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Soil Resources

Soils of the Manitoba Crop Diversification Centre

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SOILS OF THE MANITOBA CROP DIVERSIFICATION CENTRE

South 1/2 Section 8-11-14 W

by

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SOIL RESOURCE SECTION
MANITOBA AGRICULTURE

in cooperation with

MANITOBA LAND RESOURCE UNIT
AGRICULTURE AND AGRI-FOOD CANADA

and

DEPARTMENT OF SOIL SCIENCE, UNIVERSITY OF MANITOBA

PREFACE

The detailed soil survey of the Manitoba Crop Diversification Centre was carried out by staff of the Manitoba Soil Resource Section, Soils and Crops Branch, Manitoba Agriculture and the Manitoba Land Resource Unit, Centre for Land Resource and Biological Resource Research, Agriculture and Agri-Food Canada. The soil map at a scale of 1:5 000 and the accompanying report provide detailed soil resource information designed to facilitate the planning and layout of research and demonstration plots and instrumentation and detailed monitoring related to evaluation of environmental impact.

This report contains descriptive information for the major soils that occur on the Manitoba Crop Diversification Centre (MCDC), as well as interpretations for dryland and irrigation agriculture. A brief discussion of soil properties and management relationships is included.

During the course of this survey, a significant volume of site specific information was gathered that for practical reasons cannot be included in this report. The Manitoba Soil Resource Section and the Manitoba Land Resource Unit jointly maintain data files for automated manipulation and analysis for soil characterization and interpretation. Several interpretative maps showing properties such as stratigraphy and depth to sand, pH, organic matter, drainage, risk of erosion, and risk for subsoil and/or groundwater contamination have been derived from digital GIS databases. Additional requests for such data should be directed to: Manitoba Soil Resource Section, Department of Soil Science, 362 Ellis Building, University of Manitoba, Winnipeg, Manitoba, R3T 2N2.

ACKNOWLEDGEMENTS

The report on the Soils of the Manitoba Crop Diversification Centre (MCDC) was conducted as a joint project of the Manitoba Department of Agriculture, Agriculture and Agri-Food Canada and the Soil Science Department, University of Manitoba.

The soils were mapped in the 1994 by G. F. Mills assisted by L. Dudeck. Detailed soil characterization and moisture studies were carried out by P. Haluschak.

Laboratory analysis and data were provided by R. Mirza, J. Madden and E. St. Jacques under the direction of P. Haluschak.

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Report formatting was provided by Mrs. C. Fraser, Mrs. S. Becker, and C.L. Aglugub

R. G. Eilers for reviewing the manuscript.

HOW TO USE THIS SOIL REPORT

This soils report contains considerable information about the soils, their origin and formation, their classification and their potential for various uses such as dryland agriculture and irrigation. The report is divided into four parts: Part 1 provides a general description of the area; Part 2 describes the methodology used in the study; Part 3 discusses the development, scientific classification and morphological characteristics of the soils in the study area, and Part 4 provides an interpretation of soil properties and associated landscape features as they affect soil capability or suitability for various uses. Baseline data regarding soil quality is provided in summaries of key soil properties characterized during the course of the survey.

The accompanying soil map is presented at a 1:5 000 scale on an air photo base to assist the user in locating the soil areas in relation to landscape features, roads and field boundaries. The following steps are suggested to assist the user in retrieving soil information from the map and report:

STEP 1 - Consult the soil map in pocket of report folder. Locate the area(s) of interest on the map and identify the pertinent map unit symbols. Arabic numerals placed as superscripts following map symbols indicate the approximate proportion of each soil type within the map unit.

STEP 2 - Consult the extended legend accompanying the soil map for an alphabetical listing of soil symbols giving the soil name, surface texture, drainage, related information concerning landform and stratigraphy of the soil materials and soil classification.

STEP 3 - For interpretive information about the soils capability for dryland agriculture and suitability for irrigation, consult the appropriate section in Part 4. Criteria utilized as guidelines in making these interpretations are provided in Appendix A.

STEP 4 - Further information concerning the morphological properties and extent of the soils is presented in Part 3 where the soils are described alphabetically according to soil name.

STEP 5 - Additional site specific information not contained in this report is available on request from the Manitoba Soil Resource Section, Manitoba Agriculture, Ellis Bldg., University of Manitoba.

SUMMARY

The Manitoba Crop Diversification Centre is located 3.2 km north of Carberry, Manitoba at the junction of the Trans Canada Highway and PTH 5. The Centre covers the entire south half of Section 8-11-14W and consists of dominantly well drained, fine loamy, moderately to strongly calcareous, lacustrine sediments underlain by stratified, sandy deltaic deposits. The topography is dominantly level with local areas of gently sloping terrain associated with the shallow stream channel which traverses the northern portion of the Centre in a west to east direction.

The Centre is located in a region of cool to moderately cool subhumid climate with significant moisture deficits during the growing season. Long term climatic records from three weather stations, namely Carberry, Brandon to the west, and Portage la Prairie to the east indicate total precipitation ranges from 450 to 545 mm. Growing season precipitation ranges from 339 to 402 mm and is often quite variable in distribution due to the local occurrence of storm events which account for much of the summer rainfall. Mean annual air temperature at the three climatic stations ranges from 1.5 to 2.6 ^{0}C, while the average length of the frost-free season varies from 107 to 126 days. Higher values of precipitation, air temperature and length of frost free season tend to occur in eastern portions of the region.

The soils on the research Centre are dominantly well drained Chernozemic Black soils (81.4 percent of the area) developed on fine loamy lacustrine sediments. Approximately 70 percent of the soils are underlain by sandy subsoils within 1.2 m of the soil surface. Poorly to very poorly drained Gleysols are associated with the shallow drainage channel in the northern part and account for 11 percent of the area. Imperfectly drained Black soils are of minor extent (7.4 percent). All the soils have medium organic matter content (4 to 8 percent) and good moisture holding capacity (200 to 240 mm total available water to the 1.2 m depth). The pH value of the surface soil ranges from 4.8 to 7.8.

The soils on the Centre are freely drained with good internal drainage, particularly those soils in which the underlying sandy subsoil is within 1.2 metres of the surface. Surface drainage on the Centre is generally good, ranging from well to rapid on the upper slopes to poor in depressional areas of the drainage channel affected by seasonal periods of short term ponding. Slight erosion has occurred on approximately 6 percent of the soils.

The Centre contains some of the most productive agriculture soils in Manitoba. Good yields of cereals, oilseeds and forages are obtained under dryland conditions and under irrigation, excellent yields of high quality potatoes are realized.

The soils are dominantly in Agricultural Capability Class 1 and 2 with none to slight limitation for the growing of regional crops. Management concerns associated with these soils are the maintenance of adequate fertility and soil tilth and sufficient crop residues to minimize the erosion of surface horizons and organic matter by wind.

The soils on the Centre range in irrigation suitability from Excellent to Poor. The irrigation suitability classification indicates 2 percent of the soils are rated as Excellent whereas 76 percent are rated as Good, 10 percent as Fair and 11 percent as Poor. The dominant soil properties and landscape features affecting irrigation suitability are slight limitations due to permeability of the surface soil and a moderate limitation due to topography and imperfect drainage. The potential for salinization is very low as the soils are freely drained and occur in an environment in which the soil and groundwater are free of soluble salts.

The greatest concern in the use of these soils for irrigation is related to the high permeability of the sandy subsoils. Soil water moving through the root zone into the permeable subsoil has the potential to move to the watertable and thus into the aquifer. In addition, a few, small depressional sites in the landscape are characterized by strongly leached soils which indicate a point source for surface water to move below the root zone into the permeable sandy subsoil. The local areas of gently sloping relief (5 to 9 % slope) associated with the drainage channel have potential for increased surface runoff under irrigation resulting in additional water being added to the adjacent poorly drained soils with high watertable. Depending on the volume and the quality of runoff, the natural quality of the poorly drained soils and watertable could be adversely affected.

The soil and climatic conditions on the Centre constitute a window of information from which knowledge and experience gained from research and demonstration of both dryland and irrigation agriculture can be extrapolated to similar soils and landscapes in the Assiniboine Delta. This experience is particularly applicable to the sustainable management of the finer textured soils in the Delta.

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PART 1

GENERAL DESCRIPTION OF STUDY AREA

1.1 INTRODUCTION

The Manitoba Crop Diversification Centre at Carberry was established in 1994 in response to initiatives taken by the Provincial and Federal governments in consultation with agriculture industry growers and processors. The overall mission statement for the Centre is **"To develop and coordinate facility(s) and program(s) to provide demonstration, applied research and technological transfer activities in support of crop diversification and productivity enhancements to benefit the horticulture, special crops and forage industries of Manitoba."** The Centre is to have a total cropping program which would eventually deal with a range of crops in addition to those which are traditionally grown under irrigation. The major partners represent a mix of producer organizations, government, private industry and other parties reflecting needs of the agriculture industry in Manitoba.

The program will promote the use of advanced technology (including irrigation), cropping systems and soil conservation measures to support improvements in productivity and quality in horticulture, special crops and forage production in Manitoba. The program will demonstrate and promote the use of these advanced technologies in a manner which is economically and environmentally sustainable. The facility will identify and foster diversification opportunities for the benefit of the agriculture industry in Manitoba.

The Manitoba Crop Diversification Centre is located on the south half of Section 8-11-14 W.P.M. about 3.2 kilometers north of Carberry, at the northeast corner of the junction of the Trans Canada Highway and Provincial Trunk Highway 5 (Figure 1). The soils were originally mapped as the Wellwood (clay loam) Association in the Carberry Map Sheet (Ehrlich et al, 1957) and are representative of large areas of Wellwood soils in the Upper Assiniboine Delta.

Approximately 48 percent of the Centre is allocated to irrigated agriculture while the remainder is to be managed for dryland agriculture. The natural surface drain across the land occupies 12 hectares of wetland and the headquarters site utilizes some 3.4 hectares or 2.8 percent of the land base.

In order to assess the impact that irrigation will have on the sustainability of the soil and environment and the quantity and quality of the water available to all users of the aquifer, it is necessary to establish baseline conditions with respect to the nature and quality of the soil resource. A detailed study of the initial conditions, areal extent and characteristics of the soil, water and ecological resources of the management area are required. However, since it is no longer possible to document the initial, undisturbed quality of these resources, the alternative is to document the current status of the resource quality. This documentation may be used as baseline data to monitor future resource assessments and changes using Geographic Information System (GIS) technology.

Sustainable economical agricultural production is fundamentally dependent on the quality of the soil resource and climate. Soil quality must be maintained in support of sustainable economic farming systems. In order to facilitate sustainable land management, it is essential to have a detailed understanding of the soil resource quality and landscape processes relative to the Hydrologic Budget (climate, soil moisture, surface water and groundwater). To provide a detailed inventory and characterization of the soil quality and variability on the Centre, a soil survey was initiated and completed during the summer of 1994.

1.2 RELIEF AND DRAINAGE

Elevations on the farm range from 385 metres (1285 ft) in the northwest corner to 379 metres (1263 ft.) in the southeast.

Figure 1. Location of Study Area

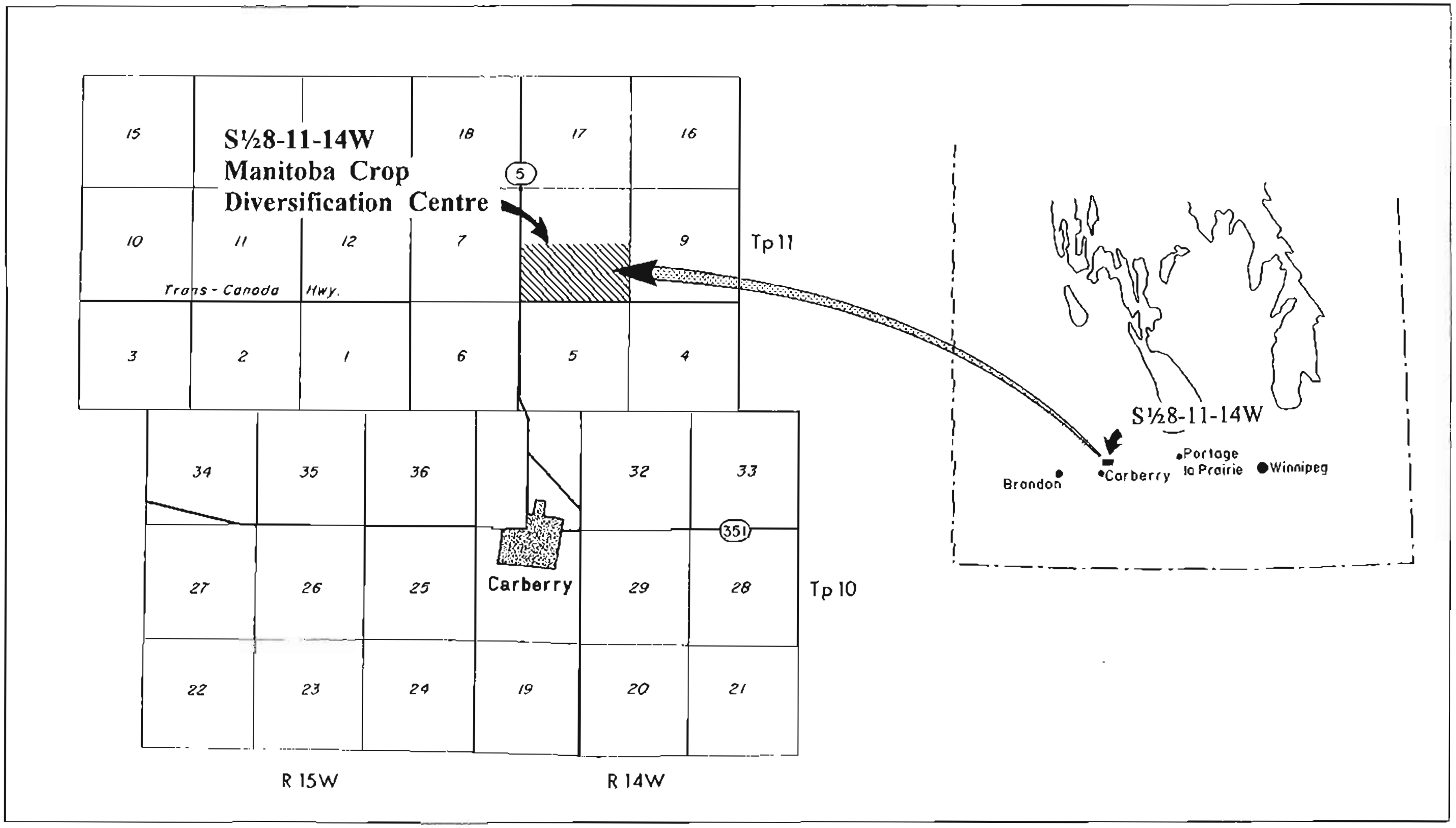
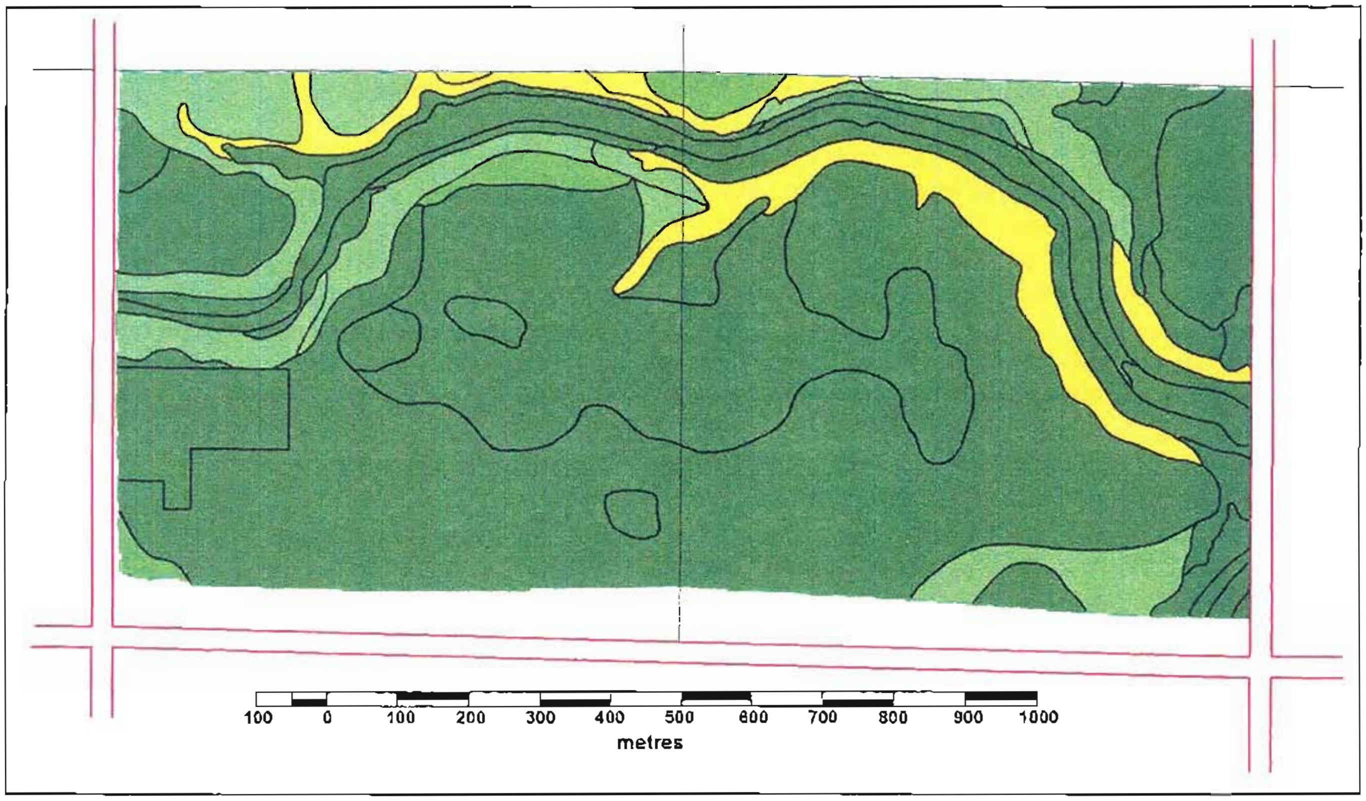


Figure 2 **Topography**

Slope describes the steepness of the landscape surface. The slope classes shown on this map are delineated from the dominant slope measurements taken during the course of the detailed soil survey. At the local level, slopes are more variable and are related to soil type. Specific colours are used to indicate the most significant, limiting slope class for each polygon.

Steepness and length of the slope are important topographic factors affecting the potential for surface runoff and infiltration of precipitation. Limitations to cultivation and kind of land use also increase with increasing steepness of slope.



Slope Classes	Area, ha	Percent of Total
level to nearly level (0-0.5%)	95.52	78.78
nearly level (0.5-2.0%)	2.35	1.94
very gently sloping (2-5%)	14.62	12.07
gently sloping (5-9%)	8.65	7.11

The regional slope being about 6 m across the Centre declining to the southeast, the general topographic gradient of the land surface is about 3.4 meters per kilometer (Rhode, H., PFRA, Personal Communication). Approximately 79 percent of the project area is level to nearly level (0 - 0.5 % slopes), about 3.2 percent is characterized by nearly level (0.5 - 2% slopes) topography (2 - 5% slopes) about 12 percent of the area is very gently sloping with the remainding percent being gently sloping (5 - 9% slopes). The more steeply sloping areas occur adjacent to the drainage channel traversing the northern portion of the Centre from west to east (Figure 2).

Surface drainage of the Centre varies from well to poor and very poor. Extensive areas of level to nearly level land are dominantly well to moderately well drained as a result of the moderate permeability of the soil surface materials and the high permeability of the underlying sandy subsoils. Most of the land surface slopes very gently towards the drainage channel which, as a tributary of Pine Creek carries surface water through the Centre property to the east during periods of spring melt and major runoff. Poorly and very poorly drained areas associated with portions of the channel are subject to ponding and prolonged inundation from spring runoff and heavy summer precipitation. The upper surface of the aquifer outcrops in the lower-lying easterly portion of the channel in most years.

Although much of the land surface slopes very gently towards the channel, effective surface water movement only occurs within a few meters of the channel. Most precipitation on the land surface infiltrates the soil.

Well drained soils extend over 81.5 % of the project, imperfectly drained areas cover 7.4 % while poorly drained soils occupying 10.3 % of the area. The very poorly drained soils of the Marsh complex occur in 0.8 % of the area (Figure 13).

1.3 PHYSIOGRAPHY AND SURFACE DEPOSITS

The Crop Diversification Centre is situated within the Upper Assiniboine Delta subsection of the Assiniboine River Plain. The delta consists dominantly of level to very gently undulating deltaic and lacustrine deposits hanging in texture from gravel and sand to loam, clay loam and silty clay loam. At locations where the surface of the delta is dominantly fine sand, wind action has modified the surface resulting in extensive areas of gently to sharply hummocky sand dunes.

Although poorly drained areas occur, the only permanent water bodies in the Delta are the Assiniboine River, Pine Creek and Sewell Lake in the Douglas Marsh. The Upper Assiniboine Delta ranges in elevation from 390 m to the west, falling gradually to 330 m along the eastern edge. The gently sloping surface of the Delta is broken by the deeply incised U-shaped valley of the Assiniboine River which dissects the southern portion of the delta area from west to east.

The dominant stratigraphic sequences have been described by Render (1988). The thin discontinuous surface veneer consisting of fine loamy to coarse loamy deltaic and lacustrine sediments is probably a residue of the delta topset beds which are underlain by a variable thickness of fine sand. Silt and silty clay bottom set beds occurring below the sandy strata were laid down on glacial till which was deposited in turn on several Mesosose Era shale units.

Stratigraphic variation within the Upper Assiniboine Delta occurs within the upper 1 to 3 metres and in the subsurface geology at depths of 20 to 30 or 40 metres. The deep stratigraphy in the vicinity of the Centre is illustrated by cross-sections of drill logs (Figure 3) compiled from test hole information supplied by PFRA (H. Rhode, PFRA, Personal communication). Drill logs from the Centre indicate that the fine sand deltaic beds are weakly stratified and extend from near the soil surface to depths ranging from 20 to 30 metres. The sand strata are underlain by an undetermined thickness of silt and silty clay sediments which in turn rest on glacial till and/or shale bedrock. These lower materials form essentially an impermeable base for the aquifer.

The near surface (upper 3 metres) stratigraphic variation is shown in Figure 4. Fine loamy (clay loam to loam) sediments form a near-continuous surface layer on the Centre varying in thickness from about 0.4 to 2.1 metres. The underlying fine sand deposits of the Delta were encountered at all sites except in the drainage channel where the probe could not be extended due to the presence of frost (in May and June) or to excessively wet soil conditions throughout the remainder of the year. Approximately 70 percent of the soils on the Centre are underlain by fine sand at depths of 20 to 120 cm whereas sandy strata occur at depths of 1.2 to 2.1 metres in the remaining 30 percent of the area.

The dominant soils formed on these deposits are the moderately to strongly calcareous, fine loamy soils of the Wellwood association. The dominant soil texture on the Centre is clay loam; the underlying sandy materials consist of stratified fine sand and very fine sand with some silt layers.

1.4 HYDROLOGY

The Upper Assiniboine Delta contains a major aquifer of high quality water. The Assiniboine Delta Aquifer has been characterized by Render (1988) as an unconfined sand and gravel deposit extending over 3800 square kilometers. Studies indicate that the thickness of the aquifer ranges from 1 to 2 m along the extremities of the delta to 30 metres in the central part.

At the Crop Diversification Centre, located in the central portion of the delta, depth to the top of the aquifer varies from 1.7 to 5.2 metres below ground level (Figure 5, compiled from drill log information supplied by H. Rhode, PFRA Geotechnical Division). The surface water associated with the Marsh area in the stream channel in the eastern portion of the Centre is likely an outcropping of the aquifer or at least a point in the landscape where the upper surface of the aquifer is very close to the soil surface.

As the aquifer is largely open to the surface, the groundwater is susceptible to influence from the soil, water and air above the aquifer. The lower boundary of the aquifer is formed by the impermeable silt and silty clay strata underlying the sand.

At the regional level the Delta is a major area of groundwater recharge. At the local level, the extent and rate at which recharge occurs varies with the near surface stratigraphy and topography of the landscape. Groundwater flow at the Centre is to the east and southeast. The average depth to the watertable measured in January and February, 1993 and May, 1994 during installation of the piezometers and observation wells is 3.7 m (12.1 ft.).

1.5 CLIMATE

The climate of the study area is characterized by short, cool summers and long cold winters. Frequent changes in the major air masses affecting the area contribute to extreme variability of weather patterns in each season.

Climatic conditions for the Centre are best represented by long term meteorological data from three weather stations within the area; namely Carberry, Brandon airport to the west, Portage la Prairie airport to the east. An automated weather station was established on-site at the Centre in 1994 to collect hourly data for relative humidity, wind speed, maximum and minimum temperature and precipitation.

Growing season characteristics (heat units and frost free period) are fairly uniform across the region, generally increasing from west to east with decreasing elevation. The mean annual temperature of the three sites is 2.1 °C. The average frost free period is 115 days. The average total precipitation is 489 mm with 391 mm of mean growing season rainfall. However, moisture distribution during the growing season may vary greatly, as much of the precipitation is received during summer storm events. Climatological data from the three stations is summarized in Tables 1 to 3.

