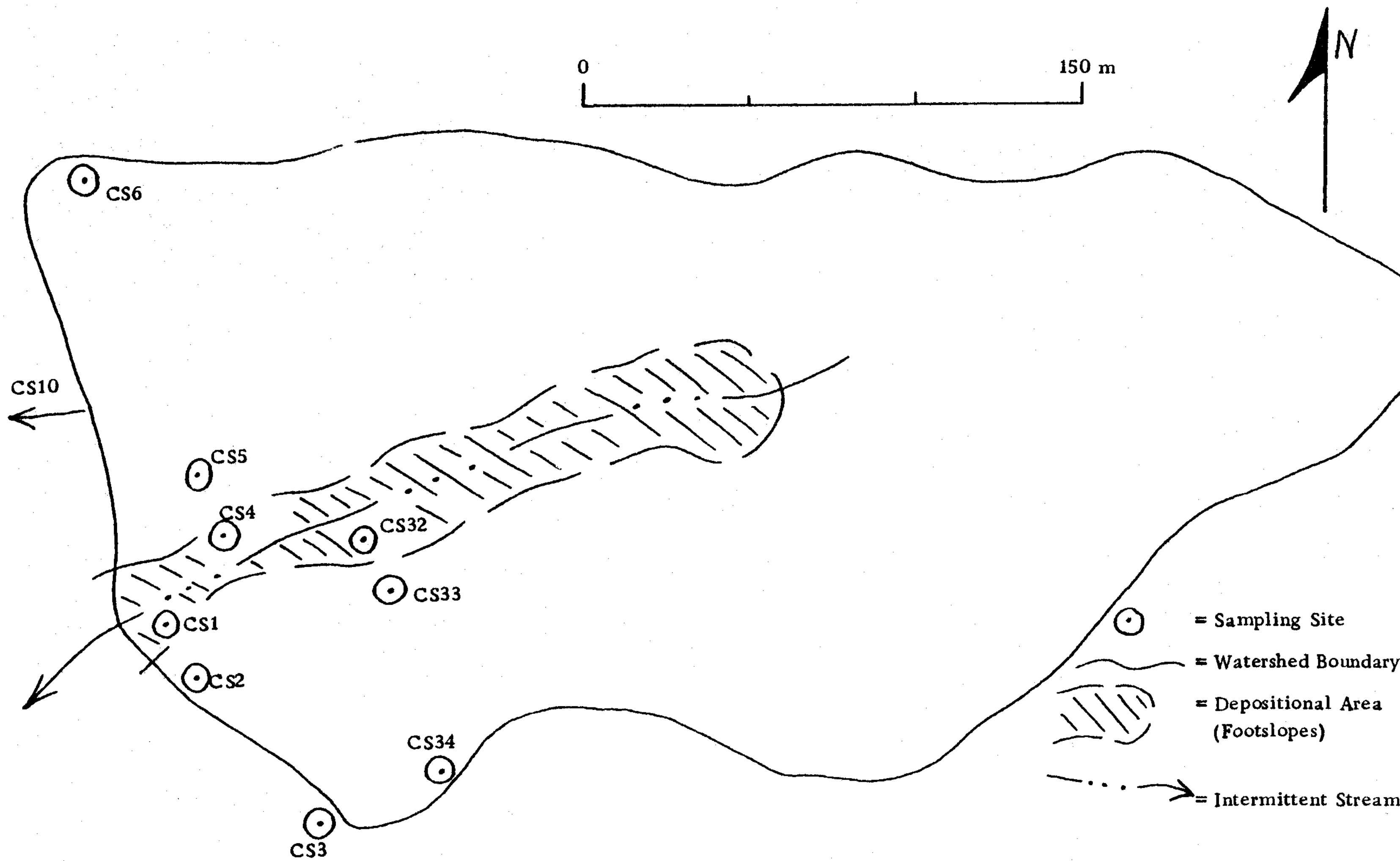

Fig. 7-4--Plan view of watershed E4F2, Elkins Road Watershed, Oregon, showing sampling sites and boundary of depositional areas.

Table 7-1--Site characteristics and dates of sampling for ^{137}Cs activity in soils at Elkins Road Watershed, Oregon.

	Site Designation	Type Landscape Position	Slope %	Slope (Aspect)	Land Shape # Radial	Land Shape # Contour	Elevation (m)	Land Use at Time of Sampling	Number of Cores Collected and Lumped^{+}	Date of Sampling
Transect	CS1	Footslope	6	NW	Concave	Convex	89	Ann. Ryegrass Stubble	2	8-78
Transect	CS2	Sideslope	11	NW	Smooth	Convex	91	"	"	"
Transect	CS3	Ridgetop	1.5	WSW	Smooth	Convex	95	"	"	"
Transect	CS4	Footslope	7	SSE	Concave	Concave	90	"	"	"
Transect	CS5	Sideslope	11	SSE	Convex	Convex	92	"	"	"
Transect	CS6	Ridgetop	2	E	Convex	Convex	97	"	"	"
	CS7	Alluvial Fan	0.5	SW	Smooth	Convex	84	"	"	"
Transect	CS8	Footslope	5.5	NW	Concave	Concave	83	"	"	"
Transect	CS9	Sideslope	15.5	NW	Smooth	Irregular	87	"	"	"
Transect	CS10	Ridgetop	3.5	SW	Smooth	Convex	95	"	"	"
	CS11	Ridgetop	2	SSW	Convex	Convex	155	Hay Stubble and Pasture	"	"
Transect	CS12	Footslope	6.5	NE	Concave	Smooth	99	Annual Ryegrass Stubble	"	"
Transect	CS13	Sideslope	13	NE	Smooth	Concave	102	"	"	"
Transect	CS14	Ridge Shoulder	10	NE	Convex	Irregular	107	"	"	"
Transect	CS15	Ridgetop	5	E	Convex	Convex	110	"	"	"

Table 7-1--continued.

	Site Designation	Type Landscape Position	Slope %	Slope (Aspect)	Land Shape# Radial	Land Shape# Contour	Elevation (m)	Land Use at Time of Sampling	Number of Cores Collected and Lumped+	Date of Sampling
Transect	CS16	Footslope	8	WSW	Concave	Concave	103	Per. Grass, New Seeding	2	8-78
Transect	CS17	Sideslope	15	WSW	Concave	Concave	105	"	"	"
Transect	CS18	Ridgetop	6	S	Convex	Convex	110	"	"	"
	CS19	Alluvial Fan	2	NW	Convex	Convex	75	Weeds	"	"
	CS20	Floodplain	2	NW	Irregular	Irregular	68	Per. Grass	"	"
	CS24	Pond, Above Low Water Line	(Not Determined)		Concave	Concave	84	Wetland Vegetation	"	"
Transect	CS25	Footslope	4	NE	Concave	Smooth	72	Per. Grass	"	10-78
Transect	CS26	Sideslope	8	NE	Smooth	Smooth	73	"	"	"
Transect	CS27	Ridgetop	2	NNW	Concave	Convex	75	"	"	"
	CS28	Floodplain	2	N	(Concave Overflow Channel)		70	"	"	"
Transect	CS29	Footslope	6	W	Concave	Concave	88	Wheat Stubble	"	"
Transect	CS30	Sideslope	17.5	W	Smooth	Smooth	89	"	"	"
Transect	CS31	Ridgetop	3.5	SSW	Irregular	Irregular	95	"	"	"

Table 7-1--continued.

Site Designation	Type Landscape Position	Slope %	Slope (Aspect)	Land Shape# Radial	Land Shape# Contour	Elevation (m)	Land Use at Time of Sampling	Number of Cores Collected and Lumped+	Date of Sampling
Transect CS32	Footslope	3	NNW	Concave	Concave	90	Wheat Stubble	3	8-79
Transect CS33	Sideslope	9	NNW	Smooth	Concave	92	"	"	"
Transect CS34	Ridgetop	1	W	Convex	Convex	96	"	"	"
CS35	Pond, Below Low Water Line	(NA)	(NA)	(Concave Pond Bottom)		81	Pond	9	10-79

#Land shape terminology after Troeh (1964).

+All cores except those at site CS35 collected with a hydraulic probe having a 7.6-cm coring tube. Cores collected at site CS35 with a hand-held corer having a 5.1-cm coring tube.

Table 7-2--Cesium-137 activities per unit weight and per unit area for cores and depth increments at Elkins Road Watershed.

Depth (cm)	Raw ^{137}Cs Activity on wt. basis (pCi/g_{sample})	^{137}Cs Activity on oven dry basis ($pCi/g_{o.d.}$)	^{137}Cs Activity on area basis † (pCi/cm^2)
Site CS1 (Footslope)			
0-15	0.35	0.38	7.2
15-30	0.25	0.28	5.4
30-40	0.05	0.06	0.8
40-50	nd‡		Σ = 13.4
Site CS2 (Sideslope)			
0-15	0.22	0.25	4.9
15-30	0.10	0.11	2.3
30-40	nd		Σ = 7.2
Site CS3 (Ridgetop)			
0-15	0.32	0.35	7.7
15-30	0.11	0.12	2.6
30-40	nd		Σ = 10.3
40-50	nd		
Site CS4 (Footslope)			
0-15	0.43	0.48	9.0
15-30	0.14	0.15	3.3
30-40	0.01	0.01	0.2
40-50	nd		Σ = 12.5
Site CS5 (Sideslope)			
0-15	0.24	0.26	5.9
15-30	0.16	0.18	3.7
30-40	nd		Σ = 9.6
Site CS6 (Ridgetop)			
0-15	0.26	0.29	5.5
15-30	0.04	0.04	0.8
30-40	nd		Σ = 6.3
Site CS7 (Alluvial Fan)			
0-15	0.30	0.37	6.3
15-30	0.27	0.35	6.3
30-40	0.10	0.13	1.5
40-50	0.01	0.01	0.2
50-60	nd		Σ = 14.3

Table 7-2--continued.

Depth (cm)	Raw ^{137}Cs Activity on wt. basis (pCi/g_{sample})	^{137}Cs Activity on oven dry basis ($pCi/g_{o.d.}$)	^{137}Cs Activity on area basis † (pCi/cm^2)
Site CS8 (Footslope)			
0-15	0.31	0.33	7.0
15-30	0.28	0.31	5.9
30-40	0.01	0.01	0.2
40-50	nd		Σ = 13.1
Site CS9 (Sideslope)			
0-15	0.19	0.21	4.6
15-30	0.10	0.11	2.3
30-40	nd		Σ = 6.9
Site CS10 (Ridgetop)			
0-15	0.30	0.33	6.9
15-30	0.07	0.08	1.6
30-40	nd		Σ = 8.5
Site CS11 (Ridgetop)			
0-15	0.26	0.29	6.0
15-30	0.17	0.19	4.3
30-40	nd		Σ = 10.3
Site CS12 (Footslope)			
0-15	0.21	0.26	5.8
15-30	0.18	0.22	4.9
30-40	0.05	0.06	0.9
40-50	0.00	0.01	0.1
50-60	nd		Σ = 11.7
Site CS13 (Sideslope)			
0-15	0.19	0.22	4.7
15-30	0.16	0.18	3.9
30-40	nd		Σ = 8.6
Site CS14 (Ridge Shoulder)			
0-15	0.22	0.26	5.6
15-30	0.11	0.13	2.7
30-40	nd		Σ = 8.3

Table 7-2--continued.

Depth (cm)	Raw ^{137}Cs Activity on wt. basis (pCi/g_{sample})	^{137}Cs Activity on oven dry basis ($pCi/g_{o.d.}$)	^{137}Cs Activity on area basis † (pCi/cm^2)
Site CS15 (Ridgetop)			
0-15	0.25	0.28	5.9
15-30	0.14	0.15	3.3
30-40	nd		Σ = 9.2
Site CS16 (Footslope)			
0-15	0.20	0.22	5.0
15-30	0.11	0.13	2.8
30-40	nd		Σ = 7.8
Site CS17 (Sideslope)			
0-15	0.27	0.31	7.2
15-30	0.08	0.09	2.1
30-40	nd		Σ = 9.3
70-80	nd		
Site CS18 (Ridgetop)			
0-15	0.25	0.28	6.5
15-30	0.08	0.09	2.1
30-40	nd		Σ = 8.6
Site CS19 (Alluvial Fan)			
0-15	0.35	0.41	7.9
15-30	0.23	0.26	4.8
30-40	0.15	0.17	2.2
40-50	0.02	0.02	0.3
50-60	nd		Σ = 15.2
Site CS20 (Floodplain)			
0-15	0.25	0.28	5.5
15-30	0.12	0.14	3.0
30-40	nd		Σ = 8.5
Site CS24 (Pond, Above Low Water Line)			
0-10	0.46	0.56	6.7
10-20	0.21	0.25	3.2
20-30	0.04	0.05	0.7
30-40	nd		Σ = 10.6
40-50	nd		

Table 7-2--continued.

Depth (cm)	Raw ^{137}Cs Activity on wt. basis (pCi/g_{sample})	^{137}Cs Activity on oven dry basis ($pCi/g_{o.d.}$)	^{137}Cs Activity on area basis † (pCi/cm^2)
Site CS25 (Footslope)			
0-15	0.21	0.25	5.2
15-30	0.12	0.15	3.2
30-40	nd		Σ = 8.4
Site CS26 (Sideslope)			
0-15	0.15	0.18	3.9
15-30	0.11	0.13	2.8
30-40	nd		Σ = 6.7
Site CS27 (Ridgetop)			
0-15	0.19	0.22	4.6
15-30	0.07	0.08	1.8
30-40	nd		Σ = 6.4
Site CS28 (Floodplain)			
0-15	0.25	0.30	6.3
15-30	0.13	0.16	3.4
30-40	nd		Σ = 9.7
Site CS29 (Footslope)			
0-15	0.14	0.16	3.1
15-30	0.22	0.25	5.8
30-40	0.24	0.27	4.0
40-50	0.12	0.13	2.0
50-60	nd		Σ = 14.9
60-70	nd		
Site CS30 (Sideslope)			
0-15	0.19	0.22	4.8
15-30	0.16	0.18	4.1
30-40	nd		Σ = 8.9
40-50	nd		
50-60	nd		
Site CS31 (Ridgetop)			
0-15	0.10	0.11	2.6
15-30	0.02	0.02	0.5
30-40	nd		Σ = 3.1

Table 7-2--continued.

Depth (cm)	Raw ^{137}Cs Activity on wt. basis (pCi/g_{sample})	^{137}Cs Activity on oven dry basis ($pCi/g_{o.d.}$)	^{137}Cs Activity on area basis † (pCi/cm^2)
Site CS32 (Footslope)			
0-7.5	0.30	0.32	3.0
7.5-15	0.31	0.34	3.0
15-22.5	0.29	0.31	2.9
22.5-30	0.18	0.19	2.1
30-40	0.04	0.04	0.6
40-50	nd		Σ = 11.6
50-60	nd		
Site CS33 (Sideslope)			
0-7.5	0.26	0.29	2.6
7.5-15	0.26	0.28	2.6
15-22.5	0.23	0.25	2.4
22.5-30	0.05	0.05	0.5
30-40	nd		Σ = 8.1
Site CS34 (Ridgetop)			
0-7.5	0.27	0.29	2.8
7.5-15	0.29	0.31	2.9
15-22.5	0.19	0.21	2.0
22.5-30	0.03	0.03	0.4
30-40	nd		Σ = 8.1
Site CS35 (Pond, Below Low Water Line)			
0-15	0.30	0.31	3.5
15-25	0.00	0.00	0.0
			Σ = 3.5

†Activity on an area basis is converted to activity on a volume basis by dividing the areal activity (in pCi/cm^2) of each increment by the depth (in cm) of that increment.

‡nd = not detected.

Table 7-3--Mean ^{137}Cs activities per unit land area in depositional, sideslope, and ridgetop positions at Elkins Road.

Depth (cm)	Means and Standard Deviations of ^{137}Cs Activities (pCi/cm^2)			
	All Depositional Sites[+]		Sideslope Sites[‡]	Ridgetop Sites
	n = 12[++]		n = 9	n = 9
0-15	6.2 ±1.5		5.2 ±0.9	5.7 ±1.5
15-30	4.5 ±1.3	**[‡‡]	3.0 ±0.7	2.2 ±1.2
30-40	0.9 ±1.2		nd[#]	nd
40-50	0.2 ±0.6		nd	nd
Σ	11.7 ±2.5	**	8.2 ±1.0	7.9 ±2.3

[+]Including footslope, alluvial fan, and floodplain positions.

[‡]Including one ridge shoulder position (CS14).

[++]One pond site (CS24) is included here only in the Σ row (where n thus = 13), because the cores at this site were split into odd increments. The other pond site (CS35) is excluded here because of its having been severely disturbed in pond construction late in the period of fallout input, which limits its use in comparisons with other sites.

[‡‡]Means separated by ** are significantly different at the 0.01 level. Means underlined together are not significantly different at the 0.05 level. Significances were determined using t-tests (assuming equal variances in 0-15 cm and 15-30 cm rows and unequal variances in the Σ row, based on Bartlett's test of homogeneity of variance, and assuming normal distributions, based on X^2 tests of normality) (Snedecor and Cochran, 1967).

[#]nd = not detected.

Table 7-4--Mean ^{137}Cs activities per unit land area in footslope, sideslope, and ridgetop positions at Elkins Road.

Depth (cm)	Means and Standard Deviations of ^{137}Cs Activities (pCi/cm^2)				
	Footslopes		Sideslopes		Ridgetops+
	n = 8		n = 8		n = 8
0-15	6.0 ± 1.8		5.2 ± 1.0		5.7 ± 1.6
15-30	4.5 ± 1.2	*‡	3.0 ± 0.8	*	1.9 ± 0.9
30-40	0.8 ± 1.3		nd++		nd
40-50	0.3 ± 0.7		nd		nd
Σ	11.7 ± 2.4	**	8.2 ± 1.1		7.6 ± 2.2

+Excluding site CS11, which was not part of a sample transect.

‡Means separated by * are significantly different at the 0.05 level. Means separated by ** are significantly different at the 0.01 level. Means underlined together are not significantly different at the 0.05 level. Significances were determined using t-tests (assuming equal variances in 0-15 cm and 15-30 cm rows and unequal variances in the Σ row, based on Bartlett's test of homogeneity of variance, and assuming normal distributions, based on X^2 tests of normality) (Snedecor and Cochran, 1967).

++nd = not detected.

Table 7-5--Erosion rate estimates for watersheds WCS7 and E4F2 based on ^{137}Cs distributions.

Watershed	Method of estimation	Range of estimates: mTon/ha/yr Low	mTon/ha/yr High	T/acre/year Low	T/acre/year High
WCS7	Volumetric	3.8	14.3	1.7	6.4
	Gravimetric	8.3	27.0	3.7	12.0
E4F2	Volumetric	3.0	9.3	1.3	4.1
	Gravimetric	5.8	17.2	2.6	7.7

SECTION III. RELATIONSHIP OF PHYSICAL PARAMETERS TO EROSION AND SEDIMENTS

CHAPTER 8. SOIL WATER STATUS OF ELKINS ROAD SUB-WATERSHEDS

B. Lowery, R. B. Brown, J. A. Vomocil, and G. F. Kling

Summary

Perched water tables are common on hillslopes of the Willamette Valley and contribute to erosion during the winter rainfall season. Where soils are less well-drained, with restrictive layers near the surface, or in lower landscape positions, perched water tables develop faster and persist for longer periods of time. Areas of saturation produced by perched water tables result in seepage and can serve as source areas of storm runoff. Drainlines were effective in lowering water tables and reducing seepage areas and runoff.

Introduction

Most precipitation in the Willamette Valley occurs between the months of September and May. The soil moisture status reflects this precipitation pattern. The soil changes from very dry in early fall to saturated or nearly saturated in late fall and/or early winter. This condition may exist until late spring. The degree and length of saturated conditions are also related to soil horizonation. Layers within the soil which restrict the vertical movement of moisture can create saturated zones within the soil profile (Childs, 1957; Weyman, 1973). The saturated zones above moisture-impeding layers may be termed ephemeral perched water tables (Childs, 1957). Areas of high water tables have been reported to be associated with overland flow and can serve as source areas of storm runoff (Minshall and Jamison, 1965; Kirkby and Chorley, 1967; Ragan, 1967; Betson and Marius, 1969; Dunne and Black, 1970a,b; Rawitz et al., 1970; Weyman, 1970).

Materials and Methods

Soil moisture conditions were monitored with wells, piezometers, and tensiometers. Overland flow measurements were made with H-flumes and erosion plots (Chapter 3).

The locations of moisture and runoff measuring devices are plotted on topographic maps of the study sites in Figures 8-1 through 8-5. Only representative moisture measuring data are discussed in this report; thus, only those sites are plotted. The soil moisture monitoring sites varied slightly in location from year to year. In each case, however, the soil moisture was monitored in both upper and lower landscape positions.

Results and Discussion

Perched water tables were observed at each of the three sub-watersheds during the winter rainfall season. In upslope and midslope positions on sub-watershed E4F1 (stations E4Z2 and E4Z3, respectively) perching occurred at depths of less than 140 cm (Table 8-1). Perching is indicated when the pore water pressure in a soil horizon is positive and larger than that of an underlying horizon. For example, on Nov. 24, 1977, pore water pressures at station E4Z2 (upslope) were 14.0 and 0 cm at a depth of 90 and 140 cm, respectively. This indicates that a water-impeding or restrictive layer exists at a depth of between 90 and 140 cm. In a lower slope position on sub-watershed E4F1 (station E4Z9), pore water pressures of 73.0 and 109.0 cm at depths of 110 and 141 cm indicate the restrictive layer is at a depth greater than 141 cm. Greater depths to restrictive layers results from increased amounts of sedimentation and soil development in lower landscape positions.

Perching occurred at depths of greater than 140 cm in both upslope (station E1Z1) and downslope (station E1Z2) positions on sub-watershed E1F1 (Table 8-1). The greater depths to restrictive layers at sub-watershed E1F1 result in smaller pore water pressures than comparable slope positions and depths on E4F1. The rapid fluctuations on E1F1 are also attributed to better drainage (e.g., Table 8-2, Feb. 1 to 10, 1978).

Perched water tables were closer to the soil surface near waterways and depressions on each of the sub-watersheds. This is indicated by larger pore water pressures (Table 8-1) and higher water table elevations (Tables 8-2--8-4) in these landscape positions. Because of the restrictive layer in sub-watershed E4F1, the perched water table was found to develop faster and last longer than other sub-watersheds. During storm events, the water table was at the soil surface on portions of E4F1; more overland flow events were observed in this sub-watershed compared with the better drained E1F1. This indicates that zones of saturated soil in lower landscape positions and adjacent to waterways can act as source areas of storm runoff.

Drainline installation in E4F1 (August, 1979) lowered the water table in 1979-80 (Table 8-4). The water table was not observed to surface to the extent that it had in previous years. The drainage system did not entirely eliminate storm runoff, however. Storms of Oct. 20, 1979, Oct. 24-25, 1979, Dec. 17, 1979, Jan. 9-10, 1980 and Feb. 20, 1980, for example, resulted in runoff from this sub-watershed. However, these runoff events were of shorter duration than in previous years.

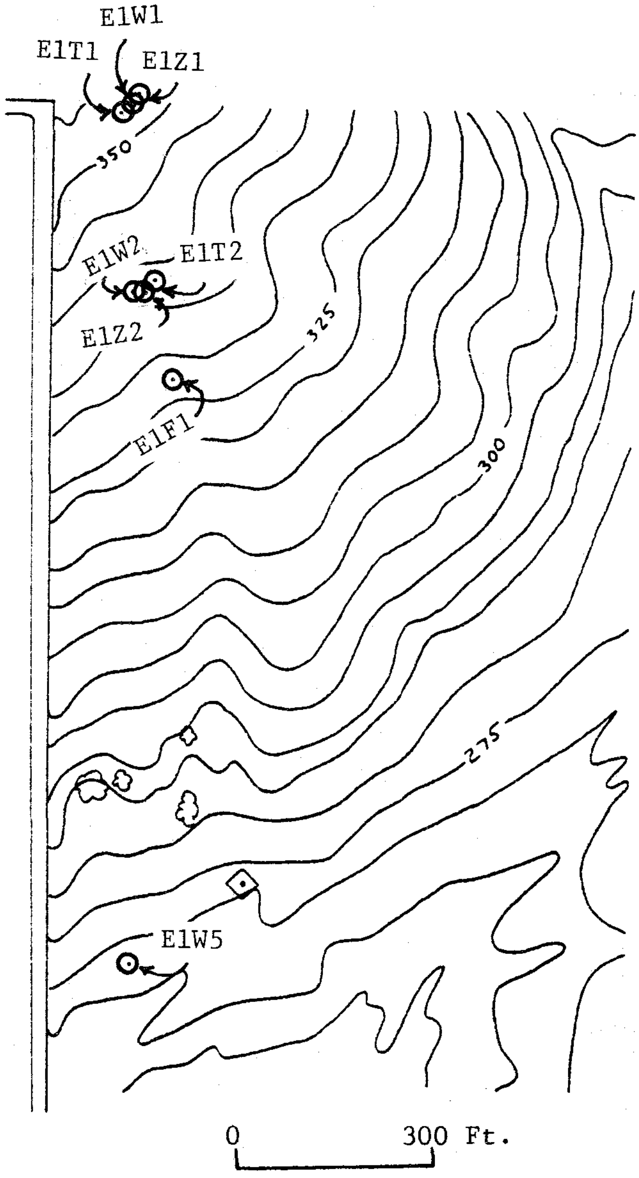

Figure 8-1 Topographic map of E1 study area with location of flume (E1F1), wells (E1W1, 2, and 5), piezometers (E1Z1 and 2), and tensiometers (E1T1, and 2) for 1977-78.

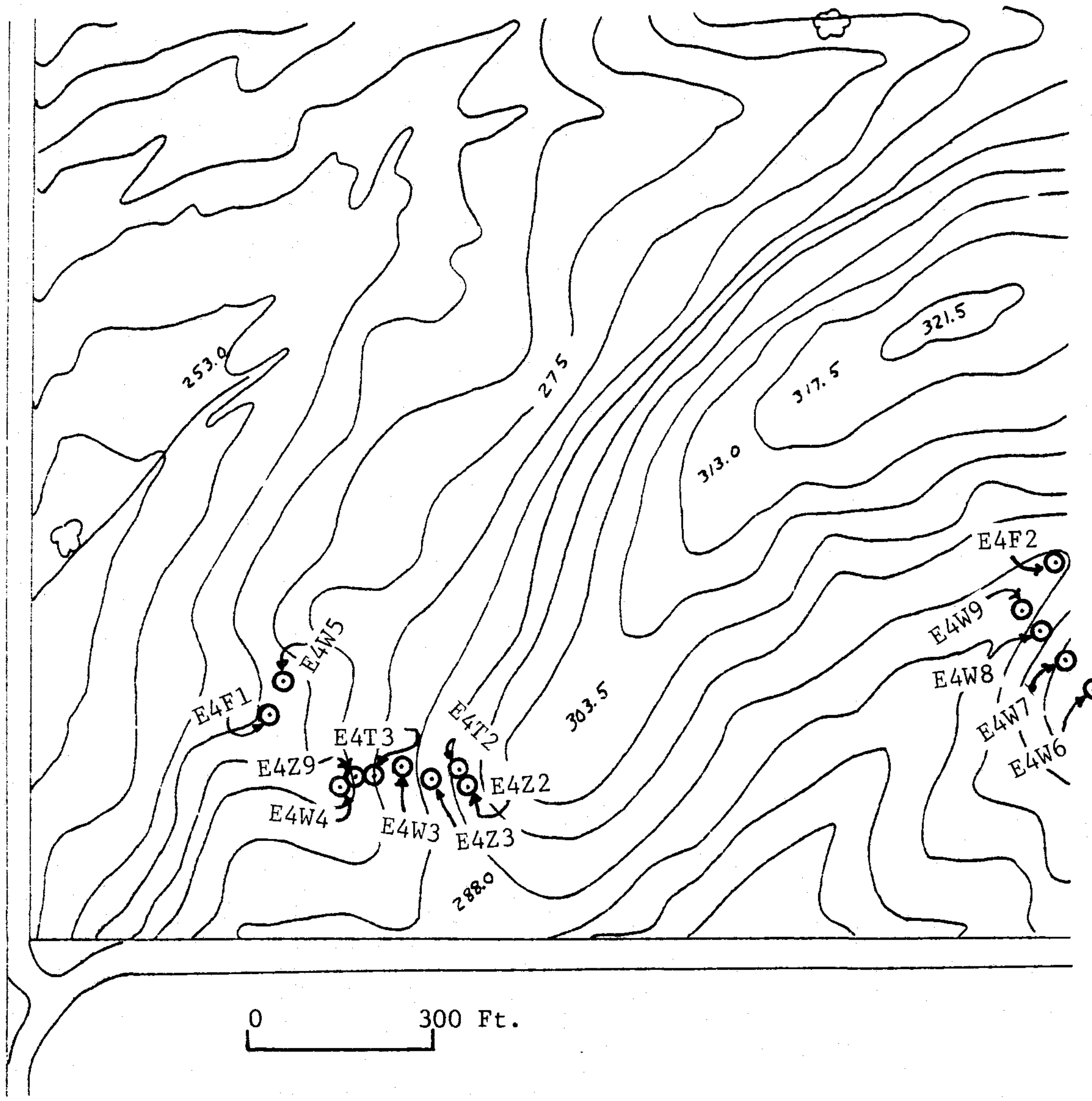

Figure 8-2 Topographic map of E4 study area with location of flumes (E4F1 and 2), wells(E4W3, 4, 5, 6, 7, 8, and 9), piezometers (E4Z2, 3, and 9), and tensiometers (E4T2 and 3) for 1977-78.

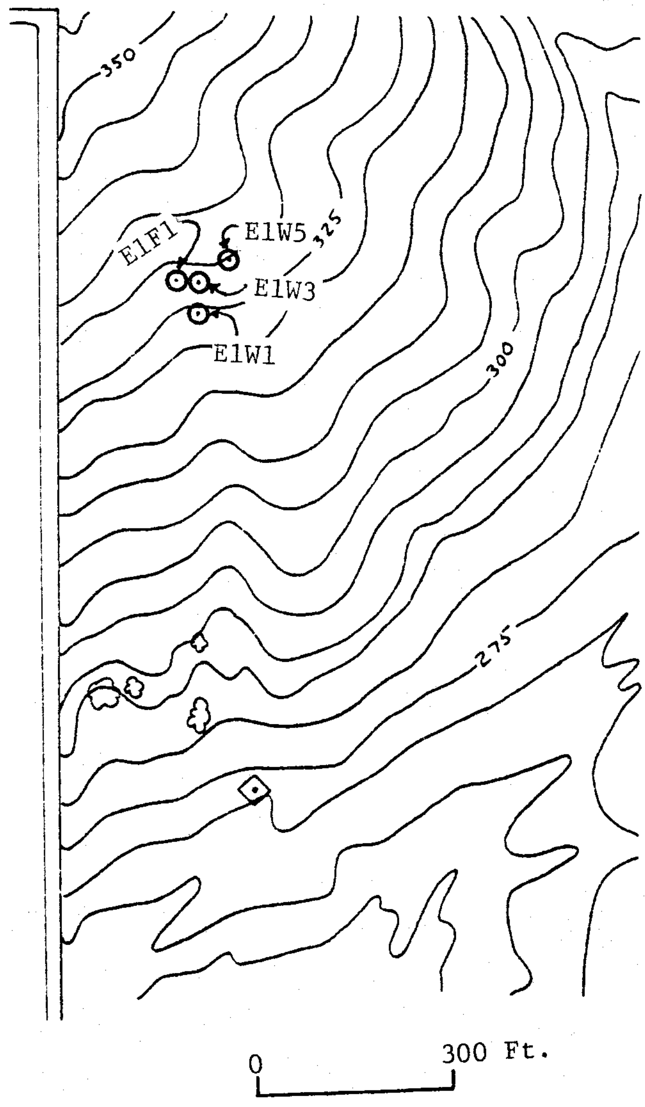

Figure 8-3 Topographic map of E1 study area with location of flume (E1F1), and wells (E1W1, 3, and 5) for 1978-79.

