Soil Survey of the Pilot Watersheds Southwestern Ontario
Soil and Water Environmental Enhancement Program

Prepared for:

Agriculture Canada

Prepared by:

ECOLOGICAL SERVICES for PLANNING LTD
361 SOUTHGATE DRIVE
GUELPH, ONTARIO
N1G 3M5

January, 1990

GAGO5

SUMMARY

This report contains the baseline soil data and soil survey maps for the soil inventories conducted within the Essex, Kettle Creek and Pittock Creek Watershed study areas.

The surveys were conducted using soil survey techniques outlined by the Expert Committee on Soil Survey (ECSS) in the Canada Soil Information System (CANSIS) manual for describing soils in the field. All data were entered and stored onto microcomputer databases.

Three types of benchmark sites were described and sampled within each watershed. They consisted of the modal benchmark site, describing the nature of the soil profile; the topsoil spatial benchmark, which will monitor soil physical changes; and cesium benchmarks which over a period of time can be used to assess the extent of erosion. Both the topsoil and cesium benchmark sites are useful to distinguish differences between conventional and conservation tillage systems.

TABLE OF CONTENTS

FIGURES

MAPS

TABLES

APPENDICES

1. INTRODUCTION

The Southwestern Ontario Soil and Water Environmental Enhancement Program (SWEEP) is a joint federal and provincial initiative to investigate soil conservation and water quality issues in southwestern Ontario over a five year period. There are two interrelated objectives for the program. They are to reduce phosphorous loadings in the Lake Erie basin from upland runoff and to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion and degradation.

One of the Sub-programs, the Pilot Demonstration Watershed Sub-program, is concerned with developing and testing the effectiveness of impleménting comprehensive soil and water conservation practises at the farm level within watersheds of Southwestern Ontario that eventually enter into Lake Erie.

Three watersheds reflecting regional differences in soil, landform and land-use patterns were selected within southwestern Ontario. Each watershed studied consisted of a "paired" control and test sub-watershed study area. Within the control watershed, traditional soil and water management practices were to be used. Within the test watershed "state of the art" soil and water conservation management practices were implemented.

Over a five year period, comparative evaluations of soil, water and crop performance can be made within the respective paired watershed study areas. As a basis for preparing detailed tillage and cropping farm management plans within each watershed and establishing the baseline soil conditions, a soil survey was undertaken for the respective watershed areas.

The specific objectives of the soil survey program are as a follows:

- to conduct an intensive soil survey within the selected watersheds as an aid to development of detailed farm management plans for assessing soil erodibility and to assist with the planning of tillage and crop prescriptions over a five year period;

- to sample benchmark sites of the major soils for the purposes of establishing the baseline soil conditions against which changes can be monitored; and

- to document the results of the soil survey by preparing appropriate soil maps for each watershed and preparing a report for the overall study.

Ecological Services for Planning Ltd. was retained to conduct the Pilot Demonstration Watershed Sub-program soil surveys and to document the results for the objectives listed above.

2. DESCRIPTION OF SOIL SURVEY AREAS

The SWEEP Pilot Demonstration Sub-program soil survey was completed for three watersheds characterised regionally by differences in land-use patterns, climate, landform, and soils. The watersheds were located in Essex, Middlesex and Oxford Counties, southwestern Ontario (Figures 1, 2 and 3).

2.1 ESSEX WATERSHED

The Essex watershed is located within Maidstone Township, Essex County, between the Town of Essex to the west and the village of South Woodslee to the east (Figure 1).

The Essex watershed is a combined total of 673.5 hectares in size. The test watershed is 393.4 hectares and the control watershed is 280.1 hectares. Agriculturally, the entire watershed is dominated by cash crop farming enterprises producing corn, soybeans, winter wheat and hay crops. The Essex Watershed is located in the Essex- Kent Climatic Region (Brown et al., 1968, Appendix A).

The Essex watershed is found within the St. Clair Clay Plains, where the soils are derived mainly from glacial till parent materials smoothed by shallow deposits of lacustrine clays (Chapman and Putnam, 1973).

The most common soil type in the watershed area are Brookston soils, which consist of clay loam overlying prominently mottled, blue-grey, gritty clay and clay loam parent materials (Richards et al, 1949). Indications of secondary glacial reworking by meltwaters may be evident within a Brookston soil profile. This is indicated as a "washed" phase and is recognized in the field generally by an increase in sand content.

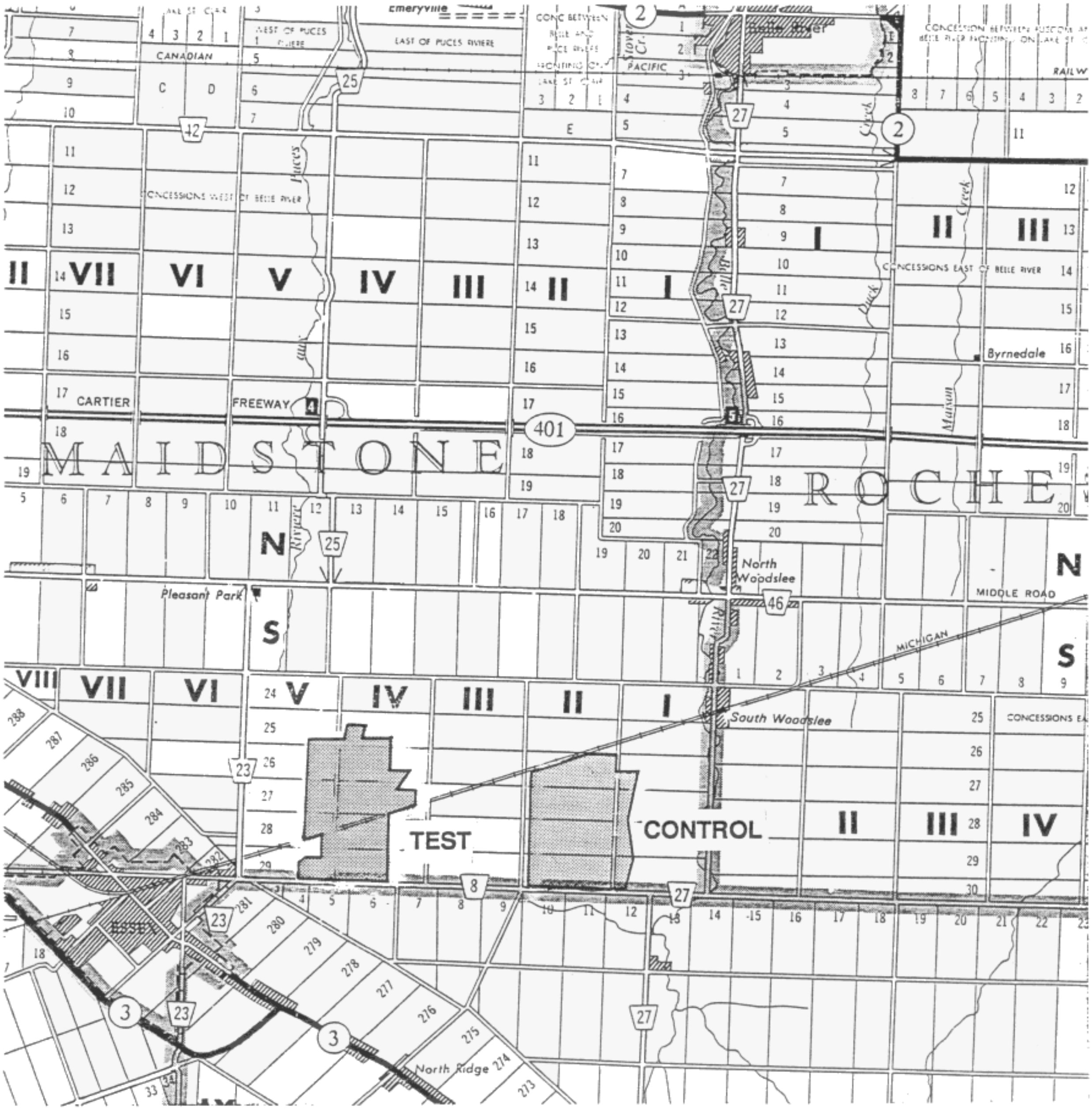


Figure 1: Location of Essex Watershed Study Area.

2.2 KETTLE CREEK WATERSHED

The Kettle Creek watershed is located within the western half of Westminster Township, Middlesex County, immediately south of the City of London (Figure 2).

The Kettle Creek watershed is 719.3 hectares in size. Both the test (394.7 ha.) and control (324.6 ha.) watersheds are located adjacent to each other. The Kettle Creek watershed is characterized by a broad range of agricultural enterprises. Corn, soybeans and winter wheat are the dominant crops produced in the watershed. The Kettle Creek watershed is located within the South Slopes climatic region (Brown et al., 1968, Appendix A).

The watershed is located within the Mount Elgin Ridges physiographic region. This region contains the Westminster moraine. Within this morainal system, the ridge areas are composed of calcareous, well to imperfectly drained, clay loam to clay till. In low lying areas that are poorly drained, it is common to find alluvial derived soils.

The preliminary soil map for this area (Hagarty and Hilborn, 1986) shows that the dominant soils within the watershed are derived from shallow water lacustrine deposits overlying till (Bennington soils), till derived soils (Muriel) and deep, lacustrine deposits (Brant soils).

2.3 PITTOCK CREEK WATERSHED

The Pittock Creek watershed is located within East Zona Township, Oxford County, south of the village of Tavistock (Figure 3). Highway 59 dissects the test watershed and forms the eastern boundary of the control watershed.

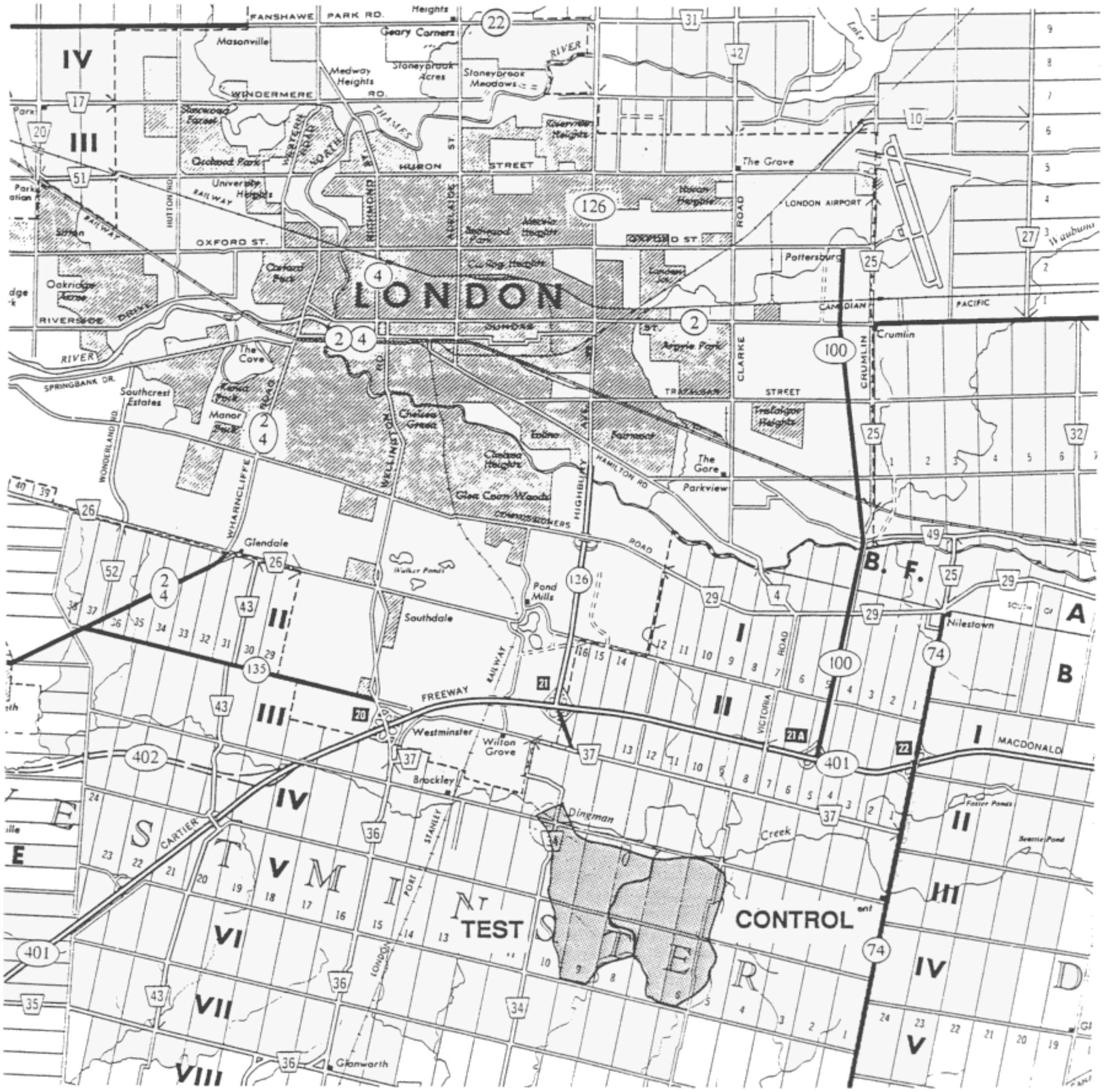


Figure 2: Location of Kettle Creek Watershed Study Area.