Figure 3. Drill Logs and Location of Test Holes (PFRA Geotechnical Division)

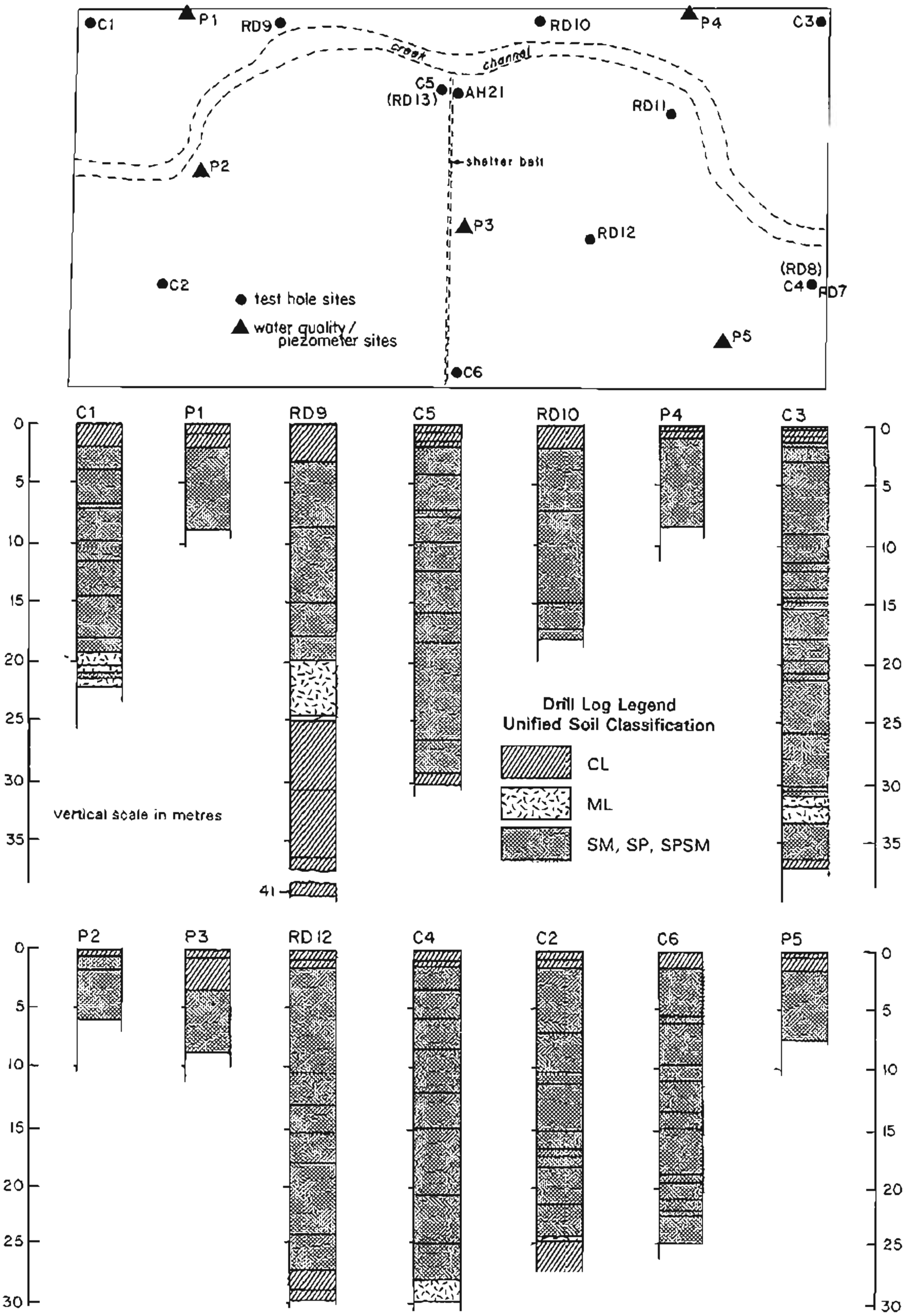
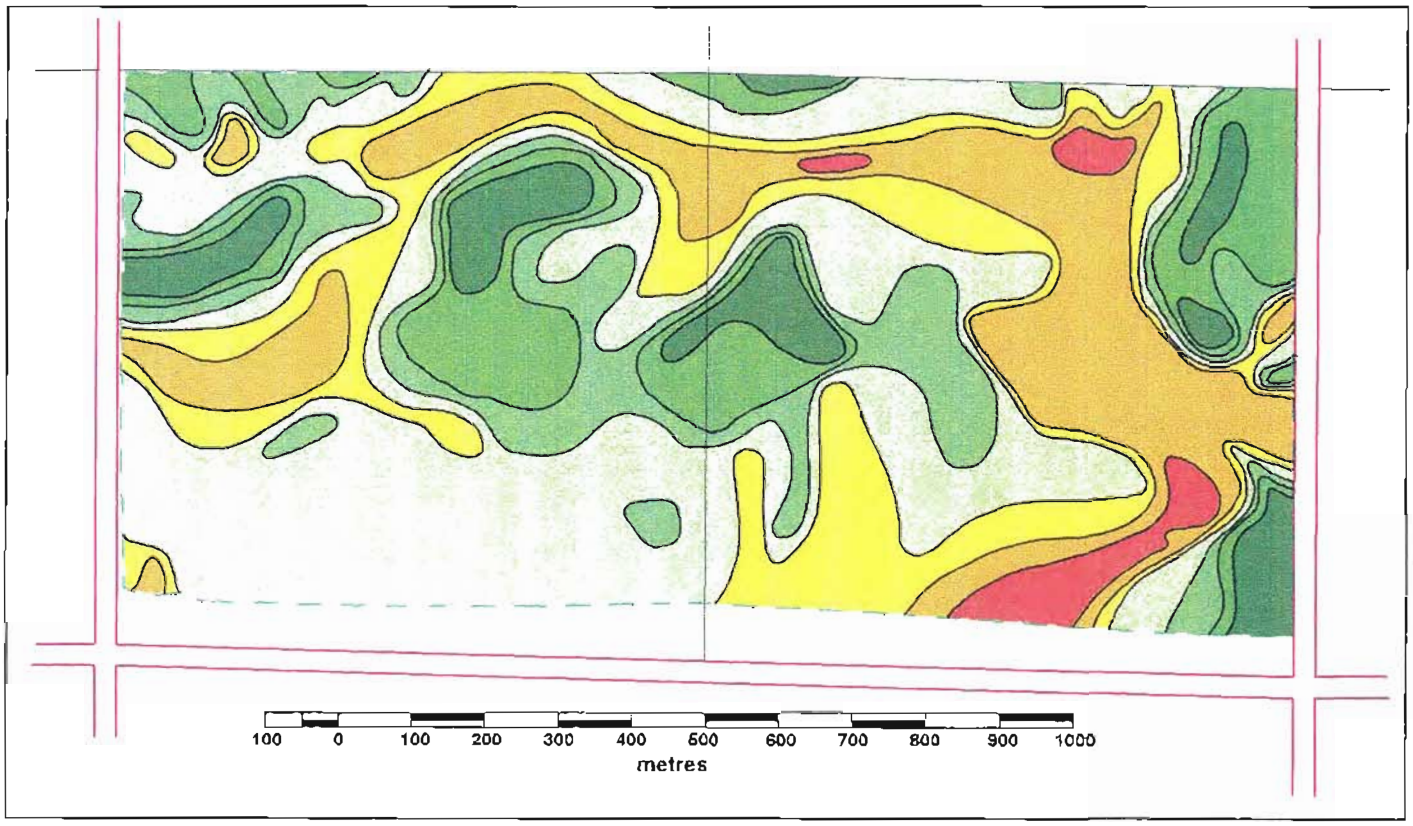


Figure 4 **Near-Surface Stratigraphy - Depth to Sand**

Near-surface stratigraphic variability influences suitability and capability for many uses of the soil and land resource. The occurrence of sand sediments within 1 to 2 metres of the soil surface influences the potential for infiltration and the water holding capacity of the soil within the rooting zone. A reduced level of available soil moisture where the sandy strata occur within the rooting zone affects the range of potential crops and crop yields under dryland conditions. Although irrigation is commonly used to offset a soil moisture deficit, stratigraphic variation can affect the environmental and economic sustainability of irrigated agriculture. Landscapes in which highly pervious subsoils occur within 1 to 3 metres must be managed with extreme care to minimize the risk for infiltration below the root zone. Soil water moving through the root zone into the permeable subsoil has the potential to move to the watertable and thus into an underlying aquifer.



Depth to Sand cm	Area ha	Percent of Area	Depth to Sand cm	Area ha	Percent of Area
>160	7.83	6.47	80-100	20.16	16.63
140-160	13.69	11.30	60-80	19.79	16.64
120-140	15.13	12.49	<60	3.11	2.57
100-120	41.43	34.20			

Figure 5. Watertable Levels and Location of Test Holes (PFRA Geotechnical Division)

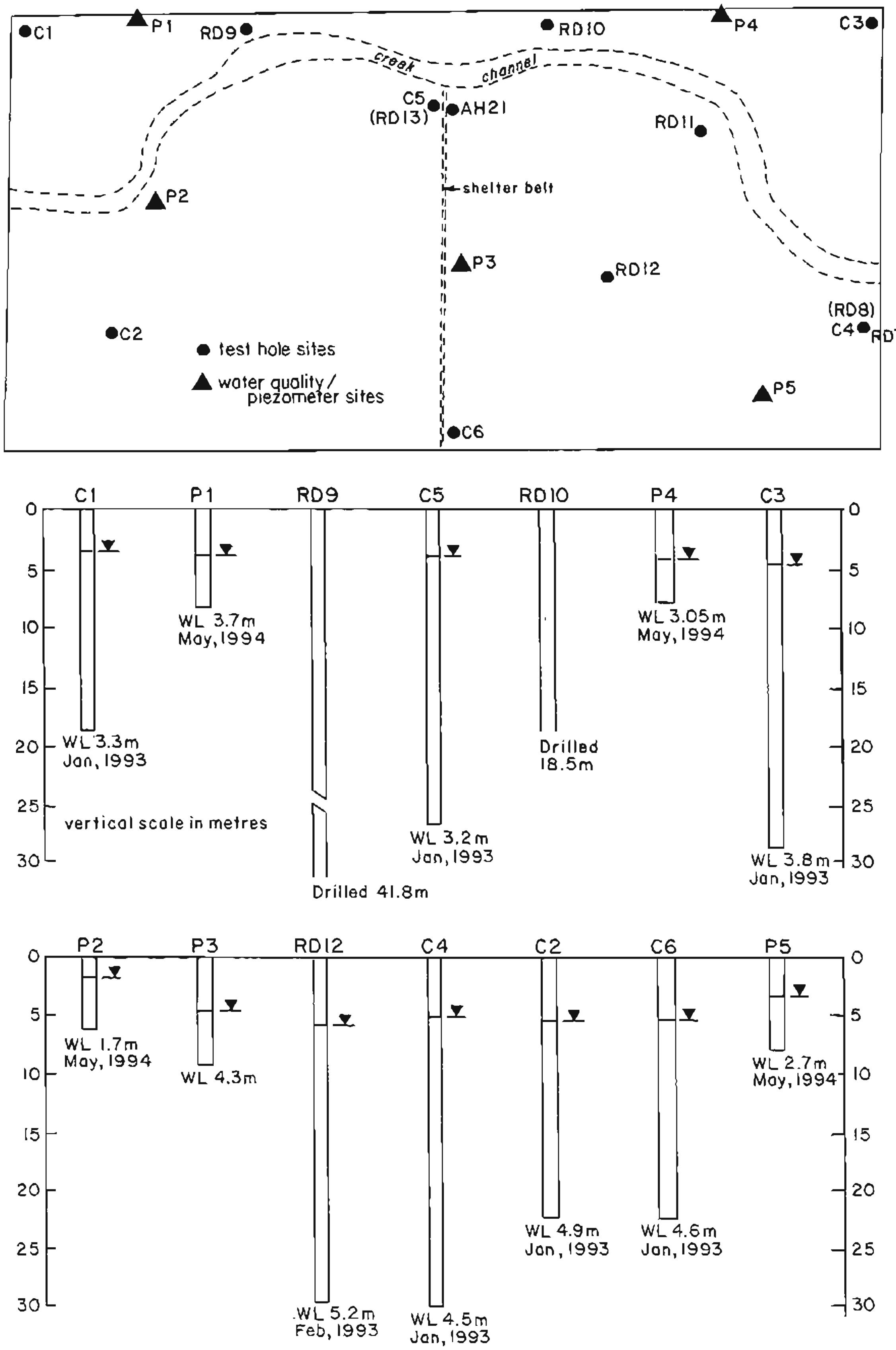


Table 1. Climatic Parameters at Selected Climate Stations in West Central Manitoba (Atmospheric Environment Service, 1982)

Climatic Parameter	Climate Station		
	Brandon	Carberry	Portage
Elevation m a.s.l	409	385	270
Temperature, °C:			
mean annual	1.5	2.1	2.6
mean maximum	7.8	8.0	8.1
mean minimum	-4.7	-3.8	-3.0
Precipitation:			
mean annual, mm	450	472	545
rainfall, mm	339	351	402
Mean Monthly rainfall, mm			
• May	45.2	57.1	59.3
• June	77.1	71.5	75.7
• July	66.6	65.1	76.3
• August	64.6	61.5	81.0
• September	44.0	46.0	49.9

Table 2. Climatic Parameters Relevant to Crop Growth at Selected Climate Stations in West Central Manitoba (Ash, 1991)

Climatic Parameter	* Probability Level %	Climate Station	
		Brandon	Portage
Corn Heat Units	50	2334	2615
	25	2211	2455
	10	2100	2311
Growing Degree-Days (base 5°C)	50	1595	1692
	25	1514	1607
	10	1441	1529
Frost-free period days (base -2.2°C)	50	127	141
	25	119	135
	10	111	129

* Probability levels indicate the percent of time that minimum values for each parameter are less than the mean ie., 50% probability.

Table 3. Frost Data and Probability for Last Freezing Temperature, Spring and First Freezing Temperature, Fall at Selected Climate stations in West Central Manitoba (Atmospheric Environment Service, 1982).

Station Location	Probability Level *						
	10% (1 year in 10)	25% (1 year in 4)	33% (1 year in 3)	50% (1 year in 2)	66% (2 years in 3)	75% (3 years in 4)	90% (9 years in 10)
Spring Frost on or after							
Brandon	June 9	June 3	May 31	May 27	May 20	May 17	May 8
Carberry	June 19	May 31	May 28	May 23	May 17	May 14	May 6
Portage	June 3	May 26	May 22	May 20	May 14	May 9	May 5
Fall Frost on or before							
Brandon	August 31	Sept 8	Sept 10	Sept 14	Sept 16	Sept 18	Sept 21
Carberry	Sept 5	Sept 11	Sept 13	Sept 15	Sept 21	Sept 28	Oct 7
Portage	Sept 11	Sept 18	Sept 19	Sept 21	Sept 25	Oct 1	Oct 6
(0°C) Frost free period (days) equal to or less than							
Brandon	94	97	99	107	116	119	128
Carberry	99	104	107	113	126	129	132
Portage	105	115	118	126	132	136	146

* Probability levels indicate the percentage of the time (number of years) that the spring and fall frost dates and frost free period deviates from the mean value (50% probability) by the amount indicated, i.e. Brandon frost free period at 10% probability will be 94 days or less 1 year in 10. The date of the last spring frost at the 10% probability level at Brandon will be on June 9 or later 1 year in 10.

PART 2

METHODOLOGY

The detailed study of soil conditions on the Crop Diversification Centre was carried out in 1994 and involved various field activities. The investigations included the following:

a) A detailed soil survey (1:5 000 scale) was conducted utilizing routine procedures for inspecting, describing, and sampling soils along a grid system (Figure 6).

b) All sites were examined by means of a hand auger to determine the depth to the underlying sand strata (depth varying from approximately 1 to 3 meters.

c) Field sampling and testing of soils for bulk density (2 sites), moisture retention (2 sites) and hydraulic conductivity properties (4 sites) was conducted during the field study.

d) Eight sites were investigated and sampled to a depth of approximately 3 metres. These sites were part of a drilling program carried out in Southern Manitoba during the fall of 1992 as part of an investigation to evaluate possible locations for the Centre.

The grid inspection sites and drill sites were sampled to determine selected chemical and physical properties of the soils. A complete morphological, chemical and physical characterization was obtained from the detailed sample sites.

2.1 SOIL SURVEY AND MAPPING

In the mapping process soils were inspected, documented and sampled systematically along a 100 meter grid across the Centre. Additional inspection sites were obtained from continuous trenches excavated for the purpose of installing the irrigation pipe. Soil inspections were made by hand spade to a depth of 120 cm and a hand auger was utilized to verify the nature of the underlying strata to a depth of 3 meters. The surface plow layer (upper 15 to 20 cm) was sampled at each site. The grid survey resulted in an average soil inspection density of 1 site per 0.9 hectares. Soil and site characteristics were recorded and each profile was classified according to standard survey procedures (Agriculture Canada, 1987). Survey grid points, drill sites, and location of detailed characterization sites are shown in Figure 6.

2.2 THE SOIL MAP

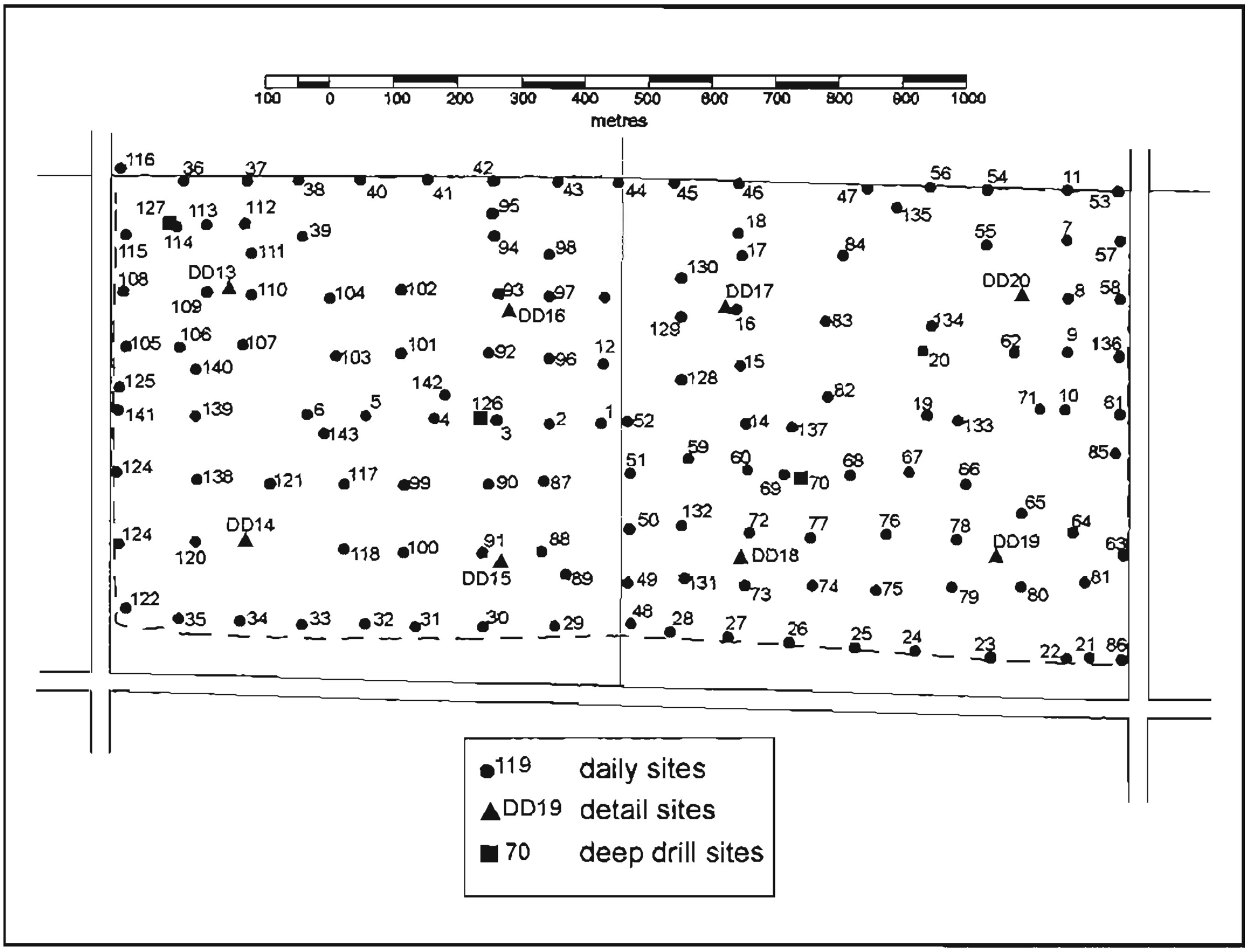
The soils of the Crop Diversification Centre were mapped on a 1:15 840 scale black and white aerial photograph which was subsequently enlarged to a scale of 1:5 000 for production of the final map manuscript. Fourteen soil series with various phases of erosion and topography were identified on the soil map for a total of 47 polygons.

The basic soil map and supporting data may be used to generate a number of derived and interpretive maps. The range of map products includes: erosion, topography, surface texture, drainage, pH, organic carbon, agricultural capability, irrigation suitability and potential environmental impact, risk for subsoil and/or groundwater contamination, wind erosion risk and water erosion risk.

2.3 DEEP DRILLING PROGRAM

Initial evaluation of the land on the Centre for irrigation suitability took place in November, 1992 when eight drill logs were sampled and described to 3 metres (Mills et. al., 1992). Subsequently, the PFRA Geotechnical Division sampled and described a series of drill logs to depths of 20 to 30 metres. Some of these boreholes were for construction of supply wells for irrigation water while others were for installation of piezometers and observation wells (H. Rhode, PFRA, Personal communication).

Figure 6. Location of Groundtruth and Sampling Sites



PART 3

DEVELOPMENT, CLASSIFICATION AND DESCRIPTION OF SOILS

3.1 INTRODUCTION

This section of the report describes the main characteristics of the soils and their relationship to the factors of soil development. It also provides a description of the classification and morphology of soils in the study. The soils of the Centre were originally mapped at a reconnaissance scale of 1:125 000 as the Wellwood Association which commonly was comprised of up to four member soil types or associates (Carberry Map Sheet Report, 1957).

The present detailed survey at a 1:5 000 scale recognizes fourteen soil series and one soil complex to characterize the soil variability on the Centre. They are all developed on moderately to strongly calcareous fine loamy (clay loam) lacustrine sediments with the exception of two soil types associated with the drainage channel. One soil is developed on fluvial (alluvial) parent material and soils of the Marsh complex are developed on undifferentiated materials. The soils are dominantly well drained Black Chernozems (81.5 percent of the area) while the remainder is comprised of imperfectly drained Rego, Eluviated and Orthic Black Chernozems soils (7.4 percent) and poorly drained Humic Gleysols (10.3 percent) and very poorly drained Humic Gleysols (0.8 percent).

3.2 SOIL DESCRIPTIONS

A general description of each soil series mapped on the Centre is given in this section. The area in hectares and percent of total areas for each soil series is included with the description. A brief convenient key to the classification of soils in the study in relation to parent material and drainage is shown in Table 4. The areal extent of each soil and phase mapped on the farm is summarized in Tables 5 and 6. Variation in depth to sand across the landscape on the Centre is indicated in Figure 4.

Generalized descriptions for each soil series are presented in alphabetical order and include genetic profile type, texture, calcareous class, parent material, topography, drainage and other chemical and physical properties. The characteristics and properties are based on summaries and averages of soil data systematically documented and recorded during the course of the soil survey. The description of soils which are of very limited occurence on the Centre is based on samples collected over a large area. Chemical and physical analysis from samples taken at grid points during the survey are presented in Tables 21 and 22.

3.2.1 Basker Series (BKR) (5.8 ha., 4.8 % of area)

The Basker series consists of poorly to very poorly drained Rego Humic Gleysol soils developed on moderately to strongly calcareous, stratified, loamy (FSL,VFSL,L,SiL,SiCL), recent alluvial deposits. These soils occur in depressional positions of nearly level slopes on flood plain landscapes and have slow permeability, very slow surface runoff, and a high water table during the growing season. Basker soils are slightly water eroded and non-stony. They have a high available water holding capacity, medium organic matter content, and low natural fertility. Native vegetation includes sedges, rushes and willows. The majority of these soils are currently in native vegetation because they are subject to flooding and saturated conditions in the spring.

A representative profile of Basker soil consists of a dark gray to light grayish brown Ah horizon, 22 to 45 cm in thickness. The profile is characterized by iron stains and mottles, and a stratified, olive brown Ckg horizon. Prominent iron mottles occur in the fine sandy loam strata. A typical profile also contains thin organic layers indicating former surfaces. These soils occur in association with the shallow channel crossing the study area and are usually free of carbonates.

Table 4. Classification of Soil Series in Relation to Drainage and Parent Material[1]

Soil Drainage	Soil Subgroup[2]	Parent Material					
		Coarse Loamy LFS, FS, FSL	Coarse Loamy/ Sandy - Fine LFS, FS, FSL/FS	Fine Loamy L, SiL, CL, SiCL	Fine Loamy/Sandy L, SiL, CL, SiCL/FS	Loamy, Fluvial Stratified	Miscellaneous
Well to moderately well	Orthic Black	Fairland (FND) 1.4 ha, 1.1%	Glenboro (GBO) 1.6 ha, 1.3%	Ramada (RAM) 35.9% ha, 29.6%	Wellwood (WWD) 59.9 ha, 49.5%		
Imperfect	Gleyed Black		Petrel (PTR) 1.5 ha, 1.3%	Charman (CXV) 0.5 ha, 0.4%	Oberon (OBR) 2.4 ha, 2.0%		
	Gleyed Rego Black			Prodan (PDA) 0.7 ha, 0.5%	Crookdale (CKD) 2.1 ha, 1.7%		
	Gleyed Eluviated Black			Gregg (GRG) 1.8 ha, 1.5%			
Poor	Rego Humic Gleysol	Vordas (VDS) 4.1 ha, 3.4%		Tadpole (TDP) 1.2 ha, 1.0%	Sutton (SXP) 1.3 ha, 1.1%	Basker (BKR) 5.8 ha, 4.8%	
Very Poor	Rego Humic Gleysol						Marsh (MHC) 1.0 ha, 0.8%

1. Dominant soils describing map units with estimated areal extent in hectares.

2. The Canadian System of Soil Classification, 2nd Ed., Agric. Canada Publication 1646. 164 pp.

Table 5. Areal Extent of Soil Series

Map Symbol	Soil Name	Areal Extent	
		Hectares	**Percent**
BKR	Basker	5.83	4.81
CKD	Crookdale	2.11	1.74
CXV	Charman	0.51	0.42
FND	Fairland	1.38	1.14
GBO	Glenboro	1.56	1.29
GRG	Gregg	1.80	1.49
MHC	Marsh	1.01	0.83
OBR	Oberon	2.40	1.98
PDA	Prodan	0.65	0.54
PTR	Petrel	1.52	1.25
RAM	Ramada	35.85	29.58
SXP	Sutton	1.31	1.08
TDP	Tadpole	1.22	1.00
VDS	Vordas	4.09	3.38
WWD	Wellwood	59.94	49.46
$UL	MCDC Yard Area*	3.41	2.81
TOTAL		**121.18**	**100.00**

* Yard area is included in the area of Wellwood soils.

Table 6. Areal Extent of Soil Phases

Map Symbol	Soil Name	Soil Phase	Areal Extent	
			Hectares	Percent
BKR/xxxx	Basker		5.83	4.81
CKD/xxxx	Crookdale		0.62	0.51
CKD/1cxx	Crookdale	slightly eroded, very gently sloping	1.49	1.23
CXV/xxxx	Charman		0.51	0.42
FND/xxxx	Fairland		1.38	1.14
GBO/xxxx	Glenboro		1.09	0.90
GBO/xcxx	Glenboro	very gently sloping	0.47	0.39
GRG/xxxx	Gregg		1.80	1.49
MHC/xxxx	Marsh		1.01	0.83
OBR/xbxx	Oberon	nearly level	1.75	1.44
OBR/xcxx	Oberon	very gently sloping	0.65	0.54
PDA	Prodan		0.65	0.54
PTR/xbxx	Petrel	nearly level	1.52	1.25
RAM/xxxx	Ramada		27.07	22.34
RAM/xbxx	Ramada	nearly level	1.98	1.63
RAM/xcxx	Ramada	very gently sloping	4.99	4.12
RAM/xdxx	Ramada	gently sloping	0.85	0.70
SXP/xxxx	Sutton		1.31	1.08
TDP/xxxx	Tadpole		1.22	1.01
VDS/xxxx	Vordas		4.09	3.38
WWD/xxxx	Wellwood		48.98	40.42
WWD/xbxx	Wellwood	nearly level	0.38	0.31
WWD/xcxx	Wellwood	very gently sloping	5.02	4.14
WWD/1cxx	Wellwood	slightly eroded, very gently sloping	2.02	1.67
WWD/1dxx	Wellwood	slightly eroded, gently sloping	3.54	2.92
TOTAL			**121.18**	**100.00**

Basker soils occur in close association with the soils of Marsh complex and the Tadpole series. They differ from the Tadpole soils by being developed in stratified alluvial deposits rather than mostly clay loam textures developed in uniform fine loamy lacustrine materials. Basker soils were previously mapped as Meadow associates of the Assiniboine Complex in the South-Central (1943) and Carberry (1957) reports.

3.2.2 Crookdale Series (CKD)
(2.1 ha., 1.7 % of area)

The Crookdale series consists of imperfectly drained Gleyed Rego Black soils developed on a mantle (25 to 100 cm) of strongly calcareous, stratified, fine loamy (CL, SiCL) lacustrine sediments over strongly calcareous, deep, uniform sandy (LFS, FS, S) deltaic lacustrine deposits. These soils occur in the lower slope positions of level to nearly level landscapes and have moderate permeability, moderately slow surface runoff and a medium watertable (1 to 2 m depth) during the growing season. Crookdale soils are non-eroded and non-stony. They have high available water holding capacity, medium organic matter content and medium natural fertility. The majority of the Crookdale soils are currently cultivated for crop production but native vegetation was tall prairie grass.

In a representative profile of the Crookdale soil, the solum is approximately 45 cm thick. The soil is characterized by a black Ah horizon, the surface 15 to 20 cm is a cultivated Ap horizon. A dark grayish brown AC horizon with faint iron mottles often marks the transition from the surface soil to the underlying parent material. A white Cca horizon, 5 to 10 cm thick of lime carbonate accumulation may occur above the sandy contact with the light olive brown IICkgj horizon marked by prominent iron mottles.

