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Abstract

The purpose of the study was to ascertain if infiltration and temperature varied significantly among the selected soil types of the Smithfield, Otonabee, Wendigo and Farmington Series. These data were gathered from field tests performed during the summer months in Ontario and Victoria Counties.

A stopwatch was used to measure the number of seconds that were required for 0.8 inches of water to disappear into the soil inside a 4 inch diameter single ring infiltrometer which had been placed one inch into the soil surface. The soil temperature was recorded at the same time.

The sites were chosen by stratified random sampling from the above soil series as depicted on the Ontario and Victoria County Soil Survey maps. A soil sample from each test site was taken to the laboratory for mechanical analysis.

Analysis of the infiltration data showed that the soil types differed in their initial infiltration response. Also mechanical analysis differentiated some of the soil series into separate soil types. The Student's 't' Test indicated that both initial infiltration and temperature were indicators of soil types.

Preface

The necessity of having an adequate supply of good quality water is vital to the operation and maintenance of a farm home and farm enterprise. In the rural setting, wells are the major source of potable water for the farmstead for both household and livestock needs. Therefore unpolluted, underground sources of water are mandatory for an efficient agricultural economy.

Vast quantities of water are used daily. Homes with running water on tap may use 60 gallons per person each day for household purposes. The daily requirements of range cattle are $3\frac{1}{2}$ to 7 gallons whereas Holstein cows producing 80 lbs. of milk per day consume 19 gallons (U.S.A. Department of Agriculture, 1955). Plants use soil water through transpiration. Watson and More as reported by Symons (1968), indicate that "a field producing 3 tons of dry matter per acre may transpire from 1200 to 2500 tons of water, equivalent to 12 to 25 inches of rain". Water requirements vary somewhat for each of the three examples depending on such factors as the temperature of the day, the dry or moist food consumed by man or animal, the type of plant (fibrous root or tap root system), humidity and cloudiness. All this necessary water must come from precipitation to supply the surface soil, underground water table, or streams for agricultural use. If the rainfall is not sufficient during the growing season, then the irrigation of fields may be beneficial wherever it is economically practical which further depletes the total available water supply.

The process of infiltration is the only natural means of replenishing the soil and underground water supply, therefore it becomes an extremely essential element of the hydrological cycle, particularly for agriculture. Some of the water that enters the soil surface will be used by the plants in growth and transpiration; some will be lost by evaporation and some will drain through the soil and enter the zone of saturation or ground-water, later emerging in springs and streams. If a constant supply of water is provided to streams, the stream flow does not change rapidly. Nevertheless, stream flow can change rapidly due to a large surface runoff, often endangering life and causing property damage by floods. Part of this stream flow change may be caused by poor infiltration.

Chow (1964) states that slow progress has been made in the development of scientific hydrology. Increased world population and generally improved economic conditions after World War 11 has rapidly brought the need for solutions of water supply and disposal problems to the attention of all. More education and research in certain aspects of hydrology must follow to maintain or improve the quality of life.

If a farmer or any man of the land could differentiate his fields and/or soils by a simple, inexpensive infiltration method, then he could utilize the renewable (but sometimes polluted) natural resource -- water, to the benefit of everyone. Then the soils that exhibit good infiltration under field conditions within an area, can be preserved for open space and not encroached with houses and pavement. To this end the present study was directed.

I wish to acknowledge the particular encouragement and patience received from my adviser Dr. Gunars Subins throughout. Also my thanks to Eric Bolton, retired Chief Chemist, for his valuable assistance in the laboratory. Lastly to my wife and family without whose understanding and cooperation in other matters this thesis would not have been attempted.

Table of Contents

Page

List of Tables

List of Figures

Page

Chapter 1

Introduction

If a classification of soils by their initial infiltration response could be established, it would be useful to many people, e.g. an agronomist interested in the varying amounts of moisture that is available to certain crops grown on various types of soils. Soil temperatures and soil texture also influence plant growth. Perhaps these could also be useful as means of classification. These soil characteristics are only three of the many soil factors involved in the soil-plant complex. For geographical study, concepts of the interrelation of many elements in the environment, their spatial distribution and their behaviour systems provide logical beginnings for a comprehension of man and the land.

In order to attempt a differentiation of soil types in the field, an infiltration test is proposed whereby a given amount of water is poured into a cylinder at different locations. The infiltration time is recorded. Infiltration apparatus may range from a complicated rainfall simulator to a simple single ring cylinder. In this case the simplest device is used.

Simultaneously the soil temperature at the different sites is measured and recorded. These two experiments are simple, inexpensive and mobile.

At each test site a soil sample is collected for laboratory analysis. In the laboratory mechanical analyses of the soil samples are performed by sieving, the pipette and the hydrometer method. Although they may not give exactly the same results, they are comparable and valid conclusions can be drawn. These tests will be used to see if distinction can be made among the soils of the test sites. As a check the sites selected in this study will be chosen from specific soil types as designated on county soils maps.

If this test procedure is successful then it could simplify soil classification, because the present soil classification procedures are elaborate and expensive, regardless whether they are performed in the laboratory or the field. Precision and accuracy are considered to be the advantages of the present methods.

The following hypotheses are proposed:

(1) That the agricultural soil types as depicted by the County Soil Survey maps can be differentiated by their initial rate of infiltration.

(2) That these same soil types can be differentiated by their temperature characteristics.

(3) That the same soil types as shown on the County Soil Survey maps can be differentiated by their texture as established by the laboratory analysis of field specimens.

The study is conducted in the following order. Review of the literature will establish the state of the art.

The location of the study area is selected and described. The test methods are explained. The field measurements are performed, recorded and reported. Data are analysed by statistical methods. Results are discussed and reported. It is shown that infiltration time and soil temperature can be used to distinguish between soil types.

Chapter 2

Literature Review

Infiltration

Although precipitation and evapotranspiration are important parts of the hydrologic cycle, infiltration is of particular interest to the agricultural geographer. The amount of surface runoff and soil moisture are greatly influenced by the process of infiltration. In general, the amount of water from rainfall that enters the soil depends directly on the infiltration process.

Various definitions for infiltration appear in the literature and several attempts have been instituted to standardize its definition. A subcommittee of the Soil Science Society of America on terminology, chaired by Richards (1952), defined infiltration as the downward entry of water into the soil, or as phrased by Hutchinson and Stoesz (1970), the flow of a liquid into a substance through pores or other openings, connoting flow <u>into</u> a soil in contradistinction to the word percolation which connotes flow <u>through</u> a porous substance. Infiltration rate is the maximum rate determined by the soil characteristics at which water can enter the soil under specified conditions including the presence of an excess of water. The rate of infiltration is usually stated in inches or centimetres per hour. Infiltration capacity, or ability to infiltrate rainfall, determines how much of the rainfall enters the soil and indirectly the amount of surface runoff. Since no restrictions are placed on the divergence of flow in the soil, it is necessary to describe the method employed for each individual research project.

Factors Affecting Infiltration

Basically the soil characteristics are the principal factors affecting infiltration. Pore-size and pore-size distribution which are directly related to soil texture and soil structures are very important. Some of the other factors that contribute to the infiltration ability of the soil are colloidal swelling, aggregate stability, compaction of soil surface, organic matter content, biological activity, entrapped air, root penetration, freezing and previous land use. Present temperature and the interception by vegetation affect the amount of water available for infiltration as well as the duration and intensity of the rainfall, size of raindrop and rainfall impact. These latter characteristics of the precipitation may account for the turbidity of the surface water (if any) and the depth of water over the soil surface or its head. Subsurface factors such as thickness of the different soil horizons, permeability of underlying strata and antecedent moisture also influence water intake.

As many variables are involved, there are diverse opinions pertaining to the ones which have the greatest influence on infiltration. Horton (1940) suggested the following factors which affect the infiltration of water into the soil. He grouped them as (1) soil type and soil profile (2) biologic and macro-structure within the soil (3) vegetal cover. Others think that the soil mass is the principal control on the infiltration rate and therefore it is largely independent of surface conditions or macro-structure near the surface of the soil. Lewis and Power (1938) listed a very large number of factors and divided them into two major groups, (a) factors influencing the infiltration rate at a given time and point, such as texture, structure and organic matter, (b) factors influencing the average infiltration rate over a considerable area and period of time such as slope, vegetation and surface roughness. As it is generally agreed that a large number of variables are involved, only a limited number of factors are studied at one time.

Porosity

Porosity is a very important factor that influences infiltration. The flow of the water into the soil depends upon the sizes, continuity and distribution of pores. The porosity of a given soil varies with its texture and structure. Soil texture is the size distribution of the individual soil particles, whereas soil structure is the arrangement of the soil particles into specific groupings. The texture varies from sandy to loamy to clayey, depending on the percentage of particles of sand, silt and clay in each type. The structure, which is strictly a descriptive field term, can vary from platy to crumb (Lyon, Buckman and Brady, 1952).

Baver (1938) classified pores as capillary and non-capillary. The diameter of the capillary pores are less than 0.05 mm. and those of the non-capillary pores are greater than 0.05 mm. In order that the water may continue to infiltrate, it must be able to move relatively freely down through the soil. However a point to be considered is that there is a major difference between saturated and unsaturated flow. As explained by Millar and Turk (1943) gravity causes water to move when the soil is saturated, hence the larger the pore the faster the flow providing that the pores are connected. When the soil is not completely wetted then forces of adhesion (mutual attraction between soil and water) and cohesion (attraction of water molecules to each other) act. Because of unequal tensions developed on the curvature of the surface water film, the direction of the flow is determined by the direction of this force. Water can move upward or outward in a drier soil as easily as it can move downward. This is called capillary movement. Gumbs and Warkentin (1972) noted that the swelling of soils increases the porosity and conductivity of the surface layers which have a large influence on the infiltration rate.

Browning (1939) found that the moisture content of the soil was a determining factor in its volume. As the soil swells or increases in volume it decreases the volume of the soil pores. Now non-capillary pores become capillary in size and smaller capillary pores may be sealed to the movement of water within the soil. Surface soil had a greater volume change than the subsoil because of the latter's higher bulk density values indicating that the subsoil was compacted, therefore it had less space for expansion.

Zimmerman (1936), Free and Palmer (1940), and Christiansen (1944) conducted studies in the laboratory on soil columns to observe the effect of entrapped air on infiltration and permeability. Complex interrelationships between pore size and air and water movement were noted which pointed to the importance of pore space in the infiltration process.

Soil Surface Factors

Duley (1939) evaluated the surface factors affecting the rate of infiltration in cultivated soils. He noted that when the surface was covered with straw and the rate of sprinkling was in excess of intake there was much more absorption than after the straw was removed. A thin compact surface layer formed on the exposed soil surface. Thus this apparent structural disturbance of the surface layer, due partially to the beating of the simulated raindrops, and partially to the surface flow, had formed a relatively thin impervious seal. His data showed that this sealing of the surface pores had more influence on infiltration than soil type, slope, moisture content or structure. Duley and Russel (1939) found that leaving crop residues on the soil surface greatly increased infiltration rate, reduced evaporation from the soil surface and also reduced water and wind erosion. Auten (1933) conducted absorption tests on field and forest soils. Forest soils were more porous than field soils and both have a greater absorption or infiltration rate than land grazed by livestock. Also noted was the fact that a bare soil's ability to absorb water was less at the surface than at a three inch depth because of the crusted surface formation.

Organic Matter

Organic matter influences the water intake of a soil in various ways. Soil that is low in organic matter content is easily eroded. Besides the litter and humus providing a spongy protection for the mineral portion of the soil particles it also aids as a binding agent in the formation of aggregates. Most research has been done on forest soils where the detection of the various stages of organic matter decomposition is more easily performed. Auten (1933), Arend (1941), and Johnson (1940) all agreed from their respective investigations that the removal of the 'forest floor' reduces infiltration. Johnson (1957) found that the decomposition of organic residues clogged pores, resulting in a decreased infiltration rate. However he concluded that this effect was offset by the high initial infiltration rate. Additional tests showed that percolation rates increased due to soil structure improvement. Wischmeier and Mannering (1965) found that wide textural ranges of soils had only minor influences on runoff. The entry of water into the soil was influenced much more by the organic matter and management than by texture and topography.

Micro-organisms

Soil micro-organisms have important direct and indirect effects on infiltration. Previous investigators have observed that soils subjected to an extended period of water submergence exhibit a typical S-shaped infiltration rate curve. According to Parr and Bertrand (1960) the initial rapid decline seems to be due to the slaking of aggregates and the swelling of soil colloids whereas the final decline in infiltration rate has been associated with microbial activity which is dependent upon the amount of organic matter in the surface soil. McCalla's (1942) work seemed to indicate that microbial slimes, gums etc. increased infiltration rate.

Compaction

Stienbrenner (1955) found that under wet conditions one pass of a tractor wheel can reduce the non-capillary pore space by 50 percent and the infiltration rate by as much as 80 percent. Doneen (1953) found two passes of a tractor wheel reduced the infiltration rate from 1.4 to 0.6 inches per hour or a net reduction of 0.8 inches per hour. Heavily grazed pastures, because of the increased compaction of the soil surface are susceptible to a higher volume of runoff and reduced infiltration. Compaction of the soil decreases its total porosity especially under wet conditions.

Seasonal Influences

Bertoni *et al* (1958) from the analysis of their data concluded that the time of year influenced the infiltration rates. Their final infiltration rates showed a gradual increase from March to the middle of June and then a sharp rise to the end of July falling off to the middle of October.

They suggested the higher infiltration rates during July were due to the vegetal cover protecting the soil from sealing at the surface. Additional factors affecting this phenomenon are lower topsoil moisture, soil surface cracking as opposed to swelling when wet, and higher soil and water temperatures. Beutner *et al* (1940) also found higher infiltration rates during the warmer summer months than during the cooler spring and autumn seasons.

Antecedent Moisture

Antecedent moisture was investigated by Tisdall (1951) using 12 inch ring infiltrometers to determine its relationship to the infiltration rates. Observation indicated the lower the soil moisture the higher the infiltration rate. Also the longer the period of water application the less the effects the antecedent moisture had on the infiltration rates.

Soil Type

Free *et al* (1940) investigated 68 soils to determine relative infiltration and the related soil characteristics. The experiments were conducted *in situ* using a tube type infiltrometer over a wide range of soil types representing most great soil groups, parent materials and climatic provinces. In the laboratory mechanical analyses of the samples were performed and the porosity of the soils measured. A definite association was indicated between infiltration and all indices of large pores or those factors affecting pore-size. Non-capillary porosity, degree of aggregation, organic matter and amount of clay in the subsoil were variables that were tested statistically. When the factors were combined in multiple regression, the correlation coefficient of 0.71 was obtained. From this study the most important single factor influencing infiltration is non-capillary porosity. Organic matter and clay content affect it to a lesser degree.

Verma and Toogood (1969) measured infiltration rates for the major soil types of the Edmonton area. High initial infiltration rates were noticed in all soils. The concentric ring method was used in which was maintained a one cm. head. A comparison of rainfall intensity with infiltration rates showed that there was little erosion hazard for the area.

It has been shown that many variables affect the infiltration process. A difficulty arises as to the relative value of each one of the individual variables that influence infiltration. It must be emphasized that the results from each investigation are <u>relevant</u> only to the specific environment and that particular technique employed. Research results tend to show considerable variance quantitatively but this should neither deter one from further research nor lead one to think that his own results are erroneous. Musgrave and Free (1937) concluded that it was unreasonable to attach a specific infiltration rate to a particular soil type and the measured rates are essentially comparative values.

The Committee on Water Resources in their Report 1 (1966, p.94), stated the following with respect to infiltration: It is still possible to predict infiltration rate from a knowledge of the physical properties of the soil .... Difficulty has also arisen in making valid projections from measurements made on one square or 20 square feet of soil surface to infiltration performance on a 40-acre field or a 10 square-mile watershed.

<u>Measurement of Infiltration</u>

Methods of testing and measuring infiltration are widely varied. In many instances the method used has been developed to meet a specific requirement and as such are not easily adapted to other situations. Parr and Bertrand (1960) classified the instruments into three groups (a) instruments in which infiltration is determined as the difference between water applied and runoff, (b) instruments which impound water in a confined area thus maintaining a head of water, (c) instruments which allow the determinations of infiltration from rainfall data. Three sub-groups add refinement to the above classification of infiltration instruments. They are (1) installations that encase the soil in various sized enclosures, such as tubes, cylinders etc. which do not allow lateral movement of the water, (2) those which allow unrestricted lateral movement, (3) those which provide buffer compartments to compensate for lateral subterranean flow of water from the plot. Musgrave and Holtan (1964) classified the methods used for infiltration work under two headings (a) the analysis of hydrographs of runoff from natural rainfall on plots and watersheds, (b) the use of infiltrometers with artificial application of water to enclosed areas. An infiltrometer is a device for measuring the rate of entry of a fluid into a porous body, for example water into soil.

Hydrograph Analysis

Watershed hydrographs have been used to estimate infiltration. As a hydro or water graph illustrates the amount of rainfall and the discharge or runoff into the stream with respect to time then the difference between these two values would essentially be the amount of water infiltrated into the soil or lost by evaporation. The smaller the drainage basin the less elapsed time or lag occurs between the beginning of the storm and the beginning of the runoff. Foster, as reported by Strahler (1969, p.423), found that on a very small watershed of one acre only 6 minutes elapsed between initial rainfall and increased stream discharge as measured by a rain gauge and current meter respectively. This particular storm lasted only one hour and twenty-nine minutes during which time 1.2 inches of rain fell and 1 inch of water constituted the runoff leaving 0.2 inches infiltrating, a little of which would evaporate. However, on larger watersheds the time lag may be several hours. Surface retention in puddles or small ponds and the vegetation complex (plant transpiration) enter into the picture thus complicating the infiltration calculations. Also rainfall may vary on different portions of the drainage basin. Zingg (1943) on an agricultural watershed of 7.5 acres attempted to determine the subsurface flow, surface storage and infiltration rates from the rainfall and runoff data. Horton (1937) used watershed hydrographs to determine the infiltration rates for large drainage basins. Since any two watersheds depict many more differences than similarities it is necessary to design the experiments properly in order to make a comparative study possible.

Infiltrometers

Infiltrometers may be classified into two general types, (1) rainfall simulators, (2) cylinders. They are usually used for experimental plots or very small watersheds. Repetitive runs for each plot are taken in order to obtain hopefully more reliable data. Much of the work that has been done using rainfall simulators was for erosion calculations but some has been done for infiltration rates.

Many types of rainfall simulators have been devised. Most of them are rather elaborate and once they have been installed are difficult to move although several portable devices have also been built. They employ a series of nozzles that spray water into the air allowing it to drop on the surface as artificial rain. Then arose the difficulty of rain drop size and intensity. Diebold (1941) tested F and FA type infiltrometers on forest soils. Both of these infiltrometers used the type F nozzle which produced drops varying in size from 3.2 to 5.0 mm. in diameter. A tent was used to protect the spray pattern from the wind. Type F has a pressure of 35 p.s.i. and type FA operates at 15 p.s.i. The type F has 13 nozzles that disperse the artificial rainfall onto a 6.6 by 12 foot plot in an arch-like pattern. The rainfall is measured by two 12-foot trough gauges. Modification of these infiltrometers have led to such instruments as the Rocky Mountain infiltrometer or the North Fork infiltrometer. Some experimenters also studied the effect of buffer areas on infiltration rates using the sprinkling infiltrometers.

Many varied types of cylinder infiltrometers have been used for collecting infiltration data. They are usually metal rings but sometimes square compartments, that are driven into the soil to depths ranging from a few inches to one or two feet. Water is added in known amounts to include such principles as falling heads, constant heads or even a sprinkling application. Single ring, double ring or multi-ring devices have been used. The latter two which attempt to control the lateral water movement in the soil by creating a buffer zone have been used in later studies. Supposedly the high variability of infiltration with the single type was due to lateral movement of water but since results are to be considered relatively then this data can be useful.

