CLASSIFICATION AND POTENTIAL LAND USE OF PRAIRIE SLOUGHS in the Minnedosa Area of Manitoba

By

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ABSTRACT

Intensification of agricultural crop production in Manitoba has resulted in increased drainage pressure on small wetlands called sloughs. Although agricultural and food production should be first priority, other resources should be considered as well. Consequently, land and water managers have become concerned over the possible environmental impacts and benefits to agriculture of extensive slough drainage.

This practicum introduces the slough drainage issue in the broader framework of conservation and goes on to discuss the environmental implications of slough drainage. The literature review describes the physical and hydrological characteristics of sloughs; discusses slough focused soil development; explains the value of wetland ecological indicators; and identifies recent wetland and land use capability classification systems. These characteristics and classification systems are then used to describe and evaluate the sloughs on the Minnedosa-Reston Till Plain in terms of the capability to produce agricultural crops. The Study Area was located immediately south of the Town of Minnedosa, Manitoba.

Four slough types were identified within the Study Area. These sloughs are described and guidelines for their management and utilization are presented.

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CHAPTER 1

INTRODUCTION

1.1 Preamble

The major thrust of early North American governments was to promote the development of natural resources, including land, on what seemed to be an ever expanding frontier (Krueger and Mitchell, 1977). Leitch (1974) refers to that period in our history as the 'pioneer era'; a time in which the objective was to conquer the land.

Economic development, then as now, depended upon the exploitation of renewable and non-renewable resources. However, as resource frontiers were pushed closer to their limits, concern arose over the apparent degradation of our environment and natural resources (i.e., soil erosion, air and water pollution) under the pressure of economic expansion.

This concern led to an international conference on conservation in the early 1900's. The concepts and ideas explored at that conference prompted the Canadian government to establish a Commission of Conservation which was to last until 1921. Throughout its brief history the Commission propagated many of the present day concepts concerning conservation and resource management such as: the co-ordinated management of groups of resources (i.e., combined wildlife, soil and water, multi-purpose management), resource use (i.e., agricultural and recreational activitities utilizing the same lands) and the idea that conservation and development need not be conflicting activities (Krueger and Mitchell, 1977).

North American governments neglected the ideals of the conservation movement to handle the problems associated with the Great Depression and the Second World War. However, the concepts were not forgotten. Men like Aldo Leopold continued to note the changing face of the North American landscape while governments struggled with the problems of economic stability.

Leopold (1949) alarmed at the rate at which the natural environment was being exploited, commented on the subtle value of our natural environment and how man's relationship to the land had become strictly economic. He pointed out that, unlike our individual relationships in society, the land and other resources were seen as property, entailing privileges but not obligations. He stressed the need for the development of a land ethic, which would expand the boundaries of the community to include soils, water, plants and animals. He said:

> All ethics so far evolved rest upon a single premise; that the individual is a mamber of a community of interdependent parts. His instincts prompt him to compete for his place in a community, but his ethics prompt him also to co-operate (perhaps in order that there may be a place to compete for).

The philosophies of Leopold were reinforced by increasing environmental problems in the years that followed. By the late 1960's, man's activities were seen to have a destabilizing influence on environmental processes. Our goal of maximum "production" from renewable resources (i.e., high production from a limited amount of biomass) started to conflict with the natural strategy of maximum "protection" (i.e., optimizing for the support of a complex living structure that buffers the physical environment). Odum (1969) stated that since the environment is our living space, providing us with food, fibre, air, water purification, climate control, recreation and aesthetic amenities, it is necessary to strike a balance between "productive" (i.e., croplands, etc.) and "protective" (i.e., watersheds and forests) landscapes if we were to ensure our lasting survival.

Environmental problems associated with resource developments led to social concerns and conflicts. Resource development and exploitation, along with advances in industrial technology, allowed society to grow more affluent. The corresponding growth in national and personal income as well as personal leisure time increased society's demands on resources for recreational and aesthetic purposes. These new demands focused society's attention on the non-industrial benefits of our natural environment and these benefits grew in relative value in the public eye (Pearse, 1968).

Conflicts between economic and socio-environmental concerns in resource development have been expressed in many ways. Over the years the concepts and ideas developed by the Canadian Commission of Conservation, Leopold's proposed land ethic, Odum's perceived need for environmental diversity and societies demand for recreational and aesthetic resources have all found relevance in the wetland drainage issue, especially where drainage involves the elimination of prairie "potholes" or sloughs.

Burwell and Sugden (1964) and Shaw and Fredine (1971) stated that drainage has added millions of hectares to the agriculture land base of North America. Cairnes (1977) observed that over one million hectares had been improved for agriculture by drainage in Manitoba by 1949 and that drainage continues today.

Initially drainage was directed toward larger marshes and seasonally flooded bottomlands that yielded substantial acreages for minimal effort and cost. More recently reclamation pressure has been turned toward smaller wetlands such as prairie sloughs.

The reasons for slough drainage are varied but basically rest upon the need for increased output and improved farm efficiency. For example, Aus (1969) stated that, in economic terms, wetlands have historically been considered "wastelands". Munro (1967) pointed out that from an agricultural viewpoint, especially on farms without livestock, small wetlands merely represent land that has yet to yield a cash return. Also, small wetlands interfere with the regular straight line operation of farm machinery. Lodge (1969) commented that improved technology, soaring production costs, and increased land prices have resulted in the intensification of agricultural operations and subsequent increased reclamation pressure on wetland acreages. Furthermore, prairie farmers have not found the fall feeding habits of wetland associated waterfowl to be in their best interest. Hedlin (1969) observed that for this reason many landowners regard the elimination of the waterfowl as an incremental benefit, that accrues from the breakup of a marsh for pasture or cultivation.

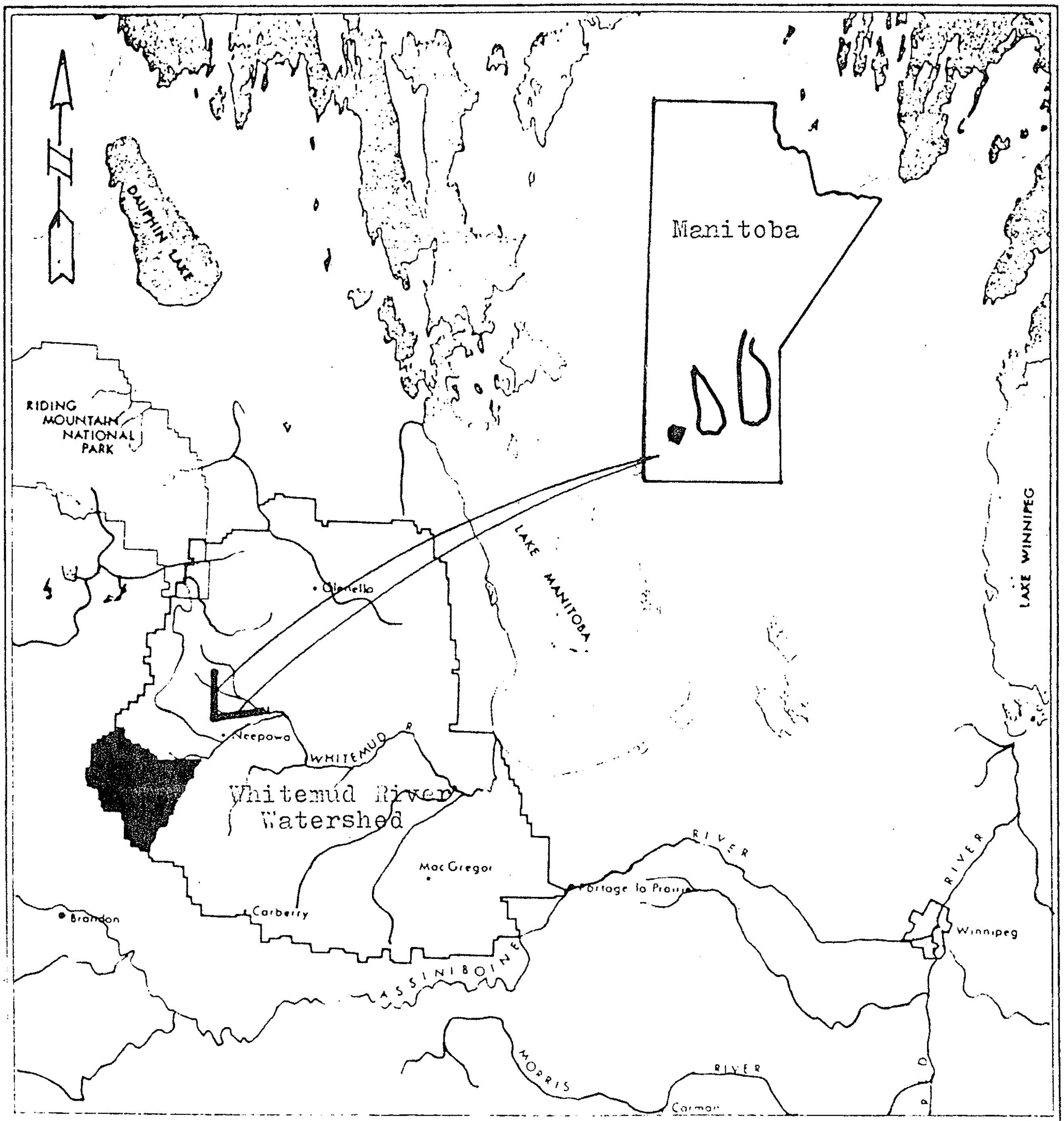
Developing and maintaining agricultural land in Manitoba today is as important now as it was eighty years ago. However, Cairns (1977) stated that with the introduction of the Watershed Conservation Districts Act in 1959, the Manitoba government looked beyond the "pioneer era" of expansion and officially recognized the need for co-ordinated management of all land and water related resources. Jenkins (Manitoba Department of Mines, Resources and the Environment, pers. comm., 1978) indicated that this recognition has led to concern, in recent years, over the advisability of continued slough drainage. He stated that questions have been raised concerning this practice which include: 1) the physical possibility of drainage, 2) the function of sloughs in the ecosystem, 3) their headwater storage capacity, 4) the relationship between sloughs and groundwater supplies, and 5) the benefits derived from drainage including the quality of soil associated with different types of sloughs. He went on to express the need for answers to these questions before drainage is allowed to continue much further.

1.2 Problem Statement

The interest in slough drainage is not restricted to one particular area of Manitoba. However, specific concerns have been expressed over the possible continuation of drainage practices on the upper reaches of the Whitemud River Watershed (Figure 1).

Since the early 1930's land use has changed considerably throughout the area. Cultivated and cleared land has increased at the expense of woodlots, brushlands and sloughs (Kiel, et al., 1972). Although consolidation of surface water has often been the objective of small drainage projects (Zittlau, 1979), slough drainage and other land use changes have seriously reduced the area's waterfowl producing capabilities. Furthermore, efforts to drain water off farms and into the Whitemud River system threaten to aggravate an already serious downstream flooding problem (Jenkins, 1974).

Toth (1966), Korven and Heinrichs (1971), and Eilers (1973) concluded that there were distinct differences between soils formed under various types of sloughs. Since the object of drainage is not only to facilitate field operations but to bring potentially productive land under cultivation, consideration must be given to the agricultural capabilities of slough bottom soils. Their observations suggest that unless each type of slough can be identified and the relationship between the wetlands hydrology and soil forming processes understood, the



Upper Whitemud River Till Plain--Study Area

FIGURE 1: Location map.

economic and environmental costs of slough drainage may be to no avail.

1.3 Objectives

This study will deal with the following objectives:

1. To inventory the sloughs in the Upper Whitemud River Watershed.
2. To classify sloughs according to their: i) chemical and physical, ii) hydrological, and iii) ecological properties.
3. To evaluate the characteristics of sloughs on the basis of agriculture land use.
4. To identify the problems associated with slough drainage and to point to alternate land uses.
5. To develop guidelines for slough management and utilization.

1.4 The Study Area

The Whitemud River Watershed is located in south-central Manitoba and occupies a total area of approximately 719,766 hectares (Figure 1). The Study Area involved the five percent of the Whitemud River Watershed identified as the Upper Whitemud River Till Plain. The Till Plain is characterized by gently undulating topography with a poorly defined drainage system and numerous depressions, ponds and wetlands.

1.5 Methodology

Wetland hydrological and land capability classification systems have been developed in the past and are directly applicable to the prairie slough situation. This practicum reviews, combines and applies these classification systems to the sloughs of the Upper Whitemud River Study Area. Combining the systems is intended to give a holistic view of the potential and problems associated with further slough drainage. Also, the characteristics described for each wetland type are used as a basis for future related land and water management recommendations.

1.6 Limitations

Field observations and data collected are the result of one summer's work. Seasonal as well as annual fluctuations in climatic conditions undoubtedly have a tendency to modify wetland characteristics from one period to the next. Therefore, the observations made during this study are more static than dynamic in nature and must be viewed in light of other more extensive wetland research projects.

1.7 Organization of the Study

The first chapter has presented the wetland drainage issue in the broader framework of conservation. Chapter II comprises the literature section. The chapter deals with the environmental implications of slough drainage, the physical and hydrological characteristics of sloughs, slough focused soil development, ecological indicators of environmental characteristics, wetland and land capability classification systems, the effects of land management on slough soils, and the chapter presents recommendations for control of water and salinity problems.

Chapter III describes the Study Area and outlines the methodology employed in detail. Chapter IV discusses the results of the inventory and classifies the sloughs of the Study Area. Chapter V concludes the study with a summary and recommendations.

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

The terms prairie 'pothole' and slough have been used interchangeably to describe small prairie lakes and ponds of glacial origin (Bird, 1961; Meyboom, 1967; and Sloan, 1970). The terms include permanent bodies of water as well as temporary ones, shallow ones, and those with and without emergent aquatic vegetation (Harmon, 1971).

Sloughs occur in the greatest number and variety in hummocky knob-and-kettle topography created by glacial ice stagnation. During the ice age this land was shaped and reshaped by massive glaciers that ground large chunks of ice into the earth. When the glaciers retreated, the buried ice chunks melted, leaving behind small basins that filled with water--sloughs. Under natural conditions, no streams lead into or out of these basins. Sloughs fill as a result of accumulations of run-off from adjacent lands due to spring snow melt or heavy rains. Sloughs lose water as a result of infiltration of water into the soil, surface evaporation and transpiration by plants (Harmon, 1971).

Petsnik (1975) outlined the area occupied by knob-and-kettle topography in western Canada and the United States (Figure 2). Harmon (1971) estimated that this

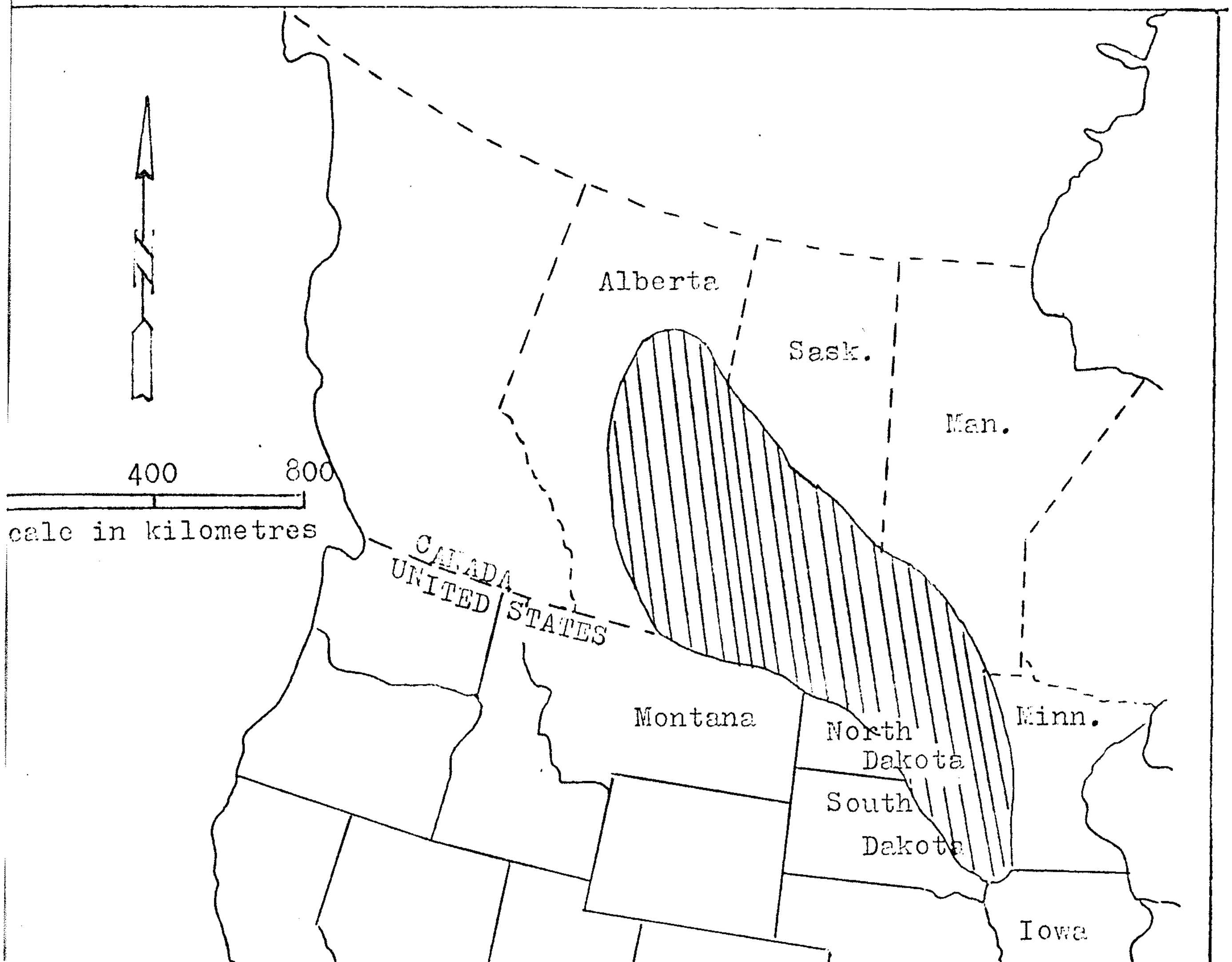


FIGURE 2: Location of Prairie Slough Region of North America.