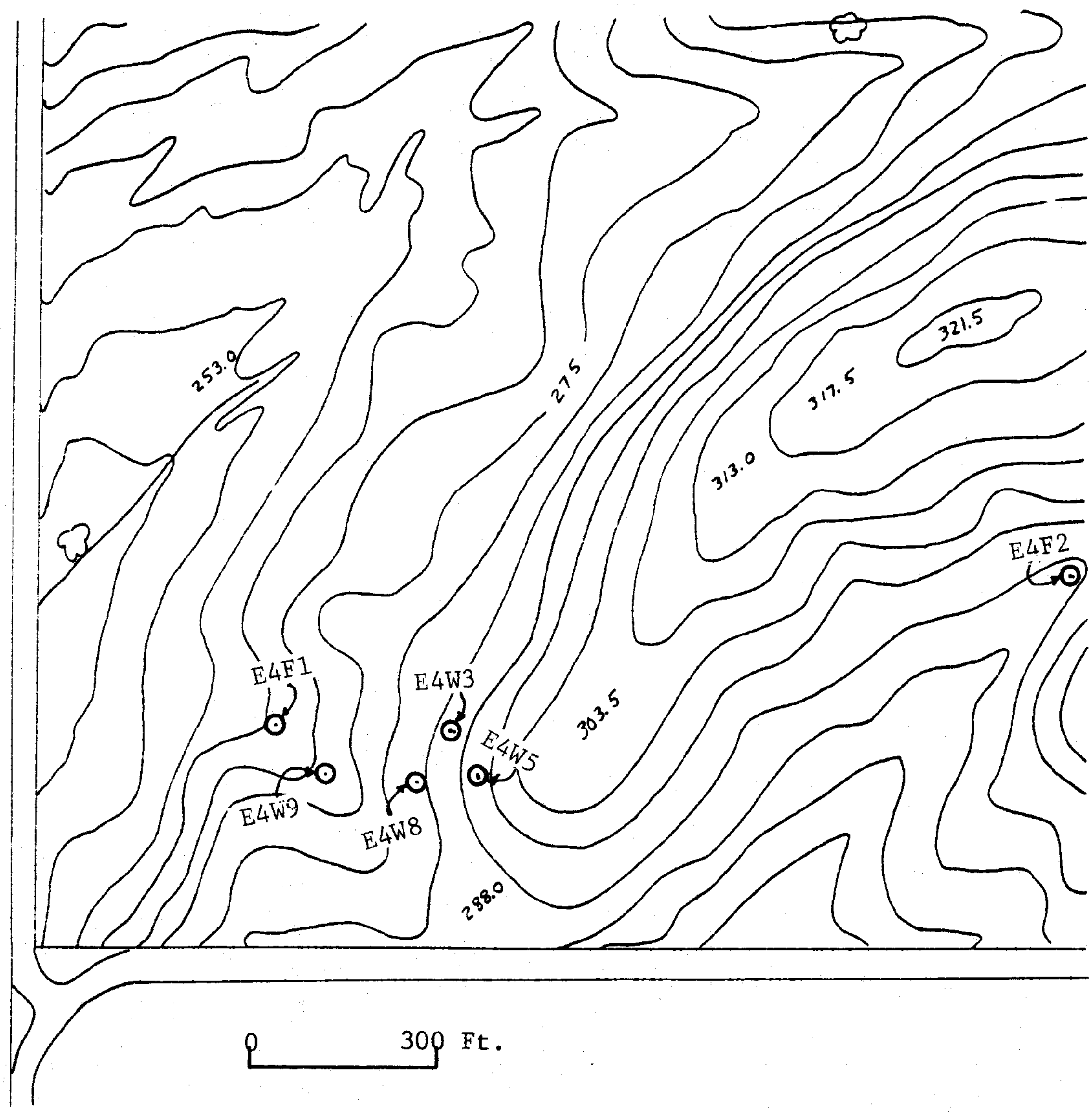

Figure 8-4 Topographic map of E4 study area with location of flumes (E4F1 and 2) and wells (E4W3, 5, and 8) for 1978-79.

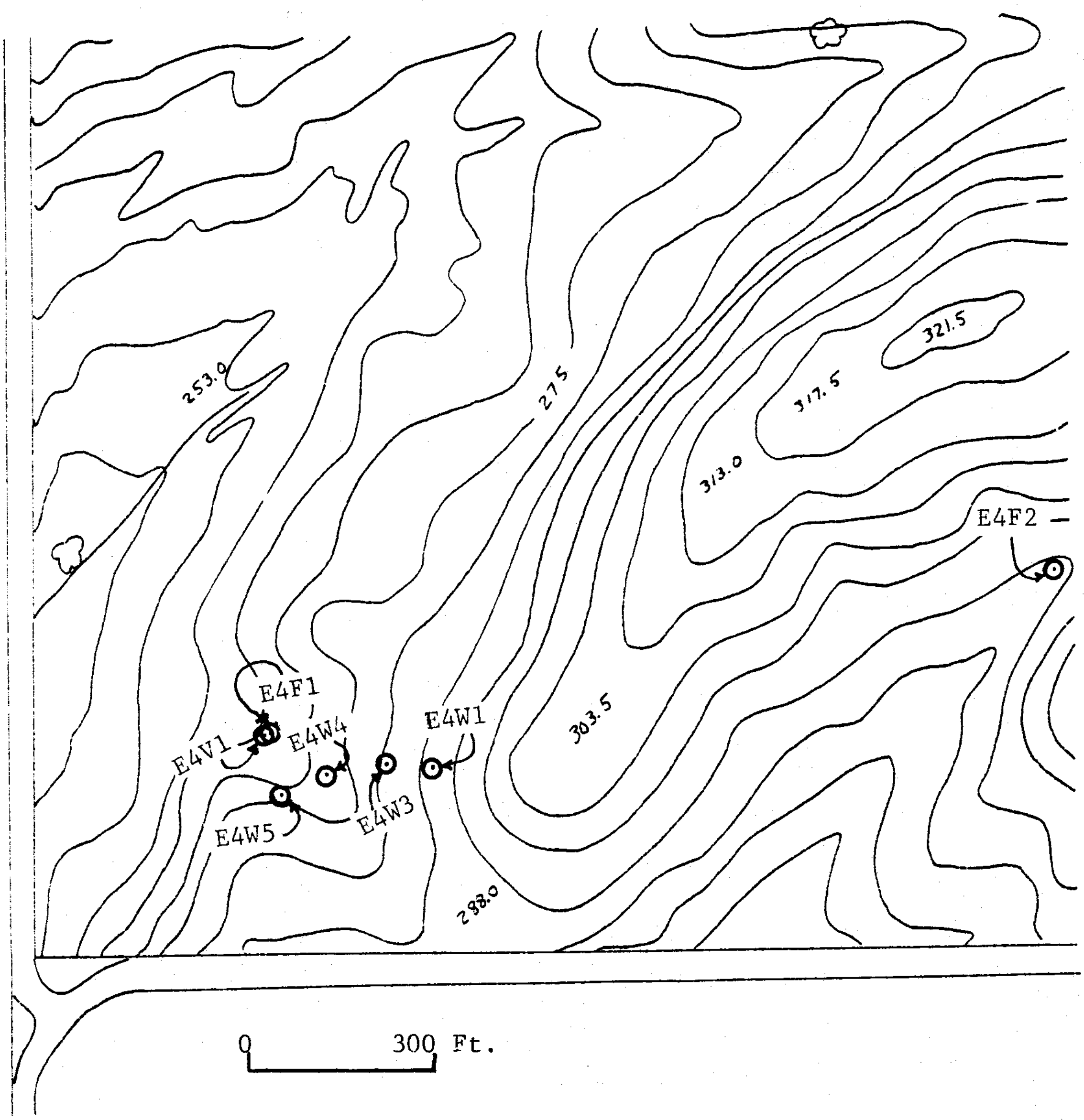

Figure 8-5 Topographic map of E4 study area with location of flumes (E4F1 and 2), weir (E4V1), and wells (E4W1, 3, 4, and 5) for 1979-80.

Table 8-1--Maximum pore water pressure as indicated by Piezometers (cm)

Date	Time	Station E4Z2				Station E4Z3				Station E4Z9				Station E1Z1				Station E1Z2			
		Piezometers depth below the soil surface (cm)																			
		20	55	90	140	17	48	72	140	20	70	110	141	20	57	90	141	20	53	73	140
1977-78																					
Nov. 24	0945	0.0	0.0	14.0	0	0.0	3.5	22.5	0	0.0	34.5	73.0	109.0	-†	---	---	----	-	----	----	-----
	1930	0.0	31.5	48.0	0	0.0	19.0	34.5	0	15.0	60.0	99.0	131.0	-	---	----	----	-	----	----	-----
Nov. 25	1140	14.0	49.0	80.0	0	14.0	38.0	50.0	0	19.5	66.0	104.2	136.5	-	---	----	----	-	----	----	-----
Nov. 26	1200	11.2	46.3	77.5	0	11.0	37.0	52.2	0	19.2	67.5	103.7	137.4	-	---	----	----	-	----	----	-----
Dec. 1	1020	0.0	6.0	40.5	0	0.0	8.0	31.5	0	9.5	62.0	97.0	129.5	-	---	----	----	-	----	----	-----
Dec. 2	1224	0.0	38.0	57.0	0	7.0	25.0	40.0	0	19.0	69.0	105.0	142.0	-	---	----	----	-	----	----	-----
Dec. 3	1140	5.5	42.3	69.0	0	11.2	35.3	49.0	0	19.5	68.5	106.3	136.8	-	---	----	----	-	----	----	-----
Dec. 10	0945	0.0	17.0	52.5	0	0.0	21.5	40.0	0	14.5	61.5	99.0	133.0	-	---	----	----	-	----	----	-----
Dec. 11	0230	0.0	34.1	57.0	0	9.5	37.0	52.0	0	19.2	66.9	103.6	143.4	-	---	----	----	-	----	----	-----
	1430	4.0	41.0	71.0	0	----	----	----	-	20.5	68.0	105.5	145.5	-	---	----	----	-	----	----	-----
Dec. 12	1510	0.0	38.5	73.0	0	8.0	35.0	52.5	0	20.0	67.5	105.3	141.2	-	---	----	----	-	----	----	-----
Dec. 13	1055	10.0	46.5	80.0	0	11.0	39.5	57.0	0	20.5	69.5	106.5	138.5	-	---	----	----	-	----	----	-----
Dec. 14	0600	8.9	44.6	83.9	0	10.5	38.5	58.1	0	20.6	72.9	109.8	141.9	-	---	----	----	-	----	----	-----
Dec. 15	1315	8.5	46.0	87.0	0	11.5	38.5	61.0	0	21.0	73.7	109.6	143.0	-	---	----	----	-	----	----	-----
Dec. 16	1200	8.5	45.7	87.0	0	10.5	37.5	61.0	0	19.5	71.0	111.0	139.5	-	---	----	----	-	----	----	-----
Dec. 17	1200	3.0	38.0	76.0	0	9.5	37.0	56.0	0	18.5	72.0	109.5	145.5	-	---	----	----	-	----	----	-----
Dec. 18	1625	0.0	35.2	68.2	0	4.7	32.8	53.3	0	17.1	67.0	109.3	141.0	-	---	----	----	-	----	----	-----
Jan. 2	1000	0.0	4.5	38.8	0	0.0	9.7	32.4	0	0.0	19.6	58.8	88.4	0	0.0	0.0	23.7	0	0.0	0.0	45.3
Jan. 3	1455	0.0	18.0	44.0	0	6.5	34.0	41.5	0	16.5	66.5	102.5	135.0	0	0.0	0.0	44.5	0	0.0	13.5	60.0
Jan. 4	1450	0.0	33.3	65.8	0	7.3	36.3	49.3	0	16.5	67.3	103.4	136.0	0	0.0	0.0	50.5	0	9.4	30.6	86.3
Jan. 5	1208	1.5	38.3	70.2	0	8.4	39.6	51.5	0	18.4	65.8	110.5	137.8	0	0.0	5.5	56.0	0	19.0	42.0	97.0
Jan. 6	1315	7.7	44.6	75.0	0	10.0	40.1	54.7	0	18.8	69.5	111.0	140.3	0	0.0	26.0	70.0	0	35.5	56.8	110.5

Table 8-1--continued.

		Station E4Z2				Station E4Z3				Station E4Z9				Station E1Z1				Station E1Z2			
		Piezometers depth below the soil surface (cm)																			
Date	Time	20	55	90	140	17	48	72	140	20	70	110	141	20	57	90	141	20	53	73	140
Jan. 7	1215	3.0	38.6	72.0	0	6.7	36.9	54.5	0	17.8	68.8	110.7	140.5	0	5.0	35.0	85.4	0	31.5	52.2	107.8
Jan. 8	1405	2.5	37.4	71.4	0	8.2	36.5	53.7	0	18.0	68.5	109.7	140.5	0	5.0	34.8	85.0	0	30.4	51.4	108.7
Jan. 9	1338	2.5	38.4	71.2	0	8.3	36.4	53.9	0	18.0	68.8	107.7	137.2	0	9.0	38.0	89.5	0	31.6	51.5	108.9
Jan. 10	1020	0.0	35.0	71.7	0	6.0	33.3	53.7	0	15.3	67.5	107.2	136.2	0	9.6	39.5	90.8	0	27.2	49.5	106.5
Jan. 11	1425	0.0	33.0	67.6	0	0.0	26.4	50.1	0	11.6	65.9	107.5	134.0	0	2.6	32.8	82.7	0	25.3	47.5	100.7
Jan. 12	1018	0.0	32.1	64.7	0	8.0	33.2	48.5	0	16.3	65.4	104.0	135.4	0	0.0	26.7	76.8	0	23.0	44.3	100.8
Jan. 13	1207	3.5	39.5	66.0	0	11.5	38.5	50.5	0	18.5	70.5	108.0	137.0	0	0.0	25.5	75.5	0	22.5	44.0	100.0
Jan. 14	1105	4.0	39.5	70.0	0	12.0	38.4	52.6	0	17.4	71.5	107.8	137.3	0	2.5	32.3	85.0	0	29.6	50.7	102.2
Jan. 15	1445	0.0	35.5	70.0	0	7.5	34.0	53.0	0	16.0	68.5	105.5	134.0	0	2.0	32.5	27.5	0	25.0	46.0	102.0
Jan. 16	1337	2.2	37.5	69.4	0	11.0	37.6	52.8	0	18.5	66.5	104.9	136.4	0	0.0	27.7	80.1	0	26.0	47.1	103.5
Jan. 17	1113	5.5	40.5	72.5	0	11.0	38.0	54.0	0	19.0	67.0	106.0	137.0	0	0.0	31.5	83.5	0	27.0	48.0	104.1
Jan. 18	1410	4.5	40.0	72.2	0	9.7	36.4	53.5	0	18.1	68.0	107.0	138.3	0	2.2	31.7	83.5	0	25.4	46.6	104.0
Jan. 20	1335	0.0	34.4	70.0	0	4.3	28.8	52.7	0	13.2	68.5	106.4	134.1	0	0.0	29.7	80.8	0	23.4	45.0	104.5
Jan. 21	1420	0.0	36.0	66.0	0	6.5	31.0	49.0	0	18.5	70.0	106.0	138.0	0	0.0	23.5	73.0	0	24.0	45.5	98.5
Jan. 22	1500	1.5	37.2	67.2	0	7.8	33.5	48.9	0	17.8	69.8	106.0	138.0	0	0.0	20.5	72.8	0	21.5	42.6	93.1
Feb. 1	1100	0.0	13.5	38.5	0	0.0	29.0	34.5	0	17.0	67.5	103.0	134.0	0	0.0	0.0	9.5	0	0.0	0.0	0.0
Feb. 2	1100	0.0	35.5	68.5	0	5.0	34.0	45.5	0	18.0	67.5	104.0	135.0	0	0.0	0.0	44.3	0	0.0	18.7	69.0
Feb. 3	1245	4.0	40.0	71.2	0	7.5	35.5	49.5	0	18.5	68.0	106.5	135.5	0	0.0	0.0	55.5	0	22.5	44.0	96.0
Feb. 4	1424	0.0	37.5	79.3	0	5.5	33.4	50.1	0	15.3	63.5	107.0	133.4	0	0.0	17.2	68.0	0	22.3	43.6	100.5
Feb. 5	1320	1.0	35.0	69.6	0	6.6	34.5	50.7	0	14.2	65.1	102.6	133.4	0	0.0	17.3	67.1	0	16.5	38.2	97.1
Feb. 6	1200	0.0	35.3	68.0	0	7.2	35.0	51.0	0	14.8	65.8	104.5	133.2	0	0.0	17.6	66.5	0	13.2	34.8	92.1
Feb. 7	1736	4.0	40.5	73.0	0	10.5	37.0	53.0	0	19.0	66.0	105.0	136.5	0	0.0	14.2	66.4	0	19.0	40.5	91.0
Feb. 8	1415	0.0	37.0	73.0	0	10.5	34.0	53.0	0	16.0	67.0	104.5	135.5	0	0.0	19.0	68.0	0	20.0	41.0	97.0
Feb. 9	1127	0.0	35.0	69.5	0	7.0	28.0	52.5	0	13.0	64.0	100.5	132.5	0	0.0	21.0	72.0	0	20.0	40.5	97.0
Feb. 10	1257	0.0	32.3	69.5	0	6.3	29.2	52.2	0	11.3	64.1	100.5	128.7	0	0.0	23.0	71.5	0	13.4	35.8	92.8

Table 8-1--continued.

Date	Time	Station E4Z2				Station E4Z3				Station E4Z9				Station E1Z1				Station E1Z2			
		Piezometers depth below the soil surface (cm)																			
		20	55	90	140	17	48	72	140	20	70	110	141	20	57	90	141	20	53	73	140
Apr. 18	1205	0.0	[illegible]	14.5	0	0.0	13.2	20.5	0	0.0	0.0	29.5	62.5	0	0.0	0.0	0.0	0	0.0	0.0	0.0
Apr. 19	1320	0.0	0.0	21.0	0	0.0	19.4	26.1	0	0.0	27.7	65.8	97.3	0	0.0	0.0	0.0	0	0.0	0.0	0.0
Apr. 20	1116	0.0	0.0	29.8	0	0.0	18.8	29.2	0	0.0	29.0	66.5	98.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0
Apr. 21	1321	0.0	0.0	30.7	0	1.5	25.6	31.7	0	0.0	28.0	64.3	94.0	0	0.0	0.0	0.0	0	0.0	0.0	2.0
Apr. 22	0851	2.0	17.5	36.0	0	4.0	32.0	36.0	0	14.0	64.5	102.0	132.0	0	0.0	0.0	0.0	0	0.0	0.0	31.5
Apr. 23	0637	1.0	16.5	46.4	0	3.5	30.0	39.5	0	14.0	53.0	92.7	133.5	0	0.0	6.0	58.3	0	0.0	22.0	68.3
May 13	1330	0.0	0.0	20.0	0	0.0	13.5	21.5	0	0.0	0.0	0.0	7.5	0	0.0	0.0	0.0	0	0.0	0.0	7.0
May 14	0700	0.0	14.0	34.5	0	0.0	28.0	25.0	0	0.0	38.6	76.3	106.1	0	0.0	0.0	0.0	0	0.0	0.0	13.0
May 15	1056	1.5	29.0	55.0	0	2.0	34.5	32.0	0	11.0	61.5	101.0	129.5	0	0.0	0.0	0.0	0	0.0	0.0	19.5

† Dashes indicate no data available.

Table 8-2--Perched water tables along topographic transects† in relation to runoff for 1977-78 rainfall season.

Date	Time	Daily depth to water table (cm)									Runoff occurred		
		E4W3 Up Slope	E4W4 Down Slope	E4W6 Up Slope	E4W7 Mid Slope	E4W8 Mid Slope	E4W9 Down Slope	E1W1 Up Slope	E1W2 Mid Slope	E1W5 Down Slope	E4F1	E4F2	E1F1
Nov. 24	0945	50.0	29.0	-‡	-	-	-	-	-	-	No	-	-
	1930	10.0	4.0	-	-	-	-	-	-	-	Yes	-	-
Nov. 25	1140	2.0	0.0	-	-	-	-	-	-	-	Yes	-	-
Nov. 26	1200	12.0	2.0	-	-	-	-	-	-	-	Yes	-	-
Dec. 1	1020	26.0	8.0	-	-	-	-	-	-	-	Yes	-	-
Dec. 2	1224	0.0	0.0	-	-	-	-	-	-	-	Yes	-	-
Dec. 3	1140	13.0	2.0	-	-	-	-	-	-	-	Yes	-	-
Dec. 10	0945	19.0	6.5	-	-	-	-	-	-	-	Yes	Yes	-
Dec. 11	0230	0.0	0.0	-	-	-	-	46.0	27.0	-	Yes	Yes	-
	1430	6.5	0.0	-	-	-	-	-	-	-	Yes	Yes	-
Dec. 12	1510	10.0	0.0	-	-	-	-	50.0	29.0	-	Yes	Yes	-
Dec. 13	1055	0.0	0.0	-	-	-	-	6.5	14.0	1.0	Yes	Yes	-
	1515	0.0	0.0	-	-	-	-	-	20.0	5.0	Yes	Yes	-
Dec. 14	0600	0.0	0.0	-	-	-	-	7.0	17.0	3.0	Yes	Yes	-
	0756	0.0	0.0	-	-	-	-	7.5	-	-	Yes	Yes	-
Dec. 15	1315	0.0	0.0	-	-	-	-	0.0	14.0	4.0	Yes	Yes	-
Dec. 16	1200	3.5	0.0	-	-	-	-	21.0	21.0	5.0	Yes	Yes	-
Dec. 17	1200	8.0	0.0	-	-	-	-	34.0	24.0	7.0	Yes	Yes	-
Dec. 18	1625	11.5	2.5	-	-	-	-	49.0	46.0	8.0	Yes	Yes	-

Table 8-2--continued.

Date	Time	Daily depth to water table (cm) E4W3 Up Slope	E4W4 Down Slope	E4W6 Up Slope	E4W7 Mid Slope	E4W8 Mid Slope	E4W9 Down Slope	E1W1 Up Slope	E1W2 Mid Slope	E1W5 Down Slope	Runoff occurred E4F1	E4F2	E1F1
Jan. 2	1000	31.5	64.0	136.0	140.0	102.0	18.0	86.0	81.0	31.0	No	Yes	No
Jan. 3	1455	6.0	2.5	132.0	140.0	97.0	11.5	86.0	67.0	6.0	Yes	Yes	Yes
Jan. 4	1450	7.0	1.0	134.0	140.0	80.0	19.0	86.0	48.0	4.0	Yes	Yes	No
Jan. 5	1208	0.0	0.0	129.0	140.0	81.0	10.0	67.0	24.0	3.0	Yes	Yes	Yes
Jan. 6	1315	7.5	1.0	99.0	99.0	67.0	9.8	51.0	28.0	4.0	Yes	Yes	Yes
Jan. 7	1215	2.0	0.0	115.5	117.0	72.5	8.5	53.0	29.0	4.0	Yes	Yes	Yes
Jan. 8	1405	4.0	0.0	116.0	128.0	70.5	9.5	48.0	29.0	4.0	Yes	Yes	Yes
Jan. 9	1338	6.0	0.0	112.0	124.0	72.0	9.0	58.0	30.0	2.0	Yes	Yes	Yes
Jan. 10	1020	12.5	3.0	119.0	124.0	74.0	10.0	62.5	33.0	7.0	Yes	Yes	Yes
Jan. 12	1018	12.0	3.0	140.0	140.0	89.0	11.0	64.0	39.0	8.0	Yes	Yes	Yes
Jan. 13	1207	0.0	0.5	140.0	140.0	76.0	7.5	62.0	37.0	4.5	Yes	Yes	Yes
Jan. 14	1105	7.5	1.0	125.0	140.0	77.0	9.5	55.0	33.0	5.0	Yes	Yes	Yes
Jan. 15	1445	11.0	3.5	140.0	140.0	80.0	10.5	60.0	36.0	7.0	Yes	Yes	Yes
Jan. 16	1337	5.0	0.0	131.0	140.0	80.0	10.0	59.0	36.0	5.0	Yes	Yes	Yes
Jan. 17	1113	3.5	0.0	127.0	140.0	74.0	9.5	56.0	33.0	5.0	Yes	Yes	Yes
Jan. 18	1410	6.0	0.0	126.0	140.0	74.0	7.0	60.0	33.0	3.0	Yes	Yes	Yes
Jan. 20	1335	10.0	5.0	140.0	140.0	80.0	10.0	65.0	37.0	7.0	Yes	Yes	Yes
Jan. 21	1420	1.0	0.0	133.0	140.0	84.0	9.5	66.0	39.0	4.0	Yes	Yes	Yes
Jan. 22	1500	7.0	0.0	136.0	140.0	89.0	9.5	65.0	40.0	6.0	Yes	Yes	Yes
Feb. 1	1100	17.0	1.0	140.0	140.0	103.0	13.0	86.0	87.0	6.0	Yes	Yes	No
Feb. 2	1100	4.0	1.0	140.0	140.0	91.5	12.5	79.0	45.0	2.5	Yes	Yes	Yes
Feb. 3	1245	7.0	5.0	129.0	140.0	82.0	11.0	68.0	35.0	5.0	Yes	Yes	Yes

Table 8-2--continued.

Date	Time	Daily depth to water table (cm)									Runoff occurred		
		E4W3 Up Slope	E4W4 Down Slope	E4W6 Up Slope	E4W7 Mid Slope	E4W8 Mid Slope	E4W9 Down Slope	E1W1 Up Slope	E1W2 Mid Slope	E1W5 Down Slope	E4F1	E4F2	E1F1
Feb. 4	1424	7.0	5.0	140.0	140.0	87.0	12.0	71.0	41.0	7.0	Yes	Yes	–
Feb. 5	1320	0.0	3.0	129.0	140.0	87.0	11.0	70.0	43.0	7.5	Yes	Yes	Yes
Feb. 6	1200	0.0	3.0	134.0	140.0	91.0	11.0	70.0	51.0	8.0	Yes	Yes	–
Feb. 7	1136	0.0	0.0	130.0	140.0	82.0	8.5	67.0	39.0	3.5	Yes	Yes	Yes
Feb. 8	1415	0.0	4.5	127.0	140.0	80.0	10.0	65.0	38.0	6.0	Yes	Yes	Yes
Feb. 9	1127	0.0	4.0	140.0	140.0	85.0	10.0	70.0	43.0	7.5	Yes	Yes	Yes
Feb. 10	1257	7.0	7.0	140.0	140.0	90.0	11.0	75.0	56.0	11.0	No	Yes	No
Apr. 18	1205	50.0	77.0	140.0	140.0	125.0	110.0	86.0	87.0	27.0	No	No	No
Apr. 19	1320	26.0	33.0	140.0	140.0	124.0	110.0	86.0	87.0	22.0	No	No	No
Apr. 20	1116	30.0	57.0	140.0	140.0	124.0	95.0	86.0	79.0	29.0	No	No	No
Apr. 21	1321	19.5	32.0	140.0	140.0	123.0	87.0	86.0	87.0	21.0	No	No	No
Apr. 22	0851	4.5	4.0	140.0	140.0	118.0	53.0	86.0	87.0	7.5	Yes	No	No
Apr. 23	0637	9.0	10.5	140.0	140.0	84.0	17.5	74.0	58.0	4.5	Yes	No	No
May 13	1330	50.0	90.0	140.0	140.0	115.0	15.0	86.0	87.0	24.0	No	No	No
May 14	0700	17.0	22.5	140.0	140.0	108.0	14.0	78.7	87.0	15.0	No	Yes	No
	1735	2.0	5.0	140.0	140.0	96.0	11.0	86.0	87.0	–	Yes	Yes	No
May 15	1056	12.0	10.0	140.0	140.0	100.0	13.0	86.0	87.0	5.0	Yes	Yes	No

† Note site locations; see Fig. 8-1 and 8-2.

‡ Dash indicate missing data. In most cases this was due to equipment not yet installed by dates indicated.

Table 3--Perched water tables along topographic transects† in relation to runoff for 1978-79 rainfall season.

		Minimum depth to water table (cm)							Runoff occurred	
Date	Time	E4W5 Up Slope	E4W3 Mid Slope	E4W8 Mid Slope	E4W9 Down Slope	E1W5 Up Slope	E1W3 Mid Slope	E1W1 Down Slope	E4F1	E1F1
Dec. 1	1035	110.6	151.0	65.1	96.0	120.2	146.0	59.2	No	No
Dec. 2	1154	110.6	151.0	64.6	45.5	111.0	98.2	-‡	No	No
Dec. 3	1300	114.0	151.0	66.0	44.0	107.0	80.0	78.0	No	No
Dec. 4	1613	105.5	104.0	46.5	23.0	102.5	66.0	75.0	No	No
Dec. 5	0945	105.0	62.5	44.2	20.5	81.8	54.1	47.0	No	No
Dec. 6	1135	61.5	50.0	43.3	-	78.3	47.1	42.8	No	No
Dec. 7	1039	62.7	50.5	44.5	-	79.7	44.5	31.0	No	No
Dec. 8	1130	56.9	57.1	45.6	-	86.4	52.0	41.0	No	No
Dec. 9	1300	69.0	56.0	45.5	20.0	92.5	57.0	45.0	No	No
Dec. 10	1300	69.3	54.8	45.3	-	100.0	67.5	58.8	No	No
Dec. 11	1035	47.8	34.0	21.0	9.5	77.6	41.5	45.1	Yes	No
Dec. 12	1205	53.8	32.0	30.0	7.0	70.5	35.3	10.3	Yes	No
Dec. 13	1400	57.0	45.3	37.0	11.5	70.0	31.7	10.5	No	No
Dec. 14	1200	59.8	50.0	40.3	-	72.1	34.8	9.6	No	No
Dec. 15	1115	60.5	50.5	41.0	-	75.0	36.0	8.7	No	No
Dec. 16	1031	60.5	52.0	41.5	14.5	80.5	39.5	15.3	No	No
Jan. 8	1340	75.5	65.5	52.6	45.0	130.3	110.5	105.5	No	No
Jan. 10	1130	0.0	60.4	10.0	-	39.5	32.5	0.0	Yes	Yes
Jan. 11	1100	0.0	46.6	0.0	-	37.0	41.5	0.0	Yes	Yes
Jan. 12	1310	52.5	44.2	23.5	-	41.7	31.6	7.4	Yes	No
Jan. 13	1315	55.0	38.5	29.0	-	76.0	27.6	1.0	Yes	No

Table 8-3--continued.

Date	Time	Minimum depth to water table (cm) E4W5 Up Slope	E4W3 Mid Slope	E4W8 Mid Slope	E4W9 Down Slope	E1W5 Up Slope	E1W3 Mid Slope	E1W1 Down Slope	Runoff occurred E4F1	E1F1
Jan. 14	1430	58.5	31.0	19.5	-	73.0	22.0	0.0	Yes	No
Jan. 15	1515	57.6	36.5	19.5	-	71.6	11.8	0.0	Yes	No
Jan. 16	1030	61.0	36.6	17.5	-	74.6	23.0	0.0	Yes	No
Jan. 17	1515	55.0	37.5	18.5	3.0	71.0	24.0	0.0	Yes	No
Feb. 6	1030	72.0	63.0	33.4	27.0	130.0	99.5	102.0	Yes	No
Feb. 7	0318	17.0	11.5	1.0	-	85.0	26.0	14.0	Yes	Yes
Feb. 8	1100	30.5	24.5	5.5	-	37.0	16.4	0.8	Yes	Yes
Feb. 9	0940	44.5	35.5	11.1	-	37.0	11.5	1.3	Yes	Yes
Feb. 10	1210	39.5	7.0	1.0	-	28.0	0.0	0.0	Yes	Yes
Feb. 11	1230	15.0	9.3	7.0	-	18.0	0.0	0.0	Yes	Yes
Feb. 12	0925	29.2	19.5	7.0	-	22.1	6.1	0.0	Yes	Yes
Feb. 13	1130	30.2	13.7	6.2	-	25.0	5.4	3.0	Yes	Yes
Feb. 14	1302	55.0	28.0	15.0	-	36.5	13.0	3.0	Yes	Yes
Feb. 15	1600	55.6	17.7	23.0	-	45.0	16.0	3.0	Yes	Yes
Feb. 16	1135	54.5	32.0	23.0	-	47.5	7.0	0.0	Yes	Yes
Feb. 17	1417	32.0	18.0	19.4	-	33.5	6.3	0.0	Yes	Yes
Feb. 18	1330	34.5	11.5	7.5	5.0	37.0	10.5	0.0	Yes	Yes
Feb. 19	0945	33.9	18.0	14.0	-	35.7	13.0	0.0	Yes	Yes
Mar. 2	1319	51.0	32.3	26.0	-	78.0	40.0	17.5	No	No
Mar. 3	1453	37.4	36.0	14.6	-	72.0	29.2	0.0	Yes	No
Mar. 4	1730	33.0	9.0	11.5	0.0	55.5	16.0	0.0	Yes	Yes
Mar. 5	1000	25.0	13.4	7.7	-	34.6	8.5	0.0	Yes	Yes
Mar. 6	1030	27.5	14.0	6.0	-	34.0	8.0	0.5	Yes	Yes

Table 8-3--continued.

		Minimum depth to water table (cm)							Runoff occurred	
Date	Time	E4W5 Up Slope	E4W3 Mid Slope	E4W8 Mid Slope	E4W9 Down Slope	E1W5 Up Slope	E1W3 Mid Slope	E1W1 Down Slope	E4F1	E1F1
Mar. 7	1502	51.0	35.0	24.2	3.0	48.5	18.0	1.0	Yes	No
Mar. 9	1500	61.7	31.4	56.6	-	56.6	23.0	8.0	No	No
May 6	1445	43.5	23.5	23.5	4.0	87.0	56.0	58.0	Yes	No
May 7	1410	43.7	31.8	20.3	-	48.2	38.5	3.0	Yes	No
May 9	1404	55.8	40.9	34.9	7.1	52.7	30.7	3.3	No	No
May 11	1359	46.5	28.0	53.5	-	55.5	28.3	12.7	No	No
May 14	1402	72.2	62.5	57.6	-	75.4	53.4	44.8	No	No

† Note site locations; see Figs. 8-3 and 8-4.

‡ (-) indicates missing data.

Table 8-4--Perched water tables along topographic transects† in relation to runoff for 1979-80 rainfall season.

		Minimum depth to water tables (cm)				Runoff or flow occurred	
		E4W1	E4W3	E4W4	E4W5	Flume	Drainline
Date	Time	Upslope	Midslope	Midslope	Downslope	E4F1	E4V1
Oct. 18	2400	147.0	-‡	120.0	-	No	No
Oct. 19	0955	147.0	-	110.0	-	No	No
Oct. 20	1015	143.0	-	-	-	Yes	Yes
Oct. 21	1615	143.0	-	56.0	-	No	No
Oct 22	1100	145.0	-	56.0	-	No	No
Oct. 24	1230	71.0	-	74.5	-	Yes	-
Oct. 25	1130	76.0	148.5	50.0	-	Yes	Yes
Oct. 26	1330	109.0	142.0	49.0	146.5	No	No
Oct. 27	1401	134.0	140.3	70.0	146.0	No	No
Oct. 28	1337	147.0	116.0	71.0	146.0	No	No
Nov. 21	1235	129.0	50.0	74.0	109.0	No	Yes
Nov. 22	1002	142.0	47.0	75.0	102.0	No	Yes
Nov. 23	1120	121.0	42.0	49.0	92.0	No	Yes
Nov. 24	1215	69.0	35.0	35.0	68.0	No	Yes
Nov. 25	1115	74.0	36.0	41.0	76.0	No	Yes
Nov. 26	1040	80.0	43.0	43.0	91.5	No	Yes
Nov. 27	1052	86.0	43.5	48.1	98.5	No	Yes
Nov. 28	1531	90.0	49.0	59.1	105.4	No	Yes

Table 8-4--continued.

