# RUNOFF LOSSES FROM EIGHT WATERSHEDS AS INFLUENCED BY SOIL COVER CONDITION AND MANAGEMENT SYSTEMS AT EL RENO, OKLAHOMA

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# CHAPTER I

# INTRODUCTION

There has been a growing public concern in recent years regarding the quality of runoff water entering surface water bodies such as lakes and streams.

Nutrients, especially nitrogen (N) and phosphorus (P), not only contribute to water quality deterioration but also represent an important soil fertility loss.

Sediment and liquid runoff quantity and quality from agricultural land are influenced by numerous factors.

More information is needed to show the effects of native watershed conditions on these parameters. The information is also needed so that management practices can be developed to minimize soil, water, and nutrient losses to preserve soil fertility and reduce pollution hazards.

A study was initiated in 1977 at El Reno, Oklahoma to investigate the effects of eight soil surface covers on the quality and quantity of liquid and sediment runoff discharged from the eight watersheds.

A 5-year data collection for the period 1977-1981 of N and P losses in surface runoff water and sediment from eight 1.62-hectare watersheds having different soil cover and management practices are reported.

Some important physical, chemical, and mineralogical characteristics of the soils occurring on these watersheds are included in this study.

# CHAPTER II

## LITERATURE REVIEW

Problems associated with detached, transported and deposited sediments along with runoff have stimulated increased interest in controlling runoff and sediment movement into streams, lakes, etc.

Many factors and their interactions are involved in runoff and soil erosion. Soil properties, slope, climate, canopy, and others have a great effect on the intensity, duration, and the quality of runoff and the sediment load. This makes the study of this process a rather complicated task under field conditions. The complexity is increased when causative factors are variable in time and space. Fogel (1969) reported that in Southwestern United States most of the annual runoff occurs as a result of a highly variable convective storm activity during summer months.

The universal soil loss equation (USLE) developed by Wischmeier and Smith (1965) includes a "C" factor which accounts for the effect of surface cover on reducing erosion by rainfall. The factor ranges from zero for complete soil cover to one for bare soil.

The physical condition of soil surfaces often controls the amount of water entering the soil during a rain.

Burwell et al. (1966) suggested that tillage should provide soil surface conditions in the inter-rows zone that enable water to be detained and infiltrate rapidly especially when runoff is most likely to occur. Romkens et al. (1975) claimed that soil losses will be appreciably reduced if soil surfaces are left in rough condition especially for well aggregated soils. They attributed the roughened surface effect to delayed surface sealing and clod disintegration by impacting raindrops and subsequent decrease of runoff rates and velocities. Moe et al. (1967) investigated the effects of some physical properties on the amount of runoff and the mineral N losses. He reported that soils having an initially sealed surface lost 62 percent of the first two and one-half inches of rain, whereas soils having an initially open surface lost only 28 percent. Their results indicate that N losses will be more severe when N fertilizers are applied to very wet soils or to fallow soils having a surface seal.

Many researchers have shown great concern, over the effects of overworking, the soil on runoff and erosion. Lloyd (1960) showed that minimum tillage drastically reduced runoff and erosion. Lillard and Jones (1964), and Harrold et al. (1967) claimed that the residue mulch on no-tillage corn land not only reduced runoff and erosion losses, but also reduced evaporation losses.

Wischmeier (1975) classified cover and management effects on soil detachment and transport into three types:

i. effects of canopy cover, ii. the effect of mulch or close-growing vegetation, and iii. tillage and residual effects of land use. Kent (1966) found that, although winter wheat lands are particularly susceptible, runoff can occur under all types of cover conditions in the Pacific Northwest. He thus concluded that in addition to varying cover conditions, specific practices to control runoff are necessary.

After considering all practices that can provide erosion control in the Corn Belt, Jacobson (1969) concluded that there are only two that farmers will accept. These are: 1. the no-plow, till-plant form of minimum tillage to control sheet erosion and 2. water control by storage fills constructed across waterways. Burwell et al. (1975) investigated the influence of five soil cover conditions on N and P in surface runoff and sediment in West Central Minnesota. They concluded that soil covers have greatly influenced the water and sediment losses. They showed that N and P transported by sediment accounted for 96 percent and 95 percent or more of the annual N and P losses, respectively, for all soil cover treatments except hay.

According to Horner et al. (1960) the greatest erosion losses in the Pacific Northwest wheat region occurred from land on which winter wheat was grown following summer fallow. Hanotiaux (1978) reported significant erosion in Belgium on mildly undulating fields with gentle slopes. He found that under winter wheat the annual erosion was less than 4.3 t/ha compared to 82.2 t/ha in case of fallow treatment, and 30.1 t/ha in case of a sugarbeet plantation. El-Swaify (1978) studied soil losses from sugarcane and pineapple lands in Hawaii. He found that sediment losses from watersheds on highly weathered volcanic ash soils were very small even when the soils were bare following sugarcane harvest. This was attributed in part to the low erodibility of this volcanic ash soil.

Crop tillage systems greatly influence soil and water losses. According to Meyer and Mannering (1966) plow-plant and wheel-track planting systems reduced soil losses as much as 50 percent compared to the conventional plow-disk-harrow system. Duly and Miller (1923) showed that soil losses from plowed soil were much greater than from unplowed soil because soil particles were detached easier.

Romkens et al. (1973) compared the effect of five tillage-planting systems on the N and P composition in runoff water and runoff sediment from corn (_Zea mays_ L.) plots which received different application rates of N and P fertilizers. They found that the conventional system, in which fertilizers were plowed under, lost the most soil and water. However, on a concentration basis the nutrient content in runoff followed a reverse sequence from that for soil loss, thus they concluded that tillage systems that control soil erosion do not necessarily reduce losses of soluble nutrients from surface-applied fertilizers.

In the Texas Blackland Prairie, terraces are commonly used to reduce soil erosion by water. Terraces, however, have two weaknesses (Richardson et al., 1969): 1. erosion occurring on the steep slope immediately below the terrace ridge results in soil deposits in the next terrace channel, and 2. the irregular horizontal spacing created by conventional terrace systems reduces the efficiency of large, modern, mechanical equipment. They claimed that a system of graded furrows may eliminate the need for some terraces and simplify field-equipment operation.

Richardson (1973) compared runoff and soil losses of a graded-furrow system with those of a terrace system. He found that runoff from the graded-furrow area was significantly less than from the terraced area, however, soil losses were essentially the same. Schuman et al. (1973) studied N losses from surface runoff from four field size watersheds in Southwestern Iowa. They claimed that the conservation practice of level-terraced corn or pasture was more effective in reducing water, sediment, and N yields compared with the contour-planted corn watershed. Their data indicates that N losses associated with sediment in runoff accounted for 92 percent of the total loss for the three-year period from the contour-planted corn watersheds.

The runoff frequency from small storms as related to various crops and management practices was investigated by Lewis et al. (1977). They reported that contouring of maize and wheat fields decreased the occurrence of a runoff event as compared with straight-row cultivation and thus reduced the probability of pollution from surface-applied chemicals. They claimed that under the prevailing conditions of the study there was little risk of surface water pollution following top dressing of N fertilizer on winter wheat especially when the soil surface was relatively dry.

Crop rotations in the U.S. are becoming obsolete and with reduced conservation benefits (Garst, 1967). Conservation tillage systems may be a practical way to reduce soil erosion at a minimal cost. According to Grant (1975) after an episode of excessive soil erosion from both wind and water in many parts of the U.S. a new surge of interest has arisen in stubble mulching, minimum tillage, and no-till farming. Widespread construction of such conservation measures as terraces and field windbreaks were also reported.

Johnson et al. (1979) investigated water, soil, and nutrient losses as related to three tillage systems. They found that the soil loss varied inversely with the amount of residue cover. They suggested that 75 to 95 percent of the N lost was associated with the sediment. However, the soluble P loss in runoff water and the available P in the sediment increased as residue cover was increased. This was attributed in part to decreased fertilizer incorporation with conservational tillage and to the release of $PO_4$-P from degrading residue. Standing crop residues such as stubble or crop residue litter on the surface reduces wind and water erosion of the soil. Stubble mulching, for example, takes advantage of the protection afforded soil by vegetative cover (Fryrear, 1969).

The role of straw mulch in water conservation has been investigated by many workers. Hanks and Woodruff (1958) found that mulches conserve extra water during frequent rainy periods but have little effect during long, dry periods. Unger and Parker (1968) reported similar results. They claimed that cumulative evaporation from soil was reduced 57 percent and 19 percent by straw applied to the surface and mixed with surface soil, respectively, compared with straw buried 1.7 inches deep.

Greb et al. (1970) reported 16 years of fallow water storage data and 13 years of wheat yield data from experiments conducted at three widely separated Great Plains locations. They demonstrated that increasing amounts of straw mulch consistently increased storage of soil water. In Nebraska, allowing wheat stubble to stand during the winter months effectively increases the amount of winter precipitation storage in the soil in the Great Plains. This soil water, available to winter wheat and grain sorghum at seeding, has a marked influence on the yield of these grains (Smika et al., 1966). Similar conclusions were suggested by Staple et al. (1960) from a study in Canada.

Although crop residues effectively reduce soil and water losses, they have some disadvantages. According to Larson et al. (1960) the most serious obstacle to adoption of residue management methods in the Northern Corn Belt is soil temperature reduction which delays germination, emergence, and early growth of corn. However, a reduction of two degrees Fahrenheit of the soil temperature due to mulch in the Southern region of the Corn Belt is not significant according to Van Wijk et al. (1959).

The merits of adding small amounts of manure to soil to improve its physical condition, such as an increase in water-stable aggregates (Guttay et al., 1956), the organic matter content of the soil (Free, 1949), and infiltration rate (Murphy et al., 1972) are well established. Recent research (Cross et al., 1973) involving large applications of manure, however, indicates a deterioration of the physical condition of soil. This was due to the rather high monovalent cations in manure. The monovalent cation concentration of manure can be reduced by limiting the salt added to rations fed to livestock (Mazurak et al., 1977). Mazurak et al. (1975) claimed that soil aggregates from manured plots were separated more easily by the impact of simulated raindrops because of reduced cohesion in these aggregates as compared to those from non-manured plots. They suggested, however, that although heavy application of manure to the soil is conducive to greater amount of splash by raindrops, this does not imply a deterioration of the physical properties of soil because soil detached by raindrops consisted of large-sized water-stable aggregates which are not readily transported any distance by water flow.

Several workers (Menzel et al., 1978; Olness et al., 1975) have reported significantly greater nutrient and soil losses in surface runoff from continuously grazed watersheds than from rotation-grazed watersheds. Menzel et al. (1978) reported that soils on continuously grazed watersheds generally contained less total Kjeldahl nitrogen (TKN) and total phosphorus (TP) than those of the rotation-grazed watersheds. Yet, surface runoff losses of TKN and TP from the continuously grazed watersheds were about three times as great as those from rotation-grazed watersheds each year. This was attributed to the larger amount of soil eroded away. In Nebraska, Dragoun et al. (1968) found that onsite surface runoff was reduced and soil water was increased by light versus heavy grazing, contour furrowing versus no treatment, and eccentric disking versus no treatment. Lusby et al. (1963) reported a difference in runoff and erosion between the grazed and ungrazed watersheds. Changes in pre-runoff water absorption may have explained this difference.

Hall and Pawlus (1973) found that runoff and sediment losses increased with each higher rate of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine; 80% WP; Geigy Agricultural Chemicals) application. They claimed that despite the fact that statistics have shown that higher levels of crop production are being achieved today on a smaller land area, a fact that can be attributed in part to widespread herbicide use, it is entirely possible that runoff and consequent sediment losses may remain at the same level or become more severe on tilled versus herbicide application on sloping cropland.

Pollution of surface water resources is attracting the attention of urban and rural dwellers alike. Lewis et al. (1977) indicated that the pollution of surface runoff water by an agricultural chemical is a function of many variables such as the kind of chemical, time since application, number of intervening rainstorms, cultural practices, erosion, and others. They claimed that high concentrations of chemicals will generally be associated with runoff from small storms because large storms will generally produce large volumes of runoff which dilute the chemicals moving into streams.

Modern agriculture which involves the use of more and more synthesized chemicals (fertilizers), has considerable impact on various aspects of the environment (Brady, 1967). However, the source of N and P causing algae and other aquatic weeds to grow is controversial. Although commercial fertilizers were suspected as a major contributor to these undesirable plants no conclusive data have been filed to support these speculations. Precipitation is a natural source of N that is independent of the soil and crop management. Schuman et al. (1974) studied the contribution of precipitation N relative to surface runoff and N discharge from two adjacent watersheds. They found that two-thirds of the soluble N, leaving watersheds fertilized at 168 kg N/ha by surface runoff, can be attributed directly to N in the precipitation that caused the runoff. This shows that soil is acting as a sink for N rather than a source.

White et al. (1967) investigated the loss of N in runoff from cropland. They reported that the application of granular ammonium nitrate fertilizer at a rate of 200 pounds N per acre, to sandy loam soils with a five percent slope, and followed by five inches of rain at an intensity of two and one-half inches per hour would result in a relatively unimportant pollution threat to streams and rivers. They noticed that only 0.15 and 2.3 percent of the applied fertilizer washed off the sod plots and fallow plots, respectively.

In another study conducted by Schuman et al. (1973) they found that during a three year period the average annual sediment N loss per unit of sediment from watersheds fertilized with 168 and 448 kg N/ha annually was 1.35 and 1.42 kg N/metric ton of sediment, respectively. They concluded that the fertility treatment had little effect on the amount of N carried by unit weight of sediment, and the most practical first step in eliminating N as a pollutant in surface runoff is to control erosion because a large part of the total N lost is associated with the sediment.

The effects of fertilization and grazing management on surface runoff water quality and forage production from grazed lands in Central Oklahoma were investigated by Olness et al. (1980). They reported a two-to-four fold increase in the concentration of N, 10-to-20 fold increase in the concentrations of TP, and 200-to-600 fold increase in total soluble P of the surface runoff of the fertilized watersheds as compared to the unfertilized watersheds.

Schuman et al. (1973) found that water-soluble N and sediment-N losses in runoff were usually highest at the beginning of the cropping season and decreased progressively throughout the year. This was attributed to nutrient removal by the crop, leaching, and N present in soil organic matter. Similar findings were reported by Barnett et al. (1972) who studied soil and nutrient losses in runoff for selected cropping systems using artificial rainfall techniques. They found that the concentrations of N, potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and chlorine (Cl) in runoff were high at the initiation of runoff and decreased with time. Thus, they concluded that an average nutrient concentration during a runoff event would be more representative of effects on downstream environment than are the instantaneous concentrations measured during an event.

Moe et al. (1967) conducted a study to compare runoff losses from various N forms and alternative management practices. They found that ammonium N was less susceptible to runoff loss in the urea-treated plots than in the ammonium nitrate-treated plots. This was explained as the ammonium nitrate is highly ionized and thus would be adsorbed near the surface of the soil, whereas the non-ionized urea would be carried down into the soil with rainwater and therefore be less subject to surface runoff loss. They claimed, although the total amount of runoff and soil losses were greater from the fallow plots than from the sod plots, the N losses from the sod plots were consistently greater than those from the fallow plots because of the direct washing of the soluble fertilizer material from the sod vegetation by the rain before the N had an opportunity to be adsorbed by the soil. Fertilizers also contain K, Ca, Mg, S, and many essential microelements, but these elements, do not limit life in lakes and streams and neither do they contribute to pollution.

Taylor (1967) provided an excellent review of previous research findings concerning P and water pollution. He indicated that soil P is basically lost through direct erosion of topsoil due to its immobility. This is in agreement with the findings of Scarseth and Chandler (1938) who found that plots receiving 345 kg/ha of P over a period of 26 years lost 60 percent of the added P by soil erosion.

Pollution of surface water resources from cattle feedlots is a growing concern to the public in the U.S. The characteristic of runoff and nitrate movement on unpaved feedlots was studied by Gilbertson et al. (1970). They found that lot size and shape, climate, topographic site, and soil type influence the runoff quality. Taylor (1967) claimed that significant amounts of P and nitrates which come from stockyards and feedlots if the animal wastes are allowed to run or wash directly into streams contribute to pollution.

According to Gifford et al. (1969) land management practices involving mechanical soil disturbance will cause a significant difference in the chemical qualities of runoff water. However, they found no correlation between water quality characteristics and the volume of runoff.

Slater and Carleton (1942) noted that the erosive processes are more selective for organic matter and plant nutrients when the amount of soil material eroded is low. Menzel et al. (1978) investigated relationships between nutrients, runoff, and sediment discharges over a 10-year period from cropland and rangeland in South Central Oklahoma. They found that annual variations in nutrient and sediment discharges often exceed the effects of treatment designed to control nutrient and sediment discharges. They concluded that records for a period more than a decade are needed before any appreciable effects in the amount of nutrients removed from soils, and sediment discharges due to different land use can be noticed.

Mineralogical analyses of soils are receiving more and more attention as a part of soil science. Knowledge of the mineral composition of soils is important for classifying, and for determining their mode of formation, and for interpreting certain aspects of fertility studies as well as basic chemical and physical properties. For this reason it is often desirable to separate the clay-size material from a natural soil and to study the characteristics of the material separated.

According to Fredrickson (1952) clay minerals are excellent indicators of environment because of their sensitivity to slight changes in composition, temperature, and pH of their surroundings. Kaolinite, for example, usually develops in an acidic or in a neutral environment where intense leaching processes prevail. Montmorillonite forms in the presence of certain alkalies and alkaline earths. Illites, on the other hand, are the dominant clay minerals in marine sediments (Grim, 1953).

X-ray diffraction (XRD), among the many methods of studying clay minerals, remains the most widely used technique for clay mineral identification and for studying their crystalline characteristics. In qualitative x-ray diffraction analysis the tendency for clay minerals to orient under stress is utilized to enhance the 001 reflections (MacEwan, 1949; Brindley, 1951). Quantitative analysis, however, remains stubbornly difficult even though the basic principles are well established and the small particle size of clays is particularly favorable.

According to Brindley (1976) the most difficult problem to overcome is related to the choice of a standard and to the tendency for preferred orientation. Norrish and Taylor (1962) stated for quantitative diffraction analysis it is necessary to use randomly oriented specimens because of the marked dependence of peak intensities on orientation. Randomness is difficult to achieve with minerals whose particle shape is only moderately anisotropic, but with clays, which generally have a pronounced platy or fibrous morphology, it is virtually impossible (Taylor and Norrish, 1965). Gibbs (1967) believes that the advancement of quantitative x-ray diffraction clay analysis techniques has been impeded by the problems created through the variable composition and degree of crystallinity of clays. He suggested a solution for these problems through the extraction of the individual clays for the samples themselves and then using these separated clays as the standards for the series of samples.

Around 1930 the classical studies of Bragg and his collaborators established the general geometrical features of layer silicates structures. The majority of clay mineral structures are composed of layers which are themselves built up from sheets of atoms having hexagonal symmetry. The layers have characteristic structures in the principal clay mineral groups and characteristic thickness which can be found from the basal x-ray reflections and which enable a broad classification of clay minerals to be made.

According to Warshaw and Roy (1961) the layer silicates can be subdivided by the successive application of three criteria: 1. height of fundamental repeat unit or "thickness of layer"; 2. gross composition, whether dioctahedral or trioctahedral, an ionic content of layers; 3. stacking sequence of layers and degree of orderliness of stacking.

Jeffries and Jackson (1949) claimed that only a relatively few mineral families comprise the bulk of the soil. These consist of feldspars, quartz, mica, clay minerals, and in the laterite soils the oxides and hydroxides of iron and aluminum. They believe that knowledge of the distribution of the gross mineral components permits a description of the principal mineralogical characteristics of soils.

The importance of the residual clay minerals in various soils from the eastern and middle-eastern parts of the United States south of the areas of pleistocene glacial that hydrous mica, inherited from the parent rocks, characterizes the clay fraction of a great many soils. Other observers (Ross and Hendricks, 1945), however, have noted that where soil-forming processes, particularly those of podzolic character, have acted on soil material for a considerable period of time, kaolinite has developed at the expense of the original hydrous mica and montmorillonite.

Since the establishment by Hendricks and Teller (1942) of the principles of scattering of x-rays by mixed layer assemblages, interlayers have become increasingly recognized. The concept of mixed layer minerals has frequently been used by clay mineralogists to explain or account for irregular basal spacings or basal spacings which could not be assigned to any single specific mineral.

Several workers have indicated that interstratification is of general occurrence in clays of soils and sediments as a resultant of weathering. Interstratification of 2:1 and 2:2 layer silicates has been noted by many workers (Pauling, 1930; Gruner, 1934, 1948). Jackson et al. (1952) suggested that weathering of micas gave "intermediate" minerals consisting of interstratified or "mixed-layer" 2:1 and 2:2 (chlorite) layer silicate series. Gruner (1934) indicated that simple binary (2-component) randomness occurs commonly to give intermediate spacings, for example the 11.3 spacings may be interpreted as ternary (mica-montmorin-vermiculite) through interstratification along the Z-axis. Weaver (1953) used x-ray diffraction methods in characterizing a mixed-layer metabentonite. Bradley (1945) has investigated several mixed-layer aggregates using x-ray techniques and has presented criteria for recognizing the various types of structural arrangements. Brown and MacEwan (1951) have constructed a series of graphs which depict the type of x-ray diffraction effect one should expect from a material consisting of mixed layers.

In the x-ray diffraction patterns of soil colloids the d (001) spacings of the clay minerals, particularly those of the mica and montmorillonite type, are reported as weak or absent although these minerals may be present in considerable amounts in the specimens studied. Several factors appear to contribute to the production of "poor" x-ray diffraction patterns of soil colloids. The presence of oxides, such as $Fe_2O_3$, and $Al_2O_3$ affect the x-ray pattern by absorbing a considerable amount of the reflected x-ray beam and thus weakening the intensities of the lines produced and producing a dark halo which extends up to about 5° - the most important region for identification of the clay minerals. Brown and MacEwan (1950) reported that the presence of randomly interstratified clay minerals causes the cancellation of the d (001) spacings of the individual clay minerals and the appearance instead of average spacings with reflections which may be weak, broad, and diffused or even absent, depending upon the kind and the magnitude of interstratification. Aldrich et al. (1944), and Barshad (1950) found that the presence of the exchangeable cations Ba, Li, Na, $NH_4$, K, Rb, and Cs will produce poorer reflections than those reflected by Ca and Mg.

Grim et al. (1937) proposed the term "illite" as "a general term for the clay mineral constituents of argillaceous sediments belonging to the mica group." The modern concept of the term "hydrous mica", however, seems to describe the clay minerals that contain less K and more water than the well crystallized micas. Included under the hydrous micas are the illites. Structurally montmorillonites and the illites are similar, both having 2:1 layer structure, and diffrentiation between them is based largely on the nature of the interlayer cation. According to White (1950), if K is the predominant interlayer cation and the lattice is consequently unexpanded, the material is classified as an "illite"; if Na, Ca, or Mg is the predominant interlayer cation, and the lattice is expanded, the clay is characterized as a montmorillonite.

The importance of the interlayer cation-water structure to swelling has been shown by Greenland et al. (1964) who found that the swelling of mixed Ca-alkyl ammonium montmorillonite was four to five times as great as Ca-montmorillonite. They attributed this to the effect of large alkyl-ammonium cations in disrupting the cation-water structure between the layers.

Curling and/or breaking up of the clay film mounted for x-ray diffraction analysis on glass or porous ceramic slides leads to lowered intensities of the 001 peaks and incorrect d-spacings since the sample surface is no longer in the plane of the holding plates on the spectrogoniometer. The curling is more pronounced in samples high in montmorillonite. Rich (1975) found that the incorporation of short rods of glass wool in the slurry of clay significantly inhibits curling and loosening of the clay film.

# CHAPTER III

## MATERIALS AND METHODS

This study was conducted on the watershed experiment station of the USDA - Oklahoma Agr. Exp. Stn. Project, located about 7 km west of El Reno, Oklahoma in SW 1/4, SE 1/4, Section 4, TWP. 12N, R8W, Indian meridian. The station is located at 35° 30' north latitude and 98° 00' west longitude and at an altitude of 600 m above sea level. The study area is characterized by a dry, subhumid climate with an average annual rainfall of about 750 mm. The monthly precipitation ranges from 23 mm in January to 130 mm in May.

The layout of the watersheds as shown in Figure 1 consists of 8 plots, each plot is about 1.62 hectares with a slope of 3-4%. All plots had been left in grass for two years before the treatments were imposed in July 1978. At the downslope, each plot is instrumented with a V-notch type weir recording station.

The soils included in the study are presented in Figure 2. These soils are transitional between claypan prairie (Kirkland, Renfrow and Aydellote series) and loamy prairie (Milan and Bethany series). They formed under a cover of grasses in material weathered from clay shale. These soils

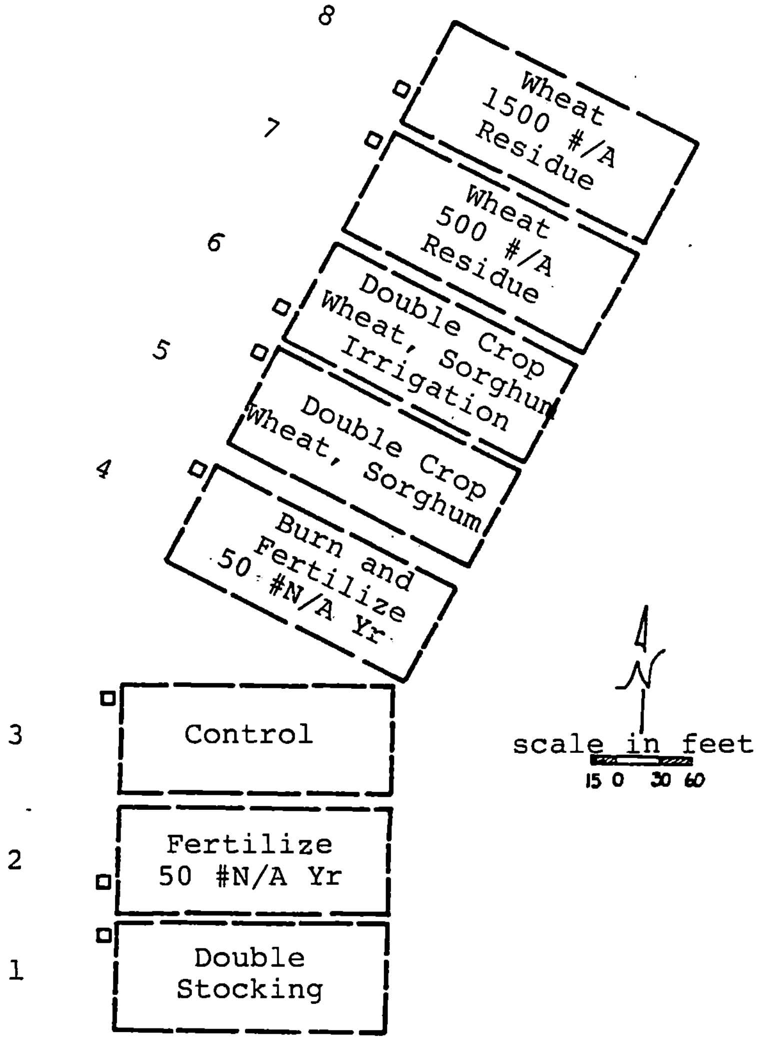

Figure 1. The Experimental Layout

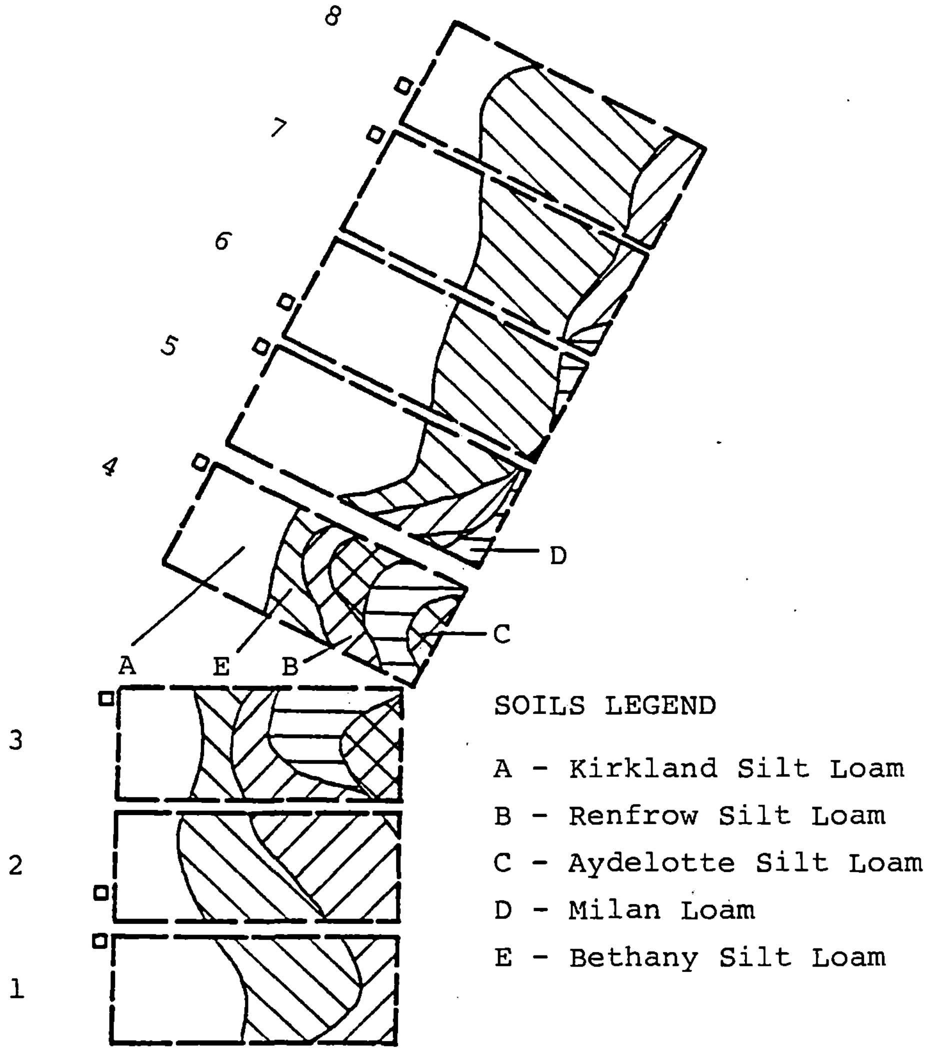

Figure 2. The Distribution of the Various Soils in the Eight Experimental Watersheds at the Water Quality Research Watershed - El Reno, Oklahoma

generally consist of nearly level to gently sloping soils on uplands, and they are characterized by well drained, to very slow to moderately slow permeability and high available water capacity. The classification and the profile descriptions of these soils are presented in the appendix.

A composite soil sample from the A horizon and a composite soil sample from the B horizon for every soil in each watershed was collected in the summer of 1981. The soil samples were air dried, crushed by hand and ground. All foreign materials, such as plant roots were removed by passing soil samples through a 20 mesh sieve. The samples were placed in paper one quart cartons for storage.

## Soil Properties

### Physical Properties

Mechanical Analysis. The hydrometer method as described by Bouyoucous (1951) was used to determine the particle size distribution, and thus the textural class of the soils was determined.

### Chemical Properties

A. Soil Reaction. The soil pH measured in water was determined as described by Peech (1964)

> A Corning model 7 pH - meter with a calomel electrode was used. The procedure involves the mixing of 20 gm of soil sample with distilled water in a 1:1 ratio. To obtain a pH that reflects a more intrinsic characteristic of the soil than the pH values measured in water, some workers (Puri and Asghar, 1938) suggested the use

of 1 N KCl. A 20 ml of a 1 N KCl solution was added to the soil - water suspension, the mixture was allowed to stand for several hours and the pH was taken.

B. Other Chemical Properties. A 1:1 soil-water extract was obtained by extracting a 100 gm soil sample with 100 ml of distilled water. This soil water extract was used to determine the following chemical properties:

1. Electrical Conductivity (EC):

This was measured directly by means of an EC-meter as described by Richards et al. (1954).

2. Total Dissolved Solids (TDS):

Place 5 ml of the 1:1 soil-water extract in a weighed aluminum evaporation pan, oven dry (100 °C). Then place in a dessicator to cool, reweigh. Determine the weight of salts deposited in gm and ppm.

3. Water - Soluble Cations:

a. Calcium ($Ca^{++}$):

Take 8 ml of the 1:1 soil-water extract, and then add 2 ml of $LaCl_3$ 5%. The ppm of water soluble Ca was determined by using atomic absorption technique with a Model 403 Perkin Elmer Atomic Absorption Spectrophotometer.

b. Magnesium ($Mg^{++}$):

For Mg the same samples and the same techniques were used as for Ca.

c. Sodium ($Na^+$):

Place 5 ml of the 1:1 soil-water extract in a test tube. Read ppm of water soluble Na using the atomic absorption technique.

d. Potassium ($K^+$):

For K the same samples and the same technique were used as for Na.

C. Ammonium Acetate ($NH_4OAc$) Exchangeable Cations. The cations that were determined are: $Ca^{++}$, $Mg^{++}$, $Na^+$, and $K^+$. The procedure involves the extraction of 20 gm of air dried soil samples with 200 ml of 1 N ammonium acetate. The ppm of these exchangeable cations were determined as were used for the water-soluble cations.

D. Cation Exchange Capacity (CEC). The method used to determine CEC was described by Reed (1974). Twenty gm of air dried soil are shaken with 150 ml of 1 N $CaCl_2$. The mixture is filtered through Whatman No. 2 filter paper with slow suction. This is followed by rinsing the soil sample with distilled water to remove excess salts. The leachate is discarded. Finally, the soil sample is leached with three portions of 1 N $NaNO_3$ solution (50 ml each). The leachate is brought to 200 ml final volume by adding distilled water. The $NaNO_3$ leachate is analyzed for $Ca^{++}$ by EDTA titration, and Cl by Mohr titration.

E. Organic Matter Percent. A modified potassium dichromate oxidation method suggested by Schollenberger

(1931) for the determination of organic matter content of soils was used. The method includes the use of 0.5 gm air dried soil sample (pass through 60 mesh sieve), followed by adding 10 ml of 0.4 N potassium dichromate ($K_2Cr_2O_7$), and 15 ml of concentrated sulfuric acid ($H_2SO_4$). Heat the mixture slowly to 161 °C. Cool, and then add 100 to 125 ml of distilled water, 2 drops of indicator and titrate excess dichromate with 0.2 N ferrous ammonium sulfate solution (0.2 N $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$)

F. Total Phosphorus (TP). Total P was determined by perchloric acid digestion as outlined by Shelton and Harper (1941). The procedure provides elimination of silica without evaporating a solution to dryness, and safe destruction of organic matter in the average soil or plant material without loss of P by volatilization, thus a complete recovery of P will be obtained. The molybdenum blue color was developed by utilizing hydrazine sulfate as a reducing agent. A Brinkman dipping probe colorimeter was then utilized to measure color intensity at 840 nm. The intensity of color is proportional to the quantity of P in the solution.

G. Total Elements. The perchloric acid ($HClO_4$) extracts were analyzed for total $Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$, $Zn^{++}$, $Mn^{++}$, $Cu^{++}$ and $Fe^{++}$ on the Perkin Elmer Model 403 Absorption spectrophotometer.

H. Soil Test Phosphorus. The No. 1 method of Bray and Kurtz (1945), (20:1) was used for the determination of this form of P.

I. Total Kjeldahl Nitrogen (TKN). This was determined by the micro-kjeldhal procedure. This procedure involves two steps: 1. digestion of the sample, to convert the N to ammonia, by digesting the sample with concentrated sulfuric acid ($H_2SO_4$) in the presence of $K_2SO_4$ and $CuSo_4$ which increases the temperature of digestion, and Se metal as a catalyst to increase the rate of oxidation of organic matter by $H_2SO_4$; 2. determination of the ammonium in the digest by distillation from a basic solution and back titration with a standard acid.

## Mineralogical Properties

The clay mineralogy of the five soil series of the eight watersheds was carried out as outlined by Jackson (1956). The procedure includes:

a. Separation of clay fractions from sand and silt fractions by utilizing Stoke's Law which relates sedimentation rate of the various soil separates to their effective radii.
b. Separation of coarse clay fractions (2 - 0.08 microns) and fine clay fractions (<0.08 microns) by utilizing the Sharples Supercentrifuge.
c. Saturation of exchange complex and solvation

with ethylene glycol for coarse and fine clay fractions as follows:

i. Ca-saturated
ii. Ca-saturated ethylene glycol solvated
iii. K-saturated
iv. K-saturated and heat (500 °C) for 4 hours

d. Samples were mounted on glass slides, and the x-ray diffraction method techniques were utilized to identify the clay minerals of these soils. A one degree slit system, a rate-meter scale factor of two and a time constant of one microsecond were employed. The gas proportional counter was operated at 200 V over threshold. The scanning speed of the goniometer was set at $2^{\circ}$ $2\theta$ per minute, with an accompanying chart speed set so that $2\theta$ per chart division was recorded.

### Runoff and Sediment Load Data

The amount of runoff in cm and the amount of sediment in kg/ha for all watersheds were recorded following rainstorm events for the period 1977-1981. The samples of runoff were compared with the runoff hydrograph and composited in proportion to total flow to provide a single representative sample of liquid and sediment for chemical analysis. The chemical analysis including the concentrations of various forms of N and P in liquid runoff and sediment was performed at the USDA laboratory in Durant, Oklahoma as described by Olness et al. (1975).