SOURCE: J. Petsnik, 1975. Background information for the development of guidelines for prairie pothole drainage, Manitoba Department of Mines, Res. and Env. Mngt.

slough dotted parkland and prairie landscape occupied over 77 million hectares (300,000 square miles) of North America. Sloan (1970) observed that a frequency of one hundred or more sloughs per 259 hectares (one square mile) was not uncommon over much of this area. An example of knob-and-kettle topography typical to Manitoba is presented below. The photograph was taken 8 kilometers west of Cartwright, Manitoba in the spring of 1974.

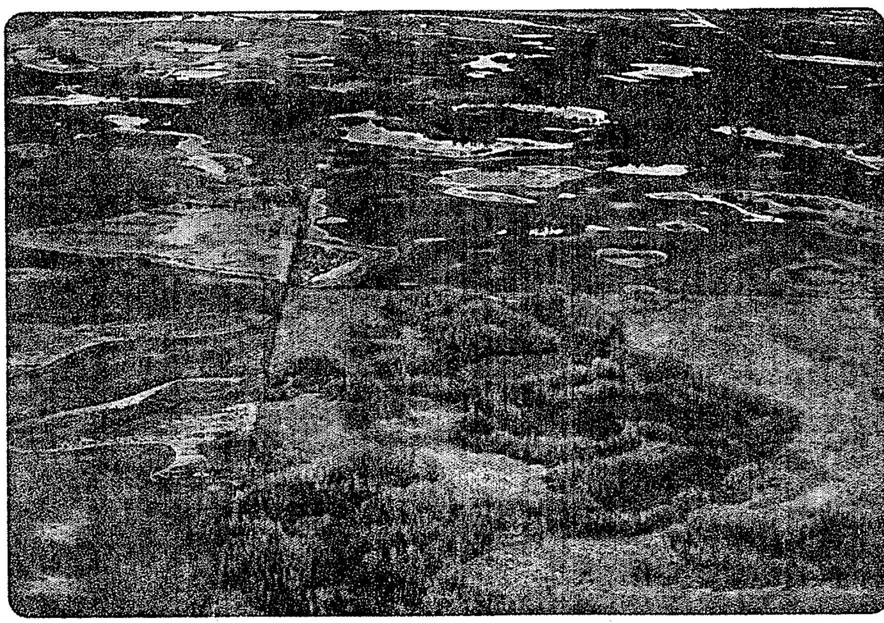


PLATE 1: Slough dotted knob-and-kettle topography common to Manitoba--a spring time aerial view near Cartwright, Manitoba, 1974.

2.2 The Role of Sloughs in the Prairie Environment

Since the retreat of the last glaciers, sloughs have become an intrinsic part of the prairie and parkland environment of North America. Research and observations by scientists and concerned conservationists have shown that undrained sloughs contribute significantly to: 1) the production of waterfowl; 2) aesthetics and recreation, 3) flood control by headwater storage; 4) pollution control, and 5) groundwater recharge.

2.2.1 Waterfowl Production

The importance of prairie sloughs for waterfowl production was expressed in a statement made by Smith, Stoudt, and Gallop (1964). They said:

> Prairie sloughs are the backbone of duck production in North America. Filled with water they contribute the most fruitful duck producing medium in the world. The prairie slough region makes up 10 percent of the waterfowl breeding area of this continent, yet it produces 50 percent of the duck crop in an average year--more than that in a bumper year.

Munro (1967) gave reasons for this high productivity in stating:

> The size and spacing of these water areas on the prairies is significant. Ducks like many other animals, space themselves out on their breeding grounds and thus the presence of numerous individual water areas is more conducive to the build up of large populations than would be in an equivalent area made up of fewer water bodies. Also, the variation in size and vegetation of sloughs serves to meet the changing habitat requirements of ducks at different stages in their breeding cycle. Small potholes provide an ideal habitat for early stages of rearing ducklings. Larger sloughs are more attractive to young birds in late summer. The neutral to basic water of prairie sloughs is very fertile and supports a rich flora and fauna upon which ducklings depend.

The Canada Land Inventory (CLI) capability classification system identified the Study Area as Class 1 to 3 waterfowl habitat. Kiel (1949), Hawkins and Cooch (1948), and Rose and Morgan (1964) referred to the Study Area as part of the largest high quality waterfowl habitat region in the province. Smith, Stoudt and Gallop (1964) called it one of the finest waterfowl breeding areas in North America. Kiel et al. (1972) concluded that "the Minnedosa district was important to the continental waterfowl picture due to its high density of breeding ducks and the consistency of production." Crissey (1964) estimated that approximately 10 percent of all canvasback ducks in North America nested in the Minnedosa area.

Slough drainage reduces habitat available for waterfowl, and ultimately reduces the capability of the prairies and parklands to produce ducks (Adams and Gentile, 1978).

2.2.2 Aesthetics and Recreation

On the subject of prairie sloughs, aesthetics and recreation, Leitch (1974) stated:

> Prairie sloughs enrich our lives. Their endless variety gives beauty and charm to the landscape. The wildlife associated with them adds excitement. Bird watching, even casual observation, hunting and just the unique aquatic situation all provide recreation. Water seems to have a fascination to us all...

Munro (1967) went on to explain the importance of prairie sloughs with respect to their contribution to the sport of duck hunting. He estimated that over 100,000 prairie dwellers hunted ducks and over 1,000,000 North

American hunters depended on prairie ducks to some extent. Those numbers have probably swollen considerably over the last twelve years.

2.2.3 Flood Control by Headwater Storage

The majority of run-off occurs during spring snow melt or after summer storms. Leitch (1974) stated that by retarding run-off from farm fields, most of which are devoid of vegetation during the spring thaw, sloughs play a vital role in reducing downstream erosion and flooding.

Jenkins (Manitoba Department of Mines, Resources, and Environment, pers. comm., 1978) mentioned that wildlife biologists in the United States had examined a slough drainage project near Bottineau, North Dakota in 1976. The biologists estimated that drainage of the approximately 1,300 square kilometre area could add an additional 50 million cubic metres of water to the spring flow of the Souris River. In years when precipitation was adequate to fill these drained areas flooding problems could occur downstream. Jenkins (pers. comm., 1978) went on to indicate that headwater storage lost by off-farm slough drainage might have to be replaced by additional reservoir capacity downstream; storage capacity that would involve public expenditures and the loss of farm and range lands and wildlife habitat.

2.2.4 Pollution Control

Environmentalists have identified pesticide and nutrient bearing run-off from farm fields as a major contributor to environmental pollution and deteriorating surface water quality in both Canada and the United States (McCarty, et al., 1966; Hammer, 1978; and Hill, 1979).

McCarty, et al. (1966) claimed that agricultural run-off was the greatest single contributor of nitrogen and phosphorus to water supplies in the Mississippi-Missouri drainage system. Hammer (University of Saskatchewan Biology Department, pers. comm., 1979) cited the Qu'Appelle River Study Board when stating that run-off from agriculture lands contributed 61 percent of the nitrogen and 59 percent of the phosphorus to the Qu'Appelle River nutrient load. Hammer (1978) later wrote that nutrient bearing run-off produces what is termed 'rush' eutrophication in rivers and lakes downstream. He defined 'rush' eutrophication as the rapid acceleration of the natural aging processes of water bodies. He stated that the indices of accelerated eutrophication is the occurence of a quantitative increase in plant biomass, either in the form of pelagic phyto-plankton or macrophytes. This increase in water plant biomass is often referred to as an algal bloom.

Hammer (1978) went on to write that for years the lakes in the Qu'Appelle River Valley north of Regina, Saskatchewan were popular with local residents and tourists as a recreation area. However, by the late 1960's persistent summer algal blooms, brought on by nutrient bearing run-off from farm fields, had deteriorated water quality to the point where swimming and boating were no longer pleasurable experiences. Furthermore, faunal changes were also characteristic of the eutrophication process. In spite of fish stocking programs in the Qu'Appelle Valley lakes, there was a gradual decline in the number of 'game' fish and an increase in the number of coarse fish such as carp.

Sloughs could be very important in maintaining downstream water quality for consumptive, recreational and fisheries management purposes. Sloughs control non-point source pollution by trapping overland flows of topsoil, nutrients and other sediments. According to Jahn and Trefethen (1973) a 600 hectare marsh can remove by photosynthesis all of the nitrogen and about 25 percent of the phosphorus from the sewage of 62,000 people. Speculation would lead us to believe that sloughs could perform the same function with respect to nutrient bearing run-off.

2.2.5 Groundwater Recharge

Toth (1966), Meyboom (1966), Rozkowski (1967), and Lissey (1968) concluded that sloughs are focal points of prairie hydrological activity. Sloughs are important to the hydrological cycle, because they constitute much of the water budget on the prairies, collecting a significant amount of precipitation by way of run-off from adjacent lands.

Unfortunately, this water rarely finds its way into groundwater acquifers.[1] The nature of glacial till parent materials often prevents surface accumulations of water in sloughs from recharging deep groundwater supplies (Rozkowski, 1967) and (Petsnik, 1975). However, investigations into prairie groundwater flow systems by Meyboom (1962, 1966) and Lissey (1968) show conclusively that the infiltration of water into the soil beneath sloughs contributes to lateral groundwater movement in moderately fine textured, compact glacial till materials. This 'surface' groundwater is often the only source of well water available to farms located on glacial till deposits (landowners throughout the Study Area, pers. comm., 1978).

2.3 Slough Focused Groundwater Hydrology

Although the majority of the water found in sloughs may be derived from local run-off, Meyboom (1966), Rozkowski (1967) and Lissey (1968) found that some sloughs receive water as a result of groundwater discharge. Furthermore, they discovered that the lateral movement of water through glacial till materials between recharge[2] and

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[1]An aquifer is any water saturated body of geological material from which enough water can be drawn at reasonable cost for the purpose required (Halstead, E. C. and J. A. Elson, 1965).

[2]Freeze (1969) defined recharge areas as sites of downward groundwater movement (i.e., the fluid potential at the water table is greater than the fluid potential below the water table; consequently the flow of water is downward).

discharge[1] sloughs resulted in the formation of local groundwater flow systems. A simple groundwater flow system involving recharge and discharge sloughs, as outlined by Lissey (1968), is illustrated in Figure 3.

Lissey (1968) found that as the ground thaws beneath recharge sloughs in the spring, water moves downward through the soil to form a groundwater mound. The groundwater mound subsides over the course of the spring and summer raising the groundwater table. As the groundwater table rises seepage occurs at nearby discharge sloughs. Although the scale of groundwater flow systems can vary considerably, uplands or topographic highs are generally considered to be areas of groundwater recharge while lowlands, or topographic lows, are usually identified as areas of groundwater discharge.

The importance of this slough focused groundwater flow phenomena was explained by Toth (1966). He stated that the appreciation of the specific characteristics and problems related to prairie groundwater flow systems will help explain the development of certain soil types and estimate the prospects for slough drainage.

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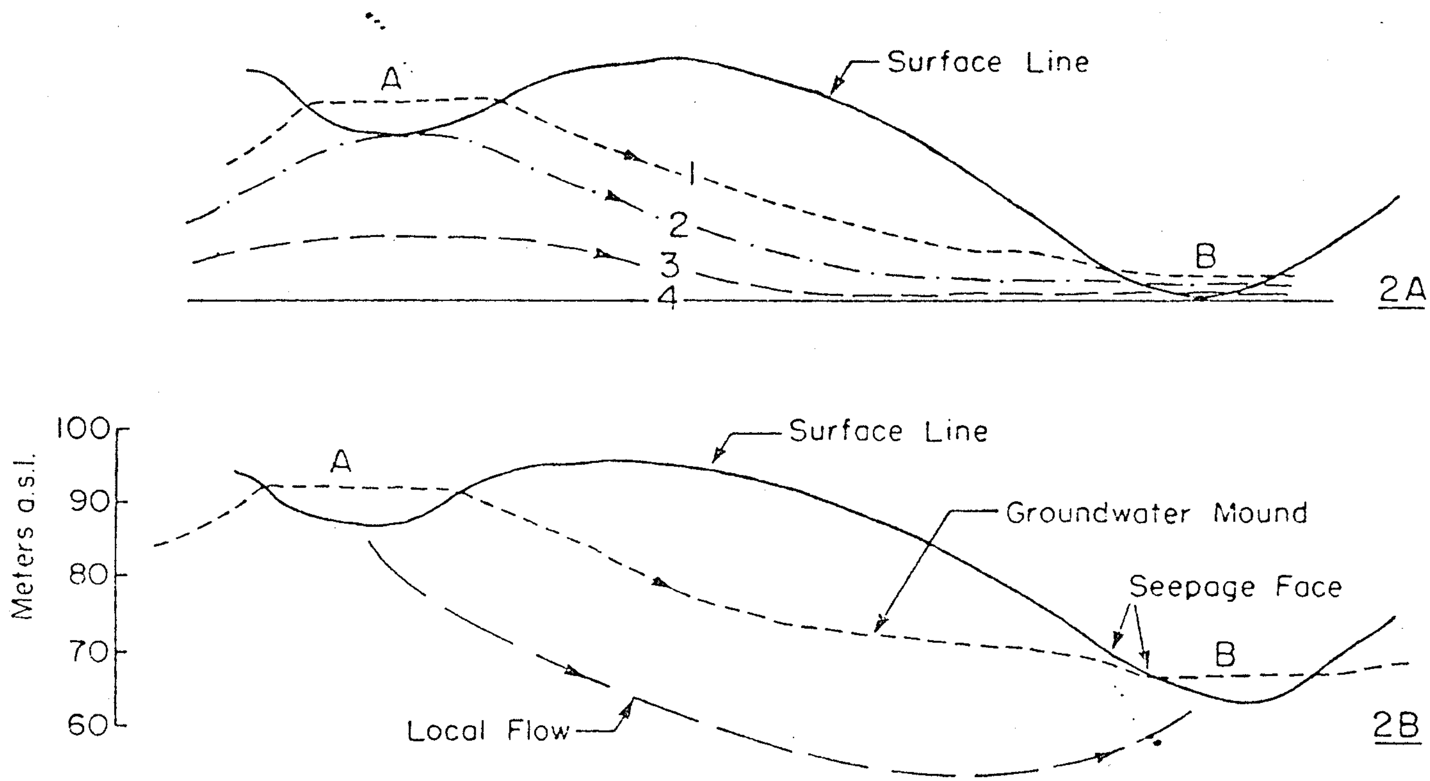
[1]Freeze (1969) described groundwater discharge as being a condition where water is removed from the saturated zone across the water table surface, together with the associated flow towards the water table within the saturated zone. When this flow brings water to the surface evaporation takes place.



Water Table Stages 1,2,3,4
Direction of Groundwater Flow ➤

Source: Lissey, A, Surficial Mapping Of Groundwater Flow Systems with application to the Oak River Basin, Manitoba, 1968; pg 25

Figure 3 Schematic Representation Of A Groundwater Flow System.

2.3.1 Surface and Groundwater Quality

Initial mineralization of groundwater depends on the chemical phenomena associated with water infiltration and groundwater movement. In recharge areas, infiltration exceeds evaporation and there is a net downward movement of water. Recharge sloughs obtain their water from precipitation, which is low in dissolved salts, approximately 15 mg./liter (Davis and Dewiest, 1967). Continued mineralization takes place within the soils below recharge sloughs.

Rozkowski (1967), Toth (1966) and Eilers (1973) stated that progressive modification of the primary mineral composition of groundwater occurs along the entire length of the groundwater flow path. The ultimate composition of groundwater arriving at discharge sloughs depends on pressure, area of water-rock interface, volume of water throughput, and duration of water movement. They concluded that examination of surface and groundwater chemistry gives important indications as to the origin of water, the velocity and direction of groundwater movement and the geologic history of enclosing subsoil.

Eilers (1973) pointed out that the chemical nature of groundwater is quite variable. He stated that all groundwater in the plains region of North America contains at least small quantities of dissolved mineral matter. Rozkowski (1967) found that the most common ions associated with groundwater taken from the glacial tills of southern

Saskatchewan were Na^+, Ca^{++}, Mg^{++}, HCO_3^{--}, Cl^-, SO_4^{--} in varying degrees and relative abundance. Eilers (1973) observed that groundwater which has travelled long distances, and which is relatively old has much more dissolved constituents than younger groundwater. Rozkowski (1967) found that the poor permeability of glacial till deposits induces slow groundwater movement and a more rapid accumulation of ions in groundwater than may be expected in a more permeable medium.

Since water chemistry influences water quality, it follows that water is often evaluated on the basis of mineral content. The measurement of total dissolved solids indicates the mineral content of surface and groundwater. Measurement of total dissolved solids is of particular significance as an indicator of the basic desirability of water for human use. Also, where groundwater discharge influences the quality of surface waters, the quality of the surface water will not only reflect groundwater activity but will also be reflected in the growth of plant life associated with it.

The water quality classification systems used by Robinove et al. (1958), Stewart and Kantrud (1972) and Millar (1976) are compared in Table 1. Robinove et al. (1958) defines water quality in terms of human use. Stewart and Kantrud (1972) and Millar (1976) developed systems which they felt encompasses conditions of maximum sensitivity to the growth of various terrestrial, amphibious, and aquatic plant species.