Figure 3: Location of Pittock Watershed Study Area.

The Pittock test watershed totals 325.7 hectares. The Pittock control watershed is 384.3 hectares. Agriculturally, swine and dairy farm enterprises dominate. The most common crops produced within the watershed consist of corn, soybeans, winter wheat and forages.

The Pittock Creek watershed borders both the Huron Slopes and South Slopes climatic region.

The Pittock Creek watershed is located within the Oxford Till Plain physiographic region (Chapman and Putnam, 1973). Topographically, this region is generally level to gently sloping. Glaciolacustrine silty materials deposited over the till within this region are common.

The dominant soil types that have developed over the till parent materials are imperfectly drained Tavistock and Embro silt loam soils. The Tavistock soils have developed on clay and clay loam till parent materials. The Embro soils have developed on loam till parent materials. Associated with the imperfectly drained soils, are inclusions of poorly drained Maplewood and Crombie soils (Wicklund and Richards, 1961).

3. STUDY APPROACH

3.1 SOIL SURVEY PROCEDURES

In the Pilot Demonstration Watershed soil survey, the following procedures were used:

- **Collection and Analysis of Existing Information:** Prior to undertaking the actual soil survey field work, available background reference information was collected. This included information on the surficial geology and existing soil survey reports. Black and white stereo air photo coverage at a scale of 1:10,000 of each study area was obtained from the Ministry of Natural Resources.

- **Reconnaissance Ground Survey:** The purpose of this phase is to familiarize the study team with landform, soil conditions and land use patterns; to assist in the initial development of the soil legend; to establish preliminary relations between soil/landform/landuse patterns and tonal patterns on airphotos; and to initiate soil correlation procedures. The reconnaissance survey was conducted using point samples along transects, and spot checking, derived from an initial air-photo interpretation of the study areas. Transects were designed to cover a range of landforms and soil conditions representative of each watershed.

- **Air-Photo Interpretation:** Following the reconnaissance survey and once the soil/landform relationships were understood, it was then possible to generate a preliminary soil map through air-photo interpretation. This was completed in the office using 1:10,000 scale black and white aerial photography. Once the soil delineations or polygons were drawn onto the air photographs, the approximate location of sample points and transects for subsequent field verification were identified.

- **Field Verification:** The purpose of the field survey was to verify the soil polygons developed using air-photo interpretation techniques. This was completed by sampling along transects located at points of change in the landscape to determine the detailed relationship between soils and landform patterns. The data collected at each site were standardized to present data collection methods used by the Ontario Institute of Pedology (OIP). Appendix B contains the list of soil data collected at each site and OIP data forms.

- **Field Procedures:** Each sample point was augered to a depth of approximately 120 centimetres, using a Dutch soil auger. Small soil pits to verify soil features were dug at regular intervals, especially whenever a different soil type was encountered. Additional field inspection to verify soil boundaries was conducted by walking the site and spot checking key soil properties. Surveyors also recorded in the field notes the approximate proportions of soil types present in compound polygons, boundary modifications and inclusions. Ground cover and tree cover were also noted for each inspection point, to aid in photo interpretation of vegetation (species identification) and/or locating sites on air photographs. As a result of field inspection, the polygon boundaries were modified or redrawn onto the airphotos to reflect the more accurate field soil information. Further inspection points or transects were located in the field in order to finalize the appropriate descriptions of each polygon. Following finalization of the soil polygons, they were transferred to a 1:10,000 OBM base map (Maps 1, 2 and 3 at - the back of this report).

3.2 LEGEND DEVELOPMENT

The reconnaissance survey provided the initial information for the preliminary development of the working legend. As the soil survey progressed and the soil/landform/drainage relationships were better understood, certain repetitive elements of the soil landscape became more evident and the legend was refined and described in more detail.

The working and published legends were developed in conjunction with the OIP to ensure continuity with ongoing soil survey programs. On the soil maps, the legend includes the following elements:

- **Polygon Number:** numerically identifies an area delineated on the soil map;
- **Location:** indicates the location of the polygon within either the test or control watershed;
- **Soil Code:** indicates the soil type found within a given polygon;

- **Soil Phase:** describes the phases that may be associated with a soil type in a specific polygon;

- **Soil Name:** provides the full name of the soil type;

- **Deposition:** indicates the depth or thickness of the Ap horizon. Three classes were used consisting of; DO which indicates that the Ap is less than 25 cm; Dl indicates that the Ap ranges from 25 to 40 cm; and D2 is used when the Ap is greater than 40 cm;

- **Percent Slope:** field measurement using a hand held inclinometer which measures the percent slope;

- **Slope Class:** based on the percent slope, the slope class can be identified. Slope class mapping guidelines are listed in Appendix B;

- **Erosion:** indicates the degree of erosion within the locale of the sample point. Three lasses were used consisting of; WO which indicates no apparent erosion; W1 indicates that the depth of carbonates is greater than 50 cm but closer to the surface than normal conditions for a specific soil type; W2 indicates that the depth of carbonates range from 20 to 50 cm from the soil surface, and W3 indicates that carbonates are present at the soil surface;

- **Drainage:** indicates the drainage class associated with specific soil types;

- **Limiting Inclusions:** indicates that the polygon is a compound unit. Limiting inclusions are associated with complex soils and slope patterns within a specific polygon.

The mapping unit used in all three watersheds is comprised of the soil series plus additional phases. A soil series has a uniform or characteristic profile development, texture, mode of deposition and drainage. Catenary sequences are developed with soils having a similar mode of deposition but different profile drainages. Table 1 lists the catenary sequences and associated profile drainage for all soil series mapped within the three watersheds.

Table 1: Catenary Sequence of Mapped Soil Series

Catena Name	Well to Moderately Well Drained	Imperfectly Drained	Poorly Drained
Bennington	Bennington	Tavistock	Maplewood
Bookton	Bookton	Berrien	Wauseon
Brant	Brant	Tuscola	Colwood
Brantford	Brantford	Beverly	Toledo
Caledon	Caledon	Camilla	Ayr
Honeywood	Honeywood	Embro	Crombie
Huron	Huron	Perth	Brookston
Plainfield	Plainfield	Walsingham	Waterin
Muriel	Muriel	Gobies	Kelvin

In the process of developing a soils legend, it became apparent that phases of individual series were occurring. Table 2 lists the phases developed for the watershed soil survey and the definitions assigned to each of the phases.

Table 2: Soil Survey Legend Phases

Phase	Code	Description
Coarse Substratum	CS	: soil profile is coarser in substratum than standard profile description
Fine Substratum	FS	: soil profile is finer in substratum than standard profile description
Loamy	L	: loamy textured surface horizon (ie. Ap), 15-40 cm in thickness
Till	T	: glacial till characteristics evident within soil profile which normally do not occur
Washed	W	: secondary glaciofluvial reworking of soil parent materials

Due to complexity of the soil landform pattern within the Kettle Creek Watershed, there are two types of map units defined on the basis of the proportions and soil associations of their components within a polygon map unit, as outlined by the ECSS (1984). Both simple and complex map units occur in the Kettle Creek watershed. The Pittock Creek and Essex watersheds are dominantly comprised of simple map units.

Based on "A Soil Mapping System for Canada: Revised" (ECSS, 1984), the following definitions have been used for the soil map units within the watershed soil survey areas. A simple map unit contains predominantly one soil. The average proportions of a simple map unit are as follows:

- predominant component - at least 80%
- limiting, dissimilar components - up to 20%.

A compound unit contains predominantly two soils or nonsoils or a combination of both (ECSS, 1984). The proportions of the two major components may vary from one considerably exceeding the other to both soil types within a map unit being approximately equal. A statement about the average proportions of a compound unit cannot be made, but a definition analogous to a simple map unit is as follows, if the components are:

- dissimilar and limiting, no single component represents more than 80%.

3.3 POLYGON SAMPLING AND BENCHMARKS

3.3.1 POLYGON TOPSOIL AND FERTILITY SAMPLING

Following preliminary finalization of the soil polygon boundaries, the topsoil (Ap) horizon was sampled at approximately five locations throughout a specific polygon. The sample was mixed thoroughly, forming a composite, and subsequently analyzed for soil fertility levels and particle size distribution. Appendix C contains the results of the analysis for each watershed.

3.3.2 MODAL PROFILE CHARACTERIZATION PROCEDURES

To determine the requirements for modal soil sampling, frequency distributions for key soil series were obtained from the field data, for each watershed. The main soil types representative of each watershed were then determined. Overall, thirty sites were selected, covering the widest possible range of dominant soils present within each watershed.

Standard lm x lm x 1m soil pits were dug, and a detailed profile description was recorded, using standard procedures (Day, 1982). Each soil horizon was sampled for subsequent laboratory analyses, when possible. Laboratory procedures are specified in Appendix D. The soil pit descriptions by horizon included horizon designation, horizon colour, field texture, mottle descriptions (colour, size and abundance), soil structure (grade, class and kind) in addition to the standard data (see Appendix B) collected at each sample point. Appendix B contains coding documents and instructions for the modal profile descriptions. When possible the samples for each of the horizons present were sent out for laboratory analyses of particle size distributions, (including a full separation of sand particle size), percent of organic matter and water pH, percent $CaCO_3$, water stable aggregates (A horizon only), bulk density, soil moisture retention, saturated hydraulic conductivity, fertility and cation exchange capacity. The results are given in Appendix E.

3.3.3 SPATIAL BENCHMARKS

In addition to the modal characterization sites, two types of spatial benchmarks were included in the watershed soil survey as a basis to monitor changes in topsoil quality and soil erosion levels.

Cesium Benchmark Methodology

The Cesium 137 benchmarks, were setup to establish baseline conditions and in time, to compare the rate of topsoil erosion between the conservation tillage methods prescribed for the test watershed and conventional tillage methods practised in the control watershed.

Benchmark site selection was based on locating an area within each of the test and control watersheds for each soil survey area having similar soil types, percent slope, drainage, and surface landform patterns.

At each Benchmark site there are a total of 9 sampling areas (see Figure 5, Appendix F) each being 3 x 3 m in area. At each sampling area there are a total of 9 sampling sites.

At the centre of each 3 x 3 m sampling site, a near surface marker was installed at a depth of approximately 40 cm. The type of marker used was a "3M" Model # - 1432 near surface marker (sonde). The square end of the sonde was placed upwards towards the soil surface.

At the centre of each sampling site, compass bearings were taken and recorded from a minimum of two directions from either man-made or natural landmarks at each site (see Appendix G). Distances were measured relative to each of the sampling sites and to the edges of fencerows when possible.