Caution and uniformity must be exercised when the rings are pressed into the soil surface. It is important to disturb the soil structure as little as possible so that replicated infiltration runs show a minimum of variation. Also, water may seep down the sides of the infiltrometer which results in unnatural flow. With columns that are driven deeply into the ground entrapped air inside the soil column will impede the downward movement of the applied water.

Auten (1933) used rings 2 inches deep and 12 inches in diameter pressed 3 centimetres into the soil surface to study infiltration characteristics. In further experiments he used a 12-inch square metal compartment and he obtained similar results. Musgrave (1935) used a 6-inch diameter cylinder jacked into the soil to reach the B horizon to obtain his infiltration data. Smith et al (1937) followed Musgrave's procedure to study the effect organic matter had on infiltration. The 6-inch diameter steel cylinder was forced into the soil to a depth of 12 inches by a jack screw set against a tractor. Although variability was obvious after repeated runs it was evident that organic matter in the form of barnyard manure significantly influenced the rate of infiltration.

Tests were conducted by Burgy and Luthin (1956) using single and double ring infiltrometers. They found no significant difference between the two types under the conditions of their experiments. Single ring cylinders 4½ inches in diameter and 4½ inches long were placed half their depth into the soil by Slater (1957). The infiltration rates were then compared with those results from an FA type infiltrometer. It was found necessary to conduct 15 replications for a 20 percent accuracy of the single ring type. The median was comparable to one run with the FA type or three runs on hand sprinkled plots.

From this brief review of the many papers written on diverse infiltration aspects it should be re-emphasized that the conclusions drawn should be considered relative to the other variables in each experiment. The results of studies completed at different times in different places may or may not be comparable. The individual focus of each study may also make it difficult to relate several studies in a general manner.

Chapter 3

Present Study

Purpose

During the summer, field tests were conducted to ascertain if infiltration and temperature varied significantly among the selected soils. The resultant data plus the laboratory findings were used to test the following hypotheses:

(1) That the agricultural soil types as depicted by the County Soil Survey maps can be differentiated by their initial rate of infiltration.

(2) That these same soil types can be differentiated by their temperature characteristics.

(3) That the same soil types as shown on the County Soil Survey maps can be differentiated by their texture as established by the laboratory analysis of field specimens.

Location

The inset in Figure 1 indicates the general location of the study area. Situated basically in the small Talbot River drainage basin that flows south-westerly into Lake Simcoe from near the edge of the Canadian Shield, the study area has been divided into three smaller, more specific areas as shown by Figure 1. Two of which are located in Mara Township, Ontario County at approximately 44^{o} 29'N, 10'W, and

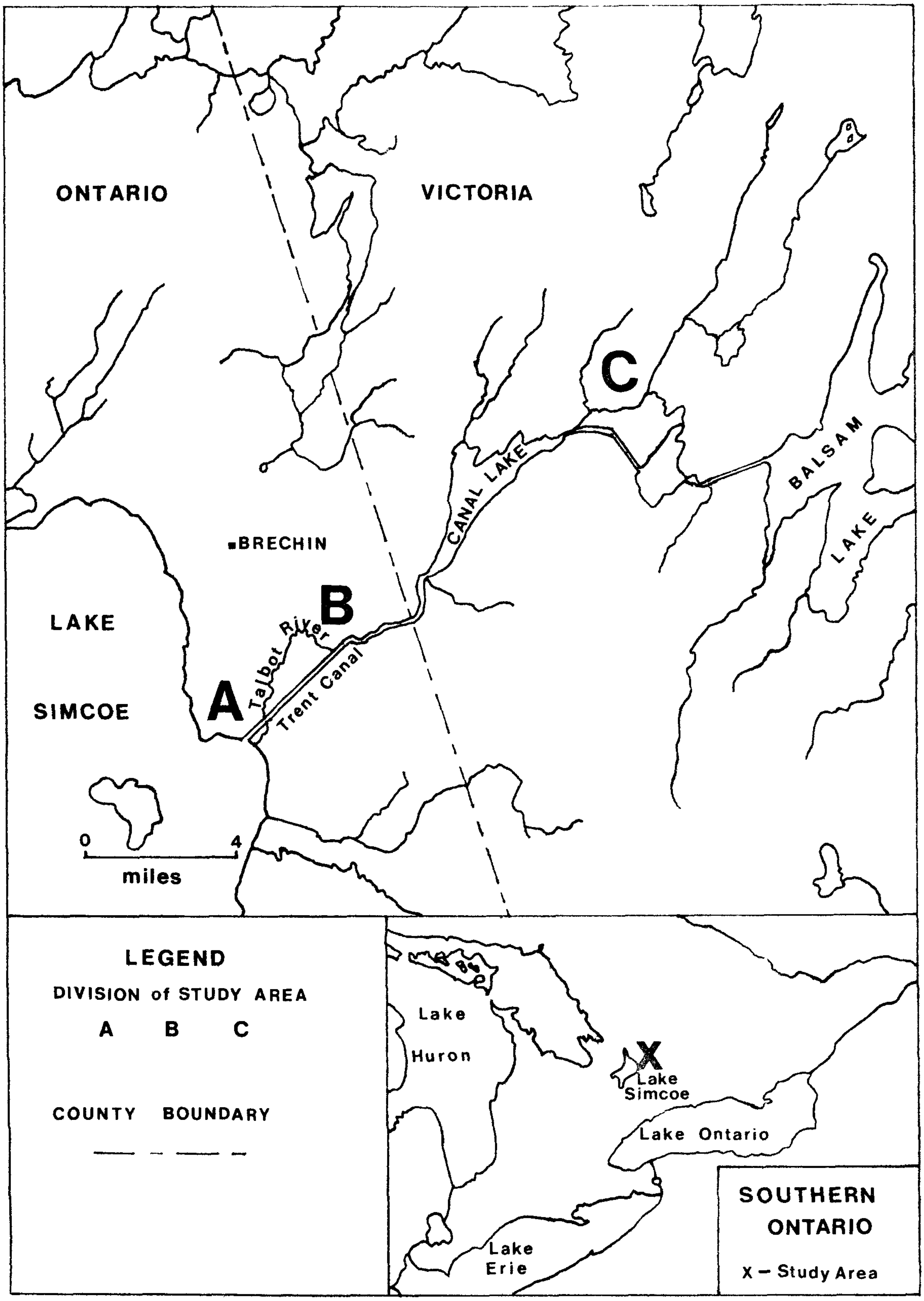


Figure 1. Location of the Study Area

secondly at 44° 32'N, 79° 07'W; the third in Carden Township, Victoria County at 44° 36'N, 78° 58'W. Portions of the Talbot River form sections of the Trent Canal water transportation system which links Lake Ontario to Georgian Bay on Lake Huron.

<u>Palaeozoic Geology</u>

Hydrological explanation of the infiltration phenomenon will be facilitated by a brief review of the geological history, topography, climate, soil development and present land use of the study area.

The Lake Simcoe drainage basin lies on the Southern Ontario Palaeozoic Plain known physiographically as the Great Lakes Lowlands specifically Interlake Ontario (Hough, 1958). Chapman and Putnam (1966) have classified this portion of the study area as the Lake Simcoe Basin of the Simcoe Lowlands. About half of the Lake Simcoe basin is occupied by the waters of Lake Simcoe. At the highest level of the hierarchy it is the eastern extremity of the Interior Plains of North America situated between the Precambrian Canadian Shield to the north and the Appalachian Highlands to the south. The study of the stratigraphy of the Lake Simcoe area by Liberty (1969) reported limestone to the depth of approximately 500 feet overlying the Precambrian and Cambrian rock. The strata which are of the Ordovician Period have a regional dip averaging about 25 feet a mile to the southwest.

A portion of the Table of Formations (Liberty, 1969) that pertain to the study area is outlined in Table 1. The

TABLE 1

Stratigraphy and Lithology of Simcoe Group after Liberty (1969)

Stage	Group	Formation		Lithology
Trenton	Simcoe	Lindsay		Grey lithographic limestone
		Verulam	Upper member	Fine, medium-coarse crystalline limestone
			Lower member	Interbedded limestone with shale
		Bobcaygeon	Upper member	Calcarenites and sublithographic limestone
			Middle member	Sublithographic limestone
			Lower member	Argillaceous limestone and calcarenite
Black River		Gull River	Upper member	Lithographic semi-crystalline limestone
			Middle member	Lithographic limestone
			Lower member	Dolomitic and lithographic limestone

two formations of the Simcoe group which form the surface bedrock of the research area are the Bobcaygeon and Verulam formations. Part of the study area is located on the Verulam

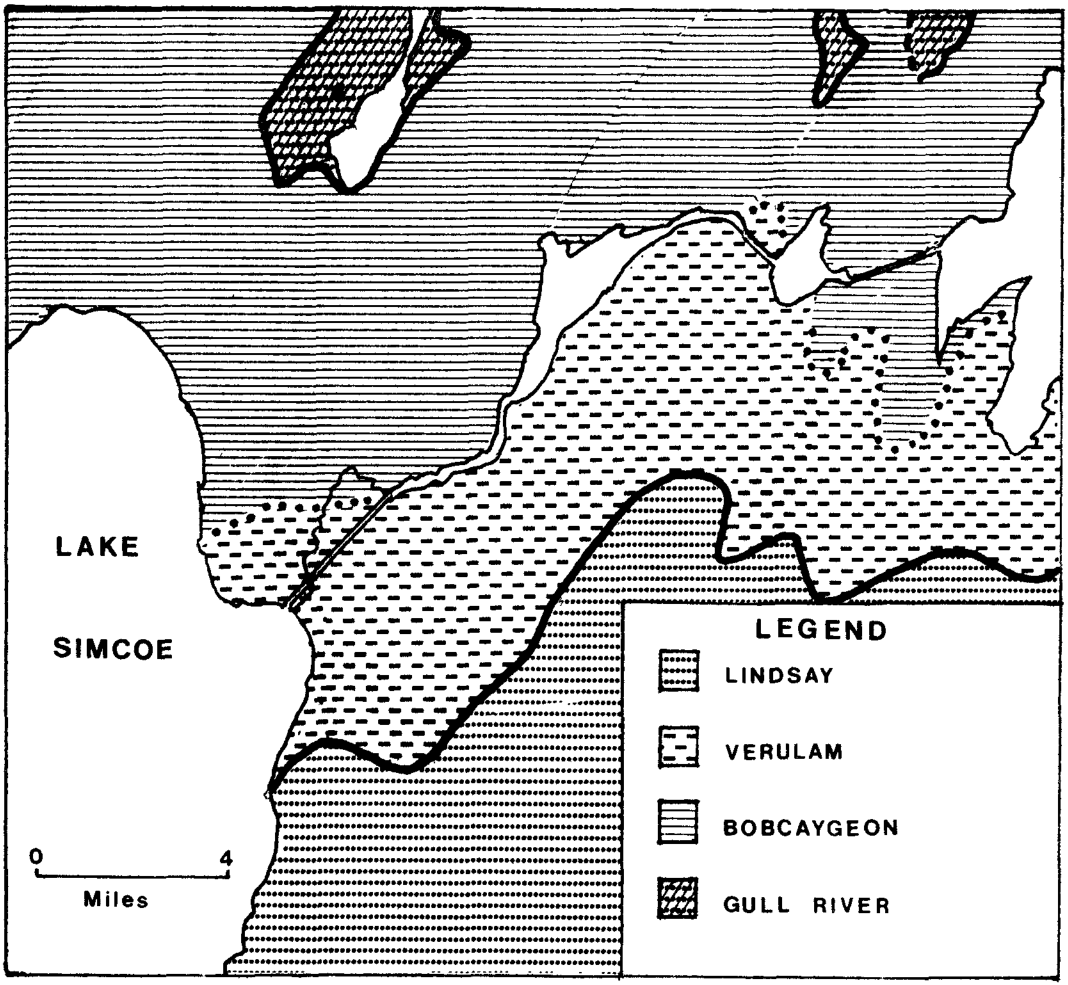


Figure 2. Bedrock Formations of the Middle Ordovician
after Liberty (1969)

formation as shown in Figure 2 and the rest of it is located on the Bobcaygeon formation. Glacial drift covers most of the Palaeozoic bedrock in the area but where it does outcrop the Bobcaygeon weathers more towards a greyish colour whereas the Verulam tends to a brownish colour.

Pleistocene Geology

With the waning of the Wisconsin ice-front the glacier left unconsolidated material of glacial, glacio-fluvial or glacio-lacustrine origin (Deane, 1950). As the study lies at the southern edge of the Canadian Shield which is composed of hard granitic rocks, the depth of till varies from several inches to several feet within a distance of twenty miles from the shield. Figure 3 depicts the glacial features of the region. The distribution of drift is not uniform as there are outcrops of limestone bedrock occurring throughout the area. The drumlins and roche moutoneés indicate that the last or most recent glacier advanced from the northeast. Some granitic erratics appear mostly on the till plain throughout the area.

As the glacier retreated, kames, eskers and moraines were formed. Glacial Lake Algonquin reworked these deposits below 825 feet creating clay and silt filled depressions (Deane, 1950). It also removed much of the till from the limestone plains at approximately the 800-825 foot altitude which settled differentially into deposits of stratified sand, silt, and clay usually only a foot or two thick.

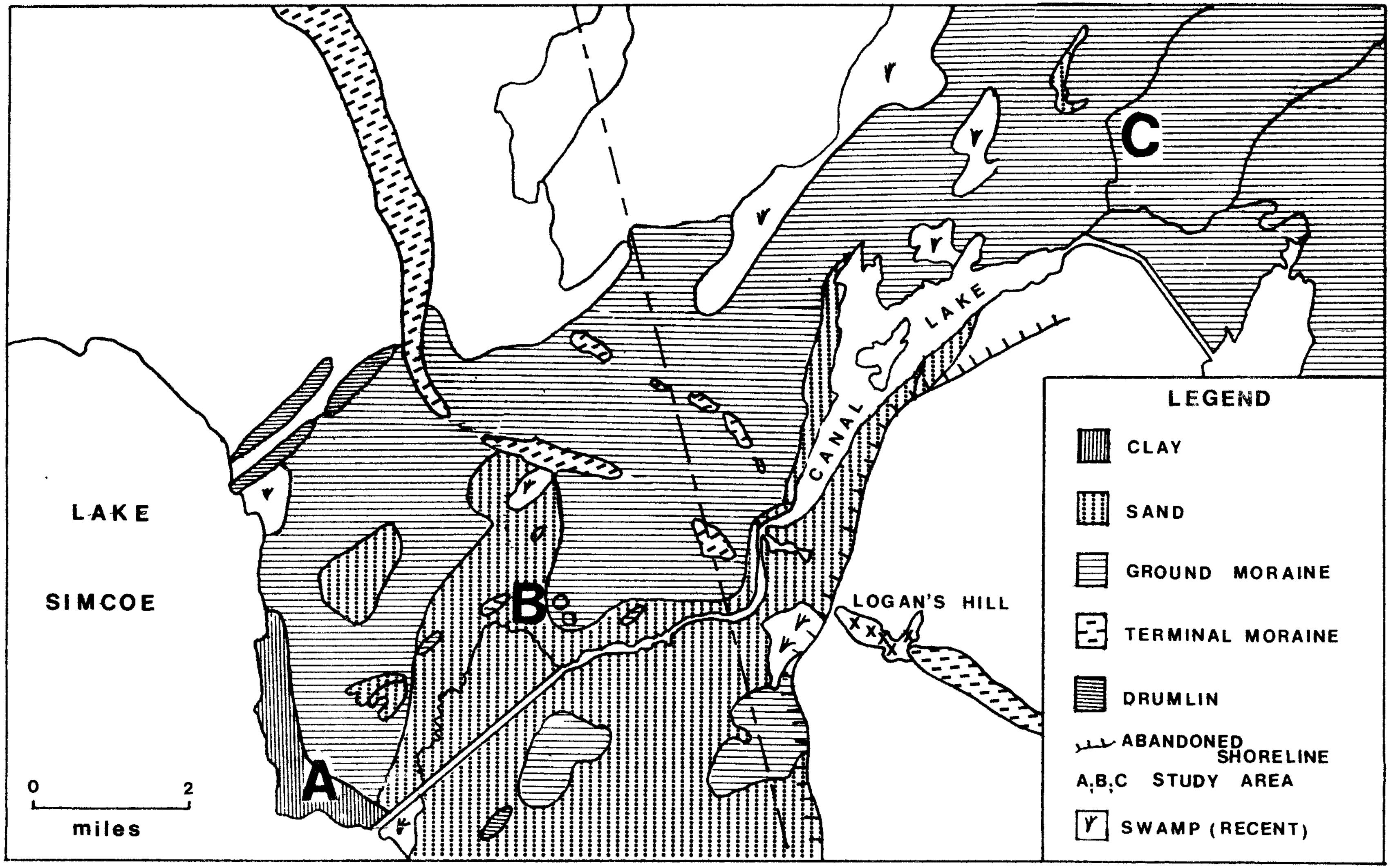


Figure 3. Glacial Features
adapted from Deane (1950)

Topography

The outlined research sections on Figure 3 show that two of the three study areas lie southwest of the two thin, discontinuous Mara moraines which extend across the limestone plain in a northwest-southwest direction marking the trend of the ice-front (Chapman and Putnam, 1966). The subdued topography and the stratified material suggest deposition in water according to Deane (1950). Note the frequency of gaps in the moraines. Logan's Hill forms a high ridge of stratified sand and gravel south of Canal Lake in direct line with the moraine. This is a kame deposit at the mouth of a glacial stream. A few drumlins are scattered throughout the study area but they are much lower and shorter than the major portion of the Mara drumlin field just north of Brechin. The latter are long narrow ridges less than 50 feet high, some with steeper sides due to Lake Algonquin wave action. These drumlins may be up to 8,000 feet long and 600 feet wide. As noted in Figure 3 the whole study area lies below the abandoned Lake Algonquin shoreline so therefore most of the materials have been reworked by water since the last glaciation. Also spreading out on either side of the Talbot River southwest of Canal Lake there is a relatively large section of sandy outwash material formed by the melt waters of the glacier. Ground moraine is the predominant glacial feature for the study area. Certainly much of it was covered by water but it was close to the shoreline and most of the lacustrine deposits were shallow and subsequently washed away by the receding water. A few rock outcrops and small drumlins break the otherwise flat surface of the ground moraine. Beside the drumlins are either clay and silt filled depressions or muck areas.

Climate

Putnam and Chapman (1938) allocate this area to the Simcoe and Kawartha Lakes climatic region, which lies between the physical features of the Oak Ridges moraine to the south and the Haliburton Highlands to the north. The winters tend to be colder and the springs come later here than in the area closer to Lake Ontario.

Briefly, the mean annual temperature is 42° to 44°F, with summer 65° to 67°F. The frost-free period ranges from 120-140 days while the growing season varies from 188-195 days (Gillespie and Richards, 1957).

The precipitation ranges from 27-34 inches per year and the growing season receives slightly more than one-half of this amount. June, July and August receive 7-9 inches. Tables 11 and 111 give the temperature and precipitation data for the two climatological stations Orillia and Lindsay, which lie on either side of the research area. These tables are adapted from Soil Survey Report 23, prepared by Olding, Wickland and Richards, (ca.1956), that have been obtained from records for a period of 38 years for Orillia and 57 years for Lindsay. As noted from Table 11 the yearly mean temperatures are identical, and in Table 111 the yearly mean precipitation varies by 0.5 inches for the study region.