Date	Time	Minimum depth to water tables (cm)				Runoff or flow occurred	
		E4W1 Upslope	E4W3 Midslope	E4W4 Midslope	E4W5 Downslope	Flume E4F1	Drainline E4V1
Nov. 30	1033	96.0	52.0	69.0	111.0	No	Yes
Dec. 1	1118	101.0	56.0	74.0	111.0	No	Yes
Dec. 2	1040	77.0	31.0	32.0	73.0	Yes	Yes
Dec. 3	1240	66.8	31.0	31.3	75.5	No	Yes
Dec. 4	1052	70.2	30.8	30.0	81.2	No	Yes
Dec. 5	1559	65.7	32.2	31.0	81.3	No	Yes
Dec. 6	1303	75.2	43.5	52.3	102.7	No	Yes
Dec. 7	1024	86.4	48.9	56.2	108.0	No	Yes
Dec. 16	1350	93.0	54.5	60.0	111.0	No	Yes
Dec. 17	1200	85.4	54.0	64.0	106.9	Yes	Yes
Dec. 18	1457	55.5	31.5	32.0	82.0	No	Yes
Dec. 19	1315	65.4	32.0	29.5	87.5	No	Yes
Dec. 20	1046	71.5	37.1	35.0	96.0	No	Yes
Dec. 21	0841	46.2	28.5	28.1	83.0	Yes	Yes
Dec. 22	1220	56.5	28.2	30.0	84.5	No	Yes
Dec. 23	1246	59.5	32.0	27.5	77.3	Yes	Yes
Dec. 24	1215	49.0	28.0	27.0	76.0	No	Yes
Dec. 25	1025	71.6	34.4	31.2	98.6	No	Yes
Dec. 26	1217	86.6	47.5	48.6	109.6	no	Yes
Dec. 27	1040	94.5	53.0	57.3	99.6	No	Yes
Dec. 28	1252	95.0	55.0	66.0	112.0	No	Yes

Table 8-4--continued.

Date	Time	Minimum depth to water tables (cm)				Runoff or flow occurred	
		E4W1 Upslope	E4W3 Midslope	E4W4 Midslope	E4W5 Downslope	Flume E4F1	Drainline E4V1
Dec. 31	1145	87.5	46.0	61.5	110.5	No	Yes
Jan. 1	1055	72.0	38.1	29.5	93.0	No	Yes
Jan. 2	1225	69.8	39.0	37.0	96.0	No	Yes
Jan. 3	1408	84.1	43.0	46.0	107.7	No	Yes
Jan. 4	0923	89.3	46.5	50.3	108.9	No	Yes
Jan. 5	0950	59.0	33.0	28.0	75.0	No	Yes
Jan. 6	1400	59.0	33.0	34.0	81.5	No	Yes
Jan. 7	0944	80.3	43.9	48.3	105.1	No	Yes
Jan. 8	1105	87.3	52.0	55.3	103.8	No	Yes
Jan. 9	1455	50.0	20.6	20.3	52.3	Yes	Yes
Jan. 10	1540	47.9	21.8	-	61.0	Yes	Yes
Jan. 13	1320	31.0	17.5	28.5	54.0	Yes	Yes
Jan. 14	0910	53.0	24.2	29.0	71.5	Yes	Yes
Jan. 15	1330	33.0	24.7	31.7	79.3	No	Yes
Jan. 16	1340	78.8	42.5	49.6	103.0	Yes	Yes
Feb. 4	1011	79.1	43.6	134.9	94.5	No	Yes
Feb. 5	1050	85.6	42.2	49.2	98.0	No	Yes
Feb. 6	1412	81.5	32.5	31.9	91.7	No	Yes
Feb. 7	1505	76.0	31.0	36.0	91.5	No	Yes
Feb. 8	0930	79.0	39.0	46.5	106.0	No	Yes

Table 8-4--continued.

Date	Time	Minimum depth to water tables (cm) E4W1 Upslope	E4W3 Midslope	E4W4 Midslope	E4W5 Downslope	Runoff or flow occurred Flume E4F1	Drainline E4V1
Feb. 16	0130	88.0	59.0	72.0	107.0	No	No
Feb. 17	1146	95.0	55.0	61.0	114.0	No	Yes
Feb. 18	0934	-	44.5	41.5	104.3	No	Yes
Feb. 19	1100	89.5	27.1	41.5	81.5	No	Yes
Feb. 20	1543	73.3	34.5	39.9	99.0	Yes	Yes
Feb. 21	1447	91.0	44.0	55.5	110.0	No	Yes
Feb. 25	0911	97.0	52.7	54.1	112.7	No	Yes
Feb. 26	1112	67.0	32.2	52.1	102.3	No	Yes
Feb. 27	0926	68.5	34.4	36.9	92.4	No	Yes
Feb. 28	1347	79.5	38.5	44.5	105.6	No	Yes
Feb. 29	1649	84.0	42.0	43.0	108.0	No	Yes
Mar. 1	1010	85.0	46.0	50.0	111.0	No	Yes
Mar. 12	1023	101.3	59.5	73.3	112.8	No	Yes
Mar. 13	1523	83.0	43.7	68.3	39.7	No	Yes
Mar. 14	1025	57.0	19.0	29.0	77.0	No	Yes
Mar. 15	1210	57.0	30.0	29.0	77.0	No	Yes
Mar. 16	0816	76.0	33.0	57.0	107.0	No	Yes
Mar. 17	1051	80.3	40.3	60.8	108.3	No	Yes

† Note site locations; see fig. 8-5

‡ (-) denotes missing data. In most cases this was due to equipment not yet installed by dates indicated.

CHAPTER 9. RELATIVE CHANGES IN INFILTRATION

B. Lowery, M. J. Pronold, and J. A. Vomocil

Summary

Rates of infiltration change throughout the rainfall season. They are high in the fall, decrease to a minimum in mid-winter, and increase in late winter or spring. These changes are attributed to the influence of soil moisture and surface condition. After fall planting, the soil surface is very rough and infiltration rates are high. Winter rains result in crusting of the soil surface and increased moisture content which decrease infiltration. Infiltration is further decreased when the soil surface is frozen. Cracking of the surface crust, drying of the soil, and increased plant cover contribute to an increase in infiltration in the late winter or spring.

Introduction

We had originally hypothesized that antecedent moisture was a dominant controlling factor in the runoff and erosion process in the high rainfall zone of the Pacific Northwest. Our first year's observations indicated that the infiltration process (water entry into the soil) also may influence runoff. There were indications that the infiltration rate changes throughout the rainfall season.

After fall planting, the soil surface is very rough with numerous macro-aggregates and pores. Kemper and Miller (1974) proposed that surface roughness would enhance vertical infiltration. Low antecedent moisture content also increases the infiltration rate (I). Philip (1957) studied the influence of antecedent moisture content on infiltration using a physically based infiltration model. He has shown that (I) decreases with increasing initial moisture content and that the effects of antecedent moisture appeared to be more pronounced during the initial infiltration events. Soil surface crusts formed by the destruction of soil aggregates by raindrop impact and subsequent plugging of pores also have been reported to impede infiltration (Kemper and Miller, 1974).

This dynamic soil surface is believed to cause changes in runoff throughout the rainfall season. The precipitation rate (R) in the Willamette Valley was thought to be much less than the infiltration rate (I). Thus, while overland flow was hypothesized to be caused primarily by perched water tables, as discussed in Chapters 8 and 10, this may not always be the case. The crusting condition as well as frozen ground may also cause overland flow.

Materials and Methods

To assess relative changes in (I) over the rainfall season, infiltration rates were measured monthly using a portable infiltrometer

(Meeuwig, 1971; Froehlich and Hess, 1976). The infiltrometer consists of a 61 x 61 cm plexiglas tank. Precipitation is produced by 517 evenly spaced stainless steel tubes (needles). A filter is located in the supply line to keep the needles from becoming plugged. The infiltrometer is supported by three legs, two of which are adjustable (Fig. 9-1) to allow the infiltrometer to be used on slopes. Water is supplied to the tank, through a (0.6 cm dia.) plastic tube from a 19 liter reservoir supported by a 1.5 m high stand. The flow rate is controlled with a small valve located in the supply line. Precipitation was applied at a constant rate of 7.2 cm/hr for each measurement.

A folded section of sheet metal placed at the base of the infiltrometer served as the collecting trough for the 1978-79 measurements (Fig. 9-1). In the 1979-80 rainfall season, this trough was replaced by a small plot equipped with a trough which improved the collection of runoff (modified trough in Fig. 9-1). All runoff from the trough was collected. The volume of runoff was measured at known time intervals to determine the amount of water which had infiltrated. Measurements were continued until steady state infiltration rate was approached.

Measurements were made in the midslope position of sub-watersheds E1F1 (0.45 ha) and E4F1 (1.4 ha). To avoid disturbance of the soil surface due to simulated raindrop impact, a new site for infiltration measurements was chosen each month. Surface soil samples were taken before and after each infiltration measurement. These samples were placed in plastic containers and taken to the laboratory for moisture content determination. Pore water pressure readings were taken from the nearest Ap horizon tensiometer (tensiometers are described in Chapter 3).

Results and Discussion

It is recognized that the data do not represent the absolute effects of natural rainfall. It is assumed, however, that measured infiltration rates are proportional to those during rainfall events. The data reflect relative differences between soils as well as changes throughout the season.

In most cases the initial infiltration rate I_i was greater than the application rate R_s, thus all the water applied infiltrated. From Figures 9-2 and 9-3 it is noted that I_i was not always greater than R_s. The point where $I_i = R_s$ will be noted as the time runoff started T_s.

Figures 9-2 and 9-3 and Table 9-1 show a decrease in T_s for both sub-watersheds. This decrease is noted from October to December, and except for the 1.4 ha sub-watershed, it continued to decrease until January (Fig. 9-3). The decreases were attributed to increasing soil moisture content with winter rainfall. The T_s increased after December and/or January, approaching that of October (Fig. 9-3). In October, 1979 the T_s for the 1.4 ha sub-watershed was much less than expected for the fall. This value is low because the measurement occurred after the rainfall season started. A more typical T_s value for early autumn is that of October, 1978 (Table 9-1 and Fig. 9-2).

The infiltration curves for January and February in Figure 9-2 are considered atypical because they reflect frozen ground. The two conditions were different with respect to the soil moisture status. The soil was nearly saturated in January and unsaturated in February. This is indicated by the change in percent moisture (Table 9-1). There was a greater increase in soil moisture after the infiltration measurements in February than January. This indicates more available pore space in February. Unsaturated frozen ground tends to increase T_s and I_s. Toy (1977) indicated an increase in (I) occurs when ice crystals form in moist soil.

Statistical data in Table 9-1 indicate a larger dispersion about the mean of T_s than I_s. The final infiltration rate also reflects surface changes more than T_s. The I_s was found to be greater in early autumn just after planting (Table 9-1 and Fig. 9-2 and 9-3). It also decreased as the soil moisture increased.

Philip (1957) presented data indicating a decrease in I_s with increasing antecedent moisture content. Data from this study generally agree with this except for periods of very pronounced surface crust conditions. For example, in the 0.46 ha sub-watershed, tensiometer readings indicated that there was less soil moisture in March (data for 1978, Table 9-1) than December, but the I_s for March was less than that for December. This was attributed to the influence of surface crust. Late in April, as rainstorms were less frequent, the crust dried and cracked. These cracks along with increased ground cover cause an increase in I_s. Surface crusting and cracking was also observed in the 1.4 ha sub-watershed but as indicated by the data in Figure 9-2 it was less dramatic. Surface sealing seemed to have occurred earlier in 1980 than in 1979. The crust formed in late January and started to crack in March (Table 9-1) as opposed to March and April for 1979.

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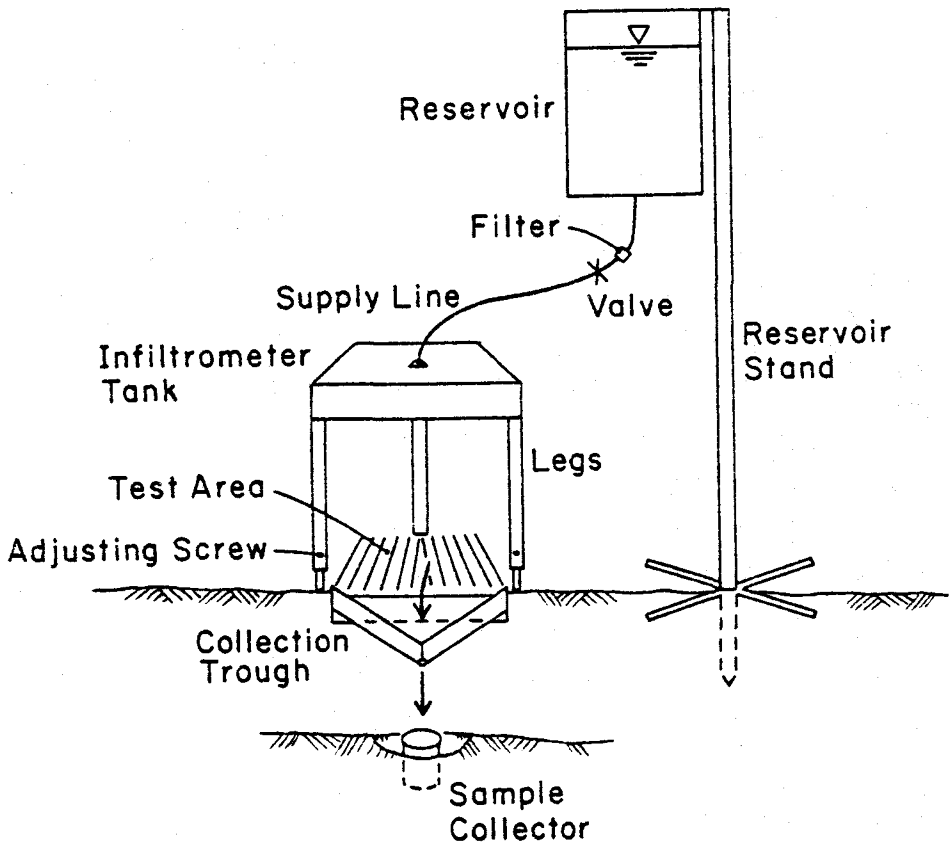

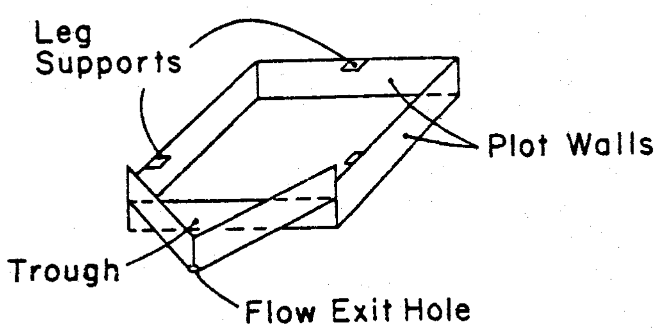

Fig. 9-1--Portable infiltrometer (upper) and modified trough apparatus (lower).

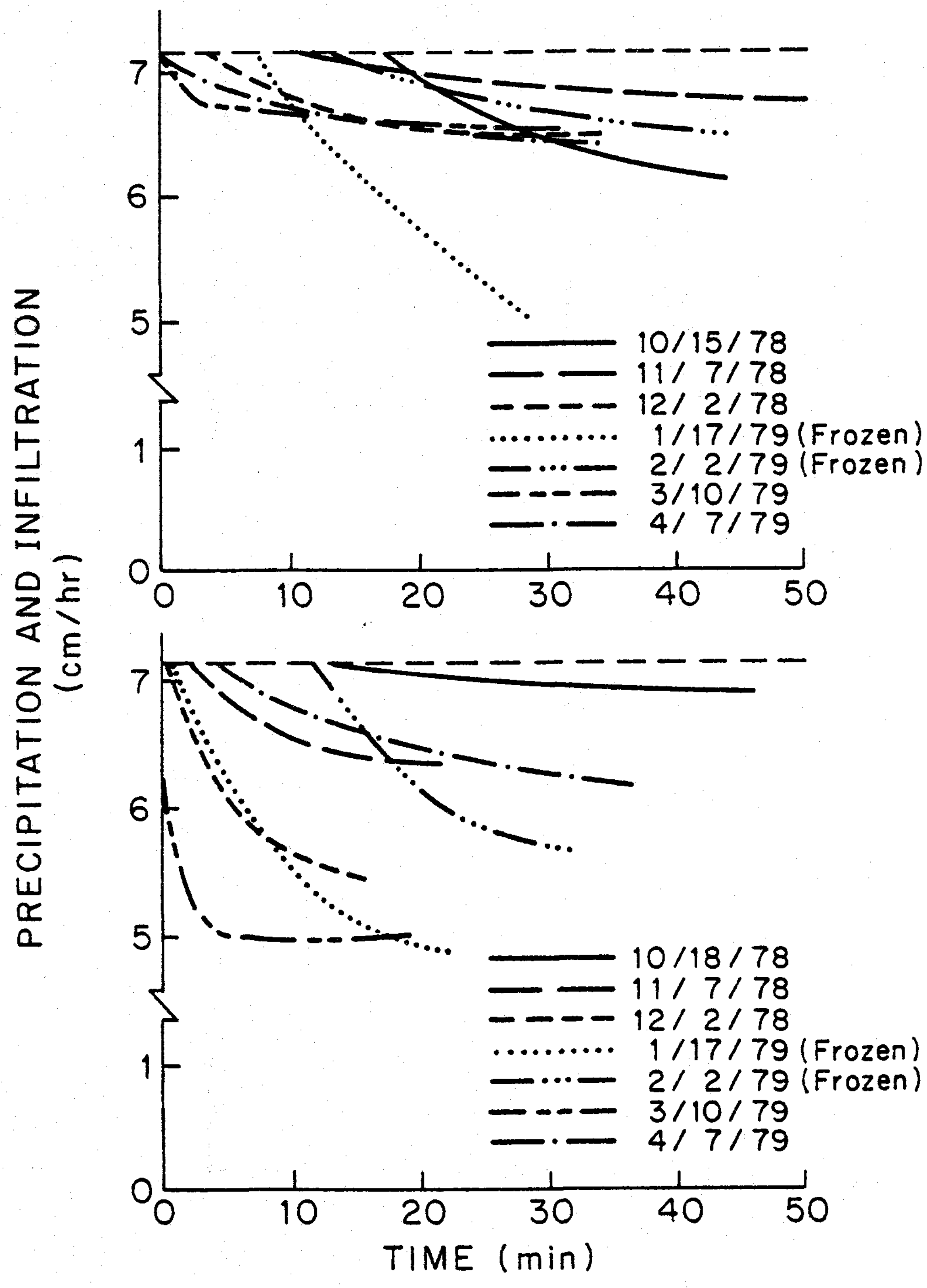

Fig. 9-2--Monthly infiltration curves for the 1.4 (top) and 0.46 (bottom) hectare sub-watersheds for the 1978-79 rainy season.

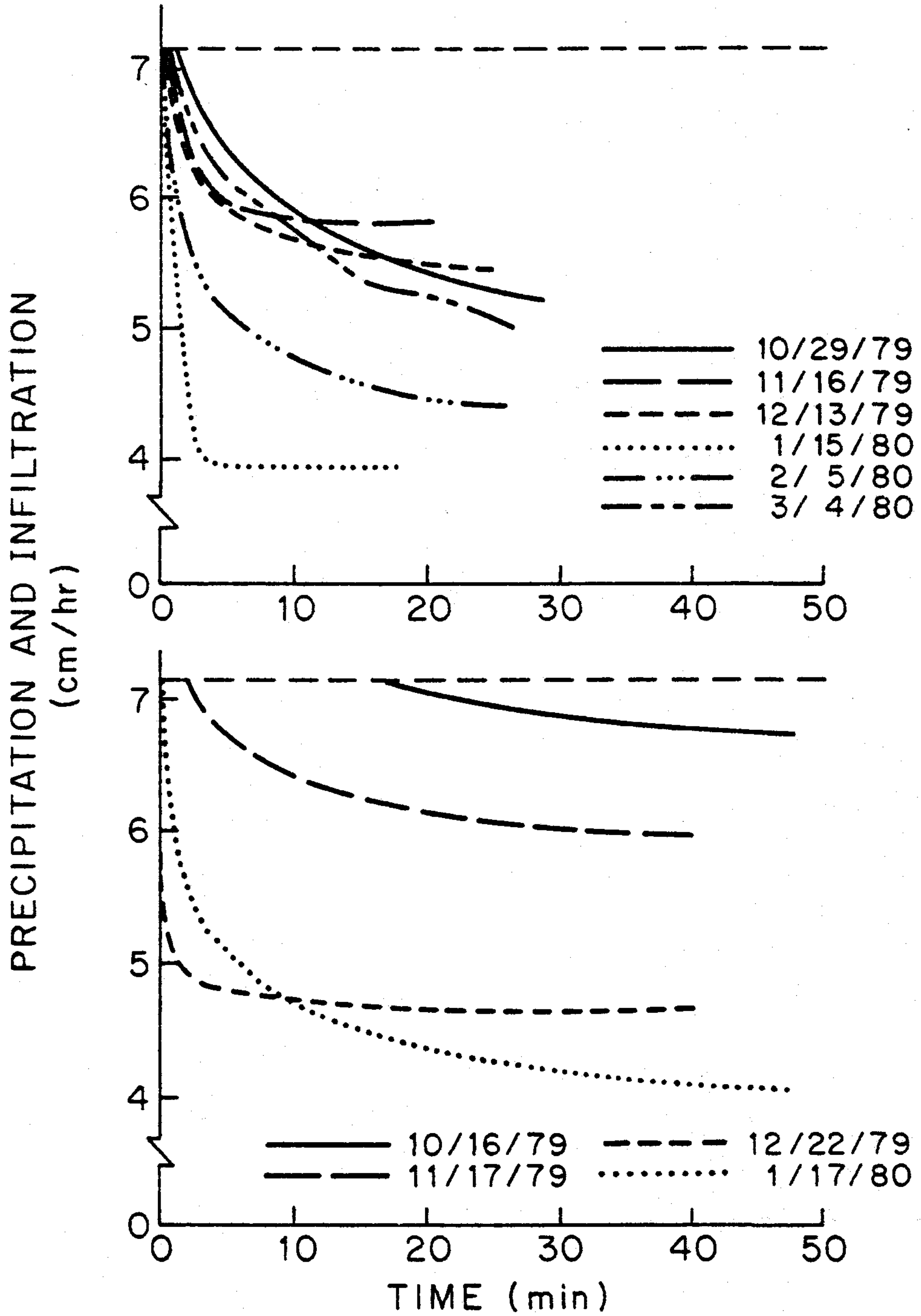

Fig. 9-3--Monthly infiltration curves for the 1.4 (top) and 0.46 (bottom) hectare sub-watershed for the 1979-80 rainy season.

Table 9-1--Sub-watershed monthly infiltration curve parameters and associated soil pore water condition.

Date	Time runoff started (min)	Final infiltration rate ($cm^3/cm^2/hr$)	Average moisture content Before (%)	Average moisture content After (%)	(Δ%)	Suction (cm of H_2O)
0.46 Ha sub-watershed						
Oct. 18, 1978	12.00	6.80	–	–	–	> 266.0
Nov. 7	2.00	6.30	13.6	26.7	13.1	199.0
Nov. 2	0.75	5.40	22.2	–	–	45.1
Jan. 17, 1979	0.75	4.80	25.7	30.5	4.8	†
Feb. 2	12.00	5.70	26.5	44.4	17.9	†
Mar. 10	0.00	4.90	27.3	28.3	1.0	72.1
Apr. 7	5.00	6.20	20.4	–	–	106.3
Oct. 16	16.00	6.80	2.4	–	–	–
Nov. 17	1.80	6.00	25.8	27.4	1.6	–
Dec. 22	0.00	4.60	26.0	29.6	3.6	–
Jan. 17, 1980	0.11	4.00	22.7	27.5	4.8	–
Mean	4.58	5.59	–	–	–	–
Standard deviation	5.89	0.93	–	–	–	–
N	11	11	–	–	–	–
1.4 Ha sub-watershed						
Oct. 15, 1978	18.00	6.10	–	–	–	> 263.0
Nov. 7	10.00	6.70	16.3	29.1	12.8	227.5
Dec. 2	4.00	6.40	25.1	–	–	38.5
Jan. 17, 1979	5.50	< 5.00	30.5	36.6	6.1	†
Feb. 2	12.00	6.40	26.7	37.4	10.7	†
Mar. 10	0.00	6.50	29.3	34.1	4.8	59.2
Apr. 7	1.00	6.40	20.8	–	–	115.2

Table 9-1--continued.

Date	Time runoff started (min)	Final infiltration rate ($cm^3/cm^2/hr$)	Average moisture content Before (%)	After (%)	(Δ%)	Suction (cm of H_2O)
Oct. 29	0.83	5.20	28.3	33.0	4.7	–
Nov. 16	0.50	5.80	28.9	34.4	5.5	–
Dec. 3, 1979	0.50	5.50	29.8	33.7	3.9	–
Jan. 15, 1980	0.00	4.10	30.4	33.4	3.0	–
Feb. 5	0.33	4.60	33.0	39.0	6.0	19.95
Mar. 4	–	5.20	29.5	33.7	4.2	25.63
Mean	4.39	5.68	–	–	–	–
Standard deviation	5.92	0.82	–	–	–	–
N	12	13	–	–	–	–

†Water frozen in the tensiometers cups and lines.

CHAPTER 10. RUNOFF-CONTRIBUTING AREAS IN FALL PLANTED FIELDS

R. B. Brown and J. S. Hickman

Summary

Many storms throughout the winter season produce runoff from limited portions of the Elkins Road watershed. The extent of this area is highly variable and depends primarily on the presence of perched water tables. Runoff from the entire watershed occurred infrequently and only during major storms associated with frozen ground, high antecedent moisture or extensive crusting.

Introduction

The influence of antecedent moisture and landscape position on runoff and erosion has been investigated intensively in fall planted fields at Elkins Road. Initial hypotheses were that the infiltration rate of these agricultural soils is seldom exceeded by rainfall intensity, and that runoff is most likely to occur from those soils that are saturated with water at or near the surface as a function of a restrictive or perching layer in the subsoil, and/or a low landscape position conducive to collection of water in the soil profile.

Research around the United States and elsewhere--chiefly but not entirely on nonagricultural lands--has shown that runoff production is often a function of degree of saturation of the soil (Betson, 1964; Dunne, 1978; Dunne et al., 1975; Harr, 1977; Henninger et al., 1976; Hewlett, 1974; Kirkby and Chorley, 1967; Ragan, 1968). On the other hand, classical concepts in agricultural erosion, as manifested in the Universal Soil Loss Equation (USLE), suggest that soil erosion is a function of rainfall intensity, surface soil erodibility, slope length and steepness, crop management, and erosion control practices (Wischmeier and Smith, 1978). No allowance for antecedent moisture conditions is made in the USLE. The implication is that runoff and erosion on a landscape are only a function of soil, management, and rainfall conditions, regardless of the degree of antecedent wetness of the soil or of the areal extent of relatively wet zones.

Results from monitoring clearly indicate differences in runoff and erosion in various parts of the Elkins Road watershed. These differences are associated with perched water tables in relation to restrictive layers in the soil and landscape position. Toeslopes and areas around waterways seem to be particularly active zones. This chapter deals with an effort to evaluate conditions under which runoff occurs and the extent of contributing areas.

Materials and Methods

The results reported here are based on observations made in the field during or soon after storm events. Observations were made while walking on and near sub-watersheds E1F1, E4F1, and E4F2 coincidental to routine checks of wells, flumes, samplers, and other monitoring devices.

Results are reported as the percent of a watershed that contributed to direct surface runoff from a particular storm. For example, if runoff contributing area is reported as being 25 percent, it means that a maximum of about one quarter of the area of that watershed yielded runoff during the storm. If contributing area is reported as 100 percent, it means that, at some time during the storm, the entire watershed contributed direct surface runoff to the watershed outlet.

In those storms where the runoff contributing area of a watershed comprised less than 100 percent of that watershed, the percent contributing area was estimated by outlining the contributing area on a contour map and determining its area with a planimeter. In those cases where the runoff contributing area comprised 100 percent of the watershed, the contributing area was either observed during the storm or induced from well records showing that the water table approached or reached the ground surface during the storm.

No statement is made or implied here as to which parts of a watershed experienced a greater or lesser "percent runoff," or a greater or lesser infiltration of rainwater. All that is reported here is the percent of a watershed that contributed runoff to some degree.

Results and Discussion

This investigation has shown that runoff can be caused by a variety of circumstances (Tables 10-1--10-3). These circumstances include (1) saturation of the soil, (2) a frozen soil surface, and (3) a "crusting" or "sealing" of surface soil under the influence of raindrop impact in late autumn and early winter storms which reduces the infiltration capacity of the soil.

Major storms tend to be associated with one or all of the above circumstances. Weather and erosion records for the Willamette Valley and observations at Elkins Road bear this out. For example, severe erosion in the Willamette Valley in January, 1956, was attributed in part to rapid runoff from soils that had been saturated under heavy rains in the previous month (Torbitt and Sternes, 1956). This type of phenomenon occurred at Elkins Road on Dec. 14-15, 1977 (Tables 10-1--10-3).

Major storms in the valley in February, 1949, and December, 1964, involved rains falling on snow-covered, frozen ground (U.S. Soil Conservation Service, 1949; Baum and Kaiser, 1965; Sternes, 1964). Frozen ground has been observed at Elkins Road, on Jan. 10-12, 1979 (Tables 10-1--10-3), to cause runoff in all parts of fall-planted fields.

Observations at Elkins Road of several other storms, including that of Feb. 10-11, 1979 (Tables 10-1--10-3) have shown that a crusting effect produced by early season rains can reduce infiltration capacity and lead to runoff from soils that are not saturated. Also, as suggested by observations of Oct. 18-19, 1979, Oct. 20, 1979, and Oct. 24-25, 1979, a perching of soil water may occur within the plow layer, causing a saturated zone in the upper several cm of soil, above a relatively dry subsoil. This effect could be caused by the pulverizing, compacting influence of moldboard plowing and repeated working of the soil in seedbed preparation.

Minor storms cause runoff in only the lowest, wettest, parts of the sub-watersheds. This was the case for storms of Dec. 10-14, 1978, Feb. 10-11, 1979, and Oct. 18-19, 1979 (Tables 10-1--10-3).

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Table 10-1--Percent of watershed E1F1 contributing to runoff for several storms.

Storm period	Runoff-contributing area %	Conditions causing runoff
Dec. 14-15, 1977	100	Saturation of soil.
Dec. 10-14, 1978	0	--
Jan. 10-12, 1979	100	Frozen surface soil; some infiltration occurred (water table rose through the period).
Feb. 10-11, 1979	∿ 25	Only lowermost, wettest section of watershed experienced runoff.
Oct. 18-19, 1979	0	Surface very wet, soggy, soft, but subsoil dry.
Oct. 20, 1979	Trace (diffuse, discontinuous)	Infiltration rate nearly exceeded by rainfall rate; runoff minor and spotty, seeping into soil a few meters down-slope.
Oct. 24-25, 1979	Unknown (but very small, possibly 0)	No observation made, but no subsequent evidence of significant runoff/erosion during the storm.

Table 10-2--Percent of watershed E4F1 contributing to runoff for several storms.

Storm period	Runoff-contributing area %	Conditions causing runoff
Dec. 14-15, 1977	100	Saturation of soil.
Dec. 10-14, 1978	10	Only lowermost, wettest part of watershed experienced runoff.
Jan. 10-12, 1979	100	Frozen surface soil; some infiltration occurred (water table rose through the period).
Feb. 10-11, 1979	100	Surface soil crusted; infiltration rate exceeded.
Oct. 18-19, 1979	Trace (diffuse, discontinuous)	Infiltration rate nearly exceeded; runoff minor and spotty, seeping into soil a few meters downslope; surface very wet, soggy, soft, but subsoil dry.
Oct. 20, 1979	100	Subsoil dry in mid and upper slope positions.
Oct. 24-25, 1979	100	Subsoil dry in mid and upper slope positions.

Table 10-3--Percent of watershed E4F2 contributing to runoff for several storms.

Storm period	Runoff-contributing area %	Conditions causing runoff
Dec. 14-15, 1977	100	Saturation of soil.
Dec. 10-14, 1978	15	Only lowermost, wettest part of watershed experienced runoff.
Jan. 10-12, 1979	100	Frozen surface soil; some infiltration occurred (water table rose through the period).
Feb. 10-11, 1979	100	Surface soil crusted; infiltration rate exceeded.
Oct. 18-19, 1979	Unknown (Assume trace as in E4F1.)	(Assume same as in E4F1.)
Oct. 20, 1979	100	Subsoil dry in mid and upper slope positions.
Oct. 24-25, 1979	100	Subsoil dry in mid and upper slope positions.

CHAPTER 11. EFFECT OF GYPSUM

M. J. Pronold[1] and M. E. Harward

Summary

Broadcast gypsum was not found to be beneficial in controlling erosion. Treated soils had lower infiltration rates, a weaker surface crust, and smaller stable aggregates than untreated soils. Higher sediment yield and concentrations were measured from soils treated with gypsum than from untreated soils.

Introduction

Management practices are the mechanisms for decreasing erosion. One management practice which may be applicable is decreasing the erodibility of the soil through the use of amendments. Soil aggregation and aggregate stability have been shown to be highly significant in determining soil erodibility (Wischmeier and Mannering, 1969; El-Swaify and Dangler, 1976). Retaining aggregate stability would keep infiltration rates high by maintaining a porous soil surface. The formation of a crust is mostly due to the breakdown of soil aggregates with the fine particles filling the pores (McIntyre, 1958b). The crust reduces infiltration resulting in increased runoff (Edwards and Larson, 1969; Duley, 1939). Duley stated this phenomenon is the most important factor affecting infiltration on the soils he studied. Even if near saturated conditions exist and infiltration is controlled by the water content of the soil, more stable aggregates are less likely to be transported by overland flow. The more stable aggregates would not break down and would need higher energy conditions to be transported than dispersed individual soil grains.