Crookdale soils occur in close association with the better drained Wellwood soils along the topographic break between the lower and mid slope position. They are similar to Oberon soils, having the same drainage position in the landscape but differ from them by the occurrence of free calcium carbonate immediately below the dark colored Ah horizon. Crookdale soils were previously mapped as the imperfectly drained Black-Meadow associate of the Glenboro association in the reconnaissance soil survey of south-central Manitoba (1943).

3.2.3 Charman Series (CXV)
(0.5 ha., 0.4 % of area)

The Charman series consists of imperfectly drained Gleyed Black soil developed on strongly to very strongly calcareous, fine loamy (CL, SiCL) lacustrine deposits. These soils occur on lower to mid slope positions of very gently sloping to undulating landscapes and have moderate permeability, slow surface runoff and a medium high water table during the growing season. Charman soils are non-eroded and non-stony. They have a moderately high available water holding capacity, moderate organic matter content and medium natural fertility. The majority of these soils are cultivated for grain crop production.

In a representative profile of Charman soil the solum is approximately 80 cm thick. The soil is characterized by a very dark gray to black Ah horizon, 40 to 80 cm thick, a dark grayish brown Bmgj horizon about 25 cm thick, a transitional BC horizon, 5 to 8 cm thick and a pale brown, silty textured Ckgj horizon with iron mottles. The Bmgj horizon of some Charman soils on the Centre is calcareous and are recognized as the Calcareous Black classification variant.

Charman soils occurs in association with Ramada soils along the transition between the lower and mid slope position and with Tadpole soils in lower lying depressional areas. Charman soils have similar drainage as the Prodan soils but differ in having a Bmgj horizon. Charman soils were previously mapped as an imperfectly drained Black-Meadow associate of the Holland association in the Carberry (1957) soil report.

3.2.4 Fairland Series (FND)
(1.4 ha., 1.1 % of area)

The Fairland series consists of moderately well to well drained Orthic Black soil developed on strongly to very strongly calcareous, deep, stratified, loamy (VFSL, L, SiL) lacustrine deposits. These soils occur in level to very gently sloping areas in upper positions of gently sloping landscapes. They have moderate permeability, moderate surface runoff and a low water table during the growing season. Fairland soils may be slightly eroded and are non-stony and non-saline. They have a medium available water holding capacity, medium organic matter content and high natural fertility. The majority of these soils are currently cultivated for grain crop production.

In a representative profile of Fairland soil, the solum is approximately 75 cm thick. The soil is characterized by a very dark gray to very dark grayish brown Ah horizon about 40 cm thick, a brown to dark brown Bm horizon, 18 to 55 cm thick, a pale brown BC horizon 5 to 10 cm thick with some carbonates and a light gray Cca horizon, 5 to 10 cm thick with accumulation of calcium carbonate. The parent material is typically pale brown, somewhat stratified and calcareous.

Fairland soils occur in close association with Glenboro soils and Petrel soils. The upper portion of the Glenboro soil is similar to Fairland soil but it is underlain by stratified sandy materials within 1.2 m of the surface. The Petrel soils differ from Fairland by being imperfectly drained and underlain by sandy substrata within 1.2 m of surface. Fairland soils were previously mapped as Blackearth associates of the Holland association in the Carberry (1957) soil report.

3.2.5 Glenboro Series (GBO) (1.6 ha., 1.3 % of area)

The Glenboro series consists of moderately well to well drained Orthic Black soil developed on a mantle (25 to 90 cm) of moderately to strongly calcareous, shallow, loamy (VFSL,L,SiL), lacustrine deposits over moderately calcareous, stratified, deep, sandy (FS,LFS,LS) deposits. These soils occur in upper positions of gentle slopes on sloping to undulating landscapes and have moderate surface permeability overlying moderately rapid subsoil permeability, moderately slow surface runoff, and a low water table during the growing season. Glenboro soils are non-stony, non-saline and are often slightly eroded. They have a medium available water holding capacity, medium organic matter content, and high natural fertility. Native vegetation includes tall prairie grasses and aspen-oak groves. The majority of these soils are currently cultivated for grain crop production.

In a representative profile of Glenboro soil the solum is approximately 30 cm thick. The soil is characterized by a very dark gray to black Ah horizon, 12 to 18 cm thick, with granular structure, a dark brown to brown Bm or Btj horizon, 10 to 16 cm thick with subangular blocky structure, a brown to pale brown BC horizon, 6 to 14 cm thick and a light gray to very pale brown Cca horizon, 5 to 8 cm thick. The parent material typically consists of pale brown to light yellowish brown sandy strata. Stratified sands to loams often occur in the transition zone between the loam and the underlying sand.

Glenboro soils occur in close association with Fairland soils. They are similar to Fairland soils by having an Orthic Black profile and loamy surface mantle but differ from them in having a sandy substrate. Glenboro soils were previously mapped as Blackearth associates of the Glenboro Association in the Carberry (1957) soil report.

3.2.6 Gregg series (GRG) (1.8 ha., 1.5 % of area)

The Gregg series consists of imperfectly drained Gleyed Eluviated Black soil developed on strongly to very strongly calcareous, fine loamy (CL, SiCL) lacustrine deposits. These soils occur in local circular depressional areas in level to very gently undulating landscapes and have moderate permeability. These sites are subject to occasional ponding and have a medium high seasonal water table. Gregg soils are non-eroded and non-stony. They have a moderately high available water holding capacity, medium organic matter content and medium natural fertility. The majority of these soils are cultivated for grain crop production.

In a representative profile of Gregg soil, the solum is approximately 105 cm thick. The soil is characterized by a very dark gray to dark gray Ah horizon, 50 cm thick, underlain by 15 to 50 cm of light gray, leached Ae or Aeg horizon with weak platy structure. Underlying the Ae horizon, a very dark grayish brown to brown Bt horizon, commonly 30 to 50 cm thick, is characterized by clay texture with well developed blocky structure. This strongly developed horizon results from the accumulation of clay and organic matter leached from the upper portion of the soil. A weakly structured BC horizon, 20 cm thick often marks the transition to the pale brown, silty textured parent material (Ckgj horizon) streaked with iron mottles.

Gregg soils occur in the lower, central positions of small circular depressions in landscapes dominated by Ramada soil. The Gregg soils are found in close association with Charman soils which often occur in a ring around the depression separating the Gregg soils from the better drained Ramada soil. The Gregg soils were previously mapped as the Degrading Black Meadow associate of the Wellwood association.

3.2.7 Marsh Complex (MHC) (1.0 ha., 0.8 % of area)

The Marsh complex consists of very poorly drained, Rego Humic Gleysol soils developed on thin mucky loam sediments overlying moderately calcareous loamy lacustrine or stratified alluvial deposits. These soils occur on level to depressional areas that are covered with water and are usually saturated for most of the year. The native vegetation consists entirely of reeds and sedges.

Soils of the Marsh complex have a thin surface layer of either organic muck or mineral material high in organic matter content and are underlain by strongly gleyed olive gray mineral materials. A thin Ahg horizon, 10 to 15 cm thick usually occurs below the muck surface layer.

Marsh soils are undifferentiated with respect to texture and composition of their parent material. They also are much more poorly drained than other Gleysolic soils (Basker, Sutton, Tadpole and Vordas series). Marsh soils were previously mapped as very poorly drained undifferentiated muck and peat soils in the Carberry (1957) report.

3.2.8 Oberon Series (OBR) (2.4 ha., 2.0% of area)

The Oberon series consists of imperfectly drained Gleyed Black soil developed on a mantle (25 to 75 cm) of strongly calcareous, shallow, uniform, fine loamy (CL,SiCL,SCL), lacustrine sediments over moderately calcareous, deep, uniform, sandy (FS,LFS,LS), deltaic deposits. These soils occur in mid to lower positions of gentle to very gentle slopes on undulating to hummocky landscapes. They have moderate surface permeability grading to rapid permeability with depth, moderate to moderately slow surface runoff, and a low water table during the growing season. Oberon soils are nonstony and occasionally slightly eroded. They have a medium available water holding capacity, medium organic matter content and high natural fertility. The majority of these soils are currently cultivated for grain crop production.

The Oberon soils on the Centre are characterized by Calcareous Black profiles mapped as a classification variant. These soils occur mainly in lower slope positions which are in receipt of a variable deposition of overwash resulting in a thicker than normal depth of A horizon. In a representative profile the solum is approximately 45 cm thick. The profile is characterized by a black to very dark gray Ah horizon, 18 to 25 cm thick, a weakly calcareous brown to olive brown Bmkgj horizon 15 to 25 cm thick with yellowish brown mottles, and a BC horizon, 8 to 16 cm thick. A lime accumulation (Cca) may occur within the loamy strata. The (IICkgj) sandy substrata is light yellowish brown with yellowish brown to strong brown iron mottles.

Oberon soils occur in the lower slope positions adjacent to Wellwood or Ramada soils. They are similar to Petrel soils by having a Gleyed Black profile and sandy substrate but differ from them in having a fine loamy rather than loamy surface. Oberon soils were previously mapped as Black Meadow associates of the Wellwood Association in the Carberry (1957) soil report.

3.2.9 Petrel Series (PTR) (1.5 ha., 1.3 % of area)

The Petrel series consists of imperfectly drained Gleyed Black soils developed on a mantle (25 to 75 cm) of moderately to strongly calcareous, shallow, loamy (VFSL,L,SiL), sediments over moderately calcareous, uniform, deep, sandy (FS,LFS,LS) lacustrine and deltaic deposits. These soils occur in lower slope and toe slope positions of very gentle slopes on undulating landscapes and have moderate surface permeability increasing to moderately rapid permeability with depth. They have moderately slow surface runoff, and a high water table during the growing season. Petrel soils are noneroded and nonstony. They have a medium available water holding capacity, medium organic matter content, and medium natural fertility. The majority of these soils are currently cultivated for crop production.

In a representative profile of Petrel soil the solum is approximately 40 cm thick. The soil is characterized by a very dark gray Ah horizon, 18 to 25 cm thick, a brown Bmgj horizon, 14 to 20 cm thick, a BC horizon, 20 to 30 cm thick with faint mottles and a light yellowish brown Ckgj horizon with yellowish brown to strong brown mottles. A typical profile also contains a weak Cca horizon in the upper part of the sandy substrate. The Petrel soils on the Centre have a thicker than normal A horizon due to the accumulation of a variable thickness of overwash from adjacent upper slopes. The Petrel soils on the Centre are also characterized by a weakly calcareous Bmk horizon which is mapped as a classification variant of normal Petrel soils.

Petrel soils occur in close association with Wellwood soils. They are similar to Crookdale soils by having imperfect drainage and a sandy substrate but differ in having coarse loamy surface soil. The Petrel soils were previously mapped as Black-Meadow associates of the Glenboro Association in the Carberry (1957) soil report.

3.2.10 Prodan Series (PDA) (0.7 ha., 0.5% of area)

The Prodan series consists of imperfectly drained Gleyed Rego Black soil developed on strongly to very strongly calcareous, fine loamy (CL, SiCL) lacustrine deposits. These soils occur on lower to mid slope positions of very gently sloping to undulating landscapes and have moderate permeability, slow surface runoff and a medium high water table during the growing season. Prodan soils are non-eroded and non-stony. They have a moderately high available water holding capacity, medium organic matter content and medium natural fertility. The majority of these soils are cultivated for grain production.

In a representative profile of Prodan soil the solum is approximately 75 cm thick. The soil is characterized by a very dark gray to black Ah horizon 25 to 40 cm thick. The underlying Ahkgj horizon extends to about 70 cm and is very dark gray, faintly mottled and calcareous. A dark gray to gray AC horizon 10 to 15 cm thick occurs as a transition to the light brownish gray Ckgj horizon marked with fine yellowish brown mottles and lime carbonate throughout. The Prodan soils on the Centre have a thicker than normal A horizon due to the accumulation of a variable thickness of overwash from adjacent upper slopes.

Prodan soils occur in close association with Charman soils in lower slope positions between the better drained Ramada soils and the poorly drained Tadpole soils. Prodan soils have similar drainage as the Charman soils but differ from them by the occurrence of free lime carbonate in lower portions of the dark coloured Ah horizon. Prodan soils were previously mapped as Black- Meadow associates of the Holland association in the Carberry (1957) soil report.

3.2.11 Ramada Series (RAM) (35.9 ha., 29.6 % of area)

The Ramada series consists of well to moderately well drained Orthic Black soil developed on strongly to very strongly calcareous, deep, uniform, fine loamy (CL,SiCL,SCL), lacustrine sediments. These soils occur on level to very gently sloping landscapes or middle and upper positions of very gentle slopes on undulating landscapes. They have moderate to moderately slow permeability, moderate to moderately slow surface runoff, and a low water table during the growing season. Ramada soils are occasionally slightly eroded and are nonstony and non-saline. They have a medium available water holding capacity, medium organic matter content, and high natural fertility. The majority of these soils are currently cultivated for grain crop production.

In a representative profile of Ramada soil the solum is approximately 60 cm thick. The profile is characterized by a black to very dark gray Ah horizon, 30 to 90 cm thick, a dark grayish brown to brown subangular blocky Bm horizon, 30 to 50 cm thick, a BC horizon, 6 to 10 cm thick with weak calcareousness and a pale brown to light yellowish brown Ck horizon.

Ramada soils occur in close association with Charman and Prodan soils. They are similar to Charman soils by having a well developed profile in fine loamy sediments but differ from them in having a prominent Bm horizon in contrast to a Bmgj horizon in the imperfectly drained Charman soils. Ramada soils were previously mapped as Blackearth associates of the Carroll and Holland Associations in the Carberry (1957) soil report.

3.2.12 Sutton Series (SXP)
(1.3 ha., 1.1 % of area)

The Sutton series consists of poorly drained Rego Humic Gleysol soil developed on a mantle (25 to 100 cm) of moderately calcareous fine loamy (CL, SiCL) lacustrine deposits over moderately calcareous, deep, stratified, sandy (FS, LFS, LS) deltaic lacustrine deposits. These soils occur in depressional positions on level landscapes and have restricted permeability, negligible surface runoff and a near-surface water table during the growing season. Sutton soils are non-eroded and non-stony and are subject to frequent surface ponding. They have a moderate available water holding capacity, medium organic matter content and low natural fertility. Native vegetation on these soils consists of sedges, hydrophytic grasses and willow. The majority of these soils are currently in native vegetation.

In a representative profile of Sutton soil the solum is approximately 35 cm thick. The profile is characterized by a moderately decomposed organic surface horizon, 2 to 4 cm thick underlain by a very dark gray Ah horizon, 10 to 18 cm thick. The Sutton soils on the Centre occur in lower slope positions adjacent to the shallow drain traversing the northern part of the area. In this landscape position, the Sutton soils are leached, resulting in development of a weak Bg horizon which is strongly mottled and free of lime. The Sutton soils on the Centre lack the development of the calcareous AC and Cca horizons typical of normal Sutton soils. The parent material is typically olive brown in colour with many prominent mottles. The underlying sandy strata are also mottled and commonly saturated throughout the year.

Sutton soils occur in close association with Wellwood soils; they are similar to Tadpole soils by having poor drainage and a fine loamy surface but differ in the occurrence of a sandy substrate. Sutton soils were previously mapped as the poorly drained Black Meadow associate of the Wellwood association in the Carberry (1957) soil report.

3.2.13 Tadpole Series (TDP)
(1.2 ha., 1.0 % of area)

The Tadpole series consists of poorly drained Rego Humic Gleysol soil developed on strongly to very strongly calcareous, deep, uniform, fine loamy (CL,SiCL,SCL), lacustrine sediments. These soils occur in depressional positions of nearly level slopes on undulating landscapes and have moderately slow permeability, very slow surface runoff, and a high water table occasionally ponded at the surface during the growing season. Tadpole soils are noneroded and nonstony. They have a medium available water holding capacity, medium organic matter content, and low natural fertility. The majority of these soils currently support native vegetation consisting of sedges, reeds, rushes and willow.

In a representative profile of Tadpole soil the solum is approximately 20 cm thick. The profile is characterized by a moderately decomposed organic horizon, 2 to 6 cm thick; a very dark gray Ah horizon, 10 to 18 cm thick; a dark gray AC horizon, 4 to 6 cm thick with moderate calcareousness and an olive to olive gray Ckg horizon with distinct yellowish brown mottles.

Tadpole soils occur in close association with Ramada and Charman soils. They are similar to Vordas soils by having poor drainage but differ in being developed on fine loamy rather than loamy materials. Tadpole soils were previously mapped as Meadow associates of the Carroll and Firdale Associations in the Carberry (1957) soil report.

3.2.14 Vordas Series (VDS)
(4.1 ha., 3.4 % of area)

The Vordas series consists of poorly drained Rego Humic Gleysol soil developed on strongly to very strongly calcareous, deep, uniform, loamy (VFSL,L,SiL), lacustrine sediments. These soils occur in level to depressional positions of very gentle slopes on undulating landscapes and have moderate permeability, very slow surface runoff, and a high water table occasionally ponded at the surface during the growing season. Vordas soils are noneroded and nonstony and may be slightly saline in landscapes affected by salinity. They have a medium available water holding capacity, medium organic matter content, and low natural fertility. The majority of these soils are currently in native vegetation consisting of sedges, rushes, reeds and willow.

In a representative profile of Vordas soil the solum is approximately 15 cm thick. The profile is characterized by a moderately decomposed organic horizon, 2 to 5 cm thick, a very dark gray Ah horizon, 10 to 18 cm thick, a dark gray AC horizon, 4 to 6 cm thick with carbonates and mottles, and an olive to pale olive Ckg horizon with yellowish brown iron mottles. A typical profile also contains white pseudomycelia of gypsum salt in the Ah and AC horizons in saline areas.

Vordas soils occur in association with Fairland and Glenboro soils. They are similar to Tadpole soils by having poor drainage but differ from them in having slightly coarser textures. Vordas soils were previously mapped as Meadow associates of the Holland Association in the Carberry (1957) soil report.

3.2.15 Wellwood Series (WWD)
(56.5 ha., 46.7 % of area)

The Wellwood series consists of well to moderately well drained Orthic Black soil developed on a mantle (25 to 120 cm) of strongly calcareous, shallow, uniform, fine loamy (CL,SiCL,SCL), lacustrine sediments over moderately calcareous, deep, uniform, sandy (FS,LFS,LS), deltaic deposits. These soils occur in level to very gently sloping landscapes or in upper positions of gentle to very gentle slopes on undulating to hummocky landscapes. They have moderate surface permeability grading to rapid permeability with depth, moderate to moderately slow surface runoff, and a low water table during the growing season. Wellwood soils are occasionally slightly eroded and are non-stony and nonsaline. They have a medium available water holding capacity, medium organic matter content, and high natural fertility. The majority of these soils are currently cultivated for grain crop production.

In a representative profile of Wellwood soil the solum is approximately 60 cm thick. The profile is characterized by a black to very dark gray Ah horizon, 18 to 70 cm thick; a dark brown to brown Bm horizon, 15 to 40 cm thick with prismatic to subangular blocky structure; a yellowish brown to pale brown BC horizon, 8 to 14 cm thick, and a Cca horizon, 7 to 10 cm thick with lime accumulation and a moderately calcareous stratified, fine sand IICk horizon.

Wellwood soils occur in close association with Oberon soils. They are similar to Glenboro soils by having an Orthic Black profile and sandy substrata but differ from them in having a fine loamy rather than loamy surface texture. Wellwood soils were previously mapped as Blackearth associates of the Wellwood Association in the Carberry (1957) soil report.

PART 4

USE AND MANAGEMENT INTERPRETATIONS OF SOILS

4.1 INTRODUCTION

This section provides predictions of performmance or soil suitability ratings for various land uses based on soil and landscape characteristics, laboratory data and on soil behavior under specified conditions of land use and management. Suitability ratings or interpretations for various land use applications are intended to serve as guides for planners and managers.

4.1.1 Single Factor and Derived Interpretive Maps

Evaluation of soil resource information (soil properties) is most appropriate in relation to the landscape and environment in which the soil occurs. Management of soil and landscape data using Geographic Information System (GIS) technology enables rapid and more quantitative analysis of natural soil variability than is possible using manual techniques. The areal distribution of various soil components and properties that occur in complex landscapes can be highlighted in map form and so assist in planning and managing the soil resource. Such single factor maps and interpretative maps show the distribution of individual soil properties and indicate the degree of soil limitation or potential for selected agricultural uses and environmental applications.

GIS techniques can help the land manager in understanding soil and landscape relations and in implementing research and demonstration activities. In addition, use of the GIS can assist in the design of sampling and instrumentation sites for monitoring soil quality and assessing environmental impact.

A series of derived and interpretive maps at a 1:10 666 scale are included in this section to assist in the interpretation of the soil resource information for the Crop Diversification Centre. These colour thematic maps are generated by the PAMAP Geographic Information System from the 1:5000 scale soil map and related soil analysis and landscape information. The maps portray a selection of individual soil properties or landscape conditions for each map unit delineation. Combinations of soil properties or landscape features affecting land use and management are derived as specific interpretations. Because the derived maps portraying specific interpretations are based on the dominant condition in each map on it, slightly difference may occur between these data and the summary provided from the soil map.

Soil properties determine to a great extent the potential and limitations for both dryland and irrigation agriculture. In this section, interpretive soil information is provided for agricultural land use evaluations such as:

a) soil capability for agriculture
b) irrigation suitability
c) risk of wind and water erosion

and environmental assessment such as:

d) relative risk of subsoil and/or groundwater contamination

A general overview of the soil and landscape characteristics on the Centre is given in Table 7. A summary of the soils on the Centre showing their areal extent and their interpretive classification for agricultural capability and irrigation suitability is provided in Table 8.

4.2 SOIL CAPABILITY FOR AGRICULTURE

The classification of soil capability for agriculture is based on an evaluation of both soil characteristics and landscape conditions that influence soil suitability and limitations for agricultural use. In this classification, mineral soils are grouped into classes of capability or general suitability; subclasses describe the type of limitation or properties that affect dryland farming. These ratings imply a risk to regional production capacity when the soils are used and the way they respond to management (Anon, 1965).

Table 7. Summary of Land Resource Characteristics

Characteristic	Areal Extent		
	Hectares	Acres	% of Area
Soil Drainage Classes			
Well	98.7	243.9	81.5
Imperfect	9.0	22.2	7.4
Poor	12.5	30.9	10.3
Very Poor	1.0	2.5	0.8
Topography (Slope) Classes			
x level to nearly level (0 - 0.5%)	94.6	233.8	78.9
b nearly level (0.5 - 2.0%)	3.9	13.8	3.2
c very gently sloping (2.0 - 5.0%)	14.6	36.1	12.1
d gently sloping (5.0 - 9.0%)	7.1	13.3	5.9
Erosion Classes			
Erosion 1 (slight)	7.9	19.5	6.5
Agricultural Capability Classes			
Class 1	80.9	199.9	66.8
Class 2	19.7	48.7	16.3
Class 3	7.1	17.5	5.9
Class 4	1.2	3.0	1.0
Class 5	5.4	13.3	4.5
Class 6	5.8	14.3	4.8
Class 7	1.0	2.5	0.8
Irrigation Suitability Rating			
Suitability Class			
Excellent	2.5	6.2	2.0
Good	92.4	228.3	76.3
Fair	12.8	31.6	10.6
Poor	13.5	33.4	11.1
Potential Environmental Impact under Irrigation			
Negligible	29.7	73.4	24.5
Low	8.1	20.0	6.7
Moderate	76.5	189.0	63.2
High	6.8	16.8	5.6

There are seven capability classes, each of which groups soils together that have the same relative degree of potential for agricultural use. Risk or hazard for use is indicated by the subclass limitation. The subclass limitation becomes progressively greater from Class 1 to Class 7.

4.2.1 Soil Capability Classes

The class indicates the general suitability of the soils for agriculture. The first three classes are considered capable of sustained production of common field crops, the fourth is marginal for sustained arable agriculture, the fifth is suitable only for improved permanent pasture, the sixth is capable of use only for native pasture while the seventh class is for soils and land types considered incapable of use for arable agriculture or permanent pasture. A description of the capability classes is provided in Appendix A, Table 15.

4.2.2 Soil Capability Subclasses

Soil capability subclasses identify the soil properties or landscape conditions that may limit use or be a hazard. The various kinds of limitations recognized at the subclass level are defined in Appendix A, Table 16.

4.2.3 Soil Capability Classification

The soils on the Crop Diversification Centre range from Class 1 to Class 7 in agricultural capability. Class 1 soils account for 80.9 hectares or 66.8%, Class 2 for 19.7 hectares or 16.3%, Class 3 for 7.1 hectares or 5.9%, Class 4 for 1.2 hectares or 1.0%, Class 5 for 5.4 hectares or 4.5%, Class 6 for 5.8 hectares or 4.8% and Class 7 soils account for 1.0 hectare or 0.8% of the land area on the Centre. The agriculture capability classification of the soils on the Centre is shown in Figure 7.

Class 1 soils on the Centre have level to very gently sloping topography, are deep and well to moderately well drained with no major limitations in use for crops. Class 2 soils include the imperfectly drained soils with a wetness limitation (2W) and the well drained and imperfectly drained soils having a topographic limitation (2T). The 2-5% slopes associated with the 2T soils may increase cultivation costs over that of a smooth landscape and increase the risk of water erosion. The Class 3 soils have a moderately severe limitation associated with gently sloping topography (5-9%) resulting in a moderate risk of water erosion. Class 4 soils on the Centre are poorly drained with a severe restriction to the growth of crops or choice of crops. The timing of cultivation or choice of crops is severely limited because of the wetness limitation. Class 5 soils on the Centre have very severe limitations as a result of excess water (5W). This class includes the lower, depressional areas of the poorly drained soils. One area of Class 6 soil has an extremely severe limitation due to excess wetness and inundation which restricts cropping to production of perennial forages (6WI). The Marsh Complex (7W) constitutes the Class 7 soils which have no capability for arable culture. However, these soils may have high capability for native vegetation species and habitat for waterfowl and wildlife. A summary for agricultural capability, irrigation suitability and areal extent of soils on the Crop Diversification Centre is presented in Table 8.