TABLE 11

Monthly and Annual Averages of Daily Mean Temperature

	J	F	M	A	M	J	J	A	S	O	N	D	YR.
Orillia	17	14	26	40	53	63	68	66	59	47	34	21	42
Lindsay	16	16	26	41	54	64	68	66	59	46	34	21	42

TABLE 111

Mean Monthly and Annual Precipitation in Inches

	J	F	M	A	M	J	J	A	S	O	N	D	YR.
Orillia	2.6	2.2	2.0	1.9	2.7	2.8	2.8	2.6	3.1	3.2	3.4	3.0	32.3
Lindsay	2.9	2.4	2.4	2.2	2.8	2.9	3.1	2.8	3.1	2.7	2.9	2.6	32.8

Agricultural productivity is directly related to the amount of water that is available for plant growth whenever water is the limiting factor. Evaporation plays a very important role in the amount of water that remains available for plant growth. Thornwaite (1948) proposed a method to estimate the potential evapotranspiration from climatic records. The potential evapotranspiration values obtained are defined as the volume of water the soil would lose to the atmosphere by evaporation and transpiration if it were constantly available. If the soil's storage capacity, the evapotranspiration and precipitation are known for an area, then it would be possible to obtain the moisture deficiency for any soil series.

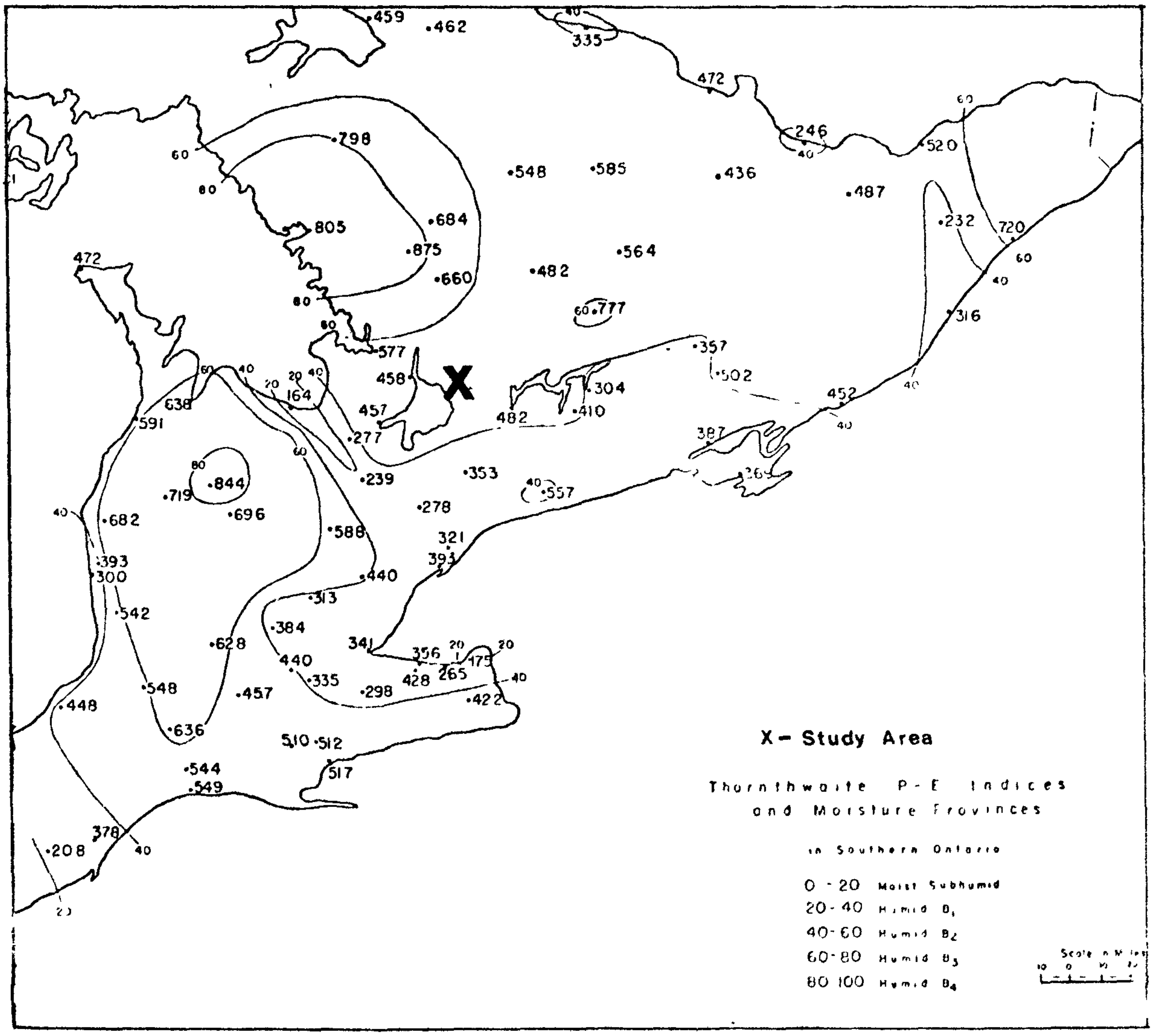


Figure 4. Potential Evaporation Indices and Moisture Provinces in Southern Ontario from Sanderson (1950)

Sanderson (1950) applied Thornwaite's classification technique to Southern Ontario. According to her calculations the study area lies in the Humid B_2 region with a Potential Evapotranspiration Index of 40-60 possibly 45-46 from Figure 4. Except on rare years the area has a moisture deficiency. The Otonabee loam soils showed a deficiency of 1.7 inches in August calculated on the monthly means for 57 years (Gillespie and Richards, 1957). This result indicates that except for extremely dry years grain and hay crops should not suffer from lack of moisture.

> Clay soils, which have a greater water-holding capacity than loam soils should have a very small deficiency in moisture in August but the coarse textured sandy soils which may not hold more than 2.0 to 2.5 inches of water will have serious moisture deficiencies in July and August (Gillespie and Richards, 1957, p.17)

Soils

Soils can be classified in many ways. The criteria used depends on the objective e.g. applied classification -- texture, pH, stoniness, structure, erosion or any one of the many other soil properties or e.g. present use -- continuous row crop, forests, permanent pasture, ranchland, industrial, residential and so on. Soil capability classification for agriculture indicates the optimum or major limitations that a farmer can put his land to use. Seven classes are recognized, e.g. class 5 -- soils unsuited for cultivated field crops except perennial forage crops and are responsive to improvement practices; they have serious soil, climatic or other limitations which deems them unsuited for the production of field crops; adapted grasses and legumes may be grown with improvement practices which may include cultivation, seeding, fertilizing and water control (Webber and Hoffman, ca.1967). Soils may be taxonomically classified with their descending hierarchy being: order, great group subgroup, family, series and type. Based on the properties and arrangement of horizons as shown in a soil profile, each soil can be classified. Final classification of the soil type into clay loam or clay is determined by the texture of the soil surface horizon.

Soil-forming processes gradually differentiate the soil material into layers or horizons distinctive from the weathered parent material and parent bedrock. The three parts are referred to as the solum (A & B horizons), subsoil (C horizon) and the bedrock (D horizon) respectively. Organic horizons overlying the mineral soil are differentiated into L, F and H depending on the amount of decay present. The mineral horizons are designated as A, B and C. Each one of these may be further divided depending on its distinguishing characteristics such as colour and organic matter content, e.g. Ap -- horizons greatly disturbed by cultivation or pasturing; Ae -- horizons eluviated of clay, iron, aluminum and/or organic matter; Bf -- horizons enriched with iron; Bg -- horizons which show chemical reduction and yellowish brown mottles; Ck -- horizons containing lime. A theoretical profile is shown in Appendix A.

The soils investigated in this study belong to the Podzol, Gray-Brown Podzolic and Brown Forest Great Soil groups. The Podzol soils have developed under a mixed forest or coniferous vegetation where the leaf litter accumulates. The decaying organic matter has a strong leaching effect which gives an eluvial grayish layer near the surface. A distinct illuvial horizon is formed by the translocated clay, organic matter and sesquioxides. They are found on well-drained sites where the climate is moist and cool. The Gray-Brown Podzolic soil which is more alkaline than the Podzol soil is inhabited by bacteria whereas fungi are prevalent in the Podzol. These are developed under a slightly warmer climate than the Podzol. The Brown Forest soils develop under similar conditions as the Gray-Brown Podzolics. They do not have the distinct eluvial or illuvial horizons.

The principal agricultural soils on which the infiltration tests were investigated belong to the Smithfield Series, Otonabee Series, Wendigo Series and Farmington Series. The specific soil types for each series are delimited in Figure 5 which contain only the portions of the Ontario County and Victoria County soil surveys maps as they appertain to this thesis. The soils as shown by Figure 5 are Smithfield clay loam, Otonabee loam, Wendigo sandy loam and Farmington loam. The A horizon is described for each series.

<u>The Smithfield Series</u> which is the imperfectly drained member of the Schomberg catena, has been developed on the lacustrine deposits of calcareous clay. They are generally stonefree with a few boulders scattered on the

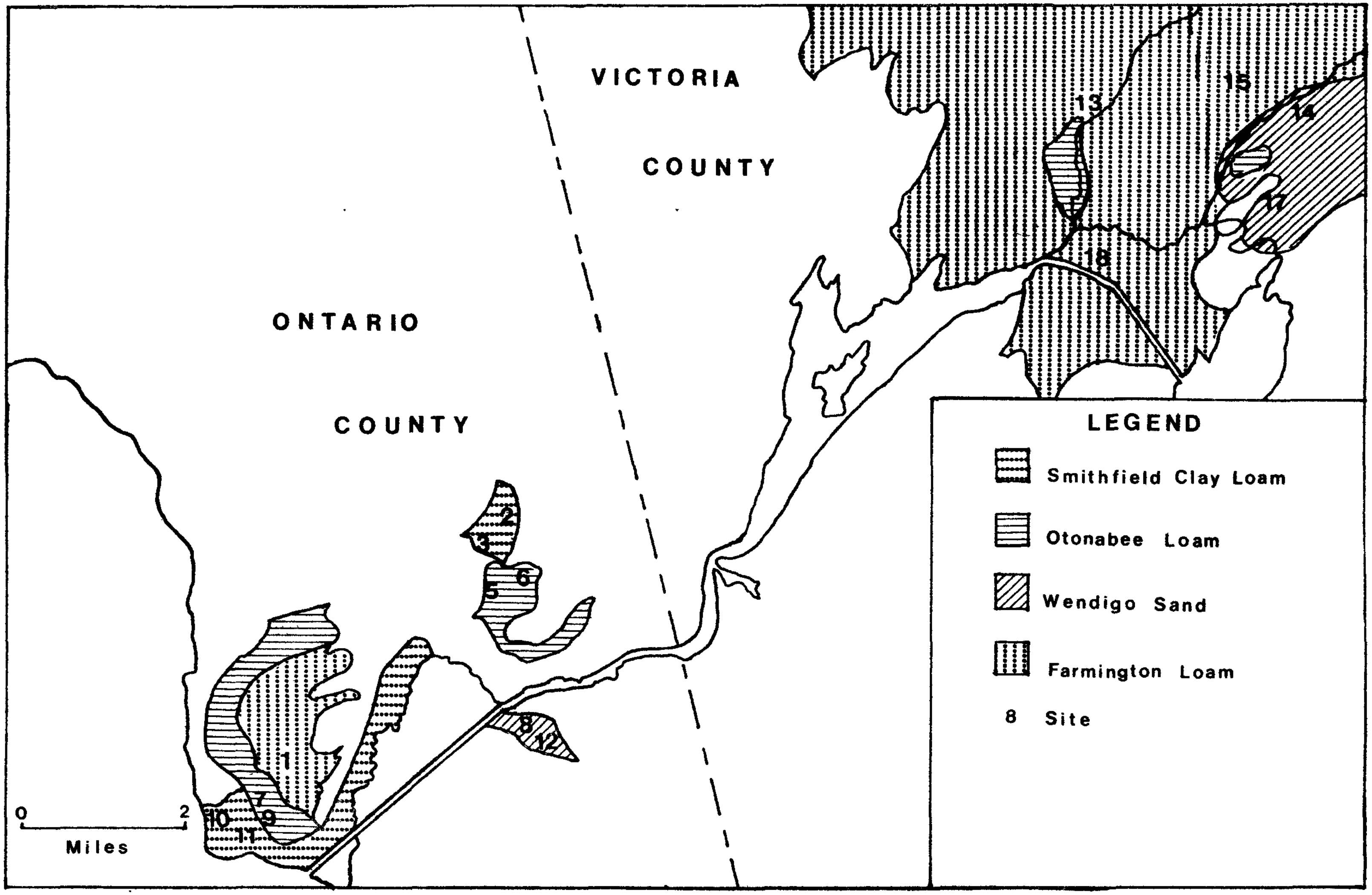
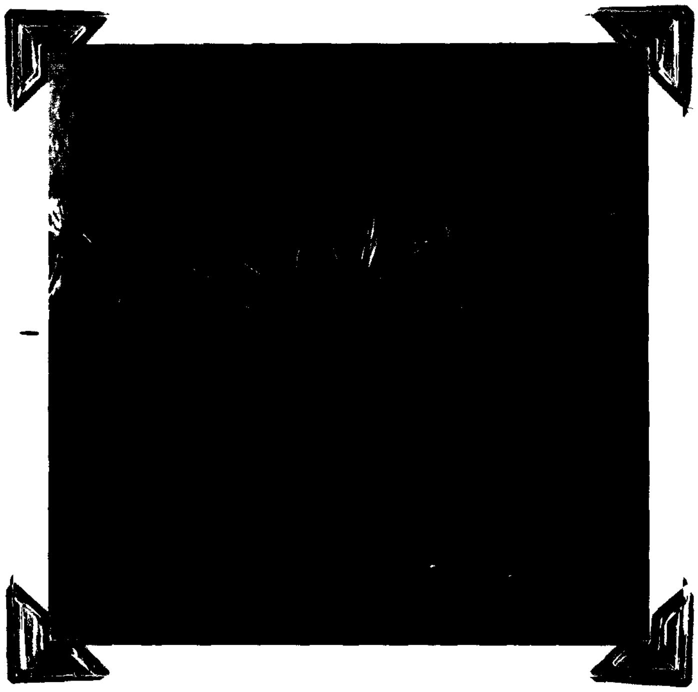


Figure 5. Study Area Soil Types adapted from County Soil Survey Reports 23 and 25

surface. The soil texture varies from a clay to a loam. It belongs to the Gray-Brown Podzolic Great Soil Group. Olding, Wickland and Richards (ca.1956) describe the A horizon of a

Figure 6.

Smithfield Series Profile



typical cultivated profile of the Smithfield Series as:

A_c --- 0-7 inches very dark grey (10 YR 3/1) clay loam; coarse granular structure; friable consistency; pH -- 7.2.

A_2 --- 7-13 inches grey-brown (10 YR 5/2 clay loam; medium subangular blocky structure; firm consistency; mottled; pH -- 7.0.

The colouring of soils is from the Munsell Notation of the Soil Survey Staff (1960) as follows:

10 YR -- hue -- dominant spectral (rainbow) colour, related to wave length
3 -- value -- relative lightness of colour function total light
1 -- chroma or saturation -- purity or strength of spectral colour and increases with decreasing greyness.

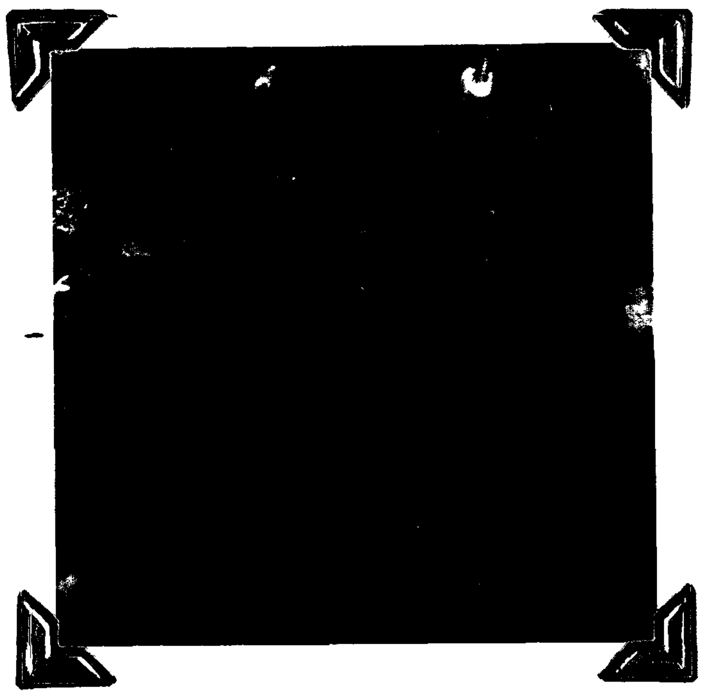
These soils are very fertile and their productivity is only limited by drainage for general farming. Figure 6 illustrates the profile of Smithfield Series observed in the study area. From this picture it can be seen that the layer of topsoil closely approximates the typical profile in depth and colour. The earth removed from the hole has coarse granular appearance.

The Otonabee Series has developed on calcareous sandy loam till which contains a moderate amount of stone. It belongs to the Brown Forest Great Soil Group. Good drainage, both internal and external, is a characteristic of this soil. A profile description by Olding, Wickland and Richards (ca.1956) of the A horizon is as follows:

A_0 --- thin layer of partially decomposed leaf litter.

Figure 7.

Otonabee Series Profile



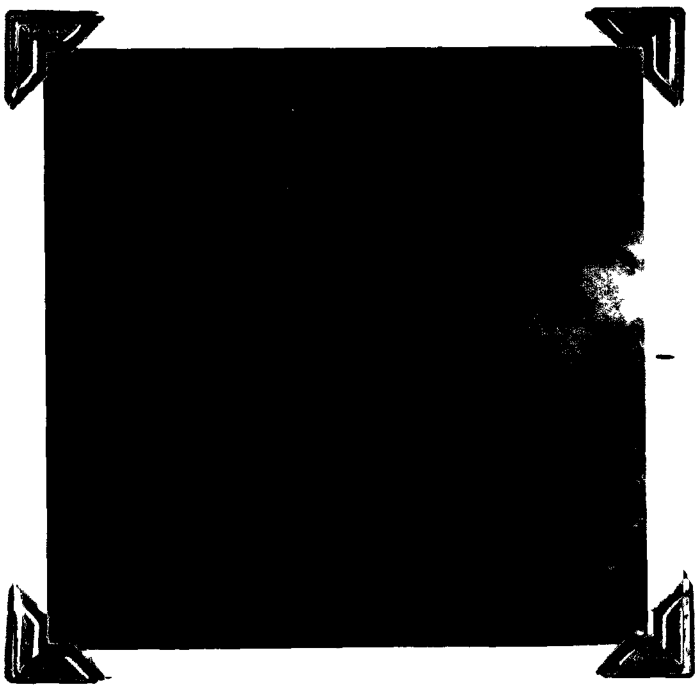
A_1 --- 0-4 inches very dark greyish brown (10 YR 3/2) loam; fine crumb structure; very friable consistency; stony; calcareous; pH -- 7.6.

The soils are of medium fertility but high in lime. Figure 7 illustrates the profile of Otonabee loam observed in a fence row within the study area. The depth of dark soil in the picture is approximately 18 inches but this includes the A and B horizons. The A horizon is only 6 inches deep and is slightly lighter in colour than the B but darker than the C. Small stones dug from the hole appear on the surface and also can be seen in the profile. The pile of earth beside the hole has a fine, crumbly appearance.