At each sampling site, a sample was taken to the lower depth of the A horizon. The 9 sampling sites were then mixed together to form a composite sample. The depth of the A horizon was also recorded.

Bulk density samples were taken at each of the 9 sampling sites of each sampling area. The bulk densities were cored at approximately 5 cm increments, representing the A horizon. The bulk density cores were taken diagonally about the sampling point (see Figure 5, Appendix F).

At each sampling site, 72 bulk density samples were cored, catalogued and sent for laboratory analysis. In total 3888 bulk density cores were taken for the Cesium spatial benchmarks.

A description of laboratory methods used to detect the concentration of cesium 137 are found in Appendix D. Normally there is a minimum five year sampling interval between the established baseline soil Cesium 137 content and the next sampling period.

Topsoil Benchmark Methodology

The topsoil spatial benchmarks were setup to establish the baseline soil conditions in both the test and control watersheds prior to implementation of the conservation and conventional tillage systems.

Within the Essex watershed there are 2 paired sites, and 3 paired sites within the Kettle Creek watershed and Pittock Creek watershed (see Appendix H).

At each benchmark site there was a total of 9 sampling areas (see Figure 5, Appendix F) each being 3 x 3 m in area. At each sampling area there is a total of 9 sampling sites.

At the centre of each 3x3 m. sampling site, a near surface marker was installed at a depth of approximately 40 cm. The type of marker used was a "3M" model# -1432 near surface marker (sonde). The square end of the sonde was placed upwards towards the soil surface.

At the centre of each sampling site, compass bearings were taken and recorded from a minimum of two directions from either man-made or natural landmarks at each site (see Appendix H). Distances were measured relative to each of the sampling sites and to the edges of fencerows when possible.

Based on criteria developed specifically for the topsoil spatial benchmarks, soil samples were collected and duplicated (when possible) for the following analyses:

	Depth	
- bulk density	0-15 cm.	15-30cm.
- Agg. stability	0-15 cm.	
- Atterberg limits	0-15 cm.	15-30cm.
- Moisture Availability (0, 100mbar, 15 Bar)	0-15 cm.	15-30cm.
- Particle Size	0-15 cm.	
- Org. Carbon	0-15 cm.	
- Avail. P	0-15 cm.	
- Exch. Ca,Mg,K	0-15 cm.	
- pH	0-15 cm.	
- CEC	0-15 cm.	
- $CaCO_3$ equiv.	0-15 cm.	

Laboratory methods used to determine the baseline topsoil conditions are found in Appendix D. The topsoil benchmark sites will be sampled annually over the lifetime of the paired watershed project.

3.4 SOIL DATABASE MANAGEMENT SYSTEM

Soil survey data were entered into a computer and managed using Ashton-Tate's dBase III program. This was done at weekly intervals throughout the survey. This allowed for quick checking and editing of the soil data on the tally sheets, and immediate feedback of summarized information for soil legend development, sampling design and soil type correlation.

The database for the watershed soil survey was structured according to the format used by OIP (Appendix B). One additional field was added to the OIP system which consisted of a polygon field. The polygon field is relational to all databases developed for the paired watershed soil survey.

After final editing of the soil survey data, polygon numbers were assigned to each sample record. Listings of the soil survey data were generated, sorted by watershed area and polygon number. The sorted information assisted in the development of the soil map legend and was useful for examining the variability of various soil attributes within the watershed study areas. Listings of the soil attributes, sorted on polygon number for the SITE, SITECAT, AND HORIZON FILES, in accordance with the present OIP soil survey methods, are included in Appendix I for each of the individual watersheds.

All laboratory data were entered into Lotus 123 spreadsheets. Similarly, all laboratory spreadsheets for this project were correlated by polygon number. The laboratory data that are used to establish the baseline soil data for the modal characterization, topsoil and cesium spatial benchmarks are located in Appendix E.

3.5 RELIABILITY ANALYSIS

Due to the natural variation of soil properties over the landscape, it is not possible to prepare a soil map which is 100 percent accurate. It is desirable, therefore to assess how well the polygon descriptions actually reflect the soils found within the delineation in the field. A measure of the reliability, was conducted according to the methods outlined by Forbes et al (1985). They suggest a sampling density of one sample point per 10 polygons, or 30 points, whichever is greater, for each stratification of the survey information.

For the watersheds tested, an X-Y co-ordinate system was overlaid onto the soils map. Random numbers were generated and then located on the grid. All points falling on soil boundaries, on non-soil areas (roads and water) or outside the mapped area, were rejected until a suitable number of sample points were selected. The random sample points are plotted on the soils maps and then checked in the field for the appropriate soil criteria used in the original survey.

The reliability data are used to test the accuracy of the soil legend, in terms of both individual soil attributes (ie drainage) for each soil polygon, and the soil series descriptions. This is done by summarizing the information in a table, comparing it against the soil legends description for the appropriate polygon, and determining a score for each attribute. The score depends on whether the attribute is correct as predicted or the number of attribute classes by which the sample deviates from the predictions. In its simplest form, this yields a percent correct score for each attribute tested.

The reliability information can be used in several key areas:

- to determine if the soil maps are sufficiently accurate to be used for different soil survey interpretations, such as soil erosion potential;
- to determine the appropriate scale for cartographic presentation; and
- to verify survey intensity levels and identify additional sampling requirements (if any).

The results of the reliability analyses are located in Section 4.3.

3.6 SURVEY INTENSITY LEVEL

Soil survey intensity level is a measure of the detail with which the soil survey was done. Local density of inspection points will vary according to the nature of the landscape. Inspection points will consist of a combination of pits dug by shovel and/or auger probes.

Table 3, shows the inspection density for each of the three watershed soil survey areas.

Table 3: Soil Survey Intensity Level

Watershed Location	Area (ha)	# of Polygons	# of Points	Inspection Density (pts/ha)	Survey Intensity Level
Essex	673.5	14	103	0.15	1
Kettle Creek	719.3	385	548	0.76	1
Pittock Creek	709.0	292	499	0.70	1

The low inspection density level used within the Essex Watershed is due to low inherent soil variability found within the test and control study areas.

The soil survey of the three watershed locations are mapped at a survey intensity level (SIL) of one. "A Soil Mapping System for Canada: Revised" (ECSS, 1984) indicates that for scales larger than 1:14,000 each soil map unit should have at least one soil inspection (ie. sample point).

The watershed soil survey areas are mapped at a scale of 1:10,000. All the polygons in the watershed soil survey areas have at least one inspection point per polygon. Exceptions to this are found in the Pittock and Kettle Creek watersheds where small soil map delineations straddle or occur outside of the watershed boundary and when access to the property was refused by the land owner. The information within the latter polygons is based on air photo interpretation and the characteristics of the surrounding soils.

4. SOIL SURVEY RESULTS

4.1 SOIL SERIES DESCRIPTIONS

This section contains generalized descriptions of the soils found within each watershed. The more detailed morphological, chemical and physical characteristics of the respective soil series associated with benchmark sites are presented under the Soil Benchmark subsection and in Appendices C, I, E and J.

The soil descriptions are arranged alphabetically by watershed and by soil series. Each soil description includes available information on the area, landscape characteristics, parent materials, texture, drainage, profile characteristics and associated soils. Selected average soil physical and chemical characteristics, when available from the modal benchmark characterization sites and polygon fertility data are listed for the dominant soil types within each watershed. Not all dominant modal soil types have been sampled. The presentation format of the hydraulic conductivity measurements as shown in the individual soil property tables; (ie.1.3E-03 cm/s) is analogous to the scientific notation expressed as 1.3×10^{-3} cm/s. Appendix J lists the average, minimum and maximum horizon depths and the range and modal textural characteristics of all soil series, mapped within each of the three watersheds. The lower average depth(s) of the A, B and C horizons were used to describe the profile horizon characteristics for each soil type. Transition horizons such as AB or BC are not included in this description. Figure 4 shows the general relationship between the mode of deposition, the type of parent materials, typical profile textures and the drainage of the soil series mapped within each watershed.

4.1.1 ESSEX WATERSHED

The Essex test and control watersheds are level, ranging in slope from 0.0 to 0.5%. The soils of the study areas are dominantly a Brookston soil that have developed on calcareous, lacustrine clay parent materials. Appendix I lists the detailed horizon and texture characteristics of the soils found within the Essex watershed. The Essex watershed soil survey map (Map #1) is located at the back of the report.

Brookston Soils

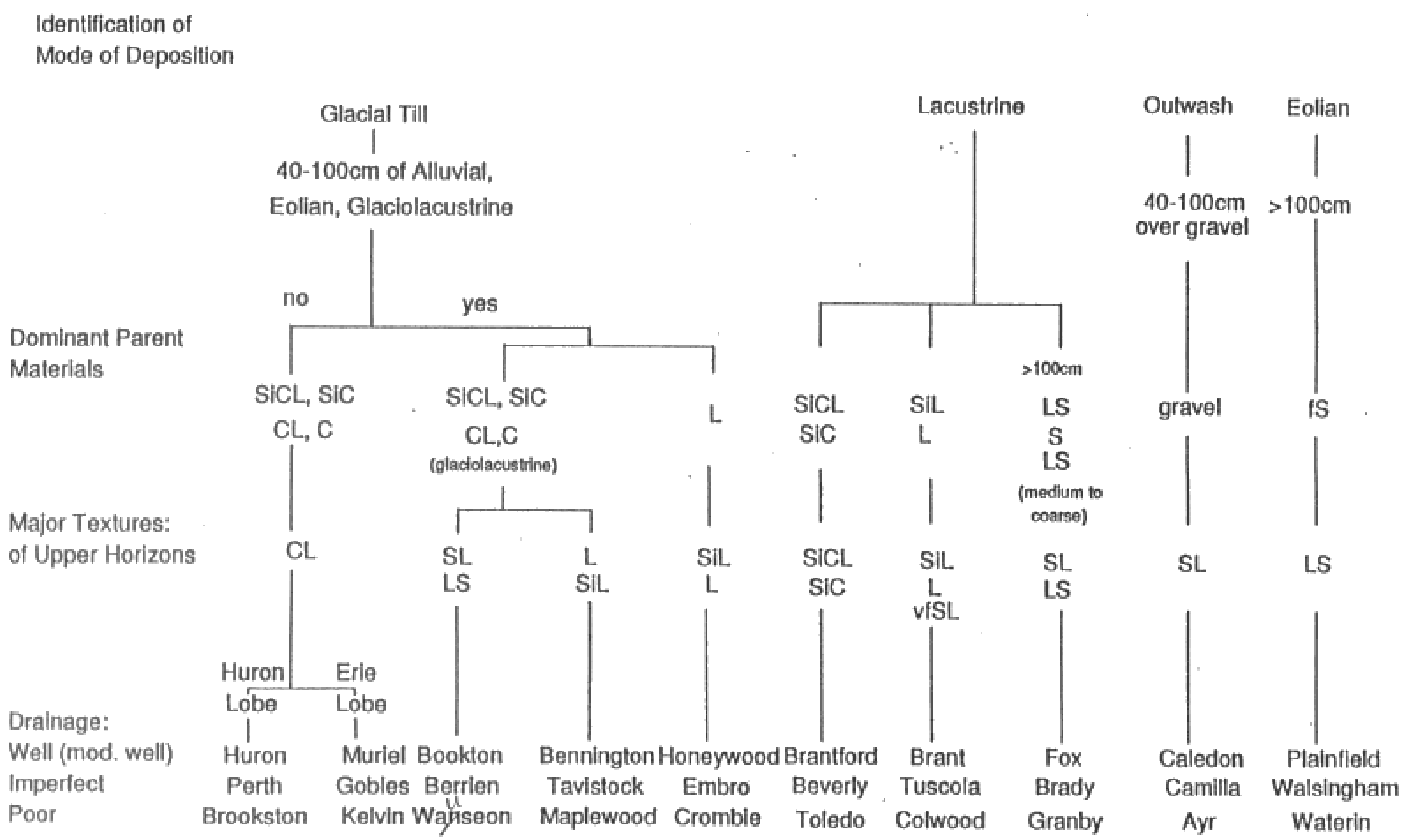
Within the Essex test and control watersheds, the dominant soil type is Brookston (BC). In the test watershed, poorly drained Brookston soils comprise 91.8% of the entire area totalling 361.0 hectares. Phases of the Brookston soils, consisting of deep loamy surface horizons or washed horizons within the soil profile comprise 32.4 ha (8.2%). of the test watershed. These soils are located within the central portion of the test watershed.