4.3 IRRIGATION SUITABILITY

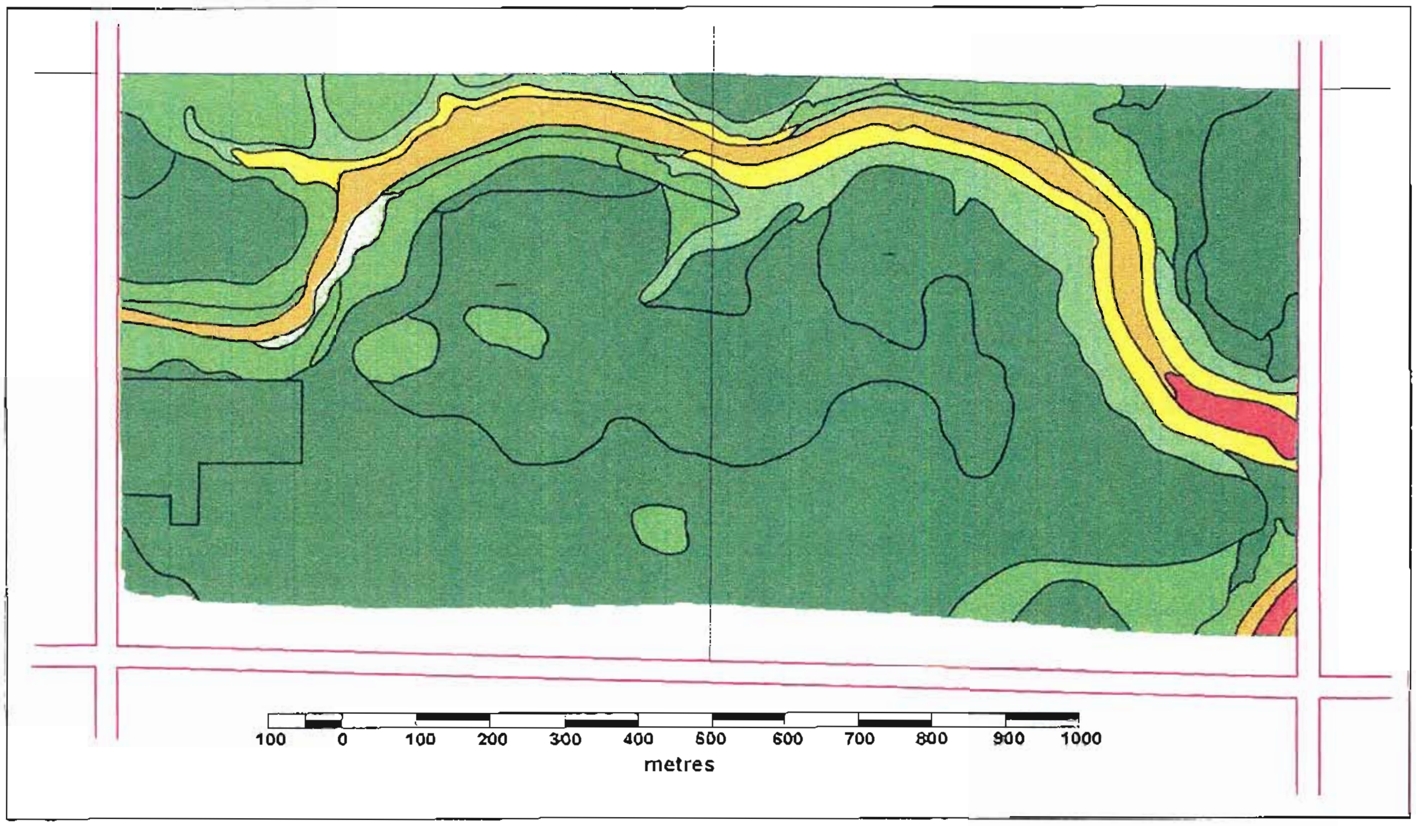
The irrigation suitability cklassification is an interpretive assessment of land suitability for irrigated agriculture and is made from soil survey data. the irrigation rating provided in this section is an initial ratings based on general information about specific soils indicated on the soil map. **It is emphasized that the decision to irrigate a parcel of land will require additional field investigation that utilize the same criteria but will include on site examination of water tables, salinity and stratigraphy to a depth of 3 meters.**

The rating guidelines in this section are derived from "An Irrigation Suitability Classification System for the Canadian Prairies" (ISC, 1987). This classification system takes into account recent advances in irrigation management and technology and provides general guidelines for irrigation suitability classification that are applicable to both local and regional conditions. The irrigation suitability rating of the soils is based on soil and landscape characteristics. these characteristics are ranked in terms of their sustained quality under long-term management under irrigation. It does not consider factors such as method of water application, water application, water availability, water quality or economics of this type of land use.

Figure 7 **Agricultural Capability**

This evaluation utilizes the 7 class Canada Land Capability Inventory (CLI, 1965) Soil Capability for Agriculture System. Classes 1 to 3 represent land which is capable of sustained arable culture, soils in class 4 are marginal for sustained arable culture, the fifth is capable of use as improvable permanent pasture and hay, the sixth is capable of use only for native pasture while soils in class 7 are are unsuitable for arable culture or permanent pasture.

This generalized interpretive map is based on rating the dominant soil type in each map unit. The classification of the subdominant soil components and the nature of the subclass limitations are indicated in the soil report.



Agricultural Capability Classes	Area ha	Percent of Area
Class 1	80.86	66.75
Class 2	18.21	15.03
Class 3	9.26	7.65
Class 4	0 57	0.47

Agricultural Capability Classes	Area ha	Percent of Area
Class 5	5.40	4.46
Class 6	5.83	4.81
Class 7	1.01	0.83

Table 8. Agricultural Capability and Irrigation Suitability Rating

Map Symbol	Soil Name	Areal Extent		Agricultural Capability Class	Irrigation Suitability Rating		
		ha	%		Class	General Rating	Potential Environmental Impact
BKR/	Basker	5.83	4.81	6WI	4wDi	Poor	High
CKD	Crookdale	0.62	0.51	2W	3wA	Fair	Moderate
CKD/lexx	Crookdale	1.49	1.23	2T	$3wBt_2$	Fair	Moderate
CXV	Charman	0.51	0.42	2W	3wA	Fair	Low
FND	Fairland	1.38	1.14	1	1A	Excellent	Low
GBO	Glenboro	1.09	0.90	1	1A	Excellent	Moderate
GBO/xcxx	Glenboro	0.47	0.39	2T	$1Bt_2$	Good	Moderate
GRG	Gregg	1.80	1.49	2W	3wA	Fair	Moderate
MHC	Marsh Complex	1.01	0.83	7W	4wDi	Poor	High
OBR/xcxx	Oberon	0.65	0.54	2T	$3wBt_2$	Fair	Moderate
OBR/xdxx	Oberon	1.75	1.44	3T	$3wCt_2$	Fair	Moderate
PDA	Prodan	0.65	0.54	2W	3wA	Fair	Negligible
PTR/xbxx	Petrel	1.52	1.25	2W	2wA	Good	Moderate
RAM	Ramada	27.07	22.34	1	2kA	Good	Negligible
RAM/xbxx	Ramada	1.98	1.64	1	2kA	Good	Negligible
RAM/xcxx	Ramada	4.99	4.12	2T	$2kBt_2$	Good	Low
RAM/xdxx	Ramada	0.96	0.79	3T	$2kCt_2$	Fair	Moderate
RAM/1dxx	Ramada	0.85	0.70	3T	$2kCt_2$	Fair	Moderate
SXP	Sutton	1.31	1.08	5W	4wA	Poor	Moderate
TDP	Tadpole	1.22	1.01	4W	4wA	Poor	Low
VDS	Vordas	4.09	3.38	5W	4wA	Poor	Moderate
WWD	Wellwood	48.98	40.42	1	2kA	Good	Moderate
WWD/xbxx	Wellwood	0.38	0.31	1	2kA	Good	Moderate
WWD/xcxx	Wellwood	5.02	4.14	2T	$2kBt_2$	Good	Moderate
WWD/1cxx	Wellwood	2.02	1.67	2T	$2kBt_2$	Good	Moderate
WWD/1dxx	Wellwood	3.54	2.92	3T	$2kCt_2$	Fair	Moderate
TOTAL AREA		**121.18**	**100.00**				

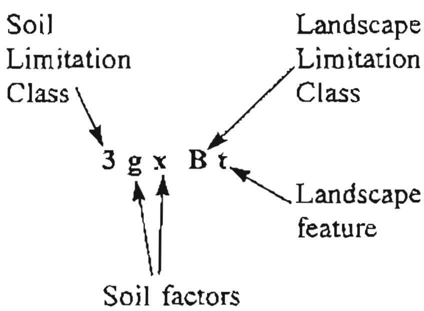
Soil properties considered important for evaluating irrigation suitability are: texture, soil drainage, depth to water table, salinity and geological uniformity. **Landscape features** considered important for rating irrigation suitability relate mainly to the influence of topography and stoniness.

The irrigation suitability classification of the soil and landscape characteristics in the study area will assist in making initial irrigation plans. The decision to irrigate a parcel of land should first be based on a ranking of suitability based on information presented in this report. The next step should involve on site field investigation to examine the depth to water table, salinity and geological uniformity to a depth of 3 m. Drainability, drainage outlet requirement, organic matter status and potential for surface crusting are other factors to consider. This assessment should also consider potential impact of irrigation on "Non-target" non-irrigated areas as well as on the irrigated area.

4.3.1 Irrigation Suitability Rating

The most limiting soil property or landscape feature is combined to determine the placement of a land area in one of 16 classes of irrigation suitability which are grouped and described by 4 ratings of general suitability as **Excellent, Good, Fair and Poor** (Appendix A, Table 17). The guidelines utilized for evaluating the effect of soil properties and landscape features on long term irrigation are included in Appendix A, (Tables 18 and 19 respectively).

An example of an irrigation suitability class rating is shown below:



A maximum of 3 codes is used to identify the subclass rating. Geological uniformity (g) and drainability (x) are soil factors contributing to the soil rating of Class 3, Moderate. Complex topography is the limiting landscape characteristic of the area for rating irrigation suitability. As the soil factor (Class 3, Moderate) is more limiting than the landscape feature (Class B, Slight) the general rating for this land area is Fair (Table 17).

An ideal soil area to be used for irrigation will have the following characteristics:

- loam texture
- uniform texture both vertically and horizontally
- uniformly well drained
- non saline
- permeable
- nearly level
- non stony

Any departure from these characteristics, ie sandy and clayey soils, presence of contrasting textural layers vertically in the soil, horizontal variation in soil texture within the landscape, imperfect and poor drainage, salinity, reduced soil permeability, undulating and hummocky topography and surface stoniness will lower the irrigation suitability. These factors may not only influence the sustainability of irrigation but can also affect the type of irrigation system that can be used and the type of management needed.

Areas with no or slight soil and/or landscape limitations are rated **Excellent** to **Good** and can usually be considered irrigable. Areas with moderate soil and/or landscape limitations are rated as **Fair** and considered marginal for irrigation providing adequate management exists so that the soil and adjacent areas are not adversely affected by water application. Soil and landscape areas rated as **Poor** have severe limitations for irrigation.

The soils on the Centre range from Excellent to Poor in suitability for irrigation (Figure 8). Soils rated Excellent for irrigation occupy only 2.5 hectares or 2.0% of the land area whereas soils rated as being Good for irrigation cover 92.4 hectares or 76.3%. Soils rated as Fair suitability cover 12.8 hectares (10.6%) and Poor suitability soils cover 13.5 hectares (11.1%) of the land area.

The irrigation suitability ratings in Table 8 are based largely on soil characteristics in the upper 1.2 m and the main landscape features for each soil series and phase. Limited information available to the 3 m depth was used to characterize the geological uniformity of major soil types. Following the initial ranking of irrigation suitability, a more detailed investigation may indicate that portions of the area are significantly better or poorer than the general rating indicated.

4.3.2 Environmental Impact

An assessment of potential environmental impact from irrigation is provided in Table 8 and Figure 9. The environmental impact from irrigation on either the irrigated land or on "non-target", non irrigated areas and crops is an important aspect to consider prior to irrigation development. The guidelines for environmental impact assessment provide a general assessment of relative ratings a **"negligible, low, moderate and high"** (Table 20). This rating recognizes soil and/or landscape conditions which under irrigation could impact on the irrigated area as well as a "non-target" non-irrigated area. Examples of adverse environmental impact are higher water tables, more persistent soil saturation, increased soil salinity and contamination of groundwater or surface water.

Use of this rating is intended to serve as a warning of possible environmental impact but it is not part of the initial irrigation suitability classification. The evaluation of potential environmental impact has been separated from the initial irrigation suitability rating provided in the ISC system (1987) since it may be possible to design and manage the irrigation system to overcome these limitations. The irrigator must determine the nature or cause of a specific environmental concern and then give special consideration to soil-water-crop management practices that will mitigate the possibility for any adverse impact.

Soil factors and landscape features considered in providing a potential environmental impact evaluation are:

1. Soil Texture
2. Geological Uniformity
3. Hydraulic Conductivity
4. Depth to Water Table
5. Salinity
6. Topography

Soil characteristics and landscape features on the Centre result in potential environmental impact ratings ranging from Negligible to High Figure 9). Soils estimated to have a Negligible potential impact on the environment under irrigation cover 29.7 hectares or 24.5%, soils rated as having potential for Low impact cover 8.1 hectares or 6.7% and soils estimated to have a Moderate potential environmental impact occupy 76.5 hectares or 63.2% of the land on the Centre. Soil and landscape conditions resulting in a High potential environmental impact occur on 6.8 hectares or 5.6% of the land area.

An initial evaluation of environmental impact is based on information on soil characteristics within the upper 1.2 m. In such cases, additional investigation to 3 m is required to verify the depth to the underlying sand substrate and to confirm the initial rating. In this portion of the Assiniboine Delta, a porous sand substrate underlies all of the soils at depths varying from a few centimeters to in excess of several metres. The occurrence and depth to the sand is part of the description of many soils on the Centre, but for soils like Ramada and Oberon, the depth at which the sand occurs is defined only as being below 1.2 m. Thus, the Ramada and Oberon soils might present a Potential Environmental Impact that varies from Negligible to Low or Moderate depending on the depth at which the underlying highly porous sand occurs.

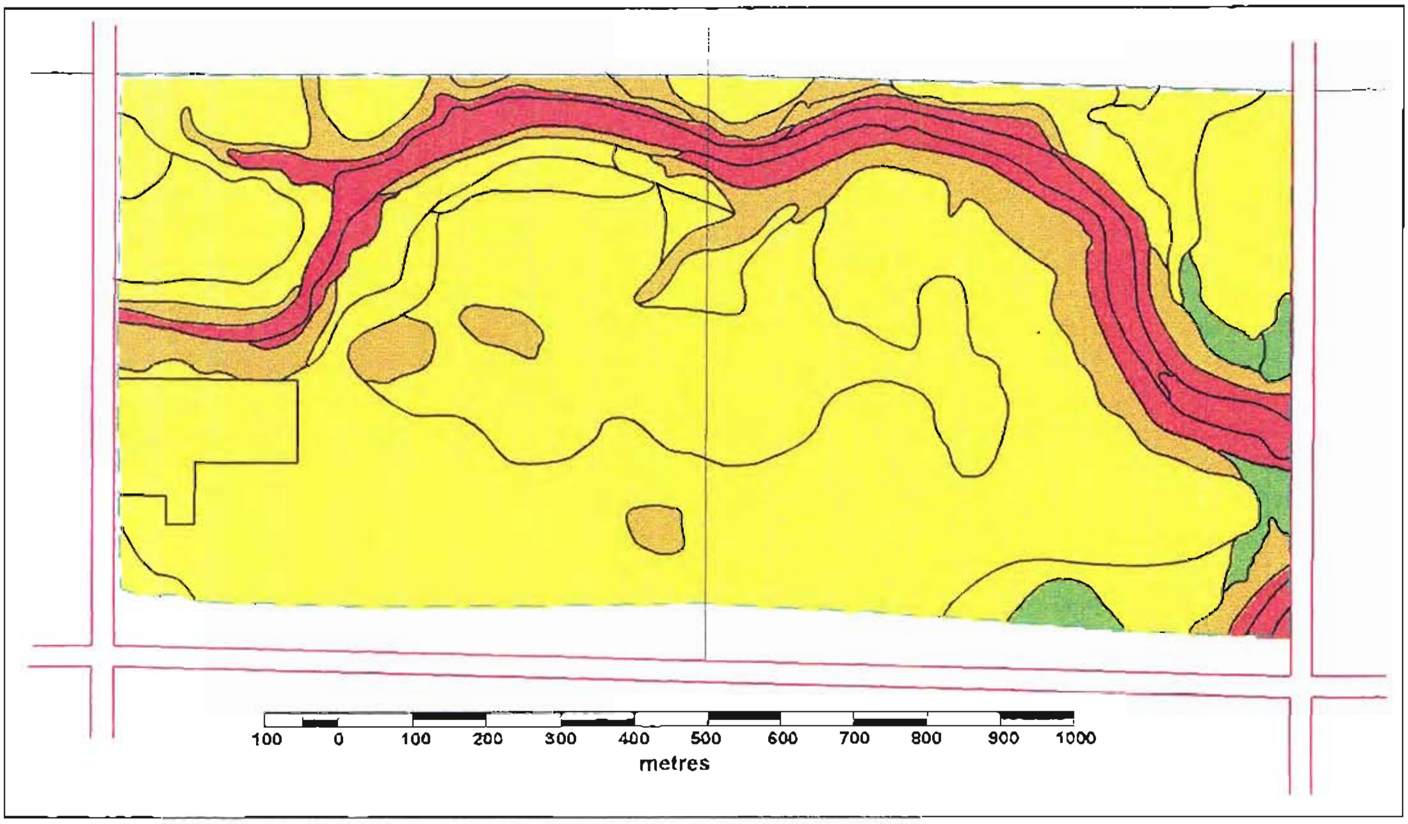
4.4 SOIL PROPERTIES AFFECTING CROP MANAGEMENT

This section of the report examines specific soil properties that affect various management and associated tillage activities for crop production. The areal distribution of selected soil and landscape properties is shown in a series of single factor and interpretive maps. Selected chemical and physical characteristics of the soils for surface horizons are summarized in Table 9. Additional data on bulk density and soil moisture retention properties for specific sites are provided in Tables 10 and 11.

Figure 8 **Irrigation Suitability**

Irrigation suitability is evaluated using a four class system: Classes are **Excellent, Good, Fair and Poor**. Irrigation ratings are based on an assessment of the most limiting combination of soil and landscape conditions. Soils and landscapes in the same class have a similar relative suitability or degree of limitation for irrigation use, although the specific limiting factors may differ.

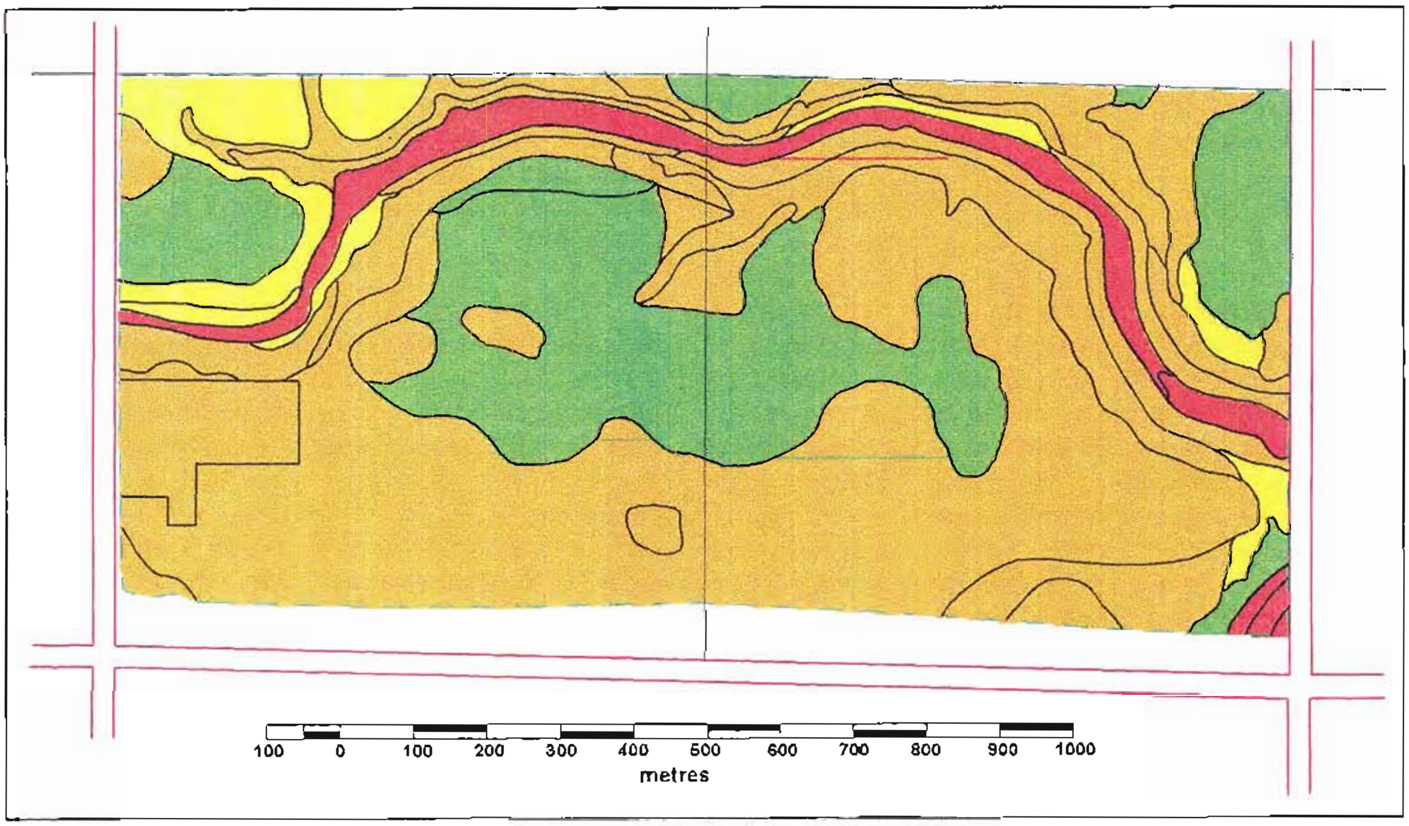
This generalized interpretive map is based on the properties of the dominant soil type and landscape feature in each polygon. The classification of the subdominant soil and landscape components and the relevant subclass limitations are indicated in the soil report. The irrigation rating does not consider water availability, water quality or economics of irrigated land use.



Irrigation Suitability Classes	Area ha	Percent of Area
excellent	2.47	2.04
good	90.88	75.02
fair	14.34	11.84
poor	13 45	11.10

Figure 9 **Potential Environmental Impact Under Irrigation**

The sensitivity or susceptibility of soils and landscapes to change resulting from irrigation should be assessed on both the irrigated land and "non target", non-irrigated areas and crops. This evaluation is intended to serve as a warning of possible change in the soil which may impact on adjacent crops or the environment. The rating provides a general assessment of relative sensitivity to change of Negligible, Low, Moderate and High. Examples of possible change to the environment are higher water tables, more persistent soil saturation, increased soil salinity and contamination of groundwater or surface water. Evaluation of soil and landscape sensitivity to potential environmental impact is separate from the initial irrigation suitability rating since it may be possible to design and manage the irrigation system to overcome these limitations.



Potential Impact	Area ha	Percent of Area
negligible	29.71	24.52
low	8.09	6.68
moderate	76.51	63.61
high	6.83	5.64

Analytical data from the inspection sites are presented in Appendix B, Tables 21 and 22 in which the data are organized by site number and series respectively.

4.4.1 Soil Texture

The proportion of individual mineral particles (sand, silt, clay) present in a soil is referred to as texture. Soil texture, or particle size distribution, strongly influences the soil's ability to retain moisture, its general level of fertility, the ease or difficulty of cultivation, permeability and susceptibility to erosion. The dominant texture on the Centre is clay loam (Sand: 38%, Silt: 33% and Clay: 29%) which contributes to good available water holding capacity, moderate to moderately slow permeability and good soil aggregation (structure) to aid in resistance against erosion.

All soils are subject to erosion if the soil surface is not covered by vegetation or crop residues. The gently sloping areas of the Ramada and Wellwood soils on the Centre are subject to erosion by water. Level and nearly level areas of all soils on the Centre are subject to wind erosion if the soil surface is exposed. Continuous cropping and minimum or zero tillage to maximize residue cover will minimize the risk of erosion. When row crops such as potatoes that produce low amounts of residue are in the crop rotation, practices such as seeding annual crops like fall rye and winter wheat will help protect the soil surface during the critical post-harvest period until the establishment of groundcover the following spring. These practices also help to maintain organic matter in the soil for improved water retention, structure and fertility.

4.4.2 Soil pH

Soil pH values express the degree of acidity and alkalinity. A summary of pH values is shown in Table 9 and the distribution of surface soil pH conditions are shown in Figure 10. Individual site data are presented in Appendix B, Tables 21 and 22. The pH values of surface soils on the Centre range from 4.8 to 7.8 (Table 22) with a mean pH of 5.9 (Table 9). This range of pH values from very strongly acid to mildly alkaline is fairly large for a small area. The more acid values occur on the deep, freely drained soils of the Ramada (RAM) and Wellwood (WWD) series and on the more strongly leached soils of the Gregg (GRG) series. Areas of the poorly drained Tadpole (TDP) soils are also leached but have neutral soil pH values. Mildly alkaline pH values occur in the imperfectly drained Oberon (OBR), Prodan (PDA), Petrel (PTR) and Crookdale (CKD) soils.

4.4.3 Organic Matter

The status of soil organic matter is important to the health and productive capacity of the soil. Soil carbon serves as an important indicator of the status of several major processes in the Biosphere which are sensitive to environmental change and related to the health of the environment. Environmental change caused by cultivation, forest fires, and changes in hydrology and climate, can alter soil moisture, soil temperature and organic matter content and result in an increase or decrease in soil carbon. Change in the carbon content of soil organic matter affects the atmosphere as well as the soil system.

The organic carbon content of the surface soils on the Crop Diversification Centre ranges from 1.41 to 5.15 percent (Table 22). The average organic matter content of the surface soil varies from 3.96 to 8.05 percent with a mean value of 6.5 percent (Table 9) (organic carbon % x 1.72 = organic matter %). These values are well within the mid to upper range for loam to clay loam textured soils in the Chernozemic Black zone of outhern Manitoba.

Soil organic carbon content varies with drainage and texture. Well drained soils on the Centre average about 3.34 percent organic carbon, imperfectly drained soils about 3.31 percent and poorly drained soils about 3.42 percent. Highest organic carbon content occurs in the well drained clay loam soils (Ramada and Wellwood series) and generally decreases in the coarser textured soils (Fairland, Glenboro and Petrel). Intermediate concentrations of organic carbon occur in depressional areas and the lower slopes which receive runoff containing sediment from adjacent upper slopes.

The total organic carbon content has been measured for the Gregg, Ramada and Wellwood soils and calculated to a depth of 1.2 m in Table 10.