TABLE 1

Comparing Water Salinity Categories as Described by Robinove et al., Stewart and Kantrud, and Millar

Salinity Category	Salinity Range: Dissolved Solids (p.p.m.)		
	Robinove et al. (1968)	Stewart and Kantrud (1971)	Millar (1976)
Fresh	<1,000	<350	<1,400
Slightly Brackish	1,000 - 3,000	351 - 1,400	-
Moderately Brackish	3,001 - 10,000	1,401 - 3,500	1,401 - 10,500
Brackish	-	3,501 - 10,500	-
Sub saline	10,001 - 35,000	10,501 - 31,500	-
Saline	-	>31,501	10,501 - 31,500
Brines	>35,001		>31,501

Stewart and Kantrud (1972) and Millar (1976) were able to find reasonable correlation between plant communities and surface water quality. However, measuring the surface water of sloughs for dissolved solids only approximately reflects the salinity regime of a given wetland. Seasonal fluctuations occur as a result of dilution by run-off, concentration by evaporation, and possible groundwater inflow. Also, the slow movement of groundwater in low permeability glacial tills, as suggested by Rozkowski (1967), may influence plant growth at discharge sites, but not be appreciably reflected in surface water accumulations.

Infiltration, evaporation and mineral concentration play a key role in soil genesis. Therefore, soil characteristics are likely to reflect long term hydrological processes and indicate the potential agricultural capabilities of drained wetlands.

2.3.2 Slough Focused Soil Development

Soil development or genesis is the result of the combined dynamic interaction of six basic factors: parent material; time; climate; topography; living organisms; and human endeavour. Each of these factors group together numerous subordinate complex processes, which produce specific influences on the soil. The influences result in four basic kinds of changes. Some of the most common changes are: additions, removals, transfers and transformations of organic and mineral materials. The influences are then expressed by the chemical and morphological properties of the soil profile (Buckman and Brady, 1972).

The basic changes that take place in the soil depend on processes such as hydration; hydrolysis; solution; oxidation; reduction; leaching; eluviation; illuviation; precipitation and mixing. In all these processes water is a basic requirement (Buckman and Brady, 1972). It follows that the direction and rate of water movement through the soil will greatly influence the type, rate and characteristics of soil development.

The sequence, the type, and degree of soil profile development is therefore an indicator of the hydrological activity of a soil. In recharge areas the net water movement is downward and soluble constitutents are generally leached out of the soil. The soils of recharge areas frequently show eluviated surface horizons.

On the other hand, soil formed where the groundwater table is high and net water movement is upward show limited soil profile development and varying degrees of salinity. Pawluk (1973) found that a groundwater table within 1 meter of the surface results in strong salinization of the top three feet. In medium textured soils, water tables below 2 meters result in thick soil profile development. Soils containing a high concentration of soluble salts are referred to as saline soils[1] or less accurately, 'white alkali soils'. Saline soils are of particular importance because their presence indicates groundwater discharge conditions (Toth, 1966). Meyboom (1966) states that hydrologists often refer to the soils of discharge areas as groundwater soils because of their mode of origin.

Examples of the ion cycles involved in the development of groundwater chemistry (i.e., the change in salt concentration along the groundwater flow path) are illustrated in Figure 4. These cycles demonstrate the influence of dissolution, leaching, percipitation, and ion-exchange processes on the ion concentration of groundwater going from recharge areas through the "Transmission Area" into discharge areas. In addition, the import of ions from the intermediate flow system and from the slough is indicated. Rożkowski (1967) developed this local and intermediate flow system from groundwater studies he conducted on glacial tills in the Moose Mountain area of Saskatchewan. Dissolution and leaching reduce the concentration of all soluble salts in the recharge areas and consequently soils of recharge areas do not have soluble salts or carbonates in the upper part of the soil profile. On the other hand, ions are transported and deposited in discharge areas and this process continues to build up the level of soluble salts in the soils of discharge areas.

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[1]Buckman and Brady (1972) stated that saline soils contain soluble salts of sodium, calcium, magnesium, and potassium. They also mentioned that the more common salts of saline soils are sulphates of calcium [$CaSO_4 . 2H_2O$ (gypsum)], sodium [NA_2SO_4 (sodium sulphate)], and magnesium [$MgSO_4$ (epsom)].

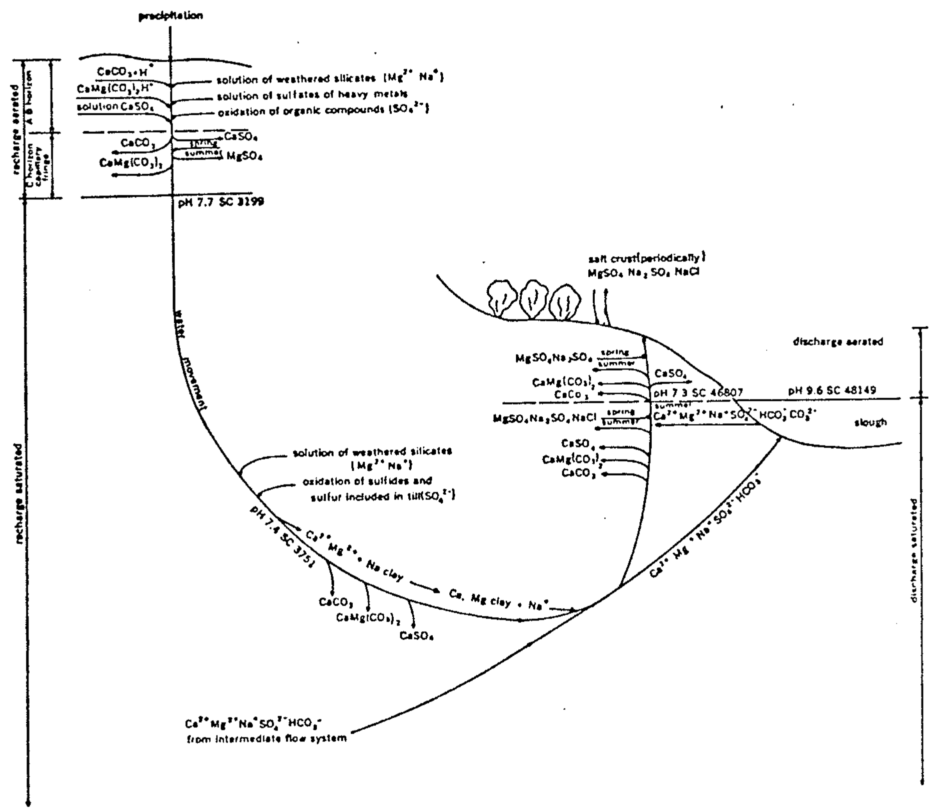

FIGURE 4: Ion Cycles in Groundwater Flow System.

SOURCE: A. Rozkowski. 1967. The origin of hydrochemical patterns in hummocky moraine. Can. Jour. of Earth Sci., Vol. 4, pp. 1085-1095.

2.4 Plants as Environmental Indicators of Surface and Soil Water Quality

The importance of groundwater related phenomena is not specific to soil profile development. Plants derive moisture and nutrients from the soil and ultimately respond to these phenomena as well. Wetland ecologists and hydrogeologists have found that the composition of a wetlands vegetation community is often a reliable indicator of environmental conditions in a slough. They have found that the indicator aspect of plant ecology provides a basis for distinguishing between sloughs that are subject to different ground, soil, and surface water conditions.

Plant species vary in their tolerance to environmental factors. The range of tolerance, or ecological amplitude, is a function of the genotype or genetic constitution of the plant. Plants with relatively restricted tolerances are confined to ecologically specialized habitats. The natural occurrence of plants, is therefore an indication that certain conditions exist in the natural environment. These conditions can be grouped into three major categories: climate, edaphic,[1] and biotic (Lissey, 1968).

Only plant indicators of water quality and degree of soil saturation are discussed in this study because they are the most important factors affecting plant growth that can

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[1]Edaphic factors, or soil characteristics include the type and texture of the parent material, the amount of organic matter, the quality of free water, and the degree

be directly related to groundwater flow and soil quality.

2.4.1 Plants as Indicators of Surface and Soil Water Quantity

Plants have been used as indicators of groundwater since the days of the Roman Empire (Meinzer, 1927) and have been classified according to their water requirements, as early as 1895 (Warming, 1909). Clements (1920) modified Warming's system into one comparing three major plant types: 1) hydrophytes, 2) mesophytes, and 3) xerophytes. Meinzer (1927) went on to identify one more plant group, the phreatophytes. Hence, naturally occurring plants, representative of a particular type, serve as broad indicators of the quantity of free water available in the natural environment.

2.4.1.1 Hydrophytes

Hydrophytes are plants that are adapted to a completely saturated soil environment. They include submerged, floating and amphibious plants.

Lissey (1968), working on the Oak River Basin of Manitoba, found that amphibious, or emergent anchored hydrophytes are especially valuable as indicators of permanent saturated soil conditions around sloughs of the aspen parkland. These plants grow with their roots in water logged soil, and are usually partially submerged in shallow water. Cattails (*Typha* sp.) spikerush (*Eleocharis palustris*), reed grass (*Phragmites communis*), and white top (*Scolochloa festucacea*) are examples of emergent anchored

2.4.1.2 Mesophytes

Mesophytes are plants that are adapted to moist but moderately aerated soil environments. They cannot inhabit saturated soil nor can they survive where soil water is significantly depleted. Most trees, shrubs and many grasses are mesophytes. The aspen poplar (Populus tremuloides), white birch (Betula papyrifera), Manitoba maple (Acer negundo), bur oak (Quercus macrocarpa), reed bentgrass (Calamagrostis sp.), water parsnip (Sium sauve), and wild mint (Mentha arvensis) are examples of aspen parkland mesophytes (Lissey, 1968).

2.4.1.3 Xerophytes

Xerophytes are plants that are adapted to a physically or physiologically dry soil environment. Physically dry conditions may exist where top soil is thin or well drained because of a sandy or gravelly texture. Physiologically dry conditions may exist due to excess soil salts or low soil temperatures. In general, xerophytes grow where the soil is physically dry due to climate. Wheat-grass (Agropyron trachycaulum), spear grass (Stipa comata), and tickle grass (Agrostis scabra) are three examples of xerophytes identified on uplands in the Oak River Basin[1] (Lissey, 1968).

2.4.1.4 Phreatophytes

Phreatophytes (literally, well plants) satisfy their moisture requirements from groundwater rather than

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[1]The Oak River Basin of Manitoba has a similar climatic and geological origin to the Minnedosa Study Area (Lissey, 1968).

soil moisture. Many physiological xerophytes and emergent hydrophytes are also phreatophytes (Meyboom, 1966 and 1967). Phreatophytes generally have very high transpiration rates and can transpire significant quantities of groundwater (Meyboom, 1966). Phreatophytic plants found on the Oak River Basin include willow (Salix sp.), baltic rush (Juncus balticus), reed grass (Phragmites communis), and saltwort (Salicornia rubra). These plants indicate a shallow depth to the water table and varying degrees of groundwater discharge (Lissey, 1968).

2.4.2 Plants as Indicators of Surface and Soil Water Quality

2.4.2.1 Soil water salinity

The primary effect of salts in saline soils is depriving plants of water containing nutrients essential for growth. The dissolved salts increase the 'osmotic pressure' of the soil solution, decreasing the rate at which water from the soil will enter plant roots. If the concentration of salts is very high plants will essentially starve even though the supply of water and nutrients in the soil may be more than adequate (Henry and Johnson, 1978).

A secondary effect of soil salinity is ionic toxicity. Some plants--depending on environmental and other conditions--may also be adversely affected by certain elements, such as sodium or magnesium. Although the effects of ionic toxicity may be masked by the presence of other ions, experiments have shown some plants to be more susceptible to certain elements than others (Black, 1957).

Plants vary in their ability to withstand various levels of mineralization in the water available to them. Therefore, plants can be categorized according to their preference for water quality. Plants that are adapted to saline conditions are called halophytes. Plants with a low salt tolerance are referred to as glycophytes.

2.4.2.1.1 Halophytes. Halophytes grow under saline soil-water conditions. Meyboom (1962) defined saline water as water containing more than 1,000 parts per million dissolved solids. According to Black (1957) plants that grow in saline soil conditions are adapted to this environment in two ways: 1) they are able to exert high osmotic pressure in their tissues and thus maintain necessary levels of moisture diffusion, and/or 2) they are able to regulate salt concentrations in their tissues which safeguards them against ionic toxicity. The degree of salt tolerance of each plant species depends on the level to which the above factors are developed. Therefore, an increase in soil salinity is clearly reflected by a marked change in vegetation.

Meyboom (1966) listed the following salt tolerant species as being common on the Canadian prairie. They are Russian thistle (*Salsola pestifer*), gumweed

(*Grindelia perennis*), saline plantain (*Plantago eriopoda*), saline goosefoot (*Chenopodium salinum*), creeping spikerush (*Eleocharis palustris*), perennial sow thistle (*Sonchus arvensis*), prairie bulrush (*Scirpus paludosus*), baltic rush (*Juncus balticus*), red goosefoot (*Chenopodium rubrum*), salt grass (*Distichlis stricta*), wild barley (*Hordeum jubatum*), and seaside arrowgrass (*Triglochin maritima*).

Domestic crops have a similar range of adaptability to saline soils. Henry and Johnson (1978) present a saline soil classification system based on the response of various crops to soil salinity. Table 2 indicates that soil salinities above 4 ms/cm. (2,800 p.p.m. dissolved solids) affects most crops to some degree.

The impact soil salinity has on crop growth and development was outlined by Toth (1966). He observed that in the early stages of development, crops were retarded in their growth in affected areas; later they were conspicuously visible by their unhealthy yellowish colour in otherwise green fields and by their non-uniform sparse pattern of growth. Finally, the affected areas became nearly barren with individual stocks being short and heads poorly developed.

TABLE 2

Soil Salinity vs Crop Production

Electrical Conductance* ms/cm	Type of Soil	Crop Response
0 - 2	non-saline	no restrictions to type of crops grown.
2 - 4	weakly-saline	some sensitive crops may be affected.
4 - 8	moderately saline	choice of crops restricted; sensitive crops may not grow, most crops affected to some degree.
8 - 16	strongly saline	choice of crops restricted; even the most tolerant crops may be adversely affected

* Parts/million values are derived by multiplying conductance values by 700, the maximum value suggested by Thomas (1953).

SOURCE: Henry, J. L. and W. E. Johnson. 1978. The Nature and Management of Salt-Affected Soils in Saskatchewan. Published by the Saskatchewan Department of Agriculture.

2.4.2.1.2 Glycophytes. Glycophytes do not inhabit saline soils and therefore include all classes of hydrophytes, mesophytes, and xerophytes which cannot also be classed as halophytes. It follows that the term glycophytic would describe many more species of plants than the term halophytic because the special adaptations necessary for a saline soil environment are not required for their survival.

2.5 Classification of Sloughs

The edaphic conditions of each slough have significant influence on associated flora and fauna. Therefore, it is not surprising that several slough classification systems designed to deal with edaphic imposed differences have been developed in Canada and the United States over the last forty years. The impetus for this work has come from waterfowl ecologists and hydro geologists. Frequently, indicators used by them to interpret groundwater and surface water phenomena are similar.

2.5.1 Slough Classification Systems by Waterfowl Ecologists

Waterfowl ecologists have primarily been concerned with studying the relationship between waterfowl production and various kinds of habitat. Initial classification systems dealt with slough permanence. Later on systems were established describing sloughs in terms of vegetation patterns and salinity.

Munro (1967) grouped sloughs into three general categories: 1) temporary-sloughs containing a depth of as much as 43 cm. of water and enduring usually for less than 6 weeks; 2) semi-permanent-sloughs containing as much as 144 cm. of water and persisting for several years without drying up; and 3) permanent-sloughs containing more than 144 cm. of water and rarely, if ever, drying up.

Stewart and Kantrud (1972) classified many of the sloughs and lakes in North Dakota. They based their evaluations entirely on vegetation--classifying these wetlands[1] according to zonal patterns, the interspersion of emergent cover, and the species composition of vegetation; all of which are factors reflecting permanence of water and salinity.

Millar (1976) discussed many of the classification systems that preceded his own. However, he based the majority of his work on the system developed by Stewart and Kantrud (1972).

Millar (1976) described six types of sloughs found in the prairie and parkland region of Saskatchewan. He identified them as: 1) wet meadows; 2) shallow marshes; 3) emergent deep marshes; 4) open water marshes; 5) shallow open waters; and 6) open water alkali marshes. Those

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[1]Millar (1976) defined wetland as that portion of a depressional area normally covered with shallow water for at least a portion of each year and, in an undisturbed state, support wetland vegetation.

sloughs modified by drainage or grazing are referred to as 'disturbed'.

Millar (1976) described wet meadows as normally being flooded for three or four weeks in the spring and usually dry by late May. Under natural conditions he observed that the vegetation communities are composed of xerophytes, mesophytes and phreatophytic willows. He described shallow marshes as being inundated until July or early August. Vegetation consists of an inner zone of hydrophytes, and an outer zone of mesophytes and phreatophytic willows. Millar's (1976) first two categories compare to temporary sloughs as described by Munro (1967).

Millar (1976) stated that emergent deep marshes were normally inundated from spring to late summer and fall and occasionally through the winter. Vegetation consists of an inner zone of deep emergent hydrophytes, surrounded by less water tolerant hydrophytes, mesophytes and sometimes phreatophytes. Emergent deep marshes as classified by Millar (1976) have similar characteristics of both temporary and semi-permanent sloughs as described by Munro (1967).

Millar (1976) based the classification of open water marshes and shallow open waters on the relative size of their open water areas. He stated that marshes were grassy areas, periodically inundated to a depth of 2 meters or less with standing or slowly moving water. Surface waters fluctuate seasonally. Shallow open waters on the other hand, are small bodies of standing water occupying a transition stage between lakes and marshes. In contrast to marshes, shallow open waters impart a characteristic open aspect, with proportionally large expanses of permanent surface water which lack emergent cover, except for relatively narrow zones adjoining shorelines. Millar (1976) went on to say that in both cases vegetation appears in bands around the open water areas with hydrophytes, both submergent and emergent occupying the inner zones. Mesophytes and occasionally phreatophytes can be found around the perifery of these sloughs. Millar's (1976) open water marshes and shallow open waters are comparable to Munro's (1967) semi-permanent and permanent sloughs.