The Wendigo Series has developed on outwash coarse sands and gravels. The profile is characteristic of the

Figure 8.

Wendigo Series
Profile



Podzol Great Soil Group. Very good drainage is a feature of this soil type but it has a tendency to be droughty. The A horizon of a cultivated profile has the following description according to Olding, Wickland and Richards (ca.1956):

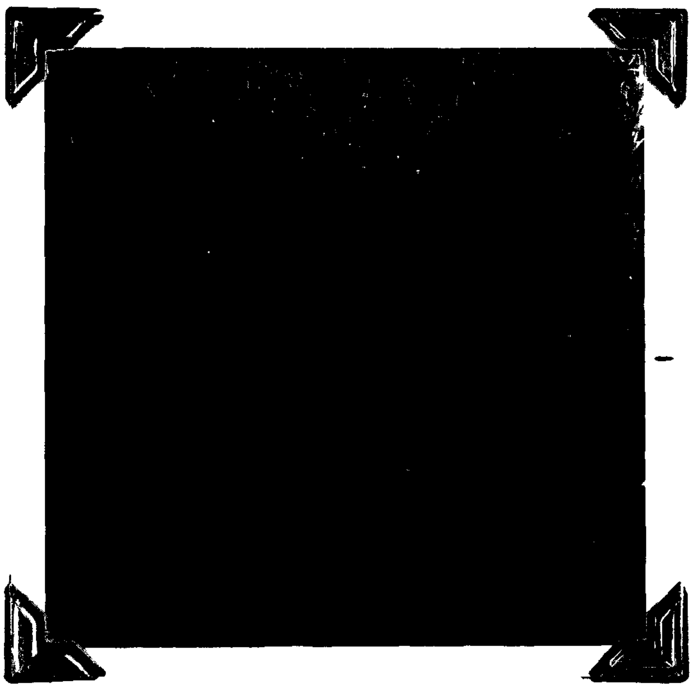
> A_c --- 0-6 inches dark brown (10 YR 4/3) sandy loam; fine crumb structure; extremely friable consistency; pH -- 6.0.

These soils are generally low in natural fertility. Figure 8 illustrates the profile of Wendigo sandy loam observed on a road allowance near site #8 in the study area. Directly below the stakes in the picture the depth of the darker soil is 5 inches. Even within the few feet shown, the A horizon becomes lighter in colour and thinner. The C horizon is very sandy and light in colour.

<u>The Farmington Series</u> has developed from a thin

Figure 9.

Farmington Series Profile



layer of till over limestone bedrock. A member of the Brown Forest Great Soil Group it varies from a few inches to one foot in thickness. A virgin profile has the following characteristics as described by Olding, Wickland and Richards (ca.1956):

A_1 --- 0-4 inches very dark brown (10 YR 2/2) loam; medium crumb structure; friable consistency; calcareous; stony; pH -- 7.2.

The soil is saturated easily because of depth and poor drainage. Figure 9 illustrates the profile of Farmington Series observed in the ranch at site #1 of the study area. The total depth is 8 inches and even then it is interlaced with pieces of limestone which jut out. It is difficult to distinguish the horizons here.

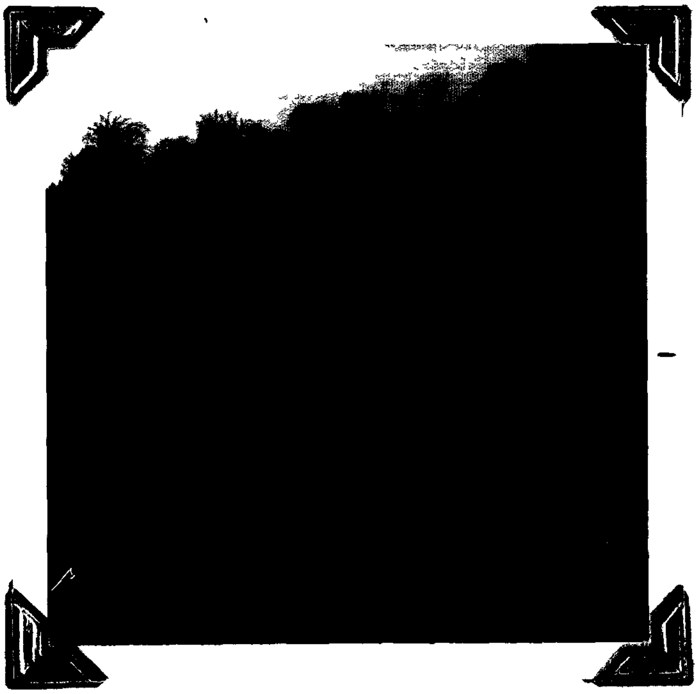
Land Utilization

Figure 10.
Corn Field

Infiltration data were gathered from soils on which various economic activities were conducted therefore it seemed in order to describe the agricultural scene of the study areas. Ranching or pasturing of beef cattle utilize the poorer areas of the shallow soils over the limestone bedrock and the droughty, sandy or gravelly soils of the kames and eskers. Intermingled with these are the pockets of lacustrine sediments of clay and silt on which mixed farming is practised. Most of these require artificial internal and external drainage for maximum production. Although they are sometimes very stony, the soils developed on the sandy loam till make very good farmland.

With proper management very good yields of ensilage corn or grain corn can be obtained. Figure 10 shows the writer's wife, who is 5 feet 7 inches tall, standing in a field of corn grown on Otonabee loam. By early August the stalks show large well-developed ears for this part of Ontario. Many farmers grow 8-10 acres of corn to store in the silo for winter feed. With the development of earlier maturing hybrids, some farmers in the area grow an additional 25-40 acres of grain corn. Mixed grain, usually of barley and oats as shown in Figure 11 is grown mainly for feeding livestock on the farm. This field has also been seeded down to a hay mixture which utilizes the grain crop as protection for the new seedlings, most clearly seen in lower right of the picture. Although Figure 10 and Figure 11 are of crops on Otonabee loam, equally as good or better yields

Figure 11.
Mixed Grain



can be produced on the Smithfield Series, particularly with artificial drainage using clay field tile or the newer poly-propolene drainage pipe.

A field of Birdsfoot Trefoil appears in Figure 12. Dotted by golden yellow blooms, the heavy crop stands waiting for the mower which will cut it in preparation for storage. Under this vegetative cover lies the fertile Smithfield clay loam at one of the test sites. In the foreground sits the infiltrometer used for the infiltration tests. Nearly any crop may be grown on these soils subject to climatic limitations and drainage mentioned above. These crops are produced to supply winter feed for the beef animals and a few dairy (cream producers) animals. Some winter wheat is

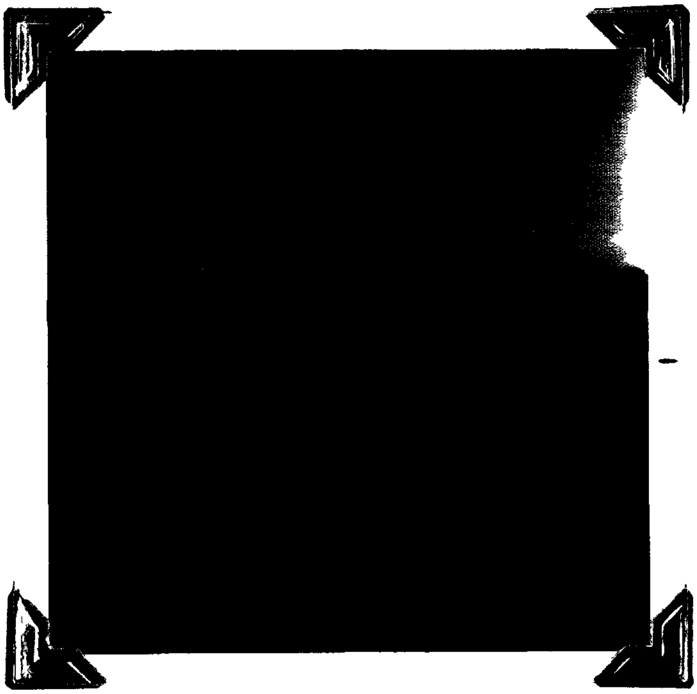
Figure 12.
Hay Field

grown on the better drained soils as a small income cash crop.

The cultivated portions of the farms have not increased in acreage during the last two generations but ranch land has been added to the farmstead which removes the summer burden of pasturing from the tillable acres, thus allowing more fodder to be produced for winter feeding and consequently increasing the number of cattle and other animals (pigs) that can be raised per farm.

The ranches, located on the shallow till soil of the Farmington Series, provide rather sparse grass vegetation but the cattle fatten quite well on it, providing the level of grazing intensity is one animal to fifteen or twenty acres. These ranches usually become quite dry during the summer mon-

Figure 13.
Ranch Land

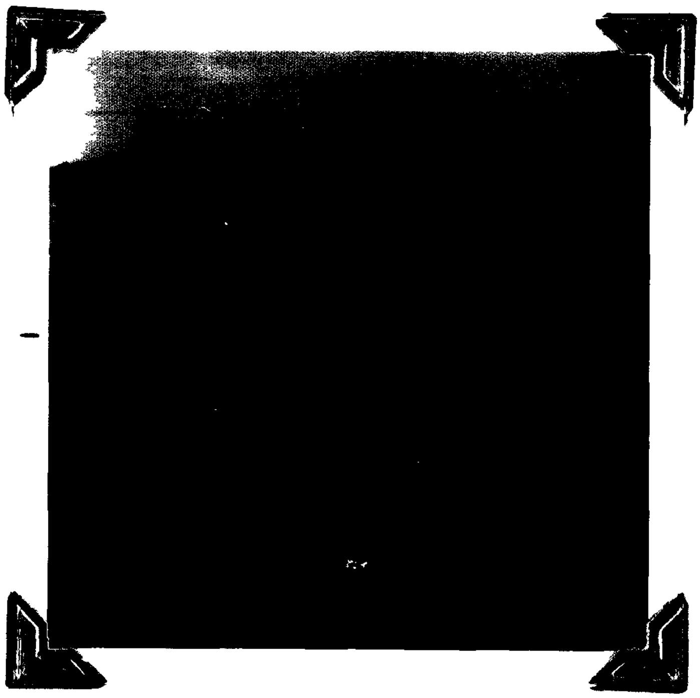


ths because the shallow soil does not have any water reserve, yet the beef cattle still thrive on the withering grasses of the sun-burned pastures. In the centre of the picture rests the remnant of a past era -- a large, uprooted, white pine stump. Lumbering and forest fires have cleared thousands of acres. Natural reforestation on these soils is extremely slow. In the background cedar, birch, poplar and elm are establishing forest cover.

On the sandier outwash materials, Figure 14, it is necessary to provide additional supplements for the live-stock during the pasturing period whereas salt is all that is required on the limestone plains. Weeds such as Golden-rod and Canadian Thistle infest the field in this picture.

Figure 14.

Old Pasture



Also the grass has been grazed in the lower part of the picture but not in the middle. On the Wendigo sandy loam the cattle tend to do this, probably because the grass is sweeter in some places than other parts of the field. Some farmers still grow grain on these soils but the crop must be planted early to gain full benefit from the available moisture and mature before midsummer when this sandy loam usually becomes droughty. This is the main reason why most of the Wendigo Series are pastures or abandoned farms now.

Chapter 4

Materials and Methodology

Figure 15.

Field Infiltration Equipment

Field Materials

(1) A cylinder 15.5 centimetres high and 12.3 centimetres in diameter, constructed of thin tin plate was used for the infiltration studies. A remodelled flour sifter was the basis for the infiltrometer illustrated in Figure 15. The handle as shown was for carrying purposes only. Hand pressure placed the infiltrometer into the soil surface.

(11) The water supply was obtained from a dug well and transported to each site in the 2 gallon pail shown in Figure 15. The cup in Figure 15 was used to measure the constant quantity of water that was poured into the infiltrometer at each site.

(111) A stopwatch measured the time in seconds that was required to complete each test.

(1V) To measure the temperature of the soil a mercury centigrade thermometer was employed. A one-quarter inch steel rod was used to make the hole in the topsoil into which the thermometer was placed.

(V) A field notebook was carried to each test site for the purpose of recording the infiltration times, temperature and any other remarks that the writer considered had changed from the previous day.

(V1) Soil sample bags and a spade were used to collect a sample of the topsoil for each test site once during the test period.

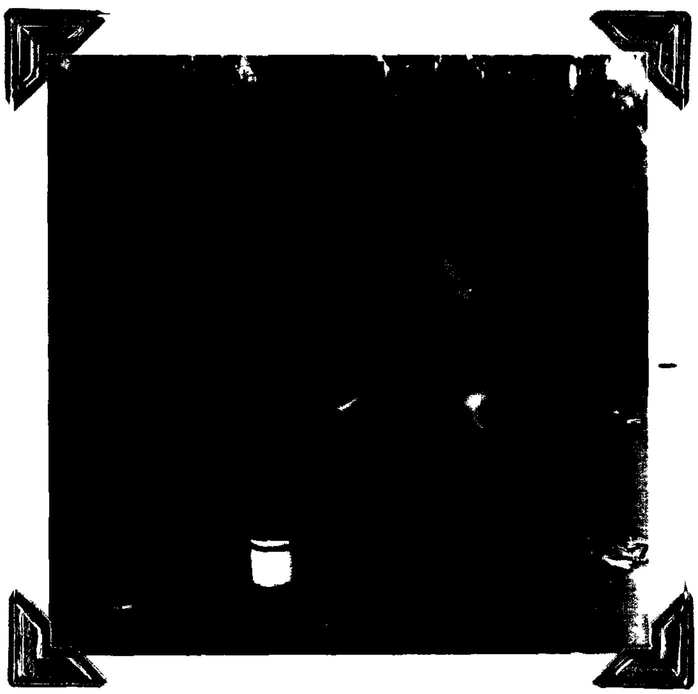
Field Methods

Actual sites on which the infiltration tests were conducted were chosen without bias. To accomplish this unbiased location or stratified random sample, a clear, square grid was placed over the county soils maps of the general study area. Numbers were called from a table of random numbers (Freund, 1960). When the coordinates coincided with the previously selected soil types of Smithfield clay loam, Otonabee loam, Wendigo sandy loam and Farmington loam, the positions were recorded on Figure 5 to give a total of 4 separate locations on each soil type. An identification number such as 2 Warren was entered in the field notebook, or 11 Trefoil. The complete set of test sites is given in Appendix B. In the field each plot was located from the soils map and marked. Each individual plot had a radius of five feet.

As the infiltration equipment had to be transported from place to place the single ring infiltrometer was chosen. Because of its very thin metal construction, it could be pressed into the topsoil to a depth of 3 centimetres at each location. The insertion was facilitated by a one-quarter clockwise turn of the infiltrometer. This technique reduced the disturbance of the soil surface. However it was necessary to insert the infiltrometer carefully as a stone in its

Figure 16.

Test in
Progress



path could bend it.

In Figure 16 the constant volume of water has just been poured into the infiltrometer at the site 9 Bush Field. The receding water is observed and the length of time it took to disappear is measured by the stopwatch which is held in the hand.

The volume of water that was used for each test, at each site, for each day the experiment was performed measured 240 cubic centimetres. This particular volume of water was chosen as it gave an initial head in the infiltrometer of no greater than 2 centimetres or 0.79 inches. Brown, McKay and Chapman (1968) state the probability of this amount of water occurring from a daily rainfall during the year is less than 4 percent at Lindsay, therefore this present infiltration test could more reasonably be related to the natural phenomenon of rainfall. Also they state the probability of precipitation of 1 inch or more on a given day is generally less than 2 percent but it is greatest in the summer because of thundershowers. The depth of the initial head would vary slightly depending on the rapidity of infiltration.

The stopwatch was started at the beginning of the pouring and stopped when the last film of water disappeared into the soil inside the infiltrometer. All the pouring and all the readings were done by the writer in order to reduce any operator error existent. The number of seconds was recorded in the field notebook immediately upon completion of the test. The tests were taken at 3 to 5 day intervals (Appendix B) during the summertime July 1 to September 14, 1968. However, they were not run during rain showers as this would change the constant volume of water supplied to the infiltrometer. A total of 21 observations for each site are recorded in Appendix B.

The soil temperature was recorded at the same time as the infiltration test was run. The one-quarter inch rod was pushed 5 centimetres into the soil to make a hole for the thermometer. This was done any place on the 5 foot radius site. After the temperature had stabilized, it was observed and recorded in centigrade degrees in the field notebook. Appendix B contains this data.

A soil sample from the uppermost 6 inches of the profile was taken once during the summer from each site. From the side of a hole, a 2 inch thick layer was sliced off with the spade. The sides of this layer were trimmed to provide a core of topsoil 2 inches square and 6 inches deep. Then the core was deposited in a waxed paper bag inside a paper box and labelled in readiness for the laboratory tests to be performed on it later.

The vegetal cover was noted in the field notebook at the initial pouring. Any noticeable change was recorded throughout the testing period.

Laboratory Methods

Additional information was gathered by conducting further tests on the soil samples in the laboratory. Detailed procedures for each test can be found in the appendices. A summary of each method for the tests used is given below.

A particle size analyses following the procedure of Bouyoucos's (1962) improved hydrometer method, was performed on the soil samples collected from the field sites. A sample splitter was used to obtain a representative sample of approximately 50 grams. To this 50 gram sample of air-dry soil which had passed through a 1 mm. sieve, was added 100 cc. of 0.5% solution of Calgon. This mixture was thoroughly stirred and allowed to stand overnight or 12 to 15 hours. Then the contents were washed into the soil cup from the dispersing machine using distilled water. The cup was filled to about 3 inches from the top and put on the dispersing machine travelling at 16,000 r.p.m. for 2 minutes. These contents plus enough distilled water to reach the 1 litre mark, were thoroughly mixed by manual agitation. The cylinder was placed in the water bath of 68°F. The initial hydrometer reading was read at 2 hours.

The combined amounts of sand, silt and clay as determined by this hydrometer method classified the soil particle size according to Canadian Department of Agriculture specifications which are sand 2.00-0.05 mm; silt 0.05-0.002 mm; clay less than 0.002 mm. To calculate the results the hydrometer reading at the end of 40 seconds was divided by the weight of the soil used and multiplied by 100. This gave the amount of soil particles still in suspension. The difference between this value and 100 was the percentage of sand in the soil sample. Similarly, this calculation was performed for the 2 hour reading, indicating the proportion of clay that remained in suspension. The difference of these two values gave the percentage of silt. This hydrometer method did not use pretreated soils, therefore the organic matter remained within the sample for this test. The detailed procedure is given in Appendix C.

For the wet sieve tests about 40 grams of soil was thoroughly pulverized with a rolling pin and was put in the oven at 105°C. to dry overnight. The samples were cooled in the desiccator and weighed. The sample was then washed into a nest of sieves comprised of 1 mm., 0.50 mm., 0.250 mm., 0.125 mm., and 0.074 mm. The soil was washed down through the sieves, being careful not to overflow them, until the clear water flowed from the bottom of the nest. The sieves were put in the oven at 110°C. to dry. After they had dried and cooled sufficiently to allow the soil particles to be whisked from each sieve they were weighed cumulatively.

Statistical analyses of the data were performed on the results collected in the field and in the laboratory. The mean and the standard deviation were calculated for the infiltration and soil temperature data. In addition to the tabulation and graphing to discover correlations or interactions, the infiltration data was subjected to an analysis of variance. Gregory (1968) applied this test and other statistical tests to various geographical problems. The analysis of variance was employed to see if the infiltration times as recorded varied significantly between the soil series as well as within each soil series. Such an assessment of whether the difference between several sets of data is significant or not is essential before any consideration is given to what is causing the difference. A null hypothesis is assumed that there is no significant difference between the samples, and that the two variance estimates are not significantly different. Using Tables for F ratio calculated at 95% or 99% level and the necessary degrees of freedom the test either indicates an acceptance or rejection of the null hypothesis.