Table 9. Summary of Surface Soil Properties For All Series

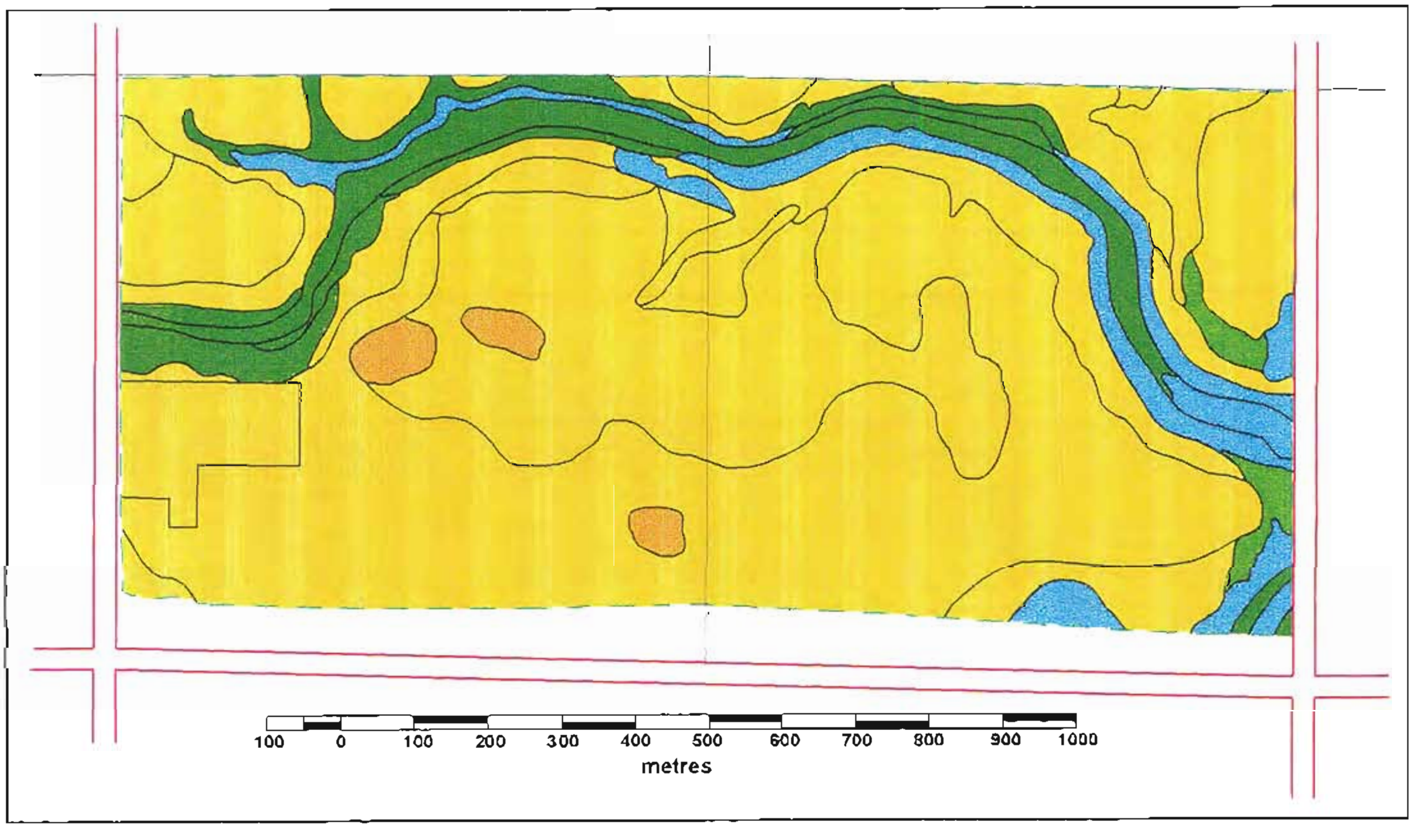
Soil Name	Series Symbol	Organic Carbon*		pH		Electrical Conductivity		Particle Size						Texture Class
								Sand		Silt		Clay		
		%	SD	Mean	SD	mS/cm	SD	%	SD	%	SD	%	SD	
Basker	BKR	2.30	---	7.2	---	0.3	---	79	---	9	---	12	---	Fine Sandy Loam
Charman	CXV	4.68	.01	6.9	.85	0.7	.07	40	4.95	30	4.24	30	.71	Clay Loam
Crookdale	CKD	3.32	---	7.3	---	1.0	---	38	---	28	---	34	---	Clay Loam
Fairland	FND	2.77	.53	6.5	.85	0.8	.34	57	10.08	21	4.44	22	5.68	Sandy Clay Loam
Glenboro	GBO	2.72	1.29	7.4	.12	1.4	.44	51	17.16	25	8.19	24	9.02	Sandy Clay Loam
Gregg	GRG	3.29	1.56	5.4	.21	0.4	.52	30	5.32	39	3.37	31	3.20	Clay Loam
Oberon	OBR	3.35	.28	7.1	.92	1.4	1.27	42	18.38	27	9.90	31	8.49	Clay Loam
Petrel	PTR	2.30	.50	7.6	.29	0.7	.35	63	6.25	19	1.53	18	5.03	Sandy Loam
Prodan	PDA	2.94	---	7.4	---	2.1	---	65	---	17	---	18	---	Fine Sandy Loam
Ramada	RAM	4.12	.87	5.7	.65	0.8	.42	32	8.51	37	5.37	31	4.24	Clay Loam
Sutton	SXP	4.53	---	7.7	---	0.4	---	33	---	35	---	32	---	Clay Loam
Tadpole	TDP	3.70	---	6.7	---	0.4	---	42	---	33	---	25	---	Clay Loam
Vordas	VDS	-	-	-	-	-	-	-	-	-	-	-	-	Fine Sandy Loam
Wellwood	WWD	3.75	.58	5.7	.62	1.0	.50	38	7.85	34	5.16	28	3.53	Clay Loam

* Organic Carbon % x 1.72 = Organic Matter%
SD = Standard Deviation

Figure 10 **Surface Soil pH**

Soil reaction or pH is a measure of the degree of acidity or alkalinity of a soil. The solubility and availability of nutrients to plants is closely related to the pH of the soil. In acid soils some nutrients may be found in such quantities to become toxic to plants whereas in soils with neutral pH, the solubility is decreased to the point at which the toxicity is corrected. In soils with alkaline pH, the solubility of certain nutrients is further decreased to the point where deficiencies of some nutrients may occur. Optimum plant growth is generally in the range of pH of 6.1 to 7.8 but many plants grow very well outside this range.

The inherent sensitivity of the soil to acidification is related to pH level and the occurrence of carbonates in surface horizons and the subsoil. Soil ecosystems containing calcareous materials have sufficient buffering capacity to neutralize incoming acidity without appreciably changing its own pH. Soils with surface pH levels of 4.6 to 6.0 and low subsoil carbonates are considered to be moderately sensitive to acidification.



pH Class	Area, ha	Percent of Area
strongly acid (5.1-5.5)	1.80	1.48
medium acid (5.6-6.0)	97.28	80.31
slightly acid (6.1-6.5)	1.38	1.14
neutral (6.6-7.3)	12.06	9.96
mildly alkaline (7.4-7.8)	8.62	7.11

Organic carbon content for the Gregg, Ramada and Wellwood soils ranges from 197.5 to 217.8 tonnes per hectare (t/ha). The total soil organic carbon to a depth of 1.2 m in these soils which cover 97.5 ha or 78 percent of the soils on the Centre, is estimated at 19 367 tonnes or an average concentration of 198.5 t/ha. These data provide a baseline estimate of the variability and distribution of organic matter and total soil organic carbon content for Black Chernozemic soils developed on fine loamy glaciolacustrine landscapes in the Parkland Region of Manitoba. The carbon content of the soils on the Centre falls within the range indicated for similar soil landscapes in Western Canada (Soil Carbon Data Base Working Group, Interim Report, January, 1993. CLBRR Cont. No. 92-179).

The overall level of soil organic matter on the farm is satisfactory but cultural practices to maintain or increase the organic matter content are required to ensure good structure, fertility and tilth. The distribution of surface organic matter in the soils is shown on Figure 11.

4.4.4 Soil Moisture Properties

Soil moisture properties were measured at six sites on the Crop Diversification Centre. Soil moisture content at field capacity, permanent wilting point and available water holding capacity were determined for a Ramada and Wellwood soil to a depth of 1.2 meters (Table 11). Hydraulic conductivity measurements are reported for the Charman, Glenboro, Ramada and Wellwood soils in Table 12. Definitions for the soil moisture properties measured follow:

> Field capacity (FC) is the maximum amount of water held in a soil, measured a few days after it has been thoroughly saturated and allowed to drain freely. This is the optimum moisture condition for plant growth.
>
> Permanent wilting point (PWP) is the water content at which plants cannot extract sufficient water to meet their requirement and therefore begin to wilt. As the moisture content of the soil declines, it becomes increasingly difficult for plants to use the remaining soil water.
>
> Available water holding capacity (AWHC) is the amount of water held in the soil that plants can use. The maximum amount of available water held in the soil is the difference between the field capacity and permanent wilting point, expressed in centimeters of water per unit depth of soil.
>
> Saturated hydraulic conductivity (Ksat) refers to the effective flow velocity in soil at unit hydraulic gradient. It is an approximation of the permeability of soil and is expressed in cm per hour.

Soil texture strongly influences important properties of the soil water regime such as available water holding capacity, hydraulic conductivity and infiltration rate. Soil water holding capacity influences use of the soils on the Centre for both dryland and irrigation agriculture. The water-holding capacity data from the Wellwood and Ramada soils and measurements from other soils in the vicinity of the Centre were used to determine the class limits for the soil water holding capacity map (Figure 12). AWHC is used as a guide for scheduling irrigation. The amount of water held in the soil is a expressed as a percent of AWHC. AWHC influences the amount of water that can be applied at one time. Irrigation is usually applied when about half the available water has been used by the crop. If a soil such as Ramada has a water holding capacity of 230 mm, and irrigation was applied at 50 percent AWHC, up to 115 mm could be added without losing any water to deep drainage. In contrast, if a soil such as the Glenboro had a water holding capacity of 120 mm and half of the available water had been used up by the crop, 60 mm of water could be added to the soil. There would be no point in adding more water because anything in excess of 60 mm would be lost to deep drainage.

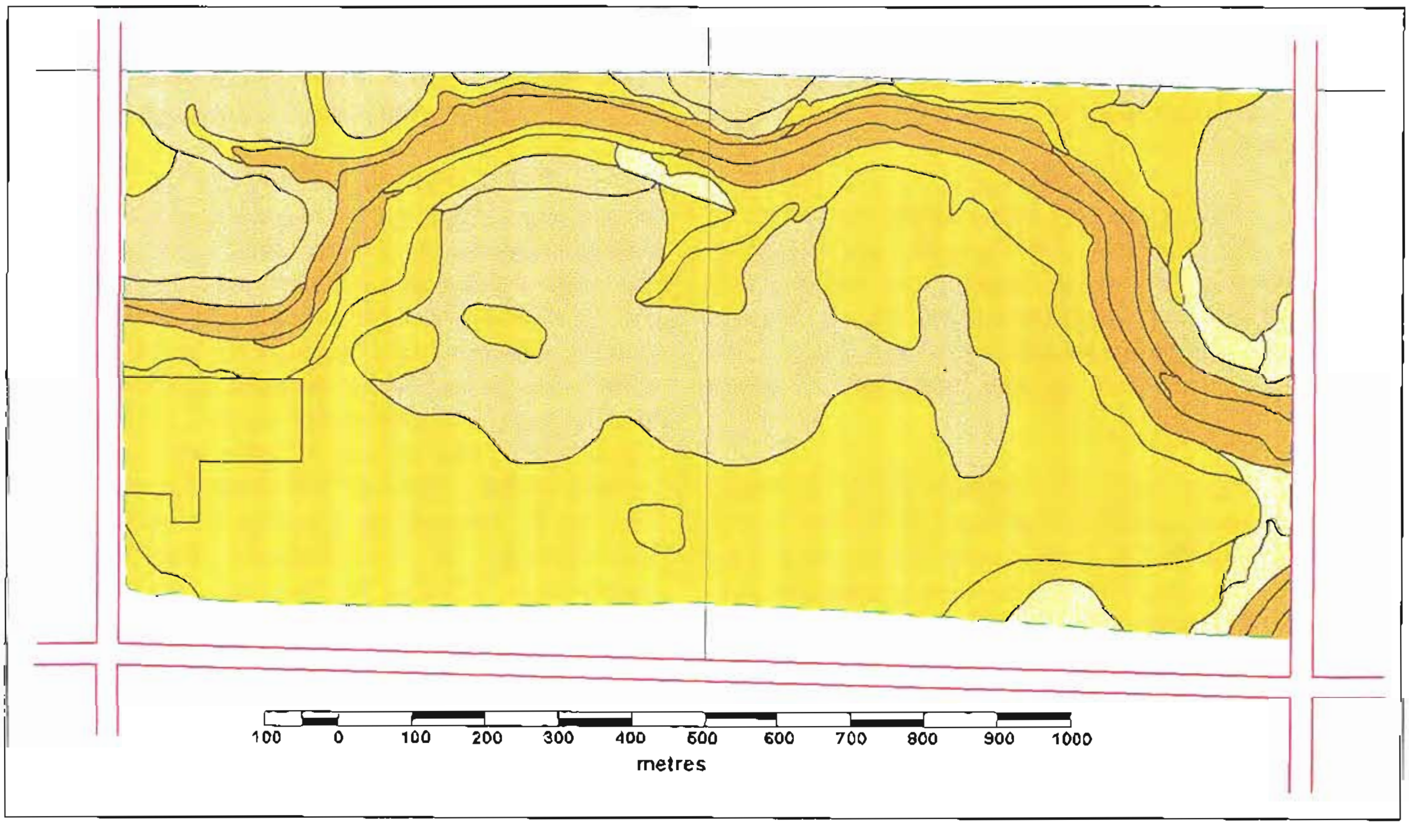
The risk of moisture movement or leaching from the soil surface to depths below the rooting one is a function of soil texture and stratigraphy of the subsoil materials. A greater degree of protection against deep leaching is provided by soils with a large water-holding capacity. A greater degree of protection against deep leaching is provided by soils with a large water-holding capacity.

Table 10. Organic Carbon Content of the Gregg, Ramada and Wellwood Soils

Soil Series	Horizon	Depth	Texture	Bulk Density g/cc	Organic Carbon %	Organic Carbon Content tonnes/hectare
Gregg(GRG)	Ap	0-15	L	1.05	4.46	70.25
	Ah	15-36	CL	1.31	2.00	55.02
	Ahe	36-59	CL	1.29	0.99	29.37
	Aeg	59-80	CL	1.46	1.02	31.27
	Btg	80-98	CL	1.55	0.95	25.95
	Btg - Cg	98-120	CL	1.59	0.45	15.74
Total Organic Carbon to 1.2 m						**227.60**
Ramada (RAM)	Ap	0-14	CL	1.02	4.55	64.97
	Ah	14-29	CL	1.23	3.03	55.90
	Bm	29-57	SiCL	1.32	1.01	37.33
	Ck_1	57-90	SiCL	1.29	0.52	22.14
	Ck_2	90-120	SiCL	1.27	0.48	18.29
Total Organic Carbon to 1.2 m						**198.63**
Wellwood(WWD)	Ap	0-14	CL	1.08	4.18	63.20
	Ah	14-29	CL	1.27	3.10	59.06
	Bm	29-52	SiCL	1.29	1.31	38.87
	Cca	52-78	SiCL	1.28	0.71	23.63
	Ck	78-110	CL	1.28	0.29	11.88
	2Ck	110-120	MS	1.64	0.05	0.82
Total Organic Carbon to 1.2 m						**197.46**

Figure 11 **Soil Organic Matter**

Soil organic matter plays a key role in soil quality. It is a source of, and a sink for plant nutrients and is important in maintaining soil tilth, aiding the infiltration of air and water, promoting water retention, reducing erosion and controlling the efficacy and fate of applied pesticides. The status of soil organic matter is important to the health and productive capacity of the soil The concept of sustainable agriculture implies that a soil must sustain its ability to produce crops over an extended period of time. Therefore, assessment of changes in soil organic matter is important in evaluating soil quality. The level of organic matter in the soils on the Crop Diversification Centre falls well within the upper range for loam to clay loam textured soils in the Chernozemic Black zone of southern Manitoba.



	Organic Matter Content, 0-20 cm %	Area ha	Percent of Area
	4.5 - 5 5	3.59	2.96
	5 6 - 6.5	67.75	55.92
	6.6 - 7.5	35.84	29.59
	7.6 - 8.5	13.96	11.53

Sandy soils have a small water-holding capacity which may be readily exceeded by a particular precipitation event. When this occurs, moisture can move freely below the rooting zone and down to the water table with time. Coarse-loamy and fine-loamy soils have a larger water-holding capacity than sand provide greater protection against moisture infiltrating below the rooting zone.

Soil texture and stratigraphy influence hydraulic conductivity which governs the rate at which saturated soil transmits water. Saturated hydraulic conductivity determines the drainability of the 1.2 to 3 m zone and hence the irrigation suitability and potential for deep infiltration. Saturated hydraulic conductivity data for selected soils on the Centre indicate the saturated flow increase dramatically in the underlying sandy strata (Table 12).

The intake rate refers to the movement of water from the surface into and through the soil. It is a function of texture, stratigraphy and structure which influence infiltration and percolation. The soil layer with the lowest transmission rate, either at the surface or below it, usually determines the intake rate.

Soils with thin surface layers of loamy sediments underlain by sand such as Wellwood soils do not provide the same degree of protection from deep infiltration as would the finer textured Ramada soils. Similarly, the thin, coarse-loamy surface sediments of the Glenboro soil is underlain by sandy strata which do not have as large a water holding capacity as the deeper coarse-loamy sediments of the Fairland soil.

4.4.5 Soil Drainage and Groundwater Hydrology

Surface drainage on the Centre varies from well to moderately well in areas of level to nearly level terrain to poorly and very poorly drained in depressional areas associated with the drainage channel. The distribution of well to moderately well, imperfect and poorly drained soil conditions is shown on Figure 13. Well drained soils account for 82 percent of the area, imperfectly drained soils cover 7 percent, poorly drained soils, 10 percent and very poorly drained soils of the Marsh complex subject to prolonged inundation comprise the remainder (0.8 percent).

Most of the precipitation and snowmelt on the Centre is retained in the local landscape where it is utilized for crop growth. Rain and snowmelt tend to infiltrate the surface soil immediately with virtually no overland flow. There is some redistribution of winter precipitation in the landscape due to drifting of snow into the drainage channel and during spring thaw, surface runoff may occur to a limited extent when the subsoil is frozen. Water from snowmelt accumulates in the drainage channel, eventually infiltrating to groundwater storage. The lower lying portion of the drainage channel is characterized by areas of shallow open water associated with emergent and aquatic marsh vegetation. Removal of water from such depressions is largely through evaporation and seepage.

The Centre is located in a regional groundwater recharge area (see Section 1.4). Research has shown that pedologic and hydrologic processes interact in the environment to influence soil profile characteristics and soil distribution. Water movement in and through the soil is directly related to two distinct features of hydrology: gradient and hydraulic conductivity. Soil profile characteristics can be used to infer the local water regimes in the landscape. The depth and degree of leaching as indicated by the type and sequence of soil horizons help to interpret local shallow groundwater activity. For example, leached and eluviated profiles result from infiltration and downward water flow through the soil. In contrast, non-leached profiles, that is soils which contain lime carbonate and soluble salts generally indicate relatively little infiltration.

The distribution of the depth to carbonate classes is shown on Figure 14. A relative measure of the potential for water to infiltrate the different soil-landscapes on the Centre is indicated by the depth at which free calcium carbonate occurs in the soil. Based on these data, approximately 8 percent of the soils on the Centre are considered to have a high relative potential for water to infiltrate to the subsoil and/or the groundwater, about 64 percent is classed as having a moderate potential and 28 percent would have a low potenital.

Table 11. Physical, Chemical and Moisture Retention Properties of Soils

Soil Series	Horizon	Depth cm	OM %	CaCO3 %	Sand %	Silt %	Clay %	Texture Class	BD g/cc	FC %	PWP %	AW mm	AW % vol
Ramada	Ap	00 - 14	7.83	0	29	41	30	CL	1.02	30.4	12.0	26	19
	Ah	14 - 29	5.22	0	23	56	31	CL	1.23	26.4	11.1	29	19
	Bm	29 - 57	1.74	0	26	45	29	CL	1.32	24.9	9.5	57	20
	Ck1	57 - 90	0.90	15.1	2	69	29	SICL	1.29	25.0	10.0	63	19
	Ck2	90 - 120	0.83	12.4	1	60	39	SICL	1.27	28.2	13.2	57	29
Total Available Water												**232**	
Wellwood	Ap	00 - 14	7.19	0	36	34	30	CL	1.08	28.8	11.0	27	19
	Ah	14 - 29	5.33	0	27	41	32	CL	1.27	27.4	11.1	31	21
	Bm	29 - 52	2.26	0	20	49	31	CL	1.29	25.0	10.6	43	19
	Cca	52 - 78	1.22	18.8	7	55	38	SICL	1.28	27.0	13.1	46	18
	Ck	78 - 110	0.50	13.0	22	54	24	SIL	1.28	26.2	8.0	74	23
	2Ck	110 - 120	0.09	7.0	90	5	5	FS	1.64	7.4	2.5	8	8
Total Available Water												**229**	

OM = Organic matter; BD = Bulk density; FC = Field capacity; PWP = Permanent wilting point; AW = Available water:

Table 12. Summary of Saturated Hydraulic Conductivity (Ksat cm/hr) Measurements

QR	SN	TP	RG	H	SOIL SERIES	SURFACE CONDITION	HORIZON	D_T cm	D_B cm	VC %	CS %	MS %	FS %	VF %	S %	SI %	C %	Text	N	K_ave cm/hr	K_Low cm/hr	K_High cm/hr
SW	8	11	14	W	Gregg	Tilled	Ahe	15	25	0	0	9	7	13	29	40	31	CL	2	0.44	0.25	0.62
							Bt1	38	48	0	0	0	0	2	2	59	39	SICL	3	0.96	0.77	1.06
							Bt2	60	70	0	0	0	0	2	2	55	43	SIC	1	0.13		
SE	8	11	14	W	Glenboro	Tilled	Ap	5	15	0	0	21	40	8	69	16	15	FSL	3	1.45	1.00	1.74
							Ck	40	45	0	0	50	40	5	95	3	2	MS	3	114.57	94.50	146.10
SW	8	11	14	W	Ramada	Tilled	Ah	12	22	0	0	6	4	13	23	46	31	CL	3	2.91	1.50	3.74
							Bm	37	47	0	0	5	4	17	26	45	29	CL	3	2.04	1.52	2.99
							Ck1	65	75	0	0	0	0	2	2	69	29	SICL	2	2.37	2.24	2.49
							Ck2	115	125	0	0	0	0	1	1	60	39	SICL	2	0.84	0.62	1.05
SW	8	11	14	W	Ramada	Canola	Ah	10	20	0	0	5	8	15	28	40	32	CL	2	1.81	1.74	1.87
							Bm	25	35	0	0	5	4	17	26	45	29	CL	2	3.55	2.37	4.73
							Ck	50	60	0	0	0	0	2	2	69	29	SICL	2	4.61	3.24	5.98
SE	8	11	14	W	Wellwood	Barley	Ah	7	17	0	0	4	9	14	27	41	32	CL	3	2.91	1.12	4.49
							Bm	25	35	0	0	3	5	12	20	49	31	CL	3	3.22	2.94	3.61
							Ck	47	57	0	0	0	0	7	7	55	38	SICL	3	3.41	2.62	4.14
							2Ck	111	116	0	0	15	65	10	90	5	5	FS	3	76.34	67.89	90.67

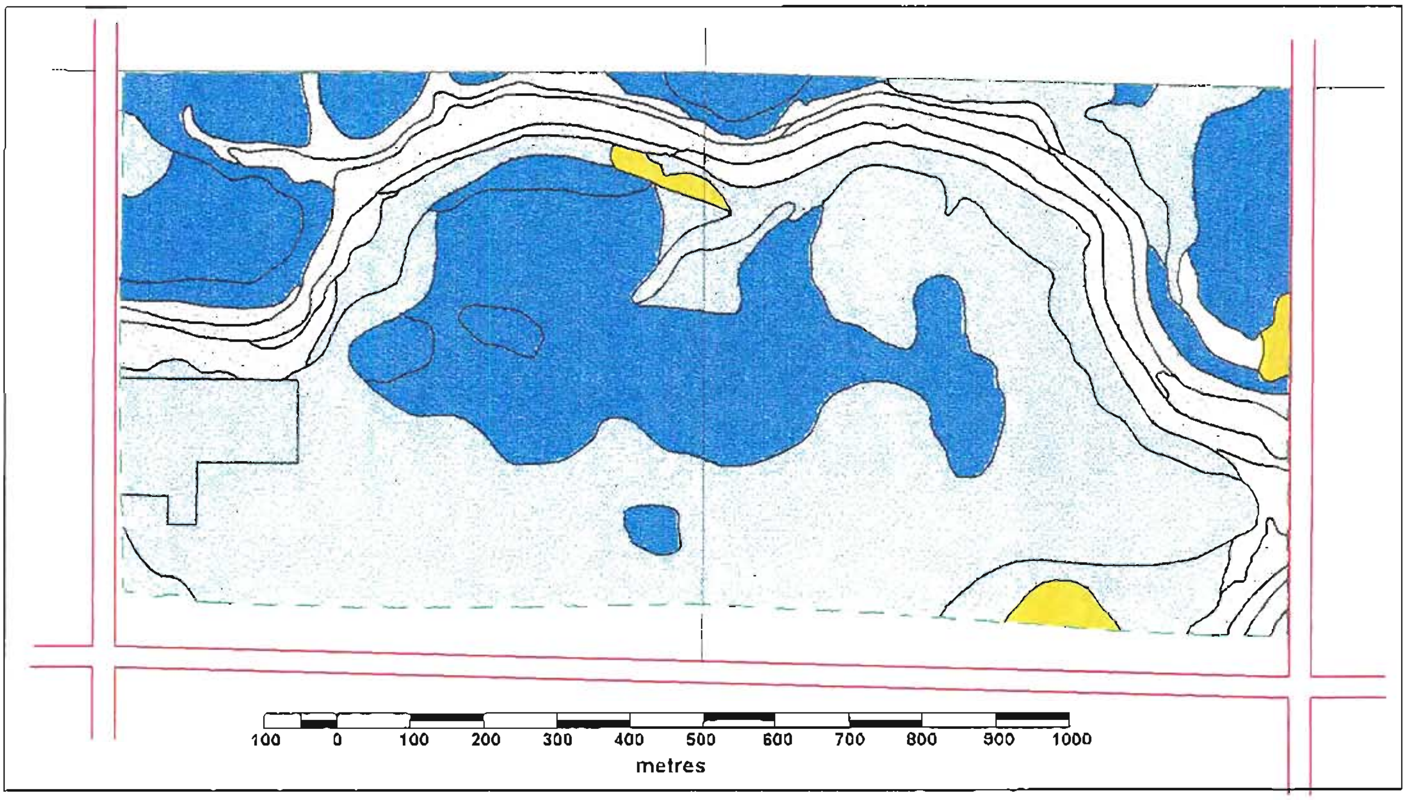
QR = Quarter; SN = Section; TP = Township; RG = Range; H = Heading; D_T = Upper depth; D_B = Lower depth; VC = Very coarse sand; CS = Coarse sand; MS = Medium sand; FS = Fine sand; VF = Very fine sand; S = Total sand; SI = Total silt; C = Total clay; Text = Textural class; N = Number of measurements:

Figure 12 **Available Water Holding Capacity**

The available water holding capacity (AWHC) of soil influences land use for both dryland and irrigation agriculture. Under rainfed agriculture and climatic conditions of moisture deficit, crop growth and agricultural production are limited by water. The AWHC of various soils determines to a large extent their ability to resist seasonal drought and hence their evaluation for dryland agriculture.

Available water holding capacity influences irrigation management in at least two ways. AWHC limits water deficits representing the difference between growing season demand by the crop and the sum of growing season precipitation and the soil moisture stored at planting time. AWHC thus affects irrigation scheduling as well as the amount of water that can be applied at any one time.

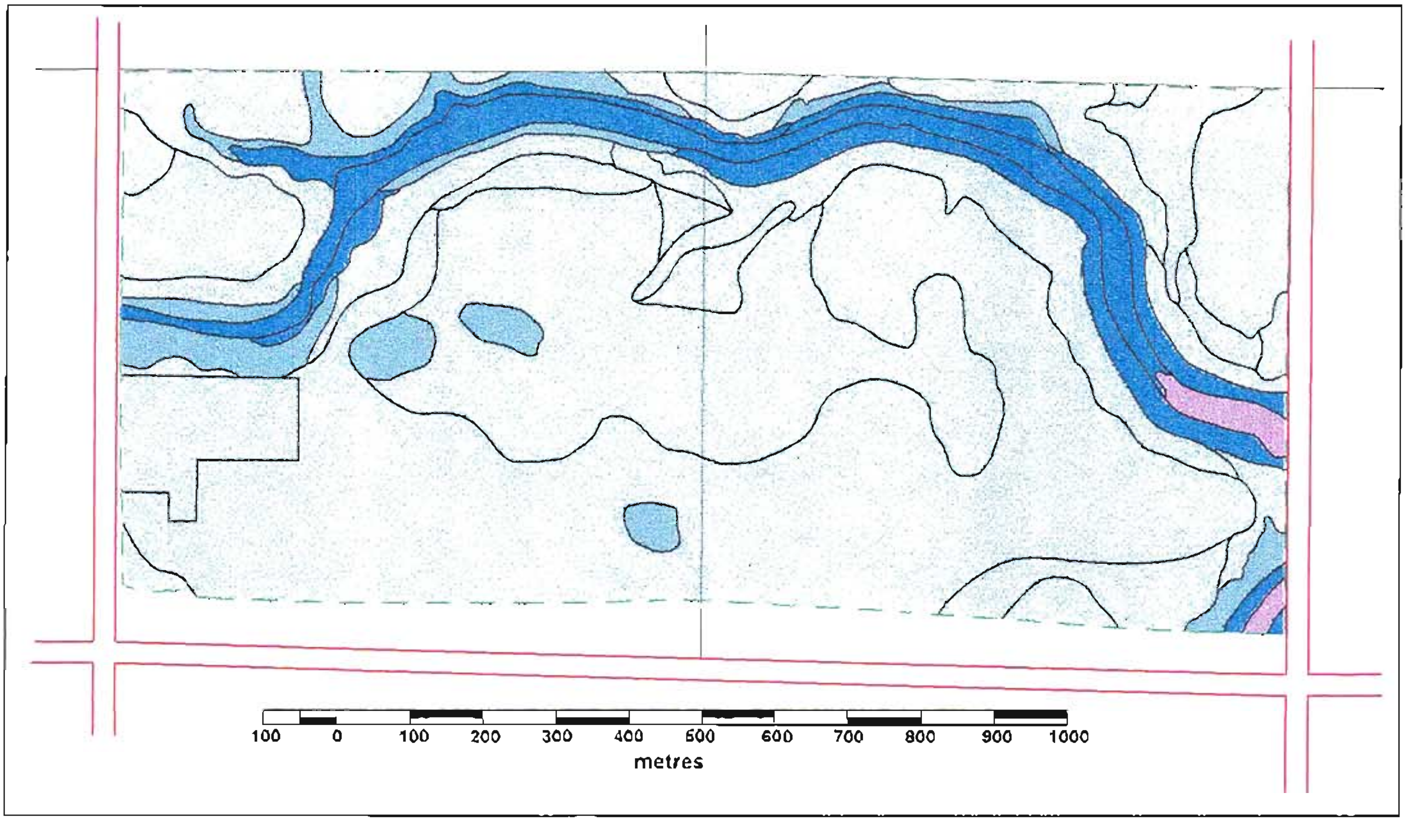
The AWHC of soil also influences the risk of moisture movement or leaching from the soil surface to depths below the rooting zone. A greater degree of protection against deep leaching is provided by soils with a large water-holding capacity. A smaller soil AWHC may be readily exceeded by a particular precipitation event so that moisture moving below the rooting zone will continue down to the water table with time.