Adsorbed divalent cations may be expected to maintain or promote aggregate stability more than monovalent cations. Gypsum and lime, which contain the divalent calcium ion, are two amendments which are agriculturally feasible. The use of gypsum for the reclamation of sodic soils is well documented. Its effect on acid soils has not been evaluated to any significant degree.

It was hypothesized that the addition of gypsum to the soil surface would maintain aggregate stability, reduce the formation of a soil crust, and result in higher infiltration rates.

[1] This phase of investigations served as the thesis project for the senior author. The major findings and interpretations are given here. For more complete data and discussion, reference should be made to Pronold (1981).

The objectives of the study were:

- To determine the effect of gypsum on some of the physical properties of acid soils.

- To determine if the resulting changes in soil properties influence runoff and erosion.

It was intended that if the results of the study were favorable, they would form a basis for recommending gypsum as a management tool for erosion control.

Materials and Methods

General

The nature of the watershed, its soils and their properties, and the soil-geomorphic relationships have been described in Chapter 4. Three study sites within the watershed were used for this phase of the investigation. Site E3 was in a perennial grass field. The slope is 5 percent, with a west aspect. The soil is mapped as a Woodburn silt loam which is classified as a fine-silty, mixed, mesic Aquultic Argixeroll. The soil is moderately well drained. Two additional sites were used in the main study area of the watershed and were planted to winter wheat. E1 is a well drained site on a 7 percent slope with a southern aspect. The soil is mapped as a Willakenzie silt loam, a fine-silty, mixed, mesic Ultic Haploxeralf. E4 is mapped the same but is underlain by a slowly permeable layer 46 cm below the surface. This site, somewhat poorly drained, has a 7 percent slope with a western aspect.

Erosion plots

Modified erosion plots with an area of about one m^2 were used at all three sites. Plots and collection devices were the same as those described in Chapter 3 except for plot size. Four plots, two treated and two untreated, were placed side by side in a midslope position at sites E1 and E4. Two plots were placed at E3. The plots at E3 and E1 were eliminated after the first season.

A broadcast treatment of gypsum was applied at the rate of zero and two mTon/ha the first season and 0, 4, 8, and 16 mTon/ha the second season. The increase in application was in response to no observable effects the first season. An adjacent area also received the highest rate of application; this area was used to determine infiltration rates and for sampling to determine crusting and aggregate stability. A reapplication of 16 mTon/ha was made to the adjacent area and to the highest rate plot on February 24 of the second rainfall season.

The runoff was measured by grab sampling. After sampling, the collection tubs were emptied. Sediment concentrations of the grab samples were determined and total sediment yields calculated. Values for sediment yields were extrapolated to kg/ha for comparative purposes.

Infiltration

Field infiltration tests were conducted using a portable, closed top infiltrometer modeled after an instrument described by Meeuwig (1971). Its construction, specifications, and operation are described in Chapter 9.

Crusting

Crusting of the soil surface for several dates was documented by the use of thin sections. Crust thickness was measured and porosity inspected to ascertain any differences between treated and untreated soil with the use of a petrographic microscope.

Aggregate Stability and Size

Soil surface aggregates were measured for stability using the water drop method described by McCalla (1944). Field moist soil was used to determine stable aggregate size distribution. A water sieve method similar to that described by Yoder (1936) was used. The equivalent of approximately 60 g of soil was placed in the top sieve of a nest of five 20 cm brass sieves. The sieves with the soil were immersed in water for 10 seconds and then oscillated for five minutes at the rate of 29 strokes per minute with a 37 mm displacement using a Yoder-type machine. The dry weight for each aggregate size was measured and used in calculating stable aggregate size distribution, percent of aggregates recovered, mean weight diameter (VanBavel, 1950) and geometric mean diameter (Mazurak, 1950).

Results and Discussion

Infiltration

For the first season of observation when gypsum was applied at 2 mTon/ha, no consistent differences in infiltration from treatment were observed (Figs. 11-1 -- 11-3). Application rates were increased to 16 mTon/ha in the second year. Steady state infiltration rates in five of six trials were higher on untreated plots than those which received gypsum (Fig. 11-4). The higher infiltration values for untreated plots were related to lower moisture contents than on plots receiving gypsum (Table 11-1). The time to initiate runoff was essentially the same for both check and treated plots.

In both years, the largest differences in infiltration were with time; the effect of time was greater than that due to treatment. Generally, infiltration rates were high in the fall and decreased to minimum values in the middle of the winter followed by increases in early spring. These seasonal trends were similar to those reported in Chapter 9. These differences in rates were interpreted as being caused by the combined effects of initial moisture contents, crusting, and cracking.

Crusting

No differences could be discerned between the treated and untreated soil in porosity or thickness of the crust. There were differences with time and site location (Table 11-2). The formation of a crust was rapid in the rills. This is illustrated in Plate 11-1 which was taken on Oct. 29, 1979, following the first storm after planting. More than eight cm of rain fell in a three days. As the year progressed, the crust thickened slightly; site E1 had a thicker crust than E4. Site E1 also had less stable aggregates than E4 (Tables 11-3, 11-4).

Gypsum did exert an effect on the crust by making it weaker. Although measurements of crust strengths were not conducted, this condition is inferred by two other results, the water sieve method for stable aggregate size distribution (Table 11-5) and sediment yield from infiltration trials (Table 11-6). When a pronounced crust had formed, water sieving was done by placing the entire crust upon the top sieve. The crusts from the gypsum treated soil broke up and dispersed much more readily than the crusts from the untreated soil. The results of a weaker crust from application of gypsum agrees with findings by Bennett et al. (1964). Bennett et al. attributed this to the increased moisture in the gypsum-treated crusts; our results are consistent with that interpretation (Table 11-1).

Formation of a crust has been attributed to dispersion of aggregates, clogging of pores, and the beating action of raindrops (McIntyre, 1958b). However, at this watershed much of the subsequent thickening of crust can be attributed to sedimentation from erosion upslope which is indicated by stratification (Plate 11-4). A smooth surface is present at the end of the season (Plate 11-2). The deposition process is also supported by the fact that the original gypsum application on Oct. 29, 1979 was observed to be buried under several mm of soil at the end of the season.

By the end of the season the growth of the wheat and wetting-drying cycles result in an increase in porosity (Plates 11-3 — 11-5).

Aggregate Stability

No consistent differences in aggregate stability from application of gypsum were obtained (Tables 11-3 and 11-4). Differences between sites and sampling dates, however, are evident. The greatest decrease in aggregate stability occurs at the beginning of the rainfall season. The initial stability value of 24 obtained in the second season for site E4 is much lower than the initial value of 47 obtained in the first year. This is because by Oct. 23, 1979 the watershed already had a storm of more than eight cm of rainfall in a three day period; the fall of the first season was dry. The first rains penetrate the dry aggregates and reduce the cementing between particles.

Size of Stable Aggregates

In all cases the geometric mean diameter (GMD) and the mean weight diameter (MWD) of aggregates were reduced by application of gypsum (Table 11-5). These differences at site E4 were statistically significant for almost all sample dates. The untreated soil contained more aggregates in the larger size classes (≥8 and 8-4.7 mm); the gypsum treated soil had more aggregates in the samller size classes (1-0.5 and <0.5 mm).

Size of stable aggregates also changes with date of sampling (Fig. 11-5). Reduction of aggregate size from the October to November sample dates is caused by raindrop impact. Subsequent increases up to early February corresponds to thickening of the surface crust. Reduction in size by early March corresponds to a period of cracking of the crust and increased root growth which induces planes of weakness.

Runoff and Erosion

The effects of gypsum on runoff and erosion were evaluated in two phases of the investigations. The amount of runoff and sediment yields from the infiltration studies were measured. Runoff and sediments also were measured using erosion plots.

Gypsum affected the yield of sediments much more than amount of runoff during the infiltration studies (Table 11-6). This is reflected in the sediment concentrations. Both sediment yield and concentrations were higher from the treated plots than from the check in five of the six dates of measurement. The concentrations of sediment reflect the relative soil erodibilities for the two treatments. The sediment concentration varies with time during a given infiltration trial (Fig. 11-6). The high initial concentration reflects the transport of available loose soil particles. This decreases with time as the amount of easily erodible particles is decreased. The increase in concentration at the last time of measurement corresponds to saturation of the soil when infiltration measurements were terminated. Soil particles are much more easily detached by falling raindrops when the soil is saturated.

Measurement of runoff and sediment yield from the erosion plots did not show any beneficial effect from applications of gypsum (Fig. 11-7). In most cases, one of the gypsum treated plots had higher runoff and sediment yields than the check. This trend is consistent with sediments measured during infiltration trials. Measurement of effects of gypsum were confounded with variability in amount of plant cover.

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Table 11-1--Moisture content of surface aggregates at site E4 1979-1980.

Date	Gravimetric moisture content	
	Treated†	Check
Oct. 23	0.248	0.248
Nov. 6	0.280	0.280
Nov. 16	0.308	0.267
Dec. 3	0.320	0.283
Jan. 3	0.280	0.285
Feb. 5	0.333	0.319
Mar. 4	0.331	0.278

†16 metric tons of gypsum per hectare.

Table 11-2--Thickness of crust at various sites, 1978-1979.

Date	Thickness of crust mm		
	E1	E3	E4
Nov. 15	0	2-3	0
Dec. 22	2-5	2-4	2-3
Jan. 21	3-5	2-5	2-4
Feb. 4		3-5	
Mar. 9	3-8		3-5
May 4	5-10	5-10	3-6

Table 11-3--Aggregate stability at various sites as determined by the water drop method using air dried soil, 1978-1979.

	Drops to destroy 0.10 gram of soil					
	E1		E3		E4	
Date	Treated†	Check	Treated	Check	Treated	Check
Nov. 15		28.40		55.40		47.00
Dec. 22	9.60	8.40			14.13	15.20
Jan. 21	10.15	10.18	13.75	16.33‡	14.23	15.05‡
Feb. 8	10.88	10.63	16.15	16.80	14.90‡	14.18
Mar. 9	10.70	12.90‡	15.15	16.08	14.53	15.05
May 4	16.13‡	14.43	25.30‡	19.80	14.45	14.20

†Two metric tons of gypsum per hectare.

‡Significant difference between treatments at the 0.05 level.

Table 11-4--Aggregate stability at various sites as determined by the water drop method using air dried soil, 1979-1980.

	Drops to destroy 0.10 gram of soil			
	E1		E4	
Date	Treated†	Check	Treated†	Check
Oct. 23				24.56
Nov. 6			16.62	17.86
Nov. 16			14.40	14.26
Dec. 3		10.72	13.46	14.20
Jan. 3	10.69	10.82	14.16	14.89
Feb. 5	8.56	8.99	11.05	11.61
Mar. 4			10.35	10.03
Apr. 23			10.75	10.22

†16 metric tons of gypsum per hectare.

Table 11-5--Geometric mean diameter (GMD) and mean weight diameter (MWD) of surface aggregates at various sites, 1979-1980.

Date	GMD		MWD	
	Treated†	Check	Treated	Check
Site E1				
Dec. 3		1.92		3.82
Jan. 3	1.90	2.12	3.97	4.19
Feb. 5	1.59	1.81	4.27	4.53
$MWD = 0.4715\ GMD + 3.32$		$r^2 = 0.11$		
Site E4				
Oct. 23		3.36‡		5.10
Nov. 6	2.38	2.88‡	4.36	4.86‡
Nov. 16	1.77	2.44	3.64	4.19
Dec. 3	2.37	3.41‡	4.42	5.09‡
Jan. 3	2.15	4.72‡	4.26	6.36‡
Feb. 5	2.88	4.85‡	5.40	6.54‡
Mar. 4	1.00	1.31‡	2.48	2.97
$MWD = 1.0017\ GMD + 1.84$		$r^2 = 0.94$		

†16 metric tons of gypsum per hectare.
‡Significant difference between treatments at the 0.05 level.

Table 11-6--Sediment, runoff and sediment concentration from infiltration trials at site E4 1979-1980.

Date	Sediment yield		Runoff		Total	Concentration	
	Treated†	Check	Treated	Check	applied	Treated	Check
	----grams/plot----		---------liters/plot---------			---grams/liter---	
Oct. 29	8.4	2.8	3.00	2.84	10.53	2.80	0.98
Nov. 16	4.1	1.5	1.59	1.60	8.35	2.58	0.94
Dec. 3	3.4	2.7	2.35	2.45	9.08	1.45	1.10
Jan. 15	5.4	3.8	2.97	2.82	6.53	1.82	1.35
Feb. 5	4.5	7.3	3.25	3.02	8.35	1.38	2.42
Mar. 4	9.4	4.8	3.09	2.81	9.80	3.04	1.71

†16 metric tons of gypsum per hectare.

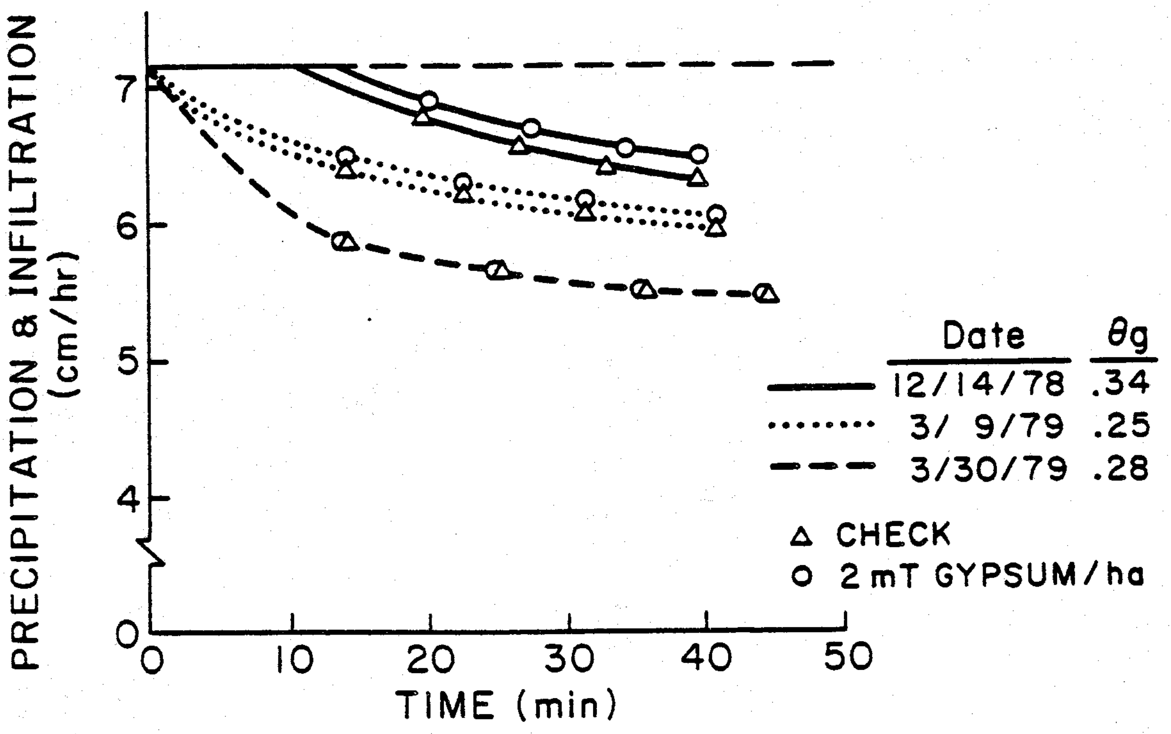

Fig. 11-1--Infiltration rates at site E4, 1978-1979.

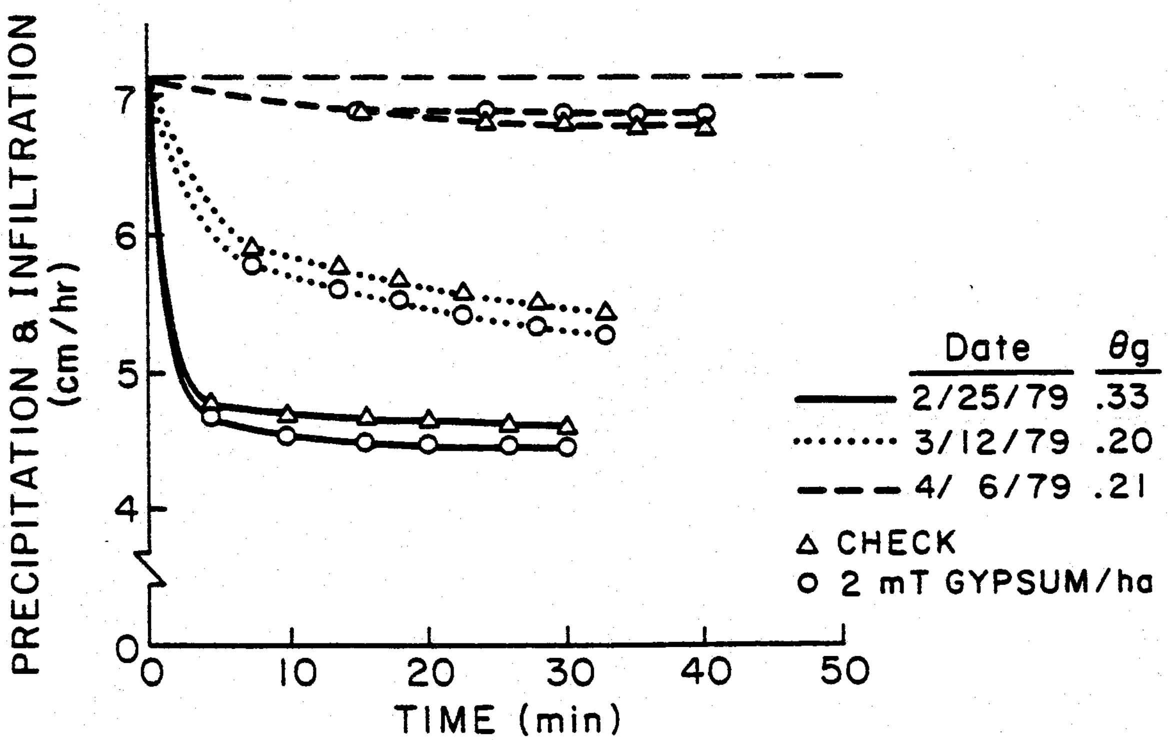

Fig. 11-2--Infiltration rates at site E1, 1978-1979.

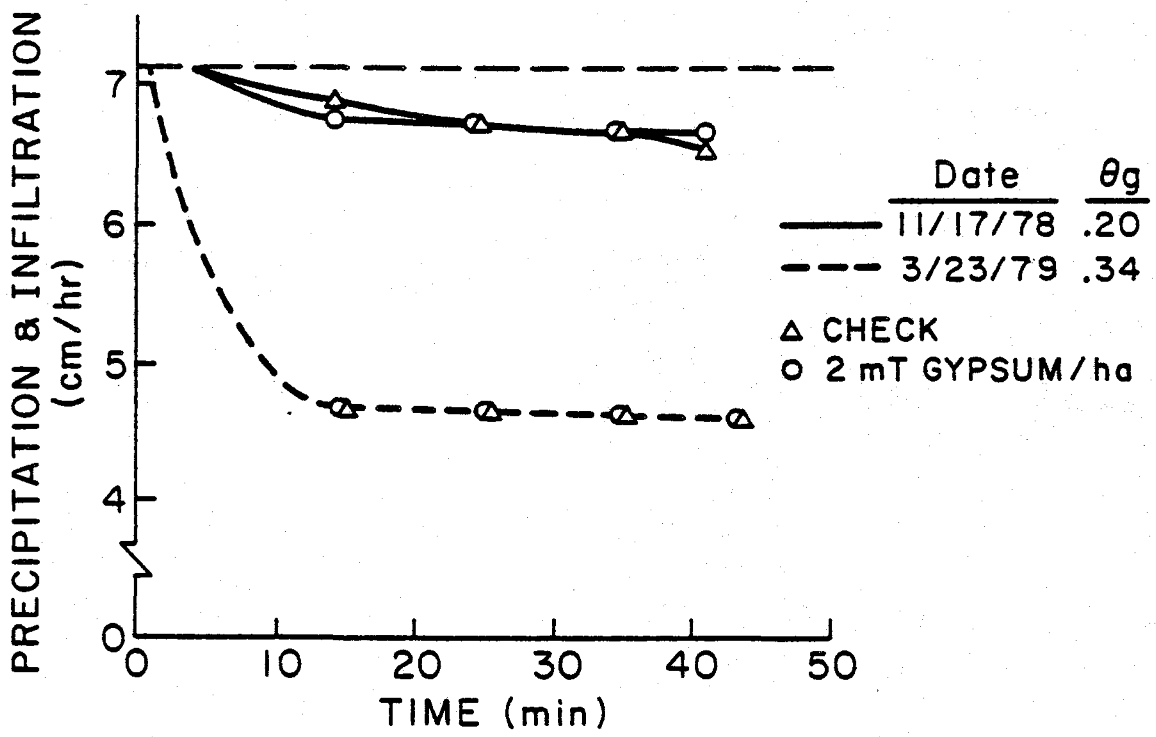

Fig. 11-3--Infiltration rates at site E3, 1978-1979.

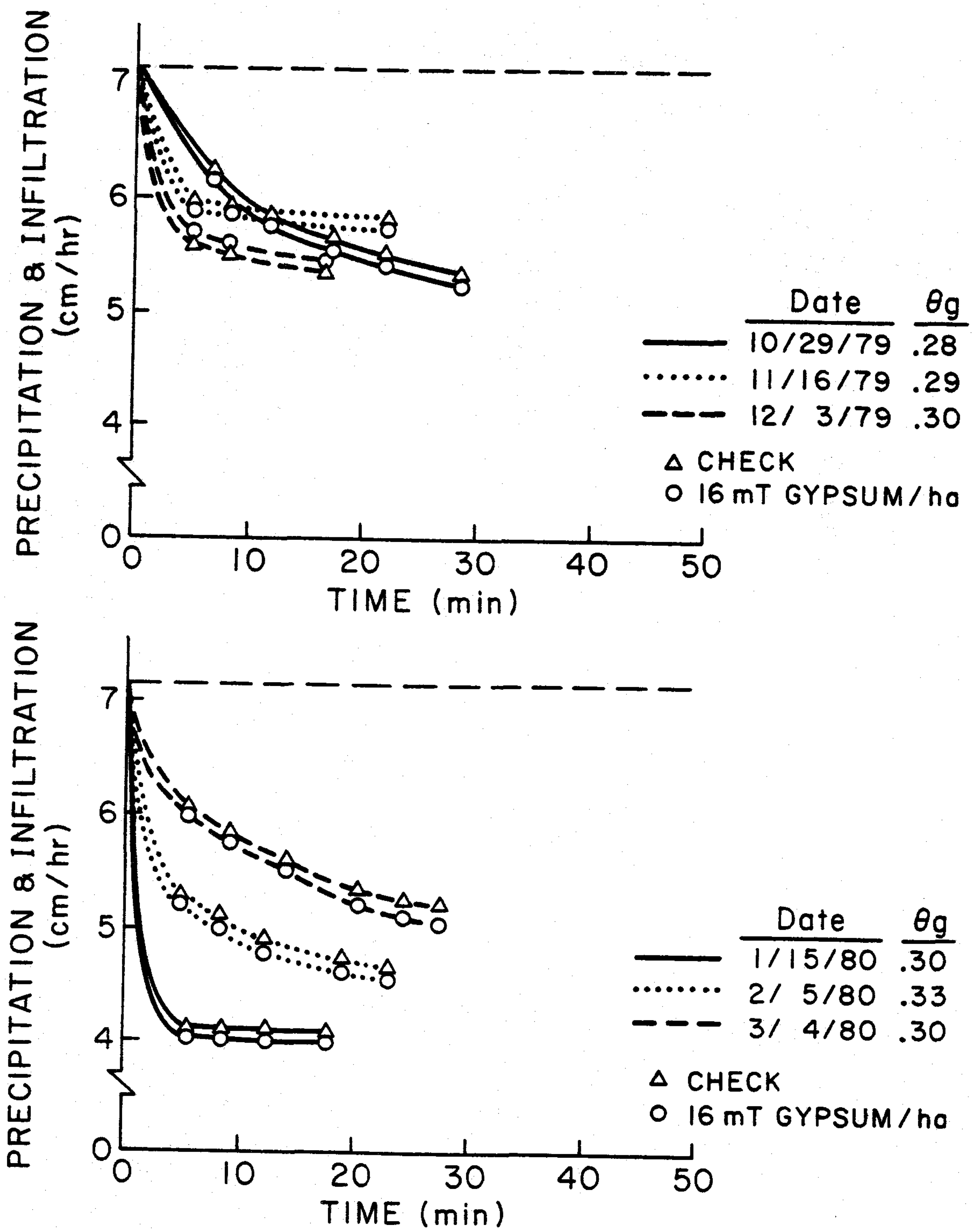

Fig. 11-4--Infiltration rates at site E4, 1979-1980.

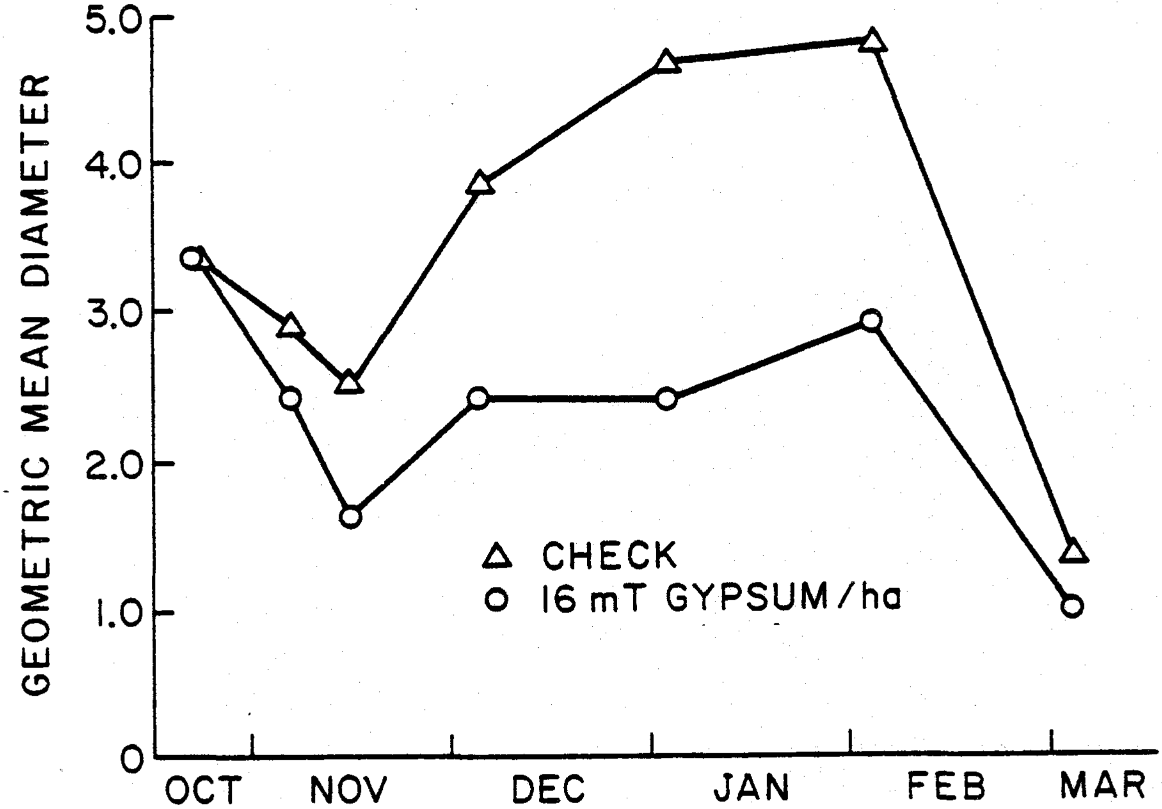

Fig. 11-5--GMD as a function of treatment and time during the rain season at site E4, 1979-1980.

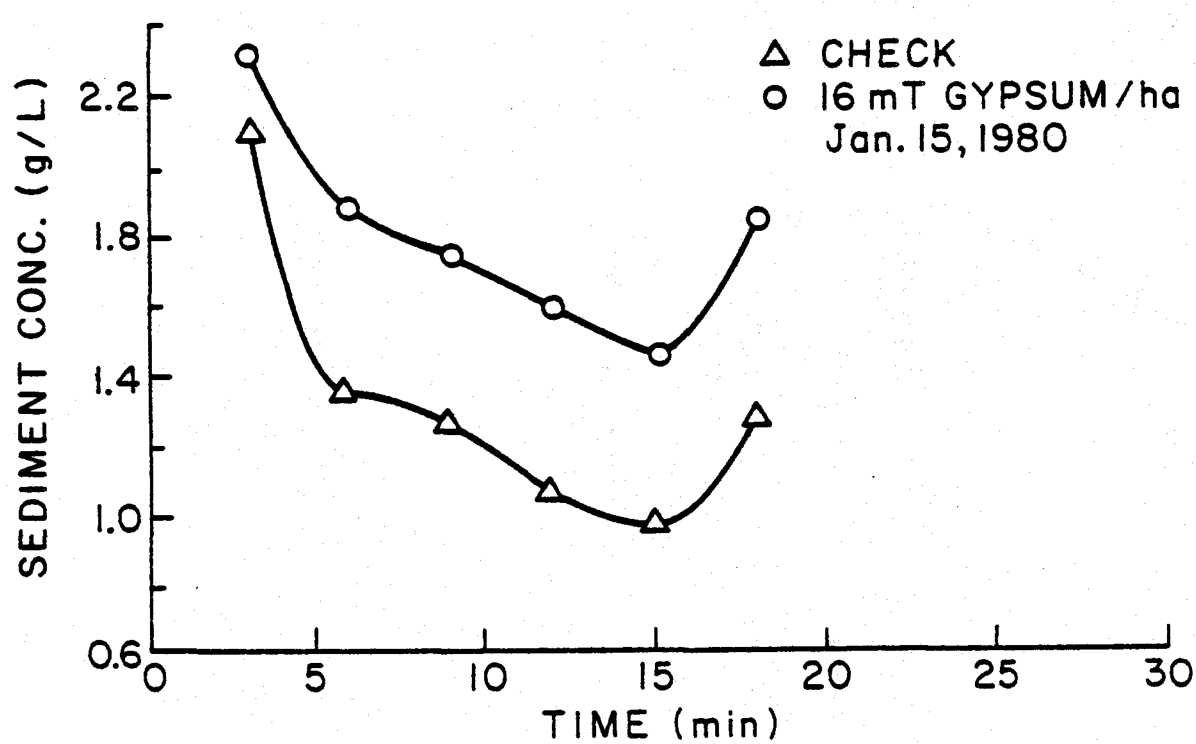

Fig. 11-6--Sediment concentration in runoff from infiltration plots.

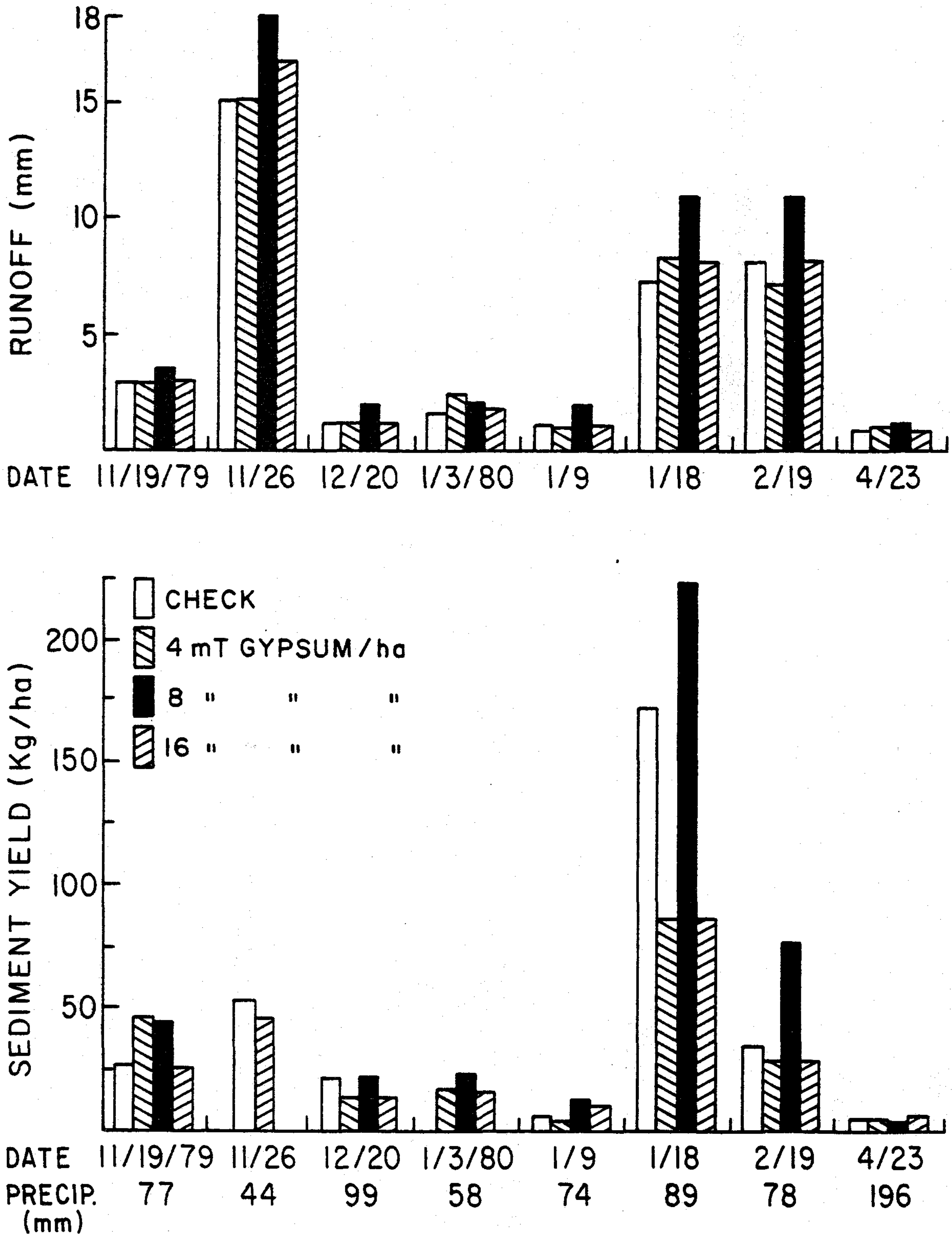

Fig. 11-7--Precipitation, runoff and sediment yields from erosion plots at site E4, 1979-1980. Precipitation data are cumulative for the sample period.