Since no replications of treatments were included in this study, the within watersheds variations were used as the error term to make comparisons between the various physical and chemical properties of the soils in these watersheds. Also, the relationships between the various runoff characteristics of every watershed averaged over five years, and the physical and chemical properties averaged over soils were studied by utilizing simple correlation and regression analyses.

# CHAPTER IV

# RESULTS AND DISCUSSION

## Physical Properties of the Soils

Table I shows the particle size distribution and the textural classification of the A and the B horizons of the five soils occurring on the eight watersheds. The sand percentage is generally higher in the A horizon as compared to its percentage in the B horizon. The change in sand percentage ranged from 2-4%. However, a wider range was observed in a few samples. The highest sand percentage in the A horizon (54.8%), and in the B horizon (52.8%) was found in the Milan series; while the lowest sand percentage in the A horizon (22.8%), and in the B horizon (22.4%) was found in the Kirkland series.

The analysis of variance (AOV) showed a significant difference in the sand percentage of the A and the B horizons of all soils. The statistical analysis has also revealed that the sand percentage of Kirkland is significantly different from its percentage in Milan, Aydellote, and Renfrow. Furthermore, it was concluded that the differences between the sand percent in Milan and Aydellote were not significant at the 0.05 level of probability.

# TABLE I

## PARTICLE SIZE ANALYSIS AND TEXTURAL CLASSIFICATION DATA FOR BETHANY, KIRKLAND, RENFROW, MILAN, AND AYDELLOTE

| No. | Soil | Depth* | Sand | Silt | Clay | Texture |
|---|---|---|---|---|---|---|
| | | --cm-- | --------- | % | ------- | |
| | | | Watershed FR1 | | | |
| 1 | Kirkland | 0-30 | 28.4 | 58.0 | 13.6 | Silt loam |
| 2 | Kirkland | 30-46 | 30.4 | 48.0 | 21.6 | Loam, silt loam |
| 3 | Renfrow | 0-23 | 36.4 | 54.0 | 9.6 | Silt loam |
| 4 | Renfrow | 23-33 | 34.4 | 50.0 | 15.6 | Silt loam, loam |
| 5 | Bethany | 0-15 | 30.4 | 56.0 | 13.6 | Silt loam |
| 6 | Bethany | 15-33 | 30.4 | 52.0 | 17.6 | Silt loam |
| | | | Watershed FR2 | | | |
| 7 | Kirkland | 0-30 | 30.4 | 54.0 | 15.6 | Silt loam |
| 8 | Kirkland | 30-46 | 22.4 | 46.0 | 31.6 | Clay loam |
| 9 | Renfrow | 0-23 | 34.4 | 56.0 | 9.6 | Silt loam |
| 10 | Renfrow | 23-33 | 30.4 | 52.0 | 17.6 | Silt loam |
| 11 | Bethany | 0-15 | 32.8 | 54.0 | 13.2 | Silt loam |
| 12 | Bethany | 15-33 | 30.8 | 48.0 | 21.2 | Loam, silt loam |
| | | | Watershed FR3 | | | |
| 13 | Kirkland | 0-30 | 28.8 | 54.0 | 17.2 | Silt loam |
| 14 | Kirkland | 30-46 | 24.8 | 52.0 | 23.2 | Silt loam |
| 15 | Renfrow | 0-23 | 50.8 | 38.0 | 11.2 | Loam |
| 16 | Renfrow | 23-33 | 46.8 | 34.0 | 19.2 | Loam |

TABLE I (Continued)

| No. | Soil | Depth* | Sand | Silt | Clay | Texture |
|---|---|---|---|---|---|---|
| | | --cm-- | | --------%------- | | |
| 17 | Aydellote | 0-18 | 46.8 | 42.0 | 11.2 | Loam |
| 18 | Aydellote | 18-28 | 34.8 | 40.0 | 25.2 | Loam |
| 19 | Milan | 0-18 | 54.8 | 28.0 | 17.2 | Sandy loam |
| 20 | Milan | 18-33 | 52.8 | 36.0 | 11.2 | Sandy loam |
| 21 | Bethany | 0-15 | 42.8 | 46.0 | 11.2 | Loam |
| 22 | Bethany | 15-33 | 32.8 | 48.0 | 19.2 | Loam, silt loam |
| | | | | Watershed FR4 | | |
| 23 | Kirkland | 0-30 | 34.8 | 52.0 | 13.2 | Silt loam |
| 24 | Kirkland | 30-46 | 28.8 | 50.0 | 21.2 | Silt loam |
| 25 | Renfrow | 0-23 | 48.8 | 42.0 | 9.2 | Loam |
| 26 | Renfrow | 23-36 | 44.8 | 40.0 | 15.2 | Loam |
| 27 | Aydellote | 0-18 | 52.8 | 40.0 | 7.2 | Loam |
| 28 | Aydellote | 18-36 | 50.8 | 36.0 | 13.2 | Loam |
| 29 | Milan | 0-18 | 48.8 | 42.0 | 9.2 | Loam |
| 30 | Milan | 18-33 | 44.8 | 38.0 | 17.2 | Loam |
| 31 | Bethany | 0-15 | 44.8 | 48.0 | 7.2 | Loam, silt loam |
| 32 | Bethany | 15-33 | 34.8 | 52.0 | 13.2 | Silt loam |
| | | | | Watershed FR5 | | |
| 33 | Kirkland | 0-30 | 22.8 | 56.0 | 21.2 | Silt loam |
| 34 | Kirkland | 30-46 | 22.8 | 52.0 | 25.2 | Silt loam |
| 35 | Renfrow | 0-20 | 38.8 | 50.0 | 11.2 | Silt loam |
| 36 | Renfrow | 20-40 | 34.8 | 50.0 | 15.2 | Silt loam |

TABLE I (Continued)

| No. | Soil | Depth* | Sand | Silt | Clay | Texture |
|---|---|---|---|---|---|---|
| | | --cm-- | --------- | % | ------- | |
| 37 | Bethany | 0-15 | 30.8 | 56.0 | 13.2 | Silt loam |
| 38 | Bethany | 15-40 | 28.8 | 54.0 | 17.2 | Silt loam |
| | | | Watershed FR6 | | | |
| 39 | Kirkland | 0-30 | 36.8 | 42.0 | 21.2 | Loam |
| 40 | Kirkland | 30-46 | 22.8 | 46.0 | 31.2 | Clay loam |
| 41 | Milan | 0-18 | 50.8 | 42.0 | 7.2 | Loam |
| 42 | Milan | 18-33 | 44.8 | 48.0 | 7.2 | Loam |
| 43 | Bethany | 0-15 | 24.8 | 62.0 | 13.2 | Silt loam |
| 44 | Bethany | 15-40 | 22.8 | 58.0 | 19.2 | Silt loam |
| | | | Watershed FR7 | | | |
| 45 | Kirkland | 0-30 | 30.8 | 54.0 | 15.2 | Silt loam |
| 46 | Kirkland | 30-46 | 24.8 | 44.0 | 31.2 | Clay loam |
| 47 | Renfrow | 0-23 | 34.8 | 54.0 | 11.2 | Silt loam |
| 48 | Renfrow | 23-40 | 30.8 | 50.0 | 19.2 | Silt loam |
| 49 | Milan | 0-18 | 50.8 | 40.0 | 9.2 | Loam |
| 50 | Milan | 18-40 | 50.8 | 42.0 | 7.2 | Loam |
| 51 | Bethany | 0-15 | 32.8 | 58.0 | 9.2 | Silt loam |
| 52 | Bethany | 15-40 | 28.8 | 58.0 | 13.2 | Silt loam |
| | | | Watershed FR8 | | | |
| 53 | Kirkland | 0-25 | 28.8 | 56.0 | 15.2 | Silt loam |
| 54 | Kirkland | 25-40 | 24.8 | 52.0 | 23.2 | Silt loam |

TABLE I (Continued)

| No. | Soil | Depth* | Sand | Silt | Clay | Texture |
|---|---|---|---|---|---|---|
| | | --cm-- | | --------%------- | | |
| 55 | Renfrow | 0-23 | 32.8 | 54.0 | 13.2 | Silt loam |
| 56 | Renfrow | 23-38 | 28.8 | 54.0 | 17.2 | Silt loam |
| 57 | Bethany | 0-15 | 26.8 | 62.0 | 11.2 | Silt loam |
| 58 | Bethany | 15-40 | 30.8 | 56.0 | 13.2 | Silt loam |

*First Depth - A Horizon.
Second Depth - B Horizon.

The silt distribution in the A and the B horizons of the soils under investigation showed a similar trend to that observed for sand. However, the silt percent was generally highest in the Bethany series, followed by the Kirkland series. The lowest silt percent in the A horizon (28%) and in the B horizon (34%) was found in the Milan series and Renfrow series, respectively.

The higher silt percentages of the soils at downslope indicates an active siltation process, in spite of the relatively mild slope in these watersheds (3-4%). The movement of silt is also suggested by the lower percentages of silt in the A horizon of Milan soil as compared to its silt content in the B horizon. This is in contrast to sand percent, which decreased downslope.

The AOV indicated a significant difference in silt percent with depth and between soils. Further statistical analysis showed that the differences between the silt percent found in Aydellote and Milan soils, and between the silt percent found in Kirkland and Bethany soils, were not significant at the 0.05 level of probability. However, it was concluded that Milan and Aydellote soils were significantly different from Bethany, Kirkland, and Renfrow soils.

The percent of clay in Kirkland, Renfrow, Aydellote, and Bethany increased substantially in the B horizon. This higher clay accumulation in the B horizon can be attributed to the process of eluviation. However, the mechanical analysis of the Milan soil samples indicated no change or a decrease in clay percent from A to B horizon. This reversed pattern may be attributed to a lesser eluviation and/or to the movement of clay with runoff water from the adjacent fields, which increased its percentage in the A horizon.

The AOV for the variable clay indicated a significant effect due to an interaction between soils and depths. Therefore, the differences among soils for each depth were analyzed. This was done by obtaining an LSD between two soils at the same depth.

The statistical analysis of the data shows there was a significant difference in the clay percent in the A and the B horizons of Kirkland soils as compared to the other four soils. However, the AOV revealed that the differences in the clay percent of the A horizon of Aydellote, Bethany, Milan, and Renfrow were not significant at the 0.05 level of probability. Furthermore, it was found that the clay percent of Milan soil in the B horizon was significantly different from the clay percent in the B horizons of Aydellote and Renfrow soils.

The increase in silt and clay percent downslope demonstrates the selectivity of the erosion process with water, which apparently favors the removal of colloidal size particles. This is in agreement with the findings of Romkens et al. (1975).

## Chemical Properties of the Soils

The reaction of the soils in the eight watersheds is acidic. Although, the results presented in Table II (a-h) indicate that the soil pH measured in water has, generally, not changed drastically from the A to the B horizon; this change in pH was found statistically significant at the 0.05 level of probability. The pH of the soil samples measured in 1N KCL solution is lower than the pH measured in water solution. It was typically lower by 0.3-0.9 units. This is in agreement with the findings of Richards et al. (1954). In contrast to the soil pH measured in water, the change in the soil pH measured in 1N KCL was found not to be significant with depth.

The AOV showed that the pH measured in water and in the salt solutions, for the five soils, was not significantly different at the same level of probability.

The electrical conductivity (EC) of the saturation extract, as a measure of soluble salts, of the 5 soil series is low (Table II, a-h). The EC of the soils in watersheds FR 1, 2, 3, 4, and 7 generally decreased with depth. However, a general increasing trend in EC from the A to the B horizon was observed in the soils of watersheds FR 5, 6, and 8. The highest EC was found for the soils in watersheds FR 1 and 4.

The EC of all soils has not changed significantly from the A to the B horizons. Also, no significant differences in the EC between soils were found at the 0.05 level of

## TABLE IIa

## SOIL CHEMICAL ANALYSES: WATERSHED FR1

| | | Depth | pH | | Total Disolved Salts | EC | Water soluble cations, ppm | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Soil | cm | $a_1$* | $a_2$** | TDS/ ppm | umhos/ cm | $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
| 1 | Kirkland | 0-30 | 5.8 | 5.2 | 1478 | 550 | 5.8 | 15.5 | 64.2 | 27.2 |
| 2 | Kirkland | 30-46 | 5.6 | 5.1 | 1080 | 550 | 16.4 | 7.2 | 48.7 | 27.1 |
| 3 | Renfrow | 0-23 | 5.4 | 5.3 | 1884 | 610 | 6.7 | 17.0 | 78.7 | 29.2 |
| 4 | Renfrow | 23-33 | 5.5 | 5.2 | 1326 | 550 | 9.0 | 7.5 | 63.2 | 26.6 |
| 5 | Bethany | 0-15 | 5.3 | 5.1 | 1982 | 600 | 4.5 | 28.6 | 73.7 | 28.5 |
| 6 | Bethany | 15-33 | 5.3 | 5.0 | 1320 | 480 | 7.1 | 15.5 | 53.7 | 23.7 |

# TABLE IIb

## SOIL CHEMICAL ANALYSES: WATERSHED FR2

| No. | Soil | Depth cm | pH $a_1$* | pH $a_2$** | Total Disolved Salts TDS/ ppm | EC umhos/ cm | Water soluble cations, ppm $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Kirkland | 0-30 | 5.9 | 5.6 | 442 | 300 | 6.6 | 6.7 | 30.0 | 12.0 |
| 8 | Kirkland | 30-46 | 5.7 | 5.1 | 198 | 130 | 10.3 | 1.4 | 10.0 | 4.4 |
| 9 | Renfrow | 0-23 | 5.4 | 5.0 | 456 | 250 | 2.9 | 27.4 | 22.5 | 7.6 |
| 10 | Renfrow | 23-33 | 5.8 | 5.5 | 276 | 210 | 5.0 | 14.1 | 21.9 | 8.6 |
| 11 | Bethany | 0-15 | 5.9 | 5.4 | 456 | 350 | 4.3 | 25.5 | 30.6 | 12.0 |
| 12 | Bethany | 15-33 | 6.2 | 5.7 | 360 | 280 | 8.3 | 11.7 | 26.4 | 10.7 |

## TABLE IIc

## SOIL CHEMICAL ANALYSES: WATERSHED FR3

| No. | Soil | Depth cm | pH $a_1$* | pH $a_2$** | Total Disolved Salts TDS/ ppm | EC umhos/ cm | Water soluble cations, ppm $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Kirkland | 0-30 | 6.3 | 5.5 | 356 | 270 | 3.7 | 14.0 | 28.1 | 12.6 |
| 14 | Kirkland | 30-46 | 6.0 | 5.4 | 234 | 140 | 9.1 | 1.8 | 12.8 | 6.0 |
| 15 | Renfrow | 0-23 | 5.8 | 5.5 | 620 | 220 | 4.2 | 5.9 | 28.3 | 11.4 |
| 16 | Renfrow | 23-33 | 5.8 | 5.3 | 172 | 130 | 7.7 | 1.7 | 10.9 | 5.1 |
| 17 | Aydelotte | 0-18 | 5.8 | 5.5 | 348 | 220 | 2.3 | 14.3 | 26.5 | 9.4 |
| 18 | Aydelotte | 18-28 | 5.9 | 5.1 | 124 | 130 | 2.5 | 3.4 | 14.4 | 5.9 |
| 19 | Milan | 0-18 | 5.8 | 5.3 | 374 | 240 | 1.6 | 15.9 | 26.6 | 8.4 |
| 20 | Milan | 18-33 | 5.8 | 5.1 | 340 | 180 | 2.0 | 5.2 | 22.4 | 7.5 |
| 21 | Bethany | 0-15 | 5.8 | 5.2 | 402 | 270 | 2.6 | 46.7 | 26.0 | 9.1 |
| 22 | Bethany | 15-33 | 5.4 | 4.7 | 260 | 130 | 2.9 | 7.4 | 13.1 | 4.3 |

## TABLE IId

## SOIL CHEMICAL ANALYSES: WATERSHED FR4

| No. | Soil | Depth cm | pH | | Total Disolved Salts TDS/ ppm | EC umhos/ cm | Water soluble cations, ppm | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $a_1^*$ | $a_2^{**}$ | | | $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
| 23 | Kirkland | 0-30 | 5.5 | 5.2 | 1608 | 570 | 6.1 | 20.8 | 73.4 | 29.0 |
| 24 | Kirkland | 30-46 | 5.6 | 5.0 | 1012 | 450 | 15.7 | 9.2 | 44.9 | 23.0 |
| 25 | Renfrow | 0-23 | 5.5 | 5.1 | 1700 | 490 | 3.7 | 23.8 | 55.0 | 25.0 |
| 26 | Renfrow | 23-36 | 5.5 | 4.9 | 1458 | 520 | 7.2 | 13.7 | 57.5 | 29.0 |
| 27 | Aydellote | 0-18 | 5.3 | 5.1 | 1822 | 520 | 2.8 | 25.8 | 69.0 | 23.0 |
| 28 | Aydellote | 18-36 | 5.5 | 5.0 | 1248 | 410 | 4.6 | 11.3 | 53.6 | 17.0 |
| 29 | Milan | 0-18 | 5.5 | 5.0 | 1550 | 440 | 3.8 | 28.0 | 59.0 | 22.0 |
| 30 | Milan | 18-33 | 5.6 | 5.3 | 1208 | 420 | 8.4 | 28.1 | 47.0 | 21.0 |
| 31 | Bethany | 0-15 | 5.5 | 5.1 | 2158 | 600 | 4.4 | 29.7 | 76.0 | 31.0 |
| 32 | Bethany | 15-33 | 5.6 | 5.0 | 1640 | 560 | 8.8 | 14.8 | 65.0 | 31.0 |

## TABLE IIe

## SOIL CHEMICAL ANALYSES: WATERSHED FR5

| No. | Soil | Depth cm | pH $a_1^*$ | pH $a_2^{**}$ | Total Disolved Salts TDS/ ppm | EC umhos/ cm | Water soluble cations, ppm $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 33 | Kirkland | 0-30 | 6.0 | 5.3 | 296 | 290 | 5.4 | 12.6 | 26.2 | 10.5 |
| 34 | Kirkland | 30-46 | 6.0 | 5.5 | 306 | 560 | 20.3 | 8.6 | 42.7 | 21.3 |
| 35 | Renfrow | 0-20 | 5.8 | 5.0 | 278 | 220 | 2.0 | 29.3 | 18.6 | 5.4 |
| 36 | Renfrow | 20-40 | 6.1 | 5.4 | 214 | 180 | 2.3 | 13.5 | 17.7 | 5.5 |
| 37 | Bethany | 0-15 | 5.6 | 5.1 | 422 | 210 | 2.8 | 17.9 | 21.6 | 6.9 |
| 38 | Bethany | 15-40 | 5.8 | 5.2 | 360 | 460 | 7.7 | 10.8 | 47.5 | 17.6 |

## TABLE IIf

## SOIL CHEMICAL ANALYSES: WATERSHED FR6

| No. | Soil | Depth cm | pH $a_1$* | pH $a_2$** | Total Disolved Salts TDS/ ppm | EC umhos/ cm | Water soluble cations, ppm $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 39 | Kirkland | 0-30 | 6.1 | 5.4 | 230 | 250 | 4.5 | 16.5 | 25.5 | 10.1 |
| 40 | Kirkland | 30-46 | 6.1 | 5.3 | 326 | 550 | 23.4 | 13.8 | 44.4 | 20.7 |
| 41 | Milan | 0-18 | 6.0 | 5.5 | 880 | 400 | 1.8 | 53.5 | 52.5 | 11.4 |
| 42 | Milan | 18-33 | 6.9 | 6.5 | 708 | 390 | 3.6 | 21.3 | 57.5 | 16.4 |
| 43 | Bethany | 0-15 | 5.7 | 5.1 | 460 | 170 | 2.4 | 24.4 | 18.5 | 5.7 |
| 44 | Bethany | 15-40 | 6.1 | 5.3 | 290 | 230 | 4.7 | 6.2 | 24.5 | 9.4 |

## TABLE IIg

## SOIL CHEMICAL ANALYSES: WATERSHED FR7

| No. | Soil | Depth cm | pH $a_1^*$ | pH $a_2^{**}$ | Total Disolved Salts TDS/ ppm | EC umhos/ cm | Water soluble cations, ppm $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 45 | Kirkland | 0-30 | 5.9 | 5.3 | 390 | 270 | 3.6 | 15.8 | 27.1 | 10.9 |
| 46 | Kirkland | 30-46 | 6.3 | 5.4 | 212 | 220 | 14.5 | 5.4 | 18.2 | 8.6 |
| 47 | Renfrow | 0-23 | 6.0 | 5.2 | 400 | 210 | 2.3 | 19.6 | 19.7 | 7.5 |
| 48 | Renfrow | 23-40 | 6.2 | 5.4 | 270 | 240 | 4.6 | 15.6 | 22.2 | 9.2 |
| 49 | Milan | 0-18 | 5.7 | 5.1 | 640 | 250 | 2.6 | 27.8 | 36.7 | 9.9 |
| 50 | Milan | 18-40 | 6.3 | 5.8 | 494 | 210 | 3.4 | 15.7 | 28.0 | 9.0 |
| 51 | Bethany | 0-15 | 5.6 | 5.0 | 502 | 270 | 2.9 | 20.8 | 27.0 | 10.1 |
| 52 | Bethany | 15-40 | 5.7 | 5.2 | 592 | 540 | 7.2 | 13.5 | 53.4 | 23.4 |

## TABLE IIh

## SOIL CHEMICAL ANALYSES: WATERSHED FR8

| No. | Soil | Depth cm | pH $a_1$* | pH $a_2$** | Total Disolved Salts TDS/ ppm | EC umhos/ cm | Water soluble cations, ppm $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 53 | Kirkland | 0-25 | 5.8 | 5.2 | 280 | 240 | 4.9 | 9.4 | 23.2 | 9.0 |
| 54 | Kirkland | 25-40 | 6.0 | 5.4 | 352 | 450 | 16.2 | 4.8 | 38.5 | 18.2 |
| 55 | Renfrow | 0-23 | 5.8 | 5.1 | 380 | 180 | 2.7 | 10.6 | 20.4 | 7.1 |
| 56 | Renfrow | 23-38 | 6.0 | 5.4 | 458 | 290 | 4.5 | 7.5 | 31.4 | 12.1 |
| 57 | Bethany | 0-15 | 5.6 | 5.0 | 528 | 180 | 2.5 | 6.9 | 23.5 | 8.1 |
| 58 | Bethany | 15-40 | 5.8 | 5.1 | 426 | 230 | 5.6 | 5.7 | 25.6 | 9.7 |

*$a_1$ = soil pH measured in water solution.

**$a_2$ = soil pH measured in KCl solution.

probability.

As expected, the total dissolved salts (TDS), expressed in ppm, had a similar distribution pattern as for EC. However, the statistical analysis indicated a significant difference in TDS of all soils with depth. On the other hand, the TDS found in these soils were not significantly different at the 0.05 level of probability.

The water extractable cations (Na, K, Ca, and Mg) concentrations, expressed in ppm, are presented in Table II (a-h).

The water extractable Na showed an increasing distribution trend with depth. This might be attributed to its high mobility.

The AOV for water extractable Na indicated a significant effect due to interaction between soils and depths. It was concluded that the differences in the Na concentrations in the A horizon of the five soil series were not significant. However, comparing the concentrations of water extractable Na in the B horizons of these soils indicated a higher concentration of this element in Kirkland, as compared to the other four soils. This difference was found significant at the 0.05 level of probability.

The water extractable K, on the other hand, decreased with depth and was consistent with the exchangeable K. The water extractable K has varied significantly from the A to the B horizon. The AOV also indicated a significant difference in the concentrations of this form of K found in Kirkland soil as compared to Milan and Bethany. However, no significant differences were detected in the amounts of the water extractable K between Milan, Bethany, and Aydellote.

The data in Table II (a-h) indicate that the water extractable Ca and Mg concentrations generally decreased from the A to the B horizon. However, the soils in watersheds FR 5, 6, and 8 have generally shown an increase in the concentrations of these cations with depth.

The statistical analysis for both cations has indicated no significant difference in their concentrations with depth. Also, no significant difference was found in the concentration of water extractable Ca and Mg between the five soil series.

The exchangeable cation composition of the five soil series occurring on the different watersheds is presented in Table III (a-h).

The exchangeable Na has generally demonstrated an increase in concentration with depth. The exchangeable Na content of these soils is low and comprises a small fraction of the CEC of these soils.

The AOV for the exchangeable Na indicated a significant effect due to interaction between soils and depths. It was concluded that the exchangeable Na concentrations in the A horizons of all soils were not significant at the 0.05 level of probability. However, at the B horizon, the exchangeable Na concentration of Kirkland soil was found to be

## TABLE IIIa

## SOIL CHEMICAL ANALYSES: WATERSHED FR1

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | CEC meq/ 100g |
| 1 | Kirkland | 0-30 | 17 | .0739 | 265 | .679 | 2019 | 10.095 | 426 | 3.55 | 14.90 |
| 2 | Kirkland | 30-46 | 40 | .1739 | 207 | .531 | 2096 | 10.48 | 612 | 5.10 | 16.92 |
| 3 | Renfrow | 0-23 | 25 | .1087 | 246 | .631 | 1752 | 8.76 | 350 | 2.917 | 12.97 |
| 4 | Renfrow | 23-33 | 30 | .1304 | 192 | .492 | 1891 | 9.455 | 444 | 3.70 | 13.92 |
| 5 | Bethany | 0-15 | 25 | .1087 | 333 | .854 | 1716 | 8.58 | 337 | 2.808 | 14.07 |
| 6 | Bethany | 15-33 | 28 | .1217 | 305 | .782 | 1800 | 9.00 | 434 | 3.617 | 13.67 |

## TABLE IIIb

## SOIL CHEMICAL ANALYSES: WATERSHED FR2

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | CEC |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | meq/ 100g |
| 7 | Kirkland | 0-30 | 33 | .1435 | 217 | .5564 | 2096 | 10.48 | 500 | 4.17 | 15.69 |
| 8 | Kirkland | 30-46 | 57 | .2478 | 216 | .5538 | 2261 | 11.30 | 650 | 5.42 | 17.50 |
| 9 | Renfrow | 0-23 | 20 | .0869 | 515 | 1.3205 | 1655 | 8.27 | 332 | 2.77 | 12.48 |
| 10 | Renfrow | 23-33 | 21 | .0913 | 368 | .9436 | 1844 | 9.22 | 467 | 3.89 | 14.80 |
| 11 | Bethany | 0-15 | 26 | .1130 | 410 | 1.0513 | 1922 | 9.61 | 382 | 3.18 | 14.45 |
| 12 | Bethany | 15-33 | 35 | .1522 | 345 | .8846 | 2204 | 11.02 | 522 | 4.35 | 17.30 |

## TABLE IIIc

## SOIL CHEMICAL ANALYSES: WATERSHED FR3

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | CEC meq/ 100g |
| 13 | Kirkland | 0-30 | 18 | .078 | 319 | .818 | 1872 | 9.36 | 446 | 3.717 | 14.80 |
| 14 | Kirkland | 30-46 | 41 | .178 | 199 | .510 | 2111 | 10.55 | 735 | 6.125 | 17.91 |
| 15 | Renfrow | 0-23 | 24 | .104 | 141 | .361 | 1312 | 6.56 | 304 | 2.533 | 9.67 |
| 16 | Renfrow | 23-33 | 32 | .139 | 107 | .274 | 1552 | 7.76 | 472 | 3.933 | 12.28 |
| 17 | Aydellote | 0-18 | 16 | .069 | 258 | .661 | 1694 | 8.47 | 366 | 3.050 | 12.31 |
| 18 | Aydellote | 18-28 | 27 | .117 | 208 | .533 | 2010 | 10.05 | 527 | 4.392 | 15.32 |
| 19 | Milan | 0-18 | 13 | .056 | 235 | .602 | 1406 | 7.03 | 254 | 2.117 | 10.16 |
| 20 | Milan | 18-33 | 14 | .061 | 190 | .487 | 1746 | 8.73 | 390 | 3.25 | 12.95 |
| 21 | Bethany | 0-15 | 29 | .126 | 366 | .938 | 1697 | 8.48 | 322 | 2.683 | 12.99 |
| 22 | Bethany | 15-33 | 19 | .083 | 267 | .685 | 1755 | 8.77 | 407 | 3.392 | 13.00 |

# TABLE IIId

## SOIL CHEMICAL ANALYSES: WATERSHED FR4

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | CEC |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | meq/ 100g |
| 23 | Kirkland | 0-30 | 25 | .109 | 275 | .705 | 1944 | 9.72 | 417 | 3.475 | 14.10 |
| 24 | Kirkland | 30-46 | 41 | .178 | 220 | .564 | 2010 | 10.05 | 667 | 5.558 | 16.76 |
| 25 | Renfrow | 0-23 | 15 | .065 | 278 | .713 | 1471 | 7.355 | 345 | 2.875 | 11.90 |
| 26 | Renfrow | 23-36 | 19 | .083 | 216 | .554 | 1511 | 7.555 | 442 | 3.683 | 12.04 |
| 27 | Aydellote | 0-18 | 22 | .096 | 245 | .628 | 1400 | 7.00 | 239 | 1.992 | 10.07 |
| 28 | Aydellote | 18-36 | 22 | .096 | 162 | .415 | 1469 | 7.345 | 289 | 2.408 | 10.95 |
| 29 | Milan | 0-18 | 21 | .091 | 269 | .690 | 1419 | 7.095 | 294 | 2.450 | 10.68 |
| 30 | Milan | 18-33 | 22 | .096 | 257 | .659 | 1435 | 7.175 | 390 | 3.250 | 12.36 |
| 31 | Bethany | 0-15 | 21 | .091 | 318 | .815 | 1672 | 8.36 | 375 | 3.125 | 14.22 |
| 32 | Bethany | 15-33 | 25 | .109 | 248 | .636 | 1701 | 8.50 | 487 | 4.058 | 14.30 |

## TABLE IIIe

## SOIL CHEMICAL ANALYSES: WATERSHED FR5

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | CEC |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | meq/ 100g |
| 33 | Kirkland | 0-30 | 27 | .117 | 278 | .713 | 1935 | 9.67 | 426 | 3.55 | 14.10 |
| 34 | Kirkland | 30-46 | 47 | .204 | 218 | .559 | 2047 | 10.23 | 682 | 5.68 | 17.46 |
| 35 | Renfrow | 0-20 | 13 | .056 | 394 | 1.010 | 1372 | 6.86 | 227 | 1.89 | 10.83 |
| 36 | Renfrow | 20-40 | 14 | .069 | 278 | .713 | 1452 | 7.26 | 285 | 2.37 | 11.43 |
| 37 | Bethany | 0-15 | 28 | .122 | 338 | .867 | 1636 | 8.18 | 312 | 2.60 | 11.81 |
| 38 | Bethany | 15-40 | 34 | .148 | 228 | .585 | 1854 | 9.27 | 397 | 3.31 | 13.32 |

## TABLE IIIf

## SOIL CHEMICAL ANALYSES: WATERSHED FR6

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | CEC meq/ 100g |
| 39 | Kirkland | 0-30 | 36 | .156 | 256 | .656 | 2071 | 10.355 | 474 | 3.95 | 15.87 |
| 40 | Kirkland | 30-46 | 76 | .330 | 258 | .661 | 2549 | 12.745 | 280 | 2.33 | 17.41 |
| 41 | Milan | 0-18 | 25 | .109 | 735 | 1.885 | 2591 | 12.955 | 305 | 2.542 | 17.61 |
| 42 | Milan | 18-33 | 39 | .169 | 367 | .941 | 2222 | 11.11 | 336 | 2.800 | 15.94 |
| 43 | Bethany | 0-15 | 31 | .135 | 357 | .915 | 1704 | 8.05 | 334 | 2.783 | 13.12 |
| 44 | Bethany | 15-40 | 33 | .143 | 225 | .577 | 1956 | 9.78 | 435 | 3.625 | 14.74 |

## TABLE IIIg

## SOIL CHEMICAL ANALYSES: WATERSHED FR7

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | CEC meq/ 100g |
| 45 | Kirkland | 0-30 | 35 | .152 | 353 | .905 | 2102 | 10.51 | 474 | 3.95 | 16.14 |
| 46 | Kirkland | 30-46 | 70 | .304 | 280 | .718 | 2365 | 11.825 | 672 | 5.60 | 18.60 |
| 47 | Renfrow | 0-23 | 32 | .139 | 458 | 1.174 | 1656 | 8.28 | 384 | 3.200 | 12.86 |
| 48 | Renfrow | 23-40 | 35 | .152 | 376 | .964 | 1754 | 8.77 | 466 | 3.883 | 13.93 |
| 49 | Milan | 0-18 | 29 | .126 | 596 | 1.528 | 2097 | 10.485 | 352 | 2.933 | 15.26 |
| 50 | Milan | 18-40 | 32 | .139 | 316 | .810 | 1697 | 8.485 | 341 | 2.842 | 12.36 |
| 51 | Bethany | 0-15 | 28 | .122 | 407 | 1.043 | 1814 | 9.070 | 391 | 3.258 | 13.90 |
| 52 | Bethany | 15-40 | 38 | .165 | 322 | .826 | 2156 | 10.780 | 496 | 4.133 | 16.22 |

## TABLE IIIh

## SOIL CHEMICAL ANALYSES: WATERSHED FR8

| | | | Amm. Acetate Exchangeable Cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | | K | | Ca | | Mg | | CEC |
| No. | Soil | Depth cm | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | ppm | meq/ 100g | meq/ 100g |
| 53 | Kirkland | 0-25 | 33 | .143 | 285 | .731 | 1944 | 9.72 | 439 | 3.658 | 14.60 |
| 54 | Kirkland | 25-40 | 56 | .243 | 221 | .567 | 2194 | 10.97 | 702 | 5.850 | 17.61 |
| 55 | Renfrow | 0-23 | 28 | .122 | 289 | .741 | 1617 | 8.085 | 351 | 2.925 | 12.16 |
| 56 | Renfrow | 23-38 | 34 | .148 | 258 | .661 | 1862 | 9.31 | 440 | 3.667 | 13.90 |
| 57 | Bethany | 0-15 | 35 | .152 | 257 | .659 | 1946 | 9.73 | 407 | 3.392 | 14.25 |
| 58 | Bethany | 15-40 | 46 | .200 | 239 | .613 | 2056 | 10.28 | 450 | 3.750 | 15.18 |

significantly different from Na concentrations in Aydellote, Renfrow, Milan, and Bethany at the same level of probability.

In contrast to Na, the exchangeable K of these soils decreased with depth. Also, it is noticeable that the change in the amounts of this cation with depth was more drastic compared to the exchangeable Na. This reversed pattern demonstrated by K may be attributed to its lower mobility as compared to Na. However, it is evident from the data in Table III (a-h) that the exchangeable K is much higher than the exchangeable Na in the A and B horizons of these soils.

The AOV indicated a significant difference in the exchangeable K found in the A horizons as compared to the B horizons at the 0.05 level of probability. However, no significant differences were observed between the different soils.

The exchangeable Ca in these soils represents the dominant cation of the exchange complex. The amount of Ca has generally increased with depth. This increase in exchangeable Ca concentration has been found to be significant at the 0.05 level of probability. The statistical analysis has also revealed a significant difference in exchangeable Ca content of Kirkland soil as compared to Aydellote, Milan, Bethany, and Renfrow soils. However, no significant differences were found between Renfrow and Aydellote soils.

A similar concentration increase trend with depth was observed for the exchangeable Mg, which represents the second most dominant exchangeable cation in these soils. The increase in the exchangeable Mg from horizon A to horizon B of all the soils included in this study, was found to be significant at the 0.05 level of probability. The statistical analysis also indicated a significant difference in the exchangeable Mg content of Kirkland as compared to the other soils. However, Milan, Aydellote, Bethany, and Renfrow soils were not significantly different at the same level of probability.

Data regarding the cation exchange capacity (CEC) of soil samples taken at two depths are shown in Table III (a-h). The CEC for the different soils generally increased with depth. This is in agreement with the pattern of distribution of clay and exchangeable Ca, which represents the major cation of the exchange complex. The highest CEC was observed in the Kirkland series for the A horizon (16.14 meq/100 g), and for the B horizon (18.60 meq/100 g). On the other hand, the lowest CEC for the A horizon was observed in the Aydellote series (10.07 meq/100 g), and in the B horizon of the Milan series (10.16 meq/100 g).

The statistical analysis indicated a significant difference in the CEC with depths and between soils. It was concluded that the differences in CEC of Kirkland were significantly different from that of Aydellote, Renfrow, Milan, and Bethany. However, the differences in CEC between

Bethany, Aydellote, and Milan soils were not significant at the 0.05 level of probability.

The organic matter percentages (OM) and the Total Kjeldahl Nitrogen (TKN) contents in the A and B horizons of the five soils are presented in Table IV (a-h). The results indicate that the percent OM and the TKN have generally a similar distribution pattern, where both decreased with depth. The organic matter was generally dominant in the A horizon in all soils. This pattern may be caused by the native grasses which have been grown on these soils for a long period of time.

The AOV showed a significant difference in the OM percent between the A and the B horizons of all the soils. However, no significant differences in the percent of OM content between the various soils were observed.

The statistical analysis suggested a significant difference in TKN with depth in all soils. It also indicated a significant difference in the TKN in Kirkland soil as compared to Renfrow and Milan soils. However, it was concluded that the differences in the TKN between Bethany, Milan, Renfrow, and Aydellote soils were not significant at the 0.05 level of probability.