Available Water Capacity (mm) in: 0-60 cm of soil	0-120cm of soil	Area, ha	Percent of Area
120	240	37.66	31.07
120	200	61.43	50.82
80	195	1.38	1.14
73	123	1.29	1.05
unclassified (imperfectly to poorly drained soils affected by moderate to high water tables)		19.11	15.81

Figure 13 **Soil Drainage**

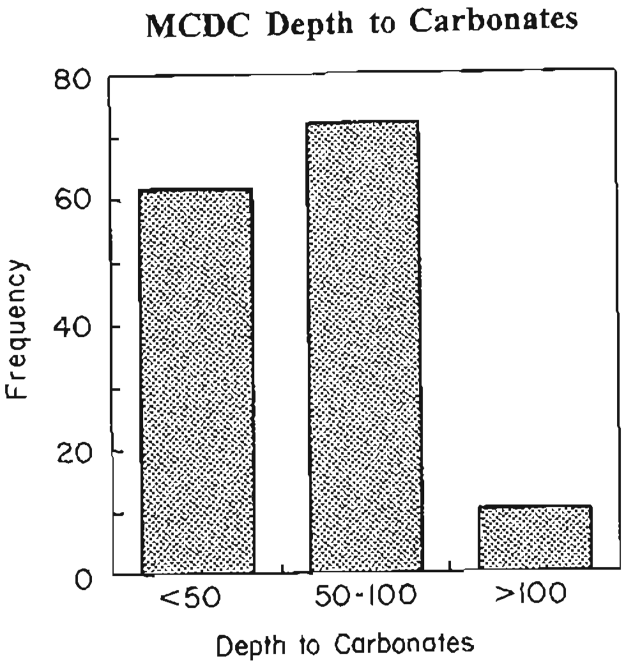
Soil drainage refers to the frequency and duration of periods when the soil is free of saturation. Four soil drainage classes are indicated on this map. Well drained - excess water is removed from the soil, flowing downward readily into underlying pervious material or laterally as subsurface flow; Imperfectly drained - water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. The source of moisture includes precipitation and/or groundwater; Poorly drained - water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time when the soil is not frozen. The main water source is subsurface flow and/or groundwater in addition to precipitation: Very poorly drained - water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time that the soil is not frozen. Excess water is present in the soil throughout most of the year.



Soil Drainage Classes	Area ha	Percent of Area
good	100.22	82.73
imperfect	7.47	7.47
poor	12.44	10.27
very poor	1.01	0.83

The frequency of occurrence of the soils in each class is summarized on Figure 15.

Figure 14. Frequency of Occurrence of Soils in Depth to Carbonate Classes



Most soils on the Centre are characterized by net **infiltration** of water as indicated by soil development and depth to free calcium carbonate. A deeper carbonate-free zone in soils developed from calcareous parent materials usually results from a greater volume of water passing through the soil profile and a greater leaching potential. Soils included in this group are the well drained Fairland, Glenboro, Ramada and Wellwood soils and the strongly leached Gregg soils. These soils are affected by leaching of soluble constituents from the soil profile and represent sites of potential groundwater recharge. The Gregg soils exhibit a greater depth of profile development and leaching resulting from greater downward movement of water through the soil.

In contrast, **exfiltration**, that is, upward water movement and evaporation from the soil surface occurs to a very limited extent on the soils on the Centre. These non-leached soils often develop as a thin band on the lower slopes adjacent to the drainage channel. In this landscape position, much of the precipitation and snowmelt runs off and the water table is closer to the surface permitting a net upward movement of moisture. Diagnostic features of these areas include imperfectly and poorly to very poorly drained soils with shallow profiles which may be carbonated to the surface. Carbonated soils of the Prodan, Petrel, Basker and Sutton series are in this group.

The degree of leaching in landscapes characterized by imperfectly drained Crookdale, Charman, Oberon, Prodan and Petrel soils is variable as some of the soils lack a B horizon whereas others are weakly calcareous to the surface. Similarly, the poorly drained Basker, Sutton and Vordas soils lack any B horizon development and in addition, are variably carbonated to the surface due to the influence of a high water table. Some soils in lower landscape positions however, particularly those associated with the drainage channel are affected by removal of carbonate to a greater depth. The soil morphology in these landscape positions results from a greater leaching potential and also indicates sites of potential groundwater recharge.

The very poorly drained soils of the Marsh complex have a persistent high water table usually above the soil surface. Although the watertable in these soils remains above the surface, they contribute to groundwater recharge because the water table intercepts the upper boundary of the aquifer.

4.4.6 Risk for Subsoil and/or Groundwater Contamination

The potential for infiltration and leaching to occur in this landscape is estimated in terms of **relative risk**. Evaluation of the potential for subsoil and/or groundwater contamination requires careful interpretation. The possibility for leaching of chemicals and fertilizer to the subsoil and groundwater should be considered in the context of proximity to a potable aquifer and the feasibility for remediation if excess chemicals accumulate in the soil environment. Pedologic and hydrologic processes influence the impact that different kinds of land use may have on the environment.

The degree of difficulty or feasibility of protecting the soil and groundwater or of applying remedial measures to reclaim contaminated soil is related to the degree of risk, ie., greatest on the high risk areas in the landscape. Given this scenario, the high risk soils are potential sites for monitoring the impact of land use on the subsoil and/or groundwater environment.

On a regional scale, the entire landscape on the Centre is described hydrologically as a groundwater recharge area characterized by slow to rapid downward hydraulic gradients. As the aquifer is unconfined at the surface, the groundwater is susceptible to influence from the soil, water and air above the aquifer. The sensitivity or risk for subsoil contamination by infiltration of surface waters varies with soil conditions and position in the landscape. The thin veneer of fine loamy surface soils on the Centre provides a measure of protection or buffer between the soil surface and the groundwater, but there are local soils in the landscape which act as focal areas for recharge to occur. In addition, the sand substrate underlying the soils on the Centre occurs within 1.2 metre of the surface in about 36 percent of the area. The presence of these more permeable sand materials close to the surface increases the risk for movement of water through the soil and to the water table. Based on these assumptions, the relative risk for subsoil contamination is estimated in Table 13 and the areal extent of the soil conditions affecting this risk is shown in Figure 16.

The kind and degree of soil profile development is a function of the local gradients in the landscape and the hydraulic conductivity of the soil parent material. Using the relative degree of leaching in the soil profile as an indicator of a soils susceptibility to surface water infiltration, it is possible to estimate the effective area of local recharge to the groundwater. Research has shown that in loamy textured glaciolacustrine landscapes, eluviated soils are the most likely sites for local groundwater recharge whereas leached and weakly leached soils are primarily sites of soil water replenishment. Moist, non-leached, salinized and carbonated profiles are typical of soils where evaporation exceeds infiltration.

Level and very gently sloping positions of the landscape are characterized by little or no runoff with most of the incoming precipitation infiltrating the soil. Accumulation of excess water in the micro-depressions occupied by the Gregg soils and the lower lying depressional areas associated with the drainage channel results in greater leaching potential. Leached soils in these depressional areas occupy 12.6 percent of the area and present the highest risk for infiltration of chemical and/or fertilizer to the subsoil and the groundwater. A moderate risk of infiltration occurs on the level to very gently sloping landscapes, particularly where the underlying sand substrate is between 60 and 120 cm of the surface (51 percent of the soils on the Centre). Portions of the landscape where the sand is closer to the surface and where the carbonates are leached from the upper sand strata indicate greater sensitivity to leaching. The risk of infiltration is low for well to imperfectly drained soils on level to gently sloping landscapes in which the sandy strata occur below 120 cm of the surface (36 percent of the area). Non-leached, carbonated soils occur as minor inclusions with other soil types on the Centre and represent a relatively low risk for infiltration to occur to the subsoil.

4.4.7 Erosion Status and Risk Assessment

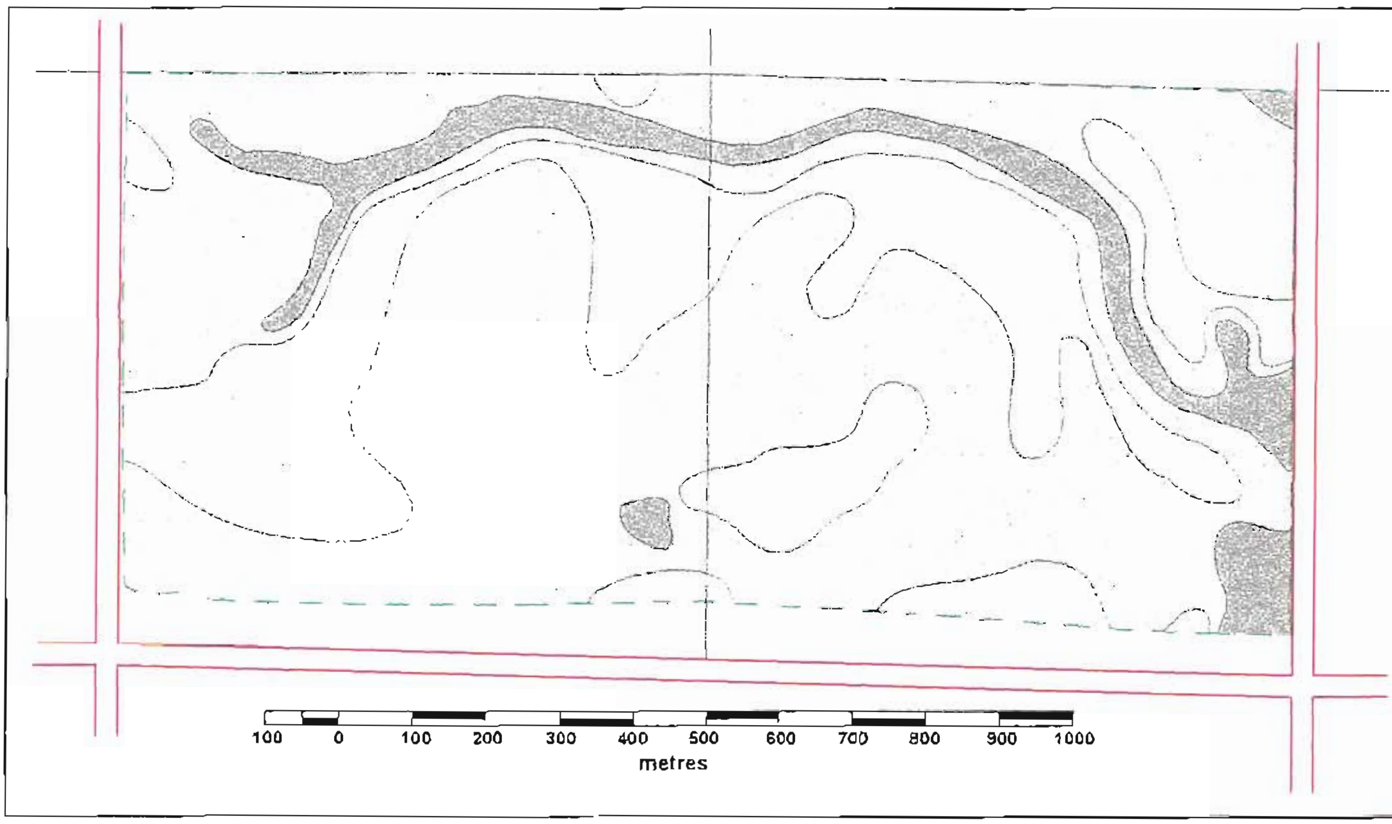
Erosion is a process in which soil is moved from one area to another by wind and water. Erosion occurs naturally on cropland, forest land and in urban areas, but can be accelerated by human activity such as agriculture, forestry and urban development to levels that cause environmental and economic problems (Wall et al., 1995).

The observed extent and severity of water erosion on the Centre is minimal because of the dominance of nearly level terrain. The risk of soil erosion by water is greatest in sloping landscapes in which soil permeability restricts infiltration and contributes to runoff of precipitation and snowmelt. Approximately 8 hectares of very gently and gently sloping soils (6.5 percent of the area) are characterized by slight erosion in which up to 25 percent of the original A horizon may have been removed. Most soils with this degree of erosion are not significantly different in use capabilities and management requirements from noneroded soil. The risk of water erosion on the Centre is estimated to be low to moderate.

Figure 15 **Depth to Carbonates**

The zone or thickness of soil from which carbonates have been leached as part of natural soil development provides an indication of the degree to which water infiltrates through the soil. Leaching of soluble constituents from the surface soil proceeds when infiltration (downward water flow) exceeds exfiltration (upward water movement and evaporation from the soil surface). Leached and eluviated soil profiles result from infiltration and downward water flow through the soil. In contrast, non-leached profiles, that is soils which contain lime carbonate and soluble salts generally indicate relatively little infiltration.

Soils in which carbonates are removed to a greater depth indicate greater sensitivity to water movement and infiltration of agrochemicals (fertilizers, herbicides and pesticides) to the subsoil and the groundwater. Non leached soils or soils in which carbonates are removed to a shallow depth are less sensitive to deep infiltration below the rooting zone into the subsoil.



Depth to Carbonates, cm	Area ha	Percent of Area
<50	33.60	27.74
50-100	77.58	64.04
>100	9.96	8.22

Early research into the causes of wind erosion in Canada and the United States resulted in the development of a Wind Erosion Equation and eight Wind Erodibility Groups (WEG) made up of soils that have similar properties affecting their resistance to soil blowing if cultivated. Each WEG is defined on the basis of soil properties such as texture, structure and calcareousness which equate with an estimated annual soil loss (tonnes/hectare) from a hypothetical, isolated, smooth, wide, unsheltered and bare field.

Although no significant evidence of wind erosion was observed during the detailed survey, the estimated risk of wind erosion for the soils on the Centre ranges from negligible to low and moderate. Soil properties measured during the course of the detailed survey are used to place the soils in appropriate WEG's in Table 14. The estimated risk of wind erosion (Table 14 and Figure 17) is based on the inherent susceptibility of the soils on the Centre to wind erosion. Assuming that the soils are are bare (without vegetation) and that they are not under conservation practices, approximately 85 percent of the soils are slightly erodible or at low risk of wind erosion and 2.4 percent of the area is at a moderate risk of erosion. An additional 11 percent of the soils are poorly to very poorly drained and usually not subject to wind erosion.

The actual erosion risk will decrease markedly according to cropping and tillage practices, crops grown and how residues from the previous crop are handled. Soil losses due to wind erosion are most likely to occur during a brief "window" of time in the spring following snowmelt. The risk is greatest following seeding and prior to germination of the crop.

Soils growing low residue-producing crops such as potatoes are at much greater risk to wind erosion than soils under cereal and oilseed production. Conservation measures with fall seeded cover crops, shelterbelt planting, strip cropping and crop residue management all help to protect the soil surface and reduce the potential for soil loss.

Annual limits of soil loss tolerance vary with individual soils and their properties. Soil loss tolerance is the maximum allowable soil loss that can occur and still maintain the long term productivity of the soil. Calculation of an annual soil loss tolerance must consider soil properties, soil depth, topography and prior erosion. The annual soil loss should recognize management concerns for the long term sustained use of the soil resource and the environment.

Table 13. Relative Sensitivity for Subsoil and/or Groundwater Contamination

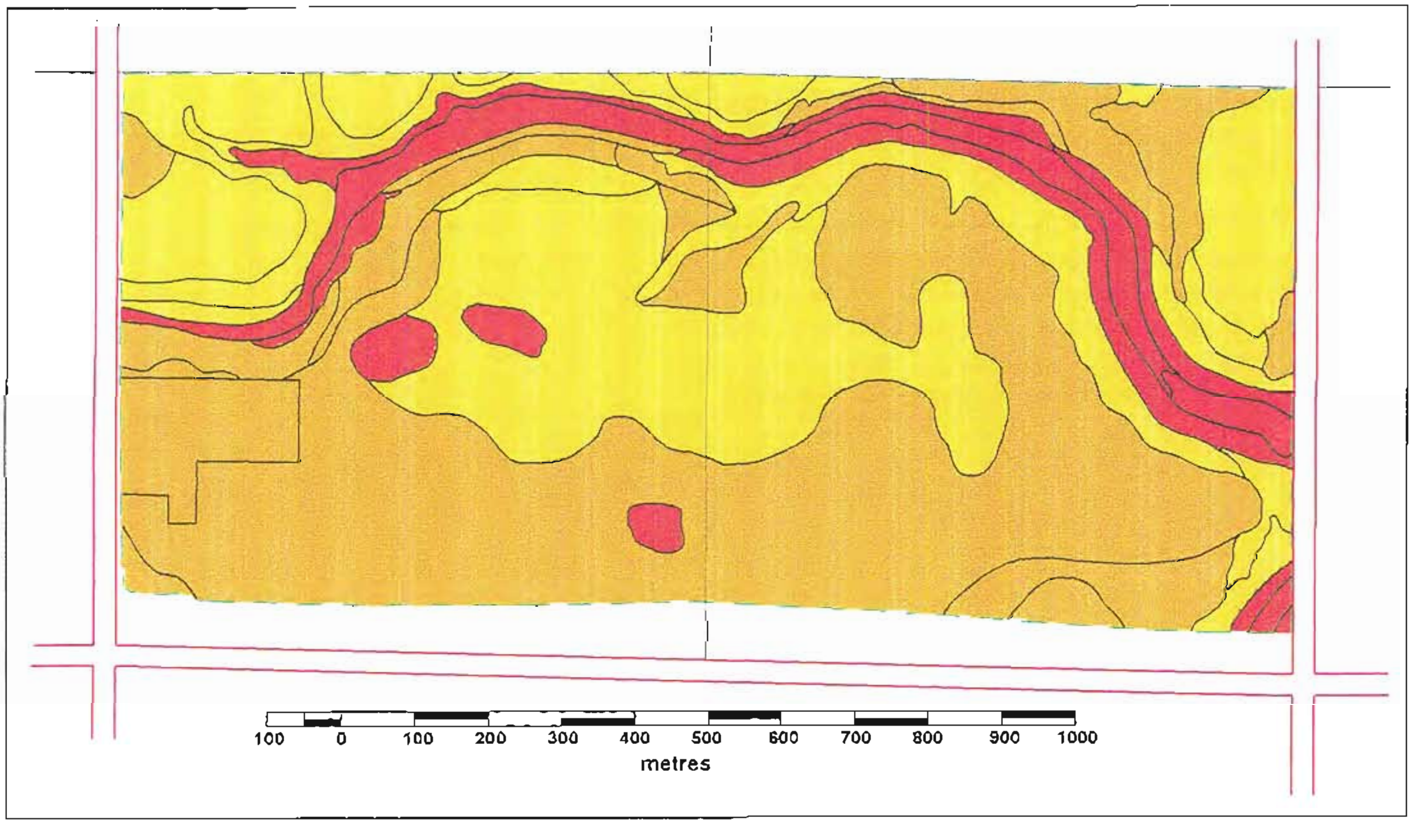
Soil Conditions	Relative Sensitivity	Extent	
		Hectares	%
Leached and eluviated soils; lower slopes and depressions: Gregg (GRG), Vordas (VDS), Tadpole (TDP), Sutton (SXP), Basker (BKR), Marsh (MHC)	High	15.3	12.7
Moderately to weakly leached, well to imperfectly drained soils underlain by sand strata from 60 to 120 cm; level to very gently sloping landscapes: Wellwood (WWD), Oberon (OBR), Crookdale (CKD), Glenboro (GBO), Petrel (PTR)	Moderate	62.2	51.7
Moderately to weakly leached, well to imperfectly drained soils underlain by sand strata below 120 cm; level to gently sloping landscapes: Ramada (RAM), Charman (CXV), Prodan (PDA), Fairland (FND), Wellwood (WWD) gently sloping phase and Oberon (OBR) gently sloping phase	Low	42.7	36.4
Non-leached, carbonated imperfectly and poorly drained soils in lower slopes and depressions: (These soils occur as minor inclusions with soils of the Oberon, Crookdale, Petrel, Charman, Prodan, Vordas, Tadpole, Sutton and Basker series and could not be mapped at this scale)	Very low	---	---

Figure 16 Sensitivity for Subsoil and/or Groundwater Contamination

Evaluation of the soils ability to regulate water movement and retention in the environment must consider soil characteristics as well as regional and local hydrology.

Landscapes characterized by regional groundwater recharge have increased potential for water movement down through the soil to the groundwater. Leached soil profiles resulting from net infiltration and occurring in landscapes characterized by groundwater recharge are most sensitive to deep infiltration of water and potential for movement to the groundwater.

Because agriculture is carried out on large areas of land, often situated over groundwater aquifers, there is a risk for agrochemicals to enter the groundwater. The potential for agrochemicals (e.g., nutrients, pesticides) to enter the groundwater is greater on soil types where intensive cropping results in substantial use of chemicals and where concentrated production of livestock results in high rates of manure being applied to the soil.



Sensitivity Classes	Area ha	Percent of Area
very low	-	-
low	45.19	37.31
moderate	60.70	50.11
high	15.25	12.58

Table 14. Estimated Risk of Soil Loss from Wind Erosion

Risk Class and Wind Erodability Group (WEG)	Description of Wind Erodibility Groups (WEG)				Representative Soils	Areal Extent	
	Dominant Soil Textural Class	Dry Soil Aggregates >0.84 m %	Soil Ridge Roughness Factor *	Inherent Soil Erodibility T/ha/Year**		Hectares	%
Negligible Risk; WEG 8	Very wet soils, undifferentiated texture usually not subject to wind erosion	-	-	-	Basker (BKR) Marsh (MHC) Sutton (SXP) Tadpole (TDP) Vordas (VDS)	13.5	11.1
Low Risk; slightly erodible; WEG 6	Non-calcareous loams and silt loams with more than 20% clay content; non-calcareous clay loams with less than 35% clay content	45	0.75	108	Charman (CXV) Crookdale (CKD) Gregg (GRG) Oberon (OBR) Prodan (PDA) Ramada (RAM) Wellwood (WWD)	103.3	85.2
Moderate Risk; moderately erodible; WEG 5	Non-calcareous loams and silt loams with less than 20% clay content, sandy clay loams; sandy clay	40	0.75	125	Fairland (FND) Glenboro (GBO) Petrel (PTR)	4.5	3.7

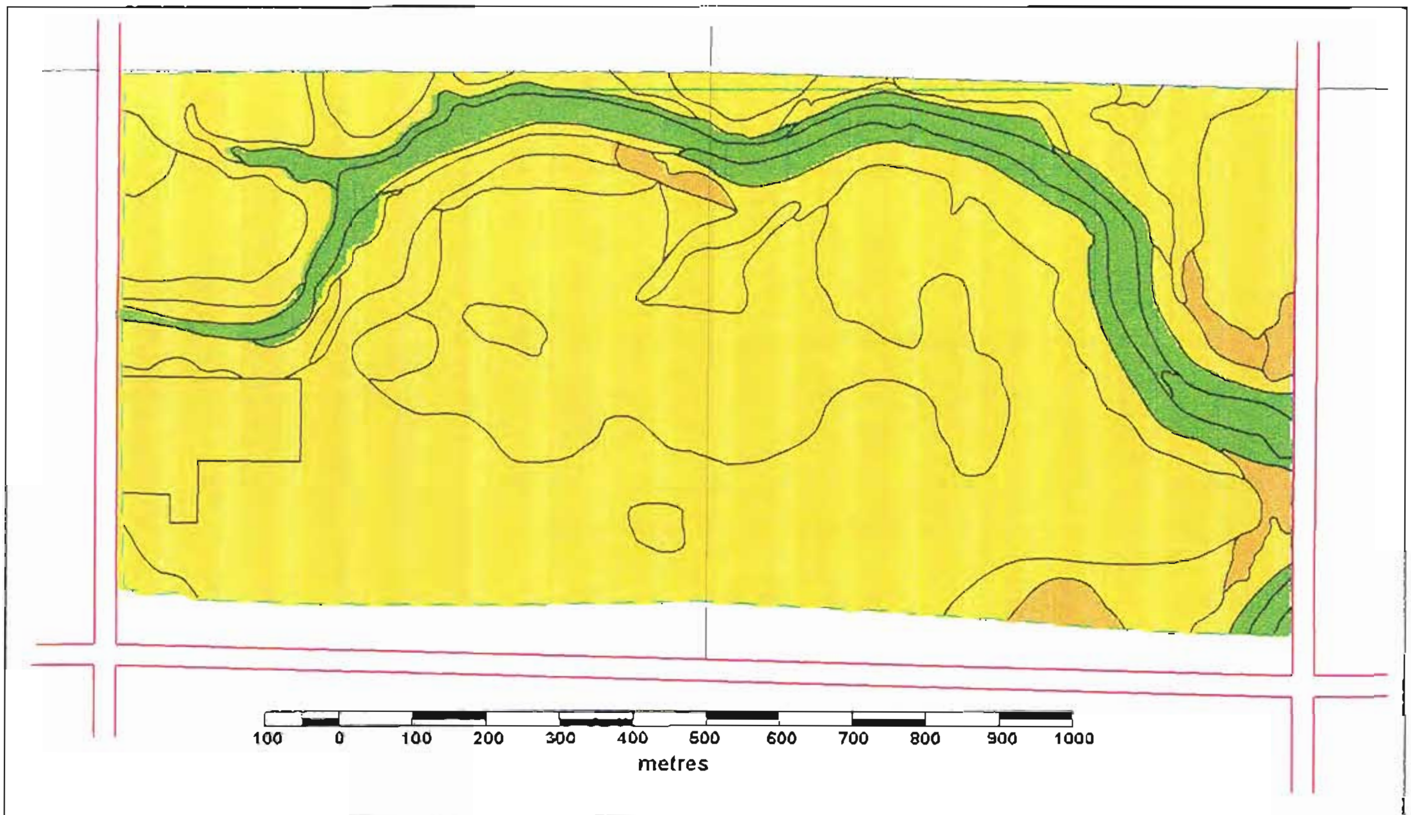
* Soil ridge roughness factor during critical spring period: 1.0 = smooth; 0.75 = semiridged; 0.5 = ridged

** Wind erodibility index is the average annual soil loss that would occur from an isolated, smooth unsheltered, wide and bare field at Gardon City, Kansas.

Figure 17 **Wind Erosion Risk**

Wind erosion is the process by which soil is moved from one area and deposited in another. Erosion occurs naturally in all landscapes but can be accelerated by human activity such as agriculture, forestry and urban development to levels that cause environmental and economic problems. Soil erosion by wind occurs wherever the soil is loose, dry and finely granulated; the soil surface is smooth and vegetative cover is sparse or non-existent; the fields are large with little or no obstruction to reduce the force of the wind and the velocity of the wind is of sufficient magnitude to initiate soil movement.