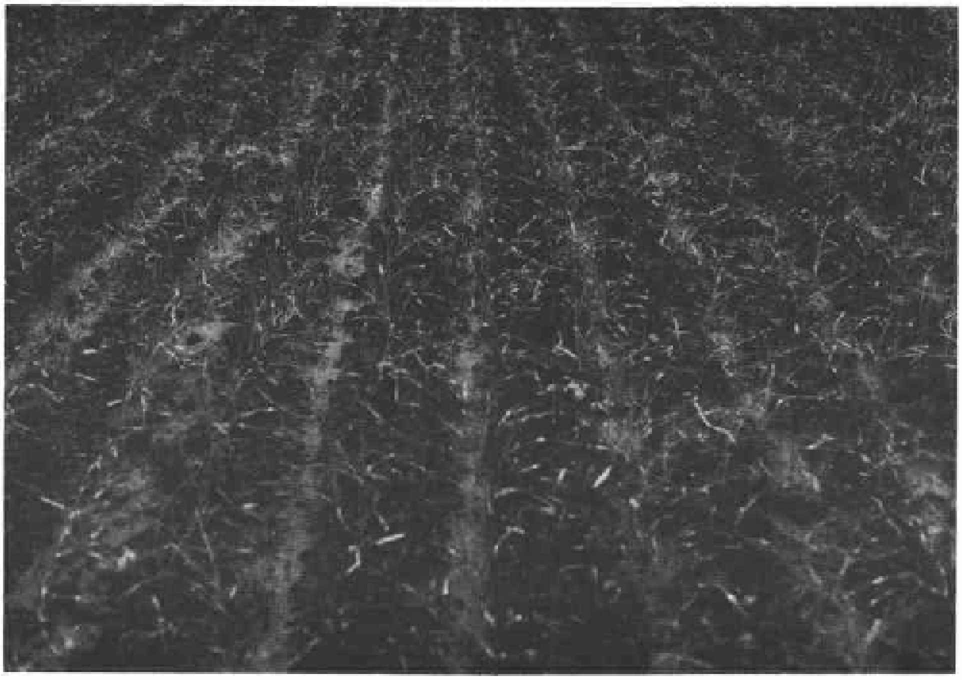

Plate 11-1--Surface condition at site E4 on Oct. 29, 1979, following first rainstorm after plowing. Note rill crust formation.

Plate 11-2--Surface condition at site E4 on Apr. 23, 1980. Note smoothness of surface and lack of plant residue from crust formation and sedimentation of eroded material.

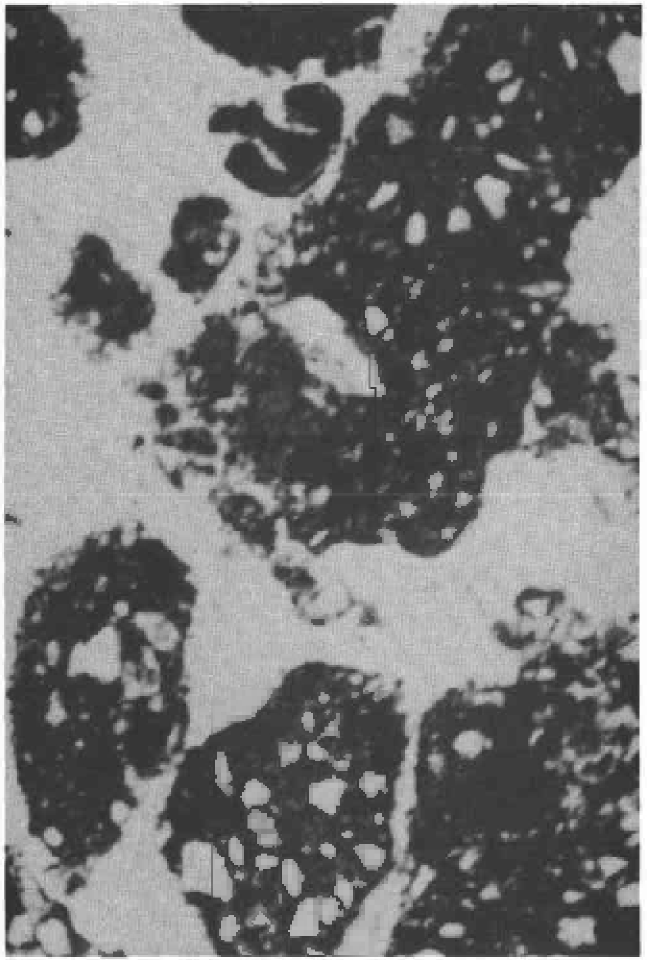

Plate 11-3--Thin section of soil surface at site E1 on Nov. 15, 1978. Note the porous nature. Image: 2 x 3 mm.

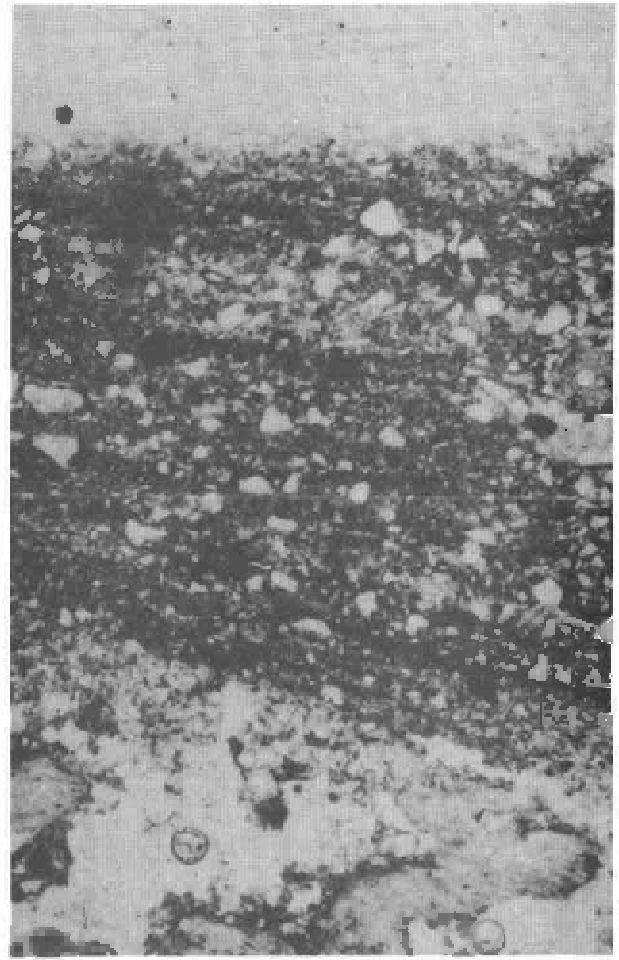

Plate 11-4--Thin section of soil surface at site E1 on Mar. 9, 1979. Note the layering indicating several cycles of deposition. Image: 2 x 3 mm.

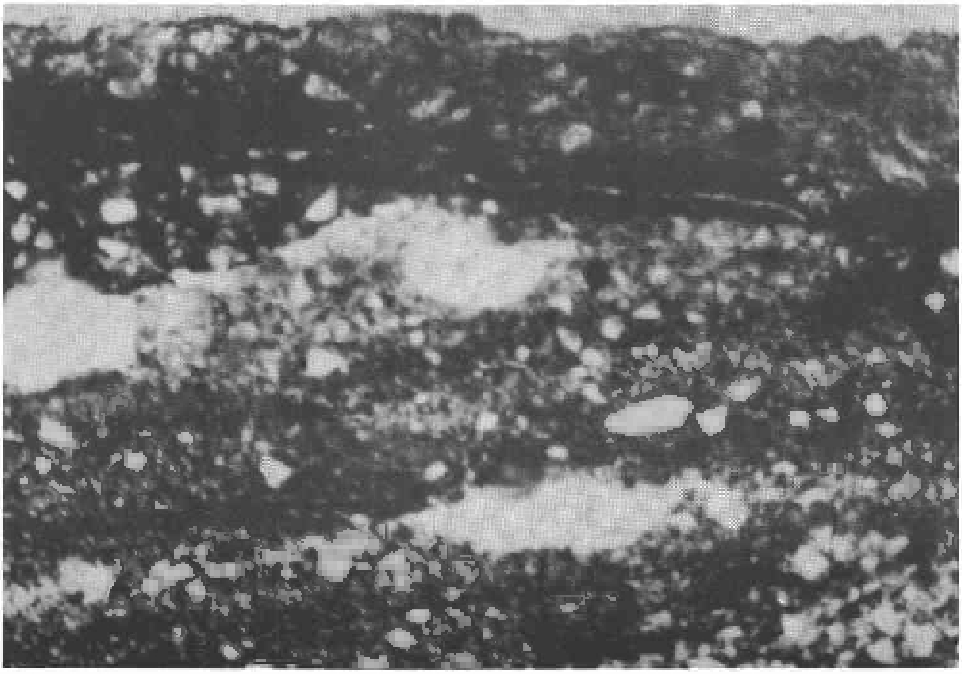

Plate 11-5--Thin section of soil surface at site El on May 4, 1979. Note layering which is now being broken up possibly from root penetration and wetting-drying cycles. Image: 3 x 2 mm.

SECTION IV. WATER QUALITY

The agricultural community is acutely aware of society's concerns for a clean and safe environment. These concerns, in addition to rapidly escalating energy costs, mandate efficient use of fertilizers and herbicides. Although data have been collected elsewhere in the United States, the climate, agricultural practices, and parent materials of the Willamette Valley make extrapolations tenuous.

Although the major emphasis of this research program has been directed towards the erosion process, it became evident that for a few additional resources, valuable data could be gathered relating agricultural practices to other aspects of water quality. Funds became available from other sources which permitted this expansion of the research program. The following two chapters report on the movement of nitrogen, phosphorus and herbicides in surface runoff and sub-surface flow.

CHAPTER 12. NITROGEN AND PHOSPHORUS IN RUNOFF

F. W. Simmons, Jr.[1]

Summary

Nitrate concentrations frequently exceeded 10 ppm in runoff from the three sub-watersheds at Elkins Road. Shallow-well nitrate concentrations were somewhat higher, ranging from 8 to 15 ppm over a four month period. Measured nitrate concentrations in runoff from Logsden Ridge sites generally were much lower except following a mid-March N fertilization when nitrate concentrations temporarily increased to 60 ppm.

Concentrations of dissolved inorganic phosphorus in runoff were generally less than 0.1 ppm. Losses of phosphorus were well correlated with sediment losses.

Introduction

This chapter briefly summarizes some results on nitrogen and phosphorus losses in runoff from shallow, sloping soils representative of the hilly margins of the Willamette Valley.

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[1] Material in this chapter has been excerpted or condensed from the M.S. thesis by the author. The research was done under the supervision of J. L. Young. A portion of the funds and equipment for this research was made available by SEA-AR and WRRI (W-57). For further information and detail, see Simmons (1981).

The major objectives of this study were:

- To obtain information on rates and amounts of total phosphorus, nitrate, and sediment discharge from selected watersheds.
- To relate phosphorus and nitrogen loss to erosion of soil.
- To contrast nutrient loss from watersheds with different fertilizer and management practices.

Materials and Methods

Study Sites

The field research involved three separate watersheds: two on Logsden Ridge in Benton County and one on Elkins Road in Polk County. Selection of the watersheds was based in part on differences in soils, crops, and landowner cooperation.

Two of the watersheds lie at opposite ends of Logsden Ridge, north and east of Lewisburg, Oregon. The primary study area was on the NW corner of the ridge on SE 1/4, NE 1/4, Sec. 1, T. 11S., R 5W. along Highway 99 about one mile north of Lewisburg. This 3.7 ha watershed was designated LR and will be referred to as such throughout the text. A second site was on the southeast side of the ridge near the intersection of Independence Highway and Pettibone Road, mostly within the NW 1/4, Sec. 4, T 11S., R 4W. This watershed had one instrumented site (B1) which monitored runoff from the entire 95 ha area, and another installation (B2) to monitor a 16 ha sub-watershed within the confines of the larger B1 drainage. The third study area was the 285 ha Elkins Road watershed and its sub-watersheds (Chapter 3).

The soil at LR is a Hazelair complex (Aquultic Haploxerolls), 12 to 20 percent slopes (Knezevich, 1975). Much of the lower part of the watershed is now a "truncated" Hazelair, with only 20 to 25 cm of silty clay loam or silty clay over a tight clay layer.

The soils in watershed B1 are a combination of Willamette, Dupee, and Hazelair complex soils. The upper two-thirds of the watershed is mapped as Hazelair complex and grades through Dupee in the lower one-third to Willamette silt loam near the watershed outlet (Knezevich, 1975). The area nearer the flume was intensively managed for ryegrass and orchard grass seed crops. The upland 30 percent of the watershed supports Oregon white oak, poison oak, and grasses.

Watershed B2 is similar to B1 in soil composition except for a slightly greater proportion of Dupee soil and less area in the 12 to 20 percent slope class. During the runoff season, cover for the upper half of B2 was unburned wheat/grain stubble; and for the lower half, mostly perennial orchard grass but with some annual ryegrass seeding.

The soils of the Elkins Road watershed are described in Chapter 4.

Sampling and Laboratory Procedures

The runoff measuring devices and sampling techniques used in this study were similar to those described in Chapter 3.

Unfiltered runoff samples were analyzed for total phosphorus. The digestion procedure was a slight modification of the one suggested by the U.S. EPA (1971). Soluble or dissolved inorganic phosphate (DIP) was determined in those B1 and B2 runoff samples which had elevated total P values but low sediment concentrations, and in samples collected after P fertilization.

Nitrate levels were determined on 25 ml aliquots of runoff samples using an Orion nitrate-electrode (Model 93-00). Samples were stored at $4^{\circ}C$ before analyses and usually analyzed within one week. Ammonium nitrogen was measured using an Orion electrode (Model 95-10).

Nitrate levels in shallow wells were measured to investigate seasonal trends and to determine the nitrate concentration in water perched above restrictive layers. Four wells were sampled at each of three sites. One site was adjacent to E1F1 (0.45 ha plot) another was adjacent to E4F1 (1.4 ha plot), and a third was a transect across and perpendicular to the main drainage of the E4F1 watershed (1.4 ha transect). Wells were sampled on seven occasions. The data were calculated by averaging the four values for each site (Fig. 12-6). The wells varied in depth but generally were about 150 cm and in every case were deep enough to penetrate into saprolite.

Results and Discussion

Phosphorus and Sediment

Annual losses of total P and sediment were largest at LR during the 1977-78 rainfall season (Table 12-1). A large portion of the annual phosphorus and sediment losses at LR during 1977-78 occurred during the first large storm of the season (57 and 70 percent, respectively). The smaller value of total P and sediment loss at LR during the 1978-79 rainfall season is attributed to a change in crop management, from annual to perennial grasses, which gave good soil protection the second year. Just two 1977-78 storms, with only 31 percent of the 1977-78 runoff, carried away 81 percent of the sediment lost that season.

Total P yield was closely related to sediment yield. When log transformed values of sediment yield and total P yield were compared on a per storm basis for individual watersheds, between 90 and 98 percent of the variation in total P yield was explained by sediment yield. Average sediment P concentration was negatively correlated with sediment yield when all fall planted watersheds were compared (Fig. 12-1). This suggests that more easily dispersed, smaller particles which were richer in P escaped from surface protected, low-sediment-yield watersheds. By contrast, high-sediment-yield watersheds apparently delivered a greater proportion of their sediment as undispersed, non P-enriched particles, regardless of aggregate size.

Dissolved inorganic phosphate (DIP) levels increased from 0.1 ppm to 5.1 ppm during a storm following a 15 kgP/ha application on Feb. 15, 1978. DIP levels subsided to preapplication levels within three days following the storm. The amount of DIP lost during that period amounted to less than one percent of the P applied for both B1 and B2. For the 1977-78 season, DIP accounted for less than seven and eight percent of the total P measured at B1 and B2, respectively.

Nitrogen

Annual Losses in Runoff

Nitrogen losses from the LR site were much lower than those observed at the two Elkins Road sites (Table 12-2) as were the concentrations of nitrate and sediment-N (Table 12-3). Low loss values cannot be attributed to the amount of runoff since runoff at LR exceeded the amount measured at E4F1 and E4F2 (Table 12-2). Rather, low concentrations of nitrate and sediment-N are responsible for the low loss values at LR (Table 12-3).

The measured values of nitrate loss and average nitrate concentration in the drainline outlet (E4V1) were high (83.0 kg/ha and 20.2 ppm, respectively). The average values of nitrate concentration are similar to the data from drainline effluent in the demonstration watershed in northern Polk County (Chapter 14).

Nitrogen Fertilizer in Runoff Water

Twice during the two year study period we were able to closely monitor nitrate concentrations in runoff waters after fertilization. Parts of B1 and B2 were fertilized in mid-March, 1978 with 140 kg N/ha as ammonium nitrate, and a portion of the Elkins Road watershed was fertilized with 120 kg N/ha as ammonium nitrate in March, 1979.

B1 and B2 Watershed. Approximately 50 percent of the B1 watershed was fertilized with 140 kg N/ha. Fertilizer coverage on the B2 subwatershed was about 80 percent. Crop cover was dense and the soil was moist yet solid enough to support specialized spreading equipment. One week after fertilization, a relatively intense storm occurred at the watershed. Total runoff was not great (0.38 cm) but sufficient to increase discharge rates briefly to 0.34 m^3/sec at the B1 outlet. The B2 watershed experienced peak flows of 0.023 m^3/sec and total runoff at 0.44 cm. At B1, nitrate and ammonium concentrations increased to more than 60 ppm N in the first small runoff peak on the morning of Mar. 23 (Fig. 12-2). Nitrate and ammonium concentrations receded to less than 20 ppm N and then to less than 5 to 10 ppm N after the second much larger pulse of runoff on the evening of Mar. 23. Nearly equal nitrate and ammonium concentrations indicate that little sorption or nitrification of applied fertilizer had occurred during the preceeding week.

Elkins Road Watershed. In March, 1979, portions of the 285 ha Elkins Road watershed were fertilized with 120 kg N/ha as ammonium nitrate. The wheat crop was sparse and the soil surface dry on the sub-watersheds at the time of application. Base flow from subsurface drainage continued at the E3Cl outlet after fertilization but declined gradually until the beginning of May. Nitrate levels remained between five and seven ppm during this period of low flow. The storm in early May brought the first substantial increase in runoff since fertilizer was applied on E4 areas. Nitrate N concentrations at E3Cl rose from 3 to 12 ppm as flow gradually increased over a six-hour period (Fig. 12-3). Concentrations stayed between 10 and 15 ppm for 48 hours, including several hours after flow rates increased ten fold, before sharply reverting to below 10 ppm as flow rates decreased. Ammonium concentrations at E3Cl were consistently less than 1 ppm N.

Seasonal Trends in Nitrate Discharge

Nitrate concentrations periodically exceeded 10 ppm at both E3Cl and E4F2 (Figs. 12-4, 12-5). Nitrate concentration response to flow was variable at E3Cl. In fall and early winter, increase in flow rates produced high nitrate concentrations at E3Cl concurrent with, or subsequent to, peak flow (Fig. 12-5). The first small increase in runoff (Dec. 3) was accompanied by a sizeable increase in nitrate concentrations while the second larger flow (Dec. 10) showed a lesser nitrate increase. After a freezing period with no runoff (Jan. 1-10), a quick rise in runoff brought a delayed increase in nitrate concentration which came as runoff flow subsided. Later when E3Cl peaked at its annual highest runoff level (Feb. 9), nitrate concentrations rose to 11 ppm. By contrast, decreases in flow through March and April were accompanied by a decrease rather than increase in nitrate concentration suggesting depletion of nitrate in the watershed.

The largest nitrate concentrations were recorded after periods of drying and freezing interspersed with some clear days and variable temperatures in the watershed. Some of any nitrate produced during this time would have been leached and transported during rewetting of the soil and renewed runoff. The runoff events in February and March that did not effect a change in nitrate levels did not have a drying or freezing period to separate them from previous periods of high flow.

Concentrations of nitrate at E4F2 showed the same general response as at E3Cl for the first few storm periods (Fig. 12-4). However, nitrate levels were reduced somewhat during the early February storm period as runoff volume increased. This indicates that dilution effects overrode the potential of an increased nitrate supply after more upland areas reached saturation and contributed runoff.

Nitrate Levels in Shallow Wells

Nitrate concentrations in the perched water tables were fairly high, especially during the period from Feb. 1 to early March, 1979, (Fig. 12-6). The concentrations remained at 8 to 12 ppm during the drying, spring-warming period from mid-March to the end of April. An increase in concentration up to 30 ppm in the transect samples did occur after the storm in early May. This was the first significant storm after fertilization and the trend was similar to that observed at E3C1 (Fig. 12-5).

The initial increase in nitrate concentration in the wells was apparently triggered by a pulse of infiltrating precipitation which leached mineralized nitrate into the temporary water table. Subsequently, the soil began to slowly dry and the nitrate concentrations also began to decrease. Several processes can serve to decrease the amount of nitrate in solution. Plant use, organic matter tie-up, denitrification, and leaching were set forth as explanations by Schuman et al. (1973). The upward movement of nitrate-laden water by capillarity into the unsaturated zone is another possible explanation.

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Knezevich, C. A. 1975. Soil Survey of Benton County Area, Oregon. USDA, SCC. Washington, D. C. pp. 119.

Schuman, G. E., R. E. Burwell, R. F. Piest and R. G. Spomer. 1973. Nitrogen losses in surface runoff from agricultural watersheds on Missouri Valley loess. J. Environ. Qual. 2:299-302.

Simmons, F. W. 1981. Sediment, phosphorus and nitrogen in storm runoff from some Willamette Valley croplands. M.S. thesis, Oregon State University, Corvallis.

U.S. Environmental Protection Agency. 1971. Methods for chemical analysis of water and wastes. E. P. A. Cincinnati, Ohio. p. 249-255.

Table 12-1. Annual phosphorus and sediment losses measured in runoff from various experimental watersheds.

Watershed	P loss	Sediment loss
	------------kg/ha------------	
LR 1977-78	20.94	32,600
LR 1978-79	0.36	340
B1 1977-78	0.97	670
B2 1977-78	1.56	930
E4F1 1978-79	2.93	3,590
E4F2 1978-79	1.77	2,390

Table 12-2. Measured annual losses of NO_3^--N, sediment-N, and total N in runoff.

Watershed	Precip.	Runoff	NO_3^--N	Sed.-N	Total N
	---------cm---------		------------kg/ha------------		
LR 1978-79	40.9	20.6	3.3	1.2	4.4
E4F1 1978-79	62.6	9.4	13.0	8.6	21.6
E4F1 1979-80	63.3	3.5	0.2	---[+]	---
E4V1(drainline) 1979-80	63.3	41.0	83.0	Nil[‡]	83.0[‡]
E4F2 1978-79	62.6	16.0	19.0	6.7	25.7
E4F2 1979-80	63.3	24.0	19.3	---	---

[+] Data not available.

[‡] Assuming no sediment in drainline effluent.

[§] Total NO_3^--N loss from E4F1 watershed is the sum this figure plus the drainline effluent in 1979-80.

Table 12-3. Average concentrations[+] of sediment-N, and NO_3^--N at selected watershed.

Watershed	NO_3^--N	Sediment-N
	---------mg/1---------	
LR 1978-79	1.58	0.57
E4F1 1978-79	13.93	9.16
E4F1 1979-80	0.60[§]	---[‡]
E4V1 (drainline) 1979-80	20.2[§]	___
E4F2 1978-79	11.83	4.15
E4F2 1979-80	8.00	---
E3C1 1978-79	9.20	0.53

[+] Values calculated as kg/ha-cm x 10 = mg/1 (Langdale et al., 1979).

[‡] Data not available.

[§] Total NO_3^--N values for the E4F1 watershed involve both the E4F1 surface runoff and the subsurface E4V1 drainline effluent in 1979-80.

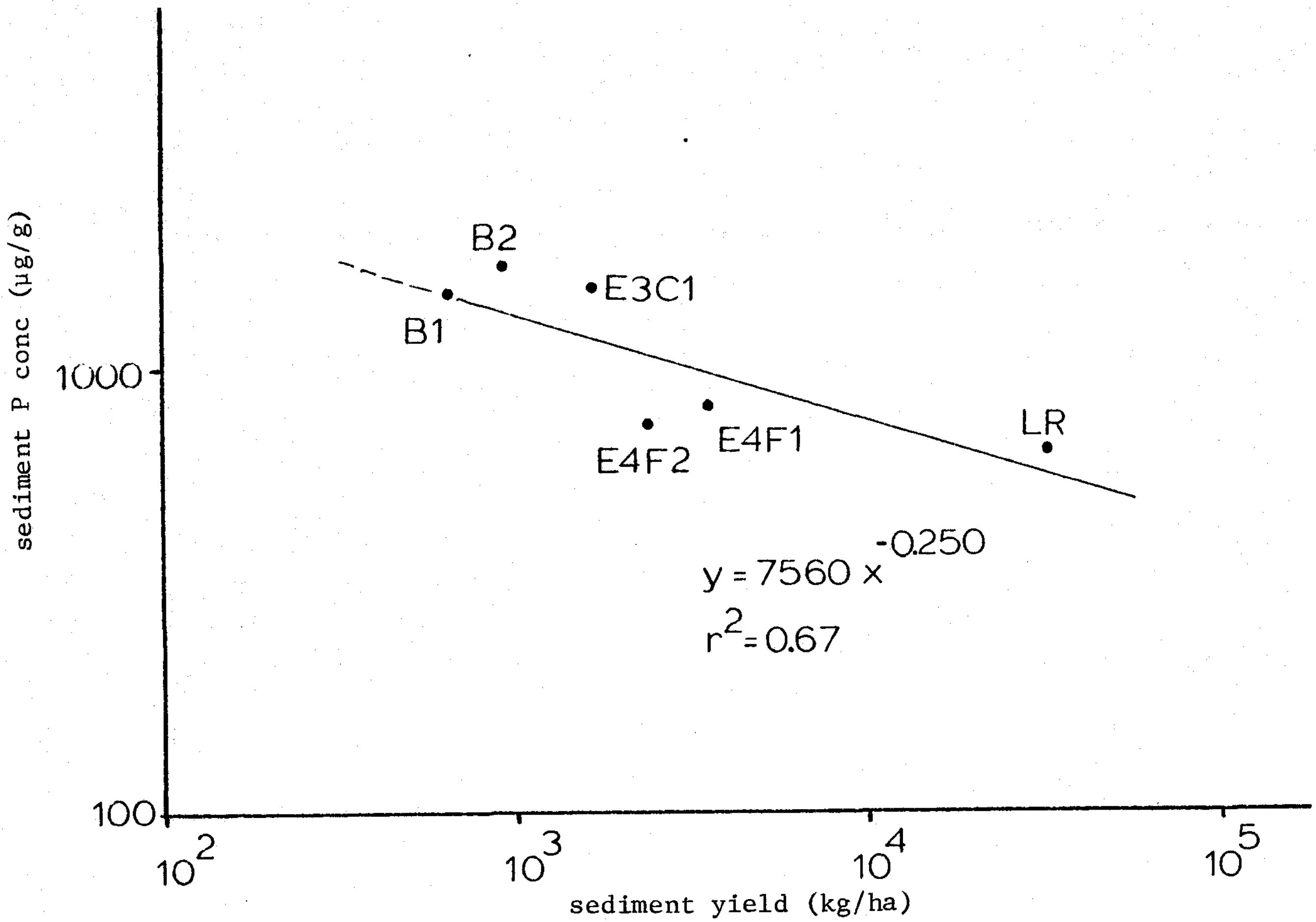

Fig. 12-1--Relationship between average sediment P concentration and annual sediment yield for fall-planted watersheds.

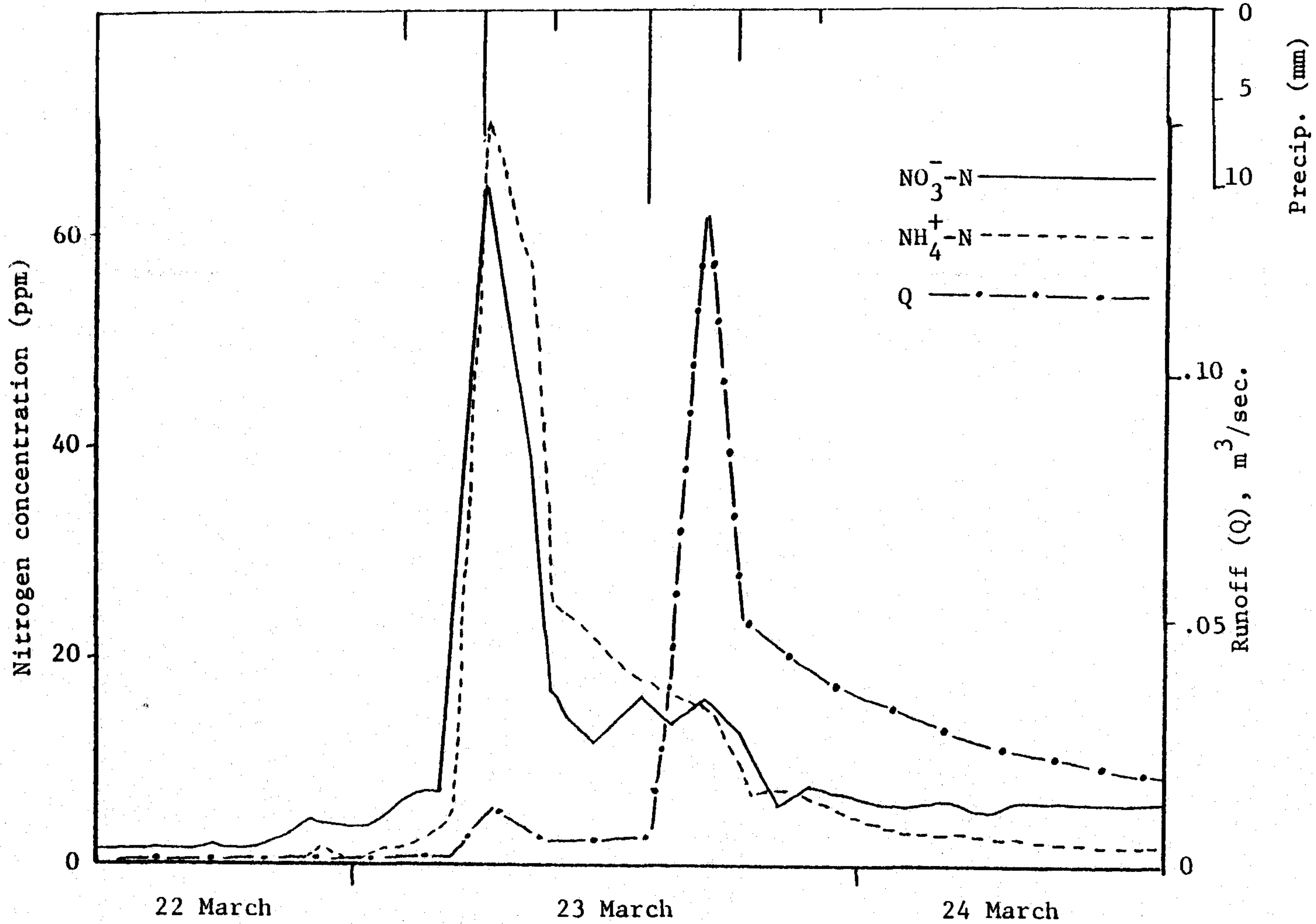

Fig. 12-2--Nitrate and ammonia nitrogen concentrations in runoff water at B1 during flush following fertilization during March, 1978.