The data presented in Table IV (a-h) indicate that the total phosphorus (TP) was dominant in the A horizon. This is in agreement with the findings of Runge and Ricken (1966), who attributed the larger amounts near the surface to organic P.

## TABLE IVa

## SOIL CHEMICAL ANALYSES: WATERSHED FR1

| No. | Soil | Depth cm | %OM | %TKN | Total P ppm | Total P kg/ha | Soil Test P (Available P) ppm | Soil Test P (Available P) kg/ha |
|---|---|---|---|---|---|---|---|---|
| 1 | Kirkland | 0-30 | 2.275 | 0.1438 | 210 | 470.4 | 16 | 35.8 |
| 2 | Kirkland | 30-46 | 1.325 | 0.0967 | 170 | 380.8 | 10 | 22.4 |
| 3 | Renfrow | 0-23 | 2.450 | 0.1483 | 220 | 492.8 | 16 | 35.8 |
| 4 | Renfrow | 23-33 | 1.550 | 0.1758 | 180 | 403.2 | 10 | 22.4 |
| 5 | Bethany | 0-15 | 2.575 | 0.1787 | 260 | 582.4 | 18 | 40.3 |
| 6 | Bethany | 15-33 | 1.625 | 0.1076 | 200 | 448.0 | 12 | 26.9 |

## TABLE IVb

## SOIL CHEMICAL ANALYSES: WATERSHED FR2

| No. | Soil | Depth cm | %OM | %TKN | Total P ppm | Total P kg/ha | Soil Test P (Available P) ppm | Soil Test P (Available P) kg/ha |
|---|---|---|---|---|---|---|---|---|
| 7 | Kirkland | 0-30 | 2.325 | 0.1442 | 250 | 560.0 | 10 | 22.4 |
| 8 | Kirkland | 30-46 | 1.975 | 0.0939 | 160 | 358.4 | 6 | 13.4 |
| 9 | Renfrow | 0-23 | 2.550 | 0.1883 | 260 | 582.4 | 10 | 22.4 |
| 10 | Renfrow | 23-33 | 1.075 | 0.1201 | 230 | 515.2 | 8 | 17.9 |
| 11 | Bethany | 0-15 | 2.825 | 0.1702 | 260 | 582.4 | 12 | 26.9 |
| 12 | Bethany | 15-33 | 1.325 | 0.1136 | 200 | 448.0 | 8 | 17.9 |

## TABLE IVc

## SOIL CHEMICAL ANALYSES: WATERSHED FR3

| No. | Soil | Depth cm | %OM | %TKN | Total P ppm | Total P kg/ha | Soil Test P (Available P) ppm | Soil Test P (Available P) kg/ha |
|---|---|---|---|---|---|---|---|---|
| 13 | Kirkland | 0-30 | 3.125 | 0.1532 | 230 | 515.2 | 8 | 17.9 |
| 14 | Kirkland | 30-46 | 1.850 | 0.0875 | 180 | 403.2 | 24 | 53.8 |
| 15 | Renfrow | 0-23 | 2.750 | 0.1503 | 190 | 425.6 | 6 | 13.4 |
| 16 | Renfrow | 23-33 | 1.250 | 0.1428 | 160 | 358.4 | 4 | 9.0 |
| 17 | Aydellote | 0-18 | 2.250 | 0.1529 | 220 | 492.8 | 8 | 17.9 |
| 18 | Aydellote | 18-28 | 1.156 | 0.1208 | 180 | 403.2 | 6 | 13.4 |
| 19 | Milan | 0-18 | 3.375 | 0.1673 | 210 | 470.4 | 8 | 17.9 |
| 20 | Milan | 18-33 | 2.475 | 0.1022 | 170 | 380.8 | 8 | 17.9 |
| 21 | Bethany | 0-15 | 3.975 | 0.1385 | 250 | 560.0 | 10 | 22.4 |
| 22 | Bethany | 15-33 | 3.700 | 0.0983 | 190 | 425.6 | 10 | 22.4 |

# TABLE IVd

## SOIL CHEMICAL ANALYSES: WATERSHED FR4

| No. | Soil | Depth cm | %OM | %TKN | Total P ppm | Total P kg/ha | Soil Test P (Available P) ppm | Soil Test P (Available P) kg/ha |
|---|---|---|---|---|---|---|---|---|
| 23 | Kirkland | 0-30 | 2.925 | 0.0947 | 230 | 515.2 | 14 | 31.4 |
| 24 | Kirkland | 30-46 | 1.800 | 0.0881 | 180 | 403.2 | 10 | 22.4 |
| 25 | Renfrow | 0-23 | 3.625 | 0.1524 | 230 | 515.2 | 14 | 31.4 |
| 26 | Renfrow | 23-36 | 2.225 | 0.1031 | 190 | 425.6 | 12 | 26.9 |
| 27 | Aydellote | 0-18 | 3.775 | 0.1658 | 270 | 604.8 | 18 | 40.3 |
| 28 | Aydellote | 18-36 | 2.400 | 0.1066 | 220 | 492.8 | 12 | 26.9 |
| 29 | Milan | 0-18 | 3.850 | 0.1516 | 220 | 492.8 | 14 | 31.4 |
| 30 | Milan | 18-33 | 2.525 | 0.1042 | 170 | 380.8 | 10 | 22.4 |
| 31 | Bethany | 0-15 | 3.825 | 0.1905 | 270 | 604.8 | 16 | 35.8 |
| 32 | Bethany | 15-33 | 3.522 | 0.0881 | 200 | 448.0 | 12 | 26.9 |

## TABLE IVe

## SOIL CHEMICAL ANALYSES: WATERSHED FR5

| No. | Soil | Depth cm | %OM | %TKN | Total P ppm | Total P kg/ha | Soil Test P (Available P) ppm | Soil Test P (Available P) kg/ha |
|---|---|---|---|---|---|---|---|---|
| 33 | Kirkland | 0-30 | 2.825 | 0.1100 | 220 | 492.8 | 12 | 26.9 |
| 34 | Kirkland | 30-46 | 2.950 | 0.0898 | 170 | 380.8 | 6 | 13.4 |
| 35 | Renfrow | 0-20 | 3.000 | 0.1370 | 250 | 560.0 | 18 | 40.3 |
| 36 | Renfrow | 20-40 | 2.500 | 0.1122 | 210 | 470.4 | 8 | 17.9 |
| 37 | Bethany | 0-15 | 3.375 | 0.1493 | 260 | 582.4 | 20 | 44.8 |
| 38 | Bethany | 15-40 | 2.750 | 0.1367 | 240 | 537.6 | 10 | 22.4 |

## TABLE IVf

## SOIL CHEMICAL ANALYSES: WATERSHED FR6

| No. | Soil | Depth cm | %OM | %TKN | Total P ppm | Total P kg/ha | Soil Test P (Available P) ppm | Soil Test P (Available P) kg/ha |
|---|---|---|---|---|---|---|---|---|
| 39 | Kirkland | 0-30 | 2.950 | 0.1390 | 230 | 515.2 | 12 | 26.9 |
| 40 | Kirkland | 30-46 | 2.675 | 0.0993 | 160 | 358.4 | 10 | 22.4 |
| 41 | Milan | 0-18 | 2.755 | 0.1248 | 215 | 481.6 | 11 | 24.6 |
| 42 | Milan | 18-33 | 2.250 | 0.1339 | 172 | 358.3 | 9 | 20.2 |
| 43 | Bethany | 0-15 | 2.550 | 0.1123 | 250 | 560.0 | 20 | 44.8 |
| 44 | Bethany | 15-40 | 2.325 | 0.1174 | 210 | 470.4 | 8 | 17.9 |

## TABLE IVg

## SOIL CHEMICAL ANALYSES: WATERSHED FR7

| No. | Soil | Depth cm | %OM | %TKN | Total P |  | Soil Test P (Available P) |  |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | ppm | kg/ha | ppm | kg/ha |
| 45 | Kirkland | 0-30 | 3.200 | 0.1590 | 260 | 582.4 | 16 | 35.8 |
| 46 | Kirkland | 30-46 | 1.500 | 0.1099 | 150 | 336.0 | 6 | 13.4 |
| 47 | Renfrow | 0-23 | 2.750 | 0.1290 | 270 | 604.8 | 24 | 53.8 |
| 48 | Renfrow | 23-40 | 1.800 | 0.0988 | 200 | 448.0 | 10 | 22.4 |
| 49 | Milan | 0-18 | 2.925 | 0.1817 | 235 | 526.4 | 12 | 26.9 |
| 50 | Milan | 18-40 | 1.800 | 0.1066 | 185 | 414.4 | 9 | 20.2 |
| 51 | Bethany | 0-15 | 3.275 | 0.1642 | 280 | 627.2 | 26 | 58.2 |
| 52 | Bethany | 15-40 | 3.100 | 0.1611 | 270 | 604.8 | 20 | 44.8 |

# TABLE IVh

## SOIL CHEMICAL ANALYSES: WATERSHED FR8

| No. | Soil | Depth cm | %OM | %TKN | Total P |  | Soil Test P (Available P) |  |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | ppm | kg/ha | ppm | kg/ha |
| 53 | Kirkland | 0-25 | 2.625 | 0.1264 | 230 | 515.2 | 10 | 22.4 |
| 54 | Kirkland | 25-40 | 1.550 | 0.0864 | 170 | 380.8 | 6 | 13.4 |
| 55 | Renfrow | 0-23 | 2.650 | 0.1323 | 250 | 560.0 | 16 | 35.8 |
| 56 | Renfrow | 23-38 | 2.000 | 0.1000 | 210 | 470.4 | 10 | 22.4 |
| 57 | Bethany | 0-15 | 2.800 | 0.1450 | 260 | 582.4 | 18 | 40.3 |
| 58 | Bethany | 15-40 | 3.200 | 0.1563 | 260 | 582.4 | 10 | 22.4 |

The AOV indicated a significant difference in TP of all soils with depth. Furthermore, it was found that the differences in the amounts of TP between Milan, Aydellote, Renfrow, and Kirkland soils were not significant at the 0.05 level of probability. However, the TP in Bethany soil was significantly higher than that in Milan, Kirkland, and Renfrow soils, but not significantly different from Aydellote soil at the same level of probability.

The Bray-1 P (available P) concentrations in these soils represent about 4-8% of the TP. The soil content of available P has generally followed a similar distribution pattern as that observed for the TP. The higher concentrations of Bray-1 P in the A horizon may be due to the more intensive chemical and biological weathering.

The change in the concentrations of Bray-1 P from the A to the B horizon of these soils was found to be statistically significant at the 0.05 level of probability. On the other hand, the statistical analysis indicated that the differences in the concentrations of this form of P between the five soils occurring on these watersheds was not significant at the same level of probability.

The results of total cations (perchloric acid digestion cations) are shown in Table V (a-h).

Total Na has generally exhibited a similar increasing distribution trend with depth as observed for its exchangeable and water extractable forms. This similarity in distribution patterns has not been found between the

## TABLE Va

## SOIL CHEMICAL ANALYSES: WATERSHED FR1

| No. | Soil | Depth cm | Perchloric Acid Extractable Cations, ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
| 1 | Kirkland | 0 - 30 | 340 | 4130 | 2212 | 3050 | 12800 | 226 | 38 | 10 |
| 2 | Kirkland | 30 - 46 | 360 | 4260 | 1725 | 3725 | 15800 | 202 | 40 | 15 |
| 3 | Renfrow | 0 - 23 | 310 | 3910 | 1937 | 2800 | 12500 | 203 | 42 | 14 |
| 4 | Renfrow | 23 - 33 | 310 | 4110 | 1612 | 3225 | 15000 | 196 | 33 | 12 |
| 5 | Bethany | 0 - 15 | 290 | 3950 | 1937 | 2750 | 12000 | 245 | 41 | 13 |
| 6 | Bethany | 15 - 33 | 310 | 4070 | 1650 | 3262 | 14200 | 213 | 31 | 13 |

## TABLE Vb

## SOIL CHEMICAL ANALYSES: WATERSHED FR2

| No. | Soil | Depth cm | Perchloric Acid Extractable Cations, ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
| 7 | Kirkland | 0 - 30 | 290 | 3850 | 1775 | 3187 | 14000 | 241 | 38 | 13 |
| 8 | Kirkland | 30 - 46 | 360 | 4400 | 1700 | 4425 | 20000 | 220 | 43 | 17 |
| 9 | Renfrow | 0 - 23 | 280 | 3150 | 1112 | 2425 | 11500 | 185 | 30 | 14 |
| 10 | Renfrow | 23 - 33 | 290 | 4010 | 1275 | 2687 | 12700 | 196 | 30 | 12 |
| 11 | Bethany | 0 - 15 | 280 | 3690 | 1800 | 2787 | 11700 | 250 | 74 | 12 |
| 12 | Bethany | 15 - 33 | 320 | 4400 | 1487 | 3500 | 14600 | 225 | 34 | 16 |

## TABLE Vc

## SOIL CHEMICAL ANALYSES: WATERSHED FR3

| No. | Soil | Depth cm | Perchloric Acid Extractable Cations, ppm<br>Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Kirkland | 0 - 30 | 300 | 3910 | 1375 | 3000 | 13800 | 221 | 36 | 12 |
| 14 | Kirkland | 30 - 46 | 330 | 4240 | 1425 | 3712 | 17000 | 176 | 38 | 13 |
| 15 | Renfrow | 0 - 23 | 310 | 3450 | 1037 | 2712 | 12200 | 151 | 30 | 10 |
| 16 | Renfrow | 23 - 33 | 350 | 4250 | 1212 | 3812 | 18600 | 125 | 52 | 12 |
| 17 | Aydellote | 0 - 18 | 250 | 3450 | 1175 | 2837 | 13400 | 168 | 43 | 11 |
| 18 | Aydellote | 18 - 28 | 300 | 4070 | 1312 | 3637 | 19900 | 150 | 49 | 13 |
| 19 | Milan | 0 - 18 | 240 | 3360 | 1200 | 2612 | 12800 | 150 | 33 | 10 |
| 20 | Milan | 18 - 33 | 340 | 4370 | 1325 | 3550 | 19800 | 141 | 43 | 14 |
| 21 | Bethany | 0 - 15 | 250 | 3380 | 1325 | 2762 | 12500 | 213 | 37 | 11 |
| 22 | Bethany | 15 - 33 | 270 | 4120 | 1200 | 3500 | 17800 | 171 | 34 | 12 |

## TABLE Vd

## SOIL CHEMICAL ANALYSES: WATERSHED FR4

| No. | Soil | Depth cm | Perchloric Acid Extractable Cations, ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
| 23 | Kirkland | 0 - 30 | 280 | 3740 | 1362 | 3137 | 14100 | 231 | 38 | 11 |
| 24 | Kirkland | 30 - 46 | 320 | 4150 | 1425 | 3875 | 18000 | 203 | 52 | 12 |
| 25 | Renfrow | 0 - 23 | 280 | 3660 | 1125 | 2937 | 12700 | 172 | 44 | 10 |
| 26 | Renfrow | 23 - 36 | 300 | 4250 | 1250 | 3550 | 15900 | 167 | 41 | 10 |
| 27 | Aydellote | 0 - 18 | 220 | 2900 | 1150 | 2550 | 10600 | 163 | 34 | 9 |
| 28 | Aydellote | 18 - 36 | 290 | 3900 | 1275 | 3462 | 13600 | 154 | 48 | 10 |
| 29 | Milan | 0 - 18 | 250 | 3110 | 1112 | 2525 | 11500 | 162 | 31 | 10 |
| 30 | Milan | 18 - 33 | 310 | 4150 | 1262 | 3425 | 16800 | 151 | 38 | 13 |
| 31 | Bethany | 0 - 15 | 270 | 3480 | 1962 | 2837 | 11900 | 220 | 41 | 11 |
| 32 | Bethany | 15 - 33 | 300 | 3960 | 1425 | 3400 | 14700 | 194 | 38 | 12 |

## TABLE Ve

## SOIL CHEMICAL ANALYSES: WATERSHED FR5

| No. | Soil | Depth cm | Perchloric Acid Extractable Cations, ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
| 33 | Kirkland | 0 - 30 | 240 | 3500 | 1625 | 3025 | 13000 | 243 | 42 | 13 |
| 34 | Kirkland | 30 - 46 | 310 | 3760 | 1525 | 3637 | 15800 | 196 | 37 | 13 |
| 35 | Renfrow | 0 - 20 | 210 | 3200 | 1200 | 2312 | 11100 | 214 | 48 | 10 |
| 36 | Renfrow | 20 - 40 | 250 | 3960 | 1312 | 2812 | 14000 | 198 | 41 | 11 |
| 37 | Bethany | 0 - 15 | 240 | 3680 | 1425 | 2687 | 12200 | 232 | 45 | 11 |
| 38 | Bethany | 15 - 40 | 290 | 3550 | 1400 | 2900 | 13300 | 218 | 42 | 12 |

## TABLE Vf

## SOIL CHEMICAL ANALYSES: WATERSHED FR6

| No. | Soil | Depth cm | Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Perchloric Acid Extractable Cations, ppm | | | | | | | |
| 39 | Kirkland | 0 - 30 | 280 | 4030 | 1650 | 3375 | 13900 | 249 | 39 | 13 |
| 40 | Kirkland | 30 - 46 | 330 | 4150 | 1750 | 4150 | 18200 | 229 | 55 | 14 |
| 41 | Milan | 0 - 18 | 200 | 3470 | 2287 | 2287 | 10000 | 268 | 63 | 13 |
| 42 | Milan | 18 - 33 | 220 | 3550 | 1987 | 2575 | 11200 | 180 | 33 | 9 |
| 43 | Bethany | 0 - 15 | 240 | 3600 | 1300 | 2787 | 12100 | 247 | 37 | 10 |
| 44 | Bethany | 15 - 40 | 240 | 3720 | 1450 | 3112 | 13700 | 239 | 40 | 10 |

## TABLE Vg

## SOIL CHEMICAL ANALYSES: WATERSHED FR7

| No. | Soil | Depth cm | Perchloric Acid Extractable Cations, ppm<br>Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| 45 | Kirkland | 0 - 30 | 230 | 3850 | 1625 | 3062 | 12600 | 241 | 40 | 10 |
| 46 | Kirkland | 30 - 46 | 320 | 4500 | 1812 | 4587 | 21800 | 235 | 41 | 13 |
| 47 | Renfrow | 0 - 23 | 230 | 4170 | 1675 | 2887 | 12600 | 168 | 30 | 8 |
| 48 | Renfrow | 23 - 40 | 270 | 4750 | 1337 | 3525 | 17000 | 167 | 35 | 10 |
| 49 | Milan | 0 - 18 | 190 | 3800 | 1650 | 2800 | 13200 | 179 | 49 | 13 |
| 50 | Milan | 18 - 40 | 240 | 3780 | 1462 | 2750 | 12900 | 156 | 31 | 12 |
| 51 | Bethany | 0 - 15 | 230 | 3800 | 1500 | 2862 | 12300 | 230 | 41 | 11 |
| 52 | Bethany | 15 - 40 | 240 | 3790 | 1587 | 3212 | 13300 | 235 | 36 | 11 |

# TABLE Vh

## SOIL CHEMICAL ANALYSES: WATERSHED FR8

| No. | Soil | Depth cm | Perchloric Acid Extractable Cations, ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Ca | Mg | Fe | Mn | Zn | Cu |
| 53 | Kirkland | 0 - 25 | 270 | 4080 | 1650 | 3287 | 14000 | 247 | 38 | 12 |
| 54 | Kirkland | 25 - 40 | 300 | 4370 | 1525 | 3862 | 17000 | 180 | 48 | 13 |
| 55 | Renfrow | 0 - 23 | 250 | 3780 | 1375 | 2800 | 12600 | 200 | 60 | 9 |
| 56 | Renfrow | 23 - 38 | 250 | 4070 | 1525 | 3187 | 14800 | 191 | 36 | 12 |
| 57 | Bethany | 0 - 15 | 230 | 3730 | 1650 | 2937 | 12900 | 221 | 36 | 12 |
| 58 | Bethany | 15 - 40 | 240 | 3630 | 1537 | 3000 | 12600 | 224 | 39 | 12 |

total and the water extractable and exchangeable forms of the elements K, Ca, and Mg.

The relative proportions of these cations followed the sequence K > Mg > Ca > Na. The high total K contents of these soils is probably due to the high K contents of the parent material (shale).

It is also evident that only a very small percentage of these elements is in the soluble and exchangeable forms directly available to growing plants. This is particularly true for K.

The AOV for the total Na (TNA) revealed a significant interaction between soils and depths. Thus the differences between soils for each horizon were compared by utilizing the LSD procedure.

It was concluded that the TNA contents of Milan soil in the A horizon were significantly different from the Na concentration in Kirkland, Renfrow, and Bethany soils at the 0.05 level of probability. Significant differences between Kirkland and Bethany were also detected. However, the differences in TNA concentrations in the A horizons between Renfrow, Aydellote, and Bethany soils were not significant at the same level of probability.

At the B horizons, the TNA content of Kirkland was found to be significantly different from that of Bethany, Milan, and Renfrow soils, but not significantly different from its concentration in the B horizon of the Aydellote soil. Furthermore, the statistical analysis indicated that the amounts of TNA in the B horizons of Bethany, Aydellote, Renfrow, and Milan were not significant at the 0.05 level of probability.

The AOV showed no significant difference in total Ca with depth. Also, the differences in the total Ca between soils were not significant at the 0.05 level of probability.

Similar conclusions were obtained for the total K and Mg concentrations in the five soil series included in this study. The differences in the concentrations of these two cations (Mg, K) in the A and the B horizons of all soils were found to be significant. The statistical analysis has also indicated a significant difference between the concentrations of the total K and Mg found in Kirkland as compared to their concentrations in the other four soils. However, the AOV has revealed that the soils Aydellote, Renfrow, Bethany, and Milan were similar.

The perchloric acid ($HClO_4$) extractable micronutrients, iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) are shown in Table V (a-h). The soil contents of these micronutrients were in the order of Fe > Mn > Zn > Cu.

The Fe concentrations in all the soils increased consistently with depth. This increase was found to be significant at the 0.05 level of probability. The AOV also revealed a significant difference in the Fe concentrations between soils. Further statistical analyses revealed that Kirkland soil was significantly different from Bethany, Milan, and Renfrow. However, no significant differences in

Fe contents were found between Bethany, Renfrow, and Milan.

Data regarding the Mn concentrations, expressed in ppm, indicate a consistent decreasing pattern from the A to the B horizons of all the soils. The AOV revealed a significant difference in Mn concentrations with depths and between soils. It was concluded that Renfrow, Aydellote, and Milan soils were not significantly different at the 0.05 level of probability. However, these soils were significantly different from Bethany and Kirkland soils at the same level of probability.

The perchloric acid ($HClO_4$) extractable Zn, and Cu have not changed significantly in these soils. Also, the statistical analysis indicated that the Zn contents of these soils has not changed significantly from the A to the B horizons. However, a significant difference was found between the concentrations of Cu in the A horizon as compared to its concentrations in the B horizons of all the soils studied.

## Mineralogical Properties of the Soils

A total of 464 X-ray powder diffractograms were run on the soil samples in this study. Representative X-ray diffractograms for the fine and the coarse clay fractions of these soils at two depths are presented in Figures 3 through 14. The horizontal axis of these diffractograms is labeled in terms of the angle of diffraction ($2\theta$), and the vertical axis is labeled as relative intensity, which is an

# TABLE VI

## CORRELATION COEFFICIENTS BETWEEN SOME CHEMICAL AND PHYSICAL PROPERTIES OF THE FIVE SOIL SERIES

| Properties | Prob > IRI | |
|---|---|---|
| | A-horizon | B-horizon |
| Clay vs CEC | 0.32 | 0.67 |
| CEC vs exchangeable K | 0.13 | -0.21 |
| CEC vs exchangeable Ca | 0.92 | 0.93 |
| CEC vs exchangeable Mg | 0.76 | 0.87 |
| CEC vs exchangeable Na | 0.27 | 0.80 |
| OM vs TKN | 0.45 | 0.13 |
| EC vs TDSP | 0.52 | 0.35 |
| pH $H_20$ vs pH KCl | 0.60 | 0.87 |
| pH $H_20$ vs water Na | 0.49 | 0.07 |
| pH KCl vs water Na | 0.68 | -0.04 |
| TNA vs water Na | 0.69 | 0.83 |
| TNA vs exchangeable Na | 0.26 | 0.82 |
| TCA vs exchangeable Ca | 0.69 | 0.78 |
| TK vs exchangeable K | -0.35 | -0.14 |
| TMG vs exchangeable Mg | 0.91 | 0.59 |
| TP vs AP | 0.74 | 0.61 |

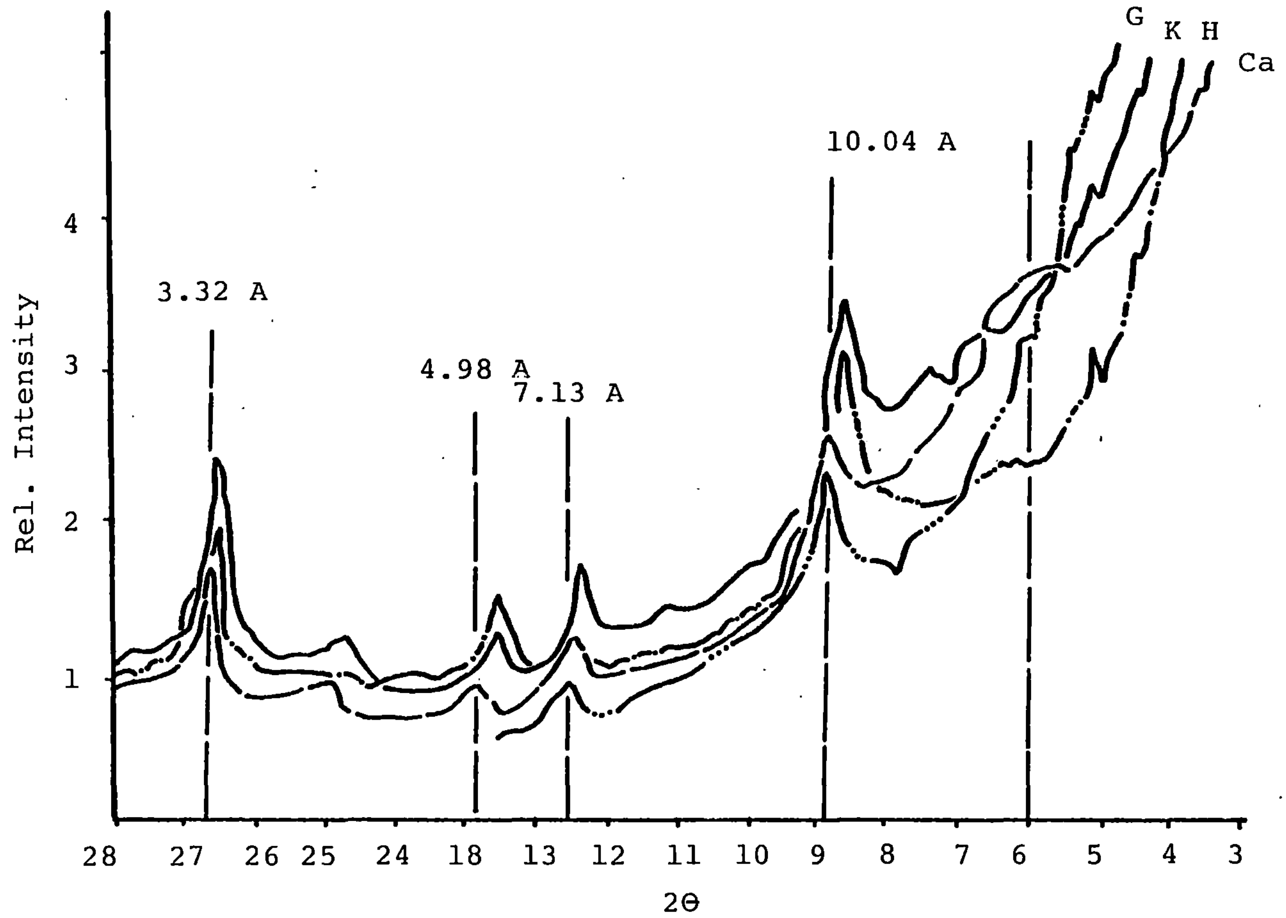

Figure 3. X-ray Diffraction Pattern and d-spacings in Angstroms of the Kirkland 0-30 cm Coarse Clay Fraction

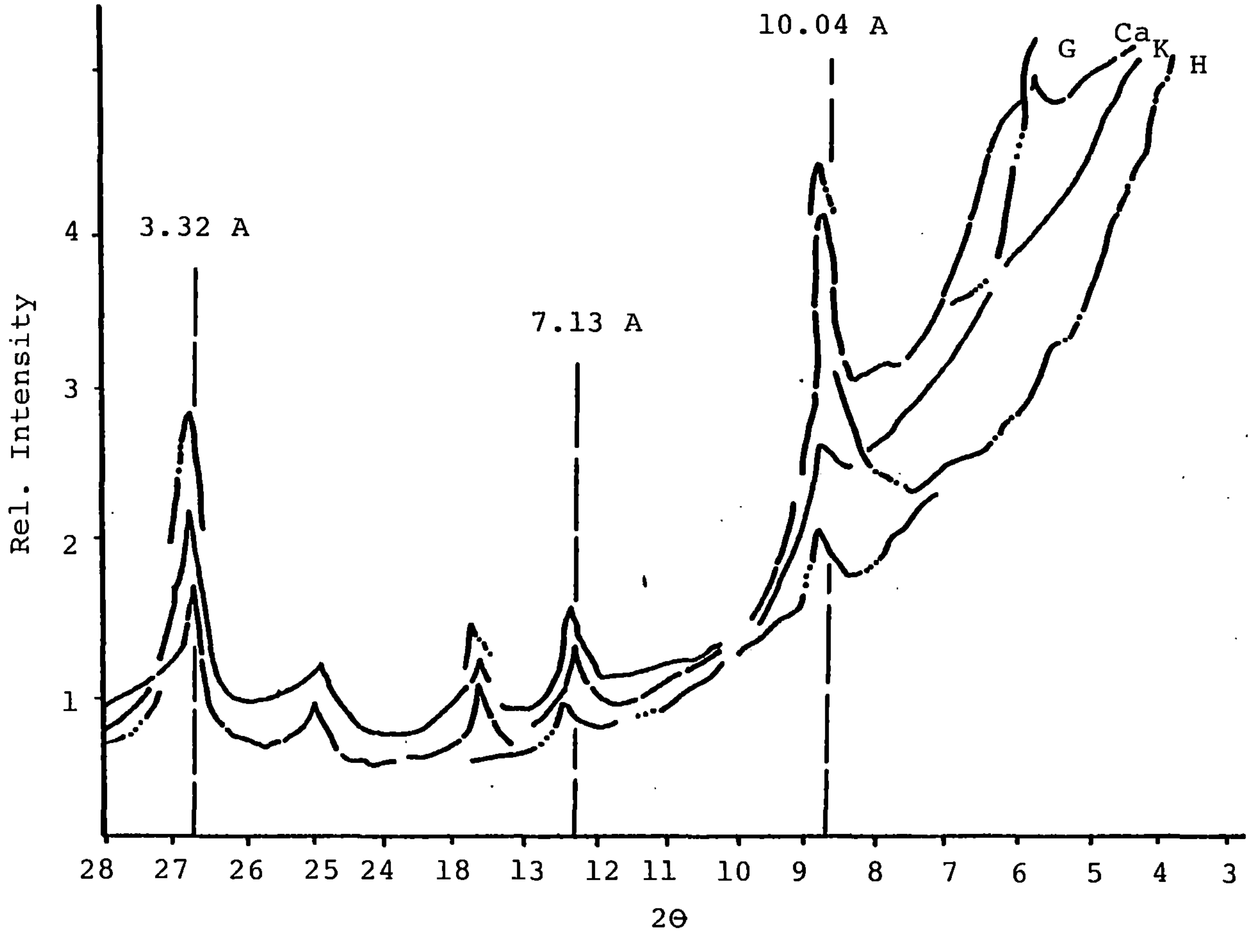

Figure 4 . X-ray Diffraction Pattern and d-spacings in Angstroms of the Kirkland 30-46 cm Coarse Clay Fraction

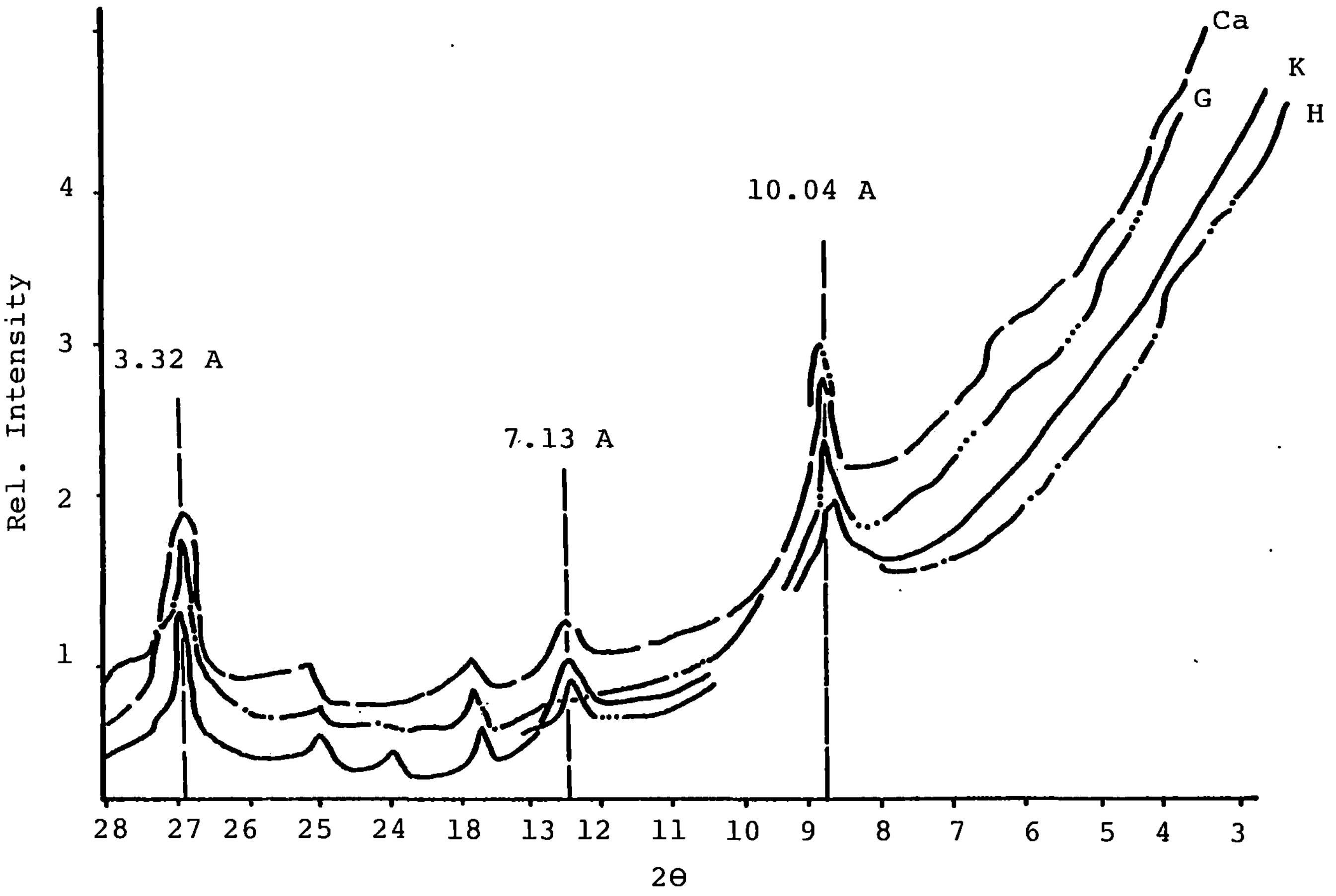

Figure 5 . X-ray Diffraction Pattern and d-spacings in Angstroms of the Renfrow 0-23 cm Coarse Clay Fraction