Surface soil properties such as texture, structure and calcareousness affect the inherent susceptibility of soil to wind erosion. Assessment of wind erosion risk assumes that the soils are bare (without vegetation) and not under conservation practices. Climatic considerations such as available moisture at the soil surface and wind speed and direction during the critical spring period must be considered in assessing soil erosion risk. Cropping and tillage practices will significantly reduce this risk depending on soil type, crop rotation and soil conservation practices.



		Area, ha	Percent of Area
(green)	negligible	13.45	11.10
(yellow)	low	104.75	86.48
(orange)	moderate	2.94	2.42
(red)	severe	-	-

APPENDIX A

GUIDES FOR EVALUATING AGRICULTURAL CAPABILITY AND IRRIGATION SUITABILITY

Table 15. Description of the Agricultural Capability Classes

Class 1

Soils in this class have no important limitations for crop use. The soils have level or gently sloping topography; they are deep, well to imperfectly drained and have moderate water holding capacity. The soils are naturally well supplied with plant nutrients, easily maintained in good tilth and fertility; soils are moderately high to high in productivity for a wide range of cereal and special crops.

Class 2

Soils in this class have moderate limitations that reduce the choice of crops or require moderate conservation practices. The soils have good water holding capacity and are either naturally well supplied with plant nutrients or are highly responsive to inputs of fertilizer. They are moderate to high in productivity for a fairly wide range of crops. The limitations are not severe and good soil management and cropping practices can be applied without serious difficulty.

Class 3

Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices. The limitations in Class 3 are more severe than those in Class 2 and conservation practices are more difficult to apply and maintain. The limitations affect the timing and ease of tillage, planting and harvesting, the choice of crops and maintenance of conservation practices. The limitations include one or more of the following: moderate climatic limitation, erosion, structure or permeability, low fertility, topography, overflow, wetness, low water holding capacity or slowness in release of water to plants, stoniness and depth of soil to consolidated bedrock. Under good management, these soils are fair to moderately high in productivity for a fairly wide range of field crops.

Class 4

Soils in this class have severe limitations that restrict the choice of crops or require special conservation practices or both. These soils have such limitations that they are only suited for a few crops, or the yield for a range of crops may be low, or the risk of crop failure is high. The limitations may seriously affect such farm practices as the timing and ease of tillage, planting and harvesting, and the application and maintenance of conservation practices. These soils are low to medium in productivity for a narrow range of crops but may have higher productivity for a specially adapted crop. The limitations include the adverse effects of one or more of the following: climate, accumulative undesirable soil characteristics, low fertility, deficiencies in the storage capacity or release of soil moisture to plants, structure or permeability, salinity, erosion, topography, overflow, wetness, stoniness, and depth of soil to consolidated bedrock.

Class 5

Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible. These soils have such serious soil, climatic or other limitations that they are not capable of use for sustained production of annual field crops. However, they may be improved by the use of farm machinery for the production of native or tame species of perennial forage plants. Feasible improvement practices include clearing of bush, cultivation, seeding, fertilizing and water control.

Some soils in Class 5 can be used for cultivated field crops provided unusually intensive management is used. Some of these soils are also adapted to special crops requiring soil conditions unlike those needed by the common crops.

Class 6

Soils in this class are capable only of producing perennial forage crops and improvement practices are not feasible. Class 6 soils have some natural sustained grazing capacity for farm animals, but have such serious soil, climatic or other limitations as to make impractical the application of improvement practices that can be carried out on Class 5 soils. Soils may be placed in this class because their physical nature prevents the use of farm machinery, or because the soils are not responsive to improvement practices, or because stock watering facilities are inadequate.

Class 7

Soils in this class have no capability for arable culture or permanent pasture because of extremely severe limitations. Bodies of water too small to delineate on the map are included in this class. These soils may or may not have a high capability for forestry, wildlife and recreation.

Table 16. Agricultural Capability Subclass Limitations

C - Adverse climate: This subclass denotes a significant adverse climate for crop production as compared to the "median" climate which is defined as one with sufficiently high growing season temperatures to bring field crops to maturity, and with sufficient precipitation to permit crops to be grown each year on the same land without a serious risk of partial or total crop failures.

D - Undesirable soil structure and/or low permeability: This subclass is used for soils difficult to till, or which absorb water very slowly or in which the depth of rooting zone is restricted by conditions other than a high water table or consolidated bedrock.

E - Erosion: Subclass E includes soils where damage from erosion is a limitation to agricultural use. Damage is assessed on the loss of productivity and on the difficulties in farming land with gullies.

F - Low fertility: This subclass is made up of soils having low fertility that either is correctable with careful management in the use of fertilizers and soil amendments or is difficult to correct in a feasible way. The limitation may be due to lack of available plant nutrients, high acidity or alkalinity, low exchange capacity, high levels of carbonates or presence of toxic compounds.

I - Inundation by streams or lakes: This subclass includes soils subjected to inundation causing crop damage or restricting agricultural use.

L - Coarse wood fragments: In the rating of organic soils, woody inclusions in the form of trunks, stumps and branches (> 10 cm diameter) in sufficient quantity to significantly hinder tillage, planting and harvesting operations.

M - Moisture limitation: This subclass consists of soils where crops are adversely affected by doughtiness owing to inherent soil characteristics. They are usually soils with low water-holding capacity.

N - Salinity: Designates soils which are adversely affected by the presence of soluble salts.

P - Stoniness: This subclass is made up of soils sufficiently stony to significantly hinder tillage, planting, and harvesting operations. Stony soils are usually less productive than comparable non-stony soils.

R - Consolidated bedrock: This subclass includes soils where the presence of bedrock near the surface restricts their agricultural use. Consolidated bedrock at depths greater than 1 meter from the surface is not considered as a limitation, except on irrigated lands where a greater depth of soil is desirable.

T - Topography: This subclass is made up of soils where topography is a limitation. Both the percent of slope and the pattern or frequency of slopes in different directions are important factors in increasing the cost of farming over that of smooth land, in decreasing the uniformity of growth and maturity of crops, and in increasing the hazard of water erosion.

W - Excess water: Subclass W is made up of soils where excess water other than that brought about by inundation is a limitation to their use for agriculture. Excess water may result from inadequate soil drainage, a high water table, seepage or runoff from surrounding areas.

X - Cumulative minor adverse characteristics: This subclass is made up of soils having a moderate limitation caused by the cumulative effect of two or more adverse characteristics which singly are not serious enough to affect the class rating.

Table 17. Description of Irrigation Suitability Classes

General Rating	Class	Degree of Limitation	Description
Excellent	**1A**	No soil or landscape limitations	These soils are medium textured, well drained and hold adequate available moisture. Topography is level to nearly level. Gravity irrigation methods may be feasible.
Good	**2A** **2B** **1B**	Slight soil and/or landscape limitations	The range of crops that can be grown may be limited. as well, higher development inputs and management skills are required. Sprinkler irrigation is usually the only feasible method of water application.
Fair	**3A** **3B** **3C** **1C** **2C**	Moderate soil and/ or landscape limitations	Limitations reduce the range of crops that may be grown and increase development and improvement costs. Management may include special conservation techniques to minimize soil erosion, limit salt movement, limit water table build-up or flooding of depressional areas. Sprinkler irrigation is usually the only feasible method of water application.
Poor	**4A** **4B** **4C** **4D** **1D** **2D** **3D**	Severe soil and/ or landscape limitations	Limitations generally result in a soil that is unsuitable for sustained irrigation. Some lands may have limited potential when special crops, irrigation systems, and soil and water conservation techniques are used.

Table 18. Soil Features Affecting Irrigation Suitability

Symbol	Soil Feature	Degree of Limitation			
		None(1)	Slight(2)	Moderate(3)	Severe(4)
d	Structure	Granular, Single Grained, Prismatic, Blocky, Subangular Blocky	Columnar Platy	Massive	Massive
k	Ksat (mm/hr) (0 - 1.2m)	>50	50 - 15	15 - 1.5	<1.5
x	Drainability (1.2 - 3m) (mm/hr)	>15	5 - 15	0.5 - 5	<0.5
m	AWHC subhumid mm/1.2m (% vol.) subarid	>120 (>10) >150 (>12)	120 - 100 (8 - 10) 120 - 150 (12 - 10)	100 - 75 (6 - 8) 100 -120 (10 - 8)	<75 (<6) <100 (<8)
q	Intake Rate (mm/hr)	>15	1.5 - 15	1.5 - 15	<1.5
s	Salinity depth(m) (dS/m) 0 - .6 .6 - 1.2 1.2 - 3	<2 <4 <8	2 - 4 4 - 8 8 - 16	4 - 8 8 - 16 >16	>8 >16 >16
n	Sodicity (m) (SAR) 0 - 1.2 1.2 - 3	<6 <6	6 - 9 6 - 9	9 - 12 9 - 12	>12 >12
g	Geological Uniformity 0 - 1.2m	1 Textural Group	2 Textural Groups, Coarser Below	2 Textural Groups Finer Below 3 Textural Groups Coarser Below	3 Textural Groups Finer Below
	1.2 - 3m	2 Textural Groups	3 Textural Groups Coarser Below	3 Textural Groups Finer Below	
r	Depth to Bedrock (m)	>3	3 - 2	2 - 1	<1
h	Depth to Watertable (m)	>2	2 - 1.2 (if salinity is a problem)	2 - 1.2 (if salinity is a problem)	<1.2
w	Drainage Class	Well, Moderately Well, Rapid, Excessive	Imperfect	Imperfect	Poor, Very Poor
	*Texture (Classes) 0 - 1.2m	L, SiL, VFSL, FSL	CL, SiCL, SCL, FSCL, SL, LVFS	C, SC, SiC VFS, LS, CoSL	HvC GR, CoS, LCoS, S
	*Organic Matter %	>2	1 - 2	1 - 2	<1
	*Surface Crusting Potential	Slight	Low	Low	Moderate

* Other important factors used to interpret type and degree of limitation but which do not present a limitation to irrigation themselves. No symbol is proposed for these factors since they will not be identified as subclass limitations.

Table 19. Landscape Features Affecting Irrigation Suitability

Symbol	Landscape Features	Degree of Limitation			
		None (A)	Slight (B)	Moderate (C)	Severe (D)
t1	Slope - Simple %	<2	2 - 10	10 - 20	>20
t2	- Complex %	<5		5 - 15	>15
e	Relief m (Average Local)	<1	1 - 3	3 - 5	>5
p	Stoniness -Classes -Cover (%)	0, 1 & 2 (0-3%)	3 (3-15%)	4 (15-50%)	5 (>50)
i	Inundation -Frequency of Flooding (period)	1:10 (yr)	1:5 (yr)	1:1 (annual-spring)	1:<1 (seasonal)

Table 20. Soil and Landscape Conditions Affecting Environmental Impact Rating

Soil Property and Landscape Feature	Potential Degree of Impact			
	Negligible	Low	Moderate	High
Textural Groups[1] (Classes[2]) Surface Strata (1.2 m)	MF (SCL,CL,SiCL) F (SC,SiC,C)	M (Si,VFSL,L,SiL)	MCo (CoSL,SL, FSL,VFS, LVFS)	VCo (VCoS,CoS); Co (LCoS,LS, FS,LFS)
Geological Uniformity Weighted textural groupings[3] Surface Strata (1.2 m) / Substrata (1.2-3.0 m)	MF to VF / M to VF; M / MF to VF	MF / MCo to Co; F / Co; MCo to Co / MF to VF	M / MCo to Co; Co / M; MF / VCo	VCo to Co / VCo to Co; MCo / Co to VCo; Co / VCo to MCo; M / VCo
Hydraulic Cond Ksat (mm/hr)	< 1.5	1.5 - 15	15 - 50	>50
Depth to Water Table (m)	> 2 m	(2 m ---------------------- 1 m)		<1 m
Salinity (dS/m)	0 - 4	4 - 8	8 - 15	>15
Topography (% Slope)	0 - 2	2 - 5	5 - 9	> 9

[1]Textural Groups: VF=Very Fine, F=Fine, MF=Moderately Fine, M=Medium, MCo=Moderately Coarse, Co=Coarse, VCo=Very Coarse

[2]Texture Classes:

Very Coarse - VCo
- VCoS -Very Coarse Sand
- CoS -Coarse Sand
- S -Sand

Coarse - Co
- LCoS -Loamy Coarse Sand
- LS -Loamy Sand
- FS -Fine Sand
- LFS -Loamy Fine Sand

Moderately Coarse - MCo
- CoSL -Coarse Sandy Loam
- SL -Sandy Loam
- FSL -Fine Sandy Loam
- VFS -Very Fine Sand
- LVFS -Loamy Very Fine Sand

Medium - M
- Si -Silt
- VFSL -Very Fine Sandy Loam
- L -Loam
- SiL -Silt Loam

Moderately Fine - MF
- SCL -Sandy Clay Loam
- SiCL -Silty Clay Loam
- CL -Clay Loam

Fine - F
- SC -Sandy Clay
- SiC -Silty Clay
- C -Clay

Very Fine - VF
- HC -Heavy Clay

[3]Slash indicates surface strata (1.2 m) overlying substrata (1.2-3.0 m), ie: MF to VF / M to VF

Notes for Table 20.

1. Guidelines developed for making this impact rating employ four relative degrees of risk of degradation: **None, Low, Moderate and High.** This rating is not part of the irrigation suitability classification, but rather is intended to serve as a warning of possible adverse impact on the soil, adjacent crops or the environment. Since all situations cannot be completely covered by general guidelines, an on-site inspection is recommended for the evaluation of potential adverse environmental impact.

2. A major concern for land under irrigation is the possibility of adverse impact on the groundwater and surface water quality in and adjacent to the irrigated area. The soil factors selected for impact evaluation include those properties that determine water retention and movement through the soil and topographic characteristics that affect runoff and redistribution of moisture in the landscape. The risk of altering the soil drainage regime and soil salinity or the potential for runoff, erosion or flooding is determined by the detailed criteria for each property. Soil factors and landscape features considered in determining an environmental impact evaluation are:

    1. Soil Texture
    2. Geological Uniformity
    3. Hydraulic Conductivity
    4. Depth to Water Table
    5. Salinity
    6. Topography

3. **Soil texture** and the **thickness and uniformity of geological deposits** (assessed by weighing textures in surface strata and subsurface strata) combine to affect the soil's water holding capacity and **hydraulic conductivity** (ability to transmit water and leachate either vertically or laterally in the soil). The presence and sequence of strongly contrasting soil textures within 3 m of the surface (**geological uniformity**) are used to determine the potential for downward movement (moderately coarse to fine materials underlain by coarse materials) or lateral movement (very coarse and coarse materials underlain by fine materials) of water and leachate. Uniform, highly permeable materials with low water holding capacity present the highest potential for adverse impact on groundwater quality. Uniform materials of low permeability provide the best buffer against impact on groundwater quality.

    A shallow **depth (< 1 m) to water table** has a higher risk for contamination than soils with a deep water table. Soils with high levels of **salinity** may adversely impact on groundwater quality due to the leaching associated with irrigation practices (ie: applied leaching fraction).

    Topographic patterns with slopes in excess of 2 percent require special consideration for soil and water management to reduce the potential for runoff and erosion. The risk of runoff and potential for local flooding, build-up of water tables and soil erosion increases with slope gradient. Soil erosion results in loss of topsoil and transport of nutrients and pesticides to non-target areas.

APPENDIX B

SOIL ANALYTICAL DATA

Table 21. Soil Analytical Data by Site No.

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
1	RAM	Ap	0	18	CL	0	0	5	9	17	31	37	32	0.0	5.5	4.00	0.3	0.00
2	RAM	Ap	0	15	CL	0	0	6	11	14	31	38	31	0.0	5.5	3.46	0.6	0.00
3	RAM	Ap	0	18	CL	0	0	8	7	14	29	39	32	0.0	5.7	4.26	0.5	0.00
4	RAM	Ap	0	15	CL	0	0	8	8	10	26	41	33	0.0	6.2	3.07	0.3	0.00
5	RAM	Ap	0	15	CL	0	0	8	7	12	27	40	33	0.0	5.5	4.51	0.6	0.00
6	WWD	Ap	0	20	L	0	0	18	14	12	44	29	27	0.0	5.7	3.56	0.7	0.00
7	RAM	Ap	0	15	SICL	0	0	2	4	12	18	43	39	0.0	6.2	4.24	0.4	0.00
8	RAM	Ap	0	15	CL	0	0	6	9	15	30	35	35	0.0	5.2	4.33	0.4	0.00
9	RAM	Ap	0	15	C	0	0	5	9	9	23	36	41	0.0	5.8	3.85	0.3	0.00
10	FND	Ap	0	15	SCL	0	0	14	30	11	55	22	23	0.0	6.2	3.26	0.6	0.00
11	WWD	Ap	0	15	CL	0	0	2	11	20	33	34	33	0.0	5.2	4.45	0.6	0.00
12	WWD	Ap	0	15	CL	0	0	9	17	11	37	32	31	0.0	7.1	3.13	0.8	0.00
13	WWD	Ap	0	15	CL	0	0	10	12	8	30	35	35	0.0	7.4	3.08	2.3	0.00
14	RAM	Ap	0	15	SICL	0	0	3	6	10	19	47	34	0.0	5.2	4.80	0.5	0.00
15	WWD	Ap	0	15	CL	0	0	11	11	13	35	34	31	0.0	5.3	3.78	0.5	0.00
16	WWD	Ap	0	15	CL	0	1	13	13	12	39	33	28	0.0	5.4	3.43	0.6	0.00
17	FND	Ap	0	15	SCL	0	1	20	17	10	48	24	28	0.0	7.5	2.90	1.2	0.00
19	WWD	Ap	0	20	SCL	0	1	21	14	11	47	27	26	0.0	5.5	3.13	0.6	0.00
20	WWD	Ap	0	15	CL	0	0	13	12	14	39	32	29	0.0	5.2	3.62	0.8	0.00
21	BKR	Ap	0	22	FSL	0	0	11	53	15	79	9	12	0.0	7.2	2.30	0.3	0.00
22	PDA	Ap	0	25	FSL	1	1	15	38	10	65	17	18	0.0	7.4	2.94	2.1	0.00
23	WWD	Ap	0	20	SCL	0	0	16	34	8	58	20	22	0.0	6.3	3.24	1.5	0.00
24	GBO	Ap	0	20	FSL	0	0	21	40	8	69	16	15	0.0	7.5	2.00	1.7	0.00
25	WWD	Ap	0	20	L	0	0	10	21	12	43	31	26	0.0	6.8	3.46	0.7	0.00
26	WWD	Ap	0	20	CL	0	0	8	15	12	35	37	28	0.0	6.6	3.40	0.9	0.00
27	WWD	Ap	0	20	CL	0	0	7	15	13	35	36	29	0.0	7.3	3.53	1.8	0.00
28	WWD	Ap	0	15	CL	0	0	6	14	11	31	40	29	0.0	5.5	3.89	2.4	0.00
29	WWD	Ap	0	20	CL	0	0	5	13	12	30	39	31	0.0	5.4	3.69	0.8	0.00
30	WWD	Ap	0	20	CL	0	0	4	12	14	30	39	31	0.0	5.1	4.11	2.1	0.00
31	WWD	Ap	0	23	CL	0	0	3	12	12	27	42	31	0.0	5.1	4.28	0.8	0.00

Table 21. Soil Analytical Data by Site No. (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
32	WWD	Ap	0	20	CL	0	0	4	12	15	31	39	30	0.0	5.8	4.52	0.8	0.00
33	WWD	Ap	0	20	CL	0	0	3	12	15	30	39	31	0.0	5.9	4.43	1.2	0.00
34	WWD	Ap	0	20	CL	0	0	4	16	15	35	37	28	0.0	6.0	3.63	0.9	0.00
35	WWD	Ap	0	15	CL	0	0	4	14	13	31	40	29	0.0	5.3	4.15	0.7	0.00
36	RAM	Ap	0	20	CL	0	0	5	8	15	28	40	32	0.0	5.2	4.45	0.9	0.00
37	RAM	Ap	0	15	CL	0	0	4	11	17	32	37	31	0.0	6.2	4.25	1.0	.00
38	RAM	Ap	0	20	CL	0	0	3	9	17	29	38	33	0.0	6.6	5.77	0.50.00	
39	OBR	Ap	0	20	CL	0	0	7	15	7	29	34	37	0.0	6.4	3.55	2.3	0.00
40	RAM	Ap	0	20	CL	0	0	3	12	15	30	36	34	0.0	6.7	4.73	0.9	0.00
41	WWD	Ap	0	20	L	0	0	6	22	17	45	28	27	0.0	6.8	3.86	0.8	0.00
42	TGR	Ap	0	20	SCL	0	0	9	28	18	55	22	23	0.0	5.7	3.99	0.9	0.00
43	RAM	Ap	0	15	CL	0	0	3	15	16	34	34	32	0.0	5.8	4.40	0.8	0.00
44	RAM	Ap	0	25	CL	0	0	3	12	20	35	33	32	0.0	5.7	4.65	0.8	0.00
45	RAM	Ap	0	20	CL	0	0	6	12	20	38	31	31	0.0	5.5	4.47	0.5	0.00
46	RAM	Ap	0	25	CL	0	0	6	15	19	40	29	31	0.0	5.7	5.19	0.5	0.00
46	RAM	Ck	105	130	SCL	0	0	9	27	15	51	27	22	0.0	5.7	0.62	0.5	0.00
47	WWD	Ap	0	20	CL	0	0	5	17	19	41	29	30	0.0	5.5	4.16	0.6	0.00
48	WWD	Ap	0	20	CL	0	0	6	19	14	39	32	29	0.0	5.5	4.00	1.0	0.00
49	WWD	Ap	0	20	CL	0	0	6	17	14	37	33	30	0.0	5.4	3.81	1.7	0.00
50	WWD	Ap	0	15	CL	0	0	5	14	14	33	37	30	0.0	5.1	4.54	1.5	0.00
51	RAM	Ap	0	15	SCL	0	0	13	19	14	46	27	27	0.0	5.0	3.75	0.8	0.00
52	RAM	Ap	0	15	CL	0	0	6	11	13	30	38	32	0.0	5.1	4.59	0.9	0.00
53	RAM	Ap	0	20	CL	0	0	2	13	19	34	33	33	0.0	5.9	4.87	0.8	0.00
54	RAM	Ap	0	20	CL	0	0	2	13	18	33	36	31	0.0	4.8	4.71	1.0	0.00
55	WWD	Ap	0	6	CL	0	0	9	8	10	27	36	37	0.0	4.8	3.40	0.3	0.00
56	WWD	Ap	0	20	CL	0	0	3	16	19	38	31	31	0.0	6.3	4.33	0.5	0.00
57	RAMc	Ap	0	20	CL	0	0	7	12	12	31	35	34	0.0	5.6	4.65	0.8	0.00
58	RAM	Ap	0	20	CL	0	0	5	10	13	28	36	36	0.0	5.5	4.85	0.5	0.00
59	RAM	Ap	0	15	CL	0	0	4	8	13	25	41	34	0.0	5.1	4.59	0.6	0.00
60	WWD	Ap	0	15	CL	0	0	5	14	15	34	35	31	0.0	5.3	3.73	0.7	0.00

Table 21. Soil Analytical Data by Site No. (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
61	GBO	Ap	0	15	CL	0	0	9	14	12	35	32	33	0.0	7.3	4.21	0.9	0.00
62	FND	Ap	0	15	SCL	0	0	16	20	12	48	25	27	0.0	5.6	3.25	0.4	0.00
63	FND	Apo	0	25	FSL	0	0	22	39	11	72	14	14	0.0	7.2	2.13	1.1	0.00
64	WWD	Ap	0	15	FSL	0	0	12	34	14	60	21	19	0.0	5.6	2.60	0.8	0.00
65	WWD	Ap	0	15	L	0	0	17	22	11	50	30	20	0.0	6.3	2.10	0.8	0.00
66	WWD	Ap	0	15	FSL	0	0	17	22	14	53	27	20	0.0	5.8	2.45	0.3	0.00
67	WWD	Ap	0	20	L	0	0	18	18	10	46	31	23	0.0	4.9	3.25	1.7	0.00
68	RAM	Ap	0	20	L	0	0	9	14	16	39	35	26	0.0	4.8	4.21	1.7	0.00
69	WWD	Ap	0	12	L	0	0	12	16	12	40	35	25	0.0	5.1	3.32	1.0	0.00
71	RAM	Ap	0	12	CL	0	0	12	12	12	36	35	29	0.0	6.5	2.60	0.5	0.00
72	WWD	Ap	0	14	CL	0	0	9	14	12	35	35	30	0.0	5.1	3.82	1.1	0.00
73	WWD	Ap	0	16	CL	0	0	11	10	11	32	38	30	0.0	5.1	4.08	1.4	0.00
74	WWD	Ap	0	15	CL	0	0	9	16	13	38	33	29	0.0	5.2	4.32	0.8	0.00
75	WWD	Ap	0	15	L	0	0	18	18	10	46	29	25	0.0	5.4	3.09	0.6	0.00
76	WWD	Ap	0	20	L	0	0	16	18	12	46	28	26	0.0	5.4	3.52	1.1	0.00
77	WWD	Ap	0	15	SCL	0	0	19	15	13	47	27	26	0.0	5.2	3.83	1.5	0.00
78	WWD	Ap	0	18	SCL	0	0	16	20	12	48	27	25	0.0	5.0	3.30	1.0	0.00
79	WWD	Ap	0	20	SCL	0	0	26	10	12	48	27	25	0.0	5.3	3.34	1.2	0.00
80	WWD	Ap	0	20	SCL	0	0	18	24	14	56	23	21	0.0	5.4	2.82	1.3	0.00
81	FND	Ap	0	20	FSL	0	0	26	23	12	61	19	20	0.0	5.8	2.30	0.7	0.00
82	RAM	Ap	0	18	CL	0	0	12	8	12	32	37	31	0.0	4.9	4.31	2.2	0.00
83	WWD	Ap	0	16	CL	0	1	17	8	14	40	31	29	0.0	5.3	3.15	1.5	0.00
84	CKD	Ap	0	16	CL	0	1	16	12	9	38	28	34	0.0	7.3	3.32	1.0	0.00
85	CXV	Ap	0	25	CL	0	0	14	16	13	43	27	30	0.0	6.3	4.67	0.7	0.00
87	WWD	Ap	0	18	CL	0	0	9	12	12	33	36	31	0.0	5.0	4.06	1.0	0.00
88	WWD	Ap	0	16	CL	0	0	16	14	11	41	31	28	0.0	5.4	3.46	0.8	0.00
89	GRG	Ap	0	20	CL	0	0	4	8	12	24	40	36	0.0	5.1	4.58	1.1	0.00
90	RAM	Ap	0	15	CL	0	0	16	7	10	33	38	29	0.0	5.3	3.96	0.4	0.00
91	WWD	Ap	0	17	CL	0	0	8	12	10	30	39	31	0.0	5.3	4.73	1.2	0.00
92	WWD	Ap	0	15	CL	0	0	13	10	12	35	33	32	0.0	5.6	4.51	1.0	0.00