Millar (1976) observed that open water alkali marshes were not always inundated but generally lack vegetation when dry. He stated that high levels of soil salts prevents the development of rooted plant growth.

2.5.2 Slough Classification Systems by Groundwater Hydrologists

Groundwater hydrologists have related groundwater flow systems to the physical features of sloughs through piezometer[1] studies. The hydrological relationship between

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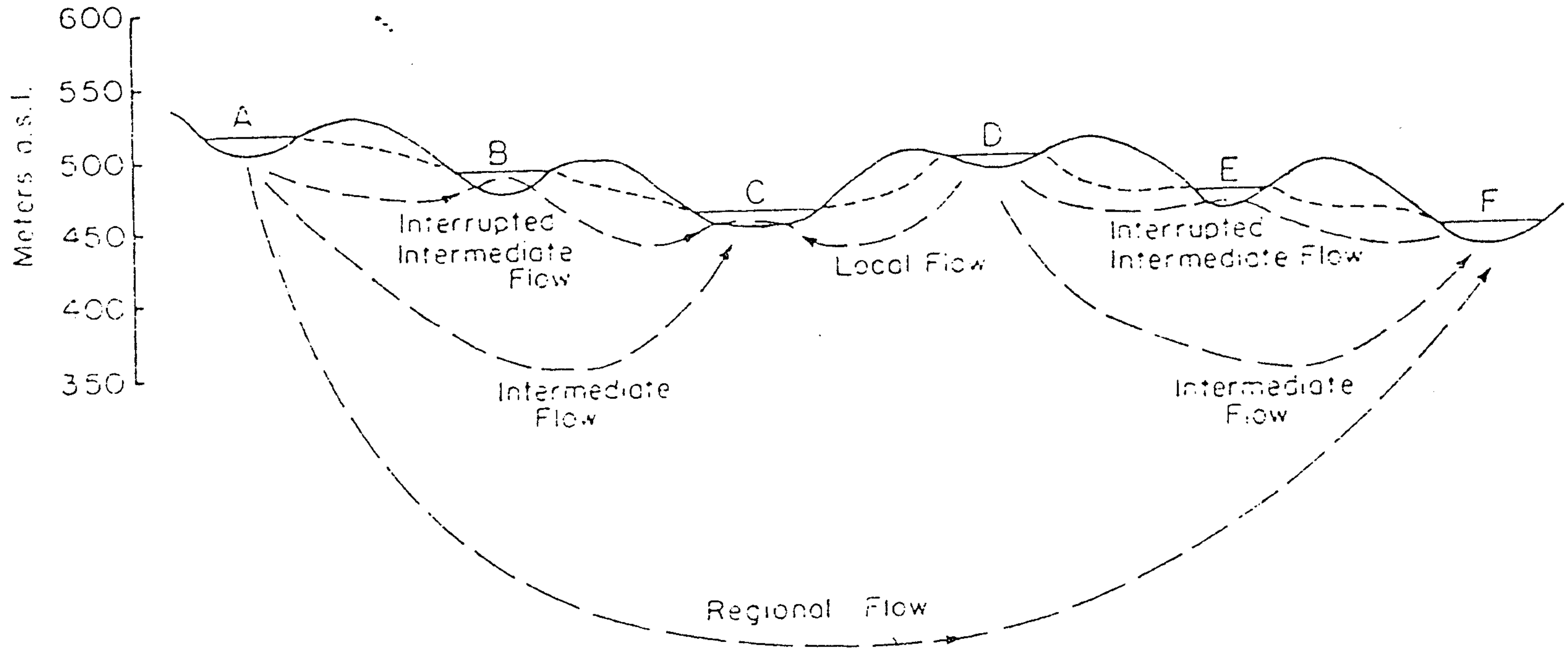
[1]A piezometer is an instrument designed to measure changes in hydrostatic pressure and is therefore useful in determining the direction of groundwater flow (Lissey, 1968).

sloughs and groundwater flow systems has led hydrologists to classify sloughs into three broad categories: 1) recharge, 2) discharge, and 3) transitional sloughs.

The recharge sloughs of southern Alberta are described by Toth (1966) as dry and highland moist depressions depending on their individual moisture regime. He stated that these sloughs were characterized by a hard bottom and the presence of grasses, poplars and/or willows. He described discharge sloughs as having permanently moist soft slough bottom soils even during dry years, open bodies of surface water, associated with shallow water tables and soil salinity. Toth (1966) went on to say that transitional sloughs show both recharge and discharge characteristics.

Lissey (1968) developed an intermediate and regional groundwater flow system including recharge, discharge, and transitional sloughs, based on piezometer studies in the Oak River Basin of Manitoba (Figure 5). Lissey (1968) described recharge sloughs as characterized by seasonal fluctuations in water levels. He observed that hydrophytes, mesophytes and phreatophytes were present around these sloughs to a greater or lesser degree dependent upon the duration of inundation. Lissey (1968) divided recharge sloughs into two groups: 1) fast recharge, and 2) slow recharge. He stated that fast recharge sloughs are characterized by the presence of a narrow outer ring of phreatophytic willows, the absence of open water, and the absence of Millars' deep marsh and shallow marsh zones.



Pothole	Status
A, D	Recharge
B, E	Transitional
C	Discharge: local and intermediate flow
F	Discharge: regional

Source: Lissey, A, Surficial Mapping Of Groundw Flow Systems with application to the Oak River Basin, Manitoba, 1966, pg 29

Figure 5 An Intermediate And Regional Groundwater Flow System.

He described slow recharge sloughs as having typically more permanent surface waters with a central zone of hydrophytes and an outer ring of mesophytes and phreatophytic willows.

Lissey (1968) described discharge sloughs by categorizing them into two groups and dividing each group into two subgroups. He identified the two main groups as being fresh and saline discharge sloughs each further described as being recipients of either fast or slow groundwater discharge. Lissey (1968) identified fresh discharge sloughs by the presence of open water in the fall and glycophytic vegetation. Saline discharge sloughs have a similar open water appearance but differ from fresh discharge sloughs by the conspicuous presence of halophytic vegetation in all wetland zones. He described slow discharge sloughs as having small centrally located permanent open water areas with surrounding zones of hydrophytes and mesophytes. Fast discharge sloughs are identified by an expanding open water zone as the season progresses toward fall.

Lissey (1968) acknowledged the presence of transitional sloughs and described them as being both recipients of groundwater discharge and contributors to groundwater recharge. However, he stated that the physical features of transitional and fresh water discharge sloughs are indistinguishable from one another.

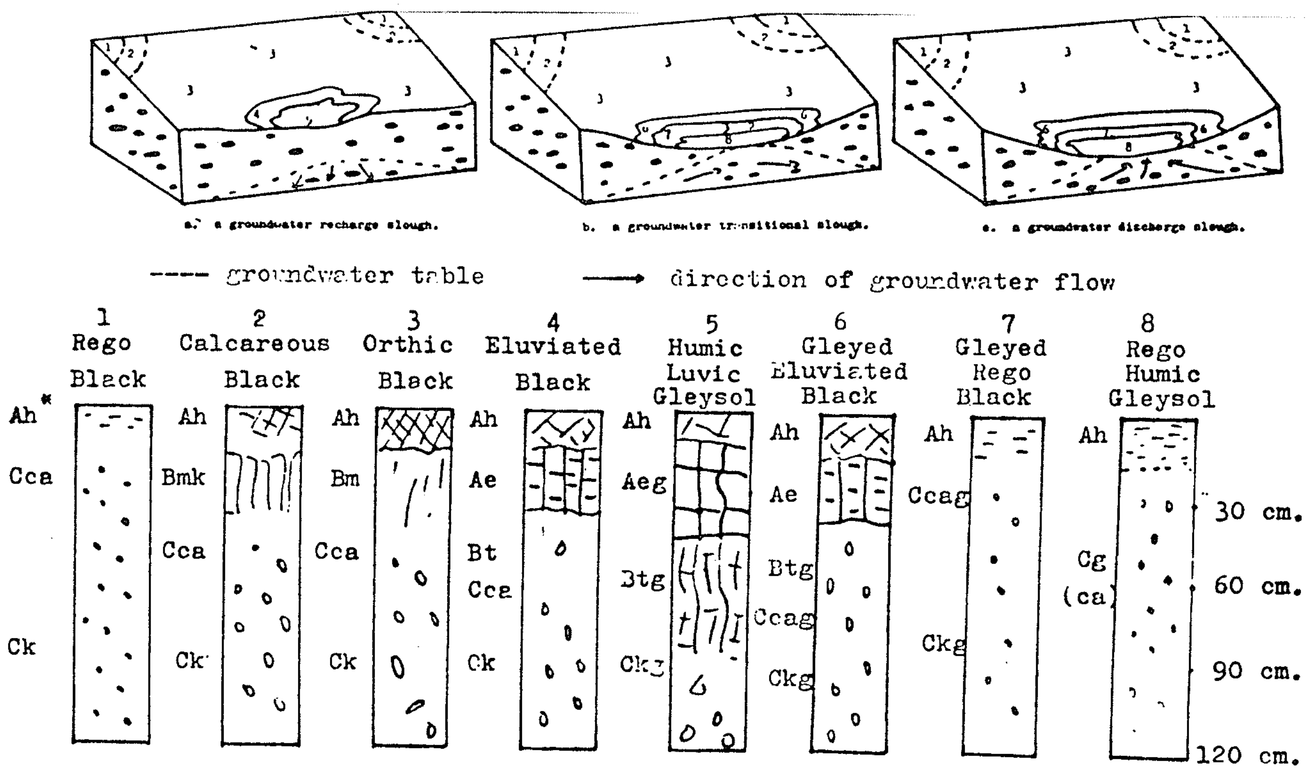
In summary, the recharge sloughs described by Toth (1966) and Lissey (1968) have similar characteristics to the temporary sloughs defined by Munro (1967) and the wet meadows and shallow marshes as outlined by Millar (1976). Furthermore, the features outlined by Toth (1966) and Lissey (1968) for transitional and discharge sloughs compare favourably to the semi-permanent and permanent sloughs described by Munro (1967) and the open water marshes and shallow open waters identified by Millar (1976).

2.6 Soil and Land Classification Systems

The Canada Soil Survey Committee (1978) has developed a soil classification system based on soil properties and environmental factors. This system identifies the soils of Canada, and can be used to describe the soils associated with prairie sloughs. Also, the system forms the basis of soil survey mapping and has led to a number of interpretive groupings one of which is the Soil Capability Classification for Agriculture.

2.6.1 The Soils of Recharge, Discharge, and Transitional Sloughs

Applying the Canada Soil Classification System to the soils that exist in and around sloughs, Eilers (1973) and Rennie and Ellis (1978) indicated that the soils belonged to several subclasses of two orders, namely the Chernozemic and Gleysolic. The soils commonly found in and around typical 1) recharge, 2) discharge, and 3) transitional sloughs are illustrated in Figures 6 a, b and c with reference to their relative location and position of



7. Gleyed Rego Black (Saline Phase)

8. Rego Humic Gleysol (Saline Carbonated Phase)

*see Canada Soil Survey Committee, 1978. The Canadian System of Soil Classification, published by Agriculture Canada, p. 23 for explaination of suffixes.

Figure 6. Topographic relationships and soil profile characteristics associated with sloughs on glacial tills.

Adapted From: D. A. Rennie and J. G. Ellis. 1978. The shape of Saskatchewan, and R. G. Eilers. 1973. Relationship between hydrologeology and soil characteristics near Deloraine, Manitoba.

the groundwater table. Chernozemic and Gleysolic Orders are represented in each case to a degree indicative of the duration of surface flooding and soil saturation.

2.6.1.1 Soils in recharge areas

Rennie and Ellis (1978) stated that in general, changes in soil properties from the knoll to recharge depression are to a large extent related to the redistribution of precipitation. The general trends from upper to lower slope positions are illustrated in Figure 6 and can be summarized as follows:

1) increased organic matter content and thickening of Ah horizon;
2) loss of soluble salts from surface horizons and their movement vertically to underlying horizons;
3) increased leaching and eluviation as evidenced by the development of Ae horizons; and
4) presence of marked Cca horizons in upper slope positions with more diffuse accumulations in moister lower slope profiles.

2.6.1.2 Soils in transitional areas

The soils in transitional areas have never really been examined. However, these soils should indicate more prolonged periods of saturation. Profiles, as illustrated in Figure 6b are not as well developed as in the case of recharge sloughs and the soils may have a tendency to be carbonated.

2.6.1.3 Soils of discharge areas

In the case of discharge slough, soil development is weak. The water table is usually near the surface and evaporation exceeds infiltration. Soils of discharge sloughs are usually wet, carbonated and saline. The location of the various soil profiles in a typical discharge area as suggested by Eilers (1973) are shown in Figure 6c.

2.6.2 Soil Agriculture Capability Classification System

The soil capability classification for agriculture is one of a number of interpretive groupings that may be made from basic soil survey data. It is a resource management and planning tool that can be used to separate agricultural and non-agricultural lands (Canada Land Inventory, 1965).

In this classification system soils are grouped into seven classes according to their potentialities and limitations for agriculture use. Class 1 soils have no significant limitations in use for crops. Class 2 soils have moderate limitations that restrict the range of crops or require moderate conservation measures. Class 3 soils have moderately severe limitations that restrict the range of crops or require special conservation practices. Class 4 soils have severe limitations that restrict the range of crops or require special conservation practices or both. Class 5 soils have very severe limitations that restrict their capability to produce perennial forages, and improvement practices are considered feasible. Class 6 soils are capable only of producing perennial forage crops, and improvement practices are not considered feasible. Class 7 soils have no capability for arable culture or permanent pasture (C.L.I., 1965).

Each class can be divided into subclasses which indicate the kinds of limitations for agriculture use. The sloughs previously discussed would have possibly one or two limiting factors of varying severity. These factors are described by the capability subclasses: 1) wetness (W); and 2) salinity (N).

Class 1 soils have no limitations for agriculture so are not modified by subclasses. Under the subclass 2w, wetness occurs as a moderate limitation correctable by drainage. Class 3w soils are poorly to imperfectly drained and water-logging remains a problem even after drainage. Class 4w soils have excess moisture conditions which cause water-logging for long periods during the year. Class 5w soils are very poorly drained. The effective grazing period is greater than 10 weeks. Class 6w soils are flooded for a large part of the year. These soils are very poorly drained and are not dependable as a source of either native hay or grazing. Open water areas are classed as 7w (C.L.I., 1965). Under the land capability system the sloughs described by Munro (1967) and Millar (1976) would have decreasing agriculture capability proportional to increasing surface water permanence.

Canada Land Inventory (1965) states that soils with enough soluble salts to adversely affect crop growth or restrict the range of crops grown are not classified above Class 3N. Class 4N soils contain sufficient soluble salts to prohibit the growth of sensitive crops such as wheat. These soils are imperfectly to poorly drained. Class 5N soils have such severe salinity problems that only salt tolerant forages can be established and maintained. Class 6N soils are very saline and produce only salt tolerant native vegetation. Class 7N soils have salinity problems severe enough to prevent plant growth. Soils of transitional and discharge sloughs as described by Eilers (1978) are the most likely to fall into one of the salinity (N) subclasses.

2.7 The Effects of Land Management on the Agricultural Capability of Slough Bottom Soils

Sloughs are focal points of prairie hydrological activity. Therefore, land management practices which result in increased rates of run-off have some effect on sloughs and their potential agricultural capabilities. Research has identified three such land management practices that are worthy of discussion: 1) summerfallow, 2) stubble burning, and 3) slough drainage.

2.7.1 Summerfallow

Summerfallowing was introduced to the Canadian prairies following successful studies by Angus MacKay in the late 1890's. He showed that farmers growing crops on the brown and dark brown soils in southern Saskatchewan could benefit through increased soil moisture and crop yields by adopting the summerfallow practice (Rennie and Ellis, 1978).

Once accepted, summerfallow gained extensive use, not only involving brown and dark brown soils but black subhumid soils as well. Although the practice may still be important for sustaining yields in drier regions the widespread application of summerfallowing has not been without costs.

Rennie and Ellis (1978) reported that extensive use of summerfallow has brought about a substantial loss in soil organic matter throughout western Canada. The loss of soil organic matter in turn has resulted in: 1) deterioration of soil structure; 2) decreased soil-water infiltration; 3) greater run-off; and 4) increased soil salinity.

The first two factors mentioned above have resulted in less precipitation entering the soil directly and more run-off concentrating in low lying areas such as sloughs. The movement of surface water in turn often contributes to erosion problems. Also, additional surface water accumulating in recharge areas is believed responsible for increased salinity problems downslope.

For example, Rennie and Ellis (1978) calculated that the acreage of saline soils in Saskatchewan has been increasing at a rate of 1 percent per year. They speculated that part of the reason for the increase was the redistribution of surface water caused by excessive summerfallow. They stated that in the Strawberry Hills east of Saskatoon, run-off from fallow lands has added to groundwater in the upland recharge areas which then moved laterally through the glacial till parent materials and has in turn resulted in severe salinity problems downslope at discharge sites.

Rennie and Ellis (1978) also stated that summerfallow makes very poor use of snow melt waters. They observed that on average 60 percent of snow that falls on stubble lands is retained while only 30 percent is retained on fallow. In total, perhaps no more than 10-20 percent moves into the soil; the remainder is redistributed (either by run-off or wind) into sloughs or creeks and rivers adding to spring flood problems.

Summerfallow is not a recommended practice on saline or salinity susceptible soils according to Henry and Johnson (1978). They stated that salt concentrations increase with depth in many cases and tillage will bring these salts to the surface. Furthermore, summerfallow accelerates the decomposition of organic matter which is valuable in controlling soil salinity. They observe that organic material holds large quantities of water and nutrients. Thus, saline soils rich in organic matter are better able to support plant growth. They also state that a layer of organic material on the surface reduces evaporation and helps to control evaporation and the concentration of soil salts.