Within the control watershed 92.5% (259.0 ha.) of the total area are mapped as Brookston soils. The remaining 20.0 ha. of the control watershed was mapped as loamy, washed and combined loamy-washed phases of the Brookston soil. The Brookston soils are located along the southern and northern boundaries of the control watershed.

Within the test watershed, the average depth of the A horizon is 22 cm and is dominantly clay loam. The average depth of A horizon in the control watershed is 25 cm and is dominantly clay loam. Based on 19 samples, the average pH and organic matter content of the A horizon is 5.8. Based on 4 samples, the average organic matter content is 3.9%.

The B horizons in the watersheds are normally gleyed. In the test and control watersheds, the average lower depth of the B horizon is 80 cm. The texture of the B horizon in both the test and control watersheds is dominantly a clay, but in the washed phases the texture is sandy clay loam to fine sandy loam. Based on 4 samples the average pH of the B horizon averages 7.1, with an average level of 0.5% calcium carbonate ($CaCO_3$) and 1.0% organic matter.

Figure 4. Soil Associations Within The Paired Watershed Soil Survey Areas



The C horizon is gleyed, calcareous and is commonly found at an average depth of 102 cm in the control watershed and 104 cm in the test watershed. The C horizon texture is commonly a clay. Based on a single sample, in the C horizon, the pH is 7.5 with a $CaCO_3$ content of 8.2%. Table 4 lists the average for some of the soil physical and chemical parameters measured and observed for a modal Brookston soil within the Essex watershed.

Table 4: Soil Properties of a Brookston Soil - Essex Watershed *

Horizon	% sand	% silt	% clay	% Moisture Saturated	% Moisture 100mbar	% Moisture 15 Bar
A	32.0 (4)	32.0 (4)	36.0 (4)			
B	22.0 (4)	33.0 (4)	46.0 (4)	26.9 (2)	25.1 (2)	22.3 (2)
C	21.0 (1)	38.0 (1)	41.0 (1)			

Horizon	Hydraulic Cond. (cm/s)	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	1.7E-03 (1)	31.06 (1)	20.9 (2)	1.4 (2)
B	6.8E-04 (4)		21.5 (4)	1.5 (8)
C			35.5 (1)	

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	moderate	medium/fine	angular/sub-angular
B	strong/moderate	very fine/medium	angular/sub-angular
C	strong	medium/coarse	angular blocky

* brackets beside value indicate total number of samples used to calculate average.

Wauseon Soils

Located in the northeastern section of the control watershed is an isolated pocket of deep glaciolacustrine soils overlying finer grained deposits (ie. clay). These soils are mapped as poorly drained Wauseon soils. The Wauseon soils comprise 1.1 ha of the control watershed. Loamy phases of Wauseon soils are found within the control watershed.

The average depth of the A horizon is 31 cm. The texture of the A horizon is loam. The B horizon may be stratified, ranging in texture from loam to clay loam, becoming increasingly heavier with depth. The average depth to the C horizon is 103 cm and the C horizon texture is clay.

4.1.2 KETTLE CREEK WATERSHED

The distribution pattern of soil types within the Kettle Creek Watershed is highly variable due to complex landscape patterns. Table 5 lists the distribution of soil series in the test and control watersheds. The soil survey Map (Map #2) of the Kettle Creek watershed is located at the back of the report.

Table 5: Distribution of Soils In the Kettle Creek Watershed

		Control		Test	
Code	**Soil Series**	**Area (ha)**	**%**	**Area (ha)**	**%**
BE	Berrien	0.0	0.0	9.5	2.4
BN	Bennington	9.2	2.8	21.0	5.3
BO	Bookton	0.0	0.0	5.5	1.4
BT	Brant	1.7	0.5	2.3	0.6
CM	Camilla	0.0	0.0	2.3	0.6
COL	Colwood	26.7	8.2	8.3	2.1
CR	Crombie	0.2	0.1	0.3	0.1
EM	Embro	6.6	2.0	4.2	1.1
GO	Gobies	108.1	33.3	139.5	35.3
HY	Honeywood	1.2	0.4	6.5	1.6
KEL	Kelvin	9.8	3.0	42.7	10.8
MW	Maplewood	12.5	3.9	34.4	8.7
MU	Muriel	19.6	6.0	29.7	7.5
TA	Tavistock	102.8	31.7	62.1	15.7
TOL	Toledo	2.8	0.9	0.0	0.0
TUS	Tuscola	10.7	3.3	24.6	6.2
WA	Wauseon	0.0	0.0	1.0	0.3
PL	Plainfield	0.0	0.0	0.8	0.2
Ditches (Waterways)		12.7	3.9	0.0	0.0
		324.6	**100.0**	**394.7**	**100.0**

The watersheds are located within the Westminster moraine area. The topography is variable and ranges from near level slopes to greater than 15% slopes. Along the drainage channels that traverse the study area in a northern to southern direction, soils which have developed on shallow water glaciolacustrine materials overlying till are found on gently to moderately sloping topography. The remaining areas are characterised by level to slightly gentle to gentle slopes of loam and clay loam soils over clay loam and day till parent materials.

4.1.2.1 DOMINANT SOIL TYPES

The Kettle Creek Watershed is dominated by till and glaciolacustrine over till derived soils. Loamy phases are common within the Kettle Creek Watershed. Occurring to a lesser extent within the watershed are soils derived from glaciolacustrine silt loam parent materials. Table 6 lists the dominant soil types, their typical horizon textures, average depths, drainage and catenary associates.

Table 6: Characteristics of Dominant Soil Series Within the Kettle Creek Watershed*

Soli Series	Average Depth to A Horizon (cm)		Texture	Average Depth to B Horizon (cm)		Texture	Average Depth to C Horizon (cm)		Texture	Drainage	Soil Association
	Test	Control		Test	Control		Test	Control			
Berrien	30	--	fSL	68	--	fSL	95	--	SiCL-CL	Imp.	Bookton-Berrien-Wauseon
Bennington	25	18	L-vfSL	64	53	L-vfSL	101	86	SiCL-SiC	Well-Mod. Well	Bennington-Tavistock-Maplewood
Colwood	33	36	SiL-fsL	86	86	SiL-SiCL	103	100	SiL-vfSL	Poor	Brant-Tuscola-Colwood
Gobies	23	19	L-CL	56	44	CL-SiCL	82	81	SiCL	Imp.	Muriel-Gobles-Kelvin
Kelvin	25	26	SiL-L	76	64	SiCL	82	70	SiCI-SiC	Poor	Muriel-Gobles-Kelvin
Maplewood	36	30	L-vfSL	84	64	variable	99	97	SiCL	Poor	Bennington-Tavistock-Maplewood
Muriel	23	17	SiL-L	55	41	SiCL-CL	72	59	SiCI	Well-Mod. Well	Muriel-Gobles-Kelvin
Tavistock	29	23	SiL-vfSL	71	62	vISL-SiC	92	90	SiCL	Imp.	Bennington-Tavistock-Maplewood
Tuscola	32	31	vfSL	83	79	vfSL-L	104	83	vfSL	Imp.	Brant-Tuscola-Colwood

' Data Values from both the Test and Control Watershed, total number of samples for each dominant horizon description are located in Appendix J

Berrien Soils

Berrien soils are only mapped within the test section of the watershed. Imperfectly drained, Berrien soils represent 2.4% (9.5 ha.) of the test watershed. Generally, the Berrien soils are located proximal to the drainage ditches where sandy, shallow water glaciolacustrine sediments were overlaid onto the till of the Westminster Moraine.

The average depth of the A horizon is 30 cm. The texture of the A horizon is normally fine sandy loam.

The B horizon of a Berrien soil is normally gleyed and prominently mottled. The texture of the B horizon is commonly fine sandy loam. The average depth of the B horizon is 68 cm.

The average depth to the calcareous C horizon is 95 cm. The texture of the C horizon is normally silty clay loam to clay loam till.

Berrien soils are the imperfectly drained member of the Bookton catena. Bookton soils are well drained while the poorly drained member of the catena are Wauseon soils (Table 4).

Bennington Soils

Bennington soils have developed on loam, silt loam and very fine sandy loam soils over silty clay loam and silty clay till parent materials. Bennington soils comprise 21.0 ha of the test watershed and 9.2 ha. of the control watershed. Inclusions commonly found within the watershed include the imperfectly drained Tavistock and Gobles soils.

The average depth of the A horizon is 18 an in the control watershed and 25 an in the test watershed. The texture of the A horizon ranges from loam to very fine sandy loam.

Based on 11 samples, the average pH is 6.7. The average level of organic matter (based on 3 samples) is 3.2%.

The texture of the B horizon ranges from loam to very fine sandy loam. Also occurring to a minor extent are silt loam textured B horizons. Faint mottling may be present in the B horizon above the till parent materials. The average depth of the B horizon is 53 cm in the control watershed and 64 cm in the test watershed.

The parent materials of the Bennington soils are generally found at an average depth of 86 cm in the control watershed and 101 cm in the test watershed. The texture of the parent materials in the control study area is commonly silty clay loam. In the test watershed, the texture of the parent materials is normally silty clay loam, although silty clay occurs.

Bennington soils are the well to moderately well drained member of Bennington catena. Associated with this soils are the imperfectly drained Tavistock and poorly drained Maplewood soils.

Colwood Soils

Poorly drained Colwood soils are found in both the test and control watersheds. The majority of these soils are developed on lacustrine silt loam parent materials. Colwood soils comprise 26.7 ha of the control watershed and 8.3 ha of the test watershed. Within the Kettle Watershed, the Colwood soils may have washed, coarse and fine substratum phases.

The Ap horizon is normally silt loam, underlaid by an eluviated Ae horizon that ranges in texture from silt loam in the control watershed to very fine sandy loam in the test watershed. The average depth of the A horizon in the test watershed is 33 cm and 36 cm in the control watershed. Based on 6 samples, the average pH is 6.8. Based on 3 samples, the average level of organic matter is 3.8%.

The gleyed, prominently mottled B horizon has an average depth of 86 cm in the test and control watershed. The texture of the B horizon commonly ranges from silt loam to silty clay loam to loam, with varying contents of sand.

The calcareous parent materials are commonly located at an average depth of 103 cm in the test watershed and 100 cm in the control watershed. In severely eroded soils, the C horizon can be found at a depth of less than 50 cm. The texture of the C horizon commonly ranges from silt loam to very fine sandy loam.

The Colwood soil is associated with the well drained Brant and imperfectly drained Tuscola soils. Well drained Brant soils are rare in the Kettle Creek Watershed.

Gobies Soils

Imperfectly drained Gobies soils are the most common soils found within the Kettle Watershed. In the test watershed, greater than 35% (139.5 ha) of the area is mapped as Gobies soil. Within the control watershed, Gobies soils represent over 33% (108.1 ha) of the area. The well drained Muriel and loamy phase Muriel and imperfectly drained Tavistock soils are often associated with Gobles soils.

The average depth of the A horizon of Gobies soils in the test watershed is 23 cm and 19 cm in the control watershed. Many of the Gobies soils in both the test and control watersheds have loamy surface texture phase. The depth of the loamy textures is between 15 cm and 40 cm. On non-eroded loamy phase areas, the texture of the A horizon ranges from loam to silt loam to very fine sandy loam. Based on 36 samples, the average pH of the A horizon is 6.8. Based on 4 samples, the average level of carbonates is 0.8%. Based on 16 samples, the average level of organic matter is 3.5%.