Table 21. Soil Analytical Data by Site No. (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
93	RAM	Ap	0	15	CL	0	0	15	12	10	37	34	29	0.0	5.3	3.55	0.8	0.00
94	RAM	Ap	0	14	MSL	0	1	37	24	8	70	17	13	0.0	7.3	1.41	1.1	0.00
96	RAM	Ap	0	15	CL	0	0	8	7	11	26	39	35	0.0	5.4	4.58	1.4	0.00
97	RAM	Ap	0	17	CL	0	0	14	10	12	36	33	31	0.0	5.5	3.42	1.1	0.00
98	GBO	Ap	0	16	SCL	0	0	25	16	7	48	27	25	0.0	7.5	1.96	1.6	0.00
99	WWD	Ap	0	14	CL	0	0	10	10	13	33	36	31	0.0	5.4	3.81	0.7	0.00
100	WWD	Ap	0	18	CL	0	0	8	13	10	31	38	31	0.0	5.4	4.58	0.7	0.00
101	RAM	Ap	0	17	CL	0	0	12	9	10	31	38	31	0.0	5.3	4.77	0.9	0.00
102	RAM	Ap	0	15	CL	0	0	15	12	11	38	32	30	0.0	5.4	4.04	1.3	0.00
103	WWD	Ap	0	18	CL	0	0	17	10	9	36	33	31	0.0	6.8	3.31	2.7	0.00
104	RAM	Apk	0	20	CL	0	1	19	12	7	39	30	31	1.8	7.6	4.64	0.9	0.00
105	RAM	Ap	0	20	CL	0	0	8	6	13	27	42	31	0.0	6.0	5.15	0.8	0.00
106	RAM	Ap	0	20	CL	0	0	5	6	11	22	45	33	0.0	5.5	4.70	0.6	0.00
107	RAM	Ap	0	15	CL	0	0	9	7	15	31	38	31	0.0	5.3	4.03	0.4	0.00
108	RAM	Ap	0	15	CL	0	0	6	4	12	22	46	32	0.0	5.7	4.46	1.2	0.00
109	RAM	Ap	0	17	CL	0	0	10	5	14	29	41	30	0.0	5.0	4.29	1.7	0.00
110	RAM	Ap	0	15	CL	0	0	6	5	13	24	40	36	0.0	5.7	3.70	0.8	0.00
111	SXP	Apo	0	20	CL	0	0	9	11	13	33	35	32	0.0	7.7	4.53	0.4	0.00
112	RAM	Ap	0	12	CL	0	0	3	7	11	21	40	39	0.0	6.0	3.78	1.4	0.00
113	WWD	Ap	0	15	CL	0	0	11	10	11	32	35	33	0.0	5.5	3.32	0.7	0.00
114	GRG	Ap	0	20	CL	0	0	14	10	12	36	35	29	0.0	5.6	4.70	0.4	0.00
115	WWD	Ap	0	10	CL	0	0	9	7	14	30	38	32	0.0	5.7	4.28	1.0	0.00
116	RAM	Ap	0	15	CL	0	0	6	6	19	31	38	31	0.0	5.9	4.58	1.0	0.00
117	WWD	Ap	0	15	L	0	0	10	11	15	36	38	26	0.0	5.4	4.05	0.7	0.00
118	WWD	Ap	0	18	L	0	0	10	11	14	35	38	27	0.0	5.5	4.73	1.1	0.00
119	WWD	Ap	0	15	CL	0	0	11	10	11	32	40	28	0.0	6.2	4.67	0.7	0.00
120	WWD	Ahk	20	35	CL	0	0	9	11	14	34	38	28	0.0	5.8	4.05	1.2	0.00
121	RAM	Ap	0	15	L	0	0	6	8	15	29	46	25	0.0	7.8	2.92	1.6	0.00
122	WWD	Ap	0	17	CL	0	0	7	11	17	35	36	29	0.0	6.8	4.46	0.9	0.00
123	WWD	Ap	0	17	CL	0	0	9	9	11	29	43	28	0.0	5.6	3.90	1.0	0.00

Table 21. Soil Analytical Data by Site No. (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
124	WWD	Ap	0	15	CL	0	0	8	9	12	29	42	29	0.0	6.2	4.18	0.5	0.00
125	TDP	2Ahg	36	80	L	2	2	19	10	9	42	33	25	0.0	6.7	3.70	0.4	0.00
128	RAM	Ap	0	20	CL	0	0	7	6	10	23	44	33	0.0	5.2	4.23	0.4	0.00
129	RAM	Ap	0	15	CL	0	0	6	10	11	27	38	35	0.0	5.3	4.51	0.5	0.00
130	OBRc	Apk	0	20	SCL	0	0	22	23	10	55	20	25	1.7	7.7	3.15	0.5	0.00
131	RAM	Ap	0	15	CL	0	0	14	14	12	40	32	28	0.0	5.3	3.43	1.4	0.00
132	WWD	Ap	0	15	CL	0	0	10	11	9	30	39	31	0.0	5.0	4.00	1.1	0.00
133	PTRc	Ap	0	22	MSL	0	1	42	11	11	65	18	17	0.0	7.3	2.04	1.1	0.00
134	PTRc	Apk	0	20	SCL	0	0	23	19	14	56	21	23	0.7	7.8	2.88	0.5	0.00
134	PTRc	Ahk	20	37	MSL	0	1	35	22	10	68	19	13	0.7	7.8	1.99	0.5	0.00
135	CXVc	Ap	0	18	CL	0	0	9	11	16	36	33	31	0.0	7.5	4.69	0.6	0.00
136	RAM	Ap	0	20	CL	0	0	11	7	15	33	37	30	0.0	5.4	4.46	0.6	0.00
137	RAM	Ap	0	15	CL	0	0	14	10	9	33	38	29	0.0	5.2	3.78	0.3	0.00
140	RAM	Ap	0	25	CL	0	0	15	10	14	39	32	29	0.0	6.4	3.36	0.5	0.00
142	GRG	Ap	0	20	CL	1	0	7	7	12	27	43	30	0.0	5.4	2.06	0.0	0.00
143	GRG	Ap	0	20	CL	0	0	12	7	13	32	38	30	0.0	5.3	1.83	0.0	0.00

Text = Soil Texture, VC = Very Coarse Sand, CS = Coarse Sand, MS = Medium Sand, FS = Fine Sand, VF = Very Fine Sand, TS = Total Sand
SI = Silt, C = Clay, OC = Organic Carbon, EC = Electrical Conductivity, SAT = Saturation Percent

Table 22. Soil Analytical Data by Series

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH %	OC %	EC mS/cm	SAT %
21	BKR	Ap	0	22	FSL	0	0	11	53	15	79	9	12	0.0	7.2	2.30	0.3	0.00
84	CKD	Ap	0	16	CL	0	1	16	12	9	38	28	34	0.0	7.3	3.32	1.0	0.00
85	CXV	Ap	0	25	CL	0	0	14	16	13	43	27	30	0.0	6.3	4.67	0.7	0.00
135	CXVc	Ap	0	18	CL	0	0	9	11	16	36	33	31	0.0	7.5	4.69	0.6	0.00
10	FND	Ap	0	15	SCL	0	0	14	30	11	55	22	23	0.0	6.2	3.26	0.6	0.00
17	FND	Ap	0	15	SCL	0	1	20	17	10	48	24	28	0.0	7.5	2.90	1.2	0.00
62	FND	Ap	0	15	SCL	0	0	16	20	12	48	25	27	0.0	5.6	3.25	0.4	0.00
63	FND	Apo	0	25	FSL	0	0	22	39	11	72	14	14	0.0	7.2	2.13	1.1	0.00
81	FND	Ap	0	20	FSL	0	0	26	23	12	61	19	20	0.0	5.8	2.30	0.7	0.00
24	GBO	Ap	0	20	FSL	0	0	21	40	8	69	16	15	0.0	7.5	2.00	1.7	0.00
61	GBO	Ap	0	15	CL	0	0	9	14	12	35	32	33	0.0	7.3	4.21	0.9	0.00
98	GBO	Ap	0	16	SCL	0	0	25	16	7	48	27	25	0.0	7.5	1.96	1.6	0.00
114	GRG	Ap	0	20	CL	0	0	14	10	12	36	35	29	0.0	5.6	4.70	0.4	0.00
142	GRG	Ap	0	20	CL	1	0	7	7	12	27	43	30	0.0	5.4	2.06	0.0	0.00
143	GRG	Ap	0	20	CL	0	0	12	7	13	32	38	30	0.0	5.3	1.83	0.0	0.00
89	GRG	Ap	0	20	CL	0	0	4	8	12	24	40	36	0.0	5.1	4.58	1.1	0.00
39	OBR	Ap	0	20	CL	0	0	7	15	7	29	34	37	0.0	6.4	3.55	2.3	0.00
130	OBRc	Apk	0	20	SCL	0	0	22	23	10	55	20	25	1.7	7.7	3.15	0.5	0.00
22	PDA	Ap	0	25	FSL	1	1	15	38	10	65	17	18	0.0	7.4	2.94	2.1	0.00
133	PTRc	Ap	0	22	MSL	0	1	42	11	11	65	18	17	0.0	7.3	2.04	1.1	0.00
134	PTRc	Apk	0	20	SCL	0	0	23	19	14	56	21	23	0.7	7.8	2.88	0.5	0.00
134	PTRc	Ahk	20	37	MSL	0	1	35	22	10	68	19	13	0.7	7.8	1.99	0.5	0.00
1	RAM	Ap	0	18	CL	0	0	5	9	17	31	37	32	0.0	5.5	4.00	0.3	0.00
2	RAM	Ap	0	15	CL	0	0	6	11	14	31	38	31	0.0	5.5	3.46	0.6	0.00
3	RAM	Ap	0	18	CL	0	0	8	7	14	29	39	32	0.0	5.7	4.26	0.5	0.00
4	RAM	Ap	0	15	CL	0	0	8	8	10	26	41	33	0.0	6.2	3.07	0.3	0.00
5	RAM	Ap	0	15	CL	0	0	8	7	12	27	40	33	0.0	5.5	4.51	0.6	0.00
7	RAM	Ap	0	15	SICL	0	0	2	4	12	18	43	39	0.0	6.2	4.24	0.4	0.00
8	RAM	Ap	0	15	CL	0	0	6	9	15	30	35	35	0.0	5.2	4.33	0.4	0.00
9	RAM	Ap	0	15	C	0	0	5	9	9	23	36	41	0.0	5.8	3.85	0.3	0.00
14	RAM	Ap	0	15	SICL	0	0	3	6	10	19	47	34	0.0	5.2	4.80	0.5	0.00

Site No.	Series	Hori-zon	Depth (cm)	Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH %	OC %	EC mS/cm	SAT %
36	RAM	Ap	0 20	CL	0	0	5	8	15	28	40	32	0.0	5.2	4.45	0.9	0.00
37	RAM	Ap	0 15	CL	0	0	4	11	17	32	37	31	0.0	6.2	4.25	1.0	0.00
38	RAM	Ap	0 20	CL	0	0	3	9	17	29	38	33	0.0	6.6	5.77	0.5	0.00
40	RAM	Ap	0 20	CL	0	0	3	12	15	30	36	34	0.0	6.7	4.73	0.9	0.00
43	RAM	Ap	0 15	CL	0	0	3	15	16	34	34	32	0.0	5.8	4.40	0.8	0.00
44	RAM	Ap	0 25	CL	0	0	3	12	20	35	33	32	0.0	5.7	4.65	0.8	0.00
45	RAM	Ap	0 20	CL	0	0	6	12	20	38	31	31	0.0	5.5	4.47	0.5	0.00
46	RAM	Ap	0 25	CL	0	0	6	15	19	40	29	31	0.0	5.7	5.19	0.5	0.00
46	RAM	Ck	105 130	SCL	0	0	9	27	15	51	27	22	0.0	5.7	0.62	0.5	0.00
51	RAM	Ap	0 15	SCL	0	0	13	19	14	46	27	27	0.0	5.0	3.75	0.8	0.00
52	RAM	Ap	0 15	CL	0	0	6	11	13	30	38	32	0.0	5.1	4.59	0.9	0.00
53	RAM	Ap	0 20	CL	0	0	2	13	19	34	33	33	0.0	5.9	4.87	0.8	0.00
54	RAM	Ap	0 20	CL	0	0	2	13	18	33	36	31	0.0	4.8	4.71	1.0	0.00
58	RAM	Ap	0 20	CL	0	0	5	10	13	28	36	36	0.0	5.5	4.85	0.5	0.00
59	RAM	Ap	0 15	CL	0	0	4	8	13	25	41	34	0.0	5.1	4.59	0.6	0.00
68	RAM	Ap	0 20	L	0	0	9	14	16	39	35	26	0.0	4.8	4.21	1.7	0.00
71	RAM	Ap	0 12	CL	0	0	12	12	12	36	35	29	0.0	6.5	2.60	0.5	0.00
82	RAM	Ap	0 18	CL	0	0	12	8	12	32	37	31	0.0	4.9	4.31	2.2	0.00
90	RAM	Ap	0 15	CL	0	0	16	7	10	33	38	29	0.0	5.3	3.96	0.4	0.00
93	RAM	Ap	0 15	CL	0	0	15	12	10	37	34	29	0.0	5.3	3.55	0.8	0.00
94	RAM	Ap	0 14	MSL	0	1	37	24	8	70	17	13	0.0	7.3	1.41	1.1	0.00
96	RAM	Ap	0 15	CL	0	0	8	7	11	26	39	35	0.0	5.4	4.58	1.4	0.00
97	RAM	Ap	0 17	CL	0	0	14	10	12	36	33	31	0.0	5.5	3.42	1.1	0.00
101	RAM	Ap	0 17	CL	0	0	12	9	10	31	38	31	0.0	5.3	4.77	0.9	0.00
102	RAM	Ap	0 15	CL	0	0	15	12	11	38	32	30	0.0	5.4	4.04	1.3	0.00
104	RAM	Apk	0 20	CL	0	1	19	12	7	39	30	31	1.8	7.6	4.64	0.9	0.00
105	RAM	Ap	0 20	CL	0	0	8	6	13	27	42	31	0.0	6.0	5.15	0.8	0.00
106	RAM	Ap	0 20	CL	0	0	5	6	11	22	45	33	0.0	5.5	4.70	0.6	0.00
107	RAM	Ap	0 15	CL	0	0	9	7	15	31	38	31	0.0	5.3	4.03	0.4	0.00
108	RAM	Ap	0 15	CL	0	0	6	4	12	22	46	32	0.0	5.7	4.46	1.2	0.00
109	RAM	Ap	0 17	CL	0	0	10	5	14	29	41	30	0.0	5.0	4.29	1.7	0.00
110	RAM	Ap	0 15	CL	0	0	6	5	13	24	40	36	0.0	5.7	3.70	0.8	0.00
112	RAM	Ap	0 12	CL	0	0	3	7	11	21	40	39	0.0	6.0	3.78	1.4	0.00
116	RAM	Ap	0 15	CL	0	0	6	6	19	31	38	31	0.0	5.9	4.58	1.0	0.00
121	RAM	Ap	0 15	L	0	0	6	8	15	29	46	25	0.0	7.8	2.92	1.6	0.00
131	RAM	Ap	0 15	CL	0	0	14	14	12	40	32	28	0.0	5.3	3.43	1.4	0.00
128	RAM	Ap	0 20	CL	0	0	7	6	10	23	44	33	0.0	5.2	4.23	0.4	0.00
129	RAM	Ap	0 15	CL	0	0	6	10	11	27	38	35	0.0	5.3	4.51	0.5	0.00
136	RAM	Ap	0 20	CL	0	0	11	7	15	33	37	30	0.0	5.4	4.46	0.6	0.00
137	RAM	Ap	0 15	CL	0	0	14	10	9	33	38	29	0.0	5.2	3.78	0.3	0.00

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH %	OC %	EC mS/cm	SAT %
140	RAM	Ap	0	25	CL	0	0	15	10	14	39	32	29	0.0	6.4	3.36	0.5	0.00
57	RAMc	Ap	0	20	CL	0	0	7	12	12	31	35	34	0.0	5.6	4.65	0.8	0.00
111	SXP	Apo	0	20	CL	0	0	9	11	13	33	35	32	0.0	7.7	4.53	0.4	0.00
125	TDP	2Ahg	36	80	L	2	2	19	10	9	42	33	25	0.0	6.7	3.70	0.4	0.00
42	TGR	Ap	0	20	SCL	0	0	9	28	18	55	22	23	0.0	5.7	3.99	0.9	0.00
6	WWD	Ap	0	20	L	0	0	18	14	12	44	29	27	0.0	5.7	3.56	0.7	0.00
11	WWD	Ap	0	15	CL	0	0	2	11	20	33	34	33	0.0	5.2	4.45	0.6	0.00
12	WWD	Ap	0	15	CL	0	0	9	17	11	37	32	31	0.0	7.1	3.13	0.8	0.00
13	WWD	Ap	0	15	CL	0	0	10	12	8	30	35	35	0.0	7.4	3.08	2.3	0.00
15	WWD	Ap	0	15	CL	0	0	11	11	13	35	34	31	0.0	5.3	3.78	0.5	0.00
16	WWD	Ap	0	15	CL	0	1	13	13	12	39	33	28	0.0	5.4	3.43	0.6	0.00
19	WWD	Ap	0	20	SCL	0	1	21	14	11	47	27	26	0.0	5.5	3.13	0.6	0.00
20	WWD	Ap	0	15	CL	0	0	13	12	14	39	32	29	0.0	5.2	3.62	0.8	0.00
23	WWD	Ap	0	20	SCL	0	0	16	34	8	58	20	22	0.0	6.3	3.24	1.5	0.00
25	WWD	Ap	0	20	L	0	0	10	21	12	43	31	26	0.0	6.8	3.46	0.7	0.00
26	WWD	Ap	0	20	CL	0	0	8	15	12	35	37	28	0.0	6.6	3.40	0.9	0.00
27	WWD	Ap	0	20	CL	0	0	7	15	13	35	36	29	0.0	7.3	3.53	1.8	0.00
28	WWD	Ap	0	15	CL	0	0	6	14	11	31	40	29	0.0	5.5	3.89	2.4	0.00
29	WWD	Ap	0	20	CL	0	0	5	13	12	30	39	31	0.0	5.4	3.69	0.8	0.00
30	WWD	Ap	0	20	CL	0	0	4	12	14	30	39	31	0.0	5.1	4.11	2.1	0.00
31	WWD	Ap	0	23	CL	0	0	3	12	12	27	42	31	0.0	5.1	4.28	0.8	0.00
32	WWD	Ap	0	20	CL	0	0	4	12	15	31	39	30	0.0	5.8	4.52	0.8	0.00
33	WWD	Ap	0	20	CL	0	0	3	12	15	30	39	31	0.0	5.9	4.43	1.2	0.00
34	WWD	Ap	0	20	CL	0	0	4	16	15	35	37	28	0.0	6.0	3.63	0.9	0.00
35	WWD	Ap	0	15	CL	0	0	4	14	13	31	40	29	0.0	5.3	4.15	0.7	0.00
41	WWD	Ap	0	20	L	0	0	6	22	17	45	28	27	0.0	6.8	3.86	0.8	0.00
47	WWD	Ap	0	20	CL	0	0	5	17	19	41	29	30	0.0	5.5	4.16	0.6	0.00
48	WWD	Ap	0	20	CL	0	0	6	19	14	39	32	29	0.0	5.5	4.00	1.0	0.00
49	WWD	Ap	0	20	CL	0	0	6	17	14	37	33	30	0.0	5.4	3.81	1.7	0.00
50	WWD	Ap	0	15	CL	0	0	5	14	14	33	37	30	0.0	5.1	4.54	1.5	0.00
55	WWD	Ap	0	6	CL	0	0	9	8	10	27	36	37	0.0	4.8	3.40	0.3	0.00
56	WWD	Ap	0	20	CL	0	0	3	16	19	38	31	31	0.0	6.3	4.33	0.5	0.00
60	WWD	Ap	0	15	CL	0	0	5	14	15	34	35	31	0.0	5.3	3.73	0.7	0.00
64	WWD	Ap	0	15	FSL	0	0	12	34	14	60	21	19	0.0	5.6	2.60	0.8	0.00
65	WWD	Ap	0	15	L	0	0	17	22	11	50	30	20	0.0	6.3	2.10	0.8	0.00
66	WWD	Ap	0	15	FSL	0	0	17	22	14	53	27	20	0.0	5.8	2.45	0.3	0.00
67	WWD	Ap	0	20	L	0	0	18	18	10	46	31	23	0.0	4.9	3.25	1.7	0.00
69	WWD	Ap	0	12	L	0	0	12	16	12	40	35	25	0.0	5.1	3.32	1.0	0.00
72	WWD	Ap	0	14	CL	0	0	9	14	12	35	35	30	0.0	5.1	3.82	1.1	0.00

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH %	OC %	EC mS/cm	SAT %
73	WWD	Ap	0	16	CL	0	0	11	10	11	32	38	30	0.0	5.1	4.08	1.4	0.00
74	WWD	Ap	0	15	CL	0	0	9	16	13	38	33	29	0.0	5.2	4.32	0.8	0.00
75	WWD	Ap	0	15	L	0	0	18	18	10	46	29	25	0.0	5.4	3.09	0.6	0.00
76	WWD	Ap	0	20	L	0	0	16	18	12	46	28	26	0.0	5.4	3.52	1.1	0.00
77	WWD	Ap	0	15	SCL	0	0	19	15	13	47	27	26	0.0	5.2	3.83	1.5	0.00
78	WWD	Ap	0	18	SCL	0	0	16	20	12	48	27	25	0.0	5.0	3.30	1.0	0.00
79	WWD	Ap	0	20	SCL	0	0	26	10	12	48	27	25	0.0	5.3	3.34	1.2	0.00
80	WWD	Ap	0	20	SCL	0	0	18	24	14	56	23	21	0.0	5.4	2.82	1.3	0.00
83	WWD	Ap	0	16	CL	0	1	17	8	14	40	31	29	0.0	5.3	3.15	1.5	0.00
87	WWD	Ap	0	18	CL	0	0	9	12	12	33	36	31	0.0	5.0	4.06	1.0	0.00
88	WWD	Ap	0	16	CL	0	0	16	14	11	41	31	28	0.0	5.4	3.46	0.8	0.00
91	WWD	Ap	0	17	CL	0	0	8	12	10	30	39	31	0.0	5.3	4.73	1.2	0.00
92	WWD	Ap	0	15	CL	0	0	13	10	12	35	33	32	0.0	5.6	4.51	1.0	0.00
99	WWD	Ap	0	14	CL	0	0	10	10	13	33	36	31	0.0	5.4	3.81	0.7	0.00
100	WWD	Ap	0	18	CL	0	0	8	13	10	31	38	31	0.0	5.4	4.58	0.7	0.00
103	WWD	Ap	0	18	CL	0	0	17	10	9	36	33	31	0.0	6.8	3.31	2.7	0.00
113	WWD	Ap	0	15	CL	0	0	11	10	11	32	35	33	0.0	5.5	3.32	0.7	0.00
115	WWD	Ap	0	10	CL	0	0	9	7	14	30	38	32	0.0	5.7	4.28	1.0	0.00
117	WWD	Ap	0	15	L	0	0	10	11	15	36	38	26	0.0	5.4	4.05	0.7	0.00
118	WWD	Ap	0	18	L	0	0	10	11	14	35	38	27	0.0	5.5	4.73	1.1	0.00
119	WWD	Ap	0	15	CL	0	0	11	10	11	32	40	28	0.0	6.2	4.67	0.7	0.00
120	WWD	Ahk	20	35	CL	0	0	9	11	14	34	38	28	0.0	5.8	4.05	1.2	0.00
122	WWD	Ap	0	17	CL	0	0	7	11	17	35	36	29	0.0	6.8	4.46	0.9	0.00
123	WWD	Ap	0	17	CL	0	0	9	9	11	29	43	28	0.0	5.6	3.90	1.0	0.00
124	WWD	Ap	0	15	CL	0	0	8	9	12	29	42	29	0.0	6.2	4.18	0.5	0.00
132	WWD	Ap	0	15	CL	0	0	10	11	9	30	39	31	0.0	5.0	4.00	1.1	0.00

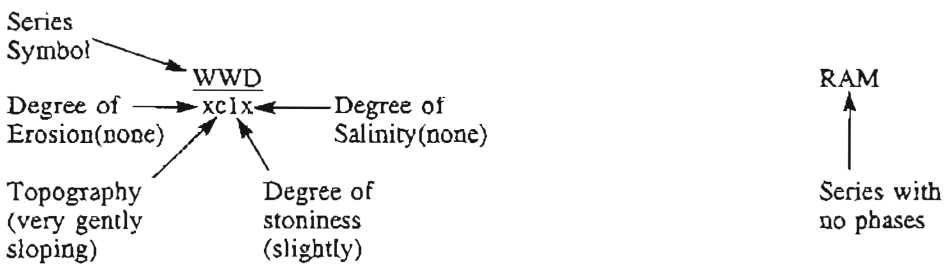
Text = Soil Texture, VC = Very Coarse Sand, CS = Coarse Sand, MS = Medium Sand, FS = Fine Sand, VF = Very Fine Sand, TS = Total Sand
SI = Silt, C = Clay, OC = Organic Carbon, EC = Electrical Conductivity, SAT = Saturation Percent

SOIL LEGEND

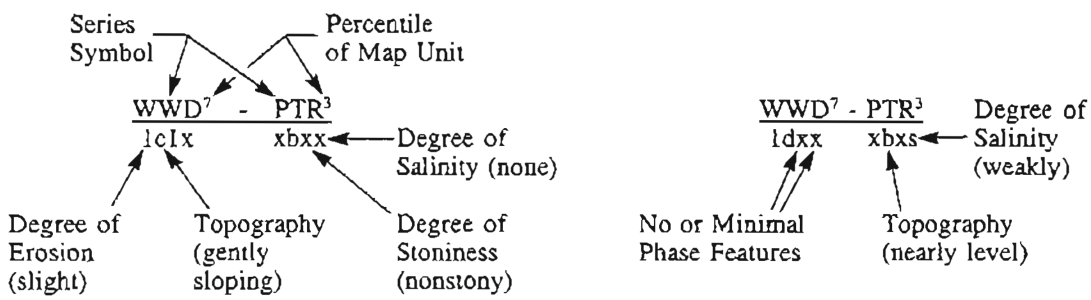
Soil Symbol	Soil Name	Surface Texture	Soil Drainage	Mode of Deposition	Family Particle Size	Soil Subgroup
BKR	Basker	Silty Clay Loam	Poor	Fluvial(Alluvial)	Loamy	Rego Humic Gleysol
CKD	Crookdale	Clay Loam	Imperfect	Lacustrine	Fine Loamy/Sandy-Fine	Gleyed Rego Black
CXV	Charman	Clay Loam	Imperfect	Lacustrine	Fine Loamy	Gleyed Black
FND	Fairland	Loam	Well	Lacustrine	Loamy	Orthic Black
GBO	Glenboro	Loamy	Well	Lacustrine	Coarse Loamy/Sandy-Fine	Orthic Black
GRG	Gregg	Clay Loam	Imperfect	Lacustrine	Fine Loamy	Gleyed Eluviated Black
MHC	Marsh Complex	Mucky Loam	Very Poor	Undifferentiated		Rego Humic Gleysol
OBR	Oberon	Clay Loam	Imperfect	Lacustrine	Fine Loamy/Sandy-Fine	Gleyed Black
PDA	Prodan	Clay Loam	Imperfect	Lacustrine	Fine Loamy	Gleyed Rego Black
PTR	Petrel	Loam	Imperfect	Lacustrine	Coarse Loamy/Sandy-Fine	Gleyed Black
RAM	Ramada	Clay Loam	Well	Lacustrine	Fine Loamy	Orthic Black
SXP	Sutton	Clay Loam	Poor	Lacustrine	Fine Loamy/Sandy-Fine	Rego Humic Gleysol
TDP	Tadpole	Clay Loam	Poor	Lacustrine	Fine Loamy	Rego Humic Gleysol
VDS	Vordas	Silt Loam	Poor	Lacustrine	Loamy	Rego Humic Gleysol
WWD	Wellwood	Clay Loam	Well	Lacustrine	Fine Loamy/Sandy-Fine	Orthic Black

MAP UNIT SYMBOLOGY

Simple Map Units



Compound Map Units



In a compound unit where two series share the same denominator, the phases apply to both series accordingly.

Phases

Degree of Erosion

x	noneroded or minimal
1	slightly eroded
2	moderately eroded
3	severely eroded
o	overblown

Stoniness

		(Surface covered)
x	nonstony	<.01 %
1	slightly stony	.01-.1 %
2	moderately stony	.1-3 %
3	very stony	3-15 %
4	exceedingly stony	15-50 %
5	excessively stony	>50 %

Slope Class

x	0-.5 %	level to nearly level
b	.5-2 %	nearly level
c	2-5 %	very gently sloping
d	5-9 %	gently sloping
e	9-15 %	moderately sloping
f	15-30%	strongly sloping
g	30-45%	very strongly sloping
h	45-70%	extremely sloping

Degree of Salinity Cond. (mS/cm)

x	nonsaline	0-4
s	weakly saline	4-8
t	moderately saline	8-15
u	strongly saline	15+

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