2.7.2 Burning

Climate and prairie vegetation have promoted the spread of prairie fires for thousands of years. However, under natural conditions, fires burned primarily during dry summer months. Vegetation had time to recover and provide a protective growth over prairie soils before fall rains arrived.

Today summer prairie fires are gone but burning continues. Spring and autumn burning of stubble, native cover, and small wetlands occurs with a frequency greater than would be expected under natural conditions in many cases (Cowan, 1977). Despite warnings by agriculture researchers burning continues in many regions today.

The Manitoba Department of Agriculture (Government of Manitoba, 1976) gives the following reasons why burning should not be used as a land management practice.

1) Burning removes crop residues. Crop residues returned to the soil add organic matter and nutrients, retain soil structure and improve soil-water infiltration.
2) Spring and autumn burning exposes soils to wind and water erosion. Erosion removes not only soil, but

nutrients and organic matter. Surface crop residues help trap snow which can contribute to soil moisture levels during dry years. Crop residues slow run-off into sloughs and rivers, reducing spring flooding problems both locally and downstream.

3) Burning produces water repelling (hydrophobic) substances in the soil surface which can reduce the infiltration capacity of soils and speed up spring run-off.

Burning has the same impact on sloughs as does summerfallow. Both practices result in increased run-off and therefore increased volumes of water available in recharge areas and subsequent increased soil salinity associated with discharge areas. Furthermore, organic matter buffers the effects of soil salinity (Henry and Johnson, 1978). Burning removes organic matter. Burning around discharge sloughs further aggravates soil salinity problems.

2.7.3 Slough Drainage

Excess water and/or soil salinity are the primary limiting factors (so far discussed) restricting the agricultural capability of slough bottom soils. In addition, Korven and Heinricks (1975) mentioned that the gleysolic soils often associated with depressional areas, present difficult soil structural problems, when cultivated. They state that gleysolic soils have a tendency to crust and bake when drained, making seed bed preparation difficult.

Slough drainage, however, can result in more evenly shaped fields and possibly additional cropland.

Korven and Heinrichs (1975) recommend three methods of slough drainage: 1) drainage ditch and gate, 2) drainage ditch and pump, and 3) drainage by irrigation. The drainage ditch and gate method allows for groundwater recharge prior to surface water removal by gravitational flow. The drainage ditch and pump method is designed for sloughs that are more than five feet below the surrounding topography. Drainage by irrigation is suited for level or slightly rolling topography with sandy loam to coarser textured soils.

To reclaim water-logged salt affected soils by drainage is a major operation. Sommerfeldt and Rapp (1977) stated that two basic steps are required. First, the water table must be lowered and second, the excess salts must be leached below the plant root zone. They listed several types of drains suitable for this purpose including: 1) open drains, and 2) subsurface drains. Both systems have their limitations. Sommerfeldt and Rapp (1977) stated that open drains occupy land that might otherwise be farmed and are recommended only for large reclamation projects where the topography is nearly flat. Open drains are an obstacle to farm machinery, a hazard to livestock, and require continuous maintenance. Subsurface drains are not an obstacle to farm operations. However, Paterson (1978) observed that subsurface drainage is expensive, costing anywhere from \$720 - \$1,440 per hectare.

Zittlau (1979) found that 66 percent of the farmers he surveyed south of Minnedosa, Manitoba, had taken steps to reduce the number of sloughs on their farms by artificial drainage. He stated that in many cases the farmers questioned were primarily concerned with slough consolidation. In most cases drainage was accomplished by digging a shallow ditch between sloughs. Soil texture, size of sloughs, topography and cost definitely limit the choice of drainage methods on knob-and-kettle landscapes. Shallow ditches help control water levels in smaller sloughs without the loss of large amounts of land and without becoming a hazzard to farm operations in themselves. Slough consolidation may be the only viable drainage alternative in many cases.

2.7.4 Summary

In summary, there is growing evidence that the loss of organic material from soils due to summerfallowing and burning has resulted in a greater redistribution of precipitation. Added run-off would mean more prolonged flooding in the local depressional areas associated with in knob-and-kettle topography. More water accumulating in local depressions would add to groundwater recharge but at the cost of soil salinity problems due to greater groundwater discharge downslope. Surface and subsurface drainage are answers to excess water and soil salinity problems. However, physical, economic, environmental and legal[1] limitations may restrict drainage options. Land management practices that make better use of available moisture are worthy of review.

2.8 Solutions to Excess Water and Soil Salinity Problems

Brown, an American soil scientist, was quoted by the Manitoba Co-operator (3-25-76) as saying, "the solution to excess water and salinity problems is to use water where it falls. Where excessive soil salinity is a problem, summerfallow should not be employed. If continuous cereal cropping cannot control soil salinity problems, deep rooted, moisture demanding forage crops should be considered for both recharge and discharge areas."

Rennie and Ellis (1978) felt that appropriate management practices on uplands would help retain moisture and prevent run-off.[2]

Sustained agricultural production from depressional areas requires the removal of excess water. Where surface

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[1]Elliot (1978) and Schellenberg et al. (1974) discuss the historical and legal aspects of drainage in Manitoba.

[2]Rennie and Ellis (1978) stated that if 75 percent of the snow precipitation could be stored in the soil through snow management, continuous cropping should be possible throughout Saskatchewan with yields in excess of 1400 kg./ha. which has been the average over the last ten years.

inundation or soil salinity does not limit crop growth, various crops can be grown that will remove moisture through evapotranspiration. American researchers found that cereal crops use an average of 21 cm. of soil water in a given year, while alfalfa, sainfoin, russian wild rye, and wheat grass use from 50 to 63 cm. of soil water (Manitoba Co-operator, 3-25-76).

Native vegetation is also very effective in lowering water tables in areas where cereal and forage crop production is not possible. Meyboom (1962) observed that native phreatophytes could remove up to 70 cm. of soil moisture in a single season. Summerfallowing crop-lands and destroying native plant communities allows water tables to build up creating excess moisture and salinity problems.

Sloughs vary from one another both physically and hydrologically. To extract maximum benefit from these wet-lands these characteristics must be considered while making management recommendations.

2.8.1 Management of Recharge Sloughs

Korven and Heinrichs (1975) state that to grow crops in sloughs and in areas around them, at least two factors should be considered: 1) the type of farming being carried out, and 2) the capability of the soil involved.

If livestock raising or feeding is the main enterprise, forage crops will give the best returns. Perennial forage crops such as Brome grass and timoth are well suited for growing in sloughs that dry up quickly. They tolerate three weeks of early spring flooding without being damaged by water. Heavy application of nitrate fertilizer is needed to sustain maximum production.

Reed canary grass is the only grass suitable for growing in sloughs where water lies for a month or more. It tolerates two or three months of flooding provided the water is shallow. Reed canary grass actually produces the highest yields when it has grown in water through May and June. Hay crops of 8,000 kilograms/hectare can be produced from one cutting in July. Reed canary grass must be heavily fertilized, preferably in late September. When harvested in July, reed canary grass makes excellent silage.

If grain farming is the main enterprise, grain crops are best. However, unless the sloughs in question dry up quickly in the spring, seeding may be delayed or impossible. In areas where persistent water problems occur in depressional areas, changes in upland management practices may be in order. Continuous cropping, over winter stubble, and the return of organic material to the soil will not only improve natural fertility, but will also increase the soil's permeability to water and therefore, prevent water from running off into sloughs. Summer-fallowing and stubble burning will continue to aggravate the problem.[1]

Of course, some sloughs will never be seeded regardless of upland management practices. In these cases, natural cover will not only supply wildlife habitat but if left intact should reduce salinity problems downslope. Willows and other phreatophitic vegetation transpire significant quantities of water. Needless destruction of these native species by continuous burning or cultivation not only destroys wildlife habitat but also allows increased groundwater recharge and exposes a seed bed for noxious weeds.

2.8.2 Management of Discharge Sloughs

To reduce or correct the salinity problems associated with discharge sloughs, and in areas where surface and subsurface drainage is not practical, a number of management practices are recommended by Korven and Heinrichs (1975).

1) Avoid summerfallowing, overgrazing or burning salinity affected areas whenever possible. Fallow and excessive grazing decreases the evapotranspiration potential of plants and encourages the build up of a water table because the water is not being used. Also, summerfallow and burning reduce the

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[1] See page 51 of this report.

TABLE 3

Scale Showing Relative Tolerance of Crop Plants to Salts

millisiemens (Tolerance increases as numbers Increase)

Scale	Forage Crops	Field Crops	Vegetable Crops
1			
2 3 4 5	Red Clover Alsike Red Top White Dutch Timothy	Corn Soybeans Field beans Peas Sunflowers	Sweet Corn Green beans Celery Radishes
5 6 7 8 9	Reed Canary Meadow Fescue Intermediate Wheat Crested Wheat Bromegrass Alfalfa Sweetclover	Rapeseed Wheat Flax Rye Oats Barley Sugar beets	Cucumber Peas Onion Carrot Potatoes ——— Spinach Asparagus Garden beets
10			
11 12 13 14 15 16	Russian wild rye Slender wheatgrass Tall wheatgrass	Occasionally the more tolerant field crops yield well. However, this land is best suited to producing salt-tolerant forage crops for hay.	
16 →	Few if any agricultural crops do well. Try tall and slender wheatgrass.		

NOTE: The number of millimhos (mmhos) indicate the range of salinity at which crops within that tolerance group can be expected to yield at least 50 percent of normal yield.

SOURCE: R. G. Eilers et al., 1977. Principles and Practices of Commercial Farming, Fifth edition, p. 55.

organic matter content and the fertility of the soil, and therefore enhance soil salinity problems.

2) Use salt tolerant crops. The salt tolerance levels of many domestic crops were listed by Eilers, et al (1977) and are presented in Table 3. Where growing vegetable crops or continuous cropping with salt tolerant barley or sugar beets is not practical, alfalfa, sweet clover, russian wild rye, slender wheatgrass and tall wheatgrass will help control soil salinity. Korven and Heinrichs (1975) recommended a mixture of forage crops as insurance against crop loss due to adverse soil moisture and salinity conditions.

3) Application of barnyard manure, crop residues, or the plowing down of green manure such as sweet clover and alfalfa will improve soil tilth and help solve salinity problems by adding valuable organic material.

4) Soil testing should be done prior to seeding or fertilizing to ensure that proper management steps are being taken.

CHAPTER III

THE STUDY AREA AND METHODS

3.1 The Study Area

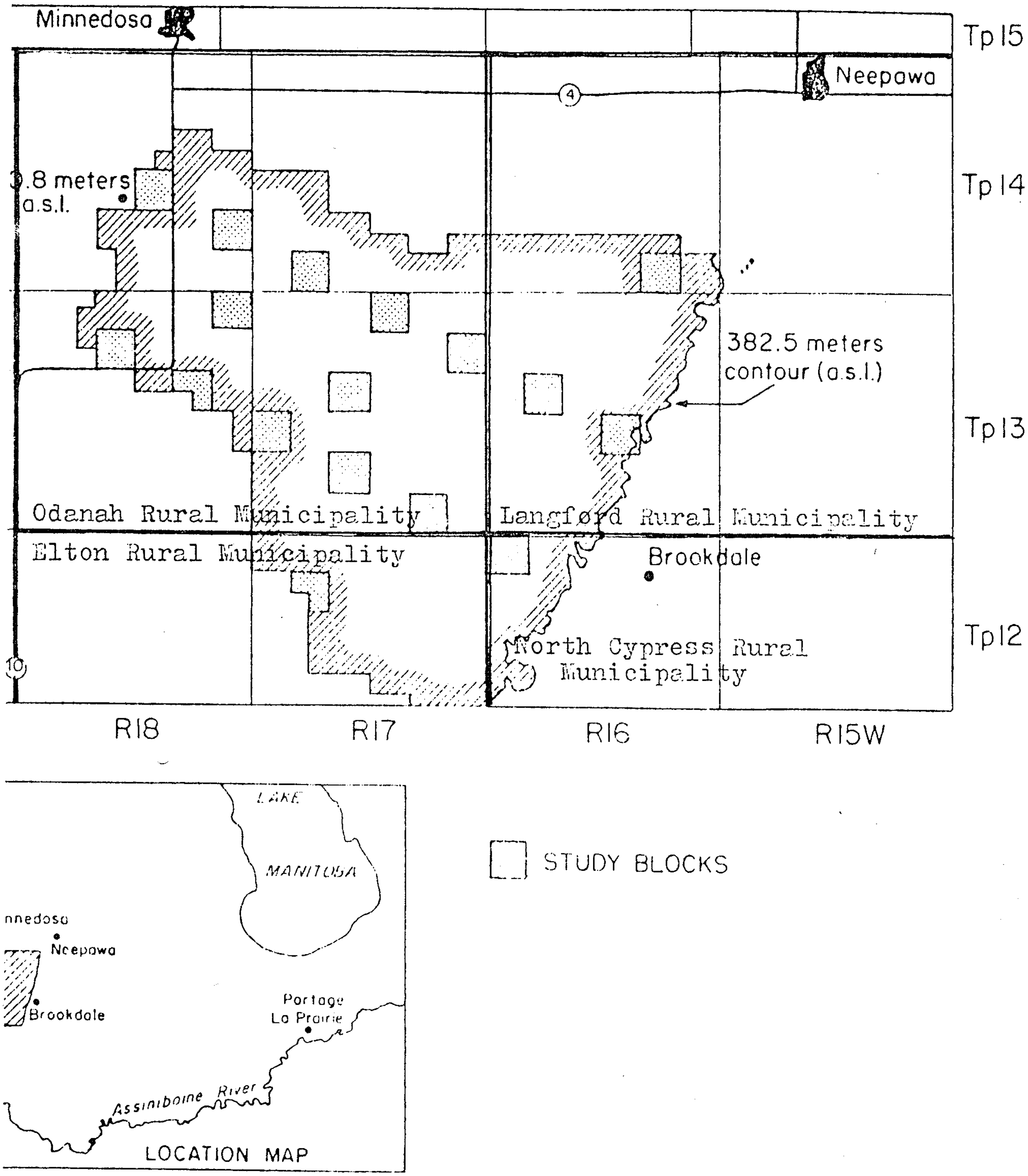
3.1.1 Location

The Study Area is situated within the aspen parkland of Manitoba which is characterized by the intermingling of aspen groves and grasslands. Bird (1961) described aspen parkland as a transition zone between the prairies of the south and the mixed wood and coniferous forests of the north.

The Study Area is located within the Whitemud Conservation Districts Subwatershed #40--Upper Whitemud River. The Study Area is referred to as the Minnedosa-Reston Till Plain and lies immediately south and east of the town of Minnedosa. The Study Area includes approximately 34,700 hectares (134 square miles) and covers two-thirds of the Rural Municipality of Odanah, the south west corner of the R. M. of Langford, the north west corner of the R. M. of North Cypress, and the north eastern segment of the R. M. of Elton (Figure 9).

3.1.2 Climate

The average temperature for July is 15° C and for January -17.8° C. The annual frost free period is 90-100



Upper Whitemud River Study Area.

days with 125-130 days between killing frosts of -2.2 C or lower (Shaykewich, 1974).

Annual rainfall is between 48.45 cm. and 51.0 cm. Twenty-eight to 30.6 centimeters of rain is expected to fall each year between May 1 and September 30. Ten to thirteen centimeters of precipitation accumulates each winter as snow (Shaykewich, 1974).

Shaykewich (1974) indicated that the area has an average annual moisture deficit of between 10.2 and 12.75 centimeters. This deficit, equal to the annual snowfall, suggests that the area is dryer than required for maximum crop production.

3.1.3 Physiography

The Study Area rises from an elevation of approximately 382 to 550 meters above sea level. It is gently rolling with a poorly defined natural drainage system and numerous water areas in glacial formed depressions called sloughs. Stream gradients are moderate, about 1.3 meters/kilometer. Natural drainage into the Whitemud River is somewhat restricted due to the hummocky terrain. Run-off accumulates in sloughs unless attempts are made to remove water artificially (Jenkins, 1974).

The surface and subsurface materials are divided into four main formations: 1) an upper drift formation of glacial till with a low permeability to water and with more permeable sand and gravel lenses; 2) an intermediate very low permeability bedrock shale; 3) a permeable limestone formation; and 4) an underlying basement Precambrian rock formation (Jenkins, 1974).

Despite surface accumulation of water in sloughs, groundwater supplies are a problem throughout the Study Area. Sloughs appear to have little effect on deep groundwater sources due to the lack of adequate aquifers within the region (Petsnik, 1974). Groundwater availability is classified as poor. Aquifers that do exist are located within sand or gravel lenses and are characteristically variable in water supply. Yield of water is low and water quality is classed as fair to poor (Government of Manitoba, 1977).

3.1.4 Soil Capability for Agriculture

The soils of the Study Area are predominately Black Chernozemic soils of the Newdale Association (smooth phase). The soils have developed on glacial till and have a high degree of natural fertility. The Canada Land Inventory (CLI) land capability classification for agriculture designates 70 percent of the soils in the Study Area as Class 2T and 30 percent as Class 6W (Government of Canada, 1966). The Class 2T soils have moderate limitations restricting crop range or requiring moderate conservation practices. Topography (T) is the chief limiting factor on these Class 2 soils. Class 6 soils are capable only of producing perennial forage crops and improvement practices are generally considered unfeasible.[1] Excess water (W) is the chief limiting factor on Class 6 soils within the Study Area.

3.1.5 Land Use

Cereal crop production constitutes the major land use throughout the Area. In the past few years, cattle herds have declined in favour of feedlot operations or no cattle at all. Consequently, pressure has been increasing on wetlands and native pasutre to bring these areas into crop production (Jenkins, 1974).