The texture of the B horizon within the test watershed ranges from clay loam to silty day loam. Within the control watershed the texture normally ranges from silty clay loam to silty clay. The average depth of the B horizon, which may have faint to distinct to prominent mottling, is 56 cm in the test watershed and 44 cm in the control watershed. Within the B horizon, the average level of organic matter is 0.9%. The average level of carbonates is 0.5%. The average pH is 6.8 for the B horizon. The above averages for pH, carbonates and organic matter are based on three samples.

Overall, the calcareous parent materials of a Gobies soil are commonly silty clay loam. Within the test watershed the textures ranged from silt loam to clay loam. Within the control watershed the textures were not as variable, ranging from silty clay to silty clay loam. The average depth to the parent materials in the test watershed is 82 and 81 cm in the control watershed. The average pH level of the parent materials is 7.6. The average level of carbonates is 21.9%. The average level of organic matter in the C horizon is 0.3%. The above averages for pH, carbonates and organic matter are based on 7 samples.

Table 7 contains selected soil physical and chemical properties for a Gobles soil.

The imperfectly drained Gobles soils are associated with the Muriel catena. This catena includes the poorly drained Kelvin soil and the moderately well-drained to well-drained Muriel soil.

Kelvin Soils

Poorly drained Kelvin soils, often occur in low-lying depressional areas and comprise 3.0% (9.8 ha.) and 10.8 % (42.7 ha.) of the control and test watersheds. Typically, Kelvin soils have formed in glacial till parent materials, but loamy and washed phases exist.

Table 7: Soil Properties of a Gobies Soil - Kettle Creek Watershed *

Horizon	% sand	% silt	% clay	% Moisture Saturated	% Moisture 100mbar	% Moisture 15 Bar
A	23.0 (16)	50.0 (16)	27.0 (16)			
B	19.0 (3)	44.0 (3)	37.0 (3)	32.9 (1)	27.0 (1)	22.1 (1)
C	11.0 (7)	51.0 (7)	39.0 (7)	26.7 (1)	22.7 (1)	19.7 (1)

Horizon	Hydraulic Cond. (cm/s)	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (q/cc)
A	5.6E-03 (2)	23.1(4)	27.8 (4)	1.3 (7)
B	2.4E-04 (2)		33.0 (3)	1.5 (7)
C	1.1E-04 (2)		40.5 (7)	1.7 (3)

Horizon	Soil Structure Grade	Class	Kind
A	weak/moderate	fine	subangular blocky
B	moderate/strong	fine/medium	angular/subangular blocky
C	strong	medium/fine	prismatic

*brackets beside value indicate total number of samples used to calculate average.

The average depth of the Ap horizon in the test watershed is 25 cm and 26 cm in the control watershed. The Kelvin soils within the test watershed also exhibit the development of eluviated A horizons and often gleying. The texture of the A horizon is commonly silt loam in the control watershed and loam in the test watershed, but the texture can range from clay loam - silty clay loam - fine sandy loam. Based on 16 samples, the average pH of the A horizon is 6.9. Based on 3 samples, the average level of organic matter is 3.6%. There were no carbonates detected in the A horizon.

The gleyed B horizon is found at an average depth of 76 cm in the test watershed and 64 cm in the control watershed. Texture of the B horizon is commonly silty clay loam but may range from silty clay to clay to clay loam. Based on 2 samples, the average level of carbonates and organic matter are 0.4% and 1.2%, respectively. Based on 2 samples, the average pH for the B horizon is 6.8.

The parent materials of the Kelvin soils are silty clay loam in the control watershed and silty clay in the test watershed. The average depth to calcareous C horizons is 82 cm in the test watershed and 70 cm in the control watershed. Based on 2 samples, the average pH of the C horizon is 7.1 and the average level of carbonates is 6.1%. There was no organic matter detected in the C horizon.

Table 8 lists the average values for selected soil physical and chemical properties associated with a Kelvin soil.

Table 8: Soil Properties of a Kelvin Soil - Kettle Creek Watershed *

Horizon	% sand	% silt	% clay	Hydraulic Cond.	% Water Stable	Cation Exchange	Bulk Density
A	33.0 (3)	41.0 (3)	26.0 (3)		28.4 (2)	31.4 (2)	1.4 (3)
B	23.0 (2)	42.0 (2)	36.0 (2)	3.2E-04 (2)		27.8 (2)	1.6 (4)
C	23.0 (2)	42.0 (2)	36.0 (2)	7.7E-05 (1)		30.1 (2)	1.5 (3)

Horizon	Soil Structure		
	Grade	**Class**	**Kind**
A	moderate	fine/medium	subangular blocky
B	moderate	fine/medium	angular blocky
C	strong	medium	angular blocky

* brackets beside value indicate total number of samples used to calculate

The poorly drained Kelvin soils are associated with the Muriel catena. The other members of this sequences includes the imperfectly drained Gobles and moderately well-drained to well-drained Muriel soils. Due to landscape position and soil erosion, Kelvin soils are often found in association with the poorly drained Colwood, Maplewood, Crombie and Wauseon soils.

Maplewood Soils

Poorly drained Maplewood soils are found in both the test watershed (34.4. ha) and the control watershed (12.5 ha). Maplewood soils have developed on silt loam-loam, glaciolacustrine materials overlying glacial till. Within the Kettle Creek Watershed, washed and loamy phases are found.

In both the test and control watershed, the texture of the A horizon was commonly loam to very fine sandy loam. The average depth of the Ap in the test watershed is 36 cm and 30 cm in the control watershed. Based on 10 samples, the average pH level of the A horizon in a Maplewood soil is 6.7. Based on 1 sample, the level of organic matter is 5.6%. Carbonates were not detected in the A horizon.

The B horizon is gleyed and occasionally shows characteristics of clay enrichment. The average depth of the B horizon in the test watershed is 84 cm and 64 cm in the control watershed. The soil texture is variable and may range from a clay to silty clay loam to silt loam to very fine sandy loam to loam, although the latter three textures are not considered modal for a Maplewood soil. Based on 1 sample, the pH level of the B horizon is 6.8 and the level of organic matter is 1.2%. Carbonates were not detected in the B horizon.

The C horizon is commonly found at an average depth of 99 cm in the test watershed and 97 cm in the control watershed. The texture of the parent materials of a Maplewood soil commonly ranges from silty clay loam to clay loam.

Table 9 lists the average values for selected soil physical and chemical properties for a Maplewood soil.

Table 9: Average Soil Properties of a Maplewood Soil - Kettle Creek Watershed *

Horizon	% sand	% silt	% clay	% Moisture Saturated	% Moisture 100mbar	% Moisture 15 Bar
A	16.0 (1)	60.0 (1)	24.0 (1)	47.4 (2)	36.1 (2)	27.6 (2)
B	36.0 (1)	44.0 (1)	20.0 (1)	33.1 (1)	25.9 (1)	20.2 (1)
C						

Horizon	Hydraulic Cond. (cm/s)	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	1.6E-02 (2)	29.9 (1)	38.8 (2)	1.2 (2)
B	1.8E-04 (1)		22.4 (1)	1.5 (1)
C				

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	weak	fine	subangular blocky
B	weak	medium	subangular blocky
C	moderate	medium	subangular blocky

*brackets beside value indicate total number of samples used to calculate average.

Maplewood soils are the poorly drained member of the Bennington catena. This catena also includes the imperfectly drained Tavistock and well drained Bennington soil. Maplewood soils commonly occur with poorly drained Kelvin, Colwood and occasionally Crombie soils.

Muriel Soil

Moderately well-drained to well-drained Muriel soils are found in areas that are generally level to gently undulating on the upland landscape. Within the test watershed there are 29.7 ha and within the control watershed there are 19.6 ha. Within both the test and control watersheds, loamy phases are found associated with Muriel soils.

The average depth of the A horizon is 23 cm within the test watershed and 17 cm in the control watershed. The texture of the A horizon in the control and test watersheds is commonly silt loam and loam. Based on 17 samples, the average pH level associated with the A horizon is 7.1. Based on 2 samples, the level of carbonates is 2.9%. Based on 9 samples, the average level of organic matter is 3.0%.

The texture of the B horizon within the control watershed ranges from silty day loam to silty clay and within the test watershed ranges from silty clay loam to clay loam. The average depth of the B horizon in the test watershed is 55 cm and 41 cm in the control watershed.

The calcareous parent materials of Muriel soils are found at an average depth of 72 cm in the test watershed and 59 cm in the control watershed. The texture of the C horizon in the control watershed is silty clay and silty day loam in the test watershed. Based on 4 samples, the average pH level of the C horizon pH is 7.6, the average level of carbonates is 22.0% and the average level of organic matter in the C horizon of a Muriel soil is 0.5%.

Table 10 lists the average values for selected soil physical and chemical properties measured for a Muriel soil.

Table 10: Average Soil Properties of a Muriel Soil - Kettle Creek Watershed *

Horizon	% sand	% silt	% clay	Moisture Saturated	Moisture 100mbar	Moisture 15 Bar
A	31.0 (9)	46.0 (9)	23.0 (9)			
C	13.0 (4)	50.0 (4)	38.0 (4)	29.7 (1)	25.5 (1)	21.9 (1)

Horizon	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	14.5 (2)	34.2 (2)	1.5 (3)
C		36.9 (4)	1.7 (6)

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	weak/strong	medium	subangular blocky
C	strong/medium	medium	angular blocky

* brackets beside value indicate total number of samples used to calculate average

The Muriel soils are the moderately well-drained to well-drained member of the Muriel catena. Muriel soils are often associated with imperfectly drained Gobies and poorly drained Kelvin soils.

Tavistock Soils

The Tavistock soils consist of glaciolacustrine silt loam and loam materials overlying clay loam glacial till. They occupy 31.7% (102.8 ha) of the control watershed and 15.7% (62.1 ha) of test watershed.

The average depth of the A horizon in the test watershed is 29 cm and 23 cm in the control watershed. The texture of the A horizon in the control watershed is generally silt loam but does range to loamy very fine sand. Within the test watershed, the texture of the A horizon is commonly silt loam. Based on 57 samples, the average pH of A horizon is 6.8. Based on 17 samples, the average level of organic matter is 3.4%.

The texture of the mottled B horizon ranges from silty day loam to very fine sandy loam in the test watershed and ranges from silty day loam to loam in the control watershed. The latter texture is not modal, although occasionally occurs. The average depth of the B horizon is 71 cm in the test watershed and 62 cm in the control watershed. Based on 3 samples, the average pH of the B horizon is 7.1. Based on 3 samples, the average level of organic matter and carbonates within the B horizon is 0.6% and 0.8% respectively.

The average depth to the calcareous C horizon is 92 cm in the test watershed and 90 cm in the control watershed. The texture of the parent materials is silty clay loam. Based on 2 samples, the average pH level of the C horizon is 7.6 and the average level of calcium carbonate is 29.5%. Organic matter was not detected in the C horizon of a Tavistock soil.

Table 11 lists the results for some of the soil physical and chemical attributes a Tavistock soil.

The Tavistock soils are the imperfectly drained member of the Bennington catena. Associated with these soils are the well to moderately well-drained Bennington and poorly drained Maplewood soils.

Tuscola Soils

Tuscola soils occupy 10.7 ha. of the control watershed and 24.6 ha. of the test watershed. The Tuscola soils are normally developed from glaciolacustrine parent materials. Within the Kettle Creek Watershed, some Tuscola soils may have a coarse substratum phase.

Table 11: Average Soil Properties of a Tavistock Soil - Kettle Creek Watershed *

Horizon	% sand	% silt	% clay
A	32.0 (17)	50.0 (17)	18.0 (17)
B	46.0 (3)	38.0 (3)	16.0 (3)
C	38.0 (2)	37.0 (2)	25.0 (2)

Horizon	Hydraulic Cond. cm/s	% Water Stable Agg.	Cation Exchange Capacity	Bulk Density (g/cc)
A		53.1 (2)	16.6 (2)	1.3 (4)
B	4.6E-04 (1)		23.2 (3)	1.5 (6)
C			37.6 (2)	1.8 (2)

Horizon	Soil Structure		
	Grade	Class	Kind
A	weak	medium	granular
B	moderate	medium	angular/subangular blocky
C	strong	coarse	angular blocky

* brackets beside value indicate total number of samples used to calculate average.