The Student's 't' Test was applied to ascertain if the difference between the infiltration means and the temperature means of the soil types, as reported from the field work, were statistically significant. As the standard error of the difference and the number of degrees of freedom are part of the 't' equation, this refinement assists one to evaluate the significance of the difference between means.

Chapter 5

Analysis

The results presented and conclusions drawn apply to the main part of the summer beginning July 1 and concluding September 14, 1968. The infiltration values were obtained by timing the disappearance into the specified soils of the given volume of water within the infiltrometer. Seasonal site and soil series means were calculated for the initial infiltration. The daily mean values for each soil type were calculated by dividing the sum of the daily results by the number of sites on each soil type, thus no weighting was given to the time between the testings.

The infiltration data are reproduced in Appendix B. Infiltration time graphs are constructed for between and within each soil series. Since the infiltration times plotted on the vertical axis, ranged from 3 seconds to 609 seconds, the graphical presentation is done on semi-log paper. Time in days is plotted on the horizontal axis.

Infiltration Between Soil Series

The daily infiltration data that was collected for each soil series was averaged and plotted to present the infiltration curves in Figure 17. The results show a separation among the three tillable agricultural soils, except

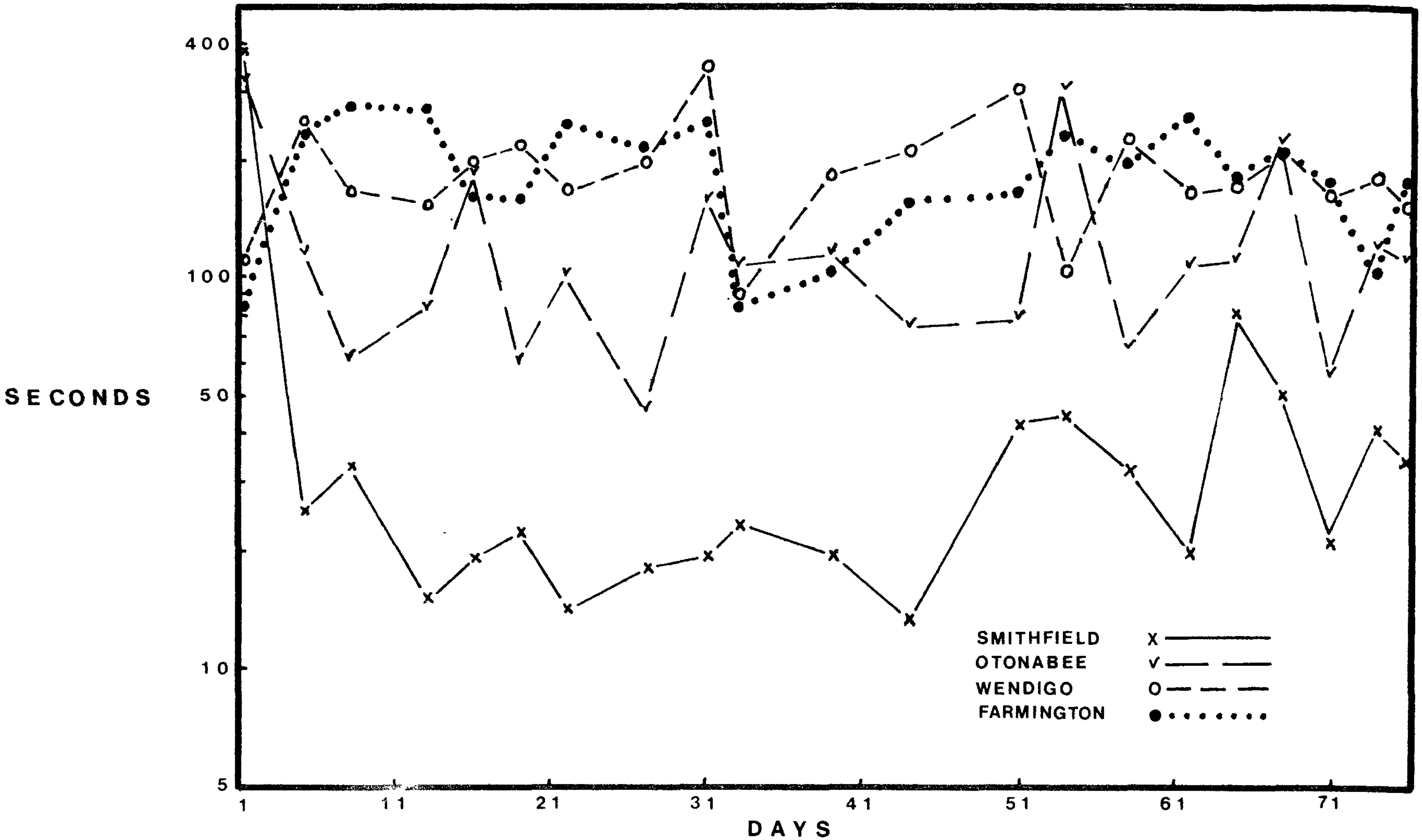


Figure 17. Soil Series Mean Daily Infiltration Time in Seconds

on three days. Thus there appears to be a distinct infiltration response pattern among the Smithfield, Otonabee and Wendigo Series. The infiltration curve of the Farmington Series which is an uncultivated, shallow soil developed on limestone bedrock, passes back and forth across the curves of the Wendigo and Otonabee Series. It is difficult to visually interpret whether the Farmington Series responds to infiltration similar to the Wendigo Series and/or the Otonabee Series.

In Table 1V the soil series infiltration means for the Smithfield, Otonabee and Wendigo Series also show a distinct infiltration response. The Farmington and Wendigo Series show an average difference of only 0.1 seconds. To substantiate the visual interpretation of Figure 17 an analysis of variance produced an F ratio of 21.45. Further analyses revealed that each soil series with the exception of Wendigo and Farmington had statistically significant different infiltration responses.

<u>Infiltration Within Soil Series</u>

Smithfield Series:

Figure 18 shows the infiltration times plotted for the Smithfield Series from sites #2, #3, #10 and #11 shown on Figure 5. The Smithfield Series give the greatest range of times, from 600 seconds to 3 seconds; yet they give the lowest series mean of 45.5 seconds. At site #10 the infiltration time never exceeds 98 seconds thus giving a much lower seasonal mean of 18.9 seconds as shown in Table 1V.

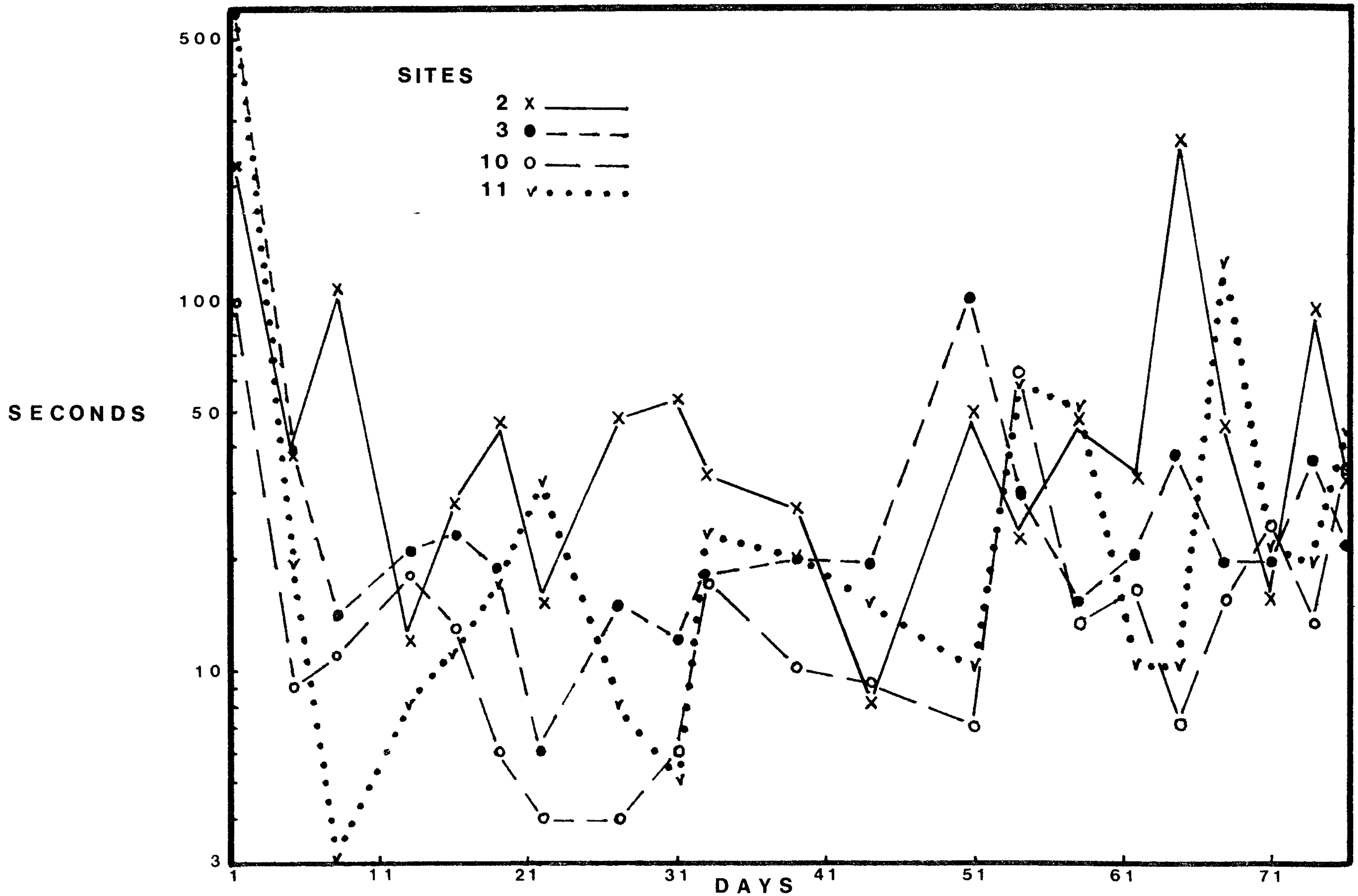


Figure 18. Infiltration Times of Smithfield Series

TABLE lV

Seasonal Infiltration Means for Each Test Site and Soil Series

Smithfield		Otonabee		Wendigo		Farmington	
Site	Mean	Site	Mean	Site	Mean	Site	Mean
#2	58.5	#5	101.9	#8	209.1	#1	376.6
#3	52.4	#6	99.0	#12	273.2	#13	191.9
#10	18.9	#7	177.4	#14	150.8	#15	103.3
#11	52.3	#9	105.9	#17	102.3	#18	64.2
Series Mean 45.5		Series Mean 121		Series Mean 183.9		Series Mean 184	

Although time variations appear within the data, they generally show a clustering toward some common parameter(s) as all the infiltration curves cross each other several times during the testing period. Analysis of variance shows that there was neither a statistically significant difference within nor between the sites, therefore the test sites #2, #3, #10 and #11 appear to be located on a soil series with a common response pattern. The calculated F ratio is 0.73. From Freund (1960) this value is less than the value of $F_{.05}$ at 3 and 80 degrees of freedom which lies between 2.76 and 2.68.

Otonabee Series:

Inspection of the curves of the infiltration times in Figure 19 for the Otonabee Series sites #5, #6, #7 and

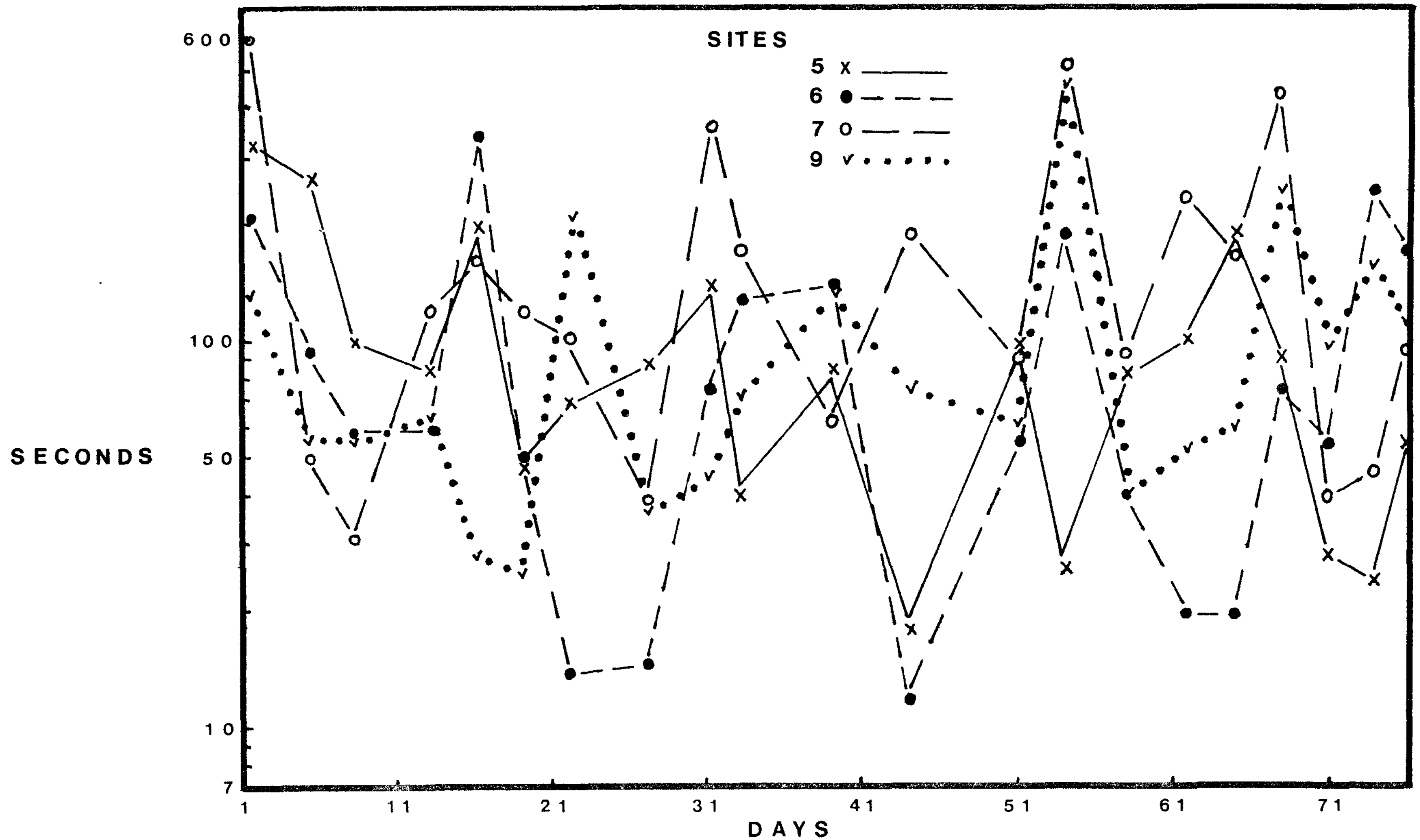


Figure 19. Infiltration Times of Otonabee Series

#9 located in Figure 5, does not show any trend in the time variations. Figure 19 data are listed in Appendix B. The data range from 600 seconds to 12 seconds. From Table 1V a minimum mean difference of 71.5 seconds between #7 and #9 can be calculated. The series infiltration mean of 121 seconds clearly separates it from the other soils series. An F ratio of 2.33 for the analysis of variance test does not establish a statistically significant difference neither within nor between the sites #5, #6, #7 and #9. Therefore there is an infiltration time homogeneity at these sites which are of the same population.

Wendigo Series:

In Figure 20 the infiltration curves of the Wendigo Series sites #8, #12, #14 and #17 located on Figure 5, cross each other several times during the first portion of the sampling period. In the first week of July the infiltration curves of #14 and #17 have lower values and actually separate from #8 and #12 which maintain the higher infiltration times for the remainder of the summer. The data range is now 600 seconds to 31 seconds. From Table 1V a mean difference of 48.5 seconds between #17 and #14 can be calculated and greater among the others that are indicated on the soils map as belonging to the Wendigo Series. The series mean of 183.9 seconds is the next highest, being only 0.1 seconds less than the Farmington Series. From the analysis of variance an F ratio of 11.05 was obtained. This value is statistically significant at the $F_{.05}$ level. Therefore, the

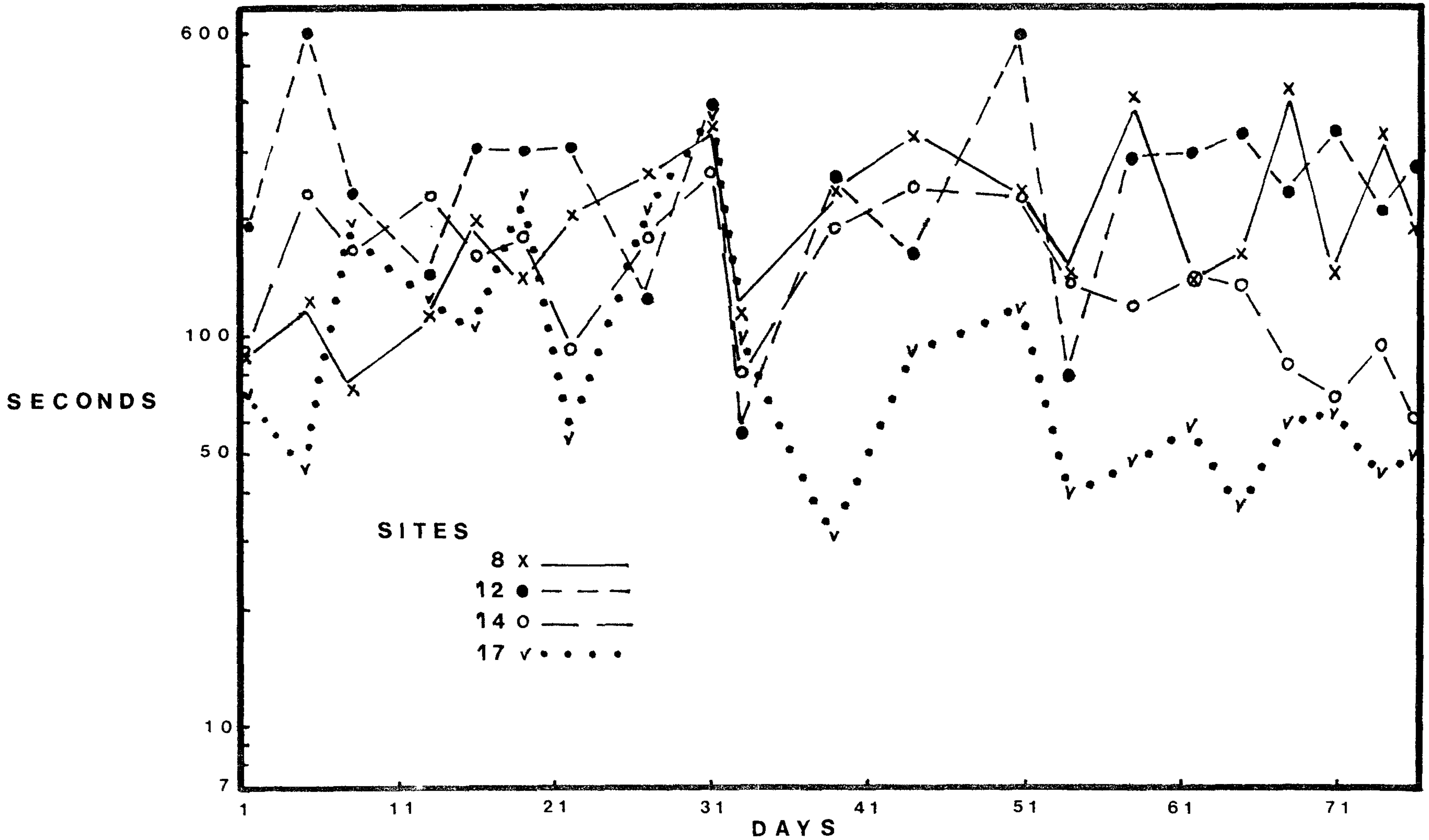


Figure 20. Infiltration Times of Wendigo Series

observation above is substantiated that the sites #8, #12, #14 and #17 appear to be drawn from at least two different populations.