Since the early 1930's land use has changed considerably throughout the area. Kiel, Hawkins and Perret (1972) stated that cultivated and cleared land increased steadily from 48 percent in 1928-30 to 68.9 percent in 1964. Correspondingly, woodlots and bushland have declined from 28.8 percent of the Area in 1928-30 to 21.4 percent of the Area in 1964. Kiel et al. (1972) pointed out that up until 1964 a small amount of the gain in cultivated acreage was attributable to wetland drainage. Today approximately 70 percent of the land is classified as

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[1] Improvement practices are considered unfeasible if the physical nature of the soil prevents improvement through the use of farm machinery (Jenkins, 1973).

cultivated, 15 percent improved pasture, 12 percent woodlot, and another 3 percent is under swamp or marshland (Jenkins, 1974).

3.2 Methodology

3.2.1 The Study Blocks

Seventeen study blocks[1] were established within the Study Area. Thirteen of the blocks were positioned 1.6 kilometers apart and along two transects running perpendicular to the topographic slope. The other four blocks were chosen to parallel those included in the two transects (Figure 7). Arranged in this manner it was felt that the sample blocks would parallel the slope of the regional groundwater table. In this position any related groundwater flow surface phenomena within the area could be identified. Also, the study blocks lent themselves to infra-red aerial photography at minimum cost with maximum coverage. Unfortunately, the weather did not co-operate and the scheduled remote sensing had to be postponed.

3.2.2 Sloughs Selected for Intensive Study

Sixty-eight sloughs--4 from each study block--were selected for more intensive examination. Sample sloughs were identified from 1:12,000 aerial photographs

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[1] Refer to Table A-1 for the exact location of the study blocks.

obtained in 1976. They were chosen in order to get a representative sample of temporary, semi-permanent and permanent sloughs throughout the Study Area. Consideration was also given to the ability of access roads to withstand all weather travel and the distance sampling equipment had to be transported from the road to the sample site.

3.2.3 Sampling Procedures

Each sample slough was visited at least once during the months of May, June, July and August.

Certain characteristics were routinely recorded for each slough such as the: 1) nature of the wetland; 2) position in the watershed; 3) upland use; 4) maximum depth at date of observation; 5) wetland type; 6) water temperature; 7) water salinity; 8) vegetation communities for each wetland zone; 9) carbonate level of soil samples; and 10) depth of humic[1] layer at plant and soil sample site. Wetland types and sample zones were categorized according to Millar (1976).[2]

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[1]Humic--highly decomposed organic material; there is a small amount of fiber that can be identified as to botanical origin. Fibers that are present can easily be destroyed by rubbing.

[2]Coding was necessary to facilitate field work. Refer to Appendix A for coding keys.

The size of each slough and the percentage of the periphery in woody vegetation were determined by examination of 1:12,000 aerial photographs. Planimeter measurements around the outer periphery of the wet meadow zones yielded the area of each slough. Later, aerial photos were again employed to determine the number of sloughs belonging to each category per study block.

Surface water salinity and temperature were determined in the field by the use of a portable temperature sensitive conductivity meter. Measurements were taken as close to the centre of the slough as possible. The categorization of water salinity followed that of Stewart and Kantrud (1972).

Soil samples were taken at depths of 0-15 and 15-60 cm. in each vegetation zone (one sample site per zone). Soil samples were tested for carbonates in the field (4 N hydrochloric acid), bagged and taken to the laboratory. Conductivity and pH measurements for each soil sample were determined in the laboratory using the saturated paste extract method (Richards, 1954). A more detailed chemical analysis of surface water and saturated paste extract samples for a selected number of sloughs was undertaken by the Provincial Soil Testing Laboratory at the University of Manitoba.[1] Mainly, those samples with the highest

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[1]For detailed discussion of water quality analysis, see Thomas (1953).

salinity readings were selected for further dissolved solid analysis. The results of that analysis are tabulated in Appendix B.

Relative densities of the three most common species of native plants on each sample site were determined by the line-intercept method (Phillips, 1959). Only those species with a relative density of greater than 30 percent were used to determine the relationship between indicator species and electrical conductance of soil samples (Appendix A). Plant nomenclature follows Budd and Best (1969).

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Characteristics of Sloughs and Their Agricultural Capability

Four major slough types, as described by Millar (1976), were found within the Study Area: 1) wet meadow; 2) shallow marsh; 3) emergent deep marsh; and 4) open water marsh. Vertical and profile diagrams of the wetland zones of the stable undisturbed sloughs examined in the Upper Whitemud River Study Area are illustrated in Figure 8. Each slough type was given the name of the wetland zone which occupied the centre.

A summary of the data collected is presented in Table A-1. The two subclasses described by Millar (1976): 1) open water marsh, and 2) shallow open water, were combined into the open water marsh subclass. Shallow open waters were denoted by the subscript s. Sloughs disturbed by burning, mowing, breaking, land leveling, pasturing, or draining were noted but classified into one of the four classes as if no disturbance had occurred.

4.1.1 Wet Meadows

Wet meadows could be distinguished by the presence of phreatophytic and mesophytic vegetation under natural undisturbed conditions. One of the wet meadows sampled is

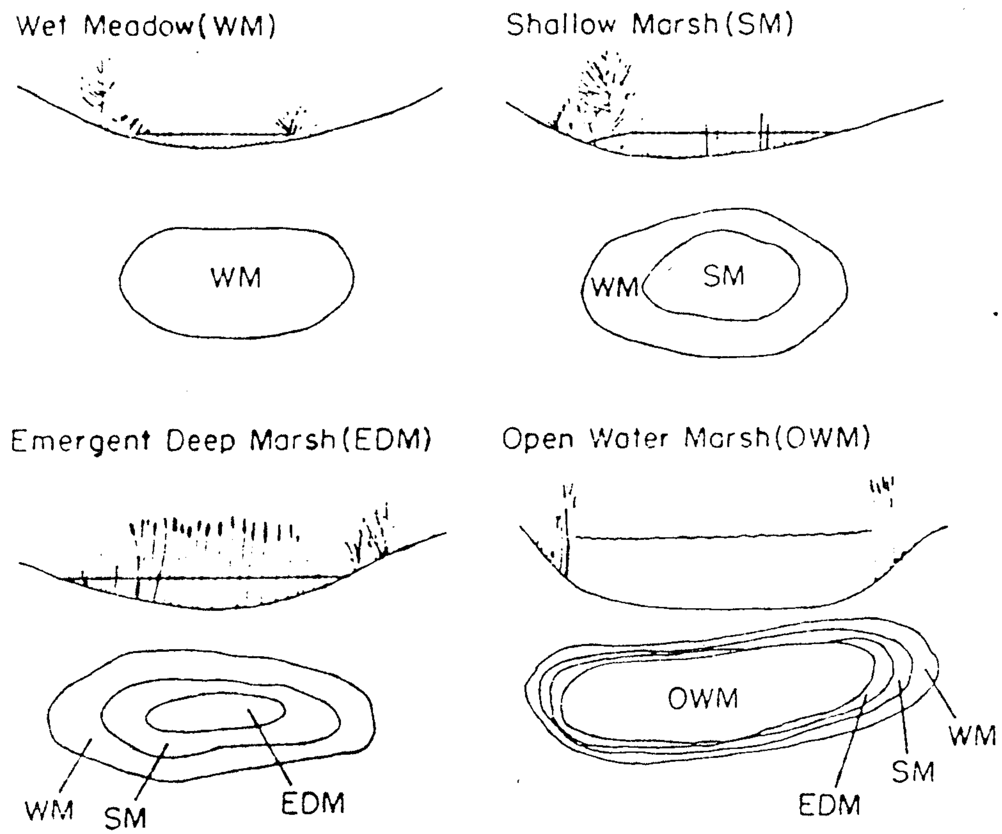

Figure 8 Vertical And Profile Diagrams Of Vegetation Patterns In Stable Wetlands Of The Upper Whitemud River Study Area. Each Wetland Type Is Given The Name Of The Vegetation Zone Which Occupies Its Centre.

Source: J.B. Millar, Wetland Classification In Western Canada, Canadian Wildlife Service, Report Series No.37 (Information Canada, Catalogue No. CW65-8/37, Ottawa), p.13.

represented in Plate 2. A study of aerial photographs showed that the most common sloughs in the Study Area were the wet meadows (20 sloughs/study block). Nine wet meadows were sampled and their mean size was .25 $\pm$ .16 hectares. Soil and vegetation sampling occurred between July 20th and August 12th, 1978. All of the wet meadows were dry at the time of sampling. Topographic highs isolated all but two of the wet meadows from other sloughs making artificial drainage difficult. Three sloughs sampled in this category remained in their natural state. Two wet meadows had been drained and these, along with four others, were cultivated.

Dominant wet meadow vegetation found within the Study Area is presented in Table 4. Wet meadows that remained undisturbed by fire or cultivation were characterized by the presence of willow (Salix sp.), and mesophytic grasses and forbes.

PLATE 2: An undisturbed wet meadow. Note the presence of willow (location: NW 31-12-16).

Wet meadows, disturbed by drainage and cultivation, either supported agricultural crops, a mixture of crops and native plant species, or they were entirely dominated by native plant species. One recently cleared and drained wet meadow produced a thin but healthy rapeseed crop (Plate 3).

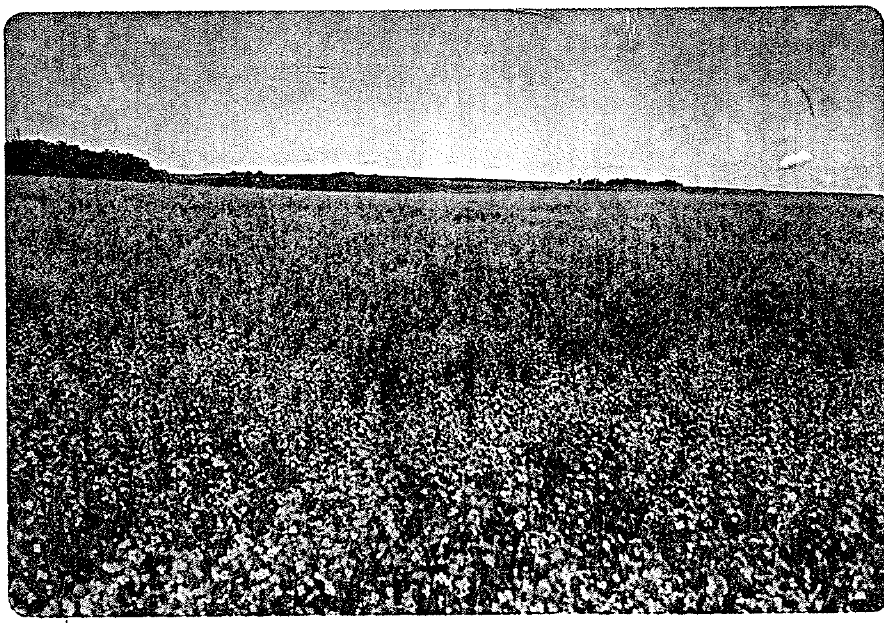

PLATE 3: A recently cleared and drained wet meadow slough. Rapeseed and persicaria weed (Polygonium coccineum) shared the wet meadow soil (location: SW 15-13-16).

Common native plant species found growing in disturbed wet meadow sloughs not supporting crop growth included: slough grass (Bechmannia syzingachne), wild barley (Hordeum jubatum), barnyard grass (Echinochloa crusgalli), Canadian thistle (Cirsium arvense),

TABLE 4

Dominant Wet Meadow Vegetation

Species	Common Name	No. of Sloughs Represented
Salix sp.	Willow	3
Echinochlloa crusgalli	Barnyard grass	2
Polygonium coccineum	Swamp persicaria	2
Eleocharis acicularis	Needle spike-rush	2
Beckmannia syzigachne	Slough grass	3
Carex sp.	Sedge	1
Hordeum jubatum	Wild barley	1
Sonchus arvensis	Perennial sow thisle	2
Cirsium arvense	Canada thistle	1

sow thistle (*Sonchus arvensis*), and needle spike rush (*Eleochoris acicularis*) and swamp persicaria (*Polygonum coccineum*).

Average soil salinity readings indicated non-saline soils (0-2 ms./cm.). Low levels of carbonates and soil salts (Table 5) suggested infiltration of surface water and associated groundwater recharge conditions. However, land leveling operations appeared to have brought about weak surface soil salinity (2-4 ms./cm.) and weak to moderate carbonate levels in three of the sloughs (Table A-1). In the land leveling operation, subsurface materials bearing higher levels of salts and carbonates were mixed with the surface soils. The average soil pH were 7.7 and 7.8 for the 0-15 and 15-60 cm. depths, respectively.

The agricultural capability of the wet meadows sampled was limited only by wetness. Although dry when sampled crops failed to develop successfully in most cases, because of wet spring conditions even where drainage ditches were installed. Conceivably, crops could germinate and grow successfully on wet meadow soils if planted during a dry spring followed by a relatively dry summer. However, periods of temporary wetness, such as in the spring or after heavy rains, would definitely limit cereal crop production unless adequate surface drainage was provided. The wet meadow soils under natural conditions would be classified between 3W and 4W in agriculture capability.

TABLE 5

Wet Meadow Soils

Sample Depth (cm.)	Average pH	Conductivity ms./cm.	Range of Carbonates Present
0 - 15	7.7	1.3	none to weakly carbonated
15 - 60	7.8	.9	none to weakly carbonated

4.1.2 Shallow Marshes

The central zones of the nineteen shallow marshes examined were dominated by grasses, sedges and forbes of intermediate height (approximately 1 m.). An example of an undisturbed shallow marsh is shown in Plate 4. There was an average of 12 shallow marshes per study block with a mean size of .71 ± .52 hectares. Soil and vegetation sampling occurred between June 20th and August 10th, 1978. During that time two of the shallow marshes viewed contained

PLATE 4: An undisturbed shallow marsh. Note the dominant presence of sedges (Carex sp.) and white top (Scolochloa festucacea) in the central shallow marsh zone. Willows appear in clumps in the surrounding wet meadow zone (location: NE 02-13-17).

water. These two sloughs had been deepened by a dugout. Encroachment by farm operations and drainage disturbed the vegetation around six shallow marshes. The remainder of these sloughs were not altered noticeably.

Dominant shallow marsh vegetation is presented in Table 6. The wet meadow zone of shallow marshes undisturbed by fire, cultivation, and/or drainage were characterized by a partial or complete willow ring. Other mesophytes and phreatophytes common to the wet meadow zone included: june grass (Koeleria cristata), baltic rush (Juncus balticus), short-awned foxtail (Alopecurus aequalis), blue grass (Poa palustris), aster (Aster pansus), brome grass (Bromus pumpellianus) and occasionally sedges (Carex sp.). Those shallow marsh wet meadow zones of sloughs that were disturbed usually supported a mixture of native plants and weeds. Perennial sow thistle and Canada thistle were the two most common weeds.

The vegetation of the central shallow marsh zone (Table 6) was generally far more limited in terms of number of plant species. The most abundant hydrophytes observed were sedges (Carex sp.), whitetop (Scolochloa festucacea), slough grass (Bechmannia syzigachne), spike rush (Eleocharis palustris), water parsnip (Sium sauve), mare's tail (Hippuris vulgaris), and occasionally cattails (Typha latifolia). Drainage and cultivation altered the dominance of plant species associated with the shallow marsh zone. Sedges and white top dominated shallow marsh zones in

TABLE 6

Dominant Shallow Marsh Vegetation

a) Wet Meadow Zone

Species	Common Name	No. of Sloughs Represented
Poa palustris	Fowl blue grass	2
Sonchus arvensis	Perennial sow thistle	2
Juncus balticus	Baltic rush	5
Hordeum jubatum	Wild barley	
Agropyron repens	Couch grass, quack grass	2
Cirsium arvense	Canada thistle	5
Koeleria cristata	June grass	10
Salix sp.	Willow	8
Bromus pumpellianus	Northern awnless brome	1
Aster panus	Many flowered aster	1
Carex sp.	Sedge	2
Beckmannia syzigachne	Slough grass	1
Alopecurus aequalis	Short-awned foxtail	1

b) Shallow Marsh Zone

Species	Common Name	No. of Sloughs Represented
Erigeron glabellus	Smooth fleabane	1
Carex sp.	Sedge	12
Scolochloa festucacea	Spangle top, white top	14
Eleocharis palustris	Creeping spike-rush	3
Sium sauve	Water parsnip	3
Hippuris vulgaris	Mare's-tail	1
Beckmannia syzigachne	Slough grass	3
Typha latifolia	Common cattail	2

undisturbed sloughs. However, after drainage and cultivation (Plate 5) slough grass and needle spike rush became dominant native species. Grazing by livestock also changed vegetation communities. Spike rush and water parsnip seemed to be less palatable and therefore more tolerant to grazing than sedges or white top.

PLATE 5: A drained and cultivated shallow marsh. Slough grass and needle spike rush replaced other common dominant marsh plants after disturbance (location: NW 36-13-18).

Average soil salinity readings indicated non-saline soil (0-2 ms./cm.) conditions (Table 7) in the wet meadow zone of shallow marshes. Low levels of carbonates and soil salts suggested downward infiltration of water and groundwater recharge conditions. The average pH were 7.9 and 8.0 for the 0-15 and 15-60 cm. depths respectively.

TABLE 7

Shallow Marsh Soils

a) Wet Meadow Zone

Sample Depth (cm.)	Average pH	Conductivity $ms./cm.^3$	Carbonates
0 - 15	7.9	1.8	weak
15 - 60	8.0	1.7	weak

b) Shallow Marsh

Sample Depth (cm.)	Average pH	Conductivity $ms./cm.^3$	Carbonates
0 - 15	7.6	1.8	none
15 - 60	7.8	1.5	none

On average, the soils of the shallow marsh zone (Table 7) were generally non-saline and non-carbonated at all measured depths. Average soil pH was 7.6 and 7.8 for the 0-15 and 15-60 cm. depths respectively. The soil characteristics in the shallow marsh zones were indicative of slow downward infiltration of water and possible slow groundwater recharge conditions.