The average depth of the A horizon is 32 cm in the test watershed and 31 cm in the control watershed. Soil texture is commonly very fine sandy loam; however loam textures also occur within the watershed. Based on 15 samples, the average pH level is 6.8 in the A horizon. Based on 7 samples, the average level of organic matter is 3.7%. Carbonates were not detected.

The texture of the mottled, B horizon ranges from very fine sandy loam to loam. The average depth of the B horizon in the test watershed is 83 cm and in the control 79 cm. Based on 1 sample, the average pH level for the B horizon is 6.6 and the average level of organic matter is 0.9%.

The calcareous C horizon is commonly found at an average depth of 104 cm in the test watershed and 83 cm in the control watershed. The texture of the parent materials is usually very fine sandy loam, although loam and loamy very fine sands do occur.

Table 12 lists the averages for measured and observed soil physical properties of a Tuscola soil in the Kettle Creek Watershed.

Table 12: Soil Properties of a Tuscola Soil - Kettle Creek Watershed *

Horizon	% sand	% silt	% clay	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	42.0 (7)	42.0 (7)	16.0 (7)	27.6 (1)	18.6 (1)	1.3 (1)
B	24.0 (1)	60.0 (1)	15.0 (1)		17.9 (1)	1.5 (2)
C						

Horizon	Soil Structure Grade	Class	Kind
A	weak	fine	subangular blocky
B	weak	medium	subangular blocky
C	weak	coarse	subangular blocky

* brackets beside value indicate total number of samples used to calculate average.

The imperfectly drained Tuscola soil is associated with the Tuscola catena. Associated with this catenary group are the well drained Brant and poorly drained Colwood soils.

4.1.2.2 SUBDOMINANT SOIL TYPES

Table 13 contains a listing of soils that are mapped within the test and control watershed, but are less than 2% of the total areas.

Table 13: Characteristics of Subdominant Soil Series Within the Kettle Creek Watershed *

Soil Series	Average Depth to A Horizon (cm)		Texture	Average Depth to B Horizon (cm)		Texture	Average Depth to C Horizon (cm)		Texture	Drainage	Soil Association
	Test	Control		Test	Control		Test	Control			
Bookton	25	–	fSL	58	–	fSL	101	–	CL	Well	Bookton-Berrien-Wauseon
Brant	28	26	L-vfSL	78	64	SiL-vfSL	115	90	vfS-vfSL	Well	Brant-Tuscola-Colwood
Camilla	32	–	vfSL	70	–	mSL	96	–	GSL	Imp.	Caledon-Camilla-Ayr
Crombie	25	33	L	76	77	SiL-vfSL	100	100	vfSL-L	Poor	Honeywood-Embro-Crombie
Embro	23	20	vfSL	48	57	SiL-vfSL	91	82	SiL-L	Imp.	Honeywood-Embro-Crombie
Honeywood	31	20	vfSL	64	42	Sil-vfSL	100	65	L	Well-Mod.	Honeywood-Embro-Crombie
Toledo	--	30	SiL	–	74	SiC	--	113	SiC	Poor	Brantford-Beverly-Toledo
Wauseon	20	–	vfSL	65	–	fSL	100	–	SiC	Poor	Bookton-Berrien-Wauseon
Plainfield	24	–	fSL	98		fSL	115		vfSL	Well	Plainfield-Walsingham- Waterin

* Data Values from both the Test and Control Watershed, total number of samples for each dominant horizon description are located in Appendix J

4.1.3 PITTOCK CREEK WATERSHED

The soils within the Pittock Creek Watershed are developed on shallow water glaciolacustrine silt loam and loam overlying loam to clay loam glacial till parent materials. Topographically, the test watershed is relatively level (0.0 to 2.0%) to gently sloping (0.0 to 4.0%) and consists of simple and complex landform patterns. Within the control watershed, topography is more variable, with greater relief and occurrences of complex slope patterns. Table 14 lists the distribution of soils within the test and control study areas. The Pittock Creek watershed soil survey map (Map #3) is located at the back of the report.

4.1.3.1 DOMINANT SOIL TYPES

The dominant soil types within the Pittock Creek Watershed have developed on loam till and glaciolacustrine silt loam parent materials. Table 15 lists the dominant soil types, their average horizon depths and texture characteristics, profile drainage and catena associations.

Brant soils

Well drained Brant soils occupy 11.4 ha within the control watershed and 2.2 ha within the test watershed. Brant soils have developed on well drained, glaciolacustrine sediments.

Table 14: Distribution of Soils in the Pittock Creek Watershed

Code	Soil Series	Area (ha) Control	% of Area	Test	% of Area
BN	Bennington	6.9	1.8	0.5	0.1
BT	Brant	11.4	3.0	2.2	0.7
BY	Brady	0.0	0.0	6.2	1.9
COL	Colwood	47.0	12.2	29.3	9.0
CR	Crombie	25.8	6.7	31.4	9.6
EM	Embro	211.6	55.1	169.1	51.9
HY	Honeywood	22.0	5.7	18.4	5.7
MW	Maplewood	1.5	0.4	7.4	2.3
MU	Muriel	0.0	0.0	5.6	1.7
TA	Tavistock	1.6	0.4	27.3	8.4
TUS	Tuscola	56.6	14.7	27.8	8.5
PL	Plainfield	0.0	0.0	0.5	0.1
		384.3	**100.0**	**325.7**	**100.0**

Table 15: Characteristics of Dominant Soil Series Within the Pittock Creek Watershed*

Soli Series	Average Depth to A Horizon (cm) Test	Control	Texture	Average Depth to B Horizon (cm) Test	Control	Texture	Average Depth to C Horizon (cm) Test	Control	Texture	Drainage	Soil Association
Brant	23	22	SiL-vfSL	72	71	vfSL	103	120	fSL	Well	Brant-Tuscola-Colwood
Colwood	29	28	SiL	77	87	SiL	120	95	SiCL-vfSL	Poor	Brant-Tuscola-Colwood
Crombie	29	27	SiL	71	73	SiL-vfSL	97	100	L	Poor	Honeywood-Embro-Crombie
Embro	27	22	SIL-vfSL	67	64	SiL-vfSL	93	93	L	Imp.	Honeywood-Embro-Crombie
Honeywood	29	24	SiL-vfSL	64	72	SiL-vfSL	92	99	L	Well	Honeywood-Embro-Crombie
Tavistock	23	23	SiL-vfSL	75	62	SIL-vfSL	95	100	CL-SiCL	Imp.	Bennington-Tavistock-Maplewood
Tuscola	30	24	SiL	70	82	SiL-L	97	95	vfSL	Imp.	Brant-Tuscola-Colwood

* Data Values for both the Test and Control Watersheds, total number of samples for each dominant horizon description are located in Appendix J

The average depth of the A horizon is 22 cm in the control watershed and 23 cm in the test watershed. The A horizon depth is more variable within the control watershed. The texture of the A horizon is very fine sandy loam to silt loam. Based on 6 samples, the average pH level of the A horizon is 6.7. Based on 3 samples, the average levels of organic matter is 3.3%. Based on 1 sample, the level of calcium carbonate is 2.5%.

The texture of the B horizon in the control watershed is very fine sandy loam. Within the test watershed, the B horizon texture is more variable and ranges from loam to fine sandy loam. The average depth of the B horizon in the test watershed is 72 cm and 71 cm in the control watershed. Based on 3 samples, the average pH level of the B horizon is 7.2, the average level of calcium carbonate is 0.7% and the average level of organic matter is 0.4%.

The average depth to the calcareous parent materials is 103 cm in the test watershed and greater than 120 cm in the control watershed. The texture of the parent material is commonly fine sandy loam.

Table 16 lists the average values for selected soil physical and chemical characteristics of a Brant soil within the Pittock Creek Watershed.

Brant soils are the well drained member of the Brant catena. Associated with this catena are the imperfectly drained Tuscola and poorly drained Colwood soils.

Colwood Soils

Colwood soils have developed on poorly drained, silt loam glaciolacustrine deposits. Colwood soils comprise 29.3 ha in the test watershed and 47.0 ha in the control watershed. Poorly drained Colwood soils are found in relatively level depressions and drainage channels. Associated with Colwood soils within the Pittock Watershed are coarse and fine substratum phases. Colwood soils are associated with well drained

Brant and imperfectly drained Tuscola soils of the Brant catena.

The dominant texture of the A horizon is silt loam, although very fine sandy loam textures do occur. The average depth of the A horizon within the test watershed is 29 cm and 28 cm within the control watershed. Based on 16 samples, the average pH of the A horizon is 6.7. Based on 5 samples, the average level of organic matter is 5.2%. Carbonates were not detected in the A horizon.

Table 16: Soil Properties of a Brant Soil - Pittock Creek Watershed *

Horizon	% sand	% silt	% clay	Hydraulic Cond. (cm/s)	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	39.0 (2)	48.0 (2)	13.0 (2)	1.9E-03 (1)	60.5 (1)	18.5 (1)	1.4 (2)
B	52.0 (3)	36.0 (3)	12.0 (3)	3.4E-04 (3)		10.9 (3)	1.6 (2)
C							

Horizon	Soil Structure		
	Grade	Class	Kind
A	weak	very fine	granular blocky
B	weak/moderate	medium	subangular blocky
C	weak	fine	subangular blocky

* brackets beside value indicate total number of samples used to calculate average.

The depth of the gleyed and heavily mottled B horizon averages 77 cm in the test watershed and 87 cm in the control watershed. The soil texture of the B horizon is commonly silt loam. Based on 4 samples, the average pH is 6.8 for the B horizon and the average level of organic matter and calcium carbonate is 1.0% and 0.9% respectively.

The calcareous C horizon is found at an average depth of 120 cm in the test and 95 cm in the control watersheds. The respective textures of the C horizon within the test and control watersheds are commonly silty clay loam and loam to very fine sandy loam. Based on 1 sample, the average pH level of the C horizon is 7.5. Organic matter was not detected in the C horizon. The level of calcium carbonate is 28.6%.

Table 17 lists the results of measured and observed soil physical characteristics, expressed as averages for the Colwood soil.

Table 17: Soil Properties of a Colwood Soil - Pittock Creek Watershed *

Horizon	%sand	%slit	%clay	% Moisture Saturated	% Moisture 100mbar	% Moisture 15 Bar
A	34.0 (5)	47.0 (5)	19.0 (5)	46.3 (3)	29.3 (3)	21.1 (3)
B	39.0 (4)	44.0 (4)	17.0 (4)	30.6 (4)	23.9 (4)	16.5 (4)
C	49.0 (1)	46.0 (1)	5.0 (1)	49.4 (1)	24.4 (1)	3.7 (1)

Horizon	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	74.3 (2)	27.2 (3)	1.3 (4)
B		30.8 (4)	1.6 (3)
C		26.1 (1)	1.6 (1)

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	weak	very fine/fine	granular
B	moderate	medium	subangular blocky
C	moderate	medium	angular blocky

* brackets beside value indicate total number of samples used to calculate average.

Colwood soils are poorly drained and are associated with imperfectly drained Tuscola and well-drained Brant soils.

Crombie Soils

The poorly drained Crombie soils are developed on loam glacial till parent materials within depressional and drainage channel areas. Crombie soils comprise 9.6% (31.4 ha.) of the test watershed and 6.7% (25.8 ha.) of the control watershed.

The average depth of the A horizon in the test watershed is 29 an and 27 cm in the control watershed. The dominant texture of the A horizon is silt loam, although very fine sandy loam does occur. Based on 24 samples, the average pH level of the A horizon is 6.7. Based on 9 samples, the average level of organic matter is 5.2%. Carbonates were not detected in the A horizon.

The texture of the gleyed, mottled B horizon is commonly silt loam in the test watershed and loam to silt loam to very fine sandy loam in the control watershed. The average depth of the B horizon is 71 cm in the test watershed and 73 cm in the control watershed. Based on 1 sample, the average pH level is 6.8 and the organic matter level is 1.0%. Carbonates were not detected in the B horizon.