Farmington Series:

Figure 21 depicts the criss-crossing of these infiltration curves of the Farmington Series sites #1, #13, #15 and #18 located in Figure 5. The data range from 609 seconds to 16 seconds with a series mean of 184 seconds. Toward the end of the summer, the infiltration at the #1 site acted very differently from the rest in that its infiltration times were much longer than the other sites. Laboratory tests also showed erratic results at this site as compared to the other sites on the Farmington soils. Also in Figure 21 it is noted that #18 curve is distinct from the other curves, having much faster infiltration times for nearly three weeks, late in the testing period. The largest variation of the site means of any soil series is shown in Table lV. The observed F ratio was 23.99 and this is significant at the $F_{.05}$ level. Therefore, these sites #1, #13, #15 and #18 are significantly different in their time infiltration response pattern.

To summarize, from both the visual interpretation of Figures 17 and 18 and the statistical analyses of these data the sites on the Smithfield Series and the sites on the Otonabee Series had an homogeneous response to the infiltration tests. The Wendigo Series was observed to separate into two groups beginning the first week of July. The analysis of

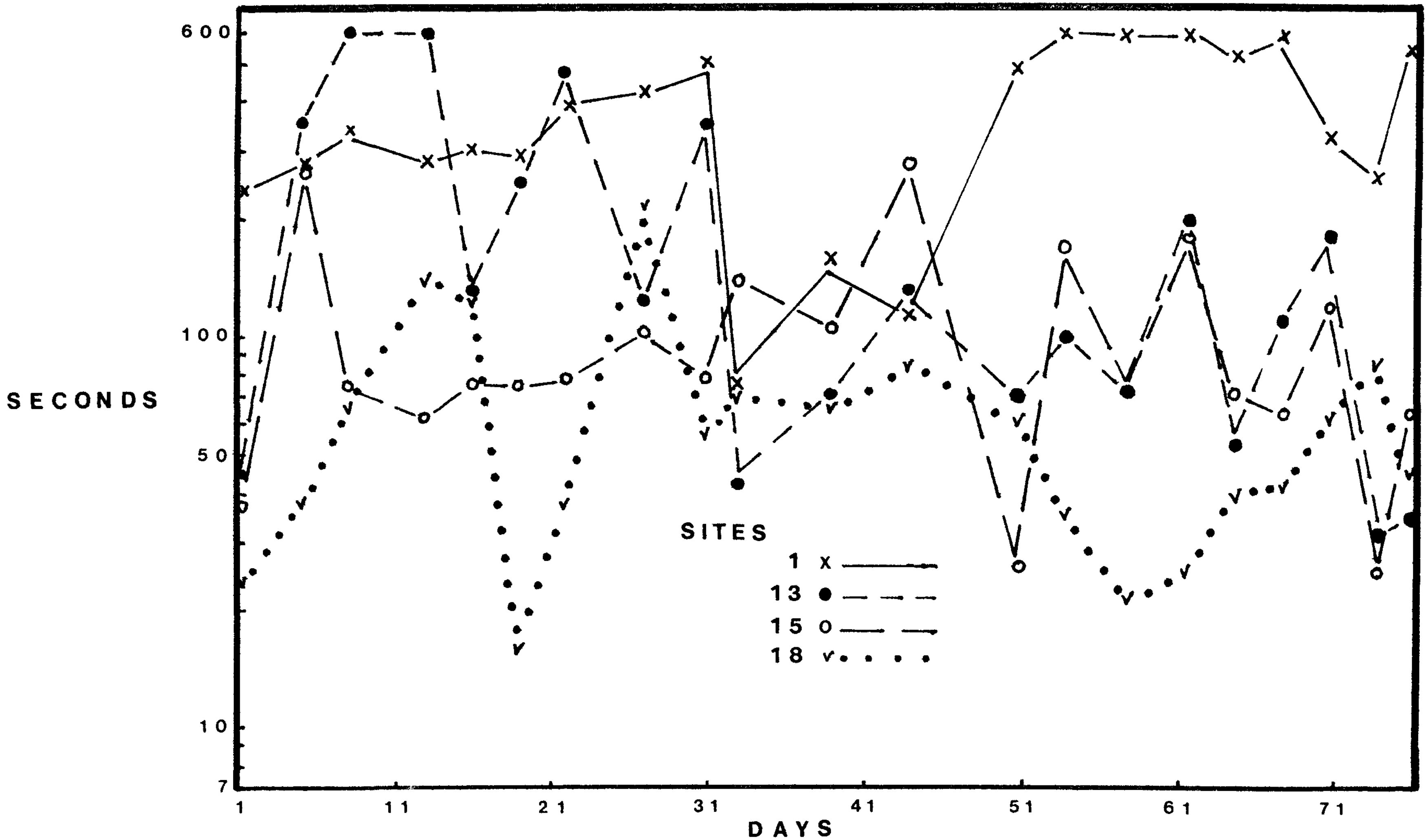


Figure 21. Infiltration Times of Farmington Series

variance test supported this observation and further indicated that there were two significantly different populations from which the infiltration data were obtained. By the last week of July, the Farmington Series developed an infiltration response pattern that generally showed three separate groups. Statistical analyses supported the observation that the infiltration data were obtained from different populations for this series, although it was not evident in the early summer from Figure 21. The trend toward differentiation of the infiltration response within the Farmington and Wendigo Series beginning in July was not evident in the Smithfield and Otonabee Series.

Particle-size Distribution of Soil Samples

One soil sample was collected from each infiltration test site. Mechanical analyses were made of these sixteen topsoils. Sampling was done mainly to verify that the sites utilized were located on the soil type indicated on the Ontario and Victoria County Soil Survey maps in Figure 5. The classification of the analysed samples is shown in Figure 22. The chart is subdivided into textural classes as used in agricultural soil science and it is explained in Appendix G.

Smithfield:

Samples taken from sites #2, #3, #10 and #11 as specified by Figure 5 as Smithfield clay loam, are in the clay and silty clay region of Figure 22. The hydrometer method used did not destroy the organic matter, thus the slightly higher percentage of clay-sized particles when

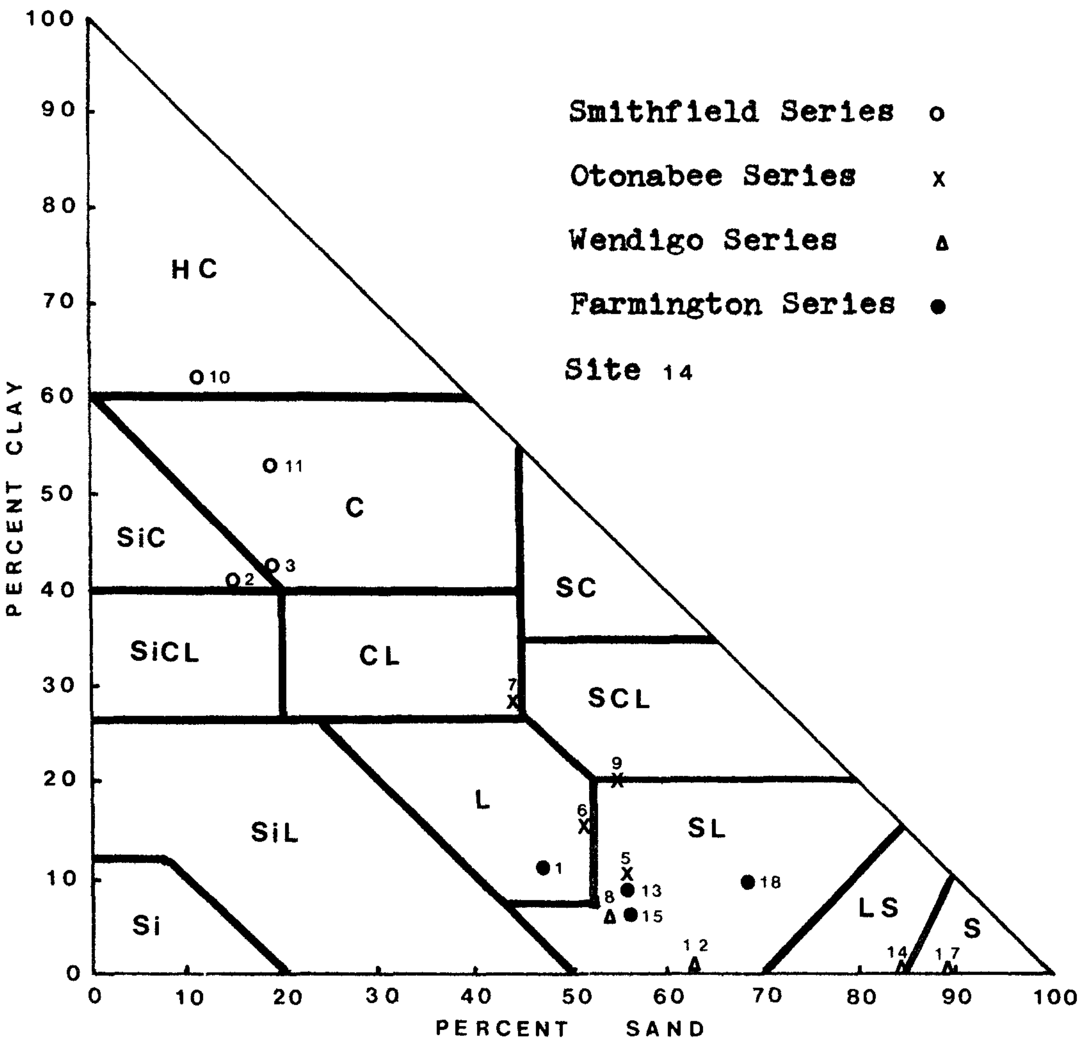


Figure 22. Textural Classification of Mechanical Analyses of Soil Samples

compared to the mechanical analysis with the organic matter destroyed. This interpretation agrees with the conclusions of Bouyoucos (1962) which he felt was a more accurate determination of the clay-sized particles still in suspension after 2 hours. From the tabulation of hydrometer results given in Appendix D the sum of the percent silt and percent clay for any of the Smithfield soils gives 81% to 89%. Webber and Tel (1966) obtained results of 83.6% and a short calculation gives an average 84% for this study. Sample #2 is very close to being classified as a clay as it contains only 4% more silt than it should by this chart. The average of the mechanical analyses for the soil samples of the Smithfield Series in Figure 23 show it to be a clay, which is 9.5% more clay than necessary to classify it as a Smithfield clay loam, thus the results of this study would place it as a Smithfield clay.

Otonabee:

The analyses of the Otonabee Series samples #5, #6, #7 and #9 are located along the division between loam, sandy loam and sandy clay loam in Figure 22. Their average mechanical analysis plotted on Figure 23 indicates that the Otonabee Series soil samples can be classified as Otonabee loam similar to those shown in Figure 5.

Wendigo:

The mechanical analyses of #8 and #12 show them to locate in the sandy loam region of Figure 22 whereas #14 and #17 lie in the sand region. Although the Ontario County Soil

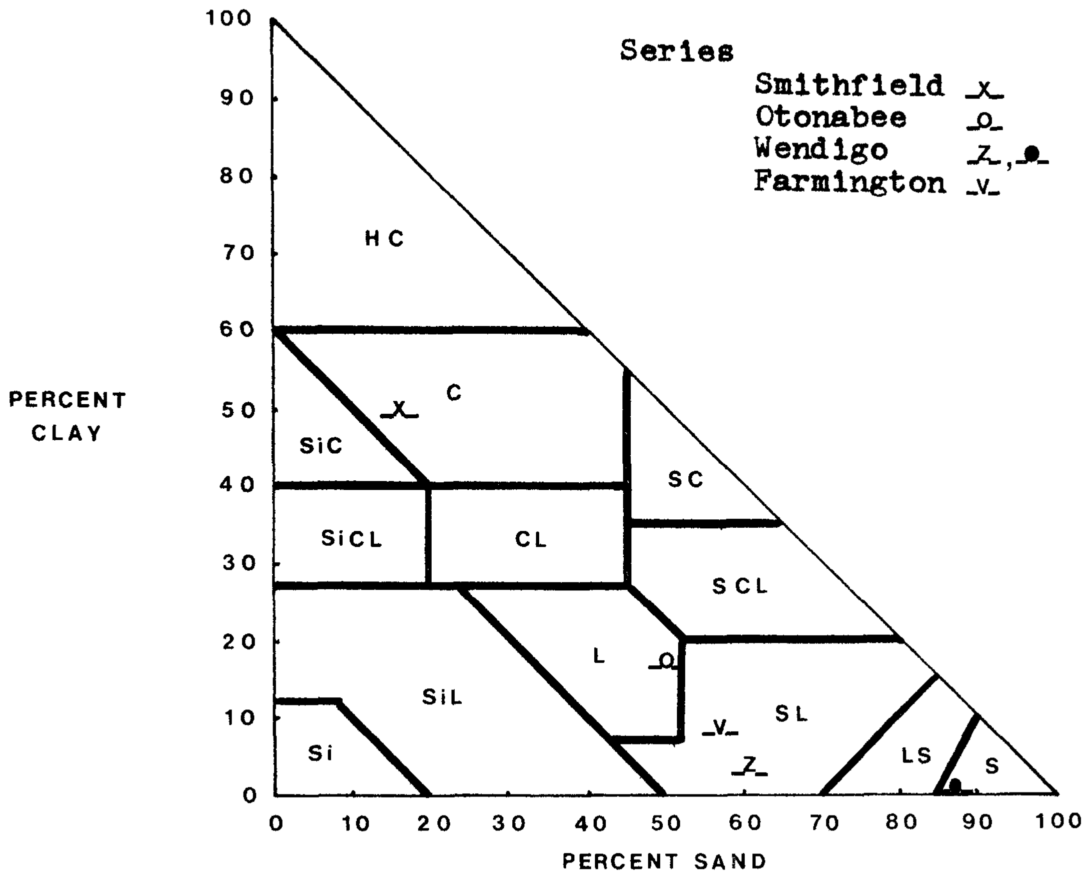


Figure 23. Grouped Mean Mechanical Analyses of Soils

Survey map (Olding, Wickland and Richards, ca.1956) is identified and coloured the same as the Victoria County Soil Survey map (Gillespie and Richards, 1957) which is "Wes and yellow", the written description is about sandy loam for the former and about sand for the latter. Thus by looking at the soil survey maps no difference can be noted. Figure 23 shows the two Wendigo soil types for the Wendigo Series as obtained from the data in Appendix D.

Farmington:

The mechanical analyses of #1 locates it in the loam region of Figure 22 whereas #13, #15 and #18 lie in the sandy loam region. However when the average results are plotted in Figure 23 they lie in the sandy loam region. Therefore the Farmington Series is treated as a Farmington sandy loam in this study.

Cumulative curves of a representative sample from each soil series are given in Figures 24, 25, 26 and 27. To obtain a more extensive view these curves are graphed by combining the particle-size data obtained by a wet sieve analysis and the mechanical analysis obtained by a hydrometer test for each soil sample. This procedure gave graphs which show the percentage of soil particles passing the indicated diameter size between 1,000 and 2 microns. Some small variations often occur between the hydrometer and the wet sieve results around the 50 micron particle size. All the curves are of the same general shape -- concave downward in the coarser particle divisions and convex downward in the finer particle