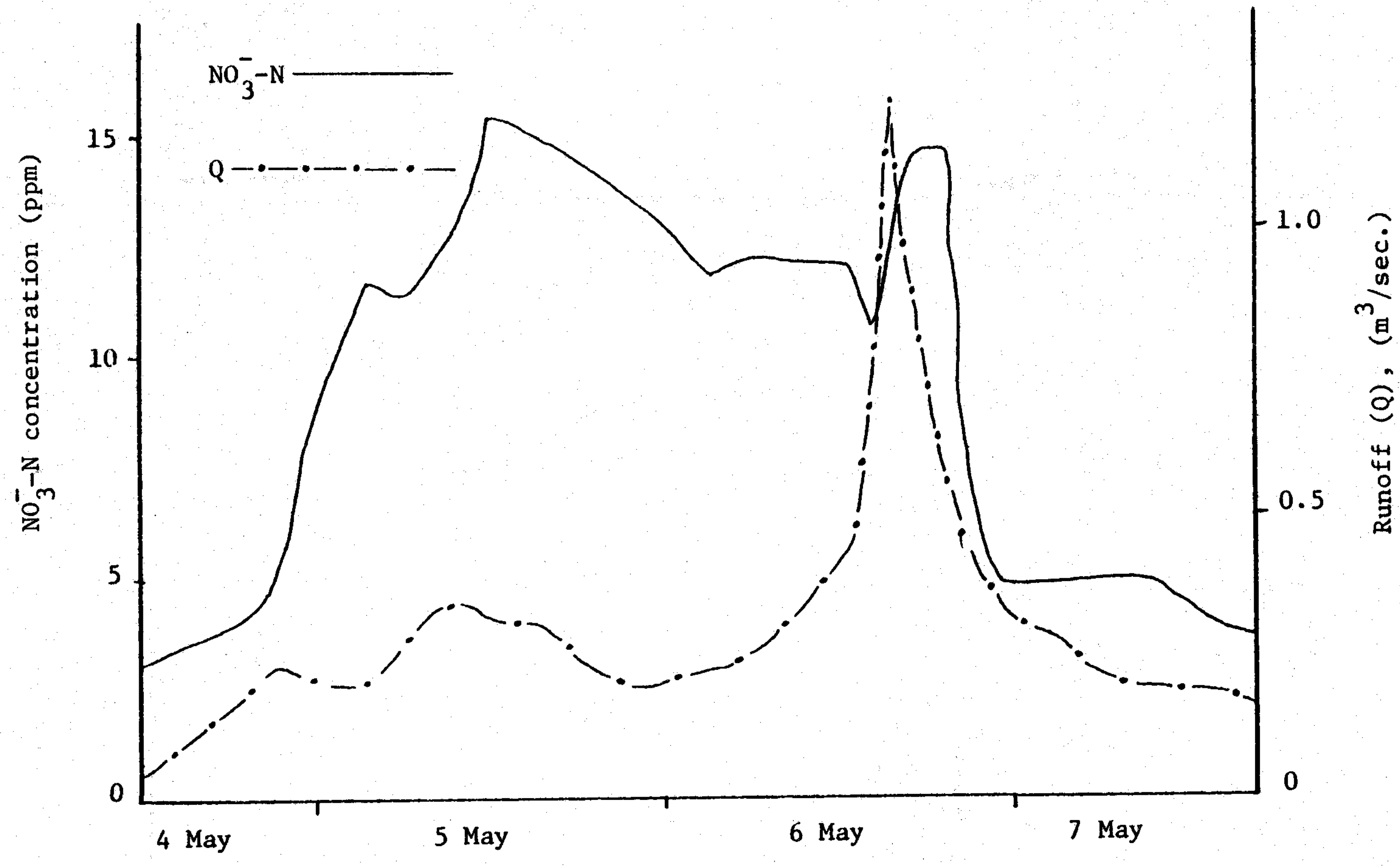

Fig. 12-3--Nitrate concentrations in E3Cl runoff during late season high flow period (1979). (Ammonium concentrations were consistently less than 1 ppm N, hence not shown.)

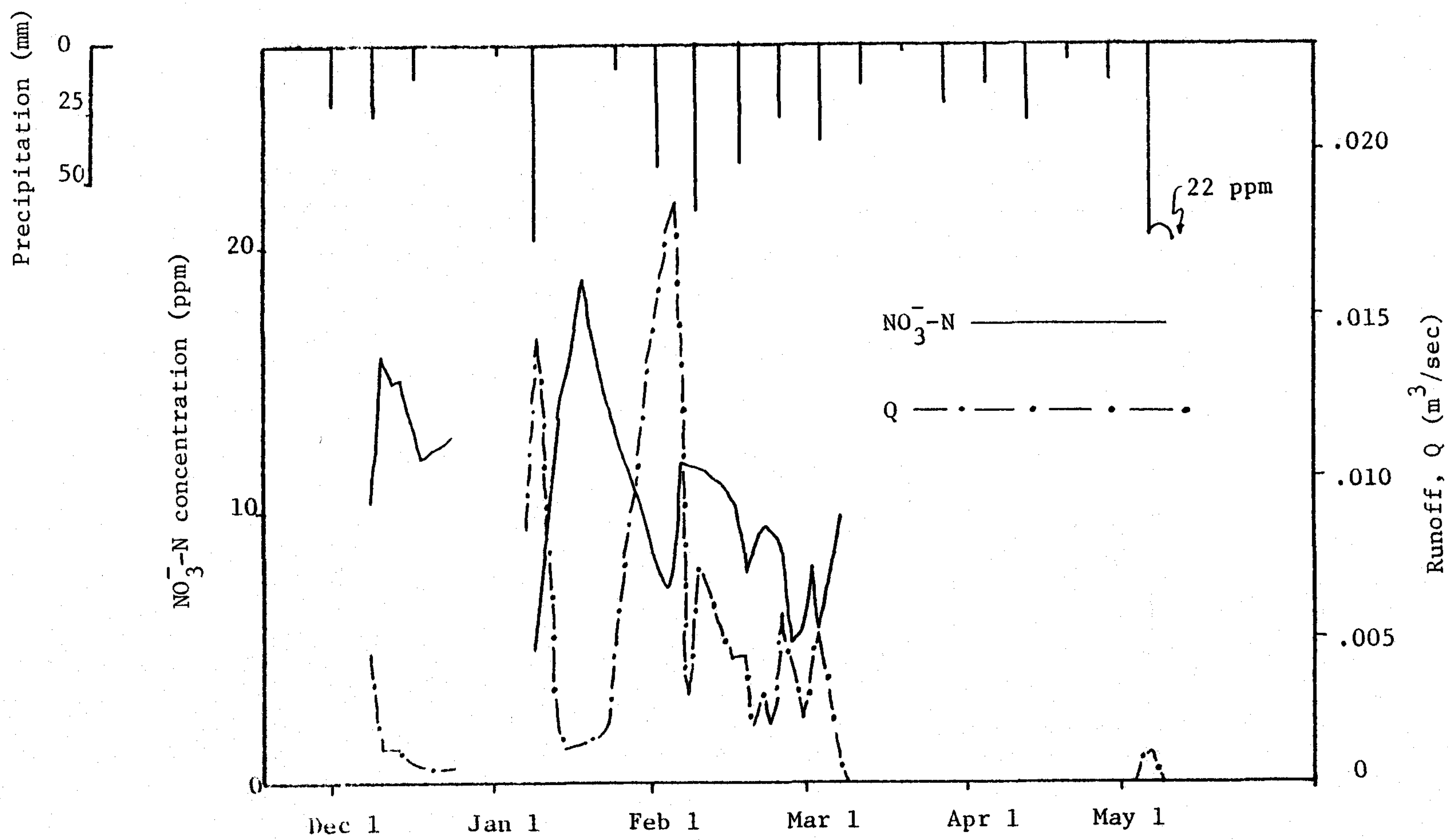

Fig. 12-4--Average daily NO_3^--N concentrations and weekly precipitation totals for E4F2 (1978-79).

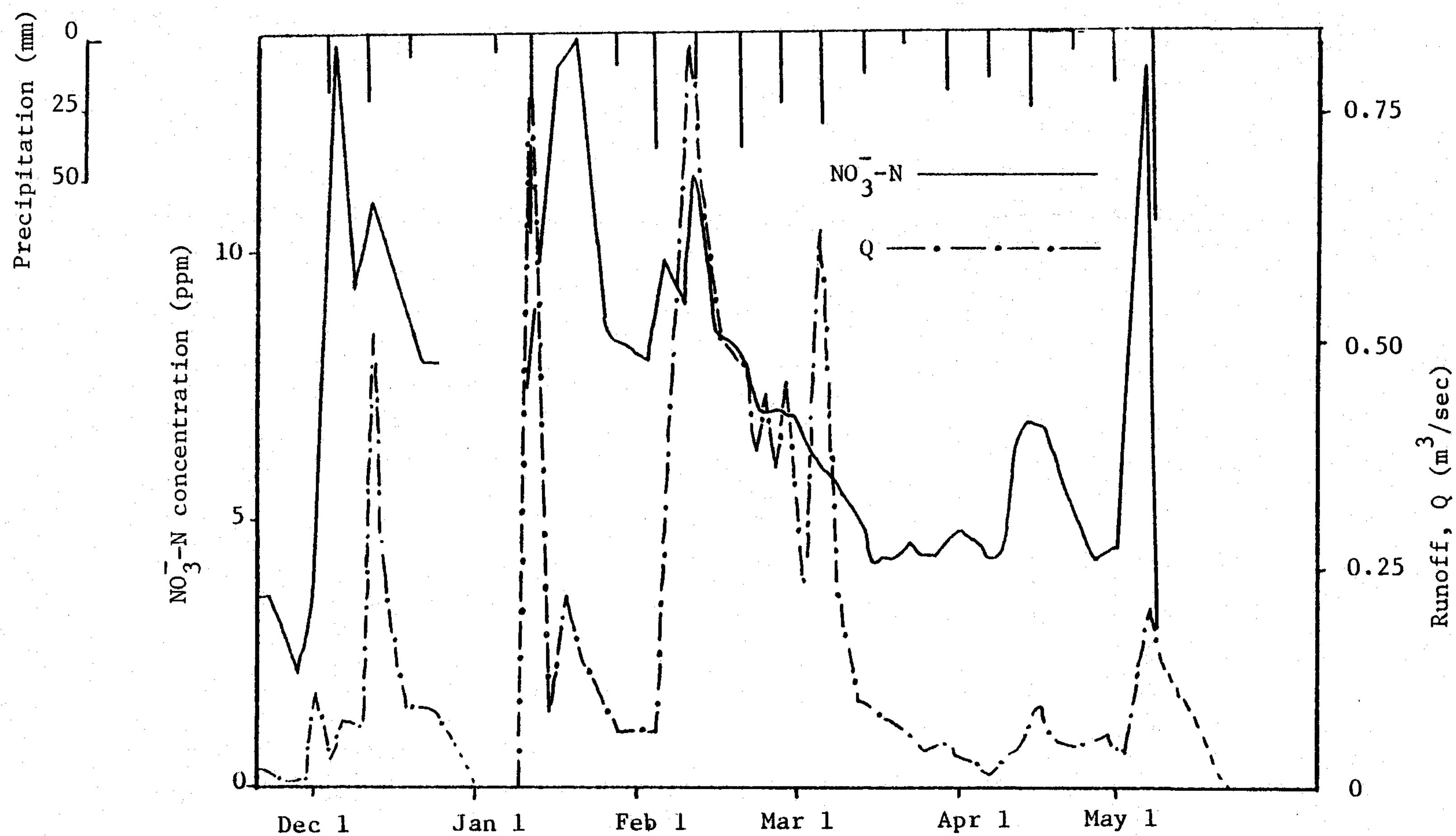

Fig. 12-5--Average daily NO$_3^-$-N concentrations and weekly precipitation totals for E3C1 (1978-79).

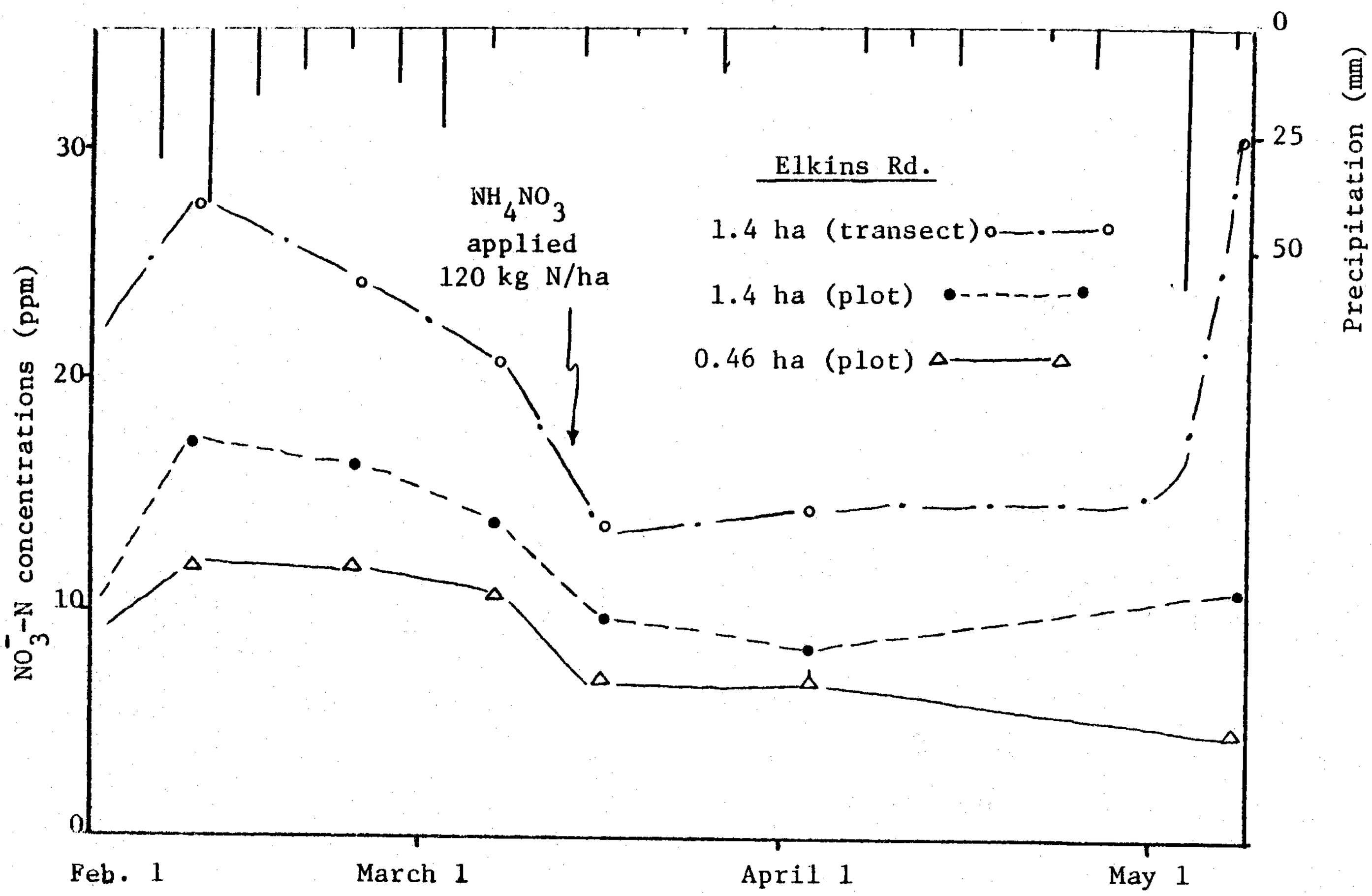

Fig. 12-6--Shallow well nitrate concentrations at Elkins Road during the 1979 spring monitoring season.

CHAPTER 13. DIURON IN RUNOFF

J. S. Hickman, M. L. Montgomery, and M. E. Harward

Summary

Total diuron loss in the 5-month period after fall application was approximately 1 percent of the total applied. Two large storms in early February, 1979, accounted for 45 percent of the total herbicide loss. The maximum herbicide concentration was 89 ppb; this occurred with the first runoff event, 45 days after application.

Introduction

Relatively little work has been done on the behavior of herbicides in relation to runoff from agricultural lands in the high winter rainfall zone of the northwestern region. Annual cropping of "hill soils" which surround the Willamette Valley presents a potential for degradation of water quality. Seeding is in the fall, thus cover is often minimal at the onset of the winter rainfall season and the potential for runoff is high. Two herbicides, 2,4-D and diuron, are commonly applied to wheat in western Oregon. A third chemical (diclofop) shows promise as a herbicide for applications on wheat; its use is expected to increase. Diuron and diclofop are often applied in the fall or winter when lower temperatures retard chemical and biological degradation and the chemicals are subject to loss by transport during the high winter rainfall season.

A preliminary study was undertaken to investigate the loss of diuron from a small sub-watershed of fall planted wheat. This study was coordinated with the on-going project on erosion and sediments.

Materials and Methods

Description of Sub-watershed and Herbicide Sampling

The herbicide concentrations were measured in selective runoff samples during storm hydrographs in sub-watershed (E4F2). The soils in the sub-watershed are comprised mainly of the Willakenzie silty clay loam (Ultic Haploxeralfs, fine-silty, mixed, mesic) and a variant of the Helmick silty clay loam (Aquic Xerochrepts, very-fine, mixed, mesic) (Chapter 4). A pre-emergence application of 1.8 kg of diuron per ha was made to winter wheat approximately 2 weeks after planting. This application was made on a 5.1 ha portion of the 6 ha sub-watershed.

Surface runoff from the sub-watershed was measured in a 1.5 foot agriculture H-flume (Chapter 3). An ISCO model 1700 flow meter and model 1710 printer gave a continuous record of flow through the flume. Integrated suspended sediment samples were taken with an ISCO model 1680 flow proportional sampler and were supplemented by manual "grab" samples.

All samples were stored at $4^{o}C$ until analyzed. Suspended sediment was measured in all samples; only selected samples were analyzed for diuron.

Determination of Diuron Residues in Water and Sediments

Before analyzing runoff water and sediments, it was necessary to develop methodology capable of separating diuron from its metabolite, 3,4-dichloroaniline. This was necessary because the accepted method of analysis involves direct alkaline hydrolysis which converts diuron to 3,4-dichloroaniline. Thus, 3,4-dichloroaniline residues resulting from metabolism of diuron would appear as parent herbicide residues; 3,4-dichloroaniline is not active as a herbicide.

The most promising approach appeared to be the extraction of residues and separation of diuron and 3,4-dichloroaniline before the hydrolysis of diuron. This approach was used since direct gas chromatographic analyses of diuron were unsatisfactory. The compound degrades to 3,4-dichlorophenylisocyanate, but not in a reproducible or quantitative manner.

Since we wished to know the diuron concentration in both water and sediments, the first step in the procedure was separation of the water and sediment phases. This was accomplished by filtering the sample through a double thickness soxhlet cup. The solution phase was measured and set aside for extraction. The residue was then shaken with methanol and the methanol also filtered through the soxhlet cup. The methanol was then transferred to a boiling flask and the sediment residue extracted overnight in the soxhlet extractor. After cooling, the methanol extract was concentrated to about 5 ml on a rotary evaporator. The residue in the evaporator flask was then rinsed into a 250 ml separatory funnel with 75 ml of benzene and 100 ml of 0.5 M sodium hydroxide. Sodium hydroxide was used to remove polar interferences from the benzene extract. After shaking to partition diuron residues into the benzene, the alkaline phase was extracted with a second 75 ml portion of benzene. The combined benzene extracts were extracted twice with 10 ml portions of 4 M hydrochloric acid to remove dichloroaniline residues. The benzene extract was concentrated to dryness using a rotary evaporator.

Diuron residues in the evaporator flask were then transferred to a 15 cm screw-cup culture tube by rinsing the evaporator flask with several 3 ml portions of ether. The ether was evaporated under a stream of nitrogen. The sample was then ready for hydrolysis to 3,4-dichloraniline.

The sample was hydrolyzed by the addition of 15 ml of 1 M sodium hydroxide and heating in the steam bath for 4 hours. After cooling in an ice bath, 1 ml of benzene was added to extract the dichloraniline produced by hydrolysis of diuron. Up to 20 μl of the benzene extract were analyzed by micro-coulometric gas chromatography.

In analyzing water samples, the water was extracted with two 75 ml portions of benzene. This benzene extract was then processed in the same manner as the benzene extract of the soils. Dichloraniline residues were analyzed on an Infotronics microcoulometric gas chromatograph. The instrument was equipped with a 120 cm column packed with 1 percent OV-1 and 1 percent carbowax 20 M on gas chrom Q. At a flow rate of about 30 cc per minute and a temperature of 190°C, the retention time was about 2 minutes. Ten µg of standard yielded about 40 percent full-scale recorder deflection. Thus, the method is sensitive to less than 1 µg in total sample extract.

Results and Discussions

The analysis of suspended sediment samples from the drainage outlet on the 6 ha watershed indicated the presence of diuron in every sample. Table 13-1 lists the diuron concentration and load in the aqueous and sediment phase along with computations for the total diuron in the sample. Although present in all samples, concentrations in the water at the termination of the study had decreased to approximately one-fourth of those present initially. A power curve comparing suspended sediment analysis (ppm) against diuron concentration (ppb) was used to calculate total diuron loss from each storm event. Samples 1-8 were used to fit a curve for the Dec. 10 storm ($r^2 = 0.98$) and samples 23 to 30 were used to calculate storm losses after Jan. 14 ($r^2 = 0.94$). Unlike other storms during the year, the mid-January storm occurred on frozen ground and the diuron concentration did not correlate with suspended sediment analysis. Diuron loss from these storms was estimated using samples 9 to 22. Table 13-2 lists the individual storms and the respective diuron losses.

Total diuron loss in the 5-month period after application was 0.016 kg/ha or 0.9 percent of total diuron applied. Two major runoff events in early February accounted for 45 percent of total herbicide loss. The peak herbicide concentration was 89 ppbw during the first runoff event 45 days after application.

Previous literature on pesticide loss from agricultural fields has been reviewed by Wauchope (1978). Losses reported by Wauchope are less than we observed (Table 13-3). This is partly caused by our higher rate of application, longer period of record, and larger number of storm events. The maximum concentrations in the runoff were comparable to those reported by Green et al. (1977) for Hawaii (Table 13-4).

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Green, R. E., K. P. Goswami, M. Mukhtar, and H. Y. Young. 1977. Herbicides from cropped watersheds in stream and estuarine sediments in Hawaii. J. Environ. Qual. 6:145-154.

Wauchope, R. D. 1978. The pesticide content of surface water draining from agricultural fields--A review. J. Environ. Qual. 7:459-472.

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Table 13-1--Diuron in suspended sediment samples and calculated diuron load from sub-watershed E4F2 for 1978-79.

Storm date	Sample number	Aqueous phase Conc		Sediment phase Conc		Total diuron loss Conc	
			Load		Load		Load
		ppbw	mg/30 min.	ppmw	mg/30 min.	ppbw	mg/30 min.
1978							
Dec. 10	1	40	61	8	21	54	82
	2	47	180	9	75	66	255
	3	47	427	9	384	89	811
	4	42	571	10	503	88	1,071
	5	49	508	10	347	82	855
	6	46	473	9	199	62	672
	7	42	275	6	31	49	306
	8	43	106	17	16	38	122
1979							
Jan. 10	9	46	258	4	17	49	275
	10	6	6	4	1	7	7
Jan. 11	11	35	342	6	87	43	429
	12	24	451	6	277	38	728
	13	28	699	6	445	46	1,144
	14	16	397	3	118	21	515
	15	23	348	4	64	27	412
	16	21	485	5	161	29	646
	17	26	168	1	4	26	172
	18	16	112	4	41	21	153
Jan. 14	19	18	40	24	10	22	50
	20	14	127	4	80	22	207
	21	15	257	3	21	16	278
	22	14	54	9	8	16	62
Feb. 7	23	12	398	4	929	40	1,327

Table 13-1--continued.

Storm date	Sample number	Aqueous phase Conc	Aqueous phase Load	Sediment phase Conc	Sediment phase Load	Total diuron loss Conc	Total diuron loss Load
		ppbw	mg/30 min.	ppmw	mg/30 min.	ppbw	mg/30 min.
1979							
Feb. 7	24	9.4	325	4	986	37	1,311
Feb. 16	25	9.2	319	4	707	30	1,026
	26	7.7	259	4	302	17	561
Feb. 19	27	12	846	4	2,959	53	3,805
Feb. 20	28	6.7	136	4	205	17	341
Feb. 27	29	10	442	5	917	37	1,359
Mar. 3	30	9.8	344	4	553	24	897

Table 13-2--Diuron loss from individual storms (1978-1979) on subwatershed E4F2†.

Storm date	Maximum concentration	Loss aqueous	Loss sediment	Total diuron loss
	--ppbw-	---%---	---%----	----mg-----
Dec. 10	89	67	33	3,800
Jan. 10	--	75	25	6,000
Jan. 11	46	84	16	8,500
Jan. 14	22	53	47	6,400
Feb. 7	89	20	80	19,900
Feb. 10	45	35	65	15,900
Feb. 16	33	45	55	4,300
Feb. 18	11	52	48	1,600
Feb. 19	57	20	80	6,700
Feb. 20	17	79	21	1,150
Feb. 27	38	34	66	3,850
Mar. 3	24	47	53	3,600
Mar. 4	14	67	33	1,750
Total		44%	56%	83,450

†Values are predicted using power curves as described in text.

Table 13-3--Seasonal loss of diuron in Oregon in comparison with other investigations.

Reference	Location	Area	Slope	Soil texture	Crop or cover	Application rate	Period or record	Runoff		Diuron loss	
								No. of events	Total amount	% of applied	Total
		(ha)	(%)			(kg/ha)	(months)		(cm)		(g/ha)
Willis,	Baton Rouge, LA	0.045	0.2	SiCL	Cotton	0.84	2	5	0.4	<0.04	<0.4
et al 1975						0.84	3	9	0.8	<0.03	<0.2
						0.84	3	4	3.3	<0.10	<1.0
	Present study	5.1	3-12	SiCL	Wheat	1.80	5	13	4.8	0.90	16.4

Table 13-4--Maximum concentrations of diuron in runoff in Oregon in comparison to other investigations.

Reference	Application rate	Runoff conc. in		Notes
		Sediment phase	Bulk	
	(kg/ha)	(ppbw)	(ppbw)	
Willis, et al 1975	0.84	--	0-<10	0.04 ha, 0.2% slopes, Baton Rouge, LA
Green, et al 1977	2.06	--	74	2.5 ha, 3-12% slope, Hawaii
Present study	1.8	24	89	5.1 ha, 1-12% slopes, Oregon

SECTION V. COOPERATIVE STUDIES

In addition to the intensive research on the Elkins Road watershed in southern Polk County, cooperative research has been conducted at other locations. There were several motivations and benefits in this additional work. First of all, monitoring of erosion at other sites provides comparisons and a means of extending the research from the primary study area to other soils in the valley. Secondly, they serve as pilot studies to assess the feasibility and reliability of techniques by which other groups can monitor erosion in their immediate area. The third benefit is that the cooperating group acquires data which is applicable to their local conditions. It would be impossible for the Agricultural Experiment Station to evaluate erosion in all of the soil-management conditions which exist in the region. We needed some means of involving a large segment of the agricultural industry in acquiring the appropriate data. A number of commodity and resource based groups had indicated willingness to assist in these investigations. One of our problems involved the need for close supervision of widely scattered experimental sites. The approach which was developed involved the installation of monitoring devices by personnel on the erosion project while the cooperating group was responsible for site monitoring and acquisition of samples.

CHAPTER 14. REPORT ON POLK SWCD DEMONSTRATION WATERSHED PROJECT

J. D. Istok, G. F. Kling, and J. A. Vomocil

Summary

There was a difference in sediment production between the two watersheds amounting to 2 to 3 fold. The total amounts were relatively small and were comparable to the Elkins Road study area. Considering several factors which influence runoff and sediment production, the data suggest a strong beneficial influence of agricultural drainlines on reducing erosion. The two watersheds respond with sufficient predictability to allow the measurement of imposed management practices on sediment yields. Maximum nitrate concentrations in the surface runoff were 5 to 10 ppm in November, 1979, but decreased to 1 to 3 ppm by January, 1980. Nitrate concentrations in the drainline effluent, however, were high (20 to 30 ppm) throughout the 5 month sampling period.

Introduction

In 1977, a cooperative program of erosion and sediment delivery research was initiated between the Polk Soil and Water Conservation District (Polk County, Oregon) and the Department of Soil Science, Oregon Agricultural Experiment Station, Oregon State University. The purpose of this research, known as the Demonstration Watershed Study, has been to assess runoff and sediment yield with respect to physiographic, soil, and precipitation patterns on two adjacent agricultural watersheds. Personnel on the erosion project were responsible for installation of monitoring devices and analyses of samples. The Polk SWCD was responsible for routine monitoring of equipment and acquisition of samples.

Objectives were:

- To obtain a basis for predicting flow and sediment discharge for one watershed relative to another.

- To assess present and proposed management practices under the guidelines of PL92-500 and Section 208.

In 1979, it became possible to include the analysis of nitrate concentration on a limited number of water samples. For this reason, the sampling program was extended to include data on nitrate in the surface runoff and in the effluent from a drainline outlet which is located downstream from one of the watersheds.

Research necessary to achieve the first objective has been completed. Analysis of the data indicate that although differences exist between the two watersheds, the sediment and flow curves are predictable on a single storm or event basis. This report summarizes hydrologic and water quality data for two rainfall seasons, 1978-79 and 1979-80.

Materials and Methods

The Study Area

The two watersheds are located in the south Yamhill River basin about 10 km north of Dallas in northern Polk County, Oregon (Fig. 14-1). Mean annual precipitation is about 130 cm, virtually all of which is rain. Elevation of the watershed ranges from 60 to 150 m with mean slopes of 15 to 20%. The western watershed (D3) has an area of 60 ha and shares a common boundary with the eastern watershed (D4) which has an area of 90 ha. During a period of particularly high flow (Jan. 6-11, 1980) runoff from an additional area north of Beck Rd. (within the dashed line in Fig. 14-1) contributed to flow through the flume at D4, increasing the watershed area by about 5 ha.

D4 has approximately 10% more forested land than D3 and has several small ponds. The distance from the H-flume to area of steeper slopes is smaller at D3 which also has shorter, less effective grassed waterways. D3 has a greater extent of soils which have restrictive layers (Fig. 14-2) and had more tile drainage. The soils within the forested areas at the higher elevations of D4 do not have restrictive layers which results in higher infiltration rates and permeabilities.

Winter wheat, orchard grass and peas are the common crops in D3. Fields within D4 have been mainly planted to fescue, orchard grass and spring wheat. D4 has more land in permanent pasture than does D3.

Data Collection

A combination of manual and automated sampling was used to measure flow, collect runoff samples, and measure rainfall amounts and intensities. At each site, flow measurements were made using a Leupold & Stevens Inc. Type F Water-level recorder in conjunction with a 91 cm H-flume. Daily measurements of present and "previous maximum" stage were used to calibrate the recorder charts. Instrumentation Specialties Co. Model 1680 wastewater samplers were used to provide sampling of runoff and were supplemented by manual "grab" samples. Grab samples were also taken frequently at the drainline outlet. Rainfall measurements were made at each site using a Meteorological Research Inc. Model 304 tipping bucket raingage and a plastic rain wedge was used as a back-up unit.

Total solids analysis was performed on all water samples and was used to estimate sediment discharges. Additional analyses (turbidity, electrical conductivity, and NO_3-N concentration) were made on every fifth sample of runoff and drainline effluent.

For a period of five months (November, 1979 to March, 1980) selected water samples were analyzed for nitrate concentration. The sampling interval varied depending on flow conditions but included samples of the runoff in each flume as well as effluent from the drainline outlet located downstream from the flume at D3 (Fig. 14-1).

Results and Discussion

Runoff and Sediment Yield

Hydrographs were selected to illustrate a range in watershed and weather conditions through two runoff seasons, 1978-79 and 1979-80 (Fig. 14-3 -- 14-13). The two watersheds, although yielding different flow rates and sediment concentrations responded consistently and with a reasonable predictability. The major differences between them can be summarized as follows.

1. In general, flow begins 1 to 2 weeks earlier at D4 which also has a much higher baseflow (Fig. 14-3).

2. Response times ("time to peak") for both watersheds are about the same.

3. D4 has higher peak flows and sediment discharges than D3; these differences decrease with time (compare Fig. 14-4 with Fig. 14-8).

4. Peak flows resulting from snowmelt were about the same for both watersheds (Fig. 14-5).

5. The largest flows recorded for both watersheds (Fig. 14-13) occurred when rain fell on a frozen soil surface that had a 10 to 25 cm accumulation of snow.

The similar response times of the two watersheds reflect their comparable sizes and surface drainage densities. The increased baseflow from D4 can be attributed to a combination of soil and management factors. The soils within the forested areas at the higher elevations of D4 do not have restrictive clay horizons which result in increased infiltration rates and permeabilities. In addition, the small ponds in D4 provide temporary storage for surface runoff which is released only slowly during non-storm periods. When the soil surface is frozen, however, the effect of soil differences are diminished and the two watersheds behave similarly (Fig. 14-5). Considering the influence of permanent cover (woodlot and pasture), extent of soils with restrictive layers, slope class, ponds, and length of grasswaterways, one would expect D3 to show greater flow and sediment discharge than D4. The fact that D3 shows consistently lower flows and sediment yields suggests the beneficial influence of agricultural drainlines on reducing erosion on sloping hillsoils with restrictive layers. The influence of drainlines on runoff and erosion is being evaluated at the Elkins Road watershed (see Chapters 6 and 8). It is important to note that although D4 had consistently higher sediment yields than D3 the overall sediment yields for the two watersheds were small. Annual sediment loss for 1978-79 was 800 kg/ha (0.38 T/acre) for D4 and 350 kg/ha (0.16 T/acre) for D3. Total losses for 1979-80 could not be calculated because storm runoff exceeded the flume capacity on Jan. 6-11, 1980.

Water Quality

Analysis of the data (Tables 14-1 and 14-2) indicates the following:

1. NO_3-N concentration in the drainline effluent was high (20 to 30 ppm) and stayed high throughout the sampling period (Table 14-1).

2. Surface concentrations of nitrate in the runoff from D3 were fairly high (10 ppm on Dec. 3, 1979) but were always lower than the drainline.

3. D3 generally had higher concentrations of nitrate than D4 (10.9 vs 5.3 ppm on Nov. 19, 1980) although the magnitudes of both and the difference between them decreases by January, 1980 (1.2 vs 1.0 ppm).

4. Suspended sediment concentrations were generally higher in the drainline compared to the surface runoff at D3.

At present no explanation is available for the high nitrate and sediment concentrations in the drainline effluent. The values are 2 to 3 times EPA standards (10 ppm) and remained high over a period of three months. These trends are similar to those observed at the Elkins Road watershed (Chapter 12). Possible reasons for the differences in nitrate concentrations between D3 and D4 are different management practices (including fertilization), cropping histories and soils.