The depth to the calcareous C horizon is 100 cm in the control watershed and 97 cm in the test watershed. The dominant texture is loam, although coarser fine sandy loam[y] and loamy sand exist. Based on 1 sample, the pH level of the C horizon is 6.9. Carbonates and organic matter were not detected in the C horizon of the modal benchmark site.

Table 18 list the average values for selected soil physical and chemical attributes for a Crombie soil in the Pittock watershed.

Table 18: Soil Properties of a Crombie Soil - Pittock Creek Watershed *

Horizon	%sand	%silt	%clay	% Moisture Saturated	% Moisture 100mbar	% Moisture 15 Bar
A	27.0(9)	54.0(9)	19.0(9)	40.3(1)	30.3(1)	25.6(1)
B	31.0(2)	46.0(2)	23.0(2)	34.6(2)	24.5(2)	17.5(2)
C	35.0(1)	40.0(1)	26.0(1)	32.6(1)	25.9(1)	19.9(1)

Horizon	Hydraulic Cond. (cm/s)	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	1.2E-03(1)	13.7(1)	22.2(1)	1.3(2)
B	1.8E-03(2)		31.2(2)	1.5(6)
C	5.7E-03(1)		39.3(1)	1.5(1)

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	moderate	fine/medium	granular/angular blocky
B	moderate	medium	subangular blocky
C	moderate	coarse	prismatic

* brackets beside value indicate total number of samples used to calculate average.

Crombie soils are poorly drained and are associated with imperfectly drained Embro and moderately well to well-drained Honeywood soils.

Embro Soils

The imperfectly drained Embro soils occupy more than 50% of the test (169.1 ha) and control (221.6 ha) watershed. Embro soils are developed on loam glacial till parent materials. The majority of Embro soils are found on simple and complex slopes ranging from 0.0 to 4.0%. Inclusions of soils often associated with Embro soils include the Honeywood and Crombie soils.

The average depth of the A horizon is 27 cm in the test watershed and 22 cm in the control watershed. The texture of the A horizon is commonly a silt loam in the test watershed and very fine sandy loam in the control watershed. Based on 81 samples, the average pH level is 6.8. Based on 24 samples, the average level of organic matter is 4.1%. Based on 5 samples, average carbonates are 0.2%.

The texture of the B horizon ranges from silt loam to loam within the test watershed and very fine sandy loam to loam in the control watershed. Within both the test and control watershed the modal texture of the B horizon is clay loam. The average depth of the B horizon in the test watershed is 67 cm and 64 cm in the control watershed. Based on 7 samples, the average pH, organic matter and carbonate levels are 6.7, 0.9% and 0.2%, respectively.

The average depth to the C horizon is 93 cm for the test and control watersheds respectively. The texture of the parent materials ranges from fine to very fine sandy loam, but the dominant texture is loam. Based on 6 samples, the average level of calcium carbonate in the C horizon is 14.4%. Organic matter was undetectable. Based on 6 samples, the average pH level is 7.4.

Table 19 lists the average values for selected soil physical and chemical properties of a Embro soil.

The imperfectly drained Embro soils are associated with the well to moderately well drained Honeywood and poorly drained Crombie soils.

Honeywood Soils

The Honeywood soils have developed on well to moderately well drained, loam till parent materials. The Honeywood soils occupy relatively small ridge areas or level to slightly inclined areas within both the test and control watersheds. Honeywood soils comprise 22 ha within the control watershed and 18.4 ha within the test watershed.

Table 19: Soil Properties of a Embro Soil - Pittock Creek Watershed *

Horizon	%sand	%silt	%clay	Moisture Saturated	Moisture 100mbar	Moisture 15 Bar
A	29.0 (24)	55.0 (24)	17.0 (24)	38.8 (5)	27.8 (5)	22.7 (5)
B	34.0 (7)	46.0 (7)	19.0 (7)	23.8 (7)	23.8 (7)	12.8 (7)
C	36.0 (6)	40.0 (6)	24.0 (6)	25.6 (6)	18.9 (6)	13.0 (6)

Horizon	Hydraulic Cond. (cm/s)	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	2.7E-03 (4)	37.0	20.5 (5)	1.3 (9)
B	2.7E-03 (6)		24.7 (7)	1.5 (13)
C	3.2E-04 (4)		21.8 (6)	1.7 (10)

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	very weak/weak	medium/fine	granular
B	weak/moderate	medium	angular/subangular blocky
C	weak/moderate	medium	platy/angular blocky

* brackets beside value indicate total number of samples used to calculate average.

The average depth of the A horizon is 29 cm in the test watershed and 24 cm in the control watershed. The texture of the A horizon is silt loam within the test watershed and very fine sandy loam within the control watershed. Based on 19 samples, the average pH is 6.7. Based on 2 samples, the average level of organic matter is 4.3% and the level of calcium carbonate in the A horizon is 1.9%.

The texture of the B horizon ranges from silt loam to loam and very fine sandy loam to loam to slit loam in the test and control watersheds, respectively. The average depth of the B horizon is 64 cm for both the test watershed and 72 cm for the control watershed. Based on 1 sample, the pH level for the B horizon is 7.4 and the levels of organic matter and calcium carbonate are 0.9 and 5.8%, respectively.

The calcareous C horizon is found at an average depth of 92 cm in the test watershed and 99 cm in the control watershed. The texture is commonly loam. Based on 2 samples, the pH level of the C horizon averages 7.7 and the calcium carbonate level is 27.8%.

Table 20 lists the average values for measured and observed soil physical properties of a Honeywood soil.

Table 20: Soil Properties of a Honeywood Soil - Pittock Creek Watershed *

Horizon	%sand	%silt	%clay	% Moisture Saturated	% Moisture 100mbar	% Moisture 15 Bar
A	33.0 (2)	48.0 (2)	20.0 (2)	35.0 (2)	23.1 (2)	19.2 (2)
B	37.0 (1)	44.0 (1)	19.0 (1)	24.5 (1)	18.4 (1)	12.7 (1)
C	40.0 (2)	45.0 (2)	16.0 (2)	18.9 (2)	13.3 (2)	8.4 (2)

Horizon	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	50.4 (1)	18.9 (2)	1.3 (2)
B		20.1 (1)	1.7 (1)
C		18.9 (2)	1.9 (2)

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	weak/moderate	fine/medium	granular
B	weak	medium	subangular blocky
C	moderate	medium	angular blocky

* brackets beside value indicate total number of samples used to calculate average.

Well to moderately well-drained Honeywood soil as are associated with imperfectly drained Embro and poorly drained Crombie soils.

Tavistock Soils

Tavistock soils have developed on 40 to 100 cm of shallow water glacio-lacustrine material overlying clay loam parent materials. They are imperfectly drained and comprise 1.6 ha of the control watershed and 27.3 ha of the test watershed.

The average depth of the A horizon is 23 cm for both the test and control watersheds. The texture of the A horizon within the test watershed is commonly silt loam while within the control watershed is very fine sandy loam. Based on 21 samples, the average pH level is 6.8. Based on 11 samples, the organic matter averages 4.6%. Carbonates were undetected in the A horizon.

The texture of the mottled B horizon ranges from silt loam to very fine sandy loam becoming increasingly finer with depth. The average depth of the B horizon is 75 cm in the test watershed and 62 cm in the control watershed. Based on 2 samples, the pH level of the B horizon averages 7.0 and the average levels of organic matter and calcium carbonate are 0.7% and 0.3%, respectively.

The average depth to the calcareous C horizon is 95 cm and 100 cm for the test and control watersheds, respectively. The texture of the parent materials ranges from clay loam to silty day loam. Based on 3 samples, the average pH level of the C horizon is 7.5 and the average level of calcium carbonate is 12.6%. Organic matter was undetectable in the C horizon.

Table 21 lists the averages for selected soil physical and chemical properties associated with a Tavistock soil.

Table 21: Soil Properties of a Tavistock Soil - Pittock Creek Watershed *

Horizon	%sand	%silt	%clay	% Moisture Saturated	% Moisture 100mbar	% Moisture 15 Bar
A	31.0 (11)	52.0 (11)	18.0 (11)	41.9 (1)	33.5 (1)	27.0 (1)
B	46.0 (2)	38.0 (2)	16.0 (2)	28.7 (1)	21.6 (1)	11.9 (1)
C	38.0 (3)	37.0 (3)	25.0 (3)	25.5 (2)	22.8 (2)	18.9 (2)

Horizon	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	32.2 (1)	1.3 (1)
B	15.5 (2)	1.5 (1)
C	26.7 (3)	1.5 (2)

Horizon	Soil Structure Grade	Soil Structure Class	Soil Structure Kind
A	moderate	very fine	angular blocky
B	moderate	medium	angular blocky
C	weak/strong	medium/coarse	platy

* brackets beside value indicate total number of samples used to calculate average.

Imperfectly drained Tavistock soils are associated with the Bennington catena. Also included in this catena are well to moderately well drained Bennington soils, and poorly drained Maplewood soils. The Bennington and Maplewood soils are limited in their occurrence within the Pittock Creek watersheds.

Tuscola Soils

The imperfectly drained Tuscola soils occupy 56.6 ha. of the control watershed and 27.8 ha of the test watershed. Tuscola soils develop on glaciolacustrine sediments. The majority of Tuscola soils within the test and control watersheds are found on areas with slopes that range between 0.0% to 2.0%.

The average depth of the A horizon is 30 cm in the test watershed and 24 cm in the control watershed. Soil texture is normally silt loam, although loam and very fine sandy loam textures occur within the control watershed. Based on 14 samples, the average pH level for the A horizon is 6.6. Based on 7 samples, the average level of organic matter is 3.8%. Carbonates were not detected in the A horizon.

The texture of the B horizon is variable within the test watershed and ranges from silt loam to loam to day loam with depth. The texture of the B horizon within the control watershed is commonly slit loam, although loam and very fine sandy loam and day loam textures occur. The average depth of the B horizon is 70 cm and 82 cm for the test and control watersheds, respectively. Based on 2 samples, the average pH level was 5.1 and the average level of organic matter was 0.7%. Carbonates were undetected in the B horizon.

The C horizon is commonly found at an average depth of 97 cm in the test watershed and 95 cm in the control watershed. The texture of the parent materials are generally very fine sandy loam and contain a high silt content. Based on 1 sample, the pH level of the C horizon is 5.4. Both organic matter and carbonates were not detected in the C horizon.

Table 22 lists the averages of both observed and measured soil physical properties associated with a Tuscola soil within the Pittock Creek watershed.

Imperfectly drained Tuscola soils are associated with well drained Brant soils and poorly drained Colwood soils. Both the Brant and Colwood soils are limited in their extent within the Pittock Creek watershed.

Table 22: Soil Properties of a Tuscola Soil - Pittock Creek Watershed

Horizon	%sand	%silt	%clay	% Moisture		
				Saturated	100mbar	15 Bar
A	33.0 (7)	53.0 (7)	14.0 (7)	30.8 (1)	26.8 (1)	12.4 (1)
B	42.0 (2)	51.0 (2)	7.0 (2)	32.2 (2)	28.2 (2)	19.2 (2)
C	41.0 (1)	41.0 (1)	17.0 (1)	22.9 (1)	19.7 (1)	13.4 (1)

Horizon	Hydraulic Cond. (cm/s)	% Water Stable Agg.	Cation Exchange Capacity (meq/100g)	Bulk Density (g/cc)
A	1.3E-04 (1)	62.5 (1)	6.9 (1)	1.4 (1)
B	5.4E-04 (2)		3.7 (2)	1.5 (2)
C	1.3E-04 (1)		8.8 (1)	1.6 (1)

Horizon	Soil Structure		
	Grade	Class	Kind
A	moderate	medium	granular
B	weak/moderate	medium	subangular/angular blocky
C	moderate	coarse	subangular blocky

* brackets beside value indicate total number of samples used to calculate average.