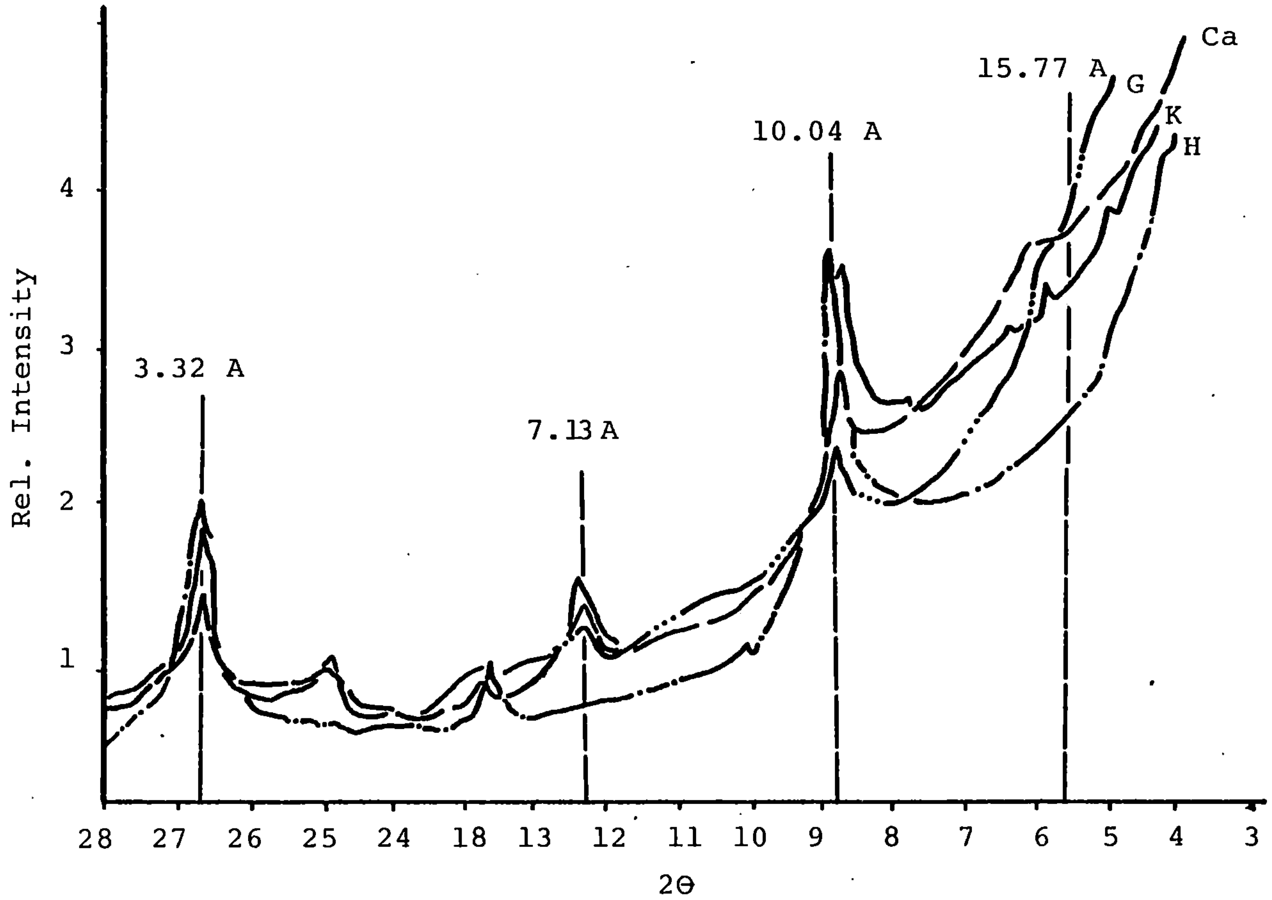

Figure 6. X-ray Diffraction Pattern and d-spacings in Angstroms of the Renfrow 23-33 cm Coarse Clay Fraction

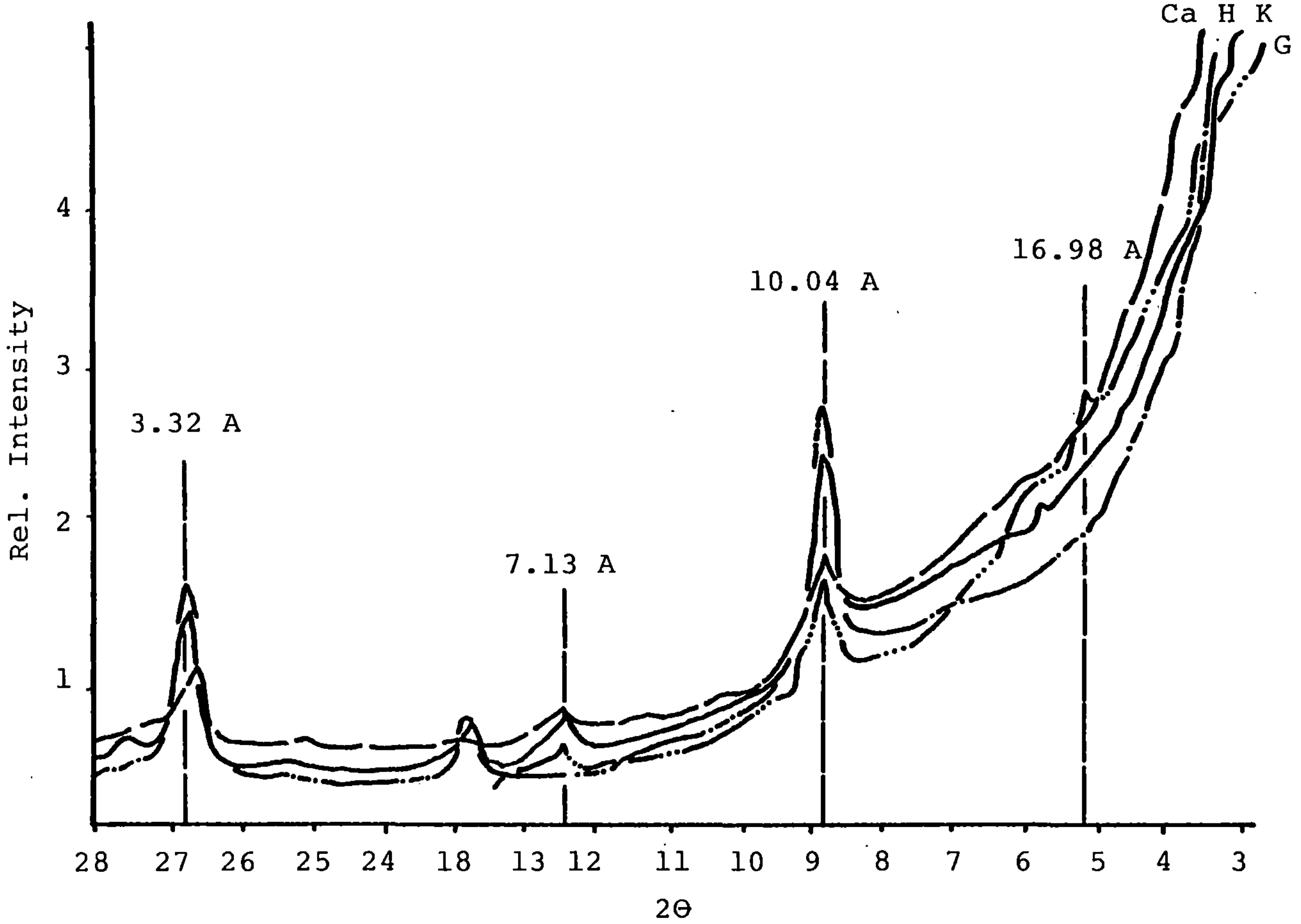

Figure 7. X-ray Diffraction Pattern and d-spacings in Angstroms of the Bethany 0-15 cm Coarse Clay Fraction

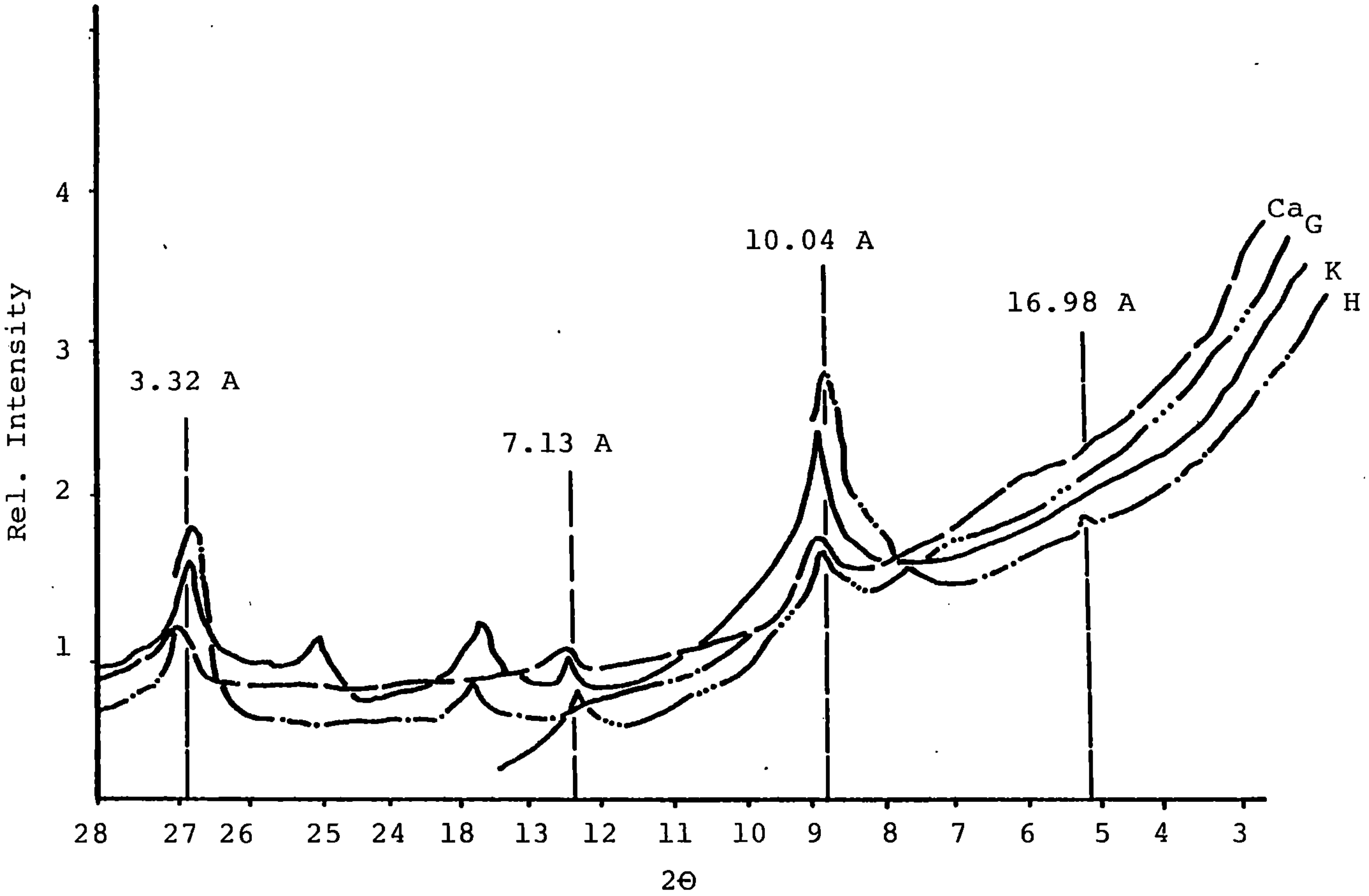

Figure 8. X-ray Diffraction Pattern and d-spacings in Angstroms of the Bethany 15-33 cm Coarse Clay Fraction

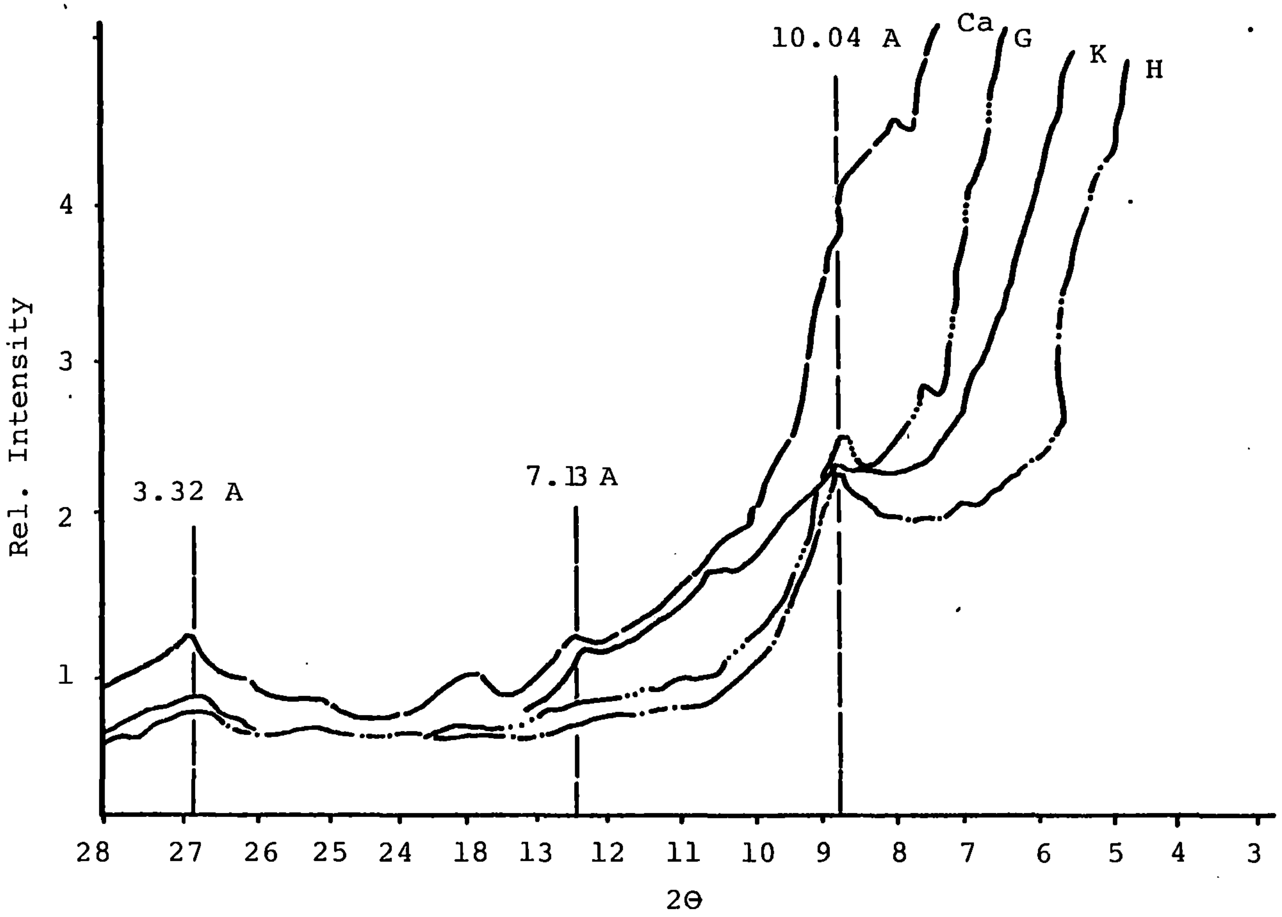

Figure 9. X-ray Diffraction Pattern and d-spacings in Angstroms of the Kirkland 0-30 cm Fine Clay Fraction

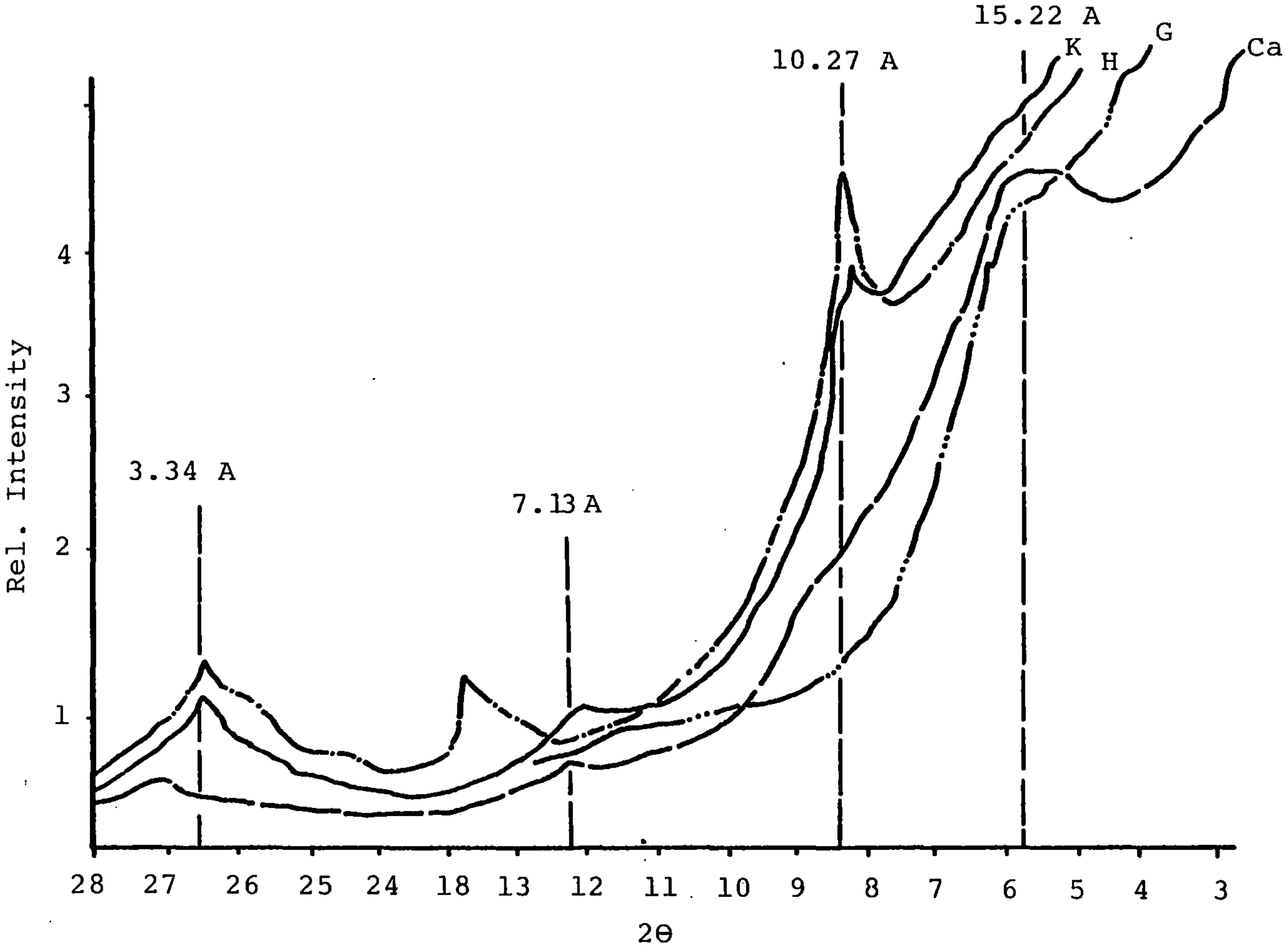

Figure 10. X-ray Diffraction Pattern and d-spacings in Angstroms of the Kirkland 30-46 cm Fine Clay Fraction

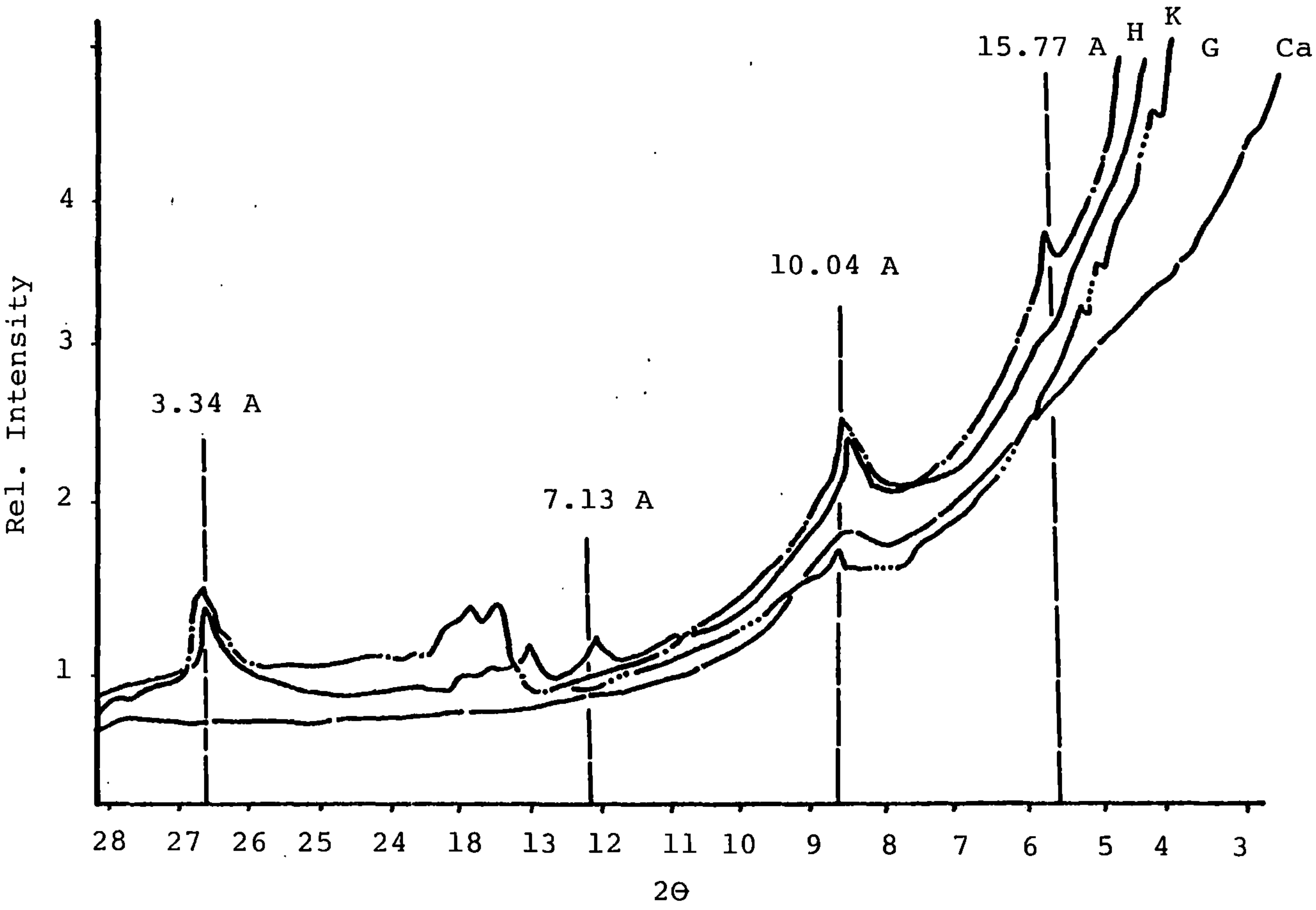

Figure 11. X-ray Diffraction Pattern and d-spacings in Angstroms of the Renfrow 0-23 cm Fine Clay Fraction

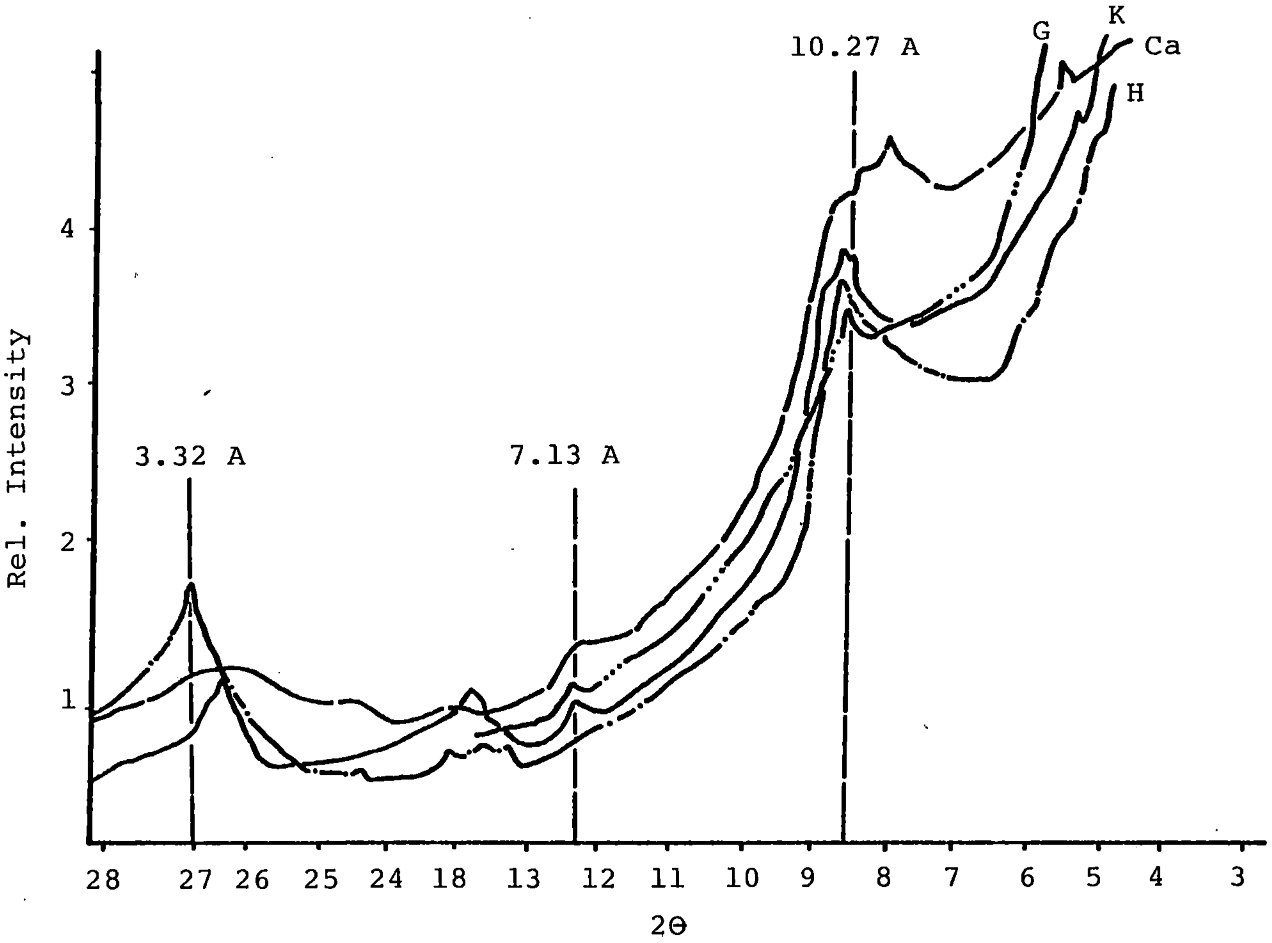

Figure 12. X-ray Diffraction Pattern and d-spacings in Angstroms of the Renfrow 23-33 cm Fine Clay Fraction

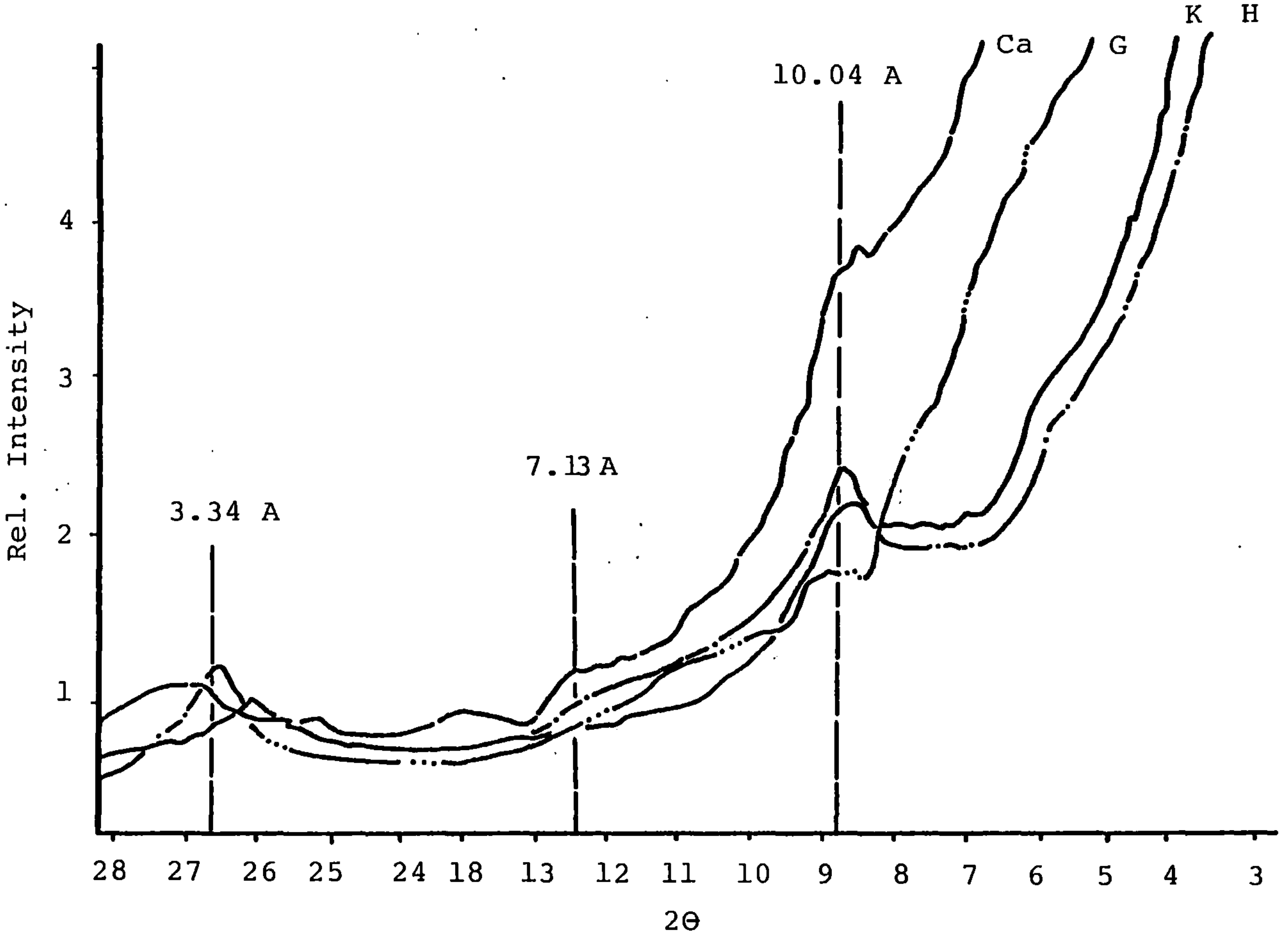

Figure 13. X-ray Diffraction Pattern and d-spacings in Angstroms of the Bethany 0-15 cm Fine Clay Fraction

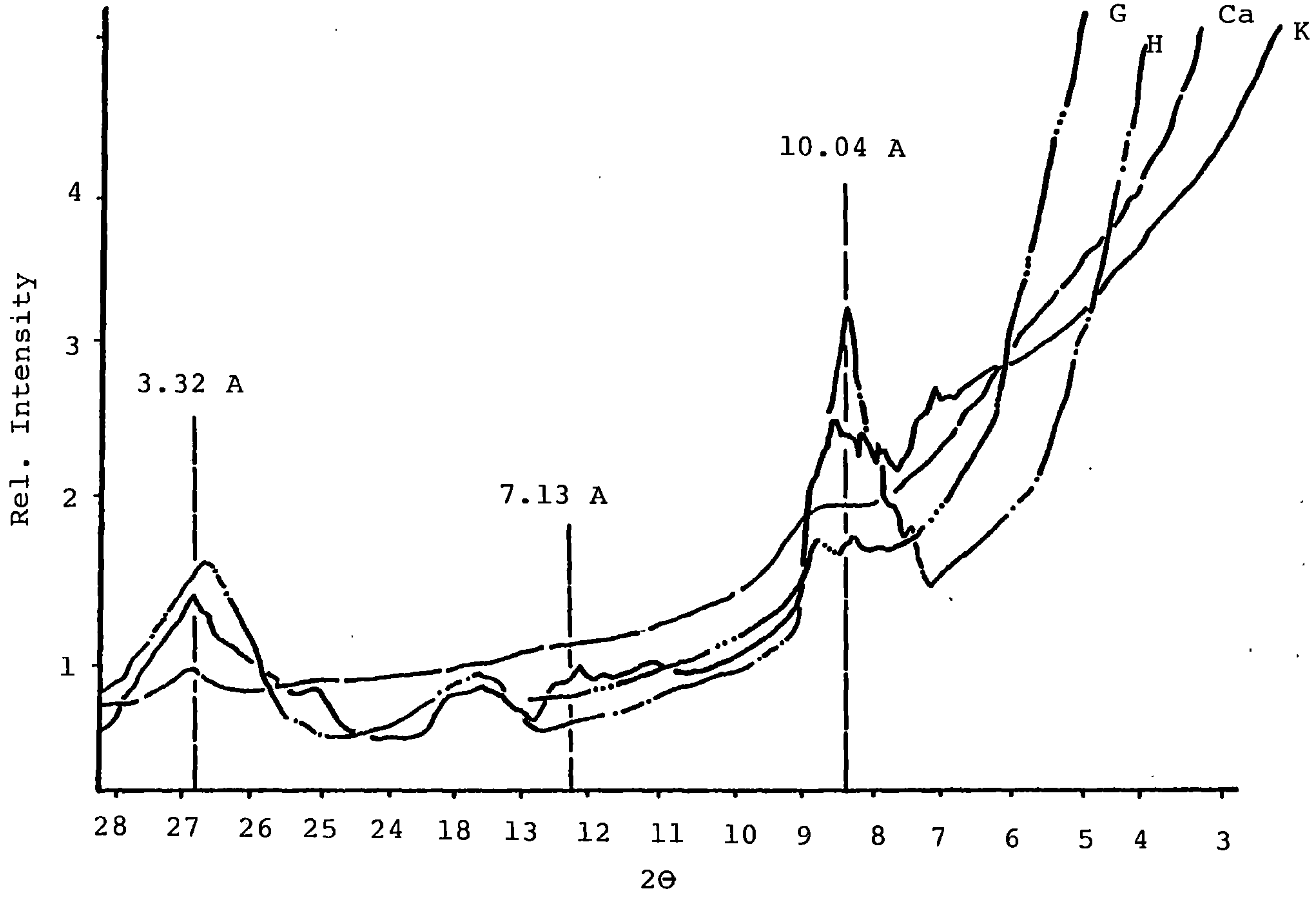

Figure 14. X-ray Diffraction Pattern and d-spacings in Angstroms of the Bethany 15-33 cm Fine Clay Fraction

indication of how crystalline the clay mineral is in a particular soil.

The diffracted rays were scanned up to 30° 2θ which, when CuK radiation is used, is sufficient to include one or more higher order reflections of common soil clay minerals.

The basic data obtained consist of distances measured in terms of angles 2θ recorded with a diffractometer. The angles were converted to lattice spacings, d, expressed in Angstroms by means of "International Tables for the Determination of Crystal Structures". These "d" values of the 001 spacings of the various clay minerals, together with eye estimated intensities and notes of any peculiarities of the line profile are presented in Table VII (a-h).

Differential cation treatment, ethylene glycol solvation and heat were all used with X-ray diffraction to aid in distinguishing the clay minerals. Brindley (1951) stated that this combination of treatments permits the detection and semi-quantitative estimation of montmorillonite, kaolinite, and illite groups of clay minerals, the chlorite minerals, and vermiculite.

For X-ray identification, the clay minerals were oriented on glass slides and a General Electric XRD 6 Spectrogoniometer using nickel-filtered copper radiation was employed with settings of 30 KVP and 20 ma. The general guidelines used to identify the most common soil clay minerals are given by Brindley (1951).