Persistent water problems restricted agricultural production in the shallow marsh zone of these sloughs. Even with present installed drainage ditches, cultivation was limited to the wet meadow zones. With adequate drainage cereal crop production could be possible, although costs of drainage could be high. Under natural conditions wet meadow zone soils would be classed 3W to 4W in agricultural capability. Shallow marsh zone soils appear suitable only for forage crops and pasture and therefore should be classed 4W to 6W in agricultural capability.

4.1.3 Emergent Deep Marshes

Six emergent deep marshes were sampled between June 25th and August 3rd, 1978. They could be distinguished from shallow marshes by the presence of coarse grasslike hydrophytes dominating the central zone which were distinctly taller than those of the shallow marsh zone. The mean size of these sloughs was .82 $\pm$ .71 hectares. One of the emergent deep marshes examined is represented in Plate 6.

Three of the emergent deep marshes sampled showed evidence of attempted surface drainage. However, drainage did not result in conditions dry enough for either cultivation or the harvest of native hay in the emergent deep zone during the summer of 1978. Two of the emergent deep marshes studied still contained surface water at the time of sampling. Salinity readings of the water showed very low levels of dissolved salts (Table A-1). The low salinity readings suggested water of run-off origin as opposed to groundwater discharge.

PLATE 6: An emergent deep marsh. The central zone is dominated by soft stem bulrush (Scirpus validus). White top occupies the shallow marsh zone and sow thistle is conspicuous in the wet meadow zone (location: SW 30-13-16).

Dominant emergent deep marsh vegetation is presented in Table 8. The vegetation of the wet meadow zone of the emergent deep marsh consisted of: baltic rush,

TABLE 8

Dominant Emergent Deep Marsh Vegetation

a) Wet Meadow Zone

Species	Common Name	No. of Sloughs Represented
Juncus balticus	Baltic rush	2
Hordeum jubatum	Wild barley	2
Koeleria cristata	June grass	2
Salix sp.	Willow	3
Carex sp.	Sedge	1
Eleocharis acicularis	Needle spike-rush	2
Cirsium arvense	Canada thistle	2
Sonchus arvense	Sow thistle	4

b) Shallow Marsh Zone

Species	Common Name	No. of Sloughs Represented
Carex sp.	Sedge	3
Scolochloa festucacea	White top	4
Eleocharis palustris	Creeping spike-rush	2
Sium sauve	Water parsnip	1
Typha latifolia	Cattail	2

c) Emergent Deep Marsh Zone

Species	Common Name	No. of Sloughs Represented
Typha latifolia	Cattail	4
Eleocharis palustris	Creeping spike-rush	2
Scirpus validus	Softstem bulrish	1
Scirpus acutus	Hardstem bulrush	1
Sium sauve	Water parsnip	1
Bechmannia syzigachne	Slough grass	1

wild barley, june grass, quack grass (Agropyron repens), sow thistle, needle spike rush, Canada thistle, and willow. Willows were not as common to the periphery of the emergent deep marshes as was the case in the previous two wetland categories. Two possible reasons for the lack of willow growth could be frequent burning or increased soil salinity levels.

The vegetation of the shallow marsh zone of the emergent deep marsh was comparable to that found in the shallow marsh zones of other wetland classes. White top and sedges were the most common. Spike rush, water parsnip and cattails could also be found in this zone in varying degrees of abundance.

The vegetation of the central emergent deep marsh zone reflected the adaptability of native plant species to withstand more prolonged periods of surface flooding and saturated soil conditions. Cattails, soft stem bulrush (Scirpus validus), hard stem bulrush (Scirpus acutus), water parsnip, spike rush, and slough grass, were all found in varying degrees of relative abundance. Cattails and bulrushes were generally the more dominant species.

Soil samples taken from the wet meadow zone of the emergent deep marshes had an average pH of 7.7 and 7.9 for the 0-15 and 15-60 cm. sample depths, respectively. Soil salinity readings indicated weakly saline conditions down to 60 cm. Carbonates were present in varying levels at

TABLE 9

Emergent Deep Marsh Soils

a) Wet Meadow Zone

Sample Depth (cm.)	Average pH	Conductivity ms./cm.^{3}	Carbonates
0 - 15	7.7	2.9	none
			to
15 - 60	7.9	2.6	strong

b) Shallow Marsh Zone

Sample Depth (cm.)	Average pH	Conductivity ms./cm.^{3}	Carbonates
0 - 15	7.8	1.8	weak
			to
15 - 60	8.0	1.2	moderate

c) Emergent Deep Marsh Zone

Sample Depth (cm.)	Average pH	Conductivity ms./cm.^{3}	Carbonates
0 - 15	7.8	1.8	weak
			to
15 - 60	8.0	1.2	moderate

all sample depths (Table 9). These soils showed signs of minimal leaching.

The soil pH of samples taken from the shallow marsh and emergent deep zones were similar to those of the wet meadow soils but the carbonate and salinity levels were lower (Table 9). The saturated soil conditions of the central wetland zone, low conductivity of surface water, the presence of carbonates and weakly saline soil conditions in the wet meadow zone all suggest minimal groundwater influence.

The agricultural capability of emergent deep marsh soils is limited primarily by excess water. The wet meadow zone soils could be seeded to cereal crops. However, salinity may be a problem if native vegetation was destroyed and cropping did not remove adequate amounts of groundwater by evapotranspiration. Wet meadow zone soils in the natural state could be classed 3W to 4W in agricultural capability. The shallow marsh zone soils offer progressively more problems with surface water and are capable only of producing perennial forages (5W agricultural capability). The central zone of emergent deep marshes has severe limitations to agriculture and would have to be classed 5W to 6W in capability.

4.1.4 Open Water Marshes

Thirty-four open water marshes were sampled between June 20th and August 10th, 1978. These sloughs occurred with an average frequency of thirteen per study block and they had a mean size of 1.52 $\pm$ .76 hectares (Table A-1). Two of the open water marshes examined are shown in Plates 7 and 8.

Only one of the open water marshes did not contain surface water at the time of sampling. Surface water salinity reading in the remaining sloughs indicated from fresh (350 p.p.m. dissolved solids) to moderately brackish (1,401-3,500 p.p.m. dissolved solids) water conditions. Open water marshes situated in the northern half of Township 13 Range 17, and the southern halves of Township 14 Range 18 and Township 17 Range 16, contained waters of the highest salinity readings. However, none of the salinity readings indicated strong regional saline discharge conditions. The presence of moderate to low levels of surface water salinity could possibly be attributed to local transitional or fresh water discharge groundwater flow conditions as described by Lissey (1968) and dilution by surface run-off.

Disturbances of the open water marshes examined were not as numerous as in other three categories of sloughs. Twenty-seven open water marshes showed little or no sign of disturbance. Three sloughs had dugouts in them, three were partially drained, and one was the recipient of drainage waters (Table A-1).

Dominant open water marsh vegetation is presented in Table 10. Willows were common but did not completely

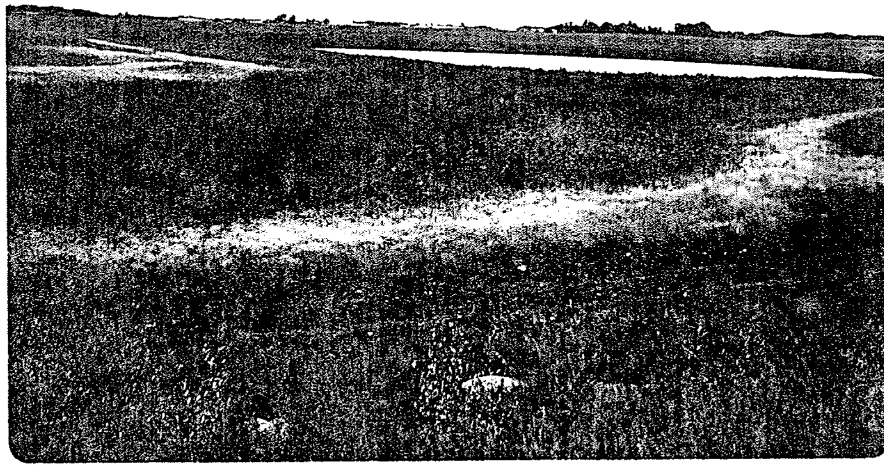

PLATE 7: An open water marsh. Hydrophytic cattails dominate the emergent deep marsh zone. Sow thistle and wild barley are common to the dryer wet meadow zone. The shallow marsh zone is not visible in this photograph (location: NE 5-14-17).

PLATE 8: An open water marsh showing signs of soil salinity around the periphery of the wet meadow zone. Flax was unable to grow on these soils (location: SW 36-13-18).

TABLE 10

Dominant Open Water Marsh Vegetation

a) Wet Meadow Zone

Species	Common Name	Sloughs Represented
Poa palustris	Fowl blue grass	2
Sonchus arvensis	Perennial sow thistle	26
Juncus balticus	Baltic rush	18
Hordeum jubatum	Wild barley	5
Koeleria cristata	June grass	10
Salix sp.	Willow	11
Aster panus	Many flowered aster	2
Erigeron glabellus	Smooth fleabane	1
Eleocharis acicularis	Needle spike-rush	2
Carex sp.	Sedge	1
Scirpus acutus	Hardstem bulrush	1
Cirsium arvense	Canada thistle	2

b) Shallow Marsh Zone

Species	Common Name	Sloughs Represented
Carex sp.	Sedge	22
Scolochloa festucacea	White top	23
Eleocharis palustris	Creeping spike-rush	4
Eleocharis acicularis	Needle spike-rush	1
Sium sauve	Water parsnip	1
Sonchus arvensis	Sow thistle	4
Mentha arvensis	Wild mint	1
Scirpus validus	Softstem bulrush	1
Typha latifolia	Common cattail	2
Scirpus acutus	Hardstem bulrush	3

Continued

TABLE 10 (Continued)

c) Emergent Deep Marsh

Species	Common Name	Sloughs Represented
Scirpus validus	Softstem bulrush	10
Typha latifolia	Common cattail	23
Scirpus acutus	Hardstem bulrush	12
Scirpus paludosus	Prairie bulrush	2
Scolochloa festucacea	White top	6
Eleocharis palustris	Creeping spike-rush	4
Beckmannia syzigachne	Slough grass	1
Sium sauve	Water parsnip	2
Hippuris vulgaris	Mare's-tail	3

encircle any of the open water marshes sampled. Since willows have a low tolerance to salinity, this observation suggested that groundwater conditions varied around many of the individual open water marshes, a phenomena that would be expected around groundwater transitional sloughs as described by Lissey (1968). Other vegetation common to the open water marsh wet meadow zone included baltic rush, couch grass, wild barley, needle spike rush, june grass, sow thistle, aster, fowl bluegrass (Poa palustris), fleabane (Erigeron glabellus), Canada thistle, and in one instance, hardstem bulrush.

The vegetation of the shallow open marsh zone was similar to that found in similar zones of other sloughs. Hydrophytes such as sedges, white top, spike rush, and water parsnip were common. In some cases, mesophytes and hydrophytes adapted to deeper water conditions invaded the shallow marsh zone.

Emergent deep marsh zone vegetation included: soft stem bulrush, hardstem bulrush, cattail, slough grass, white top, mare's tail, water foxtail (Alopecurus geniculatus) and water parsnip. In two cases where surface water conductivities exceeded 3.3 ms./cm. and soil conductivities were greater than 4 ms./cm., prairie bulrush (Scirpus paludosus) was a common plant (Table A-1).

The soils of the wet meadow zone had an average pH of 7.7 and 7.8 for the 0-15 and 15-60 cm. depths, respectively. On the average, the soils were moderately saline (4-8 ms./cm.) and salinity declined with depth.

Carbonates were present and levels increased with depth (Table 11). Saline conditions around the periphery of 21 of the 34 sloughs sampled affected the growth of agriculture crops and native plants. Agricultural encroachment on the wet meadow zone of open water marshes may have contributed to soil salinity problems in some cases.

Soil pH remained slightly basic and did not vary significantly in the inner two wetland zones. Soil salinity (2-4 ms./cm.) in the inner two wetland zones was lower than in the wet meadow zone (4-8 ms./cm.) in most cases. Soil sampling was difficult in the shallow marsh and emergent deep marsh zones of most open water marshes due to surface water conditions.

Open water marsh soils have severe limitations to agricultural production. Saline soils in wet meadow zones indicate a high water table and groundwater discharge conditions. Attempts to encroach upon these wet meadow soils left a ring of bare saline soil around the slough in many cases. Observations suggest that salinity will continue to be a problem of growing proportions in these soils if native cover is destroyed and cropping practices do not remove adequate amounts of groundwater. The wet meadow zone soils of open water marshes would probably be better left in native cover or sown to perennial forage crops. Consequently, these soils would have to be classed 4W to 6W in agricultural capability. Excess water in the central zones of open water marshes limits capability to classes 5W to 7W.

TABLE 11

Open Water Marsh Soils

a) Wet Meadow Zone

Sample Depth (cm.)	Average pH	Conductivity ms./cm.[3]	Carbonates
0 - 15	7.7	5.3	weak
			to
15 - 60	7.8	4.4	strong

b) Shallow Marsh Zone

Sample Depth (cm.)	Average pH	Conductivity ms./cm.[3]	Carbonates
0 - 15	7.9	2.9	weak
			to
15 - 60	7.9	3.0	strong

c) Emergent Deep Marsh Zone

Sample Depth (cm.)	Average pH	Conductivity ms./cm.[3]	Carbonates
0 - 15	7.9	2.8	weak
			to
15 - 60	7.9	2.7	strong

4.2 Edaphic Conditions and Vegetation

Persistence of surface water and soil salinity increased from wet meadows to open water marshes. These changing edaphic conditions were in turn reflected in the vegetation associated with each wetland zone.

The relationship between dominant marsh plant species, electrical conductance of surface soils (0-15 cm.), and the wetland zone is shown in Table 4. The native plant species presented are the most common and are likely to be the most easily identified in a reconnaissance survey. Phreatophytic willows were a sign of low soil salinity levels and therefore, were indicators of downward soil water movement. Baltic rush, a phreatophytic halophyte, and wild barley, a halophyte, were indicators of soil salinity conditions in excess of 4 ms./cm. and groundwater discharge conditions. Slough grass preferred less saline conditions than did white top in the hydrophytic zones. Similarly, hydrophytic cattails indicated lower levels of soil salinity than did hard or soft stem bulrush. Prairie bulrush, a halophytic hydrophyte (Millar, 1976), only appeared in two of the sloughs sampled, indicating weakly saline soil conditions.

Other well known indicator species such as red goosefoot (Chenopodium rubrum) and saline goosefoot (Chenopodium salinum) were noticeable around the periphery of open water marshes in late August and early September. These two halophytes appeared to have been affected by

TABLE 12

General Relationship Between Dominant Marsh Plant Species and Electrical Conductance of Surface Soils

Species	Common Names	Wetland Zone	Number of Sloughs Represented	Average Electrical Conductance (ms./cm.)	Range (ms./cm.)
Salix sp.	Willow	(WM)[a]	13	1.7 ± 1.3	.4 — 5.0
Koeleria cristata	June grass	(WM)	8	2.3 ± 1.7	.4 — 5.0
Eleocharis acicularis	Needle spike rush	(WM)	6	3.4 ± 2.6	.8 — 7.5
Agropyron repens	Quack grass	(WM)	12	4.7 ± 3.3	.5 — 10.5
Juncus balticus	Baltic rush	(WM)	22	5.1 ± 2.8	2.2 — 12.5
Hordeum jubatum	Wild barley	(WM)	7	6.3 ± 4.3	.6 — 12.5
Beckmannia syzigachne	Slough grass	(SM)[b]	7	1.7 ± .6	.7 — 2.3
Carex sp.	Sedge	(SM)	34	1.8 ± 1.0	.7 — 4.8
Eleocharis palustris	Spike rush	(SM)	39	2.3 ± 1.9	.9 — 6.5
Scolochloa festucacea	White top	(SM)	39	2.9 ± 1.9	.6 — 8.5
Typha latifolia	Cattail	(EDM)[c]	24	2.3 ± 1.3	.4 — 5.5
Scirpus acutus	Hardstem bul-rush	(EDM)	13	2.9 ± 1.2	1.1 — 3.8
Scirpus validus	Softstem bul-rush	(EDM)	9	3.8 ± .7	2.5 — 4.8

[a] wet meadow

[b] shallow marsh

[c] emergent deep marsh

herbicide applications earlier in the summer and, therefore, were not present at the time of sampling.

Native plant species associated with excessive quantities of surface water and soluble salts can be recognized as indicators of potential soil management problems. Left in their natural state native mesophytes, hydrophytes, phreatophytes and halophytes help control soil salinity problems by transpiring significant quantities of water. If disturbed by agricultural operations, this evapotranspiration potential may be reduced and native plant communities may be replaced by less desirable weed species or bare saline soils.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Developing and maintaining agricultural lands today is as important as it was eighty years ago. Land drainage, then as now, contributed significant acreages to our agricultural land base. In the case of prairie sloughs the least drainage does is to permit existing production to continue without the impediment of accumulations of surface water. Also, under proper management valuable agricultural lands can be gained by slough drainage.

Slough drainage is not without its costs, however. Drained and cultivated sloughs lose much of their value in terms of waterfowl production, pollution control, headwater storage, groundwater recharge, aesthetics and recreation. Furthermore, groundwater activity and duration of surface flooding results in distinct differences between soils formed under various types of sloughs. Unless each type can be identified and the relationship between wetland hydrology and soil forming processes understood, the costs and effort involved in drainage may be to no avail.

Sloughs representative of four major wetland types as described by Millar (1976) were present within the Study

Area. They were the wet meadow, shallow marsh, emergent deep marsh, and open water marshes.

Wet meadows could be distinguished by the presence of phreatophytic and mesophytic glycophytes under natural undisturbed conditions. Vegetation and leached soils indicated groundwater recharge conditions as described by Lissey (1968) and Toth (1966). Wet meadows were the smallest sloughs examined but offered the greatest agricultural potential. However, periods of temporary wetness, such as in the spring or after heavy rains, would definitely limit cereal crop production unless adequate surface drainage was provided. The wet meadow soils under natural conditions would be classified between 3W and 4W in agricultural capability.