4.1.3.2 SUBDOMINANT SOIL TYPES

Table 23 lists the characteristics of those soil series which are not extensive within the Pittock Creek watershed, usually occupying less than 2% or 10 ha. of the study areas.

Table 23: Characteristics of Subdominant Soil Series Within the Pittock Creek Watershed *

Soil Series	Average Depth to A Horizon (cm)		Texture	Average Depth to B Horizon (cm)		Texture	Average Depth to C Horizon (cm)		Texture	Drainage	Soil Association
	Test	Control		Test	Control		Test	Control			
Bennington	28	25	SiL	61	72	L-vfSL	92	100	CL	Well-Mod. Well	Bennington-Tavistock-Maplewood
Brady	23	–	L-SL	78	–	vfSL-fSL	97	–	fSL	Imp.	Fox-Brady-Granby
Maplewood	24	23	SiL	72	77	SiL-vfSL	93	120	CL	Poor	Bennington-Tavistock-Maplewood
Plainfield	29	–	mSL	45	–	US	100	–	S	Rapid	Plainfield-Walsingham-Waterin

* Data Values for both the Test and Control Watersheds, total number of samples for each dominant horizon description are located In Appendix J

4.2 SOIL BENCHMARKS

There are three types of benchmark sites sampled within each watershed. They consisted of the traditional modal benchmark sites; the topsoil spatial benchmark; and Cesium 137 spatial benchmark.

4.2.1 MODAL PROFILE CHARACTERIZATION

The modal profile characterizations were used to select sites for sampling the dominant soil series within each watershed. Individual horizons were cored and sampled where possible for further laboratory analyses. There was a total of 30 modal profile benchmarks identified by soil series. Maps 1 through 3 show the location for each of the modal benchmark sites.

The laboratory methods are located in Appendix D. The results of the laboratory analyses associated with the modal characterization benchmarks are located in Appendix E.

4.2.2 TOPSOIL SPATIAL BENCHMARKS

Following site selection, the topsoil of the spatial benchmarks sites were sampled at interval ranges from 0-15 an and 15-30 cm.

The general location of the topsoil benchmark sites are shown on each individual soil survey map. Individual benchmark sites can be correlated to a soil series by identifying the polygon number on the soil maps for each watershed. Detailed descriptions of site location are found in Appendix H. The laboratory procedures are located in Appendix D. The baseline results, to be used for future comparisons of conservation and conventional tillage methods are located in Appendix E.

4.2.3 CESIUM SPATIAL BENCHMARKS

The cesium spatial benchmark sites were located in areas where the topography and soil conditions are as similar as possible. The location of the cesium spatial benchmarks within each individual watershed are shown on Maps 1, 2 and 3. Individual benchmark sites can be correlated to a soil series by identifying the polygon number on the soil maps for each watershed. There are a total of six cesium benchmark sites, with one site located in the test and control watersheds of each soil survey area. Detailed descriptions of site locations are found in Appendix G. Baseline results for each of the six spatial benchmark sites are located in Appendix E. The laboratory procedures are found in Appendix D.

4.3 RELIABILITY ANALYSIS

Results of the reliability survey for the Kettle and Pittock Creek Watersheds are summarized in Appendix K. The actual soil conditions at each reliability point are listed on the right hand side and the corresponding map legend prediction is listed on the left hand side. For each reliability sample point, a score of 1 was recorded for each soil attribute if it agreed with the class indicated on the map legend. If the soil attribute was within one lass unit of that predicted by the site map, it received a part score of 0.5. If the attribute disagreed with the soil map by more than one class unit, it received a score of zero. Map reliability was calculated using two types of scoring. The first method counted only reliability points where the actual soil attribute and the attribute predicted by the map matched exactly. This is the perfect correlation score (see Tables 24, 25 and 26).

The second method counted only the reliability part scores, where the map attribute was within one class of the actual attribute. The second method results in a higher reliability rating. This reliability score is referred to as the "Part Correlation Score".

Tables 24, 25 and 26 also show the 95% confidence interval (see Appendix K for definition of a confidence interval) for both the perfect correlation and part correlation scores. The upper and lower 95% confidence interval represents the probability range of matching the soil map legend attribute to actual soil-landscape conditions.

4.3.1 KETTLE CREEK WATERSHED

Correlation scores and confidence intervals for both the perfect and part scores are shown on Table 24.

Using perfect correlation scores within the Kettle Creek Watershed, the map reliability is:

- 29.5% for the erosion class;
- 67.2% for the deposition class;
- 49.2% for the slope class;
- 47.5% for the soil series; and
- 72.1% for the soil drainage class.

Including part correlation score, the map reliability improves to:

- 54.1% for the erosion class;
- 82.8% for the deposition class;
- 70.5% for the slope class;
- 62.3% for the soil series; and
- 86.1% for the soil drainage class.

Table 24: Point Estimates of Reliability

Soil Attribute	Erosion* Class	Deposition** Class	Soil Drainage	Slope Class	Soil Series
	KETTLE CREEK WATERSHED				
Perfect Correlation Score (not including part scores)	18	41	44	30	29
Total # of Reliability Sample Points	61	61	61	61	61
Percent Correct (100% agreement) (as determined by polygon notation)	29.5	67.2	72.1	49.2	47.5
95% Confidence Interval					
Lower Limit	18.1	55.4	60.9	36.6	35
Upper Limit	40.9	78.9	83.4	61.7	60
Part Correlation Score	33	50.5	52.5	43	38
Percent Correct (Part Scores)	54.1	82.8	86.1	70.5	62.3
95% Confidence interval					
Lower Limit	45.2	76.4	80.4	62.5	52.2
Upper Limit	62.9	89.1	91.7	78.5	72.4

* Erosion Class - depth to CK

** Deposition Class - depth of A horizon

The low reliability of the erosion, slope class and soil series is due to the complexity of the terrain in the Kettle Creek Watershed.

The complex landforms within the Kettle Creek Watershed consist of highly dissected till deposits overlain by finer textured glacial lacustrine sediments of variable depth. The extent of soil erosion, and therefore the depth of the A horizon and the slope lass is extremely variable.

The point of reliability confirm that the erosion, slope class and soil series attributes listed in the soil map legend are not reliably mapped at a scale of 1:10,000 (according to criteria outlined by Forbes et al, 1985). The present scale is too small to generate pure map polygons, given the complexity of the soil landscape within the Kettle Creek Watershed. Large scale mapping (ie. 1:5,000) would be more appropriate given the degree of complexity of soil patterns in the Kettle Creek Watershed.

4.3.2 PITTOCK CREEK WATERSHED

Correlation scores and confidence intervals for both the perfect and part scores are shown on Tables 25 and 26.

Using perfect correlation scores within the control watershed, the map reliability is:

- 63.3% for the erosion class;
- 53.0% for the deposition class;
- 73.3% for the slope class;
- 63.3% for the soil series; and
- 80.3% for the soil drainage class.

Including part correlation scores, the map reliability of the control watershed improves to:

- 76.7% for the erosion class;
- 75.0% for the deposition class;
- 85.0% for the slope class;
- 90.0% for the soil drainage class; and 73.3% for the soil series.

Using perfect correlation scores within the test watershed, the map reliability is:

- 56.6% for the erosion and deposition-class;
- 60.0% for the slope class;
- 76.6% for the soil drainage class;
- 83.3% for the soil series; and
- 0 73-3% (there was no increase in the soil--series reliability).

Including part correlation scores, the map reliability of the test watershed improves to:

- 71.7% for the erosion class;
- 73.3% for the deposition class;
- 71.2% for the slope class; and
- 85.0% for the soil drainage.
-

The results of the reliability scores indicate that the soil legend attributes listed on the soil map are reliably mapped at a scale of 1:10,000.

The present scale is appropriate to generate mostly pure polygons, although the erosion and deposition class are less reliably mapped than slope class, soil drainage class and soil series within the Pittock Creek Watershed.

Table 25: Point Estimates of Reliability

	PITTOCK CREEK WATERSHED - CONTROL				
Soil Attribute	**Erosion* Class**	**Deposition** Class.**	**Soil Drainage**	**Slope Class**	**Soil Series**
Perfect Correlation Score (not including part scores)	19	16 .	24	22	19
# of Samples	30	30	30	30	30
Percent Correct (100% agreement) (as determined by polygon notation)	63.3	53	80	73.3	63.3
95% Confidence Interval					
Lower Limit	46.1	35.5	65.7	57.5	46.1
Upper Limit	80.6	71.2	94.3	89.2	80.6
Part Correlation Score	23	22.5	27	25.5	22
Percent Correct (Part Scores)	76.7	75	90	85	73.3
95% Confidence Interval					
Lower Limit	64.7	64.9	82.8	75.6	59.7
Upper Limit	88.6	85.1	97.2	94.4	86.9

* Erosion Class - depth to CK

** Deposition Class - depth of A horizon

Table 26: Point Estimates of Reliability

Soil Attribute	Erosion* Class	Deposition** Class	Soil Drainage	Slope Class	Soil Series
	PITTOCK CREEK WATERSHED - TEST				
Perfect Correlation Score (not including part scores)	17	17	25	18	23
# of Samples	30	30	30	30	30
Percent Correct (100% agreement) as determined by polygon notation	56.6	56.6	83 3	60	76.7
95% Confidence Interval					
Lower Limit	38.9	38.9	70	42.5	61.5
Upper Limit	74.4	74.4	96.7	77.5	91.8
Part Correlation Score	21.5	22	27.5	24	23
Percent Correct (Part Scores)	71.7	73.3	85	71.2	76.7
95% Confidence Interval					
Lower Limit	59.7	61.4	85	71.2	61.5
Upper Limit	83.6	85.3	98.3	88.8	91.8

* Erosion Class - depth to CK

** Deposition Class - depth of horizon

4.3.3 ESSEX WATERSHEDS

Reliability tests were not done within the Essex study areas because of the lack of soil variability and consistently uniform landscape characteristics.

This was based on additional soil inspection points and sample sites throughout the Essex Watershed, that. indicated the variability of the soils within the watershed was negligible.

5. BIBLIOGRAPHY

Agriculture Canada, 1984. A Soil Mapping System for Canada: Revised. Expert Committee on Soil Survey, Land Resource Research Institute, Ottawa, LRRI Contribution No. 142.

Brown, D.M., G.A. McKay and L.J. Chapman, 1968. The Climate of Southern Ontario. Climatological Studies #5. Dept of Transport, Meteorological Branch.

Brown, D.M., J. Rogalsky and G.A. McKay, 1969, Daily Temperature and Precipitation Frequencies in Ontario. Climatological Studies #7. Dept. of Transport, Meteorological Branch.

Chapman, L.J. and D.F. Putnam, 1973. The Physiography of Southern Ontario. Ontario Research Foundation. University of Toronto Press.

Day, J.H. (ed.) 1982. The Canadian Soil Information System. Manual for describing soils in the field. Expert Committee on Soil Survey, Land Resource Research Institute, Ottawa, LRRI Contribution No. 82-52.

Environment Canada, 1970.Temperature and Precipitation - 1941-1970. Atmospheric Environment Service.

Forbes, T., Rossiter, D. and A. Van Wambeke, 1985. Guidelines for Evaluating the Adequacy of Soil Resource Inventories USDA. Soil Mgt. Support Services.

Hagerty, T.P. and T.E. Hilborn, 1986. Preliminary Soils of .Middlesex County. Eastern Portion Southern Ontario. Ontario Institute of Pedology, Preliminary Map P. 32. Scale 1:50,000.

Ontario Institute of Pedology, 1985. Field Manual. for Describing Soils. OIP Publication No. 85-3.

Richards, N.R., Caldwell, A.G. and F.F. Morwick, 1949. Soil Survey of Essex County. Report No. 11 of the Ontario Soil Survey. Dominion Department of Agriculture and the Ontario Agricultural College.

Wicklund, R.E. and N.R. Richards, 1961. The Soil Survey of Oxford County. Report No. 28 of the Ontario Soil Survey. Research Branch, Canada Dept. of Agriculture and the Ontario Agricultural. College. (Map Scale 1:63,360).