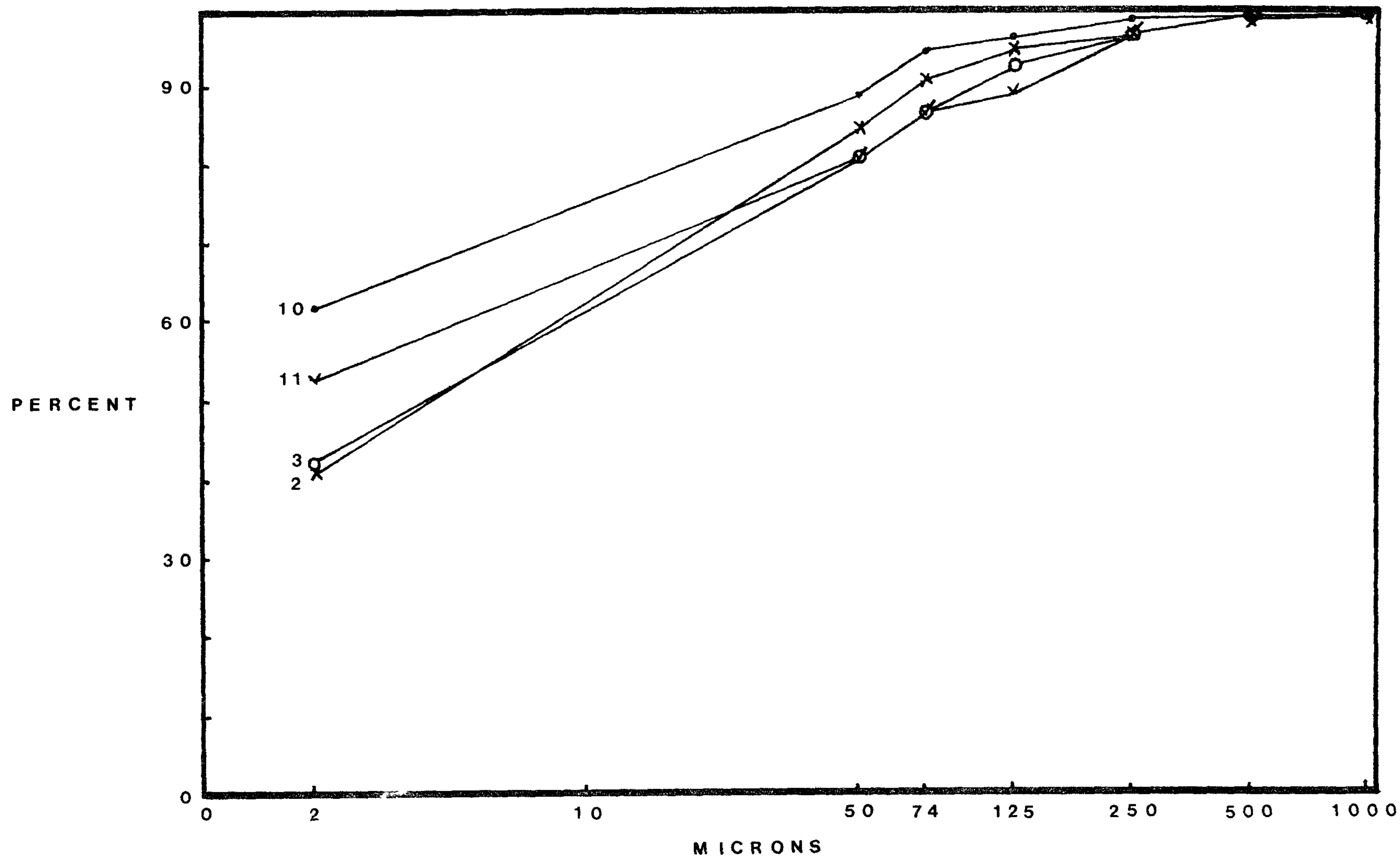


Figure 24. Mechanical Analysis Record Curves of Smithfield Series Sites

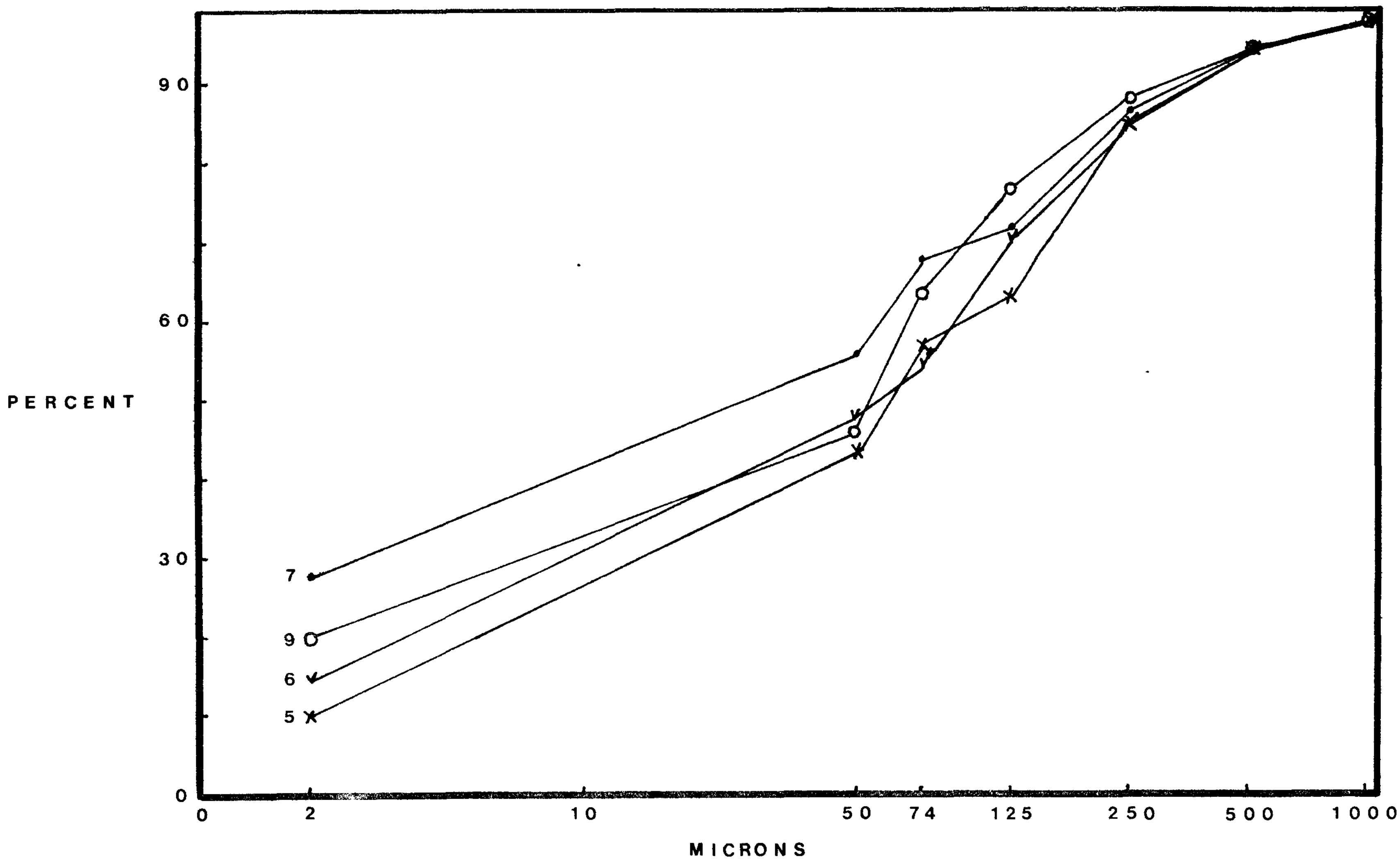


Figure 25. Mechanical Analysis Record Curves of Otonabee Series Sites

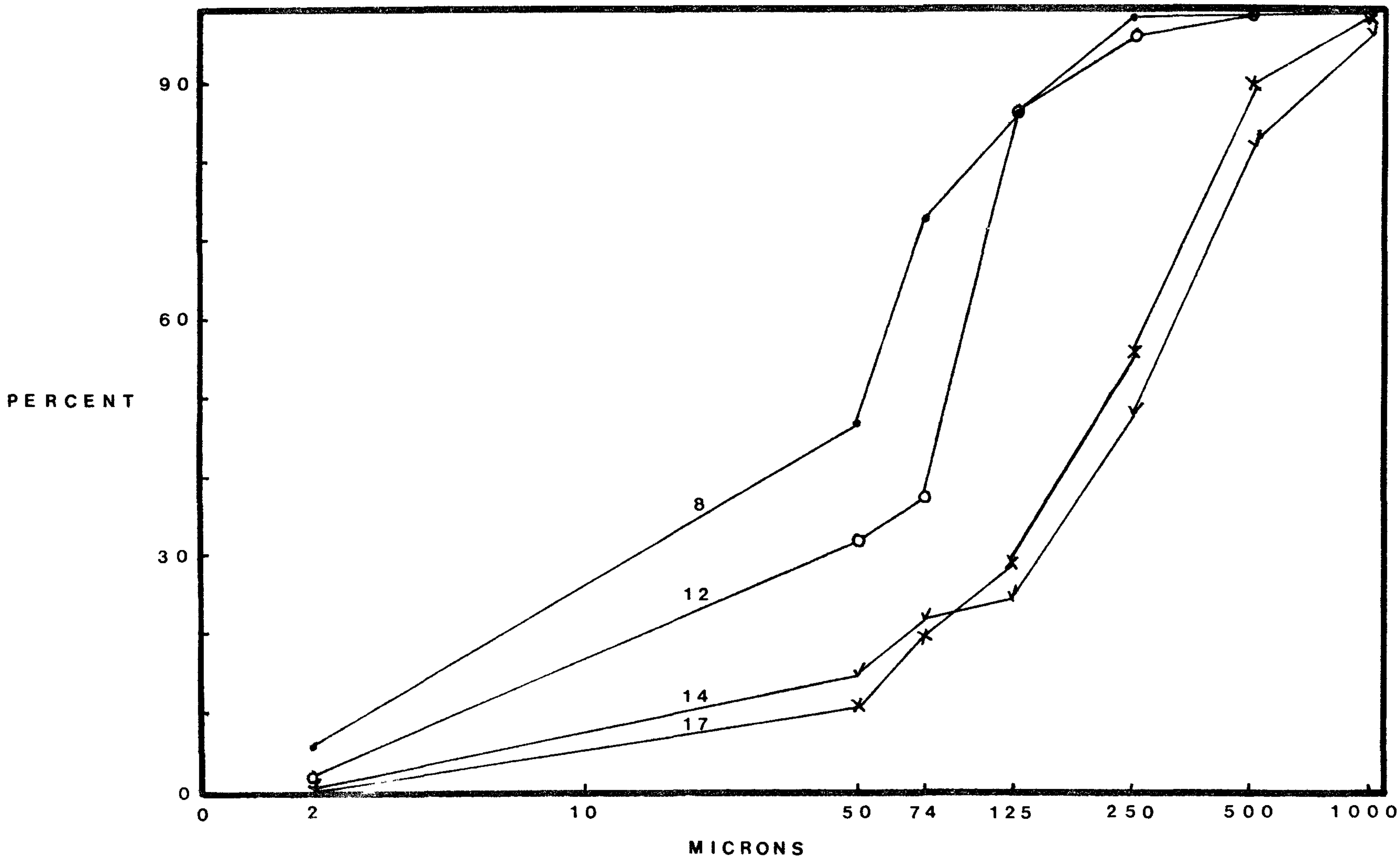


Figure 26. Mechanical Analysis Record Curves of Wendigo Series Sites

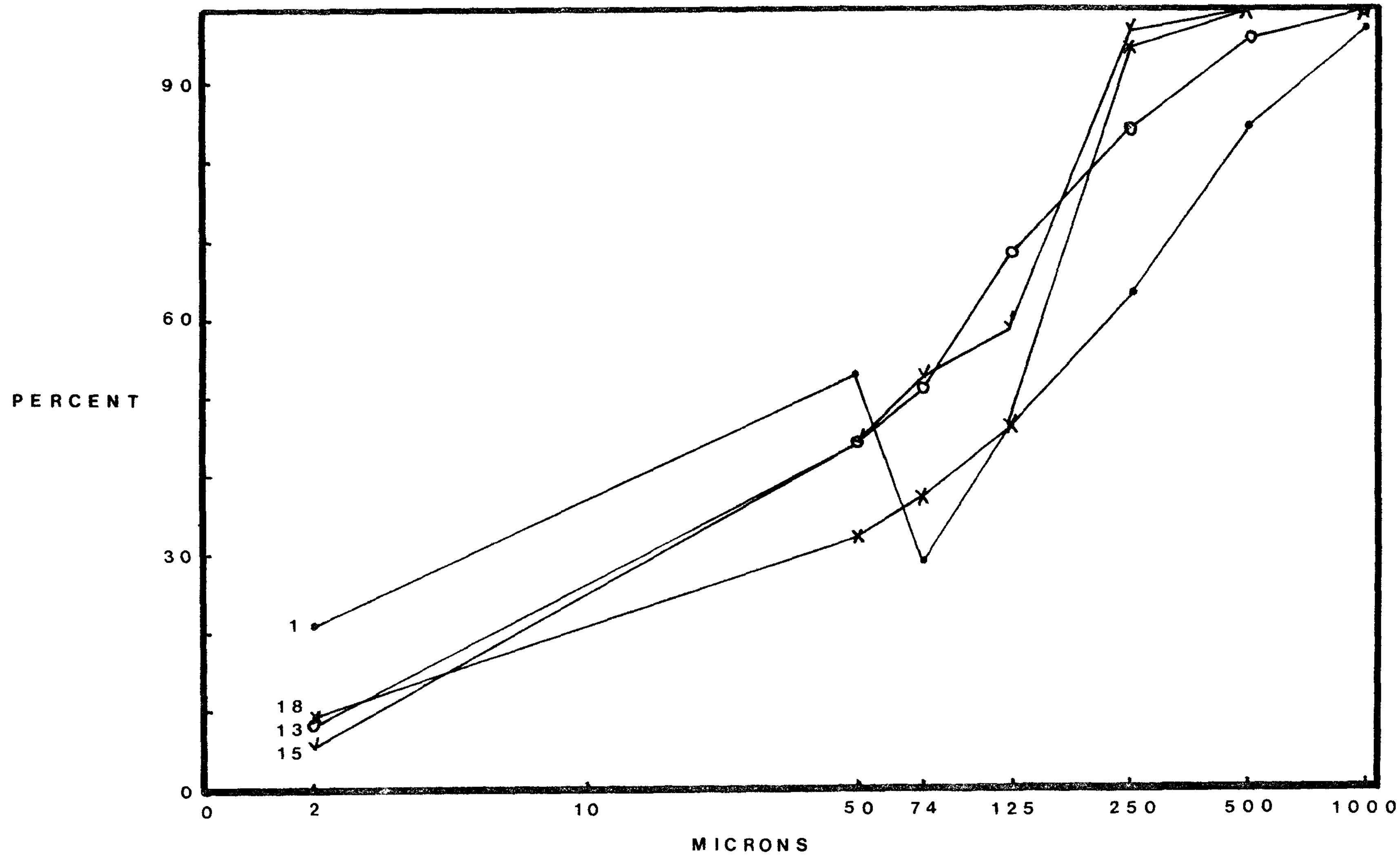


Figure 27. Mechanical Analysis Record Curves of Farmington Series Sites

divisions. If hydrometer readings had been taken between the 40 seconds and the 2 hour readings which gives the 50 micron and 2 micron particle sizes respectively, the convex downward portion of the curve would have been more apparent. It is noted that the curves in Figure 24 are grouped, show less bending than any of the other soil types, and are located in the upper part of the figure. The cumulative curves in Figure 25 are also grouped and show more of the characteristic 'S' curve, running from the upper right to the lower left. Figure 26 shows the division of the Wendigo Series into two distinct sets of curves even though #12 shows more change than #8, between 125 and 50 microns. Although large variations are observed in the Farmington Series the mechanical analysis did not give a clear pattern as in the Wendigo Series. In Figure 27 the samples from #15 and #18 group together and are separate from #1 and #8 yet at the 125 micron particle size their curves cross with #1 and #8. In Figure 22 the Farmington Series is shown to be loam and sandy loam for this study.

In summary, the particle-size distribution of the Smithfield Series shows variations among the differently located sites. When the mechanical analyses are taken individually or grouped as in Figure 23, the Smithfield Series is observed to be distinctly different from each of the other series and also all other sites in the study. The Smithfield Series is classified as a clay. Variations are noted within the Otonabee Series but they remain clustered as a group. Together they are classified as loam. They are not distinct from the Farmington Series nor #8 and #12 of the Wendigo Series in their mechanical analysis. The soil samples from #14 and #17 are seen to be distinctly different from each of the other series. There is also an apparent difference within the Wendigo Series so that #8 and #12 are sandy loam and #14 and #17 are sand. The shallow Farmington Series generally give an obscure picture but were considered as sandy loam in this study.

Infiltration and Soil Type

So far the infiltration data have been visually interpreted from the graphs and statistically tested by analysis of variance to ascertain which soil series showed different initial infiltration times. The soil samples have been delimited into five soil types or textures by mechanical analyses. To add validity to the hypothesis that soil types can be differentiated by their initial infiltration, the Student's 't' Test was performed. To calculate the indices the equation $t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$ was used as the samples were large, that is more than 30 items (Freund 1960). The variables s^2 are located in Appendix B.

Table V presents the results of the 't' test that gives the difference between the infiltration means and the standard error of the difference by soil types. With only one exception all the 't' indices are statistically signif-

TABLE V

Student's 't' Index for Infiltration
Taken by Soil Types

	Smithfield clay	Otonabee loam	Wendigo sandy loam	Wendigo sand	Farmington sandy loam
Smithfield clay	0	16.4 *	8.84 *	4.76 *	6.32 *
Otonabee loam		0	5.17 *	0.29 -	2.69 *
Wendigo sandy loam			0	4.85 *	2.08 *
Wendigo sand				0	2.45 *
Farmington loam					0

* significantly different infiltration times at .05 level
\- not significantly different

icant at 5% level of probability. This means that a difference in the initial infiltration means as large as the times observed would occur no more than one time in 20 by chance.

From Table V it is noted that Wendigo sand and Otonabee loam are the only soil types that cannot be differentiated from each other by their initial infiltration response. When the untillable Farmington sandy loam is omitted from Table V then the level of probability reaches 1% with the previously noted exception.

TABLE V1

Seasonal Temperature Means for Each Test Site and Series

Smithfield		Otonabee		Wendigo		Farmington	
Site	Mean	Site	Mean	Site	Mean	Site	Mean
#2	21.4	#5	21.5	#8	22.0	#1	22.6
#3	21.3	#6	19.8	#12	22.1	#13	23.0
#10	24.3	#7	22.3	#14	23.8	#15	22.0
#11	20.7	#9	22.6	#17	23.4	#18	22.4
Series Mean	21.9	Series Mean	21.5	Series Mean	22.8	Series Mean	22.5

TABLE V11

Student's 't' Index for Soil Temperature

	Smithfield clay	Otonabee loam	Wendigo sandy loam	Wendigo sand	Farmington sandy loam
Smithfield clay	0	0.71 -	0.15 -	2.42 *	1.05 -
Otonabee loam		0	0.72 -	2.87 *	1.67 +
Wendigo sandy loam			0	1.96 +	0.71 -
Wendigo sand				0	1.49 -
Farmington loam					0

* significantly different at .05 level
\+ significantly different at .1 level
\- not significantly different

Temperature

The temperature data that was gathered in the field is recorded in Appendix B. During the summer variations of a few degrees are noted among the soil types and also within the sites. The seasonal means and series means are tabulated in Table Vl. The highest overall temperature is 24.3°C. for #10 site in the Smithfield soils and the fastest infiltration mean from Table Vl is also for the same site. As the temperature means vary no more than 3°C. the Student's 't' Test was applied to the data. Table Vll shows the 't' indices of the soil temperature by soil types. The temperature data of Smithfield clay and Wendigo sand, along with Otonabee loam and Wendigo sand, are the only 't' indices which are statistically significant at the 5% probability level. At the 10% probability level Wendigo sandy loam can be differentiated from Wendigo sand and Otonabee loam from Farmington loam by soil temperature. It appears from the temperature data obtained in this study that there is only limited temperature response to soil series and/or soil types.

Chapter 6

Summary and Conclusions

Summary

The statistical analyses performed on the collected data have shown that the Smithfield Series has a homogeneous response to infiltration tests in this study. The mechanical analysis showed that the soil samples which were chosen at random from the same soil type were closely related in their particle size distribution. They were classified as clay in this study and not clay loam as in Figure 5. Bouyoucos (1962) found that clay content was higher by his method which is the method used in this study. The 't' test signified that the soil type, Smithfield clay, could be differentiated from the other soil types in this study by its initial infiltration response. Also noted was the fact that the shortest infiltration times resulted on this higher clay content soil. From the literature soils high in clay content have the slowest daily infiltration rates. However, from this study it is observed that the Smithfield clay has a fast initial infiltration rate during the summer months.

Analyses of data also proved that the Otonabee Series was homogeneous in its infiltration response. The mechanical analysis agreed with the information in Figure 5, that it was a loam soil even when samples were analysed from different Otonabee Series locations within the Talbot River basin. The infiltration response was not distinct from all the other soil types in the study. However, Otonabee loam can be differentiated by its initial infiltration rate from a clay soil such as Smithfield clay or a sandy loam such as the Wendigo sandy loam.

Analyses of the data for the Wendigo Series showed that it was not homogeneous in its infiltration response and its mechanical analysis. It was found that this series in the present study was composed of two soil types, Wendigo sand and Wendigo sandy loam. The 't' test of these two types on their infiltration data showed that their response was significantly different to each other as well as all other soil types in the study except Otonabee loam.

The Farmington Series data analyses gave varying results for its infiltration response as all four sites had large mean differences. Sites #15 and #28 were the closest in infiltration response. Mechanical analysis divided this series into three groups. As noted earlier in this study the Farmington Series is not an important agricultural soil type, therefore the three groups as indicated by Figure 22 were examined as one type based on Figure 23. When the 't' test was applied to the data it was noted that the Farmington's sandy loam infiltration response was significantly different from the other soil types. However the previous decision to treat it as one soil type may have biased the final results.

Very little variation was observed in the temperature means but when the 't' test was applied, a significant difference was noted between the Wendigo sand and the other soil types except Farmington loam.

Conclusions

From this study it is concluded that the cultivated soils of Smithfield clay loam, Otonabee loam, Wendigo sandy loam and Wendigo sand as shown on the county soil survey maps are in fact as depicted. The Farmington loam was a sandy loam on three of the four shallow ranchland sites.