A comparison of the intensities of the diffraction

## TABLE VIIa

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR1

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
| 1 | Kirkland | 0-30 | Coarse | 19.19(W)[1] | 18.39(W) | 20.53(W) | 21.50(W) | illite, kaolinite, |
| | | | | 16.35(W) | 11.04(B) | 14.48(W) | 12.44(B) | montmorillonite, |
| | | | | | | 12.88(W) | | vermiculite |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | | |
| | | | | 7.13(S) | 7.13(S) | 7.13(S) | 10.04(S) | |
| | | | Fine | 19.19(W) | | 15.77(W) | 15.49(W) | illite, kaolinite |
| | | | | 14.72(W) | | 12.99(W) | 12.80(W) | montmorillonite, |
| | | | | 10.04(W) | 10.04(B) | 10.04(B) | 11.94(W) | vermiculite |
| | | | | 7.13(B) | | 7.13(W) | 10.04(S) | |
| 2 | | 30-46 | Coarse | 22.07(B) | 18.78(B) | 21.53(W) | 17.31(W) | illite, kaolinite, |
| | | | | 18.78(B) | 12.27(B) | 16.35(W) | 14.48(W) | montmorillonite, |
| | | | | 16.35(B) | | | | vermiculite |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 12.62(B) | |
| | | | | 7.13(S) | 7.13(B) | 7.13(S) | 10.04(S) | |
| | | | Fine | | | 15.22(W) | 14.72(W) | illite, kaolinite, |
| | | | | | 12.27(B) | 13.80(W) | 13.18(W) | vermiculite |
| | | | | 10.27(B) | 9.81(B) | 10.04(B) | 10.04(S) | |
| | | | | | | 7.13(W) | | |

TABLE VIIa (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| 3 | Renfrow | 0-23 | Coarse | 29.42(W) | 16.35(B) | 19.19(S) | | illite, kaolinite, |
| | | | | 10.04(S) | 13.80(B) | 17.31(W) | 10.04(S) | montmorillonite, |
| | | | | 7.13(S) | 10.04(S) | 14.72(W) | | vermiculite |
| | | | | | 7.13(S) | 10.15(S) | | |
| | | | | | | 7.19(S) | | |
| | | | Fine | | | 17.66(W) | | illite, kaolinite, |
| | | | | | | 10.04(S) | 10.04(S) | montmorillonite |
| | | | | 10.04(W) | 9.81(B) | 7.13(W) | | |
| 4 | | 23-33 | Coarse | 24.52(W) | | | | illite, kaolinite, |
| | | | | 10.04(S) | 14.02(B) | 25.22(W) | | vermiculite, |
| | | | | 7.13(S) | 10.04(S) | 16.98(W) | 16.05(W) | montmorillonite |
| | | | | | 7.13(S) | 14.24(W) | 14.24(W) | |
| | | | | | | 10.04(S) | | |
| | | | | | | 7.25(S) | 10.04(S) | |
| | | | Fine | 16.35(W) | | 19.19(S) | 14.72(W) | illite, kaolinite, |
| | | | | 10.52(B) | 9.81(B) | 15.22(B) | 12.80(W) | vermiculite |
| | | | | 7.13(B) | | 10.04(B) | 10.27(S) | |
| 5 | Bethany | 0-15 | Coarse | 14.24(B) | 22.07(S) | 20.06(S) | 18.02(W) | illite, kaolinite, |
| | | | | 10.04(S) | 14.24(B) | 15.49(W) | 15.49(S) | vermiculite, |
| | | | | 7.13(S) | 10.04(S) | 13.38(W) | 12.99(B) | montmorillonite |
| | | | | | 7.13(S) | 10.04(S) | 10.04(S) | |
| | | | | | | 7.13(W) | | |

TABLE VIIa (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| | | | Fine | 15.77(B) | | 12.99(W) | | illite, kaolinite, vermicullite |
| | | | | 10.04(B) | 10.04(B) | | | |
| | | | | | | 10.04(S) | 10.04(S) | |
| | | | | 7.13(B) | | 7.13(B) | | |
| 6 | | 15-23 | Coarse | 25.96(W) | | | | illite, kaolinite, vermiculite, montmorillonite |
| | | | | 13.80(B) | 17.31(B) | 16.66(W) | 17.31(W) | |
| | | | | 10.04(S) | 14.47(B) | 15.22(B) | 13.80(W) | |
| | | | | 7.13(S) | 9.92(S) | 10.04(S) | 10.04(S) | |
| | | | | | 7.13(S) | 7.13(S) | 7.19(W) | |
| | | | Fine | | | 17.31(S) | 13.80(B) | illite, vermiculite, montmorillonite |
| | | | | 10.04(B) | 10.04(B) | | | |
| | | | | | | 12.62(S) | 10.90(S) | |
| | | | | | | 10.27(S) | 10.04(S) | |

# TABLE VIIb

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR2

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25$^{o}$ C | Ca-Sat Gly 25$^{o}$ C | K-Sat 25$^{o}$ C | K-Sat 500 $^{o}$C | |
| 7 | Kirkland | 0-30 | Coarse | 14.72(B) | 22.07(W) | 16.99(W) | 19.19(W) | illite, kaolinite, |
| | | | | 10.04(S) | 14.24(B) | 11.96(W) | 16.99(W) | montmorillonite, |
| | | | | 7.13(S) | 10.04(S) | 10.27(S) | 13.80(W) | vermiculite |
| | | | | | 7.13(S) | 7.25(S) | 10.04(S) | |
| | | | Fine | 17.66(W) | 11.94(B) | 12.44(W) | 15.77(W) | illite, kaolinite |
| | | | | | | | 14.98(W) | vermiculite |
| | | | | 10.04(B) | 10.04(W) | | 12.62(W) | |
| | | | | | | 10.15(S) | 10.04(S) | |
| | | | | 7.13(B) | | | | |
| 8 | | 30-46 | Coarse | 31.53(W) | | 19.19(S) | 18.39(W) | illite, kaolinite, |
| | | | | 21.53(W) | 18.78(B) | 16.98(W) | 16.98(W) | montmorillonite, |
| | | | | 15.22(W) | 10.04(S) | 15.77(B) | 14.24(W) | vermiculite |
| | | | | 10.04(S) | 7.13(W) | 13.80(W) | 12.99(B) | |
| | | | | 7.13(S) | | 10.04(S) | 10.04(S) | |
| | | | | | | 7.13(S) | | |
| | | | Fine | 10.04(B) | 17.66(B) | 16.05(W) | 15.49(W) | illite, kaolinite, |
| | | | | | | 10.64(W) | 13.80(W) | montmorillonite |
| | | | | 7.13(W) | 10.04(B) | 7.13(W) | 12.62(W) | |
| | | | | | | | 10.15(S) | |

TABLE VIIb (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| 9 | Renfrow | 0-23 | Coarse | 16.35(B) | 16.97(W) | | 17.66(W) | illite, kaolinite, |
| | | | | 10.04(S) | 13.59(W) | 15.77(B) | 14.24(W) | montmorillonite, |
| | | | | | 10.04(S) | 13.80(W) | | |
| | | | | 7.13(S) | 7.13(S) | 10.04(S) | 10.04(S) | |
| | | | | | | 7.13(S) | | |
| | | | Fine | | | 14.48(W) | 19.19(W) | illite, kaolinite, |
| | | | | 10.04(W) | 10.04(B) | 10.04(W) | 14.48(W) | vermiculite |
| | | | | | | 7.25(W) | 12.80(W) | |
| | | | | | | | 10.27(S) | |
| 10 | | 23-33 | Coarse | 24.52(B | 16.98(W) | 17.31(W) | | illite, kaolinite, |
| | | | | 14.04(B) | 14.72(W) | 14.72(W) | | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 12.44(W) | 10.04(S) | montmorillonite |
| | | | | | | 10.04(S) | | |
| | | | | 7.13(S) | 7.13(S) | 7.13(S) | | |
| | | | Fine | 15.77(W) | | | 14.97(W) | illite, kaolinite, |
| | | | | | | 16.35(W) | | vermiculite |
| | | | | 10.52(B) | 10.04(B) | | 12.44(W) | |
| | | | | | | 12.27(W) | | |
| | | | | 7.13(B) | | 10.27(W) | 10.04(S) | |
| 11 | Bethany | 0-15 | Coarse | 14.72(B) | 16.98(W) | 15.22(W) | 21.53(W) | illite, kaolinite, |
| | | | | 10.04(S) | 14.72(B) | 10.04(S) | 17.31(W) | vermiculite, |
| | | | | 7.13(S) | 10.04(S) | 7.13(S) | 10.04(S) | montmorillonite |
| | | | | | 7.13(W) | | 7.13(B) | |

TABLE VIIb (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| | | | Fine | 10.27(B) | 14.47(W) | 12.62(W) | | illite, kaolinite, vermicullite |
| | | | | 7.13(B) | 9.82(B) | 10.15(W) | 10.04(B) | |
| 12 | | 15-23 | Coarse | 30.44(W) | | | | illite, kaolinite, vermiculite, montmorillonite |
| | | | | | 19.62(W) | | | |
| | | | | 10.04(S) | 14.72(B) | 21.53(W) | 15.22(W) | |
| | | | | | 10.04(S) | 18.39(W) | 12.44(W) | |
| | | | | 7.13(W) | | | | |
| | | | | | 7.13(S) | 10.04(S) | 10.04(S) | |
| | | | | | | 7.13(S) | | |
| | | | Fine | | | 15.77(W) | | illite, kaolinite, vermiculite |
| | | | | | | 13.80(W) | 14.72(W) | |
| | | | | 10.04(B) | 10.04(B) | 12.44(W) | 13.18(B) | |
| | | | | | | 10.27(W) | 10.27(S) | |
| | | | | | | 7.13(B) | | |

# TABLE VIIc

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR3

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
| 13 | Kirkland | 0-30 | Coarse | 23.85(W) | 17.66(W) | 17.31(W) | | illite, kaolinite, |
| | | | | 10.04(S) | 10.04(S) | 14.24(W) | 21.53(W) | montmorillonite, |
| | | | | 7.18(S) | | 10.04(S) | 10.27(S) | vermiculite |
| | | | | | 7.13(S) | 7.13(S) | | |
| | | | Fine | | | 14.02(W) | | illite, vermiculite |
| | | | | 10.04(W) | 10.04(W) | 10.04(S) | 10.04(S) | |
| 14 | | 30-46 | Coarse | 25.22(W) | | 19.90(W) | | illite, kaolinite, |
| | | | | 10.04(S) | 14.97(W) | 15.77(W) | 14.02(B) | montmorillonite, |
| | | | | | | 12.00(W) | | vermiculite |
| | | | | 7.18(S) | 10.04(S) | 10.04(S) | 12.10(B) | |
| | | | | | 7.13(S) | 7.13(S) | 10.04(S) | |
| | | | Fine | 15.22(B) | 18.39(B) | 18.39(W) | 18.39(W) | illite, kaolinite, |
| | | | | | 16.35(SW) | 10.04(W) | 12.62(W) | montmorillonite |
| | | | | 10.04(B) | 9.80(B) | 7.13(B) | 10.04(S) | |
| 15 | Renfrow | 0-23 | Coarse | 15.22(B) | 18.02(W) | 14.24(W) | 16.98(B) | illite, kaolinite, |
| | | | | 10.04(S) | 12.27(B) | 10.04(S) | 15.77(B) | montmorillonite, |
| | | | | | 10.04(S) | | | vermiculite |
| | | | | 7.13(S) | 7.13(S) | 7.24(S) | 9.80(S) | |

TABLE VIIc (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| | | | Fine | | 12.80(B) | | | illite, vermiculite |
| | | | | | | 10.15(B) | 10.52(W) | |
| | | | | 10.04(B) | 9.80(B) | | | |
| 16 | | 23-33 | Coarse | 14.24(W) | 21.02(W) | 14.72(B) | | illite, kaolinite, |
| | | | | 10.04(B) | 13.18(B) | 10.04(S) | 18.02(W) | vermiculite, |
| | | | | | 10.04(S) | | 13.59(B) | montmorillonite |
| | | | | 7.13(W) | 7.13(B) | 7.13(S) | 10.04(S) | |
| | | | Fine | 16.35(W) | | 14.24(B) | 14.24(B) | illite, vermiculite |
| | | | | | 10.04(B) | | | |
| | | | | 10.27(B) | | 10.04(W) | 10.39(S) | |
| 17 | Aydellote | 0-18 | Coarse | 25.22(W) | | | | illite, kaolinite, |
| | | | | 14.72(W) | 16.35(B) | 13.59(B) | | vermiculite, |
| | | | | | 13.59(B) | | | montmorillonite |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 10.04(S) | |
| | | | | 7.18(S) | 7.13(W) | 7.13(S) | | |
| | | 18-28 | Fine | 10.04(B) | 10.04(B) | 10.04(W) | 10.27(W) | illite |
| 18 | | | Coarse | 15.22(B) | 17.31(B) | | | illite, kaolinite, |
| | | | | 12.27(B) | 12.80(B) | 13.80(B) | 15.77(W) | montmorillonite, |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 10.15(S) | vermiculite |
| | | | | 7.13(S) | 7.13(S) | 7.13(S) | | |

TABLE VIIc (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| | | | Fine | | 14.48(W) | 13.59(B) | 14.48(W) | illite, kaolinite, |
| | | | | 10.04(W) | | 10.04(W) | 12.62(W) | vermicullite |
| | | | | | 10.39(W) | 7.13(W) | 10.27(S) | |
| 19 | Milan | 0-18 | Coarse | 14.24(W) | 15.77(W) | 22.07(W) | | illite, kaolinite, |
| | | | | 10.04(S) | 14.24(W) | 17.66(W) | | vermiculite, |
| | | | | | 10.04(S) | 12.62(B) | 10.04(S) | montmorillonite |
| | | | | 7.18(S) | 7.13(S) | 10.04(S) | | |
| | | | | | | 7.13(S) | | |
| | | | Fine | 10.27(B) | 10.04(B) | 16.98(W) | 16.98(W) | illite, vermiculite |
| | | | | | | 13.80(B) | 11.94(B) | |
| | | | | | | 10.04(B) | 10.04(B) | |
| 20 | | 18-33 | Coarse | 14.47(W) | | | | illite, kaolinite, |
| | | | | | 17.66(W) | 17.66(B) | | vermiculite, |
| | | | | 10.04(S) | 13.80(B) | 13.38(B) | 10.04(S) | montmorillonite |
| | | | | 7.13(S) | 10.04(S) | 10.15(S) | | |
| | | | | | 7.13(S) | 7.24(S) | | |
| | | | Fine | 10.04(B) | | 12.62(W) | 14.72(B) | illite, kaolinite, |
| | | | | | 10.04(B) | | 12.27(W) | vermiculite |
| | | | | 7.13(B) | | 10.04(W) | 10.04(W) | |

TABLE VIIc (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment |  |  |  | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C |  |
| 21 | Bethany | 0-15 | Coarse | 26.75(W) | 10.04(S) | 17.66(W) |  | illite, kaolinite, |
|  |  |  |  |  |  | 13.59(B) |  | vermiculite, |
|  |  |  |  | 10.04(S) | 7.13(W) | 10.04(S) | 9.93(S) | montimorillonite |
|  |  |  |  | 7.13(B) |  | 7.13(S) |  |  |
|  |  |  | Fine | 10.04(B) | 10.04(B) | 10.27(B) | 10.39(S) | illite, kaolinite |
|  |  |  |  |  |  | 7.13(B) |  |  |
| 22 |  | 15-33 | Coarse | 17.66(B) | 16.98(W) | 17.66(W) |  | illite, kaolinite, |
|  |  |  |  | 10.04(S) | 10.04(S) | 13.39(B) |  | montmorillonite, |
|  |  |  |  |  |  | 10.27(S) | 21.02(W) | vermiculite |
|  |  |  |  | 7.13(S) | 7.13(B) | 7.25(S) | 10.27(S) |  |
|  |  |  | Fine | 10.04(B) | 10.04(B) | 14.72(W) | 14.72(B) | illite, vermiculite |
|  |  |  |  |  |  | 12.27(W) | 12.44(W) |  |
|  |  |  |  |  |  | 10.39(W) | 10.27(S) |  |

## TABLE VIId

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR4

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
| 23 | Kirkland | 0-30 | Coarse | 16.35(B) | 22.07(W) | 17.66(W) | | illite, kaolinite, |
| | | | | 14.48(B) | 19.19(W) | 10.04(S) | 10.04(S) | vermiculite, |
| | | | | 10.04(S) | 12.62(B) | | | montmorillonite |
| | | | | | 10.04(S) | 7.13(B) | | |
| | | | | 7.13(S) | 7.13(S) | | | |
| | | | Fine | | | 16.35(W) | | illite, kaolinite, |
| | | | | 10.04(W) | | 13.18(B) | 13.38(W) | vermiculite |
| | | | | | 10.04(B) | 10.04(S) | 10.04(S) | |
| | | | | | | 7.13(B) | | |
| 24 | | 30-46 | Coarse | 24.52(W) | | 16.35(B) | 17.31(W) | illite, kaolinite |
| | | | | 14.42(B) | 21.02(B) | 13.38(S) | 14.24(W) | vermiculite, |
| | | | | | | 11.32(B) | | montmorillonite |
| | | | | 10.04(W) | 10.04(S) | 10.04(S) | 10.04(S) | |
| | | | | 7.13(W) | 7.13(W) | 7.13(S) | | |
| | | | Fine | | | 14.24(B) | | illite, vermiculite |
| | | | | 10.04(B) | 10.04(B) | 10.04(W) | 10.10(W) | |
| 25 | Renfrow | 0-23 | Coarse | 25.96(W) | 20.53(W) | 16.05(B) | 14.48(S) | illite, kaolinite, |
| | | | | 14.24(W) | 17.31(S) | 14.48(W) | 11.94(S) | vermiculite, |
| | | | | 10.04(B) | 14.24(B) | 12.62(W) | 10.04(S) | montmorillonite |
| | | | | 7.13(B) | 10.04(S) | 10.04(S) | | |
| | | | | | 7.13(B) | 7.13(W) | | |

TABLE VIId (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| | | | Fine | 11.94(B) | 9.81(B) | 15.77(W) | | illite, vermiculite |
| | | | | 10.04(B) | | 10.04(B) | 10.04(B) | |
| 26 | | 23-36 | Coarse | 23.23(W) | 19.19(B) | 14.24(W) | 17.66(B) | illite, kaolinite |
| | | | | 14.47(B) | 14.48(W) | 12.99(W) | 13.80(B) | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 10.15(S) | montmorillonite |
| | | | | 7.13(S) | 7.13(B) | 7.13(S) | 7.96(W) | |
| | | | Fine | 10.27(B) | 10.04(B) | 10.04(W) | 10.15(S) | illite |
| 27 | Aydellote | 0-18 | Coarse | 14.24(B) | 16.35(W) | | | illite, kaolinite, |
| | | | | 10.04(S) | 10.04(S) | 14.24(B) | 10.04(S) | vermiculite, |
| | | | | 7.13(B) | 7.13(B) | 10.15(S) | | montmorillonite |
| | | | | | | 7.24(S) | | |
| | | | Fine | | 20.06(W) | | 12.99(W) | illite, vermiculite, |
| | | | | 10.04(B | 14.90(W) | 10.04(W) | 10.27(S) | montmorillonite |
| | | | | | 9.92(B) | | | |
| 28 | | 18-36 | Coarse | 25.22(W) | 15.77(B) | 16.35(W) | | illite, kaolinite |
| | | | | 14.47(S) | 14.47(W) | 14.72(B) | 13.38(B) | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 10.27(S) | 10.04(S) | montmorillonite |
| | | | | 7.13(S) | 7.13(S) | 7.24(W) | | |
| | | | Fine | | 19.19(W) | | | illite, |
| | | | | | 15.22(W) | 16.98(W) | | montmorillonite |
| | | | | 10.04(W) | 11.70(B) | 10.04(W) | 10.04(W) | |
| | | | | | 10.04(B) | | | |

TABLE VIId (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| 29 | Milan | 0-18 | Coarse | 23.85(W) | 15.22(W) | 17.66(B) | 14.24(W) | illite, kaolinite, |
| | | | | 14.72(B) | | 13.80(B) | | vermiculite, |
| | | | | 10.04(W) | 12.62(W) | 10.04(S) | 10.04(S) | montmorillonite |
| | | | | 7.13(W) | 10.04(S) | 7.13(W) | | |
| | | | | | 7.13(W) | | | |
| | | | Fine | 10.04(B) | 10.04(B) | 12.17(W) | 12.17(W) | illite, kaolinite |
| | | | | | | 10.04(B) | 10.04(B) | |
| | | | | 7.13(B) | 7.13(B) | | | |
| 30 | | 18-33 | Coarse | 13.80(B) | 15.22(W) | 17.66(W) | | illite, kaolinite, |
| | | | | | 14.97(W) | 14.24(W) | | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 10.27(S) | 13.80(B) | montmorillonite |
| | | | | 7.13(W) | 7.19(S) | 7.24(W) | 12.62(W) | |
| | | | | | | | 10.04(S) | |
| | | | Fine | | 17.31(W) | | | illite, kaolinite, |
| | | | | 10.27(W) | 12.26(B) | 15.22(B) | | montmorillonite |
| | | | | 7.13(B) | 10.04(B) | 10.04(W) | 10.04(W) | |
| 31 | Bethany | 0-15 | Coarse | 16.80(B) | | | | illite, kaolinite |
| | | | | 13.80(B) | 17.31(W) | 11.94(B) | 17.66(B) | montmorillonite |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 12.99(B) | |
| | | | | 7.13(B) | 7.13(S) | 7.13(W) | 10.04(S) | |
| | | | Fine | | 11.94(B) | 14.48(W) | | illite, vermiculite |
| | | | | 10.04(B) | | 12.44(W) | | |
| | | | | | 9.93(B) | 10.04(S) | 10.04(S) | |

TABLE VIId (Continued)

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
| 32 | Bethany | 15-33 | Coarse | 23.23(W) | 17.66(W) | | | illite, kaolinite, vermiculite, montmorillonite |
| | | | | 14.72(B) | 15.77(W) | | 15.77(B) | |
| | | | | 10.04(S) | 10.04(S) | 13.80(B) | | |
| | | | | 7.13(S) | 7.13(B) | 10.04(S) | 10.04(S) | |
| | | | | | | 7.13(S) | | |
| | | | Fine | | | 13.80(B) | | illite, vermiculite |
| | | | | 10.04(B) | 9.81(B) | 12.62(B) | 10.04(W) | |
| | | | | | | 10.04(B) | | |

## TABLE VIIe

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR5

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| 33 | Kirkland | 0-30 | Coarse | 25.96(W) | 21.53(B) | | 17.31(W) | illite, kaolinite, montmorillonite, vermiculite |
| | | | | 13.80(B) | 17.31(B) | 10.04(S) | | |
| | | | | 10.04(S) | 10.04(S) | 7.13(W) | 10.04(S) | |
| | | | | 7.13(S) | 7.13(S) | | | |
| | | | Fine | 10.27(B) | 12.27(W) | 12.62(W) | 10.04(W) | illite |
| | | | | | 10.04(B) | 10.04(W) | | |
| 34 | | 30-46 | Coarse | 22.64(W) | 18.39(B) | 17.66(W) | | illite, kaolinite montmorillonite vermiculite |
| | | | | 18.39(B) | 15.22(W) | 11.04(S) | 10.04(S) | |
| | | | | 10.04(S) | 10.04(W) | 10.04(S) | | |
| | | | | 7.13(S) | 7.13(W) | 7.13(W) | | |
| | | | Fine | | 21.02(W) | | | illite, vermiculite, montmorillonite |
| | | | | 10.04(W) | 13.80(W) | 17.31(W) | | |
| | | | | | | 14.24(B) | 12.62(W) | |
| | | | | | 10.04(B) | 10.04(W) | 10.04(S) | |
| 35 | Renfrow | 0-20 | Coarse | 14.24(B) | 17.66(W) | 16.35(B) | 17.66(W) | illite, kaolinite, vermiculite, montmorillonite |
| | | | | | 16.06(B) | 14.01(B) | 12.99(B) | |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 10.04(S) | |
| | | | | 7.13(S) | 7.13(W) | 7.13(S) | | |

TABLE VIIe (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| | | | Fine | 14.72(W) | 18.39(B) | | 16.35(B) | illite, kaolinite, |
| | | | | 10.04(B) | 14.24(B) | 13.18(W) | 14.72(W) | montmorillonite, |
| | | | | 7.13(B) | 9.82(B) | 10.15(B) | 10.04(S) | vermiculite |
| 36 | | 20-40 | Coarse | 13.80(B) | 28.47(B) | 17.66(W) | | illite, kaolinite |
| | | | | 10.04(S) | 14.72(S) | 15.49(W) | 12.99(B) | vermiculite, |
| | | | | | 10.04(S) | 10.04(S) | 10.04(S) | montmorillonite |
| | | | | 7.13(S) | 7.13(S) | 7.13(S) | | |
| | | | Fine | 16.98(W) | | 12.99(S) | 12.62(W) | illite, kaolinite, |
| | | | | 10.04(B) | 10.04(B) | 10.04(W) | 10.04(W) | vermiculite |
| | | | | 7.13(B) | | | | |
| 37 | Bethany | 0-15 | Coarse | | 22.07(B) | 17.66(W) | | illite, kaolinite, |
| | | | | 10.04(S) | 17.31(B) | 13.18(W) | 15.22(B) | montmorillonite |
| | | | | 7.13(S) | 15.22(B) | 10.15(S) | 10.15(S) | vermiculite |
| | | | | | 10.04(S) | 7.30(W) | | |
| | | | | | 7.13(W) | | | |
| | | | Fine | 16.35(W) | 16.05(W) | 13.80(W) | | illite, kaolinite, |
| | | | | 10.04(B) | 12.10(B) | 10.04(W) | 10.04(B) | montmorillonite, |
| | | | | 7.13(B) | 9.82(B) | | | vermiculite |

TABLE VIIe (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| 38 | | 15-40 | Coarse | 16.35(B) | 23.23(W) | 19.19(W) | 14.24(W) | illite, kaolinite, |
| | | | | 13.80(B) | 15.77(B) | 12.99(W) | 10.04(S) | montmorillonite |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | | vermiculite |
| | | | | 7.13(S) | 7.13(B) | 7.13(S) | | |
| | | | Fine | 16.35(W) | 9.82(B) | | 17.66(W) | illite, |
| | | | | 10.04(B) | | 10.04(W) | 10.39(S) | montmorillonite |

## TABLE VIIf

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR6

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment |  |  |  | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C |  |
| 39 | Kirkland | 0-30 | Coarse | 22.64(W) | 20.06(W) | 18.39(W) |  | illite, kaolinite, |
|  |  |  |  | 18.39(B) | 17.66(B) | 15.22(B) | 16.66(B) | montmorillonite, |
|  |  |  |  | 10.04(S) | 10.04(S) | 13.59(B) | 10.04(S) | vermiculite |
|  |  |  |  | 7.13(S) | 7.13(S) | 10.04(S) |  |  |
|  |  |  |  |  |  | 7.13(S) |  |  |
|  |  |  | Fine |  |  | 16.35(W) | 16.35(B) | illite, vermiculite, |
|  |  |  |  |  |  | 13.80(B) |  | montmorillonite |
|  |  |  |  | 10.04(W) | 10.04(W) | 10.04(B) | 10.04(S) |  |
| 40 |  | 30-46 | Coarse | 18.39(W) | 14.24(B) | 16.35(B) | 13.80(W) | illite, kaolinite, |
|  |  |  |  | 10.04(S) | 10.04(B) | 10.04(W) | 10.04(S) | vermiculite, |
|  |  |  |  | 7.13(S) | 7.13(B) | 7.13(S) |  | montmorillonite |
|  |  |  | Fine | 16.35(B) |  | 17.31(W) |  | illite, |
|  |  |  |  |  | 9.82(B) | 14.24(W) |  | montmorillonite, |
|  |  |  |  | 10.04(B) |  | 10.04(W) | 10.04(W) | vermiculite |
|  |  |  |  |  |  | 7.13(W) |  |  |
| 41 | Milan | 0-18 | Coarse | 19.19(B) | 20.06(W) | 14.72(W) |  | illite, kaolinite, |
|  |  |  |  | 16.35(B) | 16.35(B) |  |  | montmorillonite, |
|  |  |  |  | 10.04(S) | 10.04(S) | 10.04(W) | 10.04(W) | vermiculite |
|  |  |  |  | 7.13(W) | 7.13(W) | 7.19(W) |  |  |
|  |  |  | Fine | 17.66(B) | 21.02(W) | 10.04(B) | 10.04(B) | illite, montmorill- |
|  |  |  |  | 10.04(B) | 10.04(B) |  |  | onite, vermiculite |

TABLE VIIf (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment | | | | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| | | | | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | |
| 42 | | 18-33 | Coarse | 23.23(W) | 14.24(W) | 16.98(S) | 15.77(B) | illite, kaolinite, |
| | | | | 10.04(W) | | 10.04(S) | 10.04(S) | vermiculite, |
| | | | | 7.13(W) | 10.04(B) | 7.13(W) | | montmorillonite |
| | | | Fine | | 21.02(W) | | | illite, |
| | | | | 14.72(W) | 13.80(W) | 10.04(W) | 10.15(S) | montmorillonite, |
| | | | | 10.04(B) | 10.04(B) | | | vermiculite |
| 43 | Bethany | 0-15 | Coarse | 22.64(W) | 14.72(W) | 19.19(B) | 15.49(W) | illite, kaolinite, |
| | | | | 14.24(B) | 12.10(B) | 12.99(B) | 13.80(W) | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 10.04(S) | montmorillonite |
| | | | | 7.13(S) | 7.13(W) | 7.13(W) | | |
| | | | Fine | 17.66(W) | | 13.38(W) | 17.31(W) | illite, vermiculite, |
| | | | | 13.81(B) | 10.04(B) | 10.04(W) | 10.04(S) | kaolinite, |
| | | | | 10.04(W) | | 7.24(W) | | montmorillonite |
| 44 | | 15-40 | Coarse | 12.44(W) | 16.98(B) | | | illite, kaolinite, |
| | | | | 10.04(S) | 14.48(W) | 10.04(S) | 12.98(W) | vermiculite, |
| | | | | 7.13(S) | 10.04(S) | 7.13(W) | 10.04(S) | montmorillonite |
| | | | | | 7.13(W) | | | |
| | | | Fine | 11.94(B) | 12.99(W) | 19.19(W) | 16.35(W) | illite, kaolinite, |
| | | | | 10.27(W) | 10.15(B) | 10.04(W) | 14.02(B) | vermiculite |
| | | | | 7.13(B) | | | 10.51(S) | |

## TABLE VIIg

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR7

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mine |
| 45 | Kirkland | 0-30 | Coarse | 14.24(B) | 16.98(W) | 16.98(W) | 16.98(W) | illite, kaolinite, |
| | | | | 10.04(B) | 13.80(B) | 13.38(B) | 13.38(B) | vermiculite, |
| | | | | 7.13(B) | 10.04(S) | 10.04(S) | 10.04(S) | montmorillonite |
| | | | | | 7.13(B) | 7.13(W) | | |
| | | | Fine | | 10.04(B) | 14.24(B) | 14.02(B) | illite, kaolinite, |
| | | | | 10.04(B) | 7.13(B) | 10.04(W) | 12.10(W) | vermiculite |
| | | | | | | 7.13(W) | 10.04(S) | |
| 46 | | 30-46 | Coarse | 16.98(B) | 13.80(W) | 17.66(W) | 14.48(W) | illite, kaolinite, |
| | | | | | 12.27(B) | 13.80(W) | | vermiculite, |
| | | | | 10.04(W) | 10.04(W) | 10.04(S) | 10.04(S) | montmorillonite |
| | | | | 7.13(S) | 7.13(B) | 7.13(S) | | |
| | | | Fine | | 20.06(B) | | | illite, vermiculite, |
| | | | | 10.04(B) | 12.99(B) | 14.24(W) | 10.04(B) | montmorillonite |
| | | | | | 10.04(B) | 10.04(B) | | |
| 47 | Renfrow | 0-23 | Coarse | 13.80(WB) | 25.96(W) | | | illite, kaolinite, |
| | | | | 10.04(W) | 22.07(B) | 10.04(W) | 10.04(W) | montmorillonite, |
| | | | | 7.13(BW) | 10.27(S) | | | vermiculite |
| | | | Fine | 16.35(W) | 17.31(W) | 17.31(W) | | illite, vermiculite, |
| | | | | 10.04(B) | 10.04(B) | 12.44(W) | 10.04(S) | montmorillonite |
| | | | | | | 10.04(W) | | |

TABLE VIIg (Continued)

| Given No. | Soil Series | Depth cm | Clay Fraction | Treatment<br>Ca-Sat 25$^{o}$ C | <br>Ca-Sat Gly 25$^{o}$ C | <br>K-Sat 25$^{o}$ C | <br>K-Sat 500 $^{o}$C | Type of Clay Mineral |
|---|---|---|---|---|---|---|---|---|
| 48 | | 23-40 | Coarse | 23.86(W) | 18.39(B) | 14.48(B) | | illite, kaolinite, |
| | | | | 13.38(B) | 16.35(B) | 10.04(S) | 10.04(S) | vermiculite |
| | | | | 10.04(S) | 10.04(B) | 7.13(S) | | montmorillonite |
| | | | | 7.13(S) | 7.13(W) | | | |
| | | | Fine | 10.04(B) | | 14.72(B) | 16.98(W) | illite, kaolinite, |
| | | | | | 13.80(W) | 10.04(W) | 12.27(W) | vermiculite |
| | | | | 7.13(B) | | 7.13(B) | 10.04(S) | montmorillonite |
| 49 | Milan | 0-18 | Coarse | 18.39(B) | 16.98(B) | 18.39(W) | | illite, kaolinite, |
| | | | | 13.80(B) | | 13.80(B) | 20.06(W) | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 13.80(B) | montmorillonite |
| | | | | 7.13(B) | 7.13(W) | 7.18(W) | 10.04(S) | |
| | | | Fine | | | 17.66(W) | 15.22(B) | illite, |
| | | | | 10.04(B) | 10.04(B) | | 12.62(B) | montmorillonite, |
| | | | | | | 10.04(S) | 10.04(S) | vermiculite |
| 50 | | 18-40 | Coarse | 12.99(B) | 15.22(B) | 14.24(W) | | illite, kaolinite, |
| | | | | 10.04(S) | 13.80(W) | 12.62(B) | 15.22(B) | vermiculite |
| | | | | 7.13(B) | 10.04(S) | 10.04(S) | | montmorillonite |
| | | | | | 7.13(W) | 7.13(B) | 10.04(S) | |
| | | | Fine | | 15.49(W) | | | illite, |
| | | | | 10.27(W) | 12.62(B) | 10.04(W) | 10.27(W) | montmorillonite, |
| | | | | | 10.04(B) | | | vermiculite |

TABLE VIIg (Continued)

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
| 51 | Bethany | 0-15 | Coarse | 12.99(B) | 17.31(W) | 10.04(S) | 15.77(W) | illite, kaolinite |
| | | | | | 14.72(B) | | | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 7.13(W) | 10.04(S) | montmorillonite |
| | | | | 7.13(B) | 7.13(W) | | | |
| | | | Fine | 12.62(W) | | 13.80(B) | 13.80(B) | illite, |
| | | | | | 16.66(W) | 12.62(B) | 11.32(B) | montmorillonite, |
| | | | | 10.27(B) | 9.81(B) | 10.04(B) | 9.82(S) | kaolinite, |
| | | | | | | 7.13(W | | vermiculite |
| 52 | | 15-40 | Coarse | 25.22(W) | 17.31(B) | 16.35(B) | 16.35(B) | illite, kaolinite, |
| | | | | 14.72(B) | 12.44(B) | 13.80(B) | | montmorillonite, |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 13.80(S) | vermiculite |
| | | | | 7.13(S) | 7.13(W) | 7.13(S) | 10.04(S) | |
| | | | Fine | | 17.31(W) | 17.66(W) | 15.49(W) | illite, vermiculite, |
| | | | | | 14.72(W) | 14.24(B) | 13.80(S) | montmorillonite |
| | | | | 10.04(W) | 9.82(B) | 10.04(W) | 11.94(B) | |
| | | | | | | | 10.04(S) | |

# TABLE VIIh

## X-RAY DIFFRACTION DATA OF CLAYS EXTRACTED FROM SOILS OF WATERSHED FR8

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
| 53 | Kirkland | 0-25 | Coarse | 20.06(B) | 19.19(B) | | | illite, kaolinite, |
| | | | | 13.80(B) | 14.02(B) | 10.04(S) | 12.62(W) | vermiculite, |
| | | | | 10.04(S) | 10.04(S) | 7.13(W) | | montmorillonite |
| | | | | 7.13(S) | 7.13(S) | | 10.00(S) | |
| | | | Fine | 17.66(B) | 11.32(W) | 14.72(W) | 14.24(W) | illite, kaolinite, |
| | | | | 10.04(B) | 10.04(W) | 12.62(B) | | montmorillonite |
| | | | | 7.13(WB) | | 10.15(W) | 10.77(S) | vermiculite |
| | | | | | | 7.25(W) | | |
| 54 | | 25-40 | Coarse | | 14.24(B) | 14.24(W) | 17.66(W) | illite, kaolinite, |
| | | | | 10.04(S) | 10.04(S) | 10.04(S) | 14.72(B) | vermiculite |
| | | | | 7.13(W) | 7.13(W) | 7.13(W) | 10.04(S) | |
| | | | Fine | | | 13.80(W) | 12.62(W) | illite, kaolinite, |
| | | | | 10.04(B) | 10.04(B) | 10.27(W) | | vermiculite |
| | | | | | | 7.15(B) | 10.52(S) | |
| 55 | Renfrow | 0-23 | Coarse | 13.80(B) | 16.35(B) | 17.66(W) | 11.94(W) | illite, kaolinite, |
| | | | | 11.62(B) | 12.44(B) | 13.80(W) | | vermiculite, |
| | | | | 10.04(W) | 10.04(S) | 10.04(W) | 10.04(S) | montmorillonite |
| | | | | | 7.13(W) | 7.13(W) | | |
| | | | Fine | 10.04(B) | 10.04(B) | 10.04(W) | 12.99(W) | illite, vermiculite |
| | | | | | | | 10.15(W) | |

TABLE VIIh (Continued)

| | | | | Treatment | | | | |
|---|---|---|---|---|---|---|---|---|
| Given No. | Soil Series | Depth cm | Clay Fraction | Ca-Sat 25° C | Ca-Sat Gly 25° C | K-Sat 25° C | K-Sat 500 °C | Type of Clay Mineral |
| 56 | | 23-38 | Coarse | 21.02(B) | 22.07(B) | 13.80(B) | 16.35(W) | illite, kaolinite, vermiculite, montmorillonite |
| | | | | 13.80(B) | 18.02(W) | 10.04(S) | | |
| | | | | 10.04(B) | 13.80(B) | | 10.04(S) | |
| | | | | 7.13(B) | 10.04(W) | 7.13(B) | | |
| | | | Fine | 12.27(W) | 10.04(B) | 10.04(S) | 12.99(W) | illite, kaolinite, vermiculite |
| | | | | 10.27(W) | | 7.13(B) | 10.51(S) | |
| 57 | Bethany | 0-15 | Coarse | 13.80(W) | 21.02(B) | 20.53(W) | 15.77(W) | illite, kaolinite, vermiculite, montmorillonite |
| | | | | 10.04(S) | 16.98(B) | 10.04(S) | 13.80(B) | |
| | | | | 7.13(B) | 10.04(S) | 7.13(W) | 10.04(S) | |
| | | | | | 7.13(W) | | | |
| | | | Fine | 10.04(B) | 10.04(B) | 10.04(W) | 10.04(B) | illite |
| 58 | | 15-40 | Coarse | 22.64(W) | 14.24(B) | 17.31(W) | 15.22(W) | illite, kaolinite, vermiculite, montmorillonite |
| | | | | 14.24(B) | 10.04(S) | 14.24(B) | | |
| | | | | 10.04(S) | | 10.04(S) | 10.04(S) | |
| | | | | 7.13(B) | | 7.13(B) | | |
| | | | Fine | 10.39(B) | 9.93(B) | 10.04(B) | 12.99(W) | illite, kaolinite, vermiculite |
| | | | | 7.13(B) | | 7.13(B) | 10.51(W) | |

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[1] (W) = weak
(S) = strong
(B) = broad

maxima of pure specimens with those of soils investigated shows a relatively higher intensity of the diffraction maxima of pure specimen material. The presence of fine particle size, crystal defects, and amorphous materials may in part explain the lower basal diffraction intensity.