Shallow marshes were dominated by a central zone of hydrophytic grasses, sedges and forbes surrounded by a wet meadow zone of phreatophytic mesophytic glycophytes. Shallow marsh vegetation and soils indicated slow groundwater recharge conditions as suggested by Lissey (1968). Under natural conditions, shallow marsh wet meadow zone soils could be classed 3W to 4W in agricultural capability. Shallow marsh zone soils appeared suitable only for forage crops and pasture and therefore should be classed 4W to 6W in agriculture capability.

Emergent deep marshes could be distinguished from shallow marshes by the presence of coarse grasslike hydrophytes dominating the central zone which were distinctly taller than those of the shallow marsh zone. Emergent deep marsh vegetation and soils indicated minimal groundwater activity. These sloughs did not appear to be recipients of, or contributors to groundwater flow. The agricultural capability of emergent deep marsh soils was limited primarily by excess water. The wet meadow zone soils could possibly be seeded to agricultural crops and were therefore classed 3W to 4W in agricultural capability. Shallow marsh zone soils offer progressively more problems with surface water and are capable only of producing perennial forages (5W agricultural capability). The central zone of emergent deep marshes have severe limitations to agriculture and would have to be classified 5W to 6W in capability.

Open water marshes were characterized by water permanence, and rings of hydrophytic and mesophytic vegetation around an open water zone. Open water marsh surface waters were generally low in soluble salts. However, these sloughs were often associated with soil salinity in their wet meadow zones. The open water marshes examined were probably transitional or slow freshwater discharge sloughs.

Open water marsh soils have severe limitations to agricultural production. The wet meadow zone soils showed signs of secondary salinity and in many cases would not support cereal crop production. Consequently, these soils were classed 4^{W}_{N} and 6^{W}_{N} in agricultural capability.

Excess water in the central zones of open water marshes limited capability to classes 5W to 7W.

Vegetation was a valuable indicator of edaphic conditions throughout the Study Area. Disturbance species associated with cultivated wet meadows and shallow marshes suggested periodic periods of wetness that restricted crop growth. Also, salt tolerant halophytes associated with non saline open water marshes suggested localized groundwater discharge conditions and possible problems of soil salinity if these sloughs were drained for the purpose of agricultural cropping.

Vegetation may have only limited value by itself for the purpose of differentiating between regional and local groundwater discharge areas. However, vegetation combined with surface water phenomena such as permanence and salinity along with soil characteristics should be valuable in distinguishing between local and regional discharge areas.

The sloughs of the Study Area varied in water permanence and soil salinity levels but were all associated with only fresh to moderately brackish surface waters. These characteristics suggested only local groundwater activity associated with the sloughs examined. Under local groundwater conditions drainage of the entire Study Area would reduce or eliminate surface water and control soil salinity problems. However, more intensive groundwater studies would be needed to confirm these speculations.

Also, a thorough benefit-cost analysis which identified and quantified social, economic and environmental factors not only from a local perspective but a regional and provincial viewpoint as well, would be appropriate if such a large scale drainage project were ever seriously considered.

5.2 Recommendations

1. Wet meadow soils have the greatest agricultural capability of all the sloughs examined. Under proper management these sloughs could contribute to the agricultural land base in the Study Area. Adequate drainage and continuous cropping would help remove excess water and make these areas as productive as possible.
2. Shallow marshes have only limited capability for agriculture and are probably only suitable for native hay or forage crop production. Reed canary grass is suitable for growing in these sloughs. On grain farms, shallow marsh would be better left under native vegetation, unless complete drainage is feasible.
3. Emergent deep marshes are suitable only for pasture and should be left under native vegetation.
4. Encroachment by farm machinery around many open water marshes has left rings of bare saline soil. An inventory of these areas should be undertaken to determine the feasability of developing a government sponsored program with the objective of establishing forage crops in these areas. The establishment of forage crops would help control the spread of soil

salinity, reduce the occurrence of noxious weeds, and develop needed waterfowl habitat on lands that are currently unproductive.

5. Summerfallowing and burning of vegetation in the wet meadow zone of open water marshes should be avoided. Where native vegetation has been removed and continuous cropping is not practical, a mixture of forages should be grown. Deep rooted alfalfa is excellent for drawing down the water table. Tall wheat grass and slender wheat grass are tolerant of saline conditions and will help ensure a crop in areas not suitable to alfalfa. The inner wetland zones of open water marshes should be left in their natural state. If drainage is feasible examination of the groundwater conditions should be undertaken to ensure that surface water problems will not be replaced by soil salinity.

6. Sloughs have a valuable environmental function not only in controlling run-off but in terms of maintaining the quality and diversity of the environment. The head water storage capacity of the Upper Whitemud River sloughs should be determined accurately and alternatives to drainage examined. Continuous cropping and over winter stubble managements should be examined as means of controlling surface water problems before any major drainage projects are allowed.

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APPENDICES

APPENDIX A

FIELD DATA SHEET CODE KEY

Nature of Wetland

	Code No.
Natural	1
Cultivated	2
Grazed	3
Mowed	4
Artificial Alteration of Wetland Depth	5

Alterations

No alterations	1
Partial drainage	2
Depth increased by dam	3
Depth increased by dugout	4
Area reduced by man-made structure	5
Watershed area reduced	6
Watershed area increased	7

Wetland Size

0.10 hectare or less	1
0.11 to 0.20 hectare	2
0.21 to 0.40 hectare	3
0.41 to 1.00 hectare	4
1.01 to 2.00 hectare	5
2.01 to 4.00 hectare	6

Position in Watershed*	Code No.
Isolated Wetland	1
Overflow Wetland	2
Channel Wetland	3
Terminal Wetland	4
subgroup:	
Junction wetland	1
Perched Wet wetland	2

* Refer to Millar (1976) for complete description.

Wetland Type	
Wet meadow*	1
Shallow marsh*	2
Emergent deep marsh*	3
Open water marsh*	
a) Open water marsh	5
b) Shallow open water	5_s

* Disturbed zones codes as (7).

Salinity Category

	Dissolved Solids (ppt)	Code No.
Fresh	<.350	1
Slightly brackish	.351 - 1.400	2
Moderately brackish	1.401 - 3.500	3
Brackish	3.501 - 10.500	4
Sub saline	10.501 - 31.500	5
Saline	>31.501	6
Brines		

Carbonate Levels	Code No.
Non carbonated	0
Weakly carbonated	1
Moderately carbonated	2
Strongly carbonated	3

Humic Layer	Code No.
Humic layer greater than 6 cm. deep present	
No	0
Yes	1

PRINCIPAL ROOTED WETLAND PLANT SPECIES--THEIR VEGETATION ZONE AND COMMON NAME

Vegetation Code	Vegetation Zone (Code No.) and Species	Common Name
Wet Meadow (1)		
100	Calamagrostis canadensis	marsh reed grass
101	Poa palustris	fowl blue grass
105	Sonchus arvensis	perennial sow thistle
106	Calamagrostis inexpansa	northern reed grass
107	Juncus balticus	baltic rush
108	Hordeum jubatum	wild barley
109	Distchlis stricta	alkali grass
110	Agropyron repens	couch grass, quack-grass
111	Agrostis scabra	rough hair grass
112	Deschampsia caespitosa	tufted hair grass
113	Aster hesperius	willow asper
114	Cirsium arvense	Canada thistle
115	Koeleria cristata	june grass
116	Mentha arvensis	wild mint
118	Salix sp.	willow
119	Bromus pumpellianus	northern awnless brome
120	Aster panus	many flowered aster
121	Erigeron glabellus	smooth fleabane

(Continued)

Vegetation Code	Vegetation Zone (Code No.) and Species	Common Name
Shallow Marsh (2)		
200	Polygonum coccineum	swamp persicaria
201	Carex sp.	sedge
202	Scolochloa festucacea	spangle top, white top
203	Eleocharis palustris	creeping spike-rush
204	Puccinellia nuttalliana	nuttails salt-meadow grass
205	Salicornia rubra	red samphire
206	Phalaris arundinacca	reed canary grass
207	Sparganium eurycarpum	broad-fruited bur-reed
208	Alisma triviale	western water-plantain
209	Sium sauve	water parsnip
210	Sagittaria cuneata	arum-leaved arrow-head
211	Suaeda depressa	western sea-blite
212	Hippuris vulgaris	mare's-tail
214	Eleocharis acicularis	needle spike-rush
Emergent Deep Marsh (3)		
300	Scirpus validus	great bulrush, softstem bulrush
301	Typha latifolia	common cattail
302	Phragmites communis	common reed grass

(Continued)

Vegetation Code	Vegetation Zone (Code No.) and Species	Common Name
303	Scirpus acutus	viscid great bulrush, hard stem bulrush
304	Scirpus paludosus	prairie bulrush
Disturbed (7)[1]		
700	Glyceria grandis (2)	tall manna grass
701	Agropyron repens (1)	couch grass, quack grass
702	Beckmannia syzigachne (2)	slough grass
703	Polygonium coccineum (1) (2)	swamp persicaria
711	Alopecurus aequalis	short-awned fox tail
713	Cirsium arvense (1)	Canada thistle
714	Sonchus arvensis (1)	perennial sow thistle
715	Echinochlloa crusgalli (1)	barnyard grass
719	Polygonium sp. (2)	smart weed

[1]Most disturbance species also occur as minor elements in stable vegetation zones. The number in parentheses after each species name is the code number for the stable vegetation zone with which it is commonly associated (Millar, 1976).

STUDY NUMBER
1 2 3 4

WETLAND NUMBER
5 6

GEOGRAPHIC LOCATION
¼ Sec. Sec. Twp. Range Mer.
7 8 9 10 11 12 13 14 15

DATE OF OBSERVATION
Year Month Day
16 17 18 19 20 21

NATURE OF WETLAND
Origin Alterations
22 23 24 25

SIZE OF WETLAND
Hectares Cat.
26 27 28 29 30 31

POSITION IN WATERSHED
Cat. Sub.
32 33

UPLAND USE %
Cult. Hay Grazed Past. Wild Occ.Farm Rd. Rlwy.
34 35 36 37 38 39 40 41 42 43 44 45

MAX DEPTH ON DATE OF OBSERVATION (M)
46 47 48 49

WETLAND TYPE
50

WATER
TEMP °C
51 52 53 54

Salinity pp Thousand
Grams of Salt/Kilo Sample
55 56 57 58

CONDUCTIVITY
MMLO/CM³
59 60 61 62 63

SALINITY CATEGORY
64

% of Periphery in Woody Vegetation
65 66 67

Elevation (m)
68 69 70 71

SOIL AND VEGETATION

WETLAND NUMBER
5 6

SAMPLE ZONE
7

DOMINANT VEGETATION
1st %
8 9 10 11 12 13

2nd % 3rd % Ph 0-15 15-60
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

Conductivity MMLO/CM²
0-15 15-60
34 35 36 37 38 39 40 41 42 43

CARBONATES
44 45

HUMIC LAYER
Yes No Depth
46 47 48

SOIL AND VEGETATION

WETLAND NUMBER
5 6

SAMPLE ZONE
7

DOMINANT VEGETATION
1st %
8 9 10 11 12 13

2nd % 3rd % Ph 0-15 15-60
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

Conductivity MMLO/CM²
0-15 15-60
34 35 36 37 38 39 40 41 42 43

CARBONATES
44 45

HUMIC LAYER
46 47 48

SOIL AND VEGETATION

WETLAND NUMBER
5 6

SAMPLE ZONE
7

DOMINANT VEGETATION
1st %
8 9 10 11 12 13

2nd % 3rd % Ph 0-15 15-60
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

Conductivity MMLO/CM²
0-15 15-60
34 35 36 37 38 39 40 41 42 43

CARBONATES
44 45

HUMIC LAYER
46 47 48

SOIL AND VEGETATION

WETLAND NUMBER
5 6

SAMPLE ZONE
7

DOMINANT VEGETATION
1st %
8 9 10 11 12 13

2nd % 3rd % Ph 0-15 15-60
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

APPENDIX B

WATER ANALYSIS - Saturated paste Extracts.

Upper WHITEMUD RIVER STUDY AREA

LOCATION	Sample #	Depths in Cm.	pH	Conductivity	CATIONS Meq./L. Ca++	Mg++	Na+	Total Cations	ANIONS Meq./L. $SO_4^{=}$	Cl^-	HCO_3^-	Total Anions	Ca/Mg	Ca/Na
14 18 W	1 (1)	0-15	7.30	8.5	18.5	155.3	[illegible]	202.2	193.5	3.7 NIL	8.4	205.0 201.9	.12	.68
" "	1 (2)	0-15	8.07	4.8	16.6	60.4	13.9	90.9	83.6	2.7 NIL	7.0	93.3 90.6	.27	1.19
14 18 W	4 (1)	15-60	8.20	6.0	21.5	83.0	11.4	116.9	107.6	3.1 NIL	1.8	[illegible]	.26	1.89
"	4 (2)	0-15	8.05	3.6	23.8	26.9	4.0	54.7	48.3	5.9 NIL	3.0	57.2 51.3	.88	5.95
13 18 W	7 (2)	0-15	7.70	2.9	13.8	22.6	7.3	43.7	32.0	1.2 NIL	8.6	41.7 40.6	.61	1.99
14 18 W	17 (1)	0-15	7.90	10.5	19.0	142.2	61.8	216.0	206.[illegible]	2.3 NIL	10.4	[illegible] ~~216.4~~	.13	.35
" "	17 (3)	0-15	7.65	7.5	22.1	83.5	33.0	138.6	[illegible]	3.1 NIL	6.2	[illegible] 139.5	.26	.67
13 17 W	41 (1)	0-15	8.25	6.5	17.0	85.3	17.7	120.0	113.2	2.4 NIL	5.6	122.2 119.8	.20	.96
"	41 (2)	0-15	7.40	2.2	3.5	18.5	6.1	34.1	19.1	1.2 NIL	12.2	32.5 31.3	.51	1.56
13 17 W	43 (1)	0-15	7.7[illegible]	12.5	20.8	[illegible]	64.3	312.9	309.1	1.8 NIL	2.2	313.1 ~~311.3~~	.09	.32
"	43 (2)	0-15	7.85	3.2	5.4	34.3	9.0	48.7	42.5	1.5 NIL	8.8	52.8 51.3	.16	.60
13 17 W	44 (1)	0-15	7.85	7.0	15.9	98.6	26.0	140.5	137.0	1.5 NIL	5.2	143.7 142.2	.16	.61
"	44 (2)	15-60	7.80	4.1	17.8	59.6	15.0	92.4	91.3	1.3 NIL	4.0	97.2 95.9	.30	1.19
13 17 W	46 (1)	0-15	7.55	5.5	20.3	55.1	15.0	90.4	78.8	3.6 NIL	13.6	96.0 92.4	.37	1.35
"	46 (2)	15-60	7.22	2.2	8.3	15.6	5.2	29.1	23.9	1.1 NIL	4.6	29.6 28.5	.53	1.60
13 17 W	48 (1)	0-15	7.90	9.0	17.3	140.0	30.0	195.3	183.3	3.6 NIL	6.4	199.3 195.7	.12	.58
"	48 (2)	15-60	7.75	3.5	16.4	26.3	8.8	52.1	42.4	2.9 NIL	3.6	54.9 52.0	.61	1.86

WETLAND SAMPLE ZONE
(1) WET MEADOW
(2) SHALLOW MARSH
(3) EMERGENT DEEP MARSH

APPENDIX C

HEADWATER STORAGE CAPACITY IN THE UPPER WHITEMUD RIVER SLOUGHS

A hypothetical calculation of the headwater storage capacity in the Study Area is presented in Table C-1. The number of wetlands per study block, the average size of the wetlands, and the total area occupied by each class of wetland are figures derived from this summer's data. Average depths and headwater storage capacities are based on observation and speculation and are intended for demonstrative purposes only.

The calculations presented in Table C-1 show that complete drainage of all the sloughs in the Study Area would contribute (39 ha. x 134) 5,226 hectares of land to the agricultural land base. However, complete drainage would add 58.8 million cubic meters of water to the Whitemud River System on years when precipitation was sufficient to fill these sloughs. Off-farm drainage of wet meadows and shallow marshes alone would add 11.3 million cubic meters of water, enough to fill a reservoir 1 kilometer square to a depth of 11.3 meters.

Is drainage necessary? Spread out over the entire Study Area 58.8 million cubic meters of water is equivalent to $\frac{58.8 \times 10^6}{256 \times 10^4} \times 134 \times 100 = 17$ cm. of precipitation, or one-third of the area's annual rainfall. Rennie and Ellis (1978) suggested that proper snow management (i.e., over winter stubble, cessation of summerfallow and burning) could capture up to 75 percent of "snow" precipitation (page of this report). In the Study Area a 75 percent "snow" moisture retention rate would capture (12 cm. x .75) 9 cm. of precipitation equivalent. Converting that to total water volume for the Study Area works out to (.09 x 256 x 10^4 x 134) 30.9 million cubic meters; more than half of the calculated headwater storage capacity of the Upper Whitemud River sloughs.

TABLE C-1

Hypothetical Headwater Storage Capacity of the Upper Whitemud River Study Area

Slough Type	No. per Study	Average Size (ha.)	Area Occupied per Study Block (sq. M.)	Average Depth (M)	Head Water Storage Cap. (cu. m./Study Block) (X)	Head Water Storage Cap. in Study Area (cu. m.) (X) x 134
Wet meadow	20	.25	50,000	.5	25,000	3,350,000*
Shallow marsh	12	.77	85,000	.7	59,500	7,973,000*
Emergent deep marsh	7	.82	57,000	1.0	57,000	7,638,000
Open water marsh	13	1.52	198,000	1.5	297,000	39,798,000
			390,000		438,000	58,759,000

*Off-farm drainage of all of the wet meadow and shallow marsh sloughs in the Upper Whitemud River would remove 11,323,000 cu. m. of headwater storage capacity.