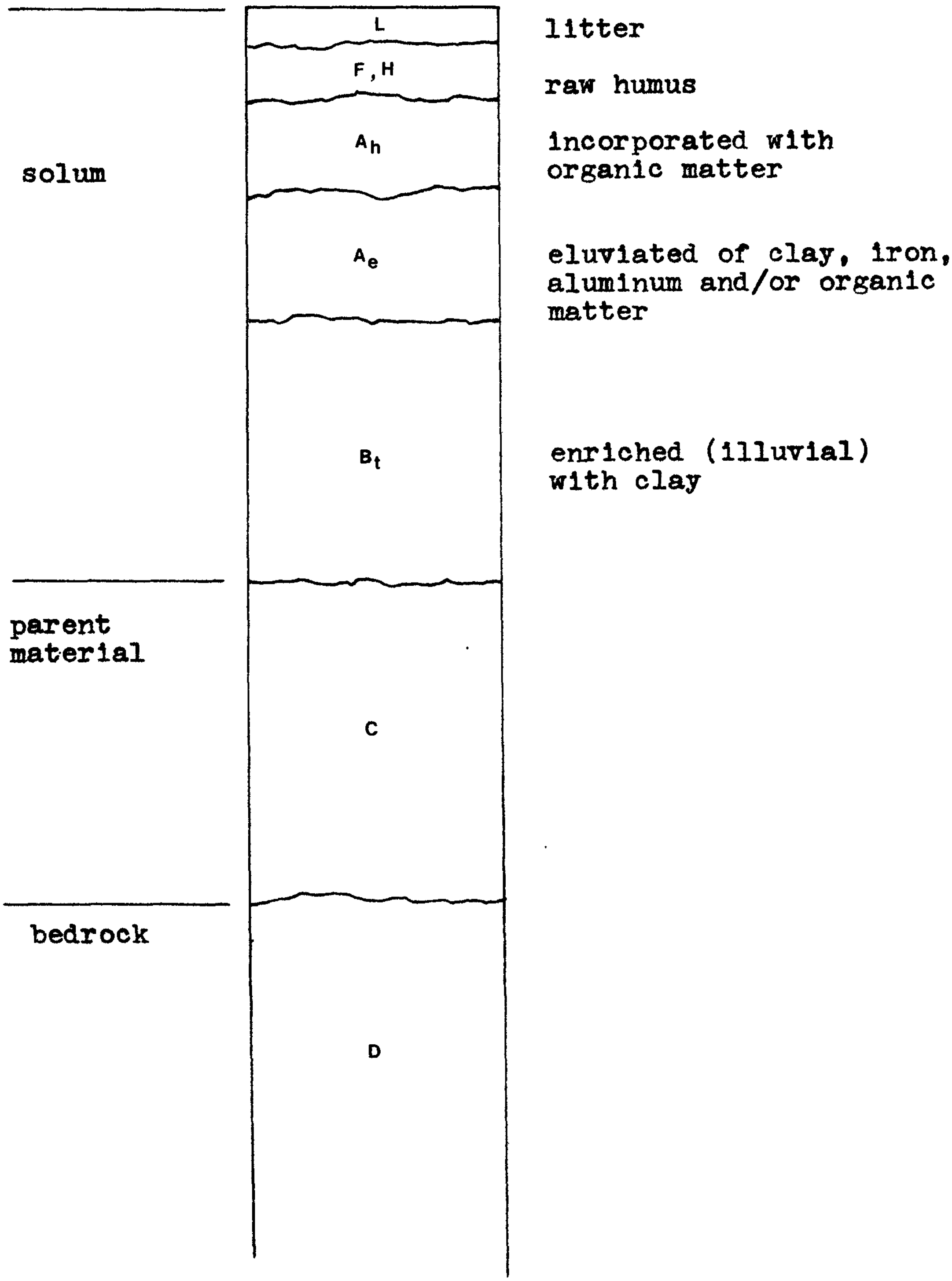
Soil types do have different initial infiltration responses. In this study it was possible to differentiate soil types by their initial rate of infiltration 90% of the time. The Wendigo Series was separated into two distinct soil types, sand and sandy loam by its initial infiltration response.

The higher the percentage of clay in the soil the faster the initial infiltration.

A sandy soil showed a greater tendency toward differentiation by soil temperature than other types.

Appendix A

Soil Profile Horizons



Appendix B

Dates Tested, Site Identification, Infiltration and Temperature Data

Smithfield Clay Loam

Date July	2 Black T.	°C.	3 Warren T.	°C.	10 Lakelodge T.	°C.	11 Trefoil T.	°C.
1	225	21	600	20	98	21	600	17
5	37	20	37	20	9	25	19	19
8	106	25	14	25	11	27	3	21
13	12	25	21	26	18	29	8	21
16	28	24	23	23	13	34	11	28
19	46	22	19	23	6	23	17	20
22	15	24	6	25	4	25	32	20
27	47	24	15	25	4	22	8	18
31	53	19	12	18	6	22	5	18
Aug. 2	33	21	18	24	17	26	23	21
8	27	25	20	24	10	28	20	24
13	8	27	19	26	9	21	15	19
20	49	21	100	22	7	28	10	23
23	22	18	30	18	62	20	57	19
27	46	13	15	12	13	22	49	18
31	32	20	20	18	16	22	10	21
Sept. 3	262	21	37	20	7	25	10	26
6	44	21	19	21	15	20	120	20
9	15	24	19	21	24	24	21	24
12	90	17	36	17	13	21	19	18
14	31	18	21	19	34	25	42	20

T. -- s^2 = 9,194

°C. -- s^2 - 12.6

T. -- Infiltration Time in Seconds.
°C. -- Temperature.
s^2 -- Variance.

Appendix B (continued)

Otonabee Loam

Date	5 Wither		6 Warren		7 House		9 Bush	
July	T.	°C.	T.	°C.	T.	°C.	T.	°C.
1	320	20	210	19	600	20	130	22
5	262	20	93	18	49	22	56	22
8	98	24	58	22	32	24	56	26
13	83	25	60	23	120	26	65	29
16	199	26	342	24	162	33	28	35
19	48	22	50	21	121	24	25	20
22	70	27	14	22	104	22	210	26
27	88	24	15	21	39	21	37	23
31	138	18	76	17	362	22	45	20
Aug. 2	40	22	130	19	173	26	74	22
8	85	25	141	22	62	29	138	26
13	18	26	12	22	187	20	75	21
20	98	22	56	21	90	28	62	25
23	26	17	191	17	510	20	457	20
27	82	12	41	11	92	14	40	20
31	100	19	20	17	234	20	53	18
Sept. 3	190	21	20	20	166	23	59	21
6	90	21	77	21	442	19	247	19
9	28	23	55	21	40	22	97	23
12	24	16	248	16	46	18	158	17
14	54	21	171	21	95	15	112	19

T. -- $s^2 = 13{,}393$

°C. -- $s^2 = 14.6$

Appendix B (continued)

Wendigo Sandy Loam

Date	8 Dixon		12 Lamrx		14 Hole		17 Cem	
July	T.	°C.	T.	°C.	T.	°C.	T.	°C.
1	87	22	193	21	91	26	71	25
5	120	26	600	23	228	26	46	25
8	72	26	234	27	165	28	192	30
13	113	26	144	24	228	26	124	25
16	196	32	307	29	160	30	106	30
19	140	24	300	22	179	24	232	25
22	202	25	306	28	93	28	55	29
27	262	21	126	21	180	23	209	23
31	343	17	392	17	263	28	372	26
Aug. 2	113	25	57	27	81	28	100	25
8	235	25	256	23	188	26	31	25
13	326	23	164	26	240	25	92	22
20	234	22	600	22	228	25	116	25
23	144	18	80	18	138	17	40	18
27	420	13	288	12	118	16	48	18
31	137	15	300	16	140	16	59	17
Sept. 3	162	23	329	22	134	23	37	19
6	422	22	236	24	85	21	60	22
9	146	21	339	21	70	22	64	22
12	332	19	210	21	96	19	45	20
14	186	18	276	21	62	22	50	21

8 and 12 T. -- s^2 = 15,914 14 and 17 T. -- s^2 = 7,493

°C. -- s^2 = 12.7 °C. -- s^2 = 15.2

Appendix B (continued)

Farmington Loam

Date July	1 Ste Ran T.	°C.	13 Roadside T.	°C.	15 Corner T.	°C.	18 Trent T.	°C.
1	236	25	41	25	37	24	23	26
5	275	22	356	23	269	21	37	21
8	341	25	609	30	75	26	66	27
13	278	29	600	25	62	26	139	24
16	301	31	133	28	76	23	125	28
19	290	24	250	24	74	22	16	23
22	392	26	468	28	78	28	37	29
27	425	22	124	23	102	22	214	21
31	506	21	356	29	79	22	56	23
Aug. 2	76	23	43	25	142	24	70	24
8	157	27	72	26	107	28	67	24
13	114	23	132	22	277	23	84	24
20	490	27	72	25	26	23	60	23
23	600	19	101	18	172	19	35	18
27	593	13	73	17	71	16	21	18
31	600	18	198	16	180	17	25	17
Sept. 3	527	24	53	21	71	21	39	21
6	600	18	109	20	63	20	42	21
9	325	22	173	21	119	21	61	21
12	252	16	32	18	25	18	86	18
14	530	20	35	20	64	19	45	20

T. -- s^2 = 30,993

°C. -- s^2 = 15.5

Appendix C

Particle Size Distribution

Bouyoucos, G.J., Hydrometer Method Improved for Making Particle Size Analyses of Soils, Agronomy Jour. 54:464.

The new procedure in detail is as follow: Dissolve 50 g. Calgon in a litre of distilled water. Pour 100 cc. of this solution into a pint jar. Add 50 g. of air-dry soil (100 g. in the case of very sandy soil). Mix thoroughly and let stand in covered jar overnight or 15 to 20 hours. Then wash contents into the soil cup (milk shake cup) with distilled water. Fill the cup with water to within 3 inches from the top. Connect cup to the dispersing machine (milk shake machine) and stir for 2 minutes. Disconnect cup and wash contents into soil cylinder using a water jet from the plastic bottle. Fill soil cylinder to the litre mark. Bring cylinder and contents to 68°F. by placing in a water bath. Remove cylinder and close mouth with rubber stopper. With right hand holding and pressing on the stopper, and left hand holding the bottom of the cylinder, turn cylinder completely upside down and back 20 times. Return cylinder to water bath and immediately start a timer or stopwatch. Quickly put 3 drops of amyl alcohol on top of soil suspension column to dissipate froth and at 15 seconds gently place hydrometer in the soil suspension column and prepare to take a hydrometer reading at 40 seconds. Remove the hydrometer and wash it. The last hydrometer reading is to be taken after sedimentation has continued for exactly 2 hours.

When floating in a 0.5% solution of Calgon the hydrometer has a stem reading of 6.5. This reading must be subtracted from every hydrometer reading obtained with soil suspensions prepared in the described manner.

To calculate the amounts of combined sands, of silt, and of clay as determined by the hydrometer method, the procedure is as follows for the U.S. Department of Agriculture soil particle size classification:

The corrected hydrometer reading at the end of 40 seconds is divided by the amount of dry soil taken and multiplied by 100. This result is the percentage of material still in suspension at the end of 40 seconds. This percentage is subtracted from 100, and the result is the percentage of material that settled out at the end of 40 seconds, which represents all the sand in the soil (2.00-0.05 mm.). The corrected hydrometer reading at the end of 2 hours is also divided by the dry weight of the soil and multiplied by 100. The result is percentage of material still in suspension at the end of 2 hours, and is the clay (below 0.002 mm.). The percentage of silt (0.05-0.002 mm.) is obtained by difference.

Appendix D

Mechanical Analyses of Agricultural Soils Showing the Percentage Composition of Sand, Silt and Clay

Sample Number	Location and Field Description[1]	Percentage Sand[2]	Silt[3]	Clay[4]
2	Lot 5 Con 2 Mara Twp Ont Co. Smithfield Silty Clay	15	44	41
3	Lot 5 Con 1 Mara Twp Ont Co. Smithfield Clay	19	39	42
10	Lot 16 Con B Mara Twp Ont Co. Smithfield Clay	11	27	62
11	Lot 15 Con B Mara Twp Ont Co. Smithfield Clay	19	28	53
MEAN		16	34.5	49.5
5	Lot 6 Con 1 Mara Twp Ont Co. Otonabee Loam	56	34	10
6	Lot 5 Con 1 Mara Twp Ont Co. Otonabee Loam	52	33	15
7	Lot 15 Con B Mara Twp Ont Co. Otonabee Loam	44	28	28
9	Lot 15 Con B Mara Twp Ont Co. Otonabee Loam	54	26	20
MEAN		51.5	30.3	18.3
8	Lot 5 Con 10 Thorah Twp Ont Co. Wendigo Sandy Loam	53	41	6
12	Lot 5 Con 10 Thorah Twp Ont Co. Wendigo Sandy Loam	63	30	2
MEAN		60.5	35.5	4
14	Lot 5 Con 1 Bexley Twp Vic Co. Wendigo Sand	85	14	1
17	Lot 2 Con 1 Bexley Twp Vic Co. Wendigo Sand	89	11	0
MEAN		87	12.5	0.5
1	Lot 13 Con B Mara Twp Ont Co. Farmington Loam	47	42	11

Appendix D (continued)

Sample Number	Location and Field Description[1]	Percentage Sand[2]	Silt[3]	Clay[4]
13	Lot 6 Con 8 Carden Twp Vic Co. Farmington Sandy Loam	56	36	8
15	Lot 5 Con 10 Carden Twp Vic Co. Farmington Sandy Loam	56	38	6
18	Lot 1 Con 8 Carden Twp Vic Co. Farmington Sandy Loam	68	23	9
MEAN		56.8	34.7	8.5

1. Field description as per Ontario (Ont) or Victoria (Vic) County Soils Surveys.
2. Particle diameter between 0.05 and 1.0 mm.
3. Particle diameter between 0.002 and 0.05 mm.
4. All particles less than 0.002 mm. in diameter.

Appendix E

Mechanical Analyses of Soil Samples by Hydrometer Method

Sample Number	Sample Weight gm.	Corrected Reading 40 seconds	Corrected Reading 2 hours
2	54	46	22
3	64	52	27
10	59.5	53	37
11	45.6	37	24
5	50	22	5
6	50	24	7.5
7	50	28	14
9	50	23	10
8	46.2	22	2.5
12	50.4	16	1
14	54.7	8	0.5
17	50	5.5	0
1	47	25	5
13	59.2	26	5
15	50	22	3
18	50	16	4.5

Appendix F

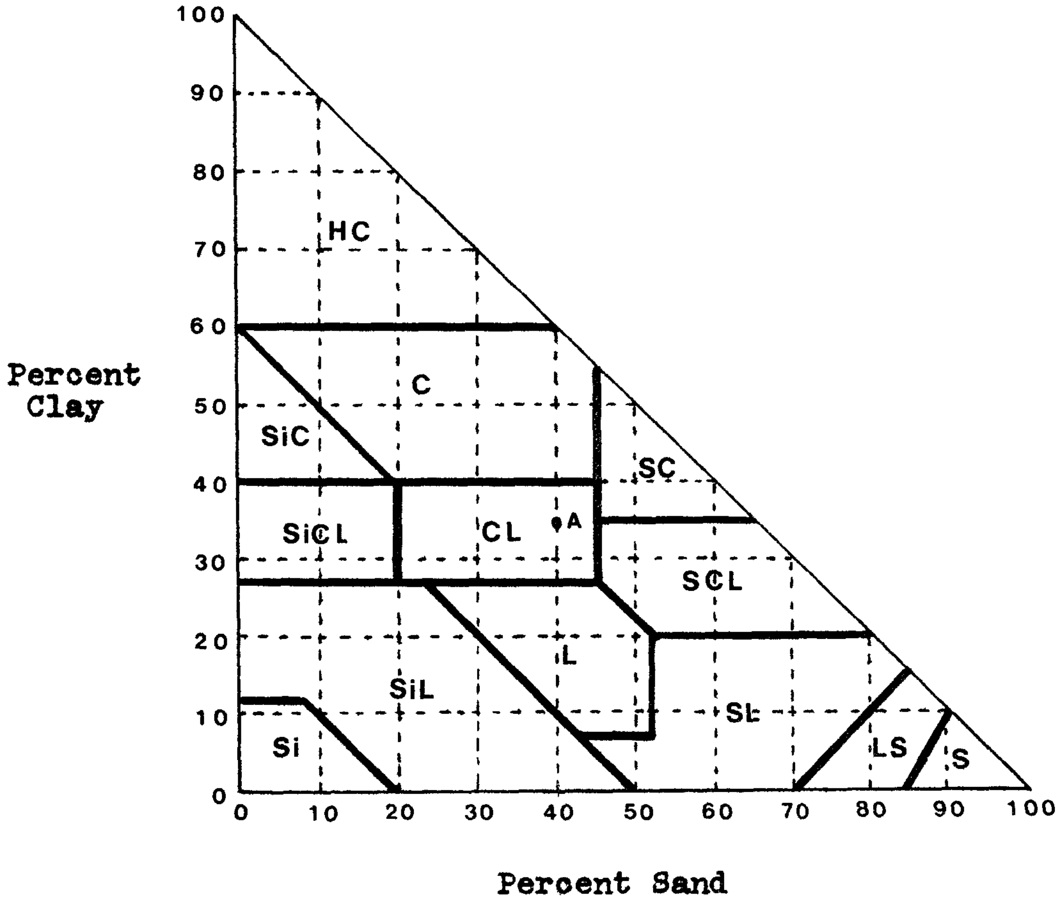
Data of Particle Size Distribution of Soil Samples (40 grams)

	1000[3]		500		250		125		74	
No.	C.W Gr.[1]	% P.[2]	C.W. Gr.	% P.	C.W. Gr.	% P.	C.W. Gr.	% P.	C.W. Gr.	% P.
2	. 1	99.8	.5	98.8	1.2	97	2.2	94.5	3.6	91
3	. 1	99.8	.4	99	1.4	96.5	2.7	93.3	5.5	86.3
10	. 1	99.8	.2	99.5	.5	98.8	1.5	96.3	1.8	95.5
11	. 2	99.5	.4	99	1	97.5	4.3	89.2	5.2	87
5	. 6	98.5	2	95	5.7	85.8	14.7	63.3	17.2	57
6	. 4	99	2.4	94	6.1	84.8	11.6	71	18.2	54.5
7	. 8	98	2.1	94.8	5.1	87.2	11.2	72	12.8	68
9	. 6	98.5	1.9	95.3	4.7	88.3	9.3	76.8	14.5	63.8
8	. 1	99.8	.2	99.5	.4	99	5.4	86.5	10.8	73
12	.05	99.9	.5	98.8	1.5	96.3	5.4	86.5	25	37.5
14	1.5	96.3	7.1	82.3	20.8	48	30.1	24.8	31.1	22.3
17	. 7	98.3	3.9	90.3	17.7	55.8	28.3	29.3	32.1	19.8
1	1.3	96.8	6.3	84.3	14.7	62.3	21.7	45.8	28.3	29.3
13	. 2	99.5	1.7	95.8	6.5	83.8	12.7	68.3	19.5	51.3
15	. 1	99.8	.3	99.3	1.3	96.8	16.6	58.5	18.8	53
18	. 1	99.8	.3	99.3	2.2	94.5	21.5	46.3	25.3	36.8

1. Cumulative Weight in Grams.
2. Percent Passing.
3. Microns.

Appendix G

Soil Textural Classes



From the soil classification system of the Canada Department of Agriculture (1970) the triangular figure is divided so that it indicates the percentages of clay and sand in the main textural classes of soils. The remainder of each class is silt. For a soil to be named clay loam the clay content can range from 27 to 40 percent and the sand content from 20 to 45 percent. Therefore a specific soil sample could contain 40 percent sand, 35 percent clay and the remaining 25 percent would be silt. This would be point A. The identification of the symbols are as follows:

HC -- heavy clay
C -- clay
SiC -- silty clay
L -- loam
SiCL -- silty clay loam
CL -- clay loam
SiL -- silty loam
Si -- silt
SC -- sandy clay
SCL -- sandy clay loam
S -- sand
LS -- loamy sand
SL -- sandy loam

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