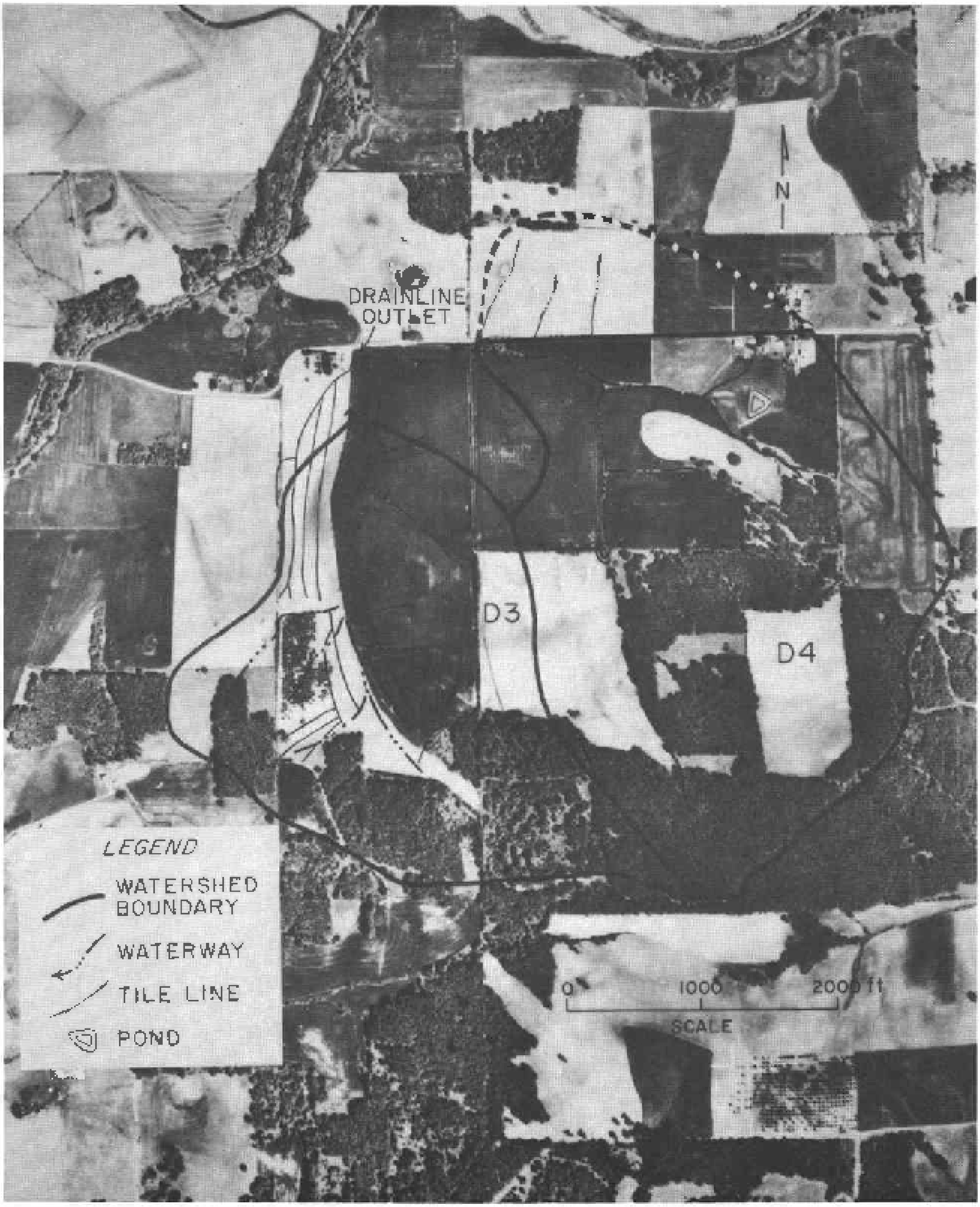

Fig. 14-1--The two watersheds in the Demonstration Watershed Study.

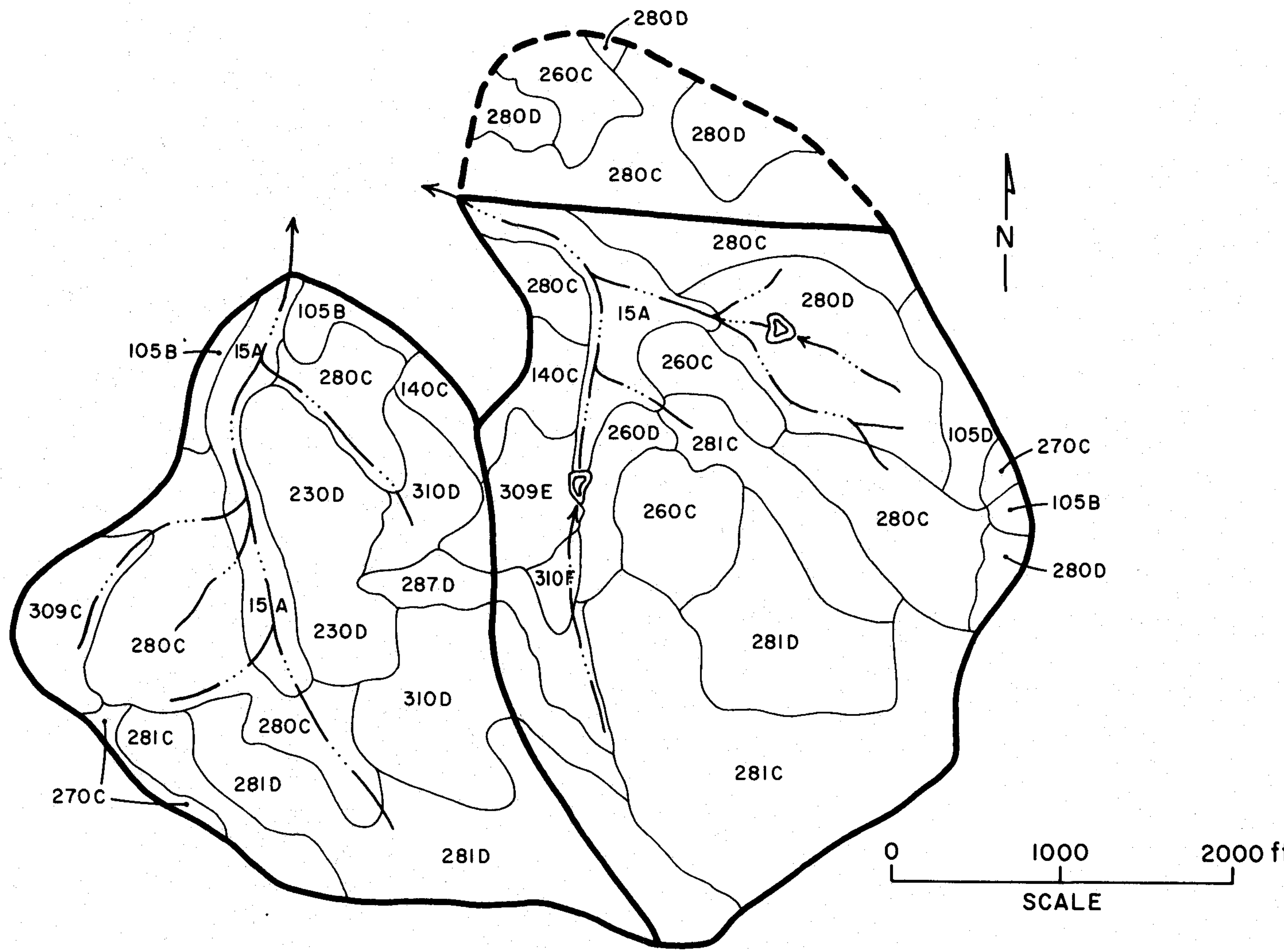

Fig. 14-2--Soils map of the study area.

Fig. 14-2--continued.

Soil map legend[+]	
Map symbol	Mapping unit
15A	Waldo silt loam, 0-3% slope
105B	Woodburn silt loam, 3-12% slope
105D	Woodburn silt loam, 12-20% slope
140C	Helvetia silt loam, 1-12% slope
230D	Willakenzie silty clay loam, 12-20% slope
260C	Steiwer silt loam, 3-12% slope
260D	Steiwer silt loam, 12-20% slope
270C	Chehulpum silt loam, 3-12% slope
280C	Hazelair silt loam, 3-12% slope
280D	Hazelair silt loam, 12-20% slope
281C	Helmick silt loam, 3-12% slope
281D	Helmick silt loam, 12-20% slope
287D	Suver silty clay loam, 12-20% slope
309C	Rickreall silty clay loam, 3-12% slope
309E	Rickreall silty clay loam, 20-50% slope
310D	Bellpine silty clay loam, 20-50% slope
310F	Bellpine silty clay loam, 30-50% slope

[+]Soils information courtesy of Polk County SWCD, Polk County, Oregon.

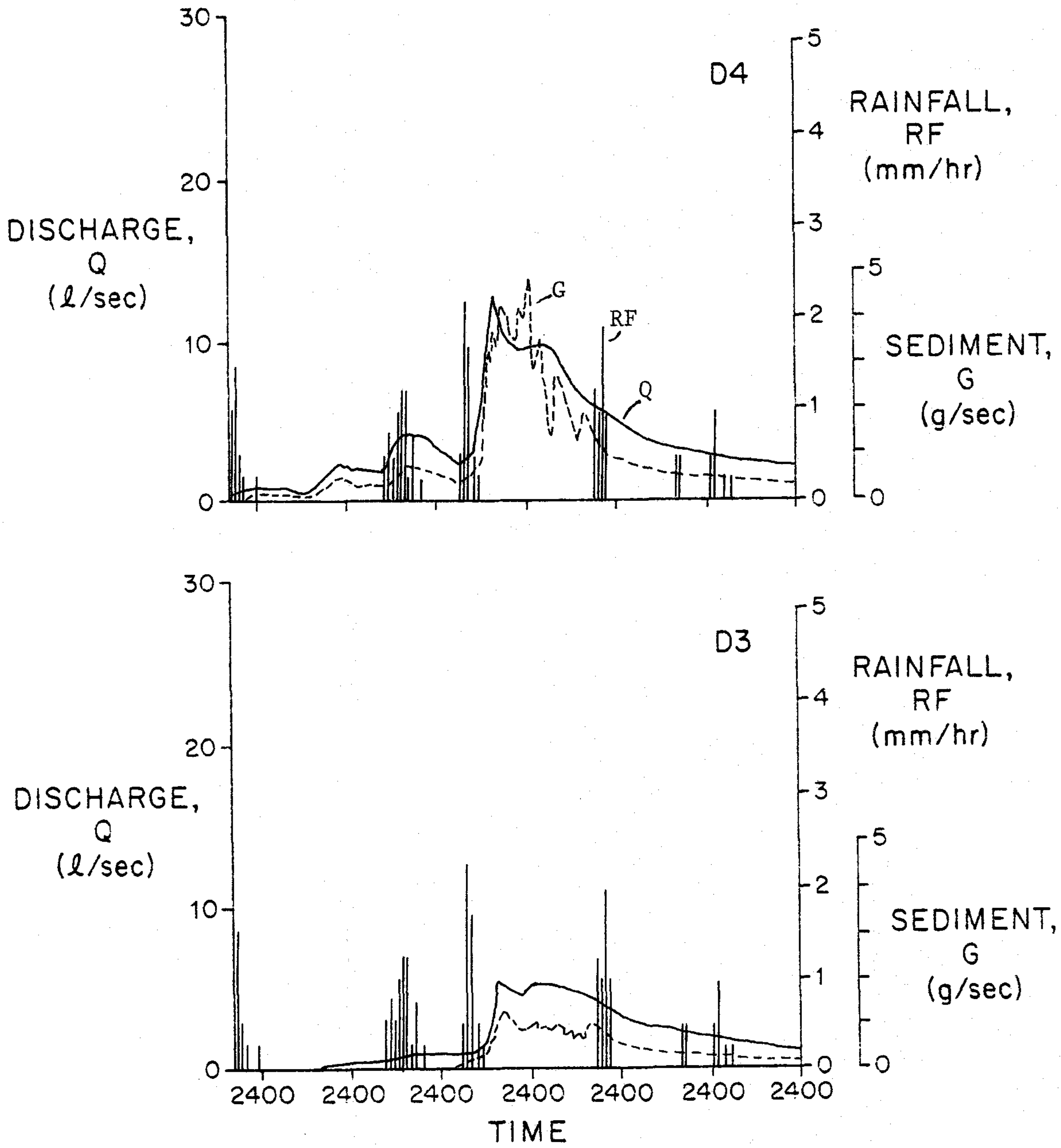

Fig. 14-3--Runoff and sediment yield for the period Nov. 28-Dec. 3, 1978.

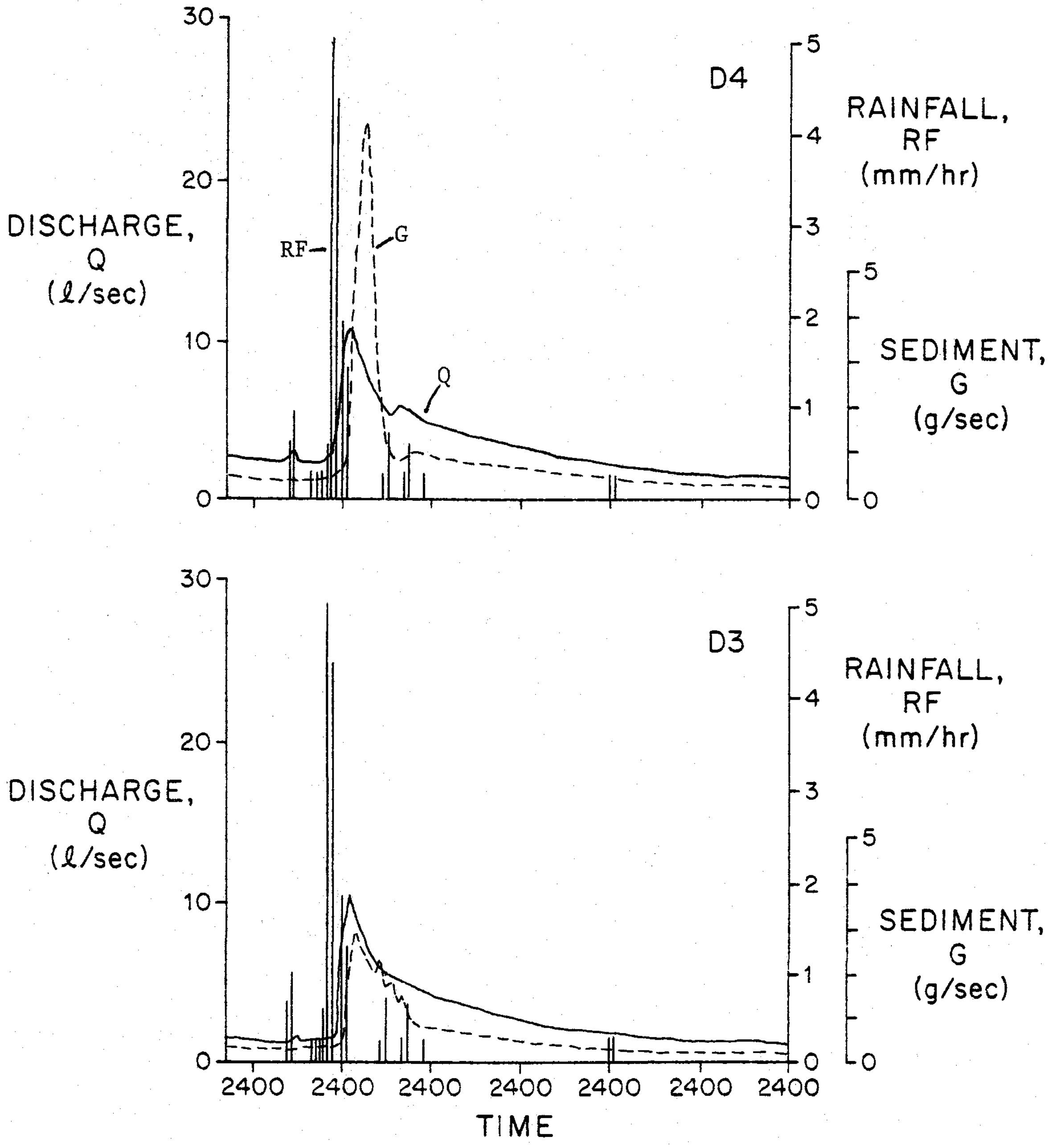

Fig. 14-4--Runoff and sediment yield for the period Dec. 4-9, 1978.

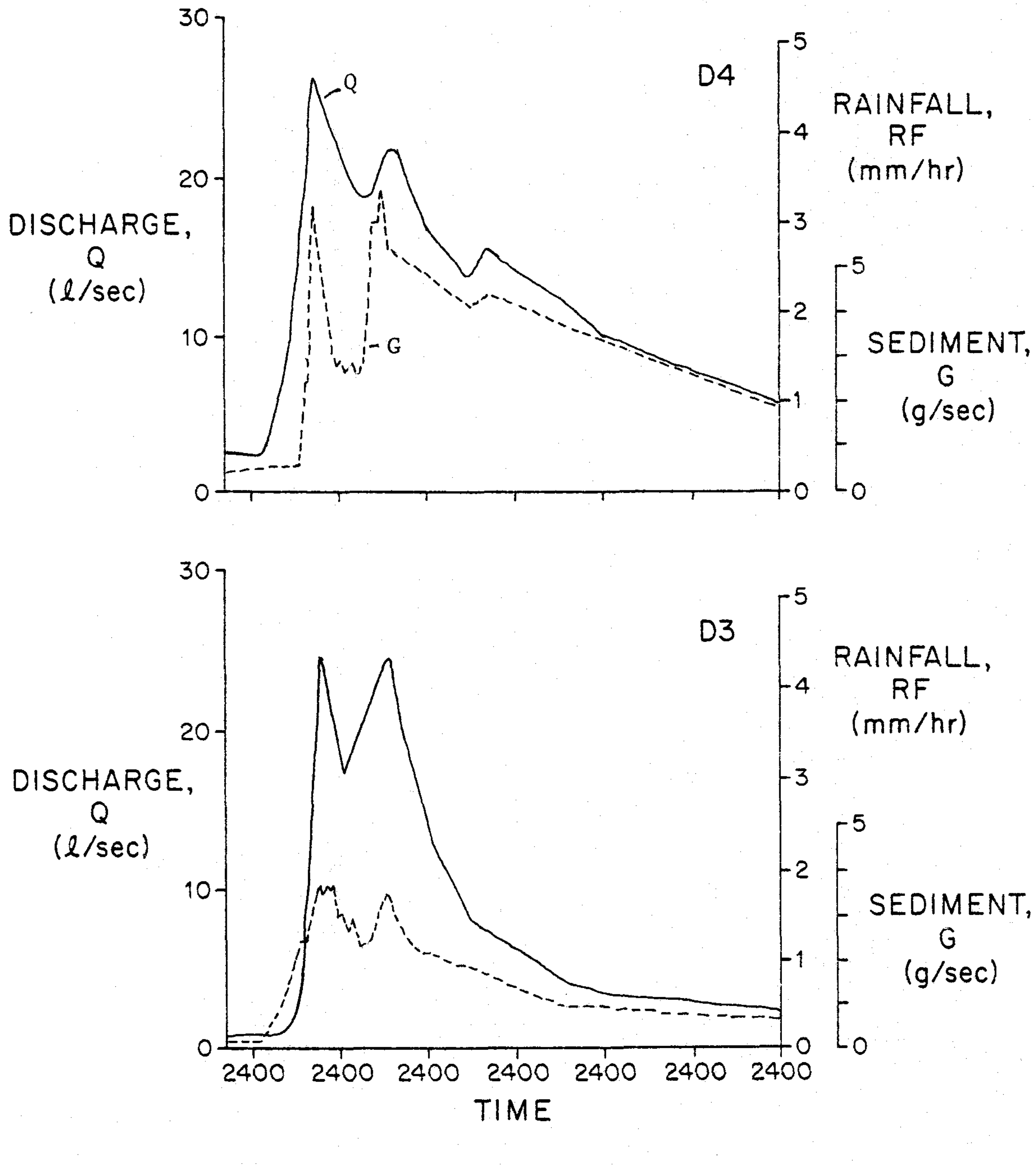

Fig. 14-5--Runoff and sediment yield for the period Dec. 21-26, 1978. Runoff was generated by snowmelt.

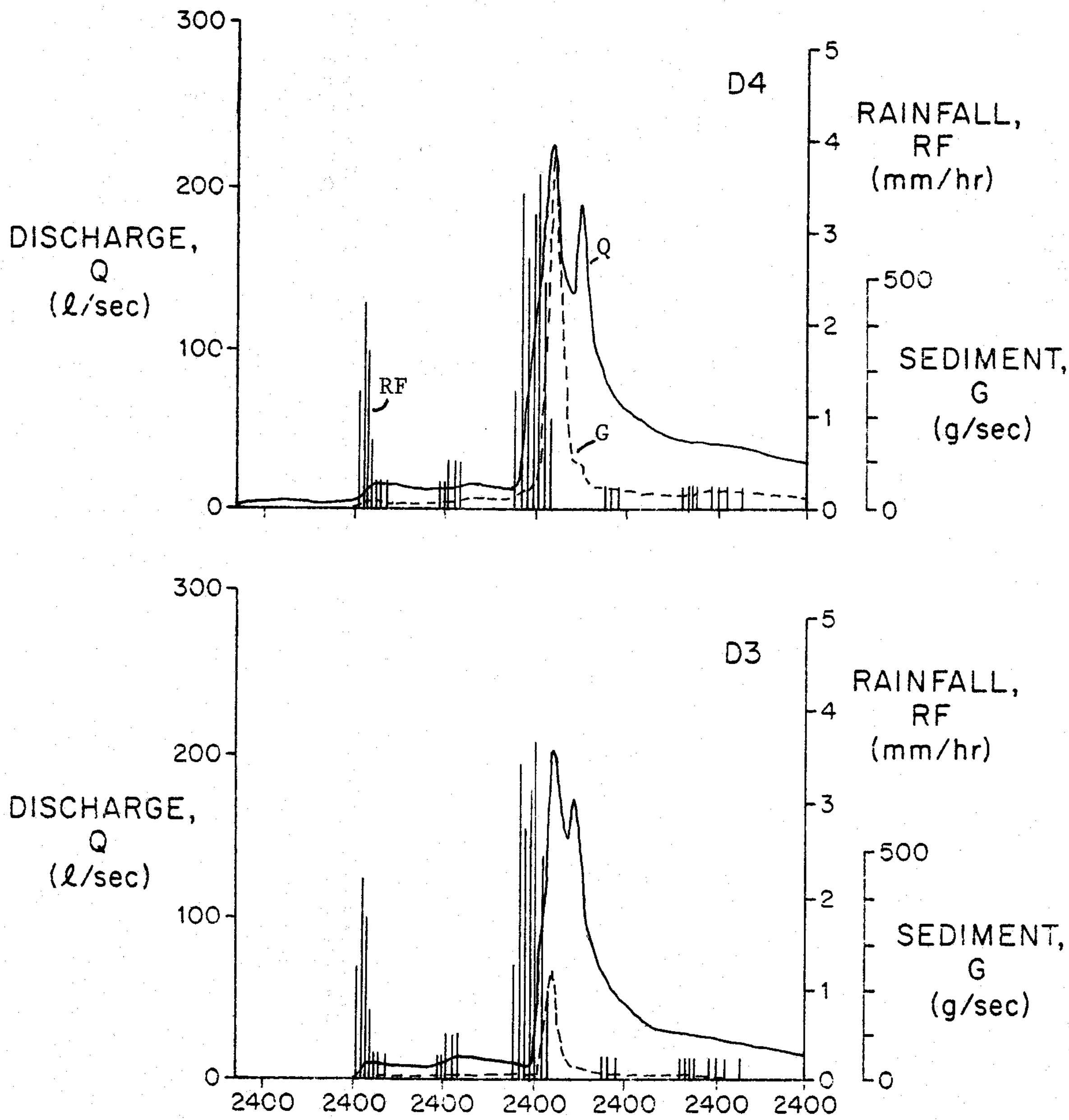

Fig. 14-6--Runoff and sediment yield for the period Feb. 4-9, 1979.

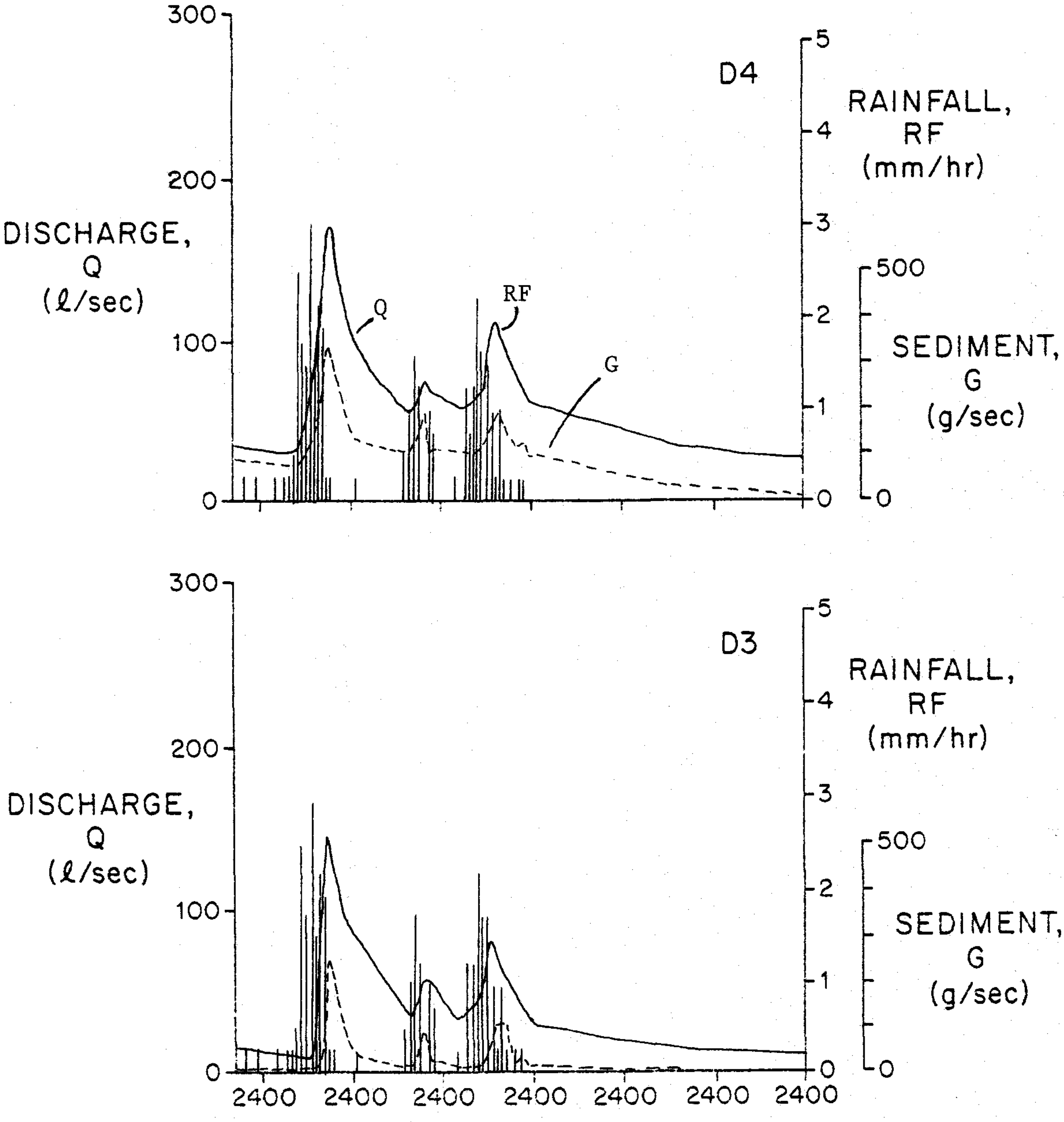

Fig. 14-7--Runoff and sediment yield for the period Feb. 10-15, 1979.

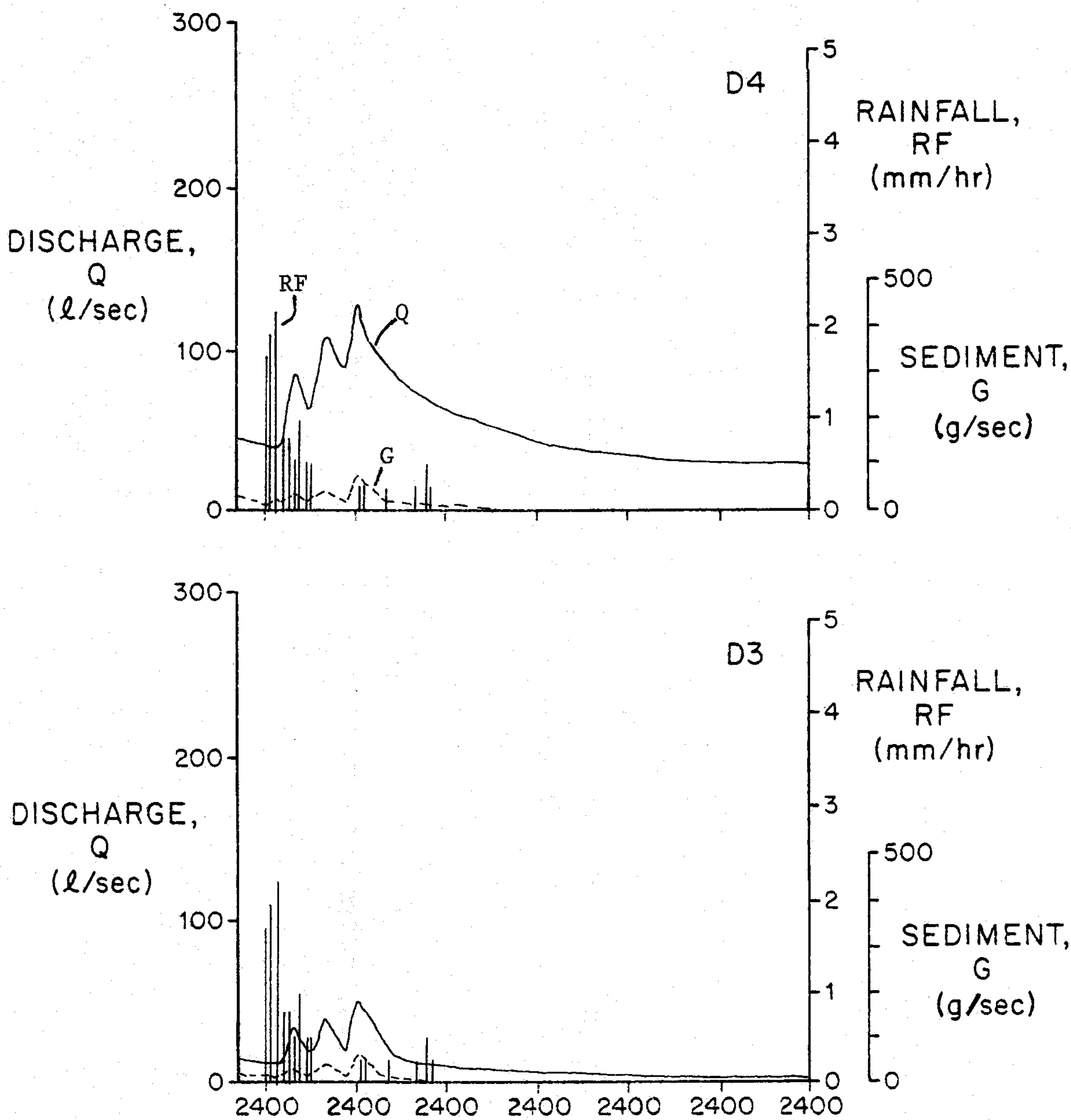

Fig. 14-8--Runoff and sediment yield for the period Feb. 17-22, 1979.

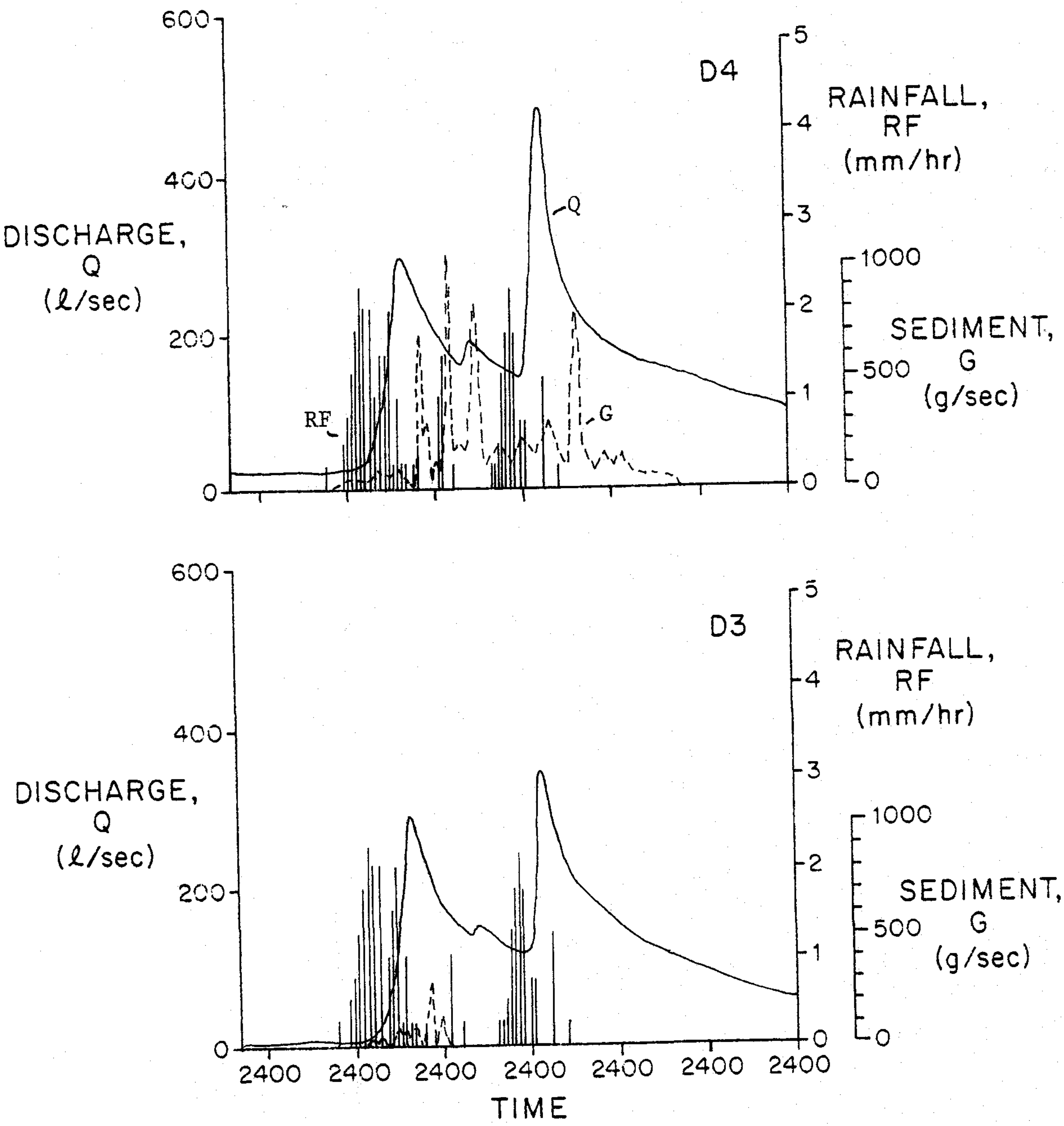

Fig. 14-9--Runoff and sediment yield for the period Nov. 21-26, 1979.