The x-ray diffraction patterns for the coarse clay fraction of the surface samples of the soils included in this study are presented in Figures 3, 5, and 7. The basal (001) reflections indicate that illite and kaolinite are the dominant clay minerals in these soils. These diffraction patterns have also revealed the presence of an appreciable amount of quartz and calcite (as indicated by their reflections at 3.35A$^{o}$ and 3.05A$^{o}$, respectively). The kinds and the degree of crystallinity of the various clay minerals have not changed significantly with depth and basically similar trends were obtained as shown in Figures 4, 6, and 8. This observation may be considered as an indication of the low weathering intensity in this area. It is also obvious from these diffraction patterns that the reflections were generally sharp and well defined. However, the weak diffraction line commencing at approximately 4$^{o}$ 2$\theta$ is indicative of the presence of poorly crystallized material, which failed to show any definite peak. This type of diffraction pattern has been observed for soils in Oklahoma which have appreciable amounts of illite. Thus, the broadening may be attributed to interstratification of low surface area minerals, such as mica, and with high surface area minerals, such as vermiculite and montmorillonite. This interstratification was revealed in many samples by the resolution of a spacing near 27 $A^o$ which suggests that there is present some regularly alternating interstratified montmorillonite and illite ($18A^o + 10A^o = 28A^o$). The resolution of near $22A^o$ peaks in this fraction also suggests that there is present regularly alternating interstratified vermiculite and illite ($14A^o + 10A^o = 24A^o$). This conclusion is supported by the fact that the occurrence of the first order spacing requires that it arise from regularly rather than randomly interstratified layers.

The K saturation (as compared with Ca saturation) enhanced both the $10A^o$ and the $7.2A^o$ diffraction maxima, of most samples, dried at room temperature. This enhancement may be attributed in part to increased basal orientation of the particles in the K saturated specimens. Barshad (1948) attributed this phenomenon to the closure of $14A^o$ spacings of Mg-treated biotite to $10A^o$ on resaturation with K. This phenomenon is referred to as "Barshad Effect".

Even with the relatively intense $10A^o$ diffraction maximum for illite in the coarse clay fraction, the intensity was markedly increased by heating. This observation may indicate the closure of spacings greater than $10A^o$ due to interstratified vermiculite or montmorillonite with consequent decrease in randomness along the Z-axis, and/or due to the decrease in randomness of basal spacings with dehydration. The heat treatment, however, resulted in the disappearance of the 7.2A$^o$ maximum, confirming that the clay mineral was kaolinite.

The clay minerals in the fine clay fraction are poorly crystallized; this expression is used to describe the clay unit layers which are either disordered and/or in which the layers are stacked in a disorderly fashion. This poor crystallinity is indicated on X-ray diffractograms because the reflections are less intense, broad, and diffuse in contrast to the sharp, intense reflections of good crystalline material.

Because of the similarity of the x-ray diffraction patterns obtained for the fine clay fraction, only representative x-ray diffraction results from samples of the soils included in this study are presented (Figures 9-14). As shown, no distinct and sharp peaks for any of the crystalline materials were found in the fine clay fractions; instead, a broad peak at about 10.04A$^o$ and a weak peak at about 7.2A$^o$ were indicated. This trend was basically repeated for the fine clay fraction of all the soils of the eight watersheds. These broad, weak, and/or diffuse peaks that were observed for this clay fraction may be attributed to interstratification of layer silicates. Also, the particle size has an important effect on the quality of reflections. However, it is evident that illite and kaolinite are still the dominant clay minerals of the fine clay fractions of these soils.

## Runoff Properties of the Eight Watersheds

Table VIII shows the annual and the total surface runoff, and sediment yield from the eight watersheds for the period 1977-1981.

As indicated in Figures 15 through 19, the runoff characteristics of the various watersheds, with the exception of watershed FR4, were similar during the calibration period (1977 and 1978), especially in the later year. However, after the treatments were applied the losses of water and sediment were significantly influenced by the soil cover-treatment. The amount of sediment and runoff discharged from these watersheds following a runoff-producing storm is shown in Table XVII (a-e) (see Appendix). As shown in Table VIII, the five year total sediment loss recovered from FR1, 2, 3, 4, which were in grass, was much lower than the amounts discharged from the cultivated watersheds (FR5, 6, 7, and 8). This demonstrates that the soil cover provided by grass effectively reduced sediment losses. The effectiveness of the grass cover in reducing soil erosion was clearly demonstrated in 1981 when those watersheds in grass (FR1-4) practically eliminated any erosional activity.

The USDA Soil Conservation Service in Oklahoma has designated 5 tons/acre-year (11,200 kg/ha-year) as the allowable limit for soil loss. Thus, despite the large differences observed between the grass-covered watersheds

## TABLE VIII

## ANNUAL AND TOTAL RUNOFF AND SEDIMENT YIELD FOR EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1977-1981

| Watershed | Surface Runoff (cm) | | | | | | Sediment Yield (kg/ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 77* | 78* | 79** | 80 | 81 | Total | 77 | 78 | 79 | 80 | 81 | Total |
| FR1 | 3.13 | 2.49 | 4.14 | 5.10 | 0.00 | 14.86 | 74.3 | 16.8 | 32.3 | 9.7 | 0.0 | 133.1 |
| FR2 | 1.89 | 1.87 | 2.76 | 8.35 | 0.00 | 14.87 | 74.3 | 16.9 | 25.6 | 12.8 | 0.0 | 129.6 |
| FR3 | 2.90 | 2.19 | 2.00 | 6.77 | 0.00 | 13.86 | 93.3 | 11.5 | 38.5 | 15.7 | 0.0 | 159.0 |
| FR4 | 3.29 | 1.60 | 2.55 | 4.26 | 0.00 | 11.70 | 274.3 | 5.9 | 24.3 | 12.9 | 0.0 | 317.4 |
| FR5 | 1.55 | 0.84 | 4.04 | 1.25 | 1.94 | 9.62 | 32.5 | 3.4 | 582.7 | 126.2 | 481.3 | 1226.1 |
| FR6 | 0.96 | 1.31 | 3.41 | 0.23 | 2.73 | 8.64 | 25.3 | 5.1 | 770.7 | 3.1 | 510.6 | 1314.8 |
| FR7 | 0.72 | 1.05 | 3.80 | 1.18 | 0.13 | 6.88 | 35.0 | 3.9 | 588.6 | 57.1 | 3.0 | 687.6 |
| FR8 | 0.90 | 1.67 | 2.23 | 1.64 | 0.29 | 6.73 | 56.1 | 5.9 | 527.5 | 107.3 | 46.9 | 743.7 |

*Calibration period of watershed.

**Treatments were imposed.

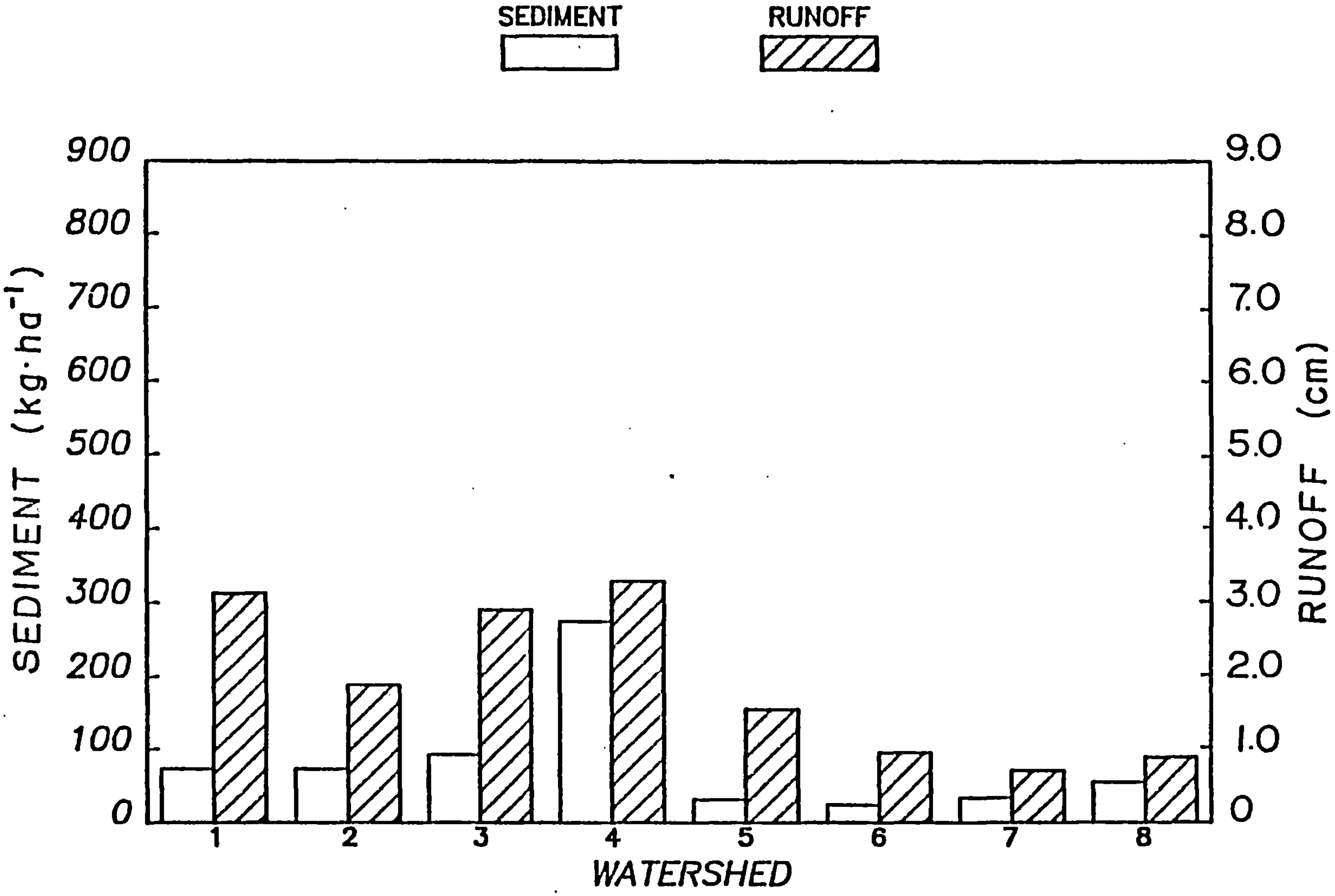

Figure 15. Sediment and Runoff 1977

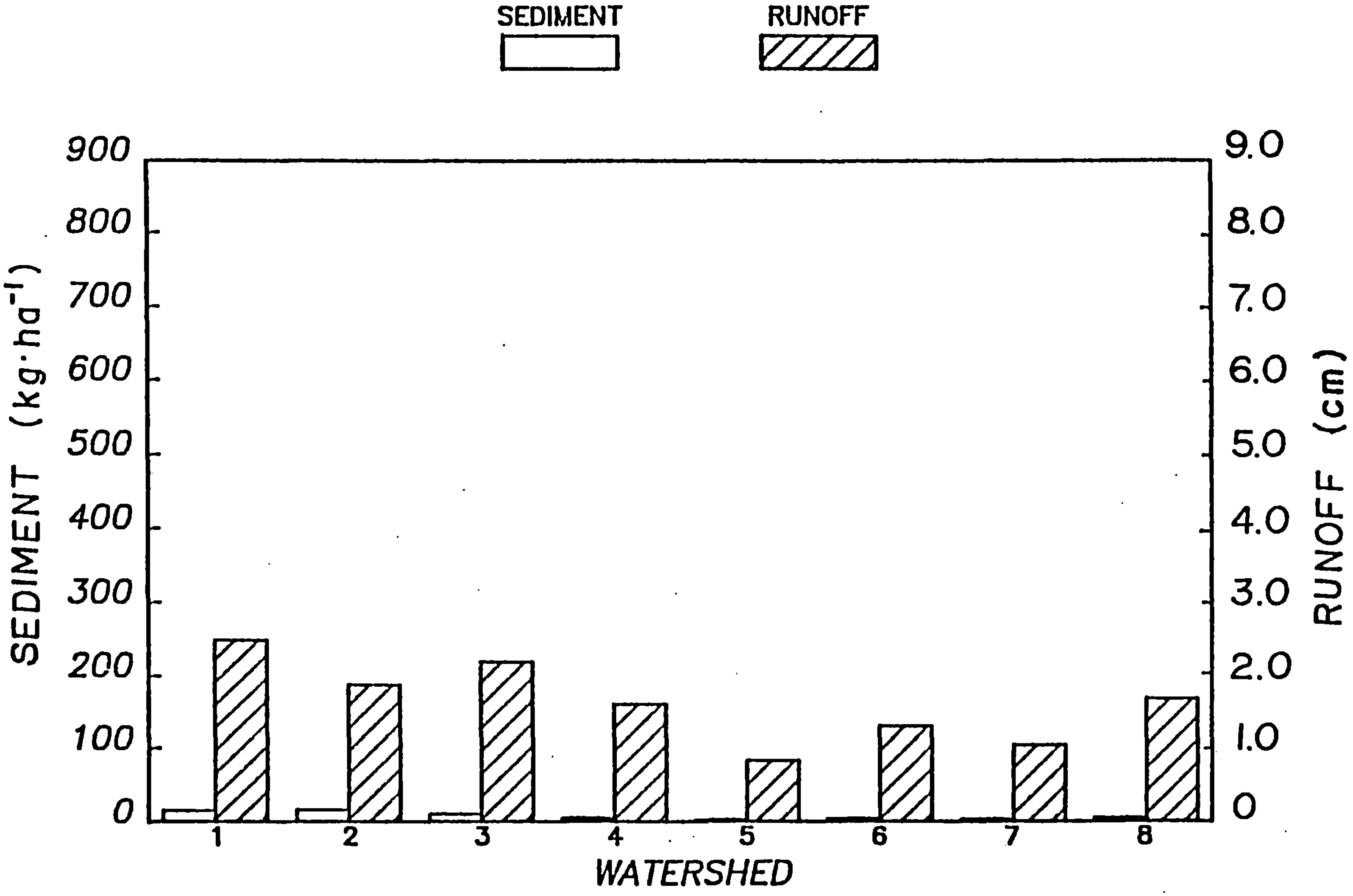

Figure 16. Sediment and Runoff 1978

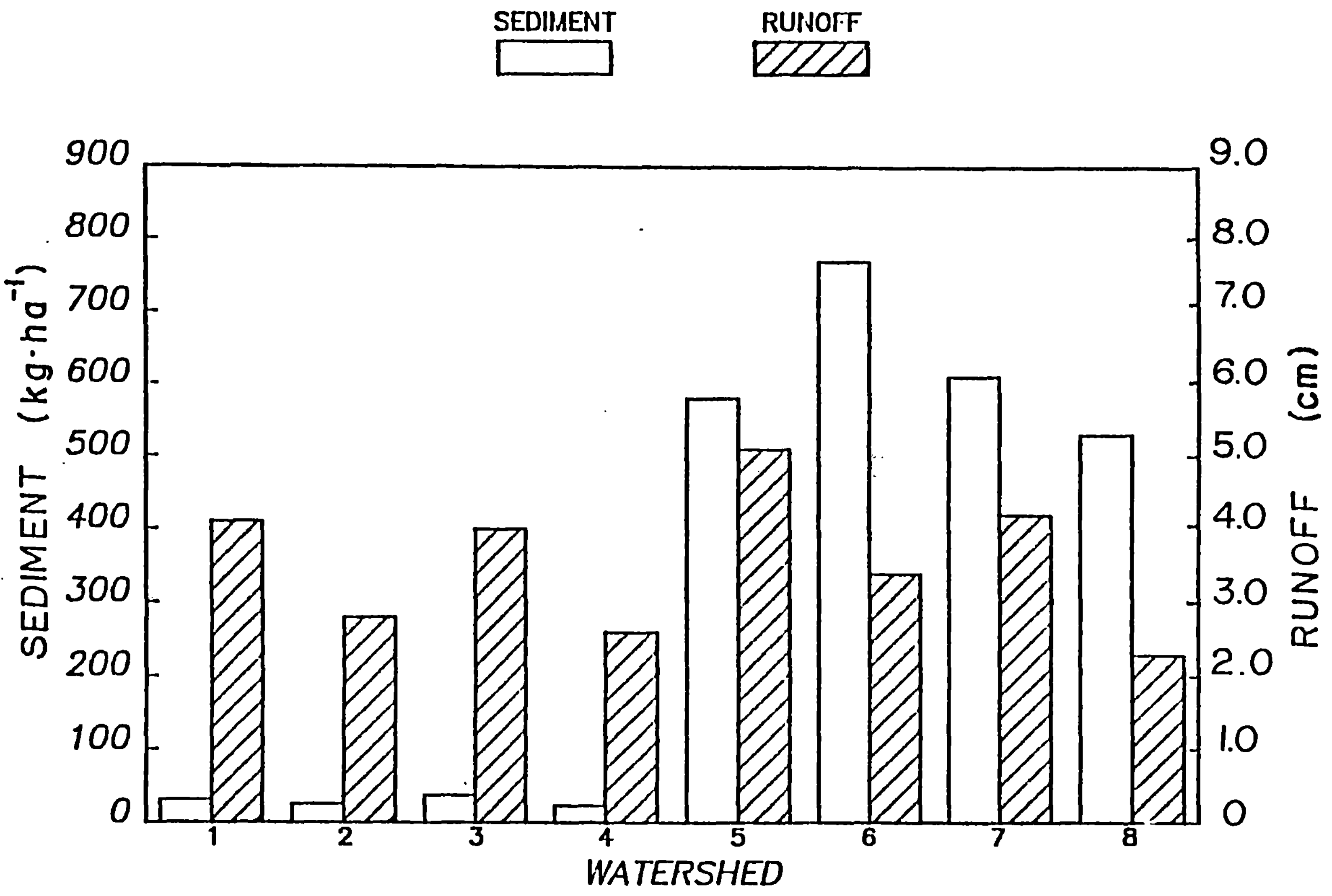

Figure 17. Sediment and Runoff 1979

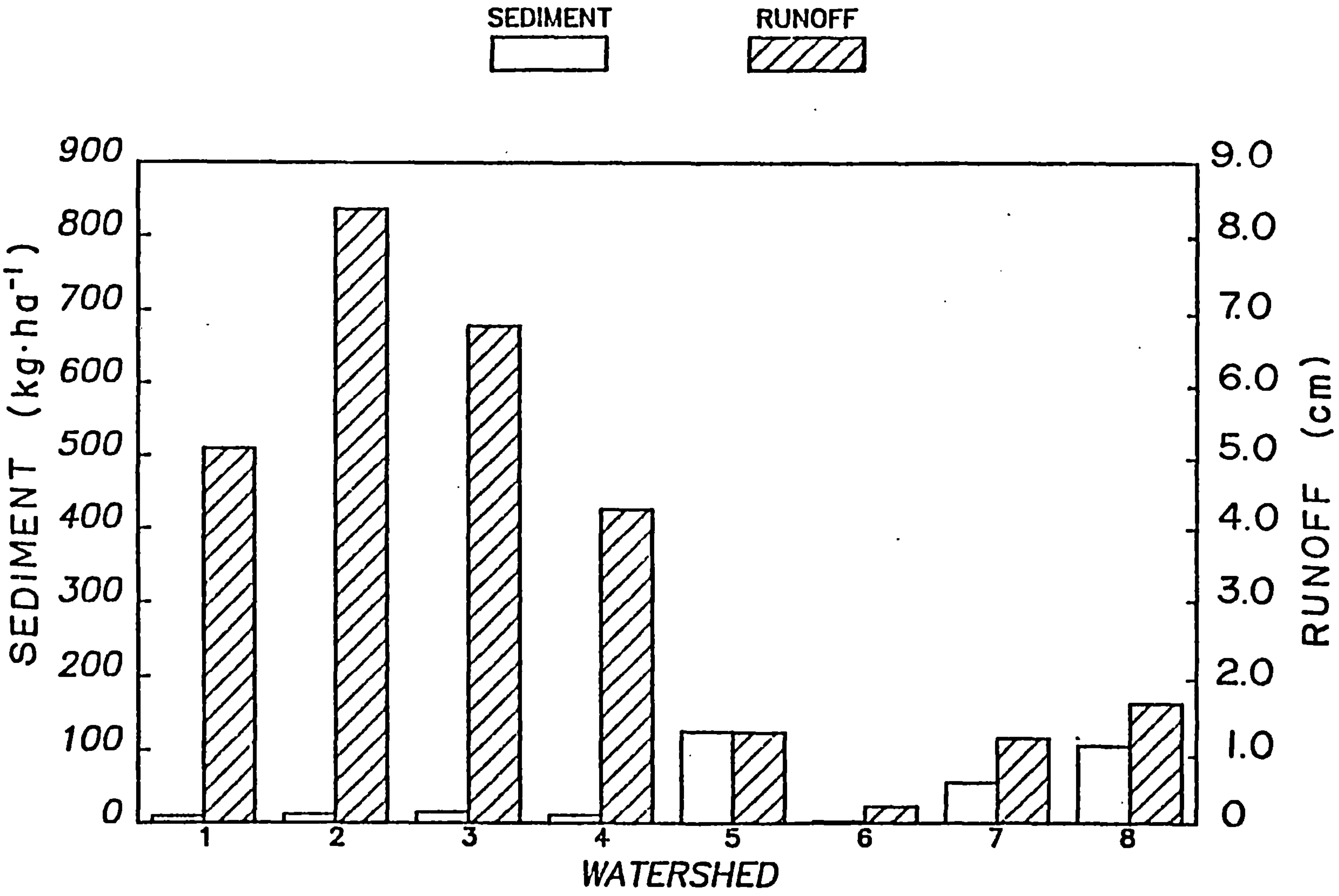

Figure 18. Sediment and Runoff 1980

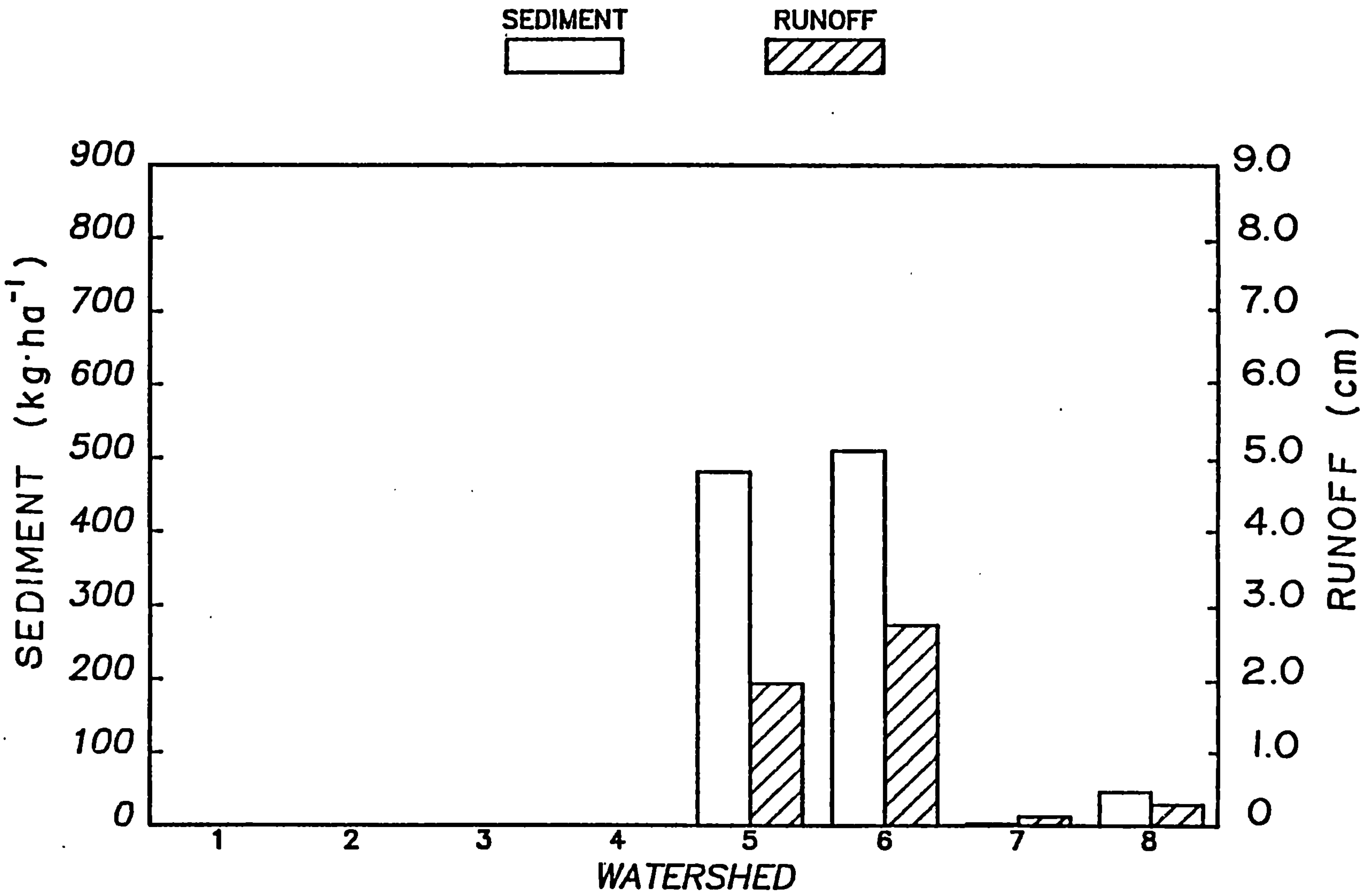

Figure 19. Sediment and Runoff 1981

and the cultivated watersheds, the recorded soil losses from each watershed remained far below the allowable limit. The findings also indicate that the soils in these watersheds were resistant to erosion. This might be attributed to their high degree of aggregation, caused in part by the aggregating effect of grasses grown in previous years.

The annual water runoff losses from the various watersheds are also presented in Table VIII. As shown, the five-year total water runoff losses, in contrast to sediment losses, were higher for grass-covered watersheds (FR1-4) as compared to the cultivated ones (FR5-8). This indicates that, although the grass cover was effective in reducing soil losses, it proved to be less effective in reducing water runoff losses. This may be attributed to higher water infiltration rates of the cultivated watersheds caused by tillage.

The water runoff in 1979 from watersheds FR1 and 5 were similar: 4.14 and 4.04 cm, respectively. However, the sediment yield of the latter was more than 18 times higher. This implies that the amount of soil loss and the volume of runoff water are not directly related.

The variability of the runoff quantity and quality of a watershed from year to year is shown in Table VIII. Although, the highest sediment load in 1979 was recovered from watershed FR6 (770.7 kg/ha), the sediment load discharged from the same watershed in 1980 was the lowest (3.1 kg/ha) as compared to the other watersheds.

It is important to note that the number of runoff events occurring on the cultivated watersheds were more than those recorded for the grass watersheds (Table XVII (a-e), Appendix). This reduction in the frequency of runoff events reduces the loss of soil, and hence the pollution of surface water resources.

The annual total and soluble N losses from the various watersheds are shown in Table IX (a-e). The total N losses ranged from 0.064 - 3.278 kg/ha-year.

Menzel et al. (1978) found that the sediment and nutrient discharge variability from year to year for a particular watershed is enormous. They claimed that long period records are essential to compare the effectiveness of various management practices.

The 5-year average losses of total-N indicated that the lowest N loss was recovered from watershed FR1 (0.49 kg/ha-year), and the highest loss was recorded for watershed FR6 (1.385 kg/ha-year).

Although these results demonstrate the differences in the effectiveness of the various treatments in this study, it is evident that these losses are low and not of practical agronomic significance.

On the other hand, the annual concentration of soluble-N ranged from 0.005 - 1.347 kg/ha (0.002 - 0.673 ppm) which indicates that the runoff water from the various watersheds, during this study, was not of eutrophic nature.

It is noticeable from the 5-year average N loss that

## TABLE IXa

## ANNUAL LOSS OF N AND P BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1977

| Watershed | Loss of nitrogen by surface runoff (kg/ha/year) | | | Percent Sediment N | Loss of phosphorus by surface runoff (kg/ha/year) | | | Percent Sediment P |
|---|---|---|---|---|---|---|---|---|
| | Total-N | Soluble-N | Sediment-N | | Total-P | Soluble-P | Sediment-P | |
| FR1 | 0.524 | 0.031 | 0.493 | 93.5 | 0.119 | 0.039 | 0.080 | 57.6 |
| FR2 | 0.530 | 0.024 | 0.506 | 94.1 | 0.104 | 0.012 | 0.092 | 75.3 |
| FR3 | 0.511 | 0.031 | 0.480 | 93.2 | 0.107 | 0.026 | 0.081 | 66.7 |
| FR4 | 0.407 | 0.026 | 0.381 | 92.6 | 0.088 | 0.038 | 0.050 | 52.5 |
| FR5 | 0.234 | 0.016 | 0.218 | 92.3 | 0.069 | 0.022 | 0.047 | 54.5 |
| FR6 | - | - | - | - | - | - | - | - |
| FR7 | 0.137 | 0.005 | 0.132 | 93.8 | 0.041 | 0.009 | 0.032 | 63.8 |
| FR8 | 0.155 | 0.008 | 0.147 | 92.3 | 0.043 | 0.013 | 0.030 | 54.5 |

TABLE IXb

ANNUAL LOSS OF N AND P BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1978

| Watershed | Loss of nitrogen by surface runoff (kg/ha/year) | | | Percent Sediment N | Loss of phosphorus by surface runoff (kg/ha/year) | | | Percent Sediment P |
|---|---|---|---|---|---|---|---|---|
| | Total-N | Soluble-N | Sediment-N | | Total-P | Soluble-P | Sediment-P | |
| FR1 | 0.300 | 0.027 | 0.273 | 94.3 | 0.039 | 0.036 | 0.003 | 37.3 |
| FR2 | 0.191 | 0.028 | 0.163 | 93.0 | 0.022 | 0.019 | 0.003 | 58.4 |
| FR3 | 0.228 | 0.030 | 0.198 | 86.7 | 0.024 | 0.017 | 0.007 | 27.3 |
| FR4 | 0.176 | 0.022 | 0.154 | 91.6 | 0.021 | 0.016 | 0.005 | 49.1 |
| FR5 | 0.080 | 0.011 | 0.069 | 86.5 | 0.015 | 0.011 | 0.004 | 27.8 |
| FR6 | 0.124 | 0.020 | 0.104 | 84.4 | 0.030 | 0.027 | 0.003 | 8.7 |
| FR7 | 0.107 | 0.019 | 0.088 | 94.8 | 0.028 | 0.022 | 0.006 | 60.3 |
| FR8 | 0.156 | 0.020 | 0.136 | 87.2 | 0.040 | 0.300 | 0.010 | 25.0 |

## TABLE IXc

## ANNUAL LOSS OF N AND P BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1979

| Watershed | Loss of nitrogen by surface runoff (kg/ha/year) | | | Percent Sediment N | Loss of phosphorus by surface runoff (kg/ha/year) | | | Percent Sediment P |
|---|---|---|---|---|---|---|---|---|
| | Total-N | Soluble-N | Sediment-N | | Total-P | Soluble-P | Sediment-P | |
| FR1 | 0.806 | 0.064 | 0.742 | 89.4 | 0.071 | 0.043 | 0.028 | 39.4 |
| FR2 | 1.799 | 1.347 | 0.452 | 49.3 | 0.042 | 0.025 | 0.017 | 48.3 |
| FR3 | 0.815 | 0.069 | 0.746 | 90.1 | 0.075 | 0.041 | 0.034 | 43.6 |
| FR4 | 1.770 | 1.209 | 0.561 | 50.6 | 0.126 | 0.087 | 0.039 | 42.3 |
| FR5 | 3.728 | 0.165 | 3.563 | 88.4 | 0.754 | 0.056 | 0.698 | 69.6 |
| FR6 | 3.223 | 0.196 | 3.027 | 77.7 | 0.802 | 0.102 | 0.700 | 47.9 |
| FR7 | 2.896 | 0.223 | 2.673 | 74.5 | 0.567 | 0.124 | 0.443 | 64.6 |
| FR8 | 1.960 | 0.091 | 1.869 | 84.2 | 0.367 | 0.043 | 0.324 | 77.1 |

## TABLE IXd

## ANNUAL LOSS OF N AND P BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1980

| Watershed | Loss of nitrogen by surface runoff (kg/ha/year) | | | Percent Sediment N | Loss of phosphorus by surface runoff (kg/ha/year) | | | Percent Sediment P |
|---|---|---|---|---|---|---|---|---|
| | Total-N | Soluble-N | Sediment-N | | Total-P | Soluble-P | Sediment-P | |
| FR1 | 0.806 | 0.217 | 0.589 | 71.9 | 0.092 | 0.065 | 0.027 | 29.5 |
| FR2 | 2.034 | 0.634 | 1.400 | 55.6 | 0.411 | 0.292 | 0.119 | 38.3 |
| FR3 | 1.138 | 0.171 | 0.967 | 84.1 | 0.107 | 0.057 | 0.050 | 44.3 |
| FR4 | 0.378 | 0.081 | 0.297 | 74.4 | 0.105 | 0.099 | 0.006 | 10.6 |
| FR5 | 0.524 | 0.096 | 0.428 | 80.2 | 0.085 | 0.010 | 0.075 | 85.3 |
| FR6 | 0.064 | 0.019 | 0.045 | 70.0 | 0.009 | 0.004 | 0.005 | 62.0 |
| FR7 | 0.495 | 0.054 | 0.441 | 88.2 | 0.086 | 0.015 | 0.071 | 80.5 |
| FR8 | 1.119 | 0.067 | 1.052 | 90.4 | 0.176 | 0.013 | 0.163 | 88.9 |

## TABLE IXe

## ANNUAL LOSS OF N AND P BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1981

| Watershed | Loss of nitrogen by surface runoff (kg/ha/year) | | | Percent Sediment N | Loss of phosphorus by surface runoff (kg/ha/year) | | | Percent Sediment P |
|---|---|---|---|---|---|---|---|---|
| | Total-N | Soluble-N | Sediment-N | | Total-P | Soluble-P | Sediment-P | |
| FR1 | 0.000 | 0.000 | 0.000 | 0.0 | 0.000 | 0.000 | 0.000 | 0.0 |
| FR2 | 0.000 | 0.000 | 0.000 | 0.0 | 0.000 | 0.000 | 0.000 | 0.0 |
| FR3 | 0.000 | 0.000 | 0.000 | 0.0 | 0.000 | 0.000 | 0.000 | 0.0 |
| FR4 | 0.000 | 0.000 | 0.000 | 0.0 | 0.000 | 0.000 | 0.000 | 0.0 |
| FR5 | 1.380 | 0.057 | 1.323 | 98.9 | 0.238 | 0.029 | 0.209 | 90.7 |
| FR6 | 3.513 | 0.042 | 3.472 | 97.9 | 0.748 | 0.601 | 0.147 | 40.8 |
| FR7 | 0.099 | 0.002 | 0.097 | 97.4 | 0.024 | 0.009 | 0.015 | 64.7 |
| FR8 | 0.210 | 0.011 | 0.199 | 94.5 | 0.042 | 0.007 | 0.035 | 81.2 |

the bulk portion of N was associated with the sediment. This is in agreement with the findings of Schuman et al. (1973). The results also suggest that the losses of N can be greatly reduced by effective erosion control practices, since a large part of the total N lost is associated with the sediment.

Phosphorus (P) is relatively immobile in soil. Several investigators (Romkens et al., 1973; Burwell et al., 1975) have found that the major portion of P lost from agricultural lands is adsorbed to the solid fraction, especially the soil colloids. Taylor (1967) claimed that the total P contents of sediment load tell very little about the rate at which P of agricultural origin moves into rivers and lakes over periods of time. He suggested interpreting the effect of P on water quality in terms of the percentages of P between dissolved and adsorbed forms. He further claimed that the percent of P entering streams in dissolved forms is more significant.

The soluble and sediment P loss from the various watersheds and the percent of P associated with sediment, on an annual basis, are presented in Table IX (a-e). As shown, the percent of sediment-P for a particular watershed varied from year to year. This is in contrast with sediment-N, which showed a more consistent pattern. The high percentage of P associated with the liquid runoff implies that the reduction of P discharged from these watersheds, under the prevailing conditions, requires both the control of sediment and water runoff. This is again in contrast with N removal, which can basically be eliminated by the control of soil erosion.

Because of the variability from year to year in the amount of sediment load, volume of runoff, and nutrient concentrations discharged from a particular watershed, the 5-year average concentrations of soluble and sediment N and P, on unit basis of water and sediment yield, were computed and reported in Tables X and XI. The nutrient losses on unit basis were calculated by dividing the soluble and sediment N and P losses by the corresponding water runoff volume and sediment yield.