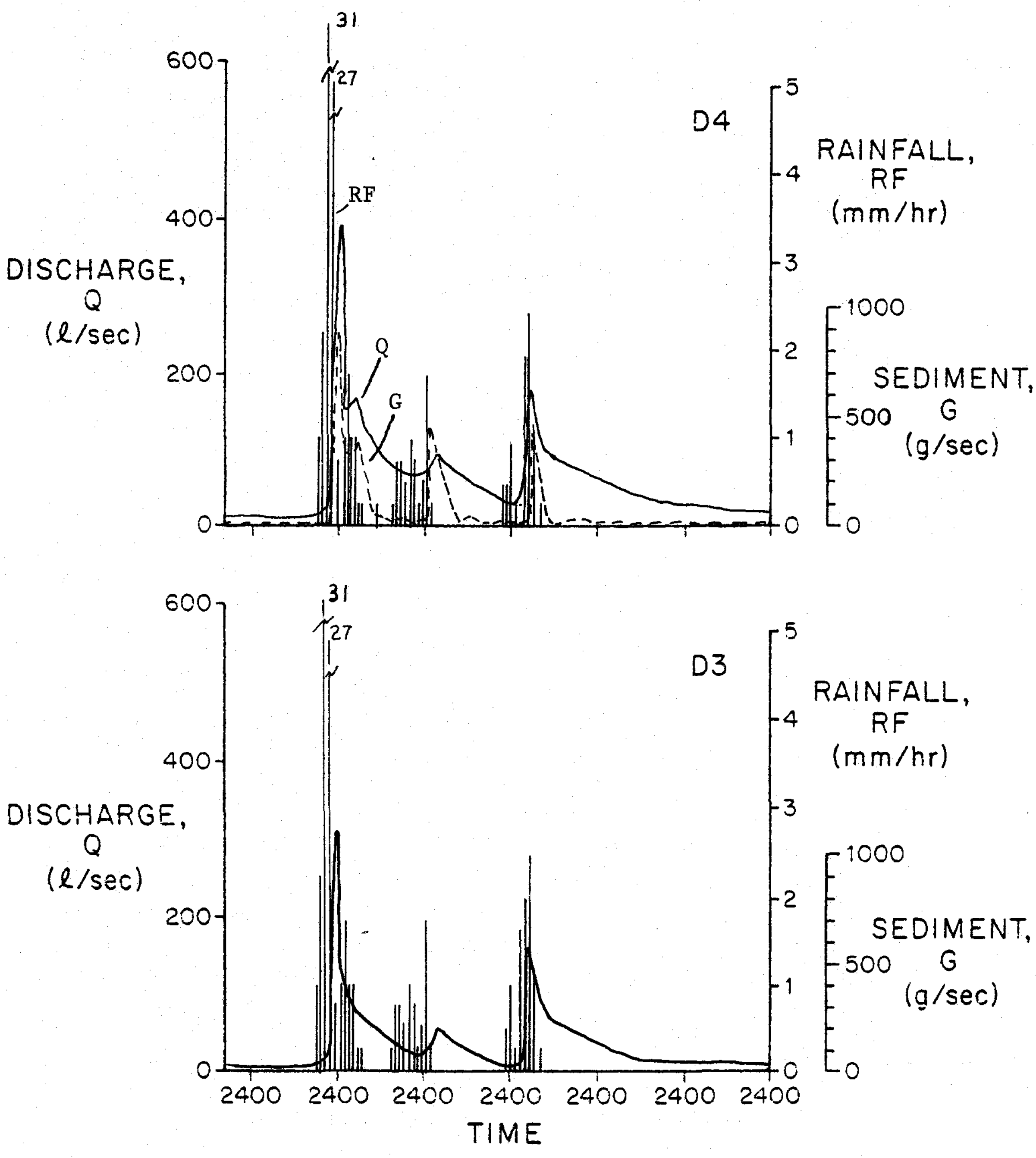

Fig. 14-10--Runoff and sediment yield for the period Dec. 1-6, 1979.

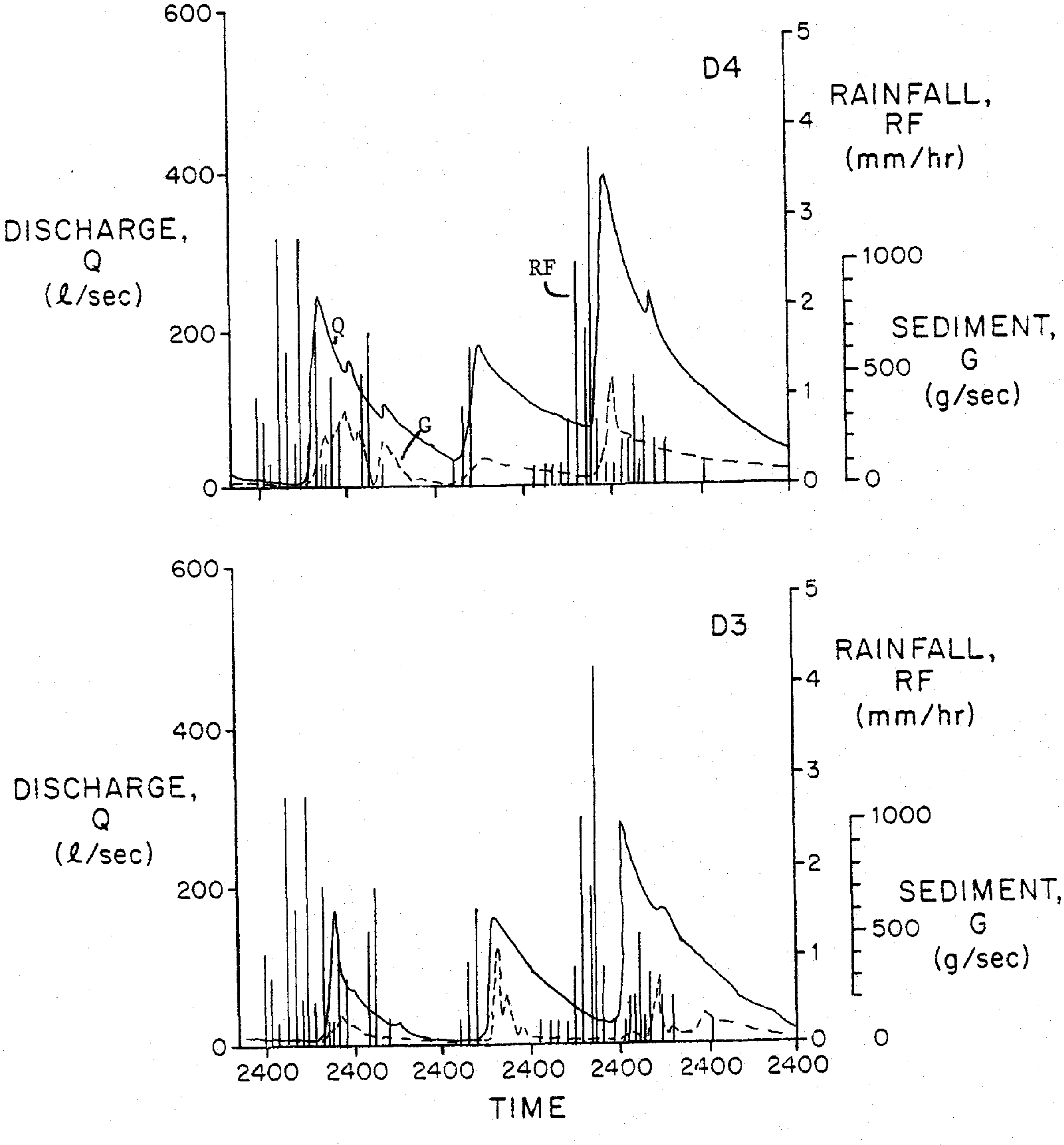

Fig. 14-11--Runoff and sediment yield for the period Dec. 17-22, 1979.

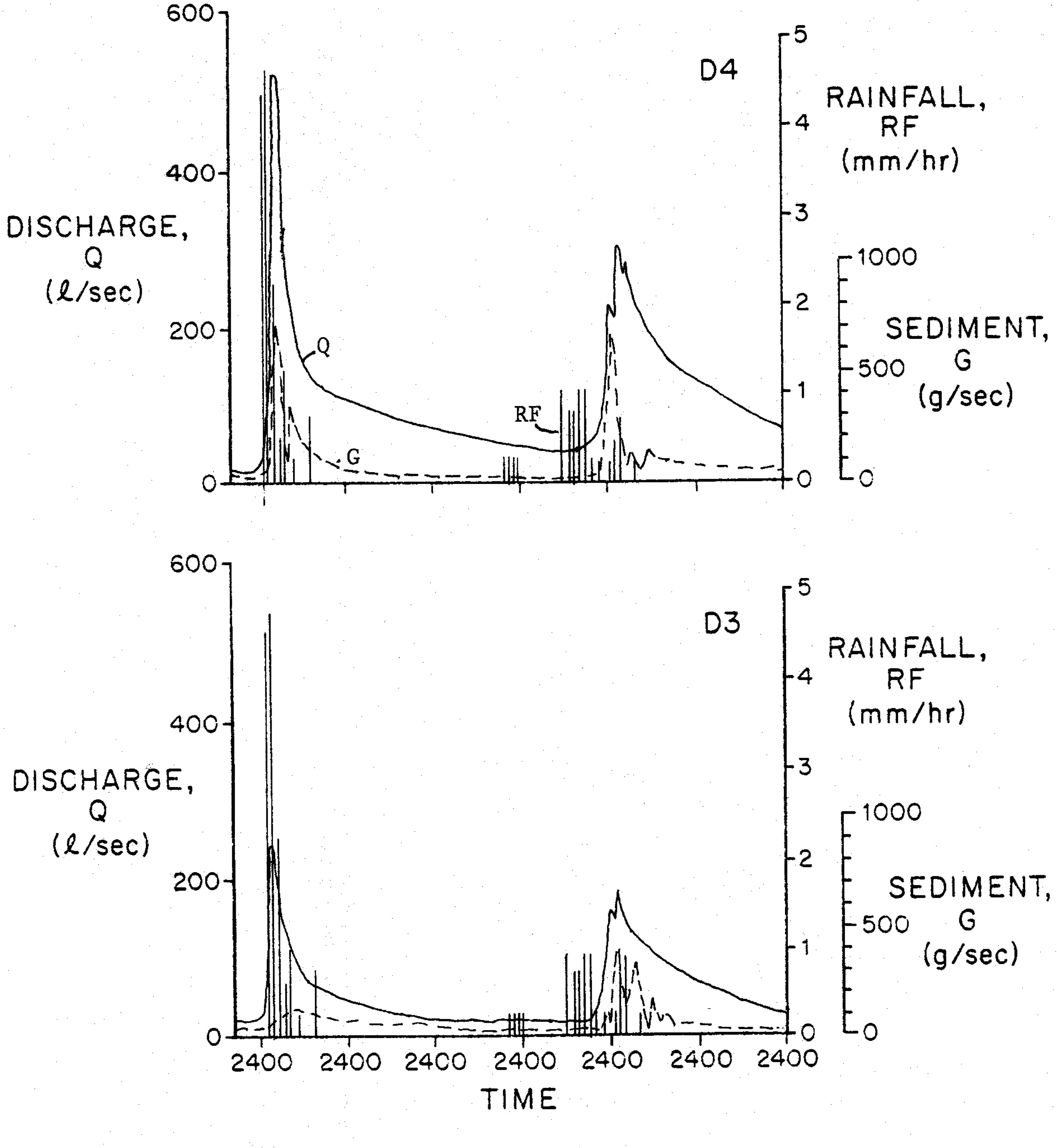

Fig. 14-12--Runoff and sediment yields for the period Jan. 1-6, 1980.

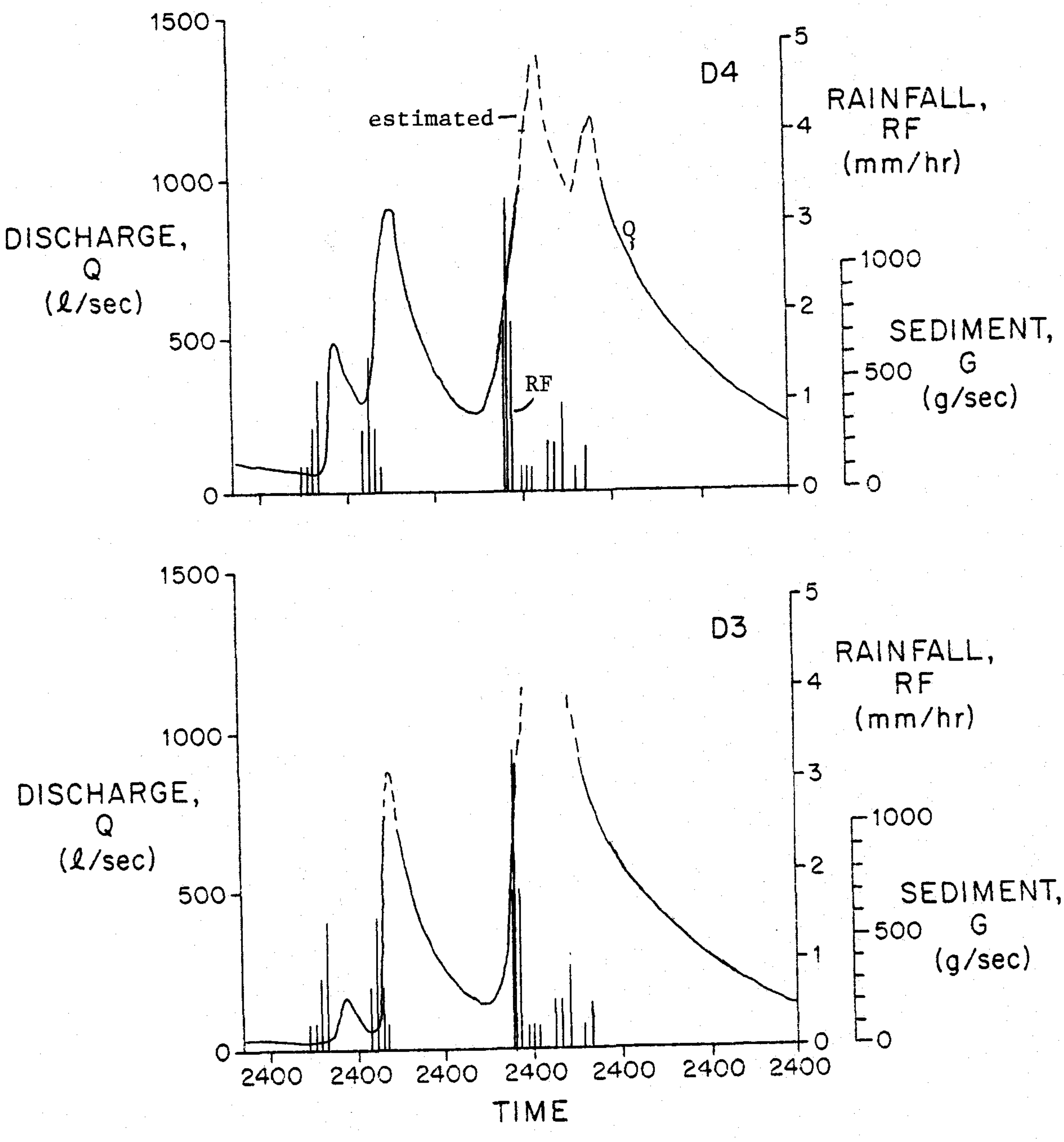

Fig. 14-13--Runoff and sediment yield for the period Jan. 6-11, 1980.

Table 14-1--NO_3-N and suspended sediment concentration, drainline vs. surface runoff - D3.

Date	Drainline		Surface runoff - D3		
	NO_3-N concentration	Suspended sediment concentration	NO_3-N concentration	Suspended sediment concentration	Discharge
	ppm	ppm	ppm	ppm	ppm
Dec. 3, 1979	27.7	131	9.6	68	34.5
Dec. 4	24.5	182	8.8	70	65.1
Dec. 5	26.1	199	8.7	80	17.6
Dec. 6	26.8	185	---	85	9.9
Dec. 7	23.0	168	8.8	85	4.8
Dec. 31	23.5	284	3.5	11	11.3
Jan. 2, 1980	25.9	---	4.9	---	23.6
Jan. 16	19.5	219	1.2	139	51.5
Jan. 17	26.0	116	1.3	57	21.2
Jan. 21	21.5	122	2.8	0	4.8
Jan. 22	21.1	99	3.3	71	4.8
Feb. 7	32.5	136	3.1	131	8.8
Feb. 11	28.3	136	---	128	3.2
Feb. 12	27.6	0	---	185	3.2
Feb. 19	22.1	91	2.6	199	34.6
Feb. 20	23.7	3	2.3	159	17.6
Feb. 21	21.6	139	2.9	134	11.4

Table 14-2--NO_3-N concentration in surface runoff, D3 vs. D4.

Date	Surface runoff - D3		Surface runoff - D4	
	NO_3-N Concentration	Discharge	NO_3-N Concentration	Discharge
	ppm-	ℓ/sec	ppm-	ℓ/sec
Nov. 19, 1979	10.9	1	5.3	2
Nov. 20	12.1	1	4.2	2
Nov. 21	10.9	1	3.4	8
Nov. 23	18.7	140	10.4	170
Nov. 29	12.4	2	6.7	10
Dec. 5	8.7	20	5.3	50
Dec. 31	3.5	25	6.2	35
Jan. 3, 1980	5.5	35	3.4	75
Jan. 4	5.1	20	3.2	28
Jan. 7	2.7	9	1.5	21
Jan. 8	3.1	18	1.1	29
Jan. 9	1.2	> 840	1.3	> 840
Jan. 11	2.7	130	1.5	240
Jan. 16	1.2	52	1.0	71
Jan. 17	1.3	21	0.9	30
Jan. 21	2.8	16	2.2	26
Jan. 22	3.3	5	2.9	10
Jan. 24	2.7	6	3.1	10
Feb. 5	3.0	25	1.4	38
Feb. 19	2.6	35	1.3	60
Feb. 20	2.3	18	1.4	31
Feb. 21	2.9	11	1.1	17
Feb. 22	2.3	18	1.2	28
Mar. 14	2.3	2	0.4	10
Apr. 4	2.1	1	0.3	2

CHAPTER 15. EROSION IN THE SILVERTON HILLS AREA, MARION COUNTY

J. D. Istok and M. E. Harward

Summary

For a two-year period, annual erosion rates ranged from 0.01 to 0.5 tons per acre. Fall-planted wheat fields had approximately five times as much erosion as those in perennial grass. These rates were comparable to the Elkins Road study area even though the Silverton hills area has longer, steeper slopes and higher rainfall. The small amounts of runoff and erosion are attributed to the influence of a strong surface structure and a deep, well-drained profile.

Introduction

The Silverton hills area has a reputation of high rates of erosion although we know of no definitive studies where these rates were determined. It is possible that this reputation results from estimates based on slope and slope length. Representatives of the agricultural industry were interested in documenting the amounts of erosion which occurs in the area. A cooperative study was developed in Marion County in the runoff seasons of 1978-79 and 1979-80.

Materials and Methods

Experimental sites were selected jointly by personnel in the erosion project, the Marion County Extension Agent, and representatives of the cooperating group.

The amounts of erosion were measured using standard erosion plots with an area of approximately 50 m^2. Runoff and sediments were measured using a combination of a settling trough and a tub used as a reservoir. The plots were installed in the fall after the wheat had been planted and removed prior to harvest. They were monitored on a periodic basis depending on weather conditions. Monitoring of the plots and procurement of samples were done by personnel working from the County Extension office. Samples were analyzed and data tabulated by the Soils Department at OSU. Continuous recording raingages were used to measure precipitation. A rain wedge which measured cumulative rainfall between readings also was used as a back-up in the event of temporary failure of the recording raingage.

1978-79 Studies

Cooperators

Marion County Extension Agent; Cascade Foothill Seed Growers; Oregon Fine Fescue Commission; Oregon Highland Bentgrass Commission; H. L. Riches & Sons; IDKA Farms; Marion County Soil and Water Conservation

District; SCS; Soil Science Department, Oregon Agricultural Experiment Station, OSU.

Location and Soils

Site A (wheat) was located in SW1/4, NW1/4, NW1/4, Section 27, T.7S., R.5W. According to the Marion County Soil Survey Report, the soil is a Jory silty clay loam. The taxonomic classifications of the soil is clayey, mixed, mesic, Xeric Haplohumult. Slope was 7%. "Well holes" dug at the upper and lower ends of the plots for use in monitoring perched water tables revealed that the silty clay of the B2t horizon extended to a depth of 155 cm.

Site B (grass) was located in SW1/4, NW1/4, NW1/4, NW1/4, Section 35, T.7S., R.1W. According to the Marion County Soil Survey Report the soil is Nekia silty clay loam. Slope was 7%. The "well hole" at the upper end of the plot for measuring perched water tables indicated a soil depth of 115 cm to rock while the hole at the lower end of the plot revealed soil to a depth of over 155 cm.

The plots were laid out with their long axis parallel to the slope gradient. No attempt was made to modify the effect of drill rows which also were parallel to the long axis of the plot.

Results and Discussion

There was more "gross" erosion from the plot on wheat than from the plot on grass (Table 15-1 and 15-2). This was expected. Quantification of the differences and the total amounts were of more interest. Approximately five times as much erosion occurred on wheat as on grass. The seasonal totals for amounts of erosion were small, 1.12 mTon/ha (0.5 T/acre) and 0.22 mTon/ha (0.1 T/acre) for wheat and grass, respectively.

The greatest amount of erosion occurred during the period of Jan. 30-Feb. 8, 1979. This probably was because of freezing which fluffed the soil making it more susceptible to erosion in subsequent storms. Intermittent freezing conditions were observed on the watershed in Polk County, beginning about mid December, 1978 and extending to Feb. 1, 1979. We assume that the conditions were similar in Marion County. The effect was much greater on the wheat plot (293 kg/ha) than on the grass plot (20 kg/ha). This storm period can be compared with one of comparable size for the period ending on Nov. 22, 1978 with only half as much erosion on the wheat plot.

After the middle of March, the amount of erosion was very small. From Mar. 7 to Apr. 13, there was 11.9 cm of accumulated rainfall; yet, we observed no runoff. This was probably a reflection of increased cover (plant growth) and/or the influence of cracks which formed in the soil surface during the intervening dry periods.

There was no evident relationship between perched water tables (Tables 15-3) and runoff (Tables 15-1 and 15-2) at these locations. No perching occurred until the latter part of December and it persisted only for short periods of time. The data recorded were for the least depth to perched water (highest level of perched water) during the intervening period of time. At the time that the monitoring was done, measurements were taken of "present" water tables. Invariably they were minimal or not present at that time. The depths to perched water tables at site B were generally greater and perching occurred less frequently at site B than it did at site A.

1979-80 Studies

Cooperators

Marion County Extension Agent, Marion County Soil and Water Conservation District; SCS; William Wolf (landowner), Bruce Jaquet (operator); Soil Science Department, Oregon Agricultural Experiment Station, OSU.

Location and Soils

Site A (wheat) was located in NE1/4, SE1/4, NW1/4, Section 5, T.85., R.1E. According to the Marion County Soil Survey Report the soil is Nekia silty clay loam. "Well holes" dug at the upper and lower end of the plot for measuring water tables revealed a soil depth of more than 155 cm indicating that the correct classification is Jory silty clay loam. Slope was 12 percent.

Site B (grass) was located in NE1/4, SW1/4, SW1/4, Section 33, T.75, R.IE. The soil is mapped as Nekia; however, "well holes" revealed that silty clay of the B2t horizon extended below 150 cm indicating that the soil is Jory silty clay loam. Slope was 12 percent.

The plots were laid out with their long axis parallel to the slope gradient. The drill rows were at right angles to the axis of the plots.

Results and Discussion

As in the previous year, sediment production was approximately 5 times greater on wheat than on grass (Tables 15-4 and 15-5). However, the totals for the season were very low, 0.11 mTon/ha (0.05 T/acre) and 0.02 mTon/ha (0.01 T/acre), respectively. The low amounts of erosion may have been caused by effects of plant cover and soil structure. Rapid early growth was observed on the wheat plot (site A); the root mat on the grass plot (site B) was very dense. Both soils had very strong surface structure which persisted throughout the season. No crust was observed.

Most of the sediment was produced early in the season. An intense rainstorm occurred during the period of Jan. 4-15, but less sediment was produced than earlier in the season during less intense storms.

There were no consistent trends in runoff data. Site B (grass) had slightly higher runoff early in the season; wheat (site A) had slightly higher runoff later in the year. The figures for percent runoff are smaller than those obtained from the watershed in Polk County which averaged about 30-40 percent, even though the Marion County sites had higher rainfall and steeper slopes.

Table 15-1--Runoff and gross erosion from Site A (wheat) in 1978-79.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Nov. 5-22, 1978	68	1.8	11.2	17	90
Nov. 22-29	35	0.8	0.3	1	20
Nov. 29-Dec. 1	27	1.3	1.4	5	40
Dec. 1-5	36	1.3	0.3	1	20
Dec. 5-11	39	1.0	0.7	2	90
Dec. 11-21	19	0.3	0.0	0	20
Dec. 21-Jan. 11, 1979	52	0.8	2.9	6	40
Jan. 11-24	20	0.3	2.5	13	20
Jan. 24-30	10	0.3	0.1	1	10
Jan. 30-Feb. 8	74	1.3	12.8	17	290
Feb. 8-13	65	1.3	0.4	1	90
Feb. 13-16	9	1.8	1.0	11	20
Feb. 16-20	36	1.3	0.4	1	90
Feb. 20-23	30	1.0	0.4	1	140
Feb. 23-27	40	1.3	2.0	5	170
Feb. 27-Mar. 7	44	0.8	2.0	5	40
Mar. 7-Apr. 13	119	0.3	0.0	0	0

Table 15-1--continued.

Storm period	Rainfall		Runoff		Gross erosion
	Total for period	Maximum intensity			
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Apr. 13-20	3	1.3	0.0	0	10
Apr. 20-May 8	5	0.8	0.0	0	0
Total	731		38.4		1,200

Soil: Jory silty clay loam, clayey, mixed, mesic Xeric Haplohumult†.
Slope: 7%
Plot Area: $50m^2$

†Source: Soil Survey of Marion County Area, Oregon, USDA Soil Conservation Service 1972.

Table 15-2--Runoff and gross erosion from Site B (grass) in 1978-79.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Nov. 5-22, 1978	68	1.8	0.7	1	10
Nov. 22-29	35	0.8	0.2	1	0
Nov. 29-Dec. 1	27	1.3	1.9	7	30
Dec. 1-5	36	1.3	2.3	6	50
Dec. 5-11	39	1.0	2.3	6	10
Dec. 11-21	19	0.3	0.0	0	10
Dec. 21-Jan. 11, 1979	52	0.8	16.8	32	10
Jan. 11-24	20	0.3	9.7	49	10
Jan. 24-30	10	0.3	0.0	0	0
Jan. 30-Feb. 8	74	1.3	1.9	3	20
Feb. 8-13	65	1.3	1.7	3	10
Feb. 13-16	9	1.8	0.0	0	0
Feb. 16-20	36	1.3	1.9	5	20
Feb. 20-23	30	1.0	0.2	1	10
Feb. 23-27	40	1.3	4.1	10	30
Feb. 27-Mar. 7	44	0.8	0.4	1	10
Mar. 7-Apr. 13	119	0.3	0.0	0	0

Table 15-2--continued.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Apr. 13-20	3	1.3	0.0	0	0
Apr. 20-May 8	5	0.8	0.0	0	0
Total	731		44.1		230

Soil: Nekia silty clay loam, clayey, mixed, mesic Xeric Haplohumult†.
Slope: 7%
Plot Area: $50m^2$

†Source: Soil Survey of Marion County Area, Oregon, USDA Soil Conservation Service 1972.

Table 15-3--Average depth to perched watertable, Site A (wheat) vs. Site B (grass) in 1978-79.

Storm period	Average depth to perched watertable	
	Site A (Wheat)	Site B (Grass)
	-cm-	-cm-
Nov. 5-22, 1978	139+	121+
Nov. 22-29	139+	121+
Nov. 29-Dec. 1	139+	121+
Dec. 1-5	139+	121+
Dec. 5-11	139+	121+
Dec. 11-21	139+	121+
Dec. 21-Jan. 11, 1979	67	87
Jan. 11-24	54	55
Jan. 24-30	139+	121+
Jan. 30-Feb. 8	74	121+
Feb. 8-13	51	117
Feb. 13-16	131	121+
Feb. 16-20	99	121+
Feb. 20-23	111	100
Feb. 23-27	114	115
Feb. 27-Mar. 7	130	116
Mar. 7-Apr. 13	139+	121+
Apr. 13-20	139+	121+
Apr. 20-May 8	139+	121+

Table 15-4--Runoff and gross erosion from Site A (wheat) in 1979-80.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Nov. 22-26, 1979	113	1.5	0.8	1	20
Nov. 26-Dec. 7	102	3.1	2.6	3	70
Dec. 7-14	19	2.0	0.3	2	0
Dec. 14-21	45	2.5	0.3	1	0
Dec. 21-28	22	1.0	0.2	1	0
Dec. 28-Jan. 4, 1980	40	1.0	1.0	3	0
Jan. 4-15	152	7.6	22.3	15	20
Jan. 15-18	18	3.6	0.2	1	0
Jan. 18-25	0	0.0	0.1	0	0
Jan. 25-Feb. 1	20	2.3	2.0	10	0
Feb. 1-8	42	1.8	0.1	0	0
Feb. 8-15	1	1.8	0.0	0	0
Feb. 15-22	25	1.3	2.7	11	0
Feb. 22-29	28	3.0	3.8	14	0
Feb. 29-Mar. 10	20	1.5	0.5	3	0
Mar. 10-14	89	2.5	2.7	3	0
Mar. 14-21	37	1.8	0.8	2	0
Mar. 21-28	13	1.8	0.1	1	0

Table 15-4--continued.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Mar. 28-Apr. 7	51	2.8	1.5	3	0
Apr. 7-11	32	2.8	0.6	2	0
Total	869		42.6		110

Soil: Jory silty clay loam, clayey, mixed, mesic Xeric Haplohumult†.
Slope: 12%
Plot area: $50m^2$

†determined in the field.

Table 15-5--Runoff and gross erosion from Site B (grass) in 1979-80.

Storm period	Rainfall		Runoff		Gross erosion
	Total for period	Maximum intensity			
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Nov. 22-26, 1979	104	1.5	0.6	1	20
Nov. 26-Dec. 7	90	3.1	2.4	3	0
Dec. 7-14	17	2.0	0.1	1	0
Dec. 14-21	39	2.5	6.0	15	0
Dec. 21-28	21	1.0	0.1	1	0
Dec. 28-Jan. 4, 1980	39	1.0	1.6	4	0
Jan. 4-15	146	7.6	24.0	16	0
Jan. 15-18	18	3.6	0.0	0	0
Jan. 18-25	0	0.0	0.0	0	0
Jan. 25-Feb. 1	15	2.3	2.6	17	0
Feb. 1-8	37	1.8	0.0	0	0
Feb. 8-15	3	1.8	0.0	0	0
Feb. 15-22	27	1.3	1.5	6	0
Feb. 22-29	31	3.0	4.0	13	0
Feb. 29-Mar. 10	21	1.5	0.2	1	0
Mar. 10-14	76	2.5	0.1	0	0
Mar. 14-21	34	1.8	0.0	0	0
Mar. 21-28	11	1.8	0.0	0	0

Table 15-5--continued.

Storm period	Rainfall: Total for period	Rainfall: Maximum intensity	Runoff		Gross erosion
	---mm----	mm/15 min	-mm-	%-	-kg/ha-
Mar. 28-Apr. 7	46	2.8	0.0	0	0
Apr. 7-11	28	2.8	0.0	0	0
Total	803		43.2		20

Soil: Jory silty clay loam, clayey, mixed, mesic Xeric Haplohumult†.
Slope: 12%
Plot area: 50m^2

†Determined in the field.

Table 15-6--Average depth to perched watertable, Site A (wheat) vs. Site B (grass) in 1979-80.

Storm period	Average depth to perched watertable	
	Site A (Wheat)	Site B (Grass)
	-cm-	-cm-
Nov. 22-26, 1979	149+	147+
Nov. 26-Dec. 7	134	137
Dec. 7-14	149+	147+
Dec. 14-21	149+	147+
Dec. 21-28	149+	147+
Dec. 28-Jan. 4, 1980	149+	147+
Jan. 4-15	100	141
Jan. 15-18	113	87
Jan. 18-25	145	138
Jan. 25-Feb. 1	105	131
Feb. 1-8	120	130
Feb. 8-15	149+	147+
Feb. 15-22	149+	147+
Feb. 22-29	149+	147+
Feb. 29-Mar. 10	149+	147+
Mar. 10-14	140	147+
Mar. 14-21	141	147+
Mar. 21-28	149+	147+
Mar. 28-Apr. 7	143	138
Apr. 7-11	148	147+