The soluble N loss per unit of runoff of the various watersheds, with the exception of watersheds FR2 and 4, were similar. The concentrations ranged from 0.0217 - 0.0440 kg/ha-cm. The highest soluble N concentration per unit of runoff was recovered from watersheds FR2 and 4 (0.1367 and 0.1143 kg N/ha-cm, respectively). The N loss per unit sediment shows that watersheds FR1 and 2 are similar to the control watershed (FR3). Also, the unit N concentrations discharged from watersheds FR4, 5, 6, 7, and 8 were very similar, ranging from 0.0044 - 0.0050 kg N/kg sediment.

It is evident that the unit concentration of N per unit sediment discharged from the control watershed is more than three times its concentration in watersheds FR4-8. This may indicate an inverse relationship between the N concentration in sediment and the amount of sediment discharge, which will

## TABLE X

## AVERAGE LOSS OF SOLUBLE AND SEDIMENT NITROGEN (N) PER UNIT OF WATER AND SEDIMENT YIELD FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA 1977-1981

| Watershed | Runoff (cm) | Sediment Yield (kg/ha) | Average Total N (kg/ha) | Nitrogen (N) Concentration | | | |
|---|---|---|---|---|---|---|---|
| | | | | Soluble N | | Sediment N | |
| | | | | kgN/ha | kg N/ha-cm | kgN/ha | kg N/kg sediment |
| FR1 | 14.86 | 133.1 | 0.487 | 0.339 | 0.0228 | 2.097 | 0.0157 |
| FR2 | 14.87 | 129.6 | 0.910 | 2.033 | 0.1367 | 2.521 | 0.0194 |
| FR3 | 13.86 | 159.0 | 0.538 | 0.301 | 0.0217 | 2.391 | 0.0150 |
| FR4 | 11.70 | 317.4 | 0.546 | 1.338 | 0.1143 | 1.393 | 0.0044 |
| FR5 | 9.62 | 1226.1 | 1.189 | 0.345 | 0.0359 | 5.601 | 0.0046 |
| FR6 | 8.64 | 1314.8 | 1.385 | 0.277 | 0.0321 | 6.648 | 0.0050 |
| FR7 | 6.88 | 687.6 | 0.747 | 0.303 | 0.0440 | 3.431 | 0.0050 |
| FR8 | 6.73 | 743.7 | 0.720 | 0.197 | 0.0293 | 3.403 | 0.0046 |

## TABLE XI

## AVERAGE LOSS OF SOLUBLE AND SEDIMENT PHOSPHORUS (P) PER UNIT OF WATER AND SEDIMENT YIELD FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA 1977-1981

| Watershed | Runoff (cm) | Sediment Yield (kg/ha) | Average Total P (kg/ha) | Phosphorus (P) Concentration | | | |
|---|---|---|---|---|---|---|---|
| | | | | Soluble P | | Sediment P | |
| | | | | kgP/ha | kg P/ha-cm | kgP/ha | kg P/kg sediment |
| FR1 | 14.86 | 133.1 | 0.064 | 0.183 | 0.0123 | 0.138 | 0.0010 |
| FR2 | 14.87 | 129.6 | 0.116 | 0.348 | 0.0234 | 0.231 | 0.0018 |
| FR3 | 13.86 | 159.0 | 0.063 | 0.141 | 0.0102 | 0.172 | 0.0011 |
| FR4 | 11.70 | 317.4 | 0.068 | 0.240 | 0.0205 | 0.100 | 0.0003 |
| FR5 | 9.62 | 1226.1 | 0.232 | 0.128 | 0.0133 | 1.033 | 0.0008 |
| FR6 | 8.64 | 1314.8 | 0.318 | 0.734 | 0.0849 | 0.855 | 0.0006 |
| FR7 | 6.88 | 687.6 | 0.149 | 0.179 | 0.0260 | 0.567 | 0.0008 |
| FR8 | 6.73 | 743.7 | 0.134 | 0.376 | 0.0559 | 0.562 | 0.0007 |

further indicate a higher selectivity for colloidal size fraction when the amount of sediment load is low, as suggested by Romkens (1973). This conclusion does not hold when one compares the weight of sediment load from watersheds FR4-8 for the period 1977-1981, which ranged from 317.4 - 1314.8 kg/ha, but the unit N loss per unit sediment for these watersheds was very similar. These findings indicate that, under the prevailing conditions of this study, the erosion process by water will not be selective when the annual sediment load discharged exceeds 60 kg/ha.

The unit concentration of P per unit sediment recovered from watershed FR1 was about 1.25 and 1.67 times its concentration in the sediment discharged from watersheds FR5 and 6, respectively. However, the sediment yield from watersheds FR5 and 6 was more than 9 times higher than that discharged from watershed FR1. This indicates that even though the sediment yields were quite different, the P concentration per unit sediment has not changed drastically. This fact was further demonstrated upon comparing the 5-year sediment discharge from watersheds FR5 and FR7 (1226.1 and 687.6 kg/ha, respectively), yet the unit concentration of P per unit sediment remains the same (0.0008 kg P/kg sediment).

The unit concentration of P per unit runoff showed that watersheds FR1, 3, and 5 had the lowest concentrations. The unit P concentrations in these watersheds ranged from 0.0102 - 0.0133 kg P/ha-cm. On the other hand, the unit concentrations of P discharged from watershed FR6 was the highest (0.0849 kg P/ha-cm). This indicates that the concentration of P in runoff water from watershed FR6 is more than 8 times its concentration in the runoff water of the control watershed (FR3).

It is interesting to note that although the volume of runoff discharged from watersheds FR1 and 2 are similar, the unit concentration of P per cm of runoff in the latter was two times higher.

The eroded material is different in composition from the original soil. Slater (1942) and Massey et al. (1952) noted that the erosive processes are more selective for organic matter and plant nutrients when the amount of soil material eroded is low.

Burrows et al. (1963) found that the loss of nutrients in runoff can be expressed in terms of an enrichment ratio (ER). The enrichment ratios for nitrogen (N) and phosphorus (P) of the eight watersheds are presented in Tables XII and XIII. These ratios were computed by dividing the concentration of the fertility constituent in the eroded material by its average concentration in the A-horizon of the soils in each watershed, both on oven-dry soil basis.

The N enrichment ratio (NER) and the P enrichment ratio (PER) indicate that the concentrations of these two nutrient elements in the sediment discharged from the eight watersheds were consistently higher than their average concentrations in the A-horizon of the soils occurring on

## TABLE XII

## ENRICHMENT RATIOS FOR N IN SEDIMENT DISCHARGED FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA

| Watershed | Sediment N |  | PPM Average TKN (A-horizon) | Nitrogen Enrichment Ratio (NER) |
|---|---|---|---|---|
|  | kg N/ kg sediment | PPM |  |  |
| FR1 | 0.0157 | 15700 | 1569 | 10.01 |
| FR2 | 0.0194 | 19400 | 1676 | 11.57 |
| FR3 | 0.0150 | 15000 | 1524 | 9.84 |
| FR4 | 0.0044 | 4400 | 1510 | 2.91 |
| FR5 | 0.0046 | 4600 | 1321 | 3.48 |
| FR6 | 0.0050 | 5000 | 1254 | 3.99 |
| FR7 | 0.0050 | 5000 | 1585 | 3.15 |
| FR8 | 0.0046 | 4600 | 1346 | 3.42 |

## TABLE XIII

## ENRICHMENT RATIOS FOR P IN SEDIMENT DISCHARGED FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA

| Watershed | Sediment P | | PPM Average P (A-horizon) | Phosphorus Enrichment Ratio (PER) |
|---|---|---|---|---|
| | kg P/ kg sediment | PPM | | |
| FR1 | 0.0010 | 1000 | 230 | 4.35 |
| FR2 | 0.0018 | 1800 | 257 | 7.00 |
| FR3 | 0.0011 | 1100 | 220 | 5.00 |
| FR4 | 0.0003 | 300 | 244 | 1.23 |
| FR5 | 0.0008 | 800 | 243 | 3.29 |
| FR6 | 0.0006 | 600 | 232 | 2.59 |
| FR7 | 0.0008 | 800 | 261 | 3.06 |
| FR8 | 0.0007 | 700 | 247 | 2.83 |

these watersheds. This demonstrates the selectivity of the erosive processes for colloidal soil particles with which these elements are basically associated. The degree of selectiveness, as measured by the enrichment ratio, varied between watersheds.

It is noticeable that the watersheds in grass, with the exception of FR4, which had lost smaller amounts of soil, had higher NER and PER than the cultivated watersheds. The highest NER and PER (11.57 and 7.00, respectively) were found for watershed FR2. However, the lowest NER and PER (2.91 and 1.23, respectively) were found for watershed FR4.

## TABLE XIV

## RELATIONSHIP BETWEEN VARIOUS WATERSHED CHARACTERISTICS AND THEIR CORRELATION COEFFICIENT (R) VALUES

| Relationship | Watershed | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Precipitation vs Runoff | 0.55 | 0.33 | 0.56 | 0.55 | 0.37 | 0.38 | 0.40 | 0.59 |
| Precipitation vs Sediment | 0.56 | 0.64 | 0.54 | 0.48 | -0.18 | -0.01 | 0.02 | 0.14 |
| Runoff vs-Sediment | 0.40 | 0.23 | 0.50 | 0.67 | 0.64 | 0.88 | 0.78 | 0.28 |
| TRN (a) vs Sol N (b) | 0.15 | 0.97 | 0.53 | 0.98 | -0.23 | 0.35 | 0.81 | 0.58 |
| TRN vs Sed N (c) | 0.94 | -0.01 | 0.97 | 0.77 | 1.00 | 0.96 | 0.77 | 0.94 |
| TRP (d) vs Sol P (e) | 0.56 | 0.93 | 0.46 | 0.97 | 0.66 | 0.91 | 0.96 | 0.93 |
| TRP vs Sed P (f) | 0.92 | 0.96 | 0.96 | 0.28 | 1.00 | 0.43 | 0.99 | 0.99 |

a = Total runoff N

b = Soluble runoff N

c = Sediment runoff N

d = Total runoff P

e = Soluble runoff P

f = Sediment runoff P

# CHAPTER V

## SUMMARY AND CONCLUSIONS

The texture of the soils occurring on these watersheds ranged from silt loam to loam.

The sand percent was higher in the A horizon of all the soils included in this study. The highest sand percent in the A and B horizons was found in the Milan series, and the lowest in the Kirkland series.

The silt contents of the various soils exhibited similar distribution trends as those for sand. However, the highest silt percent was found in Bethany and Kirkland, and the lowest was found in Milan.

The clay percent increased with depth in all soils except Milan, where no change was observed. The clay percent in the A and B horizons of Kirkland was found to be significantly higher than its percentage in the other four soils. This may be attributed to the movement of clay from upslopes with runoff water, and more downward movement of clay with percolating water (eluviation). On the other hand, no significant differences were found in the percent of clay in the A horizon of Aydellote, Bethany, Milan, and Renfrow soils.

The particle size distribution analysis indicated that as we move downslope, the sand percent decreases, and the silt and clay percents increase.

The soil reactions (pH) were acidic, ranging from 5.3 to 6.3. It was concluded that there were no significant differences in the pH of the five soils in the various watersheds. Significant relationships were found between the pH values measured in water solution and KCl solution. This was revealed by the r values (r = 0.60 and 0.87) for the A and the B horizons, respectively.

The EC of these soils was generally low. The highest EC values were found in the soils occurring on watersheds FR1 and 4. The statistical analysis indicated that the EC of the various soils was similar.

Poor relationships were found between the electrical conductivity (EC) and the total dissolved salts (TDSP). The r values were 0.52 and 0.35 for the A and the B horizons, respectively.

The water extractable Na increased with depth in all soils. The AOV indicated that the Na concentration in the A horizon of the five soils was not significantly different. However, in the B horizon, the water extractable Na concentration in Kirkland was significantly higher than the other four soils.

Contrary to Na, the water extractable K decreased with depth. This change in K concentration was found to be statistically significant. However, it was concluded that the concentrations of this form of K in Milan, Bethany, and

Aydellote soils were similar.

The water extractable Ca and Mg concentrations generally decreased with depth. However, the soils in watersheds FR5, 6, and 8 showed an opposite trend. The differences in the concentrations of these two soluble cations from the A to the B horizons were not significant. Also, it was found that the concentrations of these two elements in the various soils were similar.

The exchangeable Na was found to comprise a small fraction of the CEC of these soils. The concentrations of this cation in the A horizon of the various soils were not significantly different. However, it was significantly higher in the B horizon of Kirkland than in the B horizon of the other soils, as was found in the case of water extractable Na.

In contrast to exchangeable Na, the exchangeable K contents of the various soils decreased with depth. However, the amount of exchangeable K in all soils included in this study was found to be similar.

The exchangeable Ca and Mg were the dominant cations in these soils. The concentrations of these two cations were found to increase significantly with depth. Also, it was concluded that the Kirkland series has significantly higher amounts of these two cations as compared to the other four soil series.

The CEC in the B horizon of the various soils was generally higher than the CEC of the A horizon. This was in agreement with the concentration distribution patterns of the two most dominant cations, Ca and Mg. The relationships between the CEC and exchangeable Ca, as indicated by the correlation coefficients (r) in the A and B horizons of the different soils, were 0.92 and 0.93, respectively. The r values between the CEC and exchangeable Mg were 0.76 and 0.87 for the A and B horizons, respectively. Good correlation was found between the clay percent and the CEC in the B horizon (r = 0.67). It was concluded that the CEC of the Kirkland series was significantly different from the Aydellote, Milan, and Bethany series.

The OM percent and TKN both decreased with depth. The statistical analysis showed that this difference was significant at the 0.05 level of probability. However, it was concluded that the differences in the OM percent and TKN between soils were not significant, with the exception of a significant difference in TKN content of Kirkland as compared to the TKN found in Renfrow and Milan soils.

The OM percent and TKN were poorly correlated as revealed by the small correlation coefficient (r = 0.45 and 0.13 for the A and B horizons, respectively).

The data showed that the amount of total phosphorus (TP) in the five soil series was higher in the A horizon.

It was concluded that the TP contents of Milan, Aydellote, Renfrow, and Kirkland soils were similar. However, the TP found in Bethany was significantly different from that of Kirkland and Renfrow.

The Bray-1 P followed a similar trend as that observed for TP. The statistical analysis revealed that the concentrations of this available form of P is similar in the five soils included in this study. Significant relationships were found between the TP and Bray-1 P. This was reflected by the correlation coefficients between their concentrations in the A and B horizons ($r = 0.74$ and 0.61, respectively).

The perchloric acid digestion extractable cation concentrations were in the order K > Mg > Ca > Na.

The total Na (TNA) content and exchangeable Na of these soils followed a similar increasing trend with depth. The AOV showed that the TNA concentration in the A horizon of Milan soil was significantly different from its concentrations in the A horizons of Kirkland, Renfrow, and Bethany. It was also concluded that the TNA concentration in the B horizon of Kirkland was significantly different from that of Bethany, Milan, and Renfrow soils.

The perchloric acid extractable calcium (TCA) concentrations did not change significantly from the A to the B horizon, or between the various soils.

The total K (TK) and Mg (TMG) changed significantly with depth. Their concentrations in Kirkland soil were found to be significantly different from their concentrations in the other four soil series.

The perchloric acid extractable micronutrients Fe, Mn, Zn, and Cu were determined. The Fe contents of the various soil increased significantly with depth. It was concluded that the Fe content of Kirkland was significantly different from that of Bethany, Milan, and Renfrow. On the other hand, the Mn concentrations decreased with depth. The AOV indicated that the Mn concentrations in Renfrow, Aydellote, and Milan soils were similar. The statistical analysis revealed that the Zn and Cu concentrations in the five soil series were similar.

X-ray diffraction patterns were obtained by means of a recording x-ray diffractometer. Only the 001 reflections were recorded from randomly oriented aggregates. The diffraction data were obtained for samples that were (a) calcium saturated, (b) calcium saturated, ethylene glycol solvated, (c) potassium saturated, and (d) potassium saturated plus heating.

It was thus possible to reveal the presence of illite and kaolinite as the major clay mineral constituents of these soil clays. Kaolinite was identified by its characteristic reflections related to a 7.2 A$^{o}$ periodicity which disappeared following heat treatment. Illite, on the other hand, was identified on the basis of characteristic reflections related to a 10 A$^{o}$ periodicity which remained unchanged following treatment with ethylene glycol.

Montmorillonite, which expanded from 14 A$^{o}$ to 17 A$^{o}$ following ethylene glycol treatment, was detected in some samples. However, in no case was it thought that montmorillonite was a major component.

The x-ray spectrograms revealed that the coarse clay fractions had better crystallinity. Also, the kinds of clay minerals did not change from the A to the B horizons of the five soil series.

It was concluded that the clay mineralogy of these soils at this location was very similar.

The five-year average runoff and sediment yield indicated that watersheds FR1, 2, 3, and 4 had higher water runoff losses (2.34 - 2.97 cm) as compared with watersheds FR5, 6, 7, and 8 (1.35 - 1.92 cm). However, the average annual sediment yield showed that watersheds FR1, 2, 3, and 4 lost smaller amounts of sediment which ranged from 25.92 - 63.48 kg/ha, while the average annual sediment loss from watersheds FR5, 6, 7, and 8 for the same period ranged from 137.52 - 262.96 kg/ha. This indicates that the watersheds which had grass cover lost smaller amounts of soil, but higher amounts of runoff water than the cultivated watersheds. This is in agreement with the findings of Menzel et al. (1978).

It was concluded that the N and P losses from these watersheds under the prevailing conditions of this study are not agronomically significant, and not of eutrophic nature. Also, the amount of soil eroded in each watershed was lower than the tolerable level set by the Oklahoma Soil Conservation Service.

The computation of the percent of N and P associated with sediment and liquid runoff revealed that the control of soil erosion will basically eliminate N losses by runoff. However, to reduce P losses it appears that the control of soil and water runoff losses are equally important.

The NER and PER values indicated that the concentrations of N and P in the eroded material, irrespective of the soil cover, were higher than their concentrations in the A horizons of the soils occurring on these watersheds. This indicates the selectivity of the erosion process with water for the colloidal soil fractions which adsorb these plant nutrients.

The NER and PER values also revealed that under severe erosion, the eroded materials tend to approximate the composition of the eroding soil, that it is, in effect, "removed layer by layer." However, with more moderate runoff there is a selective removal of the finer fractions.

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# APPENDIX

## AYDELOTTE SERIES

Taxonomic Class: Fine, mixed, thermic Udertic Paleustalfs.

Typical Pedon: Aydelotte silt loam, on a convex 2 percent slope, in native grass vegetation. (Colors are for moist soils unless otherwise stated). Note - top two horizons appear to be a mantle of old alluvium.

A1--0 to 7 inches; dark brown (7.5YR 3/2) silt loam, brown to dark brown (7.5YR 4/2) dry; weak coarse platy breaking to moderate medium granular structure; hard, friable; many fine roots; less than 2 percent quartz gravel from 2 mm to 75 mm in size; (pH 6.8) neutral; clear smooth boundary.

B1--7 to 11 inches; reddish brown (5YR 4/3) silty clay loam, reddish brown (5YR 5/3) dry; moderate fine subangular blocky breaking to moderate medium granular structure; hard, friable; many fine roots; less than 2 percent quartz gravel from 2 mm to 75 mm in size; (pH 6.8) neutral; clear smooth boundary.

B21t--11 to 22 inches; reddish brown (5YR 4/4) silty clay, reddish brown (5YR 5/4) dry; moderate coarse subangular blocky structure; common fine roots; very hard, very firm; nearly continuous clay films; (pH 7.0) neutral; gradual smooth boundary.

B22t--22 to 36 inches; reddish brown (2.5YR 4/4 silty clay, red (2.5YR 5/6) dry; weak medium prismatic breaking to moderate medium blocky structure; extremely hard, extremely firm; common fine roots; nearly continuous clay films; few fine black concretions; (pH 8.0) moderately alkaline; gradual smooth boundary.

B31--36 to 51 inches; reddish brown (2.5YR 3/6) silty clay, red (2.5YR 4/6) dry; weak coarse blocky structure; very hard, very firm; few fine roots; patchy clay films; few fine black concretions; many coarse masses of soft calcium carbonate; slight effervescence (pH 8.0) moderately alkaline; gradual smooth boundary.

B32--51 to 72 inches; reddish brown (2.5YR 4/4) silty clay, reddish brown (2.5YR 5/4) dry; weak coarse subangular blocky structure; extremely hard, extremely firm; few fine roots; patchy clay films, common fine black concretions; many coarse masses of soft calcium carbonate; slight effervescence (pH 8.0) moderately alkaline; gradual smooth boundary.

C--72 to 76 inches; red (2.5YR 5/6) silty clay, light red (2.5YR 6/6) dry, massive with few laminated shale fragments; very hard, very firm; few fine black concretions; many masses of soft calcium carbonate; violent effervescence (pH 8.0) moderately alkaline.

Type Location: Stop No. 1, Plot No. 3 in SE 4, Sec. 4, T. 12 N., R. 8 W.

## BETHANY SERIES

Taxonomic Class: Fine, mixed, thermic Pachic Paleustolls.

Typical Pedon: Bethany silt loam, on a convex 3 percent slope, in native grass vegetation. (Colors are for moist soils unless otherwise stated.)

A11--0 to 6 inches; very dark gray (10YR 3/1) silt loam, dark grayish brown (10YR 4/2) dry; weak coarse platy breaking to moderate medium granular structure; hard, friable; many fine roots; (pH 6.8) neutral; clear smooth boundary.

A12--6 to 13 inches; very dark grayish brown (10YR 3/2) silt loam, brown to dark brown (10YR 4/3) dry; moderate medium granular structure; slightly hard, friable; many fine roots; (pH 6.5) slightly acid; clear smooth boundary.

B1--13 to 18 inches; dark brown (7.5YR 3/2) silty clay loam, brown to dark brown (10YR 4/3 dry; moderate fine subangular blocky breaking to moderate medium granular structure; hard, firm; many fine roots; patchy clay films; (pH 6.8) neutral; clear smooth boundary.

B21t--18 to 36 inches; very dark grayish brown (10YR 3/2) silty clay, brown to dark brown (10YR 4/3) dry; weak medium prismatic breaking to moderate medium blocky structure; extremely hard, extremely firm; common fine roots; nearly continuous clay films; few fine black concretions; slight effervescence (pH 8.0) moderately alkaline; clear smooth boundary.

B22t--36 to 50 inches; dark grayish brown (10YR 4/2) silty clay, brown (10YR 5/3) dry; few fine distinct dark gray (10YR 4/1) and strong brown (7.5YR 5/6) mottles; weak medium blocky structure; extremely hard, extremely firm; few fine roots; nearly continuous clay films; few fine black concretions; common calcium carbonate concretions; few small masses of soft calcium carbonate; slight effervescence (pH 8.0) moderately alkaline; gradual smooth boundary.

B23t--50 to 60 inches; brown to dark brown (10YR 4/3) silty clay; common coarse prominent yellowish red (5YR 4/6) mottles; weak coarse subangular blocky structure; extremely hard, extremely firm; few fine roots; nearly continuous clay films; common fine black concretions; common calcium carbonate concretions; few small masses of soft calcium carbonate; slight effervescence (pH 8.0) moderately alkaline; gradual smooth boundary.

B3--60 to 84 inches; yellowish red (5YR 4/6) silty clay; few fine faint strong brown (7.5YR 5/8) mottles; weak coarse subangular blocky structure; extremely hard, extremely firm; few fine roots; patchy clay films; ped faces coated with material similar in color to horizon above; common fine black concretions; few masses of calcium sulfate; (pH 8.0) moderately alkaline.

Type Location: Stop No. 4, Plot No. 2 in SE 4, Sec. 4, T. 12 N., R. 8 W.

## MILAN SERIES

Taxonomic Class: Fine, loamy, mixed, thermic Udic Arquistolls.

Typical Pedon: Milan loam, on a convex 3 percent slope, in native grass vegetation, quartz gravel throughout the profile. (Colors are for moist soils unless otherwise stated.)

A1--0 to 7 inches; dark brown (7.5YR 3/2) loam, brown (7.5YR 4/4) dry; weak coarse platy breaking to weak medium granular structure; hard, friable; many fine roots; 5 percent quartz gravel from 2 mm to 75 mm in size; (pH 6.3) slightly acid; clear smooth boundary.

B1--7 to 13 inches; reddish brown (5YR 4/3) clay loam, reddish brown (5YR 5/4) dry; weak medium subangular blocky breaking to moderate medium granular structure; very hard, firm; many fine roots; patchy clay films; 5 percent quartz gravel from 2 mm to 75 mm in size; (pH 6.6) neutral; clear smooth boundary.

B21t--13 to 30 inches; reddish brown (5YR 4/4) clay loam, yellowish red (5YR 5/6) dry; weak medium subangular blocky structure; very hard, very firm; common fine roots; patchy clay films; 10 percent quartz gravel from 2 mm to 75 mm in size; (pH 7.0) neutral; gradual smooth boundary.

B22t--30 to 40 inches; yellowish red (5YR 4/6) clay loam, yellowish red (5YR 5/6) dry, few coarse distinct red (2.5YR 5/8) mottles; weak coarse subangular blocky structure; very hard, very firm; few fine roots; patchy clay films; few fine black concretions; 10 percent quartz gravel from 2 mm to 75 mm in size; (pH 7.2) neutral; gradual smooth boundary.

B31--40 to 50 inches; red (2.5YR 4/6) gravelly sandy clay loam, red (2.5YR 5/6) dry, few medium distinct reddish brown (5YR 4/3) mottles; weak coarse subangular blocky structure; very hard, firm; few fine roots; patchy clay films; common fine black concretions; 15 percent quartz gravel from 2 mm to 75 mm in size; (pH 7.4) mildly alkaline; gradual smooth boundary.

B32--50 to 55 inches; red (2.5YR 4/6) gravelly sandy clay loam, red (2.5YR 5/6) dry; weak coarse subangular blocky structure; hard, firm; few fine roots; patchy clay films; common fine black concretions; 25 percent quartz gravel from 2 mm to 75 mm in size; (pH 7.5) mildly alkaline.

Type Location: Stop No. 2, Plot No. 3 in SE 4, Sec. 4, T. 12 N., R. 8 W.

## KIRKLAND SERIES

Taxonomic Class: Fine, mixed, thermic Udertic Paleustolls.

Typical Pedon: Kirkland silt loam, on a single 2 percent slope, in native grass vegetation. (Colors are for moist soils unless otherwise stated.)

A1--0 to 12 inches; dark brown (7.5YR 3/2) silt loam, brown (7.5YR 4/3) dry; weak coarse platy breaking to moderate medium granular structure; hard, friable; many fine roots; (pH 6.2) slightly acid; abrupt smooth boundary.

B21t--12 to 23 inches; dark brown (7.5YR 4/3) silty clay, brown (7.5YR 5/3) dry; moderate medium blocky structure; very hard, very firm; common fine roots; nearly continuous clay films; few fine black concretions; (pH 6.8) neutral; gradual smooth boundary.

B22t--23 to 35 inches; brown to dark brown (7.5YR 4/2) silty clay, brown (7.5YR 5/2) dry; few medium distinct strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; extremely hard, very firm; common fine roots, nearly continuous clay films; few fine black concretions; (pH 7.5) mildly alkaline; gradual smooth boundary.

B23tca--35 to 43 inches; brown to dark brown (7.5YR 4/2) silty clay, brown (7.5YR 5/2) dry; few medium distinct strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; extremely hard, very firm; few fine roots; nearly continuous clay films; few fine black concretions; few calcium carbonate concretions; few masses of soft calcium carbonate; slight effervescence (pH 8.0) moderately alkaline; gradual smooth boundary.

B24tca--43 to 53 inches; brown to dark brown (10YR 4/3) silty clay, brown (10YR 5/3) dry; common medium distinct strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; extremely hard, very firm; few fine roots; nearly continuous clay films; few fine black concretions; common calcium carbonate concretions, few masses of calcium carbonate; slight effervescence (pH 8.0) moderately alkaline; gradual smooth boundary.

B31--53 to 65 inches; brown to dark brown (7.5YR 4/4) silty clay, brown (7.5YR 5/4) dry; common coarse distinct strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; extremely hard, extremely firm; few fine roots; patchy clay films; few fine black concretions; few calcium carbonate concretions; few masses of soft calcium carbonate; (pH 8.0) moderately alkaline; gradual smooth boundary.

B32--65 to 82 inches; yellowish red (5YR 4/6) silty clay, yellowish red (5YR 5/6) dry; common medium distinct grayish brown (10YR 5/2) and strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; extremely hard, extremely firm; few fine roots; patchy clay films; common fine black concretions; few calcium carbonate concretions; few masses of soft calcium carbonate; (pH 8.0) moderately alkaline.

Type Location: Stop No. 3, Plot No. 5 in SE 4, Sec. 4, T. 12 N., R. 8 W.

## RENFROW SERIES

Taxonomic Class: Fine, mixed, thermic Udertic Paleustolls.

Typical Pedon: Renfrow silt loam, on a convex 3 percent slope, in native grass vegetation. (Colors are for moist soils unless otherwise stated.)

A1--0 to 9 inches; dark brown (7.5YR 3/2) silt loam, brown (7.5YR 4/2) dry; moderate medium granular structure; hard, friable; many fine roots; (pH 6.8) neutral; clear smooth boundary.

B1--9 to 13 inches; dark reddish brown (5YR 3/2) silty clay loam, reddish brown (5YR 4/3) dry; moderate medium subangular blocky breaking to moderate medium granular structure; hard, firm; many fine roots; patchy clay films; (pH 7.0) neutral; clear smooth boundary.

B2t--13 to 25 inches; reddish brown (5YR 4/3) silty clay, reddish brown (5YR 4/4) dry; moderate medium subangular blocky structure; extremely hard, very firm; common fine roots; nearly continuous clay films; (pH 7.5) mildly alkaline; clear smooth boundary.

B31--25 to 47 inches; reddish brown (5YR 4/4) silty clay, yellowish red (5YR 4/6) dry; weak coarse subangular blocky structure; extremely hard, very firm; few fine roots; nearly continuous clay films; common fine black concretions; common $CaCO_3$ concretions, few masses of soft $CaCO_3$; slightly effervescent; (pH 8.0) moderately alkaline; clear smooth boundary.

B32--47 to 63 inches; dark red (2.5YR 3/6) silty clay, red (2.5YR 4/6) dry; weak coarse subangular blocky structure; extremely hard, very firm; few fine roots; patchy clay films; few fine black concretions; few $CaCO_3$ concretions, few masses of soft $CaCO_3$; slightly effervescent; (pH 8.0) moderately alkaline; clear smooth boundary.

BC--63 to 74 inches; red (2.5YR 4/6) silty clay with bits of weakly laminated shale, red (2.5YR 5/6) dry; weak coarse subangular blocky structure; very hard, very firm; few fine roots; patchy clay films; few fine black concretions; few masses calcium sulfate crystals; many masses soft $CaCO_3$; strongly effervescent; (pH 8.0) moderately alkaline.

Type Location: Stop No. 1, Plot No. 1 in SE 4, Sec. 4, T. 12 N., R. 8.

## TABLE XV

## FERTILIZER SUMMARY SHEET[1] EL RENO WATERSHEDS

| Watershed (FR) | Season | N | | | $P_2O_5$ | | | $K_2O$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 78 | 79 | 80 | 78 | 79 | 80 | 78 | 79 | 80 |
| 1 | Spring | | | | | | | | | |
| | Fall | | | | | | | | | |
| 2 | Spring | | 50 | 50 | | | 20 | | | |
| | Fall | | | | | | | | | |
| 3 | Spring | | | | | | | | | |
| | Fall | | | | | | | | | |
| 4 | Spring | | 50 | 50 | | | 20 | | | |
| | Fall | | | | | | | | | |
| 5 | Spring | | 34 | 34 | | | | | | |
| | Fall | 75 | 48 | | 33 | 60 | | | 18 | |
| 6 | Spring | | 34 | 34 | | | | | | |
| | Fall | 75 | 48 | | 33 | 60 | | | 18 | |
| 7 | Spring | | 34 | | | | | | | |
| | Fall | 75 | 24 | | 33 | 30 | | | 9 | |
| 8 | Spring | | | | | | | | | |
| | Fall | 75 | 24 | | 33 | 30 | | | 9 | |

[1] Values are given as #/Ac (0.9 #/Ac is equivalent to 1 kg/ha).

# TABLE XVIa

## DETAILED N AND P LOSSES BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1977

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR1 | 1.15 | 0.368 | 0.09 | 0.022 | 1.06 | 0.346 | 0.42 | 0.102 | 0.11 | 0.027 | 0.31 | 0.075 |
| | 2.26 | 0.156 | 0.13 | 0.009 | 2.13 | 0.147 | 0.24 | 0.017 | 0.17 | 0.012 | 0.07 | 0.005 |
| FR2 | 3.01 | 0.442 | 0.11 | 0.016 | 2.90 | 0.426 | 0.62 | 0.091 | 0.03 | 0.004 | 0.59 | 0.087 |
| | 2.09 | 0.088 | 0.19 | 0.008 | 1.90 | 0.080 | 0.31 | 0.013 | 0.20 | 0.008 | 0.11 | 0.005 |
| FR3 | 1.71 | 0.433 | 0.10 | 0.025 | 1.61 | 0.408 | 0.38 | 0.096 | 0.08 | 0.020 | 0.30 | 0.076 |
| | 2.11 | 0.078 | 0.16 | 0.006 | 1.95 | 0.072 | 0.31 | 0.011 | 0.15 | 0.006 | 0.16 | 0.005 |
| FR4 | 1.14 | 0.333 | 0.07 | 0.020 | 1.07 | 0.313 | 0.26 | 0.076 | 0.11 | 0.032 | 0.15 | 0.044 |
| | 1.99 | 0.074 | 0.16 | 0.006 | 1.83 | 0.068 | 0.33 | 0.012 | 0.17 | 0.006 | 0.16 | 0.006 |

TABLE XVIa (Continued)

| Water-shed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR5 | 1.42 | 0.183 | 0.09 | 0.012 | 1.33 | 0.171 | 0.45 | 0.058 | 0.12 | 0.015 | 0.33 | 0.043 |
| | 1.98 | 0.051 | 0.17 | 0.004 | 1.81 | 0.047 | 0.43 | 0.011 | 0.28 | 0.007 | 0.15 | 0.004 |
| FR6 | - | - | - | - | - | - | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| FR7 | 1.85 | 0.113 | 0.05 | 0.003 | 1.80 | 0.110 | 0.59 | 0.036 | 0.10 | 0.006 | 0.49 | 0.030 |
| | 2.20 | 0.024 | 0.20 | 0.002 | 2.00 | 0.022 | 0.46 | 0.005 | 0.28 | 0.003 | 0.18 | 0.002 |
| FR8 | 1.58 | 0.115 | 0.06 | 0.004 | 1.52 | 0.111 | 0.47 | 0.034 | 0.09 | 0.007 | 0.38 | 0.027 |
| | 2.33 | 0.040 | 0.24 | 0.004 | 2.09 | 0.036 | 0.52 | 0.009 | 0.36 | 0.006 | 0.16 | 0.003 |

## TABLE XVIb

## DETAILED N AND P LOSSES BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1978

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR1 | 1.13 | 0.265 | 0.11 | 0.026 | 1.02 | 0.239 | 0.14 | 0.033 | 0.14 | 0.033 | 0.00 | 0.000 |
| | 2.59 | 0.035 | 0.10 | 0.001 | 2.49 | 0.034 | 0.45 | 0.006 | 0.23 | 0.003 | 0.22 | 0.003 |
| FR2 | 0.97 | 0.176 | 0.15 | 0.027 | 0.82 | 0.149 | 0.10 | 0.018 | 0.10 | 0.018 | 0.00 | 0.000 |
| | 2.59 | 0.015 | 0.10 | 0.001 | 2.49 | 0.014 | 0.67 | 0.004 | 0.22 | 0.001 | 0.45 | 0.003 |
| FR3 | 1.05 | 0.228 | 0.14 | 0.030 | 0.91 | 0.198 | 0.11 | 0.024 | 0.08 | 0.017 | 0.03 | 0.007 |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| FR4 | 1.08 | 0.165 | 0.14 | 0.021 | 0.94 | 0.144 | 0.12 | 0.018 | 0.10 | 0.015 | 0.02 | 0.003 |
| | 1.66 | 0.011 | 0.09 | 0.001 | 1.57 | 0.010 | 0.43 | 0.003 | 0.18 | 0.001 | 0.25 | 0.002 |

TABLE XVIb (Continued)

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR5 | 0.96 | 0.080 | 0.13 | 0.011 | 0.83 | 0.069 | 0.18 | 0.015 | 0.13 | 0.011 | 0.05 | 0.004 |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| FR6 | 0.96 | 0.124 | 0.15 | 0.020 | 0.81 | 0.104 | 0.23 | 0.030 | 0.21 | 0.027 | 0.02 | 0.003 |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| FR7 | 0.96 | 0.100 | 0.18 | 0.019 | 0.78 | 0.081 | 0.25 | 0.026 | 0.21 | 0.022 | 0.04 | 0.004 |
| | 4.83 | 0.007 | 0.12 | 0.000 | 4.71 | 0.007 | 1.11 | 0.002 | 0.33 | 0.000 | 0.78 | 0.002 |
| FR8 | 0.94 | 0.156 | 0.12 | 0.020 | 0.82 | 0.136 | 0.24 | 0.040 | 0.18 | 0.30 | 0.06 | 0.010 |
| | - | - | - | - | - | - | - | - | - | - | - | - |

## TABLE XVIc

## DETAILED N AND P LOSSES BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1979

| | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR1 | 2.86 | 0.166 | 0.29 | 0.017 | 2.57 | 0.149 | 0.26 | 0.015 | 0.14 | 0.008 | 0.12 | 0.007 |
| | 1.89 | 0.423 | 0.13 | 0.029 | 1.76 | 0.394 | 0.17 | 0.038 | 0.11 | 0.025 | 0.06 | 0.013 |
| | 1.75 | 0.052 | 0.37 | 0.011 | 1.38 | 0.041 | 0.15 | 0.005 | 0.11 | 0.003 | 0.04 | 0.002 |
| | 1.62 | 0.165 | 0.07 | 0.007 | 1.55 | 0.158 | 0.13 | 0.013 | 0.07 | 0.007 | 0.06 | 0.006 |
| FR2 | 2.50 | 0.120 | 0.14 | 0.007 | 2.36 | 0.113 | 0.27 | 0.013 | 0.10 | 0.005 | 0.17 | 0.008 |
| | 8.90 | 1.584 | 7.50 | 1.335 | 1.40 | 0.249 | 0.13 | 0.023 | 0.10 | 0.018 | 0.03 | 0.005 |
| | 2.02 | 0.008 | - | - | 2.02 | 0.008 | 0.10 | 0.001 | 0.07 | 0.000 | 0.03 | 0.001 |
| | 1.89 | 0.087 | 0.12 | 0.005 | 1.77 | 0.082 | 0.12 | 0.005 | 0.04 | 0.002 | 0.08 | 0.003 |
| FR3 | 2.56 | 0.161 | 0.15 | 0.009 | 2.41 | 0.152 | 0.26 | 0.016 | 0.13 | 0.008 | 0.13 | 0.008 |
| | 1.90 | 0.405 | 0.18 | 0.038 | 1.72 | 0.367 | 0.18 | 0.038 | 0.10 | 0.021 | 0.08 | 0.017 |
| | 2.69 | 0.067 | 0.45 | 0.011 | 2.24 | 0.056 | 0.17 | 0.004 | 0.12 | 0.003 | 0.05 | 0.001 |
| | 1.84 | 0.182 | 0.11 | 0.011 | 1.73 | 0.171 | 0.17 | 0.017 | 0.09 | 0.009 | 0.08 | 0.008 |

TABLE XVIc (Continued)

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR4 | 1.99 | 0.020 | 0.09 | 0.001 | 1.90 | 0.019 | 0.26 | 0.003 | 0.11 | 0.001 | 0.15 | 0.002 |
| | 8.90 | 1.673 | 6.40 | 1.203 | 2.50 | 0.470 | 0.61 | 0.115 | 0.42 | 0.083 | 0.19 | 0.032 |
| | 1.14 | 0.011 | 0.06 | 0.001 | 1.08 | 0.010 | 0.10 | 0.001 | 0.04 | 0.000 | 0.06 | 0.001 |
| | 1.41 | 0.066 | 0.09 | 0.004 | 1.32 | 0.062 | 0.14 | 0.007 | 0.07 | 0.003 | 0.07 | 0.004 |
| FR5 | 5.03 | 0.176 | 1.20 | 0.042 | 3.83 | 0.134 | 1.07 | 0.037 | 0.64 | 0.002 | 0.43 | 0.035 |
| | 5.29 | 0.127 | 0.80 | 0.019 | 4.49 | 0.108 | 1.66 | 0.040 | 1.30 | 0.031 | 0.36 | 0.009 |
| | 3.24 | 0.113 | 0.35 | 0.012 | 2.89 | 0.101 | 1.09 | 0.038 | 0.08 | 0.003 | 1.01 | 0.035 |
| | 13.32 | 2.983 | 0.23 | 0.051 | 13.09 | 2.932 | 2.56 | 0.573 | 0.05 | 0.011 | 2.51 | 0.562 |
| | 3.61 | 0.253 | 0.32 | 0.022 | 3.29 | 0.231 | 0.69 | 0.048 | 0.05 | 0.003 | 0.64 | 0.045 |
| | 4.78 | 0.076 | 1.19 | 0.019 | 3.59 | 0.57 | 1.12 | 0.018 | 0.37 | 0.006 | 0.75 | 0.012 |
| FR6 | 2.96 | 0.050 | 1.12 | 0.019 | 1.84 | 0.031 | 1.10 | 0.019 | 0.66 | 0.011 | 0.44 | 0.008 |
| | 13.60 | 0.054 | 5.00 | 0.020 | 8.60 | 0.034 | 3.81 | 0.015 | 2.67 | 0.011 | 1.14 | 0.004 |
| | 7.18 | 0.108 | 1.80 | 0.027 | 5.38 | 0.081 | 2.46 | 0.037 | 1.85 | 0.028 | 0.61 | 0.009 |
| | 11.80 | 2.631 | 0.44 | 0.098 | 11.36 | 2.533 | 2.89 | 0.644 | 0.15 | 0.033 | 2.74 | 0.611 |
| | 4.74 | 0.346 | 0.29 | 0.021 | 4.45 | 0.325 | 1.07 | 0.078 | 0.20 | 0.015 | 0.87 | 0.063 |
| | 3.82 | 0.034 | 1.20 | 0.011 | 2.62 | 0.023 | 0.99 | 0.009 | 0.42 | 0.004 | 0.57 | 0.005 |

## TABLE XVIc (Continued)

| Water-shed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR7 | 6.69 | 0.154 | 1.28 | 0.029 | 5.41 | 0.125 | 1.48 | 0.034 | 0.88 | 0.020 | 0.60 | 0.014 |
| | 22.10 | 0.088 | 14.20 | 0.057 | 7.90 | 0.031 | 9.20 | 0.037 | 2.29 | 0.009 | 6.91 | 0.028 |
| | 3.68 | 0.048 | 0.44 | 0.006 | 3.24 | 0.041 | 1.61 | 0.021 | 1.44 | 0.019 | 0.17 | 0.002 |
| | 11.00 | 1.548 | 0.53 | 0.074 | 10.47 | 1.466 | 1.96 | 0.274 | 0.22 | 0.031 | 1.74 | 0.243 |
| | 4.14 | 0.389 | 0.22 | 0.021 | 3.92 | 0.368 | 0.98 | 0.092 | 0.33 | 0.031 | 0.65 | 0.061 |
| | 8.62 | 0.069 | 0.65 | 0.005 | 7.97 | 0.064 | 1.37 | 0.011 | 0.19 | 0.001 | 1.18 | 0.010 |
| | 8.13 | 0.252 | 0.52 | 0.016 | 7.61 | 0.236 | 1.34 | 0.041 | 0.08 | 0.002 | 1.26 | 0.039 |
| | 5.20 | 0.348 | 0.22 | 0.015 | 4.98 | 0.333 | 0.85 | 0.057 | 0.16 | 0.011 | 0.69 | 0.046 |
| FR8 | 3.37 | 0.030 | 1.84 | 0.016 | 1.53 | 0.014 | 1.44 | 0.013 | 0.66 | 0.006 | 0.78 | 0.007 |
| | 19.40 | 0.058 | 7.60 | 0.023 | 11.80 | 0.035 | 7.76 | 0.023 | 1.77 | 0.005 | 5.99 | 0.018 |
| | 8.19 | 0.057 | 0.86 | 0.006 | 7.33 | 0.051 | 2.52 | 0.018 | 1.53 | 0.011 | 0.99 | 0.007 |
| | 14.20 | 0.824 | 0.14 | 0.008 | 14.06 | 0.816 | 2.46 | 0.143 | 0.12 | 0.007 | 2.34 | 0.136 |
| | 6.19 | 0.470 | 0.19 | 0.014 | 6.00 | 0.456 | 1.06 | 0.081 | 0.12 | 0.009 | 0.94 | 0.072 |
| | 14.30 | 0.172 | 0.38 | 0.005 | 13.92 | 0.167 | 2.60 | 0.031 | 0.03 | 0.000 | 2.57 | 0.031 |
| | 6.01 | 0.349 | 0.33 | 0.019 | 5.68 | 0.330 | 1.00 | 0.058 | 0.09 | 0.005 | 0.91 | 0.053 |

## TABLE XVId

## DETAILED N AND P LOSSES BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1980

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR1 | - | - | - | - | - | - | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1.50 | 0.361 | 0.53 | 0.128 | 0.97 | 0.233 | 0.16 | 0.039 | 0.15 | 0.036 | 0.01 | 0.003 |
| | 1.59 | 0.383 | 0.29 | 0.070 | 1.30 | 0.313 | 0.19 | 0.046 | 0.10 | 0.024 | 0.09 | 0.022 |
| | 2.22 | 0.062 | 0.67 | 0.019 | 1.55 | 0.043 | 0.26 | 0.007 | 0.18 | 0.005 | 0.08 | 0.002 |
| FR2 | 8.53 | 0.486 | 6.70 | 0.382 | 1.83 | 0.104 | 2.67 | 0.152 | 1.26 | 0.072 | 1.41 | 0.080 |
| | 2.91 | 0.515 | 0.53 | 0.094 | 2.38 | 0.421 | 0.50 | 0.089 | 0.43 | 0.076 | 0.07 | 0.013 |
| | 1.34 | 0.340 | 0.10 | 0.025 | 1.24 | 0.315 | 0.31 | 0.079 | 0.29 | 0.074 | 0.02 | 0.005 |
| | 1.82 | 0.462 | 0.34 | 0.086 | 1.48 | 0.376 | 0.23 | 0.058 | 0.17 | 0.043 | 0.06 | 0.015 |
| | 2.30 | 0.085 | 0.42 | 0.015 | 1.88 | 0.070 | 0.31 | 0.011 | 0.26 | 0.010 | 0.05 | 0.001 |
| | 2.61 | 0.146 | 0.58 | 0.032 | 2.03 | 0.114 | 0.39 | 0.022 | 0.31 | 0.017 | 0.08 | 0.005 |
| FR3 | 1.96 | 0.223 | 0.36 | 0.041 | 1.60 | 0.182 | 0.14 | 0.016 | 0.08 | 0.009 | 0.06 | 0.007 |
| | 1.17 | 0.303 | 0.16 | 0.041 | 1.01 | 0.262 | 0.09 | 0.023 | 0.07 | 0.018 | 0.02 | 0.005 |
| | 1.98 | 0.459 | 0.27 | 0.063 | 1.71 | 0.396 | 0.24 | 0.056 | 0.10 | 0.023 | 0.14 | 0.033 |
| | 2.00 | 0.050 | 0.31 | 0.008 | 1.69 | 0.042 | 0.15 | 0.004 | 0.09 | 0.002 | 0.06 | 0.002 |
| | 2.20 | 0.103 | 0.38 | 0.018 | 1.82 | 0.085 | 0.17 | 0.008 | 0.10 | 0.005 | 0.07 | 0.003 |

TABLE XVId (Continued)

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR4 | 3.72 | 0.186 | 1.34 | 0.067 | 2.38 | 0.119 | 1.14 | 0.057 | 1.04 | 0.052 | 0.10 | 0.005 |
| | 1.06 | 0.164 | 0.006 | 0.009 | 1.00 | 0.155 | 0.28 | 0.043 | 0.28 | 0.043 | 0.00 | 0.000 |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| | 2.56 | 0.028 | 0.48 | 0.005 | 2.08 | 0.023 | 0.47 | 0.005 | 0.37 | 0.004 | 0.10 | 0.001 |
| FR5 | 3.77 | 0.053 | 0.89 | 0.012 | 2.88 | 0.041 | 0.77 | 0.011 | 0.09 | 0.001 | 0.68 | 0.010 |
| | 6.67 | 0.086 | 0.90 | 0.012 | 5.77 | 0.074 | 1.14 | 0.015 | 0.10 | 0.001 | 1.04 | 0.014 |
| | 2.23 | 0.029 | 0.55 | 0.007 | 1.68 | 0.022 | 0.51 | 0.007 | 0.12 | 0.002 | 0.39 | 0.005 |
| | 4.34 | 0.299 | 0.69 | 0.048 | 3.65 | 0.251 | 0.66 | 0.045 | 0.04 | 0.003 | 0.62 | 0.042 |
| | 3.58 | 0.057 | 1.05 | 0.017 | 2.53 | 0.040 | 0.47 | 0.007 | 0.17 | 0.003 | 0.30 | 0.004 |
| FR6 | - | - | - | - | - | - | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1.78 | 0.018 | 0.44 | 0.004 | 1.34 | 0.014 | 0.29 | 0.003 | 0.08 | 0.001 | 0.21 | 0.002 |
| | - | - | - | - | - | - | - | - | - | - | - | - |
| | 3.54 | 0.046 | 1.16 | 0.015 | 2.38 | 0.031 | 0.50 | 0.006 | 0.22 | 0.003 | 0.28 | 0.003 |
| FR7 | 5.44 | 0.049 | 0.48 | 0.004 | 4.96 | 0.045 | 1.10 | 0.010 | 0.15 | 0.001 | 0.95 | 0.009 |
| | 6.67 | 0.067 | 0.90 | 0.009 | 5.77 | 0.058 | 1.14 | 0.011 | 0.10 | 0.001 | 1.04 | 0.010 |
| | 1.90 | 0.025 | 0.00 | 0.000 | 1.90 | 0.025 | 0.39 | 0.005 | 0.18 | 0.002 | 0.21 | 0.003 |
| | 4.26 | 0.332 | 0.46 | 0.036 | 3.80 | 0.296 | 0.72 | 0.056 | 0.13 | 0.010 | 0.59 | 0.046 |
| | 2.74 | 0.022 | 0.63 | 0.005 | 2.11 | 0.017 | 0.44 | 0.004 | 0.18 | 0.001 | 0.26 | 0.003 |

TABLE XVId (Continued)

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR8 | 4.87 | 0.049 | 0.37 | 0.004 | 4.50 | 0.045 | 1.02 | 0.010 | 0.10 | 0.001 | 0.92 | 0.009 |
| | 8.11 | 0.097 | 0.44 | 0.005 | 7.67 | 0.092 | 1.60 | 0.019 | 0.10 | 0.001 | 1.50 | 0.018 |
| | 2.10 | 0.042 | 0.21 | 0.004 | 1.89 | 0.038 | 0.44 | 0.009 | 0.05 | 0.001 | 0.39 | 0.008 |
| | 8.76 | 0.876 | 0.41 | 0.041 | 8.35 | 0.835 | 1.32 | 0.132 | 0.08 | 0.008 | 1.24 | 0.124 |
| | 3.11 | 0.019 | 0.85 | 0.005 | 2.26 | 0.014 | 0.41 | 0.002 | 0.15 | 0.001 | 0.26 | 0.001 |
| | 2.28 | 0.036 | 0.52 | 0.008 | 1.76 | 0.028 | 0.28 | 0.004 | 0.08 | 0.001 | 0.20 | 0.003 |

## TABLE XVIe

## DETAILED N AND P LOSSES BY SURFACE RUNOFF AND SEDIMENT FROM EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1981

| Water- | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| shed | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR5 | 4.67 | 0.004 | 1.09 | 0.001 | 3.58 | 0.003 | 0.519 | 0.001 | 0.030 | 0.000 | 0.489 | 0.001 |
| | 68.40 | 0.137 | 0.11 | 0.000 | 68.29 | 0.137 | 1.538 | 0.003 | 0.108 | 0.000 | 1.430 | 0.003 |
| | 5.58 | 0.056 | 0.14 | 0.001 | 5.44 | 0.055 | 1.260 | 0.013 | 0.138 | 0.001 | 1.122 | 0.012 |
| | 1.74 | 0.029 | 0.00 | 0.000 | 1.74 | 0.029 | 0.356 | 0.006 | 0.091 | 0.001 | 0.265 | 0.005 |
| | 13.40 | 0.040 | 0.00 | 0.000 | 13.40 | 0.040 | 2.734 | 0.008 | 0.121 | 0.000 | 2.613 | 0.008 |
| | 5.84 | 0.438 | 0.25 | 0.019 | 5.59 | 0.419 | 1.275 | 0.096 | 0.255 | 0.019 | 1.020 | 0.077 |
| | 7.86 | 0.676 | 0.42 | 0.036 | 7.44 | 0.640 | 1.286 | 0.111 | 0.089 | 0.008 | 1.197 | 0.103 |
| FR6 | 4.69 | 0.066 | 0.18 | 0.002 | 4.51 | 0.064 | 1.202 | 0.017 | 0.169 | 0.002 | 1.033 | 0.015 |
| | 15.60 | 2.855 | 0.07 | 0.013 | 15.53 | 2.842 | 3.455 | 0.632 | 3.207 | 0.587 | 0.248 | 0.045 |
| | 7.80 | 0.593 | 0.35 | 0.027 | 7.45 | 0.566 | 1.304 | 0.099 | 0.152 | 0.012 | 1.152 | 0.087 |
| FR7 | 7.00 | 0.007 | 0.26 | 0.000 | 6.74 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 9.60 | 0.010 | 0.09 | 0.000 | 9.51 | 0.010 | 2.723 | 0.004 | 1.156 | 0.003 | 1.567 | 0.001 |
| | 9.00 | 0.063 | 0.09 | 0.001 | 8.91 | 0.062 | 2.321 | 0.016 | 0.594 | 0.004 | 1.727 | 0.012 |
| | 4.80 | 0.019 | 0.36 | 0.001 | 4.44 | 0.018 | 1.093 | 0.004 | 0.418 | 0.002 | 0.675 | 0.002 |

TABLE XVIe (Continued)

| Watershed | Loss of nitrogen by surface runoff | | | | | | Loss of phosphorus by surface runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total N | | Soluble N | | Sediment N | | Total P | | Soluble P | | Sediment P | |
| | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha | Mg/l | Kg/ha |
| FR8 | 5.86 | 0.012 | 0.73 | 0.001 | 5.13 | 0.011 | 0.701 | 0.001 | 0.021 | 0.000 | 0.680 | 0.001 |
| | 6.63 | 0.007 | 0.18 | 0.000 | 6.45 | 0.007 | 0.921 | 0.002 | 0.181 | 0.000 | 0.740 | 0.002 |
| | 9.45 | 0.066 | 0.44 | 0.003 | 9.01 | 0.063 | 2.201 | 0.016 | 0.405 | 0.003 | 1.796 | 0.013 |
| | 8.44 | 0.025 | 0.28 | 0.001 | 8.16 | 0.024 | 1.663 | 0.006 | 0.436 | 0.001 | 1.227 | 0.005 |
| | 6.24 | 0.100 | 0.38 | 0.006 | 5.86 | 0.094 | 1.056 | 0.017 | 0.189 | 0.003 | 0.867 | 0.014 |

## TABLE XVIIa

## PRECIPITATION, RUNOFF, AND SEDIMENT YIELD FOR EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1977

| Watershed | Date | Precipitation (cm) | Runoff (cm) | Sediment Yield (kg/ha) |
|---|---|---|---|---|
| FR1 | 5/20/77 | 9.40 | 2.44 | 56.6 |
| | 5/26/77 | 3.81 | 0.69 | 17.7 |
| FR2 | 5/20/77 | 9.40 | 1.47 | 63.9 |
| | 5/26/77 | 3.81 | 0.42 | 10.4 |
| FR3 | 5/20/77 | 9.40 | 2.53 | 86.0 |
| | 5/26/77 | 3.81 | 0.37 | 7.3 |
| FR4 | 5/20/77 | 9.40 | 2.92 | 270.1 |
| | 5/26/77 | 3.81 | 0.37 | 4.2 |
| FR5 | 5/20/77 | 9.40 | 1.29 | 29.7 |
| | 5/26/77 | 3.81 | 0.26 | 2.8 |
| FR6 | 5/20/77 | 9.40 | 0.81 | 23.3 |
| | 5/26/77 | 3.81 | 0.15 | 2.0 |
| FR7 | 5/20/77 | 9.40 | 0.61 | 33.3 |
| | 5/26/77 | 3.81 | 0.11 | 1.7 |
| FR8 | 5/20/77 | 9.40 | 0.73 | 54.1 |
| | 5/26/77 | 3.81 | 0.17 | 2.0 |

## TABLE XVIIb

## PRECIPITATION, RUNOFF, AND SEDIMENT YIELD FOR EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1978

| Watershed | Date | Precipitation (cm) | Runoff (cm) | Sediment Yield (kg/ha) |
|---|---|---|---|---|
| FR1 | 5/27/78 | 11.81 | 2.35 | 16.0 |
| | 6/21/78 | 4.65 | 0.14 | 0.8 |
| FR2 | 5/27/78 | 11.81 | 1.81 | 16.3 |
| | 6/21/78 | 4.65 | 0.06 | 0.6 |
| FR3 | 5/27/78 | 11.81 | 2.17 | 11.2 |
| | 6/21/78 | 4.65 | 0.02 | 0.3 |
| FR4 | 5/27/78 | 11.81 | 1.53 | 5.3 |
| | 6/21/78 | 4.65 | 0.07 | 0.6 |
| FR5 | 5/27/78 | 11.81 | 0.84 | 3.1 |
| | 6/21/78 | 4.65 | - | 0.3 |
| FR6 | 5/27/78 | 11.81 | 1.30 | 4.8 |
| | 6/21/78 | 4.65 | 0.01 | 0.3 |
| FR7 | 5/27/78 | 11.81 | 1.04 | 3.6 |
| | 6/21/78 | 4.65 | 0.01 | 0.3 |
| FR8 | 5/27/78 | 11.81 | 1.66 | 5.6 |
| | 6/21/78 | 4.65 | 0.01 | 0.3 |

## TABLE XVIIc

## PRECIPITATION, RUNOFF, AND SEDIMENT YIELD FOR EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1979

| Watershed | Date | Precipitation (cm) | Runoff (cm) | Sediment Yield (kg/ha) |
|---|---|---|---|---|
| FR1 | 3/22/79 | 3.81 | 0.58 | 18.2 |
| | 4/10/79 | 5.08 | 2.24 | 8.8 |
| | 5/04/79 | 0.64 | 0.30 | 1.1 |
| | 5/21/79 | 2.18 | 1.02 | 4.2 |
| FR2 | 3/22/79 | 3.81 | 0.48 | 12.7 |
| | 4/10/79 | 5.08 | 1.78 | 11.4 |
| | 5/04/79 | 0.64 | 0.04 | 0.1 |
| | 5/21/79 | 2.18 | 0.46 | 1.4 |
| FR3 | 3/22/79 | 3.81 | 0.63 | 15.8 |
| | 4/10/79 | 5.08 | 0.13 | 16.9 |
| | 5/04/79 | 0.64 | 0.25 | 0.8 |
| | 5/21/79 | 2.18 | 0.99 | 5.0 |
| FR4 | 3/22/79 | 3.81 | 0.10 | 0.9 |
| | 4/10/79 | 5.08 | 1.88 | 22.2 |
| | 5/04/79 | 0.64 | 0.10 | 0.3 |
| | 5/21/79 | 2.18 | 0.47 | 0.9 |
| FR5 | 4/10/79 | 5.08 | 0.35 | 15.5 |
| | 5/04079 | 0.64 | 0.24 | 56.7 |
| | 5/21/79 | 2.18 | 0.35 | 11.5 |
| | 6/23/79 | 0.64 | 2.24 | 287.0 |
| | 6/24/79 | 9.14 | 0.70 | 203.3 |
| | 7/17/79 | 4.06 | 0.16 | 8.7 |
| FR6 | 4/10/79 | 5.08 | 0.17 | 4.1 |
| | 5/04/79 | 0.64 | 0.04 | 1.2 |
| | 5/21/79 | 2.18 | 0.15 | 3.4 |
| | 6/23/79 | 0.64 | 2.23 | 590.0 |
| | 6/24/79 | 9.14 | 0.73 | 169.8 |
| | 7/17/79 | 4.06 | 0.09 | 2.2 |

TABLE XVIIc (Continued)

| Watershed | Date | Precipitation (cm) | Runoff (cm) | Sediment Yield (kg/ha) |
|---|---|---|---|---|
| FR7 | 4/10/79 | 5.08 | 0.23 | 9.9 |
| | 5/04/79 | 0.64 | 0.04 | 2.4 |
| | 5/21/79 | 2.18 | 0.13 | 1.3 |
| | 6/23/79 | 0.64 | 1.40 | 298.5 |
| | 6/24/79 | 9.14 | 0.94 | 173.4 |
| | 7/05/79 | 4.32 | 0.08 | 6.8 |
| | 7/17/79 | 4.06 | 0.31 | 44.4 |
| | 7/18/79 | 3.12 | 0.67 | 51.9 |
| FR8 | 4/10/79 | 5.08 | 0.09 | 5.5 |
| | 5/04/79 | 0.64 | 0.03 | 1.0 |
| | 5/21/79 | 2.18 | 0.07 | 3.5 |
| | 6/23/79 | 0.64 | 0.58 | 373.3 |
| | 6/24/79 | 9.14 | 0.76 | 88.2 |
| | 7/17/79 | 4.06 | 0.12 | 34.4 |
| | 7/18/79 | 3.12 | 0.58 | 21.6 |

## TABLE XVIId

## PRECIPITATION, RUNOFF, AND SEDIMENT YIELD FOR EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1980

| Watershed | Date | Precipitation (cm) | Runoff (cm) | Sediment Yield (kg/ha) |
|---|---|---|---|---|
| FR1 | 4/25/80 | 4.57 | - | - |
| | 5/02/80 | 2.79 | - | - |
| | 5/15/80 | 10.92 | 2.41 | 1.0 |
| | 5/18/80 | 2.92 | 2.41 | 8.2 |
| | 5/29/80 | 5.08 | 0.28 | 0.5 |
| FR2 | 4/25/80 | 4.57 | 0.57 | 0.5 |
| | 5/02/80 | 2.79 | 1.77 | 0.2 |
| | 5/15/80 | 10.92 | 2.54 | 2.5 |
| | 5/18/80 | 2.92 | 2.54 | 8.1 |
| | 5/20/80 | 2.41 | 0.37 | 0.8 |
| | 2/29/80 | 5.08 | 0.56 | 0.7 |
| FR3 | 5/02/80 | 2.79 | 1.14 | 0.7 |
| | 5/15/80 | 10.92 | 2.59 | 1.8 |
| | 5/18/80 | 2.92 | 2.32 | 11.7 |
| | 5/20/80 | 2.41 | 0.25 | 0.9 |
| | 5/29/80 | 5.08 | 0.47 | 0.6 |
| FR4 | 5/02/80 | 2.79 | 0.50 | 0.1 |
| | 5/15/80 | 10.92 | 1.55 | 1.1 |
| | 5/18/80 | 2.92 | 2.10 | 11.6 |
| | 5/29/80 | 5.08 | 0.11 | 0.1 |
| FR5 | 4/25/80 | 4.57 | 0.14 | 25.1 |
| | 5/02/80 | 2.79 | 0.13 | 17.2 |
| | 5/15/80 | 10.92 | 0.13 | 4.6 |
| | 5/17/80 | 2.92 | 0.69 | 75.1 |
| | 5/29/80 | 5.08 | 0.16 | 4.2 |
| FR6 | 4/25/80 | 4.57 | - | - |
| | 5/02/80 | 2.79 | - | - |
| | 5/15/80 | 10.92 | 0.10 | 2.1 |
| | 5/18/80 | 2.92 | - | - |
| | 5/29/80 | 5.08 | 0.13 | 1.0 |

TABLE XVIId (Continued)

| Watershed | Date | Precipitation (cm) | Runoff (cm) | Sediment Yield (kg/ha) |
|---|---|---|---|---|
| FR7 | 4/25/80 | 4.57 | 0.09 | 8.1 |
| | 5/02/80 | 2.79 | 0.10 | 11.7 |
| | 5/15/80 | 10.92 | 0.13 | 2.3 |
| | 5/18/80 | 2.92 | 0.78 | 34.1 |
| | 5/29/80 | 5.08 | 0.08 | 0.9 |
| FR8 | 4/25/80 | 4.57 | 0.10 | 12.7 |
| | 5/02/80 | 2.79 | 0.12 | 20.4 |
| | 5/15/80 | 10.92 | 0.20 | 8.1 |
| | 5/18/80 | 2.92 | 1.00 | 62.0 |
| | 5/20/80 | 2.41 | 0.06 | 1.6 |
| | 5/29/80 | 5.08 | 0.16 | 2.5 |

# TABLE XVIIe

## PRECIPITATION, RUNOFF, AND SEDIMENT YIELD FOR EXPERIMENTAL WATERSHEDS, EL RENO, OKLAHOMA, 1981

| Watershed | Date | Precipitation (cm) | Runoff (cm) | Sediment Yield (kg/ha) |
|---|---|---|---|---|
| FR5 | 3/28/81 | 1.27 | 0.01 | 0.0 |
| | 6/30/81 | 4.83 | 0.02 | 0.0 |
| | 8/06/81 | 9.40 | 0.10 | 8.6 |
| | 8/16/81 | 4.57 | 0.17 | 3.5 |
| | 10/11/81 | 8.25 | 0.03 | 2.2 |
| | 10/15/81 | 3.68 | 0.75 | 345.0 |
| | 10/31/81 | 4.95 | 0.86 | 122.0 |
| FR6 | 8/06/81 | 9.40 | 0.14 | 4.3 |
| | 10/11/81 | 8.25 | 1.83 | 419.0 |
| | 10/31/81 | 4.95 | 0.76 | 87.3 |
| FR7 | 8/16/81 | 4.57 | 0.01 | 0.7 |
| | 10/11/81 | 8.25 | 0.01 | 0.1 |
| | 10/16/81 | 6.10 | 0.07 | 0.0 |
| | 10/31/81 | 4.95 | 0.04 | 2.2 |
| FR8 | 3/28/81 | 1.27 | 0.02 | 4.3 |
| | 5/29/81 | 2.92 | 0.01 | 0.2 |
| | 10/11/81 | 8.25 | 0.07 | 18.4 |
| | 10/16/81 | 6.10 | 0.03 | 11.4 |
| | 10/31/81 | 4.95 | 0.16 | 12.6 |

# TABLE XVIII

## MEAN SQUARES AND PROBABILITY OF F VALUES FROM ANALYSIS OF VARIANCE ON KIRKLAND, BETHANY, RENFROW, MILAN, AND AYDELLOTE SOILS

| Source | Degrees of Freedom | % Sand | | % Silt | | % Clay | |
|---|---|---|---|---|---|---|---|
| | | MS | P | MS | P | MS | P |
| Total | 57 | | | | | | |
| Soil | 4 | 838.215 | <0.005 | 400.529 | <0.005 | 202.760 | <0.005 |
| WSNO (Soil | 24 | 50.345 | | 52.362 | | 16.074 | |
| Depth | 1 | 211.209 | 0.0001 | 33.250 | 0.0496 | 412.064 | 0.0001 |
| Soil depth | 4 | 4.036 | 0.7497 | 19.286 | 0.0709 | 34.678 | 0.0062 |
| Residual | 24 | 8.399 | | 7.774 | | 7.423 | |

TABLE XVIII (Continued)

| Source | Degrees of Freedom | $H_2O$ pH | | KCl pH | | EC | | TDSP | |
|---|---|---|---|---|---|---|---|---|---|
| | | MS | P | MS | P | MS | P | MS | P |
| Total | 57 | | | | | | | | |
| Soil | 4 | 0.192 | >0.1 | 0.148 | >0.1 | 6984.375 | >0.1 | 156504.252 | >0.1 |
| WSNO (Soil) | 24 | 0.130 | | 0.076 | | 43654.212 | | 653858.740 | |
| Depth | 1 | 0.271 | 0.0077 | 0.030 | 0.4235 | 2342.981 | 0.6269 | 595960.635 | 0.0001 |
| Soil depth | 4 | 0.058 | 0.1591 | 0.122 | 0.0574 | 5243.973 | 0.7060 | 11302.518 | 0.7879 |
| Residual | 24 | 0.032 | | 0.046 | | 9665.290 | | 26492.116 | |

## TABLE XVIII (Continued)

| | | Water Extractable Cations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Na | | K | | Ca | | Mg | |
| Source | Degrees of Freedom | MS | P | MS | P | MS | P | MS | P |
| Total | 57 | | | | | | | | |
| Soil | 4 | 113.014 | <0.005 | 315.740 | <0.025 | 114.156 | >0.1 | 13.281 | >0.1 |
| WSNO (Soil) | 24 | 7.769 | | 89.374 | | 705.183 | | 140.634 | |
| Depth | 1 | 158.651 | 0.0001 | 1360.472 | 0.0001 | 272.239 | 0.1315 | 0.2187 | 0.9145 |
| Soil depth | 4 | 49.627 | 0.0001 | 28.944 | 0.6084 | 46.415 | 0.7956 | 9.261 | 0.7371 |
| Residual | 24 | 4.225 | | 42.166 | | 111.633 | | 18.581 | |

TABLE XVIII (Continued)

| Source | Degrees of Freedom | Exchangeable Cations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Na | | K | | Ca | | Mg | |
| | | MS | P | MS | P | MS | P | MS | P |
| Total | 57 | | | | | | | | |
| Soil | 4 | 701.788 | <0.005 | 25481.070 | >0.1 | 478457.976 | <0.005 | 82222.171 | <0.005 |
| WSNO (Soil) | 24 | 127.581 | | 14282.820 | | 90892.532 | | 6841.815 | |
| Depth | 1 | 851.662 | 0.0001 | 83160.168 | 0.0001 | 156742.912 | 0.0035 | 126461.121 | 0.0001 |
| Soil depth | 4 | 314.036 | 0.0001 | 5519.395 | 0.1416 | 34982.442 | 0.0834 | 5400.478 | 0.3296 |
| Residual | 24 | 20.222 | | 2891.392 | | 14917.289 | | 4437.289 | |

TABLE XVIII (Continued)

| Source | Degrees of Freedom | CEC |  | %OM |  | TKN |  | TP |  | Brayl-P |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | MS | P | MS | P | MS | P | MS | P | MS | P |
| Total | 57 |  |  |  |  |  |  |  |  |  |  |
| Soil | 4 | 32.404 | <0.005 | 1.0636 | >0.1 | 0.0017 | <0.01 | 4788.498 | <0.005 | 40.916 | >0.1 |
| WSNO (Soil) | 24 | 3.567 |  | 0.5007 |  | 0.0004 |  | 614.340 |  | 24.735 |  |
| Depth | 1 | 19.955 | 0.0001 | 8.217 | 0.0001 | 0.0165 | 0.0001 | 24232.352 | 0.0001 | 175.398 | 0.0031 |
| Soil depth | 4 | 2.398 | 0.0599 | 0.164 | 0.3274 | 0.0001 | 0.8504 | 385.955 | 0.2149 | 8.995 | 0.7033 |
| Residual | 24 | 0.914 |  | 0.134 |  | 0.0005 |  | 246.093 |  | 16.260 |  |

TABLE XVIII (Continued)

| Source | Degrees of Freedom | Perchloric acid extractable macronutrients |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Na |  | K |  | Ca |  | Mg |  |
|  |  | MS | P | MS | P | MS | P | MS | P |
| Total | 57 |  |  |  |  |  |  |  |  |
| Soil | 4 | 5322.635 | <0.1 | 327791.825 | <0.025 | 232354.928 | >0.1 | 1126126.976 | 0.005 |
| WSNO (Soil) | 24 | 1997.478 |  | 96524.909 |  | 111143.357 |  | 107391.689 |  |
| Depth | 1 | 19846.209 | 0.0001 | 2738659.341 | 0.0001 | 9607.111 | 0.5162 | 4528325.873 | 0.0001 |
| Soil depth | 4 | 826.339 | 0.0204 | 94211.61 | 0.1703 | 27630.007 | 0.3172 | 102553.969 | 0.1242 |
| Residual | 24 | 231.920 |  | 53580.283 |  | 22125.650 |  | 50862.820 |  |

TABLE XVIII (Continued)

| | | Perchloric acid extractable micronutrients | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Zn | | Mn | | Cu | | Fe | |
| Source | Degrees of Freedom | MS | P | MS | P | MS | P | MS | P |
| Total | 57 | | | | | | | | |
| Soil | 4 | 16.453 | >0.1 | 8572.006 | <0.005 | 6.959 | >0.1 | 1564.445 | <0.025 |
| WSNO (Soil) | 24 | 57.816 | | 893.476 | | 3.228 | | 412.021 | |
| Depth | 1 | 4.207 | 0.8230 | 4729.866 | 0.0001 | 13.371 | 0.0178 | 13763.750 | 0.0001 |
| Soil depth | 4 | 149.435 | 0.1585 | 371.370 | 0.1510 | 1.277 | 0.6542 | 290.978 | 0.3268 |
| Residual | 24 | 82.260 | | 200.081 | | 2.067 | | 237.696 | |

# VITA

Fawzi Mohamed Eldoumi

Candidate for the Degree of

Doctor of Philosophy

Thesis: RUNOFF LOSSES FROM EIGHT WATERSHEDS AS INFLUENCED BY SOIL COVER CONDITION AND MANAGEMENT SYSTEMS AT EL RENO, OKLAHOMA

Major Field: Soil Science

Biographical:

Personal Data: Born in Benghazi, Libya, September 23, 1947, the son of Mohamed Eldoumi Khleif and Ghazala ElMarymi.

Education: Graduated from Benghazi Secondary School, Benghazi in 1966; received the Bachelor of Science degree from University of Tripoli with a major in Soil Science in May, 1971; received the Master of Science degree from Oklahoma State University with a major in Agronomy in May, 1979; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in May, 1986.

Professional Experience: Director of Wadi Gattara Irrigation project south of Benghazi from December, 1971 to December, 1974; Assistant lecturer on the faculty of Agriculture, University of Garyounis at Beida, Libya from September, 1979 to